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A Contribution to the Geology of Part of the Indonesian Tinbelt: the Sea Areas Between Singkep and Bangka Islands and Around the Karimata Islands

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Abstract: An acoustic continuous profiler survey over extensive sea areas between Singkep and Bangka and around the Karimata Islands, supplemented by sea drillings, indicates the following sedimentary succession: below the sea, the basement, which on the islands consist of folded sediments and granitic rocks, is covered by unconsolidated sub-horizontal, mostly sandy sediments with intercalated peat layers near the top, probably of Tertiary age. Next a sequence of sediment-filled gullies incised into the older sediments and sometimes also into the basement is present. Again, peat layers are of common occurrence, indicating a terrestrial origin for most of these sediments; at least part of these deposits seems to be of young Tertiary age.

An extensive, nearly horizontal planation surface is found at depths of 20–30 m below sea level. This surface is at remarkably constant depth and very flat. indicating a marine origin. Spotty red clay is present on part of this surface, indicating a temporary emergence of the abraded surface.

A young sedimentary deposit, mainly of marine origin, represents the latest post-glacial transgression. Part of its material is derived from the surrounding islands.

INTRODUCTION

Whereas in Burma, Thailand and Malaysia the tin belt is composed of chains of hills and mountains, in Indonesia it consists of a few islands with extensive, sea-covered stretches in between. Consequently, it has been difficult to obtain insight into the regional geological problems of the tin belt in Indonesia. During submarine prospecting for tin ores carried out by the Billiton Company in the sea areas between Singkep and Bangka and in the Karimata Archipelago (see fig. 1), much data became available which may throw some light on these problems. In this paper an outline is given of the information now available and an attempt is made to assess its significance.

The Indonesian tin islands Bangka, Belitung and Singkep, together with the Riau Archipelago, the small islands of the Tudjuh group and the Karimata Islands were generally thought to be remnants of the divide areas of the submerged continuation of the Malayan tin belt. (Van Bemmelen, 1949, p. 319).

In 1967 the Indonesian Government offered some of the sea areas in this region for offshore tin prospection. From the brochure distributed by the Ministry of Mines at that time (see reference) we quote the following: "It is a generally accepted conception that the shallow sea surrounding the tin islands represents a peneplain, submerged by the last post-glacial eustatic rise of the sea level. An aureole of submerged river valleys, containing the valuable tin ores, is surrounding the islands of Singkep, Bangka and Belitung at present".

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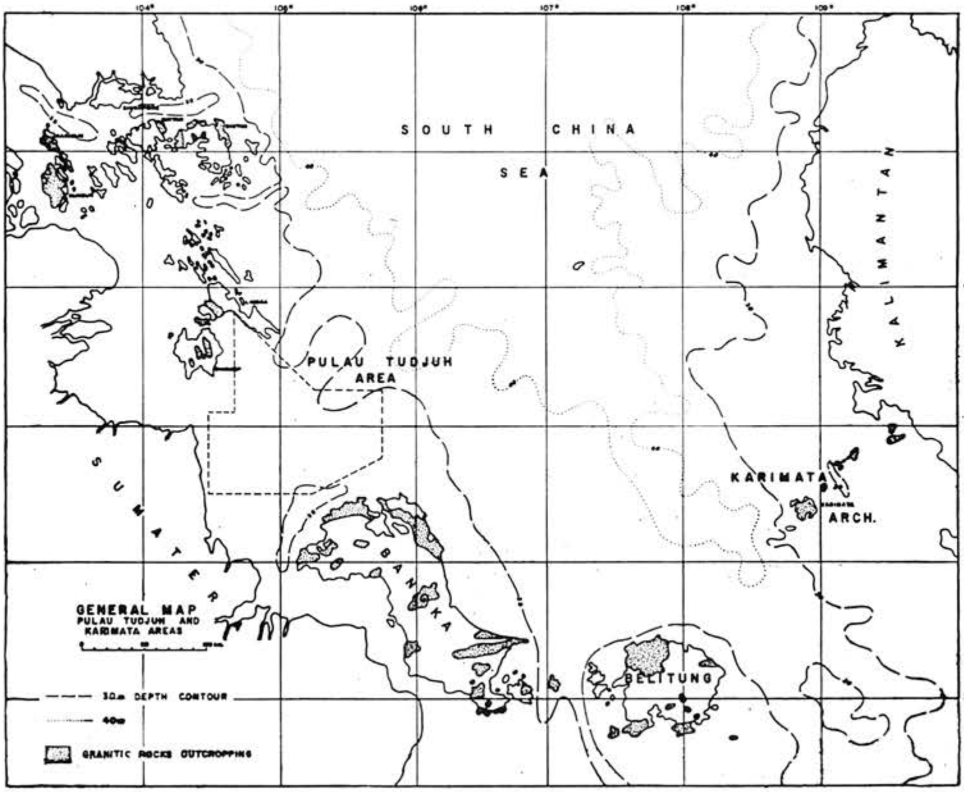

Fig. 1. Location map of the Tudjuh and Karimata areas.

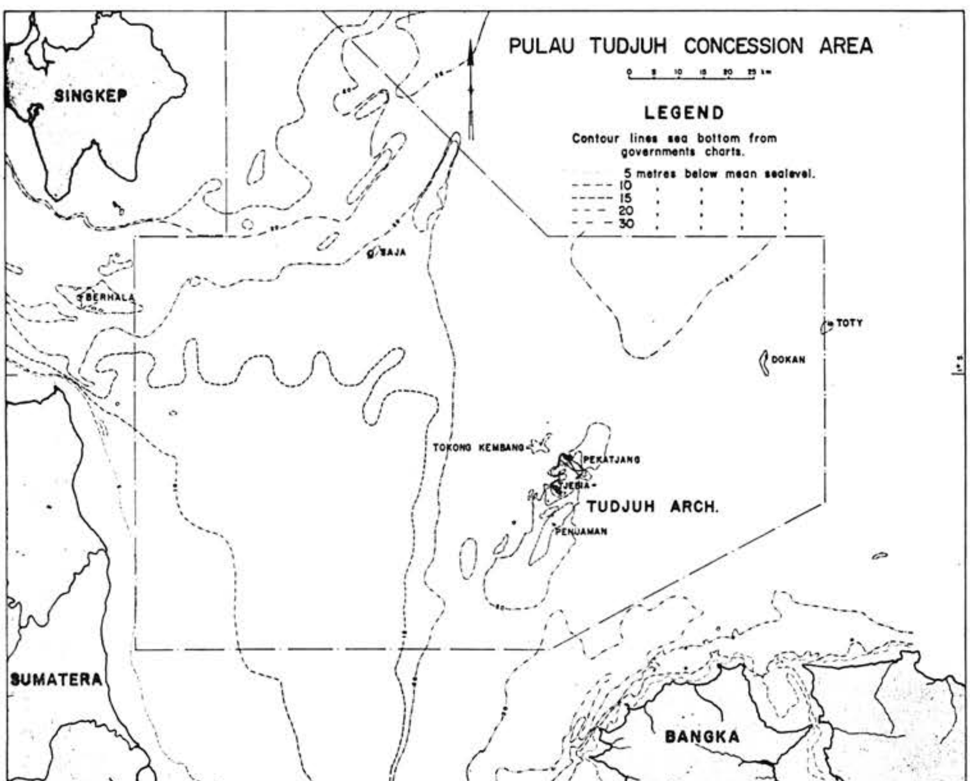

Fig. 2. Map of the Tudjuh area with sea-bottom contours. From hydrographical chart.

The hydrographical information available for the sea area between Singkep and Bangka is illustrated in fig. 2. With regard to the geology, granite was known to exist on some islands of the Tudjuh Group and on the small islands of Saya and Berhala (see fig. 3). Folded sedimentary rocks were reported on Pekatjang and Tokong Kembang (Tudjuh Group) and on Dokan and Toty. Elsewhere, it was thought that a relatively thin series of marine deposits would overlie the bedrock "peneplain".

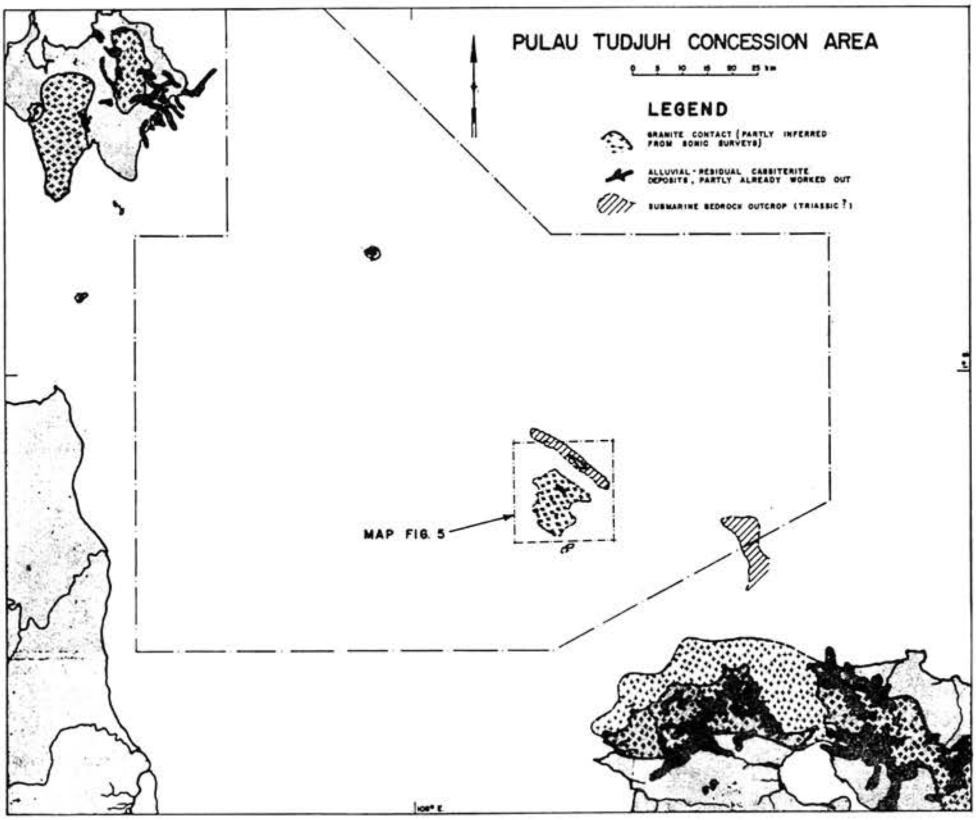

Fig. 3. Geological map of the Tudjuh area and its surroundings, with submarine bedrock outcrops.

As will be shown, the present investigation indicates that the sequence of events was far more complicated. The old planated bedrock surface lies at greater depth and is covered with a much thicker series of sediments than originally supposed. This makes most of the area a difficult mining proposition. Dredging tin deposits offshore has long been restricted to a maximum depth of 30 m; it has only been since 1966 that the first sea-going bucket dredge for a depth of 40 m became operational off Bangka. However, nowadays the exploitation of deposits lying at a depth of 40–60 m with up to 20 m of overburden would be technically possible.

EXPLORATION METHODS AND PROGRESS

Most of the new information was obtained by means of a system of continuously recorded acoustic profiling (trade name "SONIA", operated by Cesco N.V., The

Hague, Netherlands). The SONIA system can be described as a high-powered echo-sounder. The acoustic pulses (frequency 3 kHz, power 7.5 kW) are electronically generated and projected to the sea bottom by a heavy transducer mounted in the survey vessel. These pulses penetrate the sea bottom and are reflected by acoustic discontinuities, i.e. surfaces where the sound velocity changes. The reflected pulses are received, amplified and continuously recorded on a moving paper strip as the vessel proceeds on her course. Thus, a continuous profile is obtained with a useful penetration of up to 50 m and sometimes more. From comparison of SONIA profiles with drill logs it appears that sedimentary layering, abrasion planes, incised valley walls and crystalline-sedimentary contacts give good reflections (van Overeem, 1960).

To date a total of 10,240 line-kilometres has been surveyed by using the SONIA profiling system in the Tudjuh and Karimata areas. The Decca Sea-Fix system has been used for positioning the survey vessel by giving a fix about every five hundred metres. Studying the sonograms one should realize that in general they have a ten times exaggerated vertical scale, which means that a real dip of 30° would appear as ±80° on the sonogram. Furthermore, the sound velocity varies slightly in different sediments—in fact, this gives rise to the acoustic discontinuities which are recorded on the sonogram. For the purpose of depth measurements, an average velocity of 1500 m/sec. is assumed for unconsolidated sediments and of 1250 m/sec. for sea water.

A total of 190 drill holes in the Tudjuh concession area and of 100 holes in the Karimata concession area furnish available checks on the SONIA interpretation. Drilling was done from a self-elevating pontoon using a power-driven water jet drill with a 4″ diameter casing and also with a floating pontoon using a 3″ diameter Becker counter-flush hammer drill. To ensure the best possible correlation between drilling results and SONIA profiles, most of the drill holes were located on SONIA profile lines.

A comparison of sonograms with drill hole data indicates that the acoustic discontinuities do not always coincide with visible lithological changes, while the reverse can also be true. In practice, layered zones of transitions in detrital grainsize, clay, sand and peat layers are examples of good reflectors.

DISCUSSION OF RESULTS

The Basement

In the areas studied, the basement, according to observations made on the islands, consist of granitic rocks, presumably of Jurassic age, and folded sediments, probably of Permo-Triassic age (Kruizinga, 1950).

a. *Granitic basement*. In the Malayan Peninsula the tin belt is characterized by many and often extensive granitic areas. By contrast, the largely submarine continuation of the tin belt in Indonesia appears to be underlain by subordinate areas of granitic rocks (fig. 3). In the Tudjuh concession granitic outcrops and sub-crops are only found on and around some islands of the Tudjuh Group and on the small island of Saya.

In general, the granitic basement is clearly definable on the sonogram as a structureless mass with characteristic peak-shaped reflection surfaces at greater depth

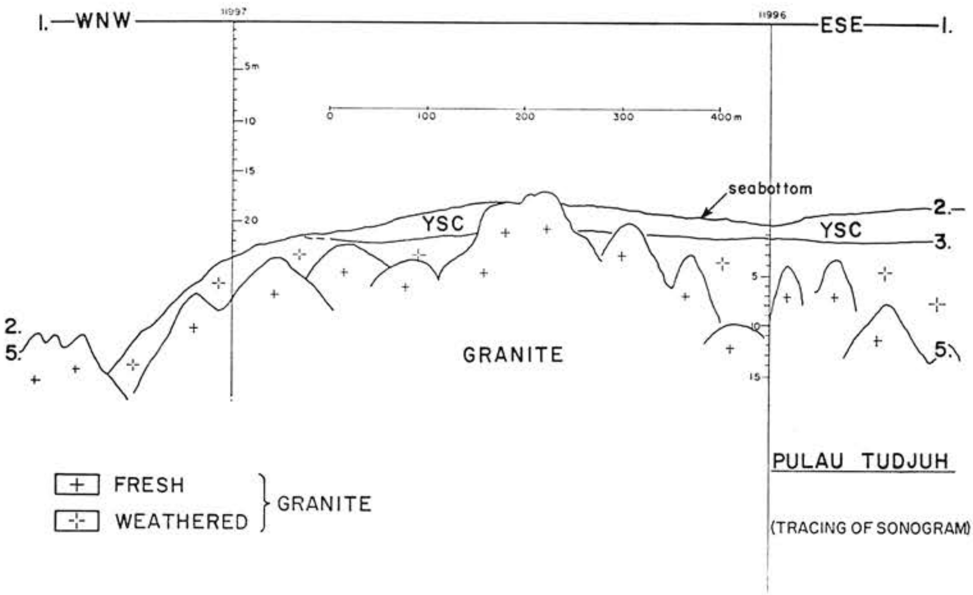

Fig. 4. Tracing of sonogram showing the appearance of granite.
YSC = Younger Sedimentary Cover
1 — Sea surface
2 — Sea bottom
3 — Top of weathered granite
5 — Top of unweathered granite

(fig. 4). Drilling proves that the structureless mass consists of *in situ* chemically weathered granite, comparable with the weathered granite found in the valley floor in the granite areas on the tin islands (see Aleva, 1956) and that the "peaks" represent the surfaces of the hard, unweathered granitic cores.

The submarine extension of the Tjebia granite (named after the main island of the Tudjuh Group) has been mapped in some detail (fig. 5). It has an irregular outline with a diameter of 13–15 km. Northeast of the granite mass drilling indicated a fringe of metamorphic rocks. Here the contact runs more or less parallel to the northwestern strike of the folded sediments. Away from the granitic body the basement dips gradually below the surrounding younger sediments. The utmost limit where the granite is still detectable below the overburden is indicated on the map.

The granite of the island of Saya, 60 km to the northwest of Tjebia, appears to be an isolated stock of less than 5 km in diameter, as SONIA profiling close to the shore did not indicate granite below the overburden. The granite of northwest Bangka does not continue farther than 4–6 km offshore. In the sea areas between the islands of Bangka and Singkep the SONIA survey found no other granites within the recorded depth below the sea bottom. A small submarine emergence of the basement in the southeastern part of the concession proved upon drilling to consist of sedimentary basement (fig. 3).

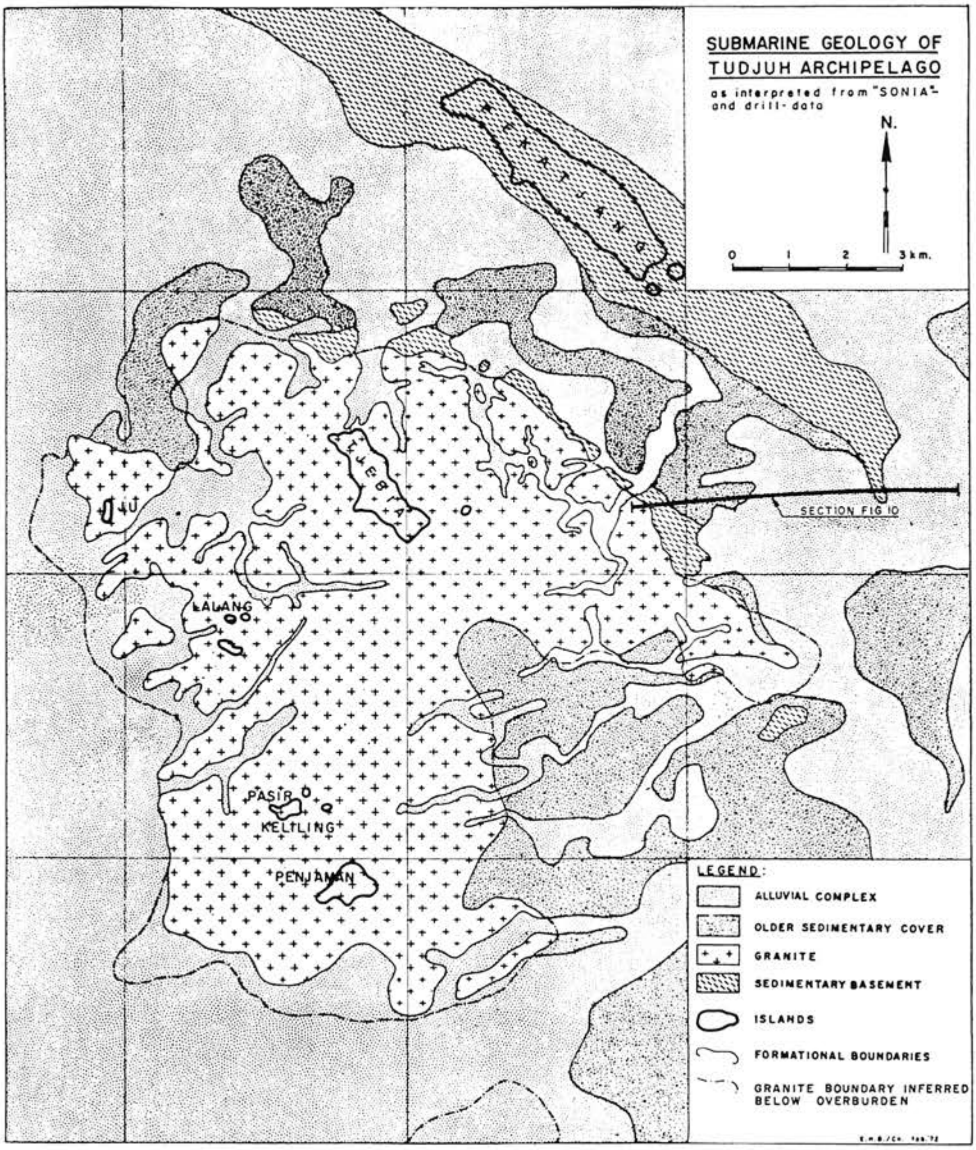

Fig. 5. Submarine geological map of the Tjebia granite, Tudjuh Islands.

The offshore extension of the Karimata granite proved to be negligibly small (fig. 6).

b. *Sedimentary basement.* The folded sedimentary formation appears on the sonogram as a bottomless mass with vague parallel echo-traces, indicating dips in the stratification of up to 50°. More massive formations, without bedding traces,

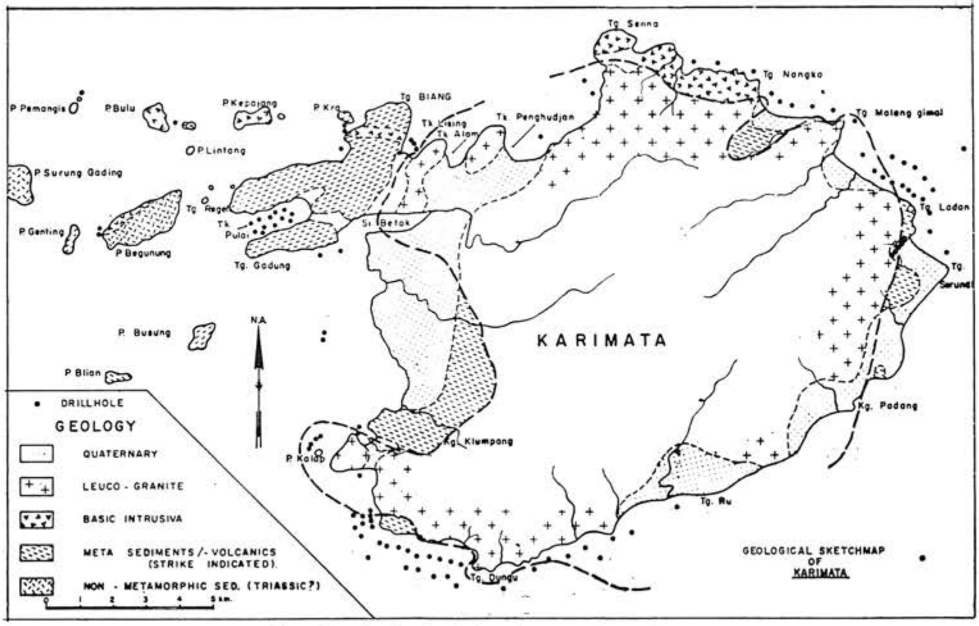

Fig. 6. Geological sketch map of Karimata.

can be easily confused with granite. This is especially the case in the Karimata Archipelago where the sedimentary country rock is often strongly metamorphosed. In the central parts of the Tudjuh concession, the information about the basement surface is very spotty; however, wherever this surface is visible its maximum depth below the present sea level does not exceed 100 m.

Where there is no cover of younger sediments, a characteristic feature of the basement is its irregular surface, with often steep slopes. This is especially the case in some deep channels near the islands, which must be caused by tidal scouring (fig. 4).

The Sedimentary Cover

Three sedimentary episodes have been distinguished in the area:

a. the "Older Sedimentary Cover",
b. the "Alluvial Complex",
c. the "Younger Sedimentary Cover",

while (c), and possibly also (a) are underlain by an erosional surface.

a. The "*Older Sedimentary Cover*" occurs over the major part of the Tudjuh concession area. On the sonogram the formation appears as a fairly constant, sparsely bedded, subhorizontal mass of rather massive appearance. Where this cover has been sampled by drilling, it consists mostly of rather massive clayey sand with intercalations of peat. This, together with the complete absence of marine fossils, indicates a terrestrial origin. Pollen separated from the peat layers indicate a Miocene-Pliocene age.*)

*Oral communication from W.O. Tichler, Koninklijke Shell Exploratie & Productie Laboratorium Rijswijk, Netherlands.

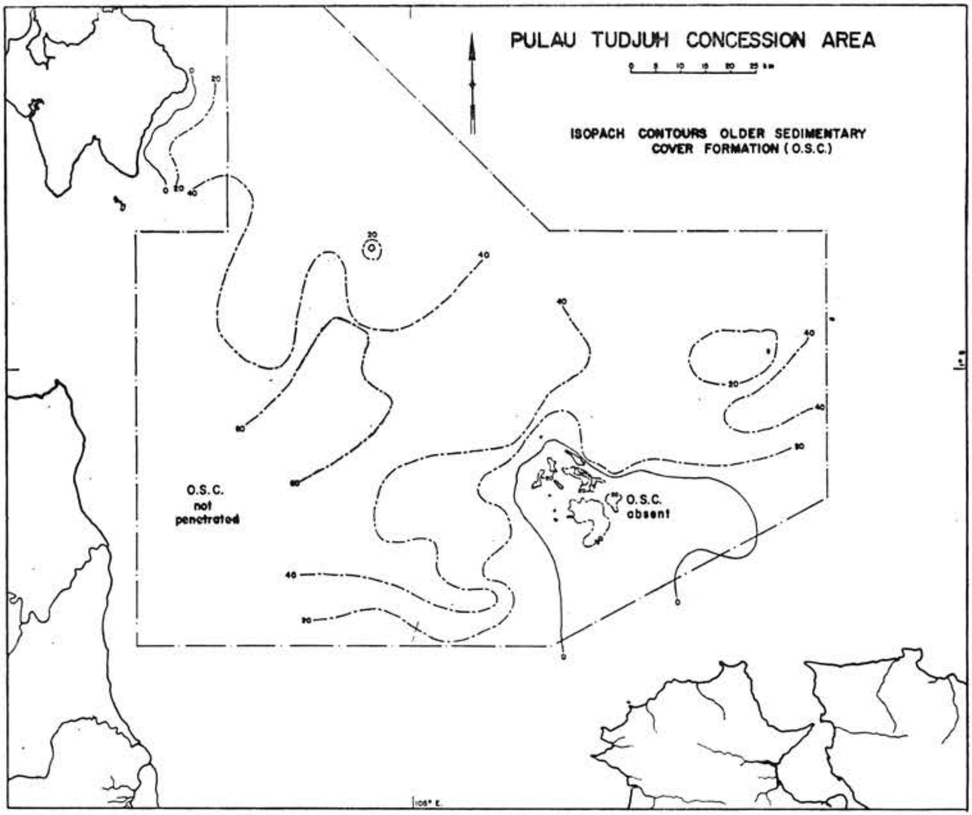

Fig. 7. Generalized isopachs of the Older Sedimentary Cover, Tudjuh area.

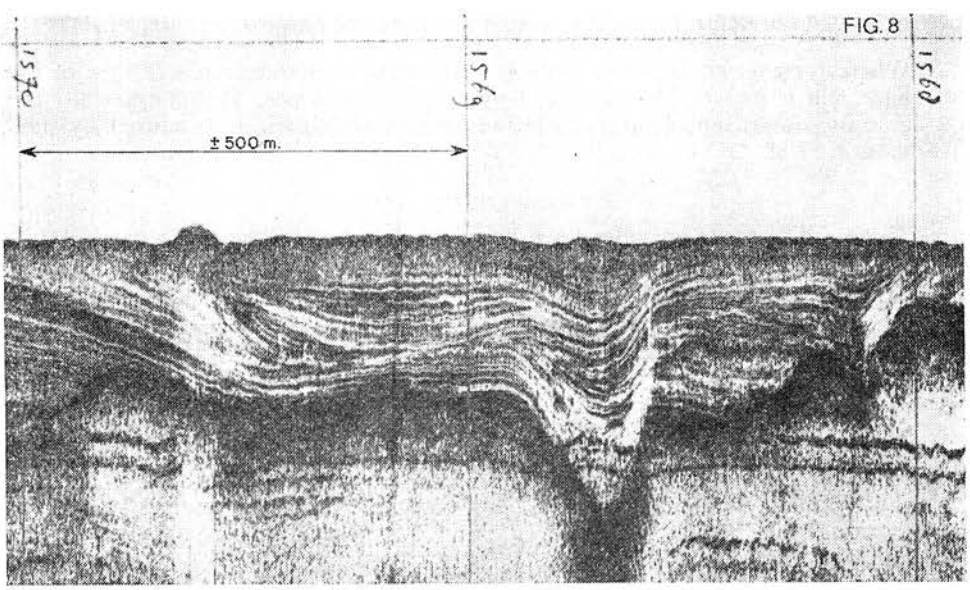

Fig. 8. Alluvial Complex: Gully, filled with well layered deposits, incised in subhorizontal sedimentary bedrock. Reproduction of sonogram, Karimata. (Vertical exaggeration about 10x).

In the central parts the thickness of this cover may be over 100 m, while it wedges out completely in the Tudjuh Archipelago, on Singkep and on Bangka where the granitic or sedimentary bedrock approaches the surface (fig. 7). Fig. 10 is a tracing of a sonogram where the subhorizontal "older" sediments can be seen to wedge out and slope upwards against uprisings of the bedrock surface. The bedrock surface dips downwards below the sediments at a true angle of about 5°, which, if constant, would indicate a maximum bedrock depth in between both uprisings of about 80 m.

b. The "*Alluvial Complex*" is the name given to an extensive system of complicated valleys and depressions, incised in the "Older Sedimentary Cover" and in the basement, reaching depths of 60–100 m below the present sea level (fig. 8). It is made up of a series of largely sandy layers, locally with peat intercalations. The sonograms show strong variations in depth of the fossil valley bottoms. Repeated erosion phases and infilling of incised gullies appear to have taken place; although too complex to be fully unraveled with the available density of SONIA profiles, it is clear that during the formation of the "Alluvial Complex" repeated vertical movements of the erosional base level took place. Besides, there are some indications of small scale block movements and tilting which produced sediment filled depressions.

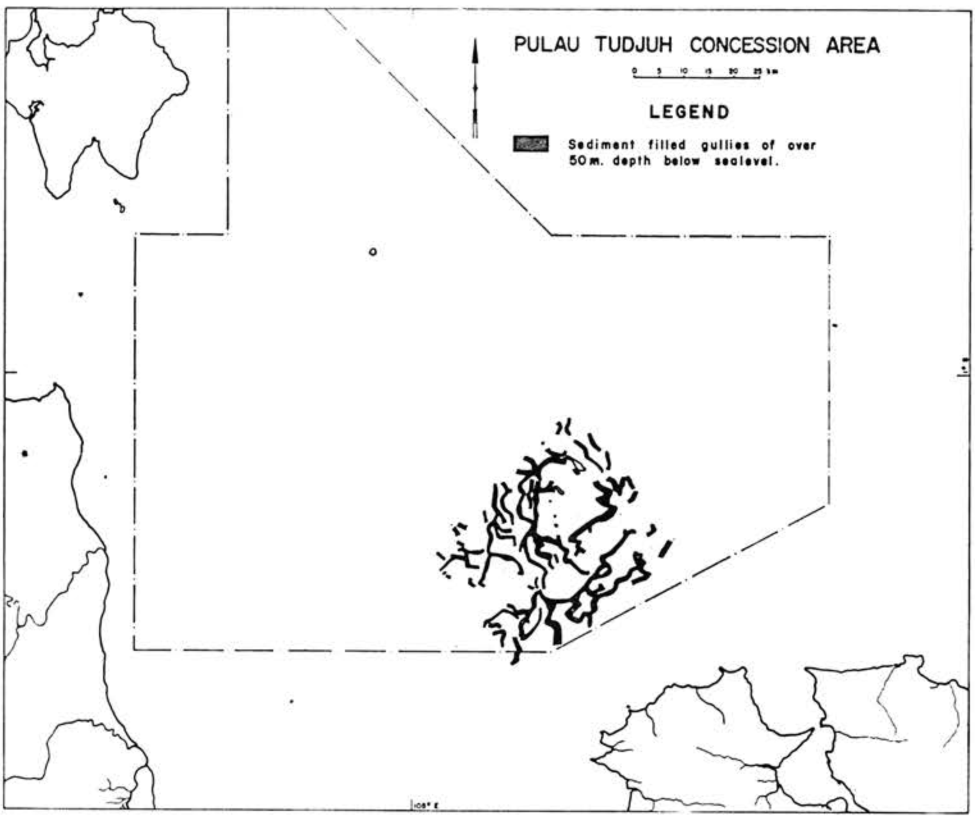

Fig. 9. Pattern of deep, sediment-filled gullies around the Tudjuh Islands.

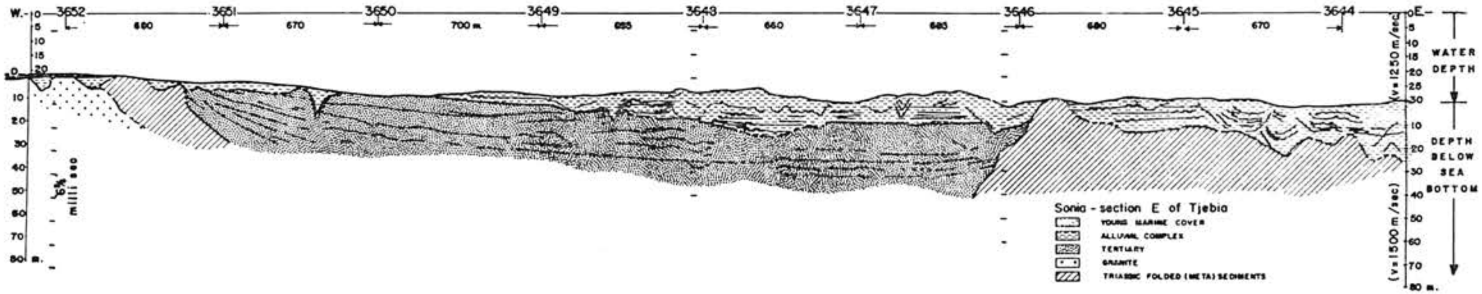

Fig. 10. Sonia Section E. of Tjebia (Tudjuh Islands).

The deepest channels around the Tudjuh Islands were mapped (fig. 9). Their pattern is not consistent with a river pattern. They may be explained as filled-in tidal scour channels.

Generally the "Alluvial Complex" and the "Older Sedimentary Cover" can be easily distinguished on the sonogram. However, preliminary palynological study did not give a clear indication of a difference in age. Drill cores indicate a rather similar lithology.

c. The "*Younger Sedimentary Cover*" is a flat-lying blanket-like formation of up to 20 m thickness, consisting predominantly of a soft greenish-grey mud, rich in shell fragments; plant or wood remains are occasionally present. It forms the present seabottom in most of the studied area (fig. 11).

In some places a layering can be observed in the Younger Sedimentary Cover, with very slight dips, varying from 1:100 to 1:500. This layering dips to the east in the western part of the Tudjuh Area and to the southwest in the Karimata area. This indicates that the fine clastics were derived from Sumatra in the first area and from Kalimantan (Borneo) in the second area.

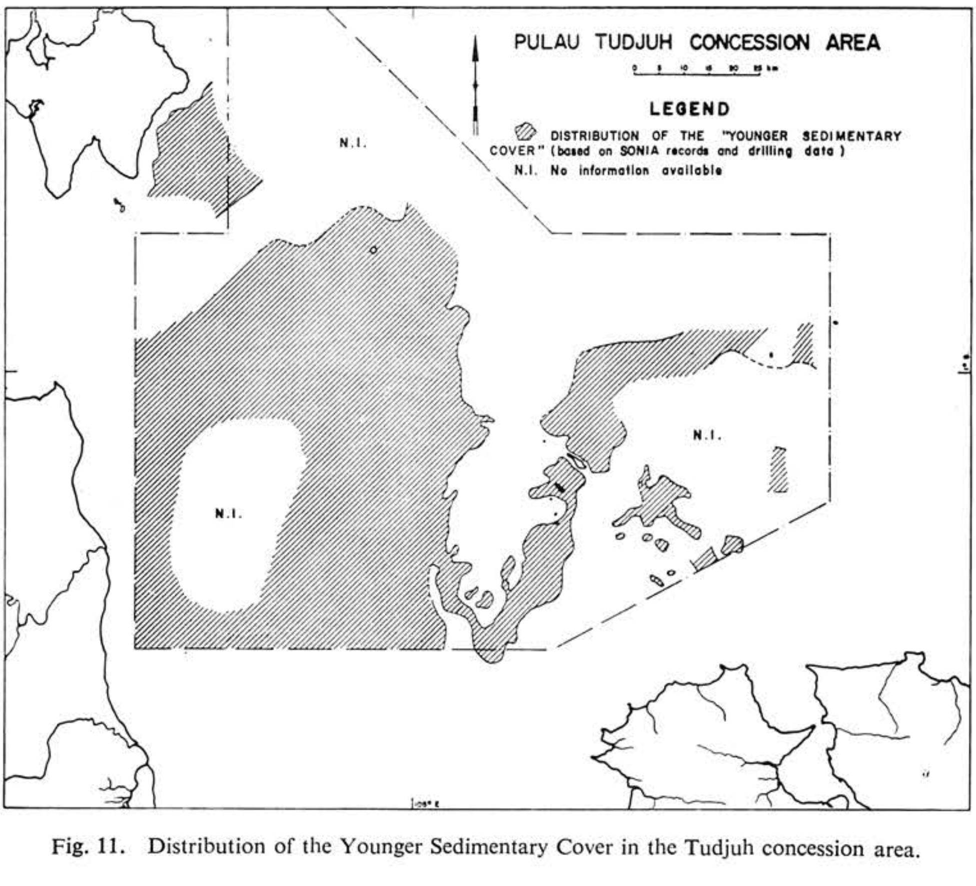

Fig. 11. Distribution of the Younger Sedimentary Cover in the Tudjuh concession area.

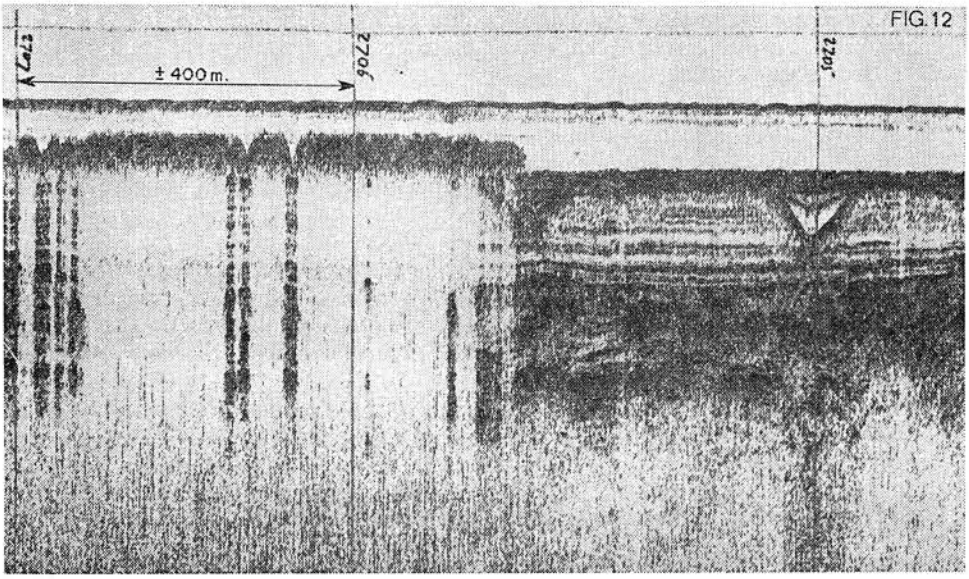

Fig. 12. Fossil coral reef, embedded in the Younger Sedimentary Cover (Reproduction of sonogram, Karimata). (Vertical exaggeration about 10x).

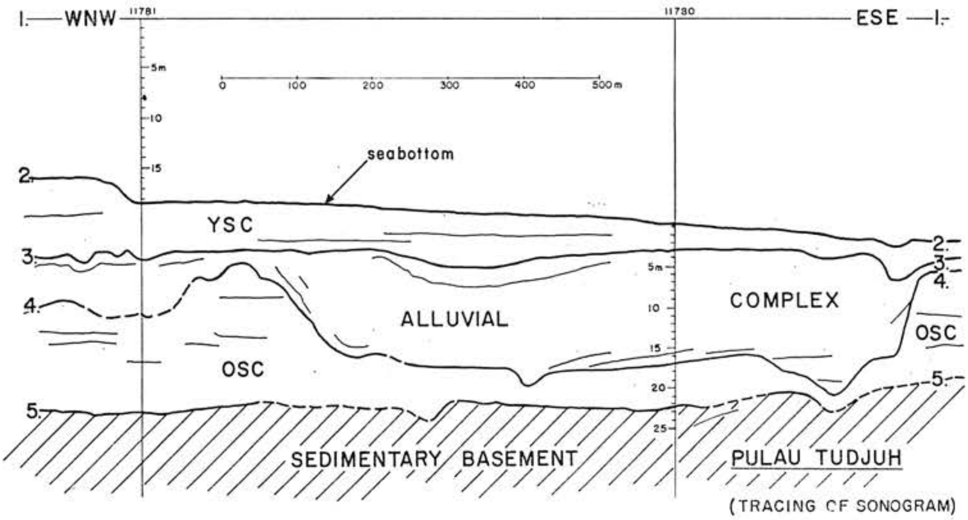

Fig. 13. Tracing of sonogram, showing the relationship between the Alluvial Complex and the Sedimentary Covers.

YSC = Younger Sedimentary Cover
OSC = Older Sedimentary Cover
1 — Sea Surface
2 — Sea bottom
3 — Upper Planation Surface
4 — Base of Alluvial Complex
5 — Lower Erosional Surface

In some places fossil coral reefs are present, which are embedded in the Younger Sedimentary Cover (fig. 12). Locally, mega-ripples or submarine "dunes" occur on the seabottom (fig. 13). At the base of the Younger Sedimentary Cover, which lies at depths of 20–30 m below the present sea level, a layer of tough, spotty red clay is often found, suggesting a period of desiccation and oxidation caused by emergence and subsequent soil formation. The occurrence of peat immediately above or below the red clay also indicates a terrestrial origin. The reddish clay layer was also found in places where the Younger Sedimentary Cover is absent, in which case it occurs as a thin horizon capping the the Alluvial Complex or even the sedimentary basement. The layer cannot be distinguished on the sonogram, its occurrence being known from drilling results.

Recurring Levels

Two erosional surfaces of regional extent could be distinguished in the Tudjuh area.

Away from the islands the older surface, which constitutes the top of the basement, generally dips to an untraceable depth. However, the scant information available would suggest a rather flat morphology. It is unlikely that in the Tudjuh area its depth would greatly exceed 100 m (fig. 10).

The second, younger, surface, occurring at a depth of 20–30 m below sea level, is remarkably uniform throughout the whole Tudjuh area and recurs again in the Karimata area. It truncates all the older formations with the exception of the present-day islands and their immediate surroundings. It is very flat, except for a few depressions not more than 10 m deep. The uniform depth and flatness of this surface indicate that it is a marine abrasion surface. The shallow depressions indicate a fluviatile system which started to develop on this surface prior to its final submergence and the deposition of the Younger Sedimentary Cover. This valley system radiates away from the islands; elsewhere it has a northerly to northwesterly trend.

Summary and Conclusions

Summarizing, the following succession, from top to bottom, can be distinguished (see also fig. 14):

Younger Sedimentary Cover: mainly soft marine clays;

Marine Abrasion Surface: now at a depth of 20–30 m;

Alluvial Complex: clay and sand layers with intercalations of peat, deposited in intersecting valley systems;

Older Sedimentary Cover: subhorizontal, rather massive sandy formation, probably terrestrial; peat layers near the top;

Older Erosional Surface: now at 30 m to unknown depth, but probably not much more than 100 m;

Basement rocks: deeply chemically weathered granite intrusions in folded, locally metamorphosed, sedimentary rocks, mainly consisting of sandstones and shales.

When this succession is compared with the regional geological history as summarized by van Bemmelen (*op.cit.*). It seems reasonable to attribute the "Older Surface" to the long period of peneplanation of the "Sunda Peneplain". The lower part of the "Older Sedimentary Cover" may then be correlated with the terrestrial Lower Tertiary, deposited on the lower parts of this surface.

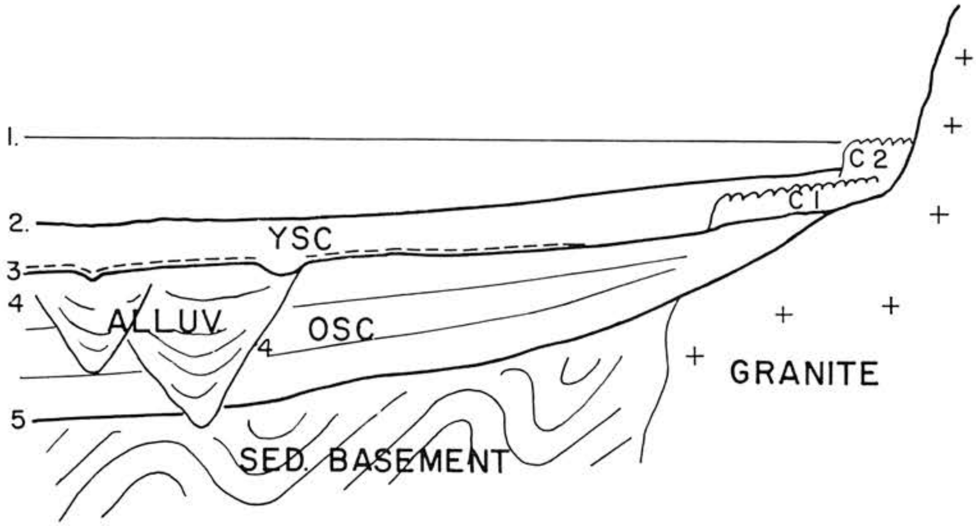

Fig. 14. Schematic section (vertical exaggeration about 10x), showing the relationship between the rock-units described in the text.

ALLUV. = Alluvial Complex
Stippled: Red clays
C_1 = Fossil coral
C_2 = Recent coral

Van Bemmelen's view, that during the Tertiary and Quaternary the Sunda land was subjected to strong vertical oscillations, tilting and warping, agrees well with the considerable variations in the erosional base of the "Alluvial Complex" and with the noted small-scale block movements and flexures.

The upper planation surface may have been formed by marine abrasion, which must have taken place after the termination of the tectonic movements, as this surface lies at nearly equal depth throughout the Tudjuh and Karimata areas.

As indicated by the widespread occurrence of the red clay, this surface has subsequently emerged. It would seem possible to correlate this event with the last glaciation and the previous marine abrasion with the interglacial period preceding it, during which period the sea level should have remained stationary for some time at about 20 m below the present sea-level.

The post-glacial transgression covered the whole of the studied area with the exception of the present small islands which must have constituted elevated areas ever since the beginning of the Tertiary.

These considerations would indicate the following timetable:

Younger Sedimentary Cover	—	Holocene to recent
Red Clay formation	—	Würm Glacial
Younger Planation Surface	—	Riss-Würm Interglacial
Alluvial Complex	—	Upper Tertiary to Pleistocene

Older Sedimentary Cover	—	Tertiary
Older Planation Surface	—	Cretaceous?
Granitic bedrock	—	Jurassic?
Folded Sedimentary Bedrock	—	Triassic (and older?)

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