

“Geology of the colony of North Borneo” (1951): The first fundamental publication on the geology of Sabah

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Abstract: Our present-day understanding of the geological evolution of northeast Borneo has its foundations in Bulletin No. 1 of the “Geological Survey Department of the British Territories in Borneo”. Since it was published in 1951, fundamentally new geological concepts have been introduced and the penetration of geologists into what at the time was still largely a “terra incognita” has greatly advanced our comprehension of the Sabah geology. A review of the salient elements of this publication is presented here.

Keywords: Max Reinhard, Eduard Wenk, Geological Survey Department of the British Territories in Borneo, Danau Formation, circular basins, Mount Kinabalu granitoid

INTRODUCTION

Until WWII, northeast Borneo was still largely a “terra incognita”, particularly as far as geological mapping was concerned. Late 19th century exploration trips, in search of coal, precious metals and gems did not involve mapping and have rarely been documented. Scientific exploration was late in coming and was driven by companies searching for oil and employing professional geologists, later assisted by topographic crews, with access to aerial pictures for structural analysis.

The Nederlandsche Koloniale Petroleum Maatschappij (NKPM) and the Royal Dutch-Shell Group (Shell) carried out large-scale geological exploration campaigns in NE Borneo, respectively in the years 1912-1915 and 1935-1939. The results of these campaigns laid down the foundations for the regional geological understanding of NE Borneo.

OBJECTIVES OF BULLETIN #1 AND SHELL’S SUPPORT

Following World War II, when much of the exploring companies’ archives had been destroyed, Shell engaged in an effort to consolidate the pre-war geological data and learnings on NE Borneo. In 1948, Shell contacted the newly established Geological Survey Department of the British Territories in Borneo with an offer to make available all historical geological data for publication. It was then jointly decided to take this opportunity and publish it in the form of Bulletin No.1, laying the ground for further such geological publications to follow.

Bulletin No. 1 carries the title “Geology of the Colony of North Borneo”; it was co-authored by Prof. M. Reinhard and Dr. E. Wenk from the University of Basel, and published in London in 1951.

The generic objectives of this Bulletin were to “*throw light on the geological history and structure of Borneo*” such that it will lay “*a foundation upon which the newly-formed Geological Survey of North Borneo may base future research*”. It was also mentioned that this publication

“might assist in the search for mineral deposits of economic importance and in the classification of soil-types for agricultural and arboricultural purpose.”

In detail, the purpose was to gather and validate all available geological information including micropaleontological, petrological and mineralogical analyses of geological samples, to formulate a stratigraphic and structural framework and to compile geological maps.

Shell opened its archives, made available the topographical data, coordinated the release of geological information with the NKPM, paid for the compilation work of authors, arranged for the English translation (the report was originally written in German) and carried the costs of publishing 3 coloured maps.

THE AUTHORS, PROF. M. REINHARD AND DR. E. WENK

Max Reinhard was at the time Professor of Mineralogy and Petrology at Basel University. Born in 1882, he studied geology in Geneva, completed a PhD on the geology of the Carpathians after living some 7 years in Rumania (Wenk, 1975). During the years 1911-1915, he joined the NKPM and later the Standard Oil Company and worked as an oil geologist in Sumatra, Java and then Borneo, before going to Colombia and Venezuela. He returned to Switzerland in 1916 and started his life-long academic career.

Eduard Wenk was at the time a colleague of M. Reinhard, working as a lecturer in Petrology at Basel University. Born in 1907, he studied geology and mineralogy in Basel and worked in the high Alps to earn his PhD (Trommsdorff, 2002). Thereafter he moved for two years to the University of Uppsala from where he could participate in a geological expedition to Greenland. He later joined Shell and worked as an oil geologist in NE Borneo from 1936 to 1939. He returned to Switzerland at the start of World War II, where he pursued a successful academic career, marked by his work on the structure and metamorphic history of the Central Alps that earned him the Gottlob Abraham and the Steinmann medals.

DATABASE

One of the major achievements of the compilation work published in Bulletin No.1 is the comprehensive geological database.

They include a comprehensive list of rock samples collected by J.J. Pannekoek van Rheden (1909-1910), G. Niethammer (1911-1914), M. Reinhard, F. Spiegelhalter, H. Jetzler, K. Stamm (1913-1914), W. Hotz (1914-1915), L. Leicester (1936) and E. Wenk (1936-1939). The description of all these samples is listed in Appendix I of the Bulletin. Over a thousand samples and over 770 thin sections were examined and described and chemical analyses performed. Most of the samples consist of volcanic and plutonic rocks, reflecting the geological make-up of Sabah.

A significant effort consisted in the validation of all available micropaleontological data. This task was given to two foremost specialists at the time, I.M. van der Vlerk and M. Reichel and reported in the form of two Appendices to the Bulletin. The former author wrote: *"Since it is one of the main objects of this paper to pass on to future explorers and to scientists interested in the geology of the East Indian Archipelago all exact information so far acquired, it has been thought necessary to publish a complete list of the macro-foraminiferal samples examined from North Borneo."*

Mention is also made of the 9 exploration wells drilled between 1911 and 1921: 5 wells in the Klias Peninsula, 2 wells on the island of Mangalum, 1 well on the island of Sebatik and 1 well on the Kudat Peninsula.

A list of North Borneo astro-fixes, consisting in the latitude and longitude of 20 stations is given in Appendix IV.

In a chapter dedicated to the history of geological exploration in NE Borneo, the names of 31 pioneer geologists can be found, as well as the various companies involved (9) in the search for gems, minerals, coal and hydrocarbons.

Finally, the bibliography lists over 150 pre-WWII publications, including unpublished reports by the NKPM and by Shell.

All hard data, rock samples and copies of all reports consulted were deposited at the Museum of Natural History in Basel.

BASEMENT

The authors claim the first recognition of continental basement rocks in NE Borneo, albeit limited geographically to small outcrops. *"Without a doubt the crystalline schists and the quartz-dioritic to dioritic intrusive rocks associated with them may be regarded as the oldest rocks of North Borneo and evidence of an ancient basement now eroded."* ... *"A characteristic feature is the almost complete absence of biotite and the scanty occurrence of muscovite."*

Yet, because of the difficulties to access large areas of NE Borneo, the authors say: *"It seems very probable that crystalline schists have played an important part in the formation of that wide area, where no geologist has yet set foot, between the upper courses of the Segama and the head-waters of the Tingkayu, Klumpang, Marutai, Masmah and Blantian."*

"We are completely in the dark as to the age of the crystalline schists. Any pronouncement must be considered a matter of feeling; the gneisses and crystalline schists, together with the associated intrusives, may have originated between the pre-Cambrian and the Upper Paleozoic, and thus represent old crystalline rocks."

STRATIGRAPHIC FRAMEWORK

Today, the stratigraphic framework proposed by Reinhard and Wenk has only historical value and many of the "Formations" mentioned in Bulletin No.1 are no longer in use. The Cenozoic is divided into intervals corresponding to the larger foraminifera "Letter Classification". In the text, most references to the time scale are indicated in the Letter Classification code: Ta-Tb (Eocene), Tc-Td (Early Oligocene, reported as missing), Te1-4 (Late Oligocene), Te5-Tf (Miocene). Mention is made of the sandstones outcropping in the Crocker Range, but these are not identified as a separate unit, nor is their turbiditic, deep-marine nature recognized. This significant omission is probably due to the fact the Reinhard and Wenk relied on the few data gathered in 1911-1915, and had not visited the area themselves. The term turbidite for the deposit of a turbidity current was first introduced by Kuenen (1957). Turbidites were first properly described by Arnold H. Bouma only in 1962.

Much progress has been made in refining the stratigraphic framework since Bulletin No. 1 was published, but it must be acknowledged that this original framework was based on solid ground, even by today's standards. *"The main criteria for the subdivision and correlations have been: (I) lithology of the sediments, (II) paleontological evidence, (III) established transgressions and unconformities."*

THE DANAU FORMATION

Reinhard and Wenk rightly associated the Danau Formation (now largely referred to as the Chert-Spilite Formation) with an ophiolitic suite. In the field this formation is strongly tectonized such that it is difficult to recognize its internal stratigraphy. At the time, the link between ophiolites and oceanic basement had not yet been established, and while the associated presence of radiolarites had in one case been calibrated with oceanic sediments (Molengraaff, 1900), this interpretation was still a subject of debate.

In its main aspects, the stratigraphic succession of the ophiolitic-sedimentary suite is correctly portrayed, but the interpretation of depositional environment is off the mark.

"The typical feature of this formation is the association of radiolarian cherts, sometimes variegated but mostly red, with ophiolites among which serpentine, gabbro, diabase and spilites are of particularly frequent occurrence. In the beds overlying the radiolarian cherts or interbedded with them, variegated calcareous marls bearing micro-foraminifera are occasionally found. These key rocks of the Danau Formation occur in a highly folded and often imbricated sedimentary complex consisting of alternating beds of shales and sandstones. These appear to be of approximately the same age as the radiolarian cherts and

the ophiolites, and therefore belong to the sedimentary part of the Danau Formation. In their lithological and structural features these sediments are highly reminiscent of alpine flysch. Sediments and ophiolites are not only imbricated but kneaded together. They form giant breccias, which probably arose through the sub-aqueous penetration of the ophiolites into the as yet unconsolidated sediments, followed by sliding of the whole down the continental slope."

"... in spite of the unquestionably strong diastrophism to which these rocks have been subjected, it seems most unlikely that folding alone could produce such a chaotic assemblage, and it appears far more likely that these manifestations are connected with the intrusion of the ophiolites. The still partly unconsolidated sediments were subjected to subaquatic penetrations, from below and probably also laterally, by basic magmas, which crumpled and intermingled with them, especially where, in consequence of the high vapour pressure of the magma, saturated in carbonic acid and water, ophiolitic breccias and tuffs were formed and pressed in or through the sediments. Moreover, subaquatic landslides (slumping) might have occurred. (...) ...we see no reason for regarding the radiolarian cherts as deep-sea sediments."

TERTIARY FORMATIONS

The recognition of regional unconformities formed the basis for the subdivision of Tertiary-aged sediments: *"It was possible in the northern and eastern part of the country to distinguish in the field three major unconformities within the Tertiary series. These stratigraphical breaks of regional importance were subsequently used as key horizons and afforded a four-fold division of the Tertiary in North Borneo."*

The age-dating of each of the unconformity-bounded sections was based on the occurrence of age-diagnostic larger foraminifera, verified by the foremost authority, Professor Isaak Martinus van der Vlerk. The presence of reworked ophiolites, red chert and Eocene foraminifera within the Lower Miocene was taken as further evidence for unconformities associated with erosional events.

The stratigraphic framework for the Cenozoic was interpreted in terms of paleogeography, unfortunately without any accompanying illustration.

"All proven Eocene (Ta-b) sediments in North Borneo are epi-continental deposits. The transgressive character of the Eocene beds upon the peneplained pre-Tertiary incl. Paleocene is clearly evidenced by basal conglomerates (...) from the Segama River, and by sandstone and limestone breccias with fragments of pre-Tertiary igneous rocks and cherts found on Banggi Island and Kudat Peninsula." ... "A strong argument in favour of the existence of islands in a shallow Eocene sea and of lagoons surrounded by pre-Tertiary uplifts, is seen in the development of the facies."

"It is an interesting fact that in Te times (i.e. Late Oligocene to Miocene) the waters had free access right across North Borneo, and the important Tertiary basins of Sarawak-Brunei, Tarakan and northeastern Borneo

communicated via the Upper Kinabatangan-Kuamut region. This fact is supported by micropaleontological evidence."

PHASES OF DEFORMATION

The authors invoke a phase of basement peneplanation, following which the Slate and the Danau formations were deposited and subsequently eroded, prior to deposition of the Tertiary formations. They recognize that the pre-Tertiary formations *"have undergone one more period of orogenesis than have the Tertiary beds."*

The Cenozoic sequence comprises 3 major unconformities, one at roughly the Miocene/Pliocene boundary (may correspond to the Shallow Regional Unconformity), one at around the Oligocene/Miocene boundary and one at approximately the Eocene/Oligocene boundary.

The near base Miocene unconformity is recognized as a major tectonic event, which now corresponds to the "Sabah Orogeny". The authors mention that *"The series of Te5-f age (i.e. Aquitanian/Burdigalian) are clearly distinguishable from the older formations, not only on account of their lithology and fossil content, but also by a marked regional unconformity and a lesser degree of folding. The subsidence of the basins was interrupted by diastrophism near the end of the Te stage (i.e. Aquitanian). Part of the pre-Tertiary and the Tertiary sediments were folded and imbricated and subsequently eroded. The maximum movement appears to have taken place between Te4 and Te5 (i.e. Oligocene/Miocene boundary). This is the most important Tertiary orogeny of North Borneo. It appears to have been connected with and followed by igneous intrusions (Kinabalu) and extrusions (east coast) which do not occur in the sedimentary cycle of Te5-f age."*

Reinhard and Wenk also concluded for a young age of the Sulu Sea.

"The Tertiary folds are cut off, almost at right-angles to the direction of strike, by the NE coast of North Borneo, which is fronted by the Sulu Sea (3-5,000m deep). This fact suggests that the Sulu Sea is comparatively recent."

CIRCULAR BASINS

At the time, geologists had not yet visited larger tracts of Sabah; to gather structural information on some key inaccessible areas, Shell carried out photogeological interpretations, one of the results being the first-time identification of circular basins. This work was carried out by H. Boissevain.

"The Tertiary Te5-f (i.e. Early and Middle Miocene) is well preserved in some flat synclinal basins, a good example of which is the Bongaya syncline in Labuk Bay, where this phenomenon was studied first. Other synclines of similar shape were discovered in the interior, but their particular shape was only revealed by aerial photography. Photogeological maps of the almost circular basins of S. Malua and of S. Bangan south of Tangkulap..." are shown here in Figures 1 and 2. *"The Malua synclinal basin has a diameter of 13km."*

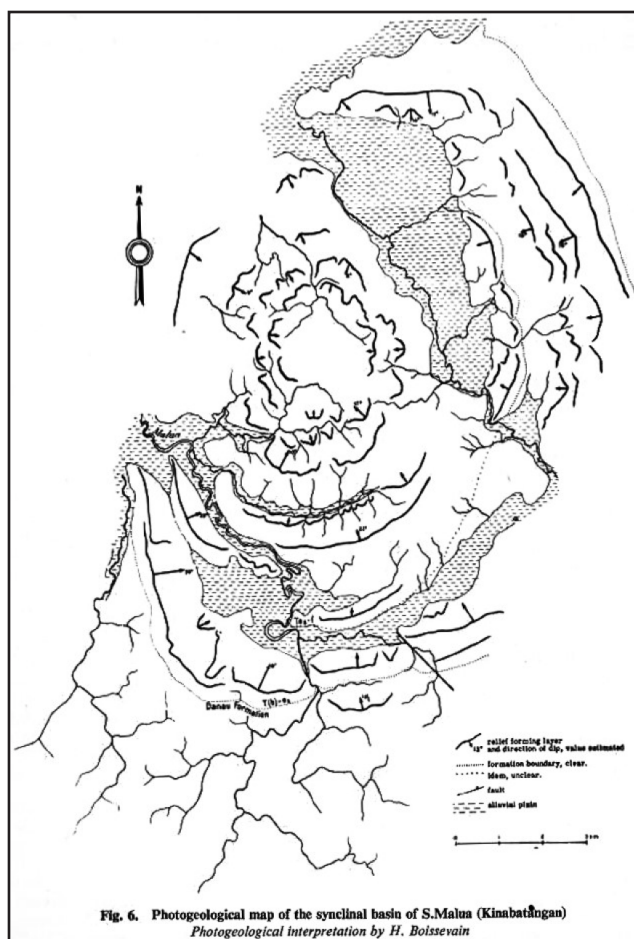


Figure 1: Photogeological map of the synclinal basin of Sungai Malua.

"It seems impossible to explain such structures by tangential compression alone, without taking into consideration local downward movements. To the SW of the Bangan synclinal basin a regularly shaped, elliptical plutonic body of similar dimensions occur (Gunong Rara), which appears to be of Tertiary origin. It is logical to ascribe the synclinal troughs to a compensating subsidence of the magmatic basement."

TERTIARY VOLCANIC ROCKS

Reinhard and Wenk provided the first detailed description of the volcanic rocks from the Simporna Peninsula, accompanied with an interpretation of their age and genesis.

The composition of volcanic rocks outcropping on the SE coast in the Simporna Area is described as "... the Tertiary volcanic formation consists of volcanic breccias, agglomerates and conglomerates which pass laterally into tuff-breccias and tuffs, and alternate with tuffs to tuffites, or with lava beds."

"In P. Gaya, north-east of Simporna, the pyroclastic series forms cliffs more than 100m high. Here it has the nature of a volcanic agglomerate which alternates with beds of lava and of tuff, the whole being traversed by andesitic dykes."

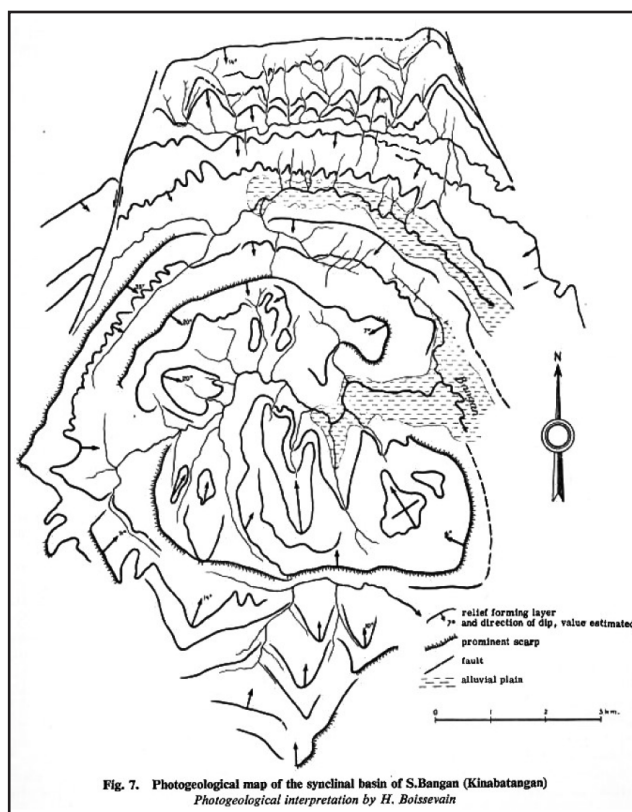


Figure 2: Photogeological map of the synclinal basin of Sungai Bangan.

A particularly explosive type of volcanism is inferred: "The Tertiary volcanism was of a highly explosive type. The materials discharged were predominantly loose products, such as ashes and ejectamenta varying in size from that of lapilli to that of blocks, and lavas only to a lesser extent. Together with the bombs of vitrophyric to holocrystalline volcanic material, blocks of the Tertiary and pre-Tertiary basement were also ejected, but mainly the latter. The ejectamenta were deposited in the sea, as is proven by their admixture with sedimentary material, which locally contains foraminifera."

A Miocene age for this volcanism is based on the associated foraminiferal fauna.

"Field observations show that the andesitic rocks break through sediments of Tertiary e age (i.e. Chattian to Aquitanian). In the Tertiary f formation (i.e. Burdigalian to Serravallian) neither conformable nor unconformable lavas have been found, solely tuffitic sediment occur therein."

MOUNT KINABALU GRANITOID

E. Wenk investigated the Kinabalu pluton in much detail, sampled it, and as a result of his analyses provided the first geological cross section of that major intrusion (Figure 3). The report includes in-depth petrological, mineralogical and chemical analysis including mineral composition, structure and texture of volcanic rocks, mineral successions, weight percentages and Niggli values, various 2-axis and triangular diagrams and optical properties measurements. Based on his observations and those of Niethammer, he concluded for a young Neogene age of this intrusion.

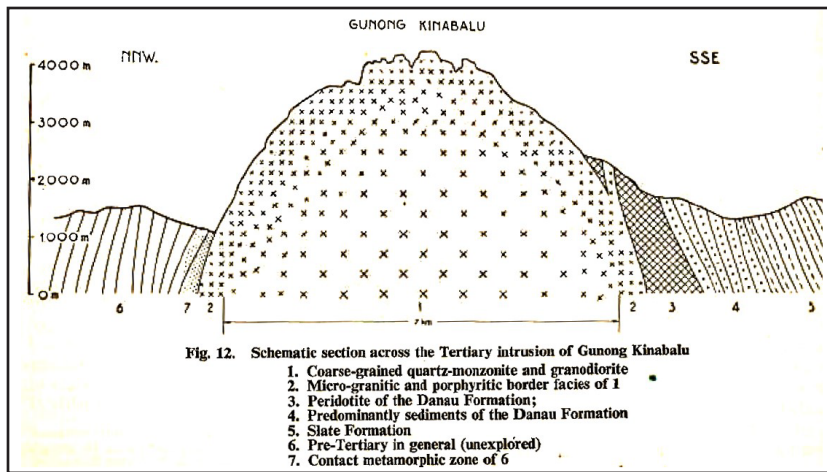


Figure 3: Schematic cross-section across the Tertiary intrusion of Gunong Kinabalu.

"Far more important for the dating of the Kinabalu intrusion are the occurrences of granodioritic and quartz-monzonitic rocks within Tertiary sediments, mapped by Niethammer in S. Merali, a tributary of S. Sugut. These minor intrusions and dykes are younger than the undivided group of sediments Ta+b to Te age, and effected a low-grade metamorphic alteration of the Tertiary strata. The petrographical and petrochemical examination of these igneous rocks proved their consanguinity with the major intrusion of Mt. Kinabalu, which, as far as it has been explored, does not come into contact with the Tertiary strata. To the WNW of Mt Kinabalu, in the Tuaran river system, sills or possibly laccoliths of hornblende-biotite-granodiorite-porphyry were located within Tertiary sediments at Batu Lugas by Niethammer and in S. Mantaranau by Wenk. All these exposures of igneous rocks occur within the Tertiary sandstone-shale formation, which is characterized by red shales. This formation is foraminiferal in the southern part of the Kudat Peninsula, and there contains fauna of Ta-b and Te age (i.e respectively Eocene and Chattian to Aquitanian) as well as mixed faunal associations which the old forms (Ta-b) are considered to have been reworked and redeposited in beds of Te age. In this formation another interesting occurrence of Tertiary volcanic rocks is reported by Niethammer from Tanjong and Pulau Sirar (SW coast of Kudat Peninsula). Here augite-hornblende-andesite, showing columnar structure and being rich in inclusions of quartzite, slightly metamorphic quartz-sandstone and shale, is intercalated within the Tertiary sequence, together with andesitic agglomerate and beds and lenses of tuff. The sandstone layer situated at the bottom of the volcanic intercalation is indurated and ore-bearing. Unfortunately the sample of this sandstone (...) examined by Rutten (...) contained only Operculina, which is non-diagnostic. Rutten mentions, however, the lithological resemblance to samples from Tg. Loro (Kudat Peninsula, west coast) which are of Te age. With regards to the mineralogical and chemical composition, the hornblende-andesite from Sirar compares well both with rocks of the Kinabalu intrusion and with volcanic rocks from the east coast of North Borneo. Niethammer concluded from his observations that the

Sirar andesites and volcanic agglomerates were roughly of the same age as the accompanying sediments, and that presumably they had been folded together."

GEOLOGICAL MAPPING

The geological maps included in Bulletin No. 1 are one of the major scientific legacy left by the authors; they include a geological map of Borneo (1:500,000), a structural map of North Borneo and adjacent Philippine islands (1:2,500,000) and various geological maps and sketch maps (Wannier, 2017).

All the sample locations are carefully inscribed on the maps, most following the river systems: the demarcation between area with geological data points and those without any is clearly indicated on the maps, showing the lack of coverage of larger tracts of land. The amount of geological details that can be read from the maps is staggering (Figure 4) demonstrating the meticulous efforts of these geologists in the field.

ECONOMIC GEOLOGY CONSIDERATIONS

Reinhard and Wenk did not engage in a discussion of the hydrocarbon potential of Sabah, but their comments on the limited occurrence of oil seeps and the negative results of the drilling campaigns point to little upside.

In the same way, the coal occurrences did not receive much attention in the report, but at the time coal exploration had been intensively pursued, with limited success.

As hard rock geologists, the authors considered ore mineralization in more details and they also mentioned the occurrence of gold and of favourable soils for agriculture.

"The ophiolites have locally been ore-bearers. In contact with the radiolarites, manganese ores frequently occur in small quantities, accompanied in one case by the rare mineral inosite. Chromite has occasionally been found in the serpentines." "The chromite is accumulated in placers in the sands of rivers flowing through large peridotite outcrops."

"Occurrences of placer gold seem to be limited to the area bordering the Davel Bay to the north and west." "... The quantity of gold must have been everywhere extremely small. It appears mainly in the form of tiny flakes, and only seldom

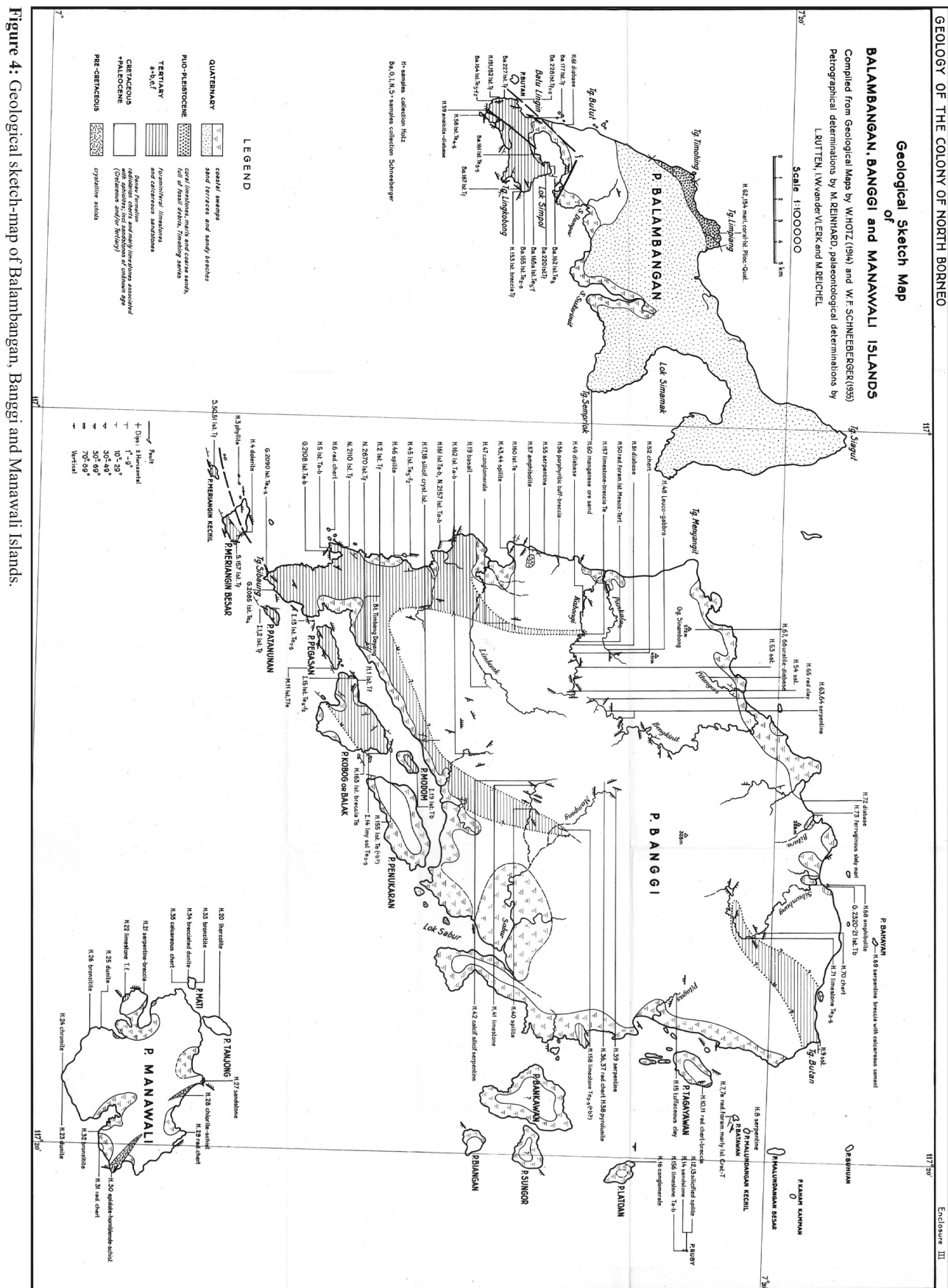


Figure 4: Geological sketch-map of Balambangan, Banggi, and Manawali Islands

in larger nuggets. In the Subahan one such nuggets of 27 gr. was found, the heaviest ever obtained from these placers."

"It may incidentally be observed that the presence of much loose, easily weathered volcanic material, frequently mixed with clayey-sandy sediments, will have a very favourable effect on the formation of agricultural soil. The tuffitic beds make especially fertile soils (Tawau, Tungku), of which so far only a very small part has been made arable."

"As the igneous subsoil, the high daily precipitation and the altitude of the Kinabalu region offer conditions similar to those found in the Ceylon tea plantations, a study of the soils is to be recommended. Favourable terrains might be found to the SE and E of Mt. Kinabalu. A similar survey is advisable for the volcanic areas of the Simporna and Dent peninsulas. A map should be made of this area showing the fertile areas formed of fine-grained tuffs and tuffites, indicating their contact with the regions formed by coarse volcanic agglomerates, conglomerates and lava flows which originated from the same volcanic eruptions as the tuffs. These little-developed east coast districts offer much better soils than the predominantly sandy coastal plains in western North Borneo, which so far as served as the main agricultural land of the country."

CONCLUSIONS

Despite all of the limitations highlighted above, the publication of Reinhard and Wenk has firmly laid the ground for the modern understanding of the geological evolution of NE Borneo. The fact-based professionalism shown by the authors and the encompassing geological subjects treated in Bulletin No. 1 make this publication a landmark in the regional geological evaluation of Sabah.

For the first time a detailed description is given of intrusive, extrusive, plutonic and metamorphic rocks outcropping in NE Borneo, accompanied by numerous plates.

The series of maps included in the Bulletin, with the sampling locations precisely indicated formed a solid reference for the geological mapping undertaken by subsequent geologists working for the survey, avoiding to a large extent duplication of work.

It reads well still today because the basis for argumentation is always laid out; furthermore, the authors have been careful not to enter into theoretical argumentation, particularly regarding the geosynclinal theory.

Based on loose rock sampling, it is evident that even the main features of a geology as complicated as that of Sabah cannot be satisfactorily understood. This is exemplified by the failure to identify the important significance of the deepwater Crocker turbidite sequence. The authors themselves recognized their own limitation: "...many geological problems...are far from having been elucidated."

Bulletin No. 1 is a rare example of a regional geological synthesis sponsored by an oil company that includes a full disclosure of proprietary, confidential geological reports.

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