

BULLETIN

of the

Geological Survey of Indonesia

K. Kusumadinata, Editor
S. Wirjosujono, Assistant Editor

V. 4

April, 1978

n. 1

Page

CONTENTS

- | | |
|---------|--|
| 1 - 28 | <i>T. Sato, G.E.G. Westermann, S.K. Skwarko & F. Hasibuan</i>
Jurassic Biostratigraphy of the Sula Islands, Indonesia |
| 29 - 47 | <i>M.K. Adisaputra-Sudinta, R. Smit & E.J. van Vessem</i>
<i>Miogypsina cushmani</i> and <i>Miogypsina antillea</i> from
Jatirogo (East Java) |
| 49 - 63 | <i>S. Tjokrosoetro</i>
Holocene tectonics on Timor Island, Indonesia |
| 65 - 69 | <i>T. Suyitno</i>
Depositional pattern of coastal sand bars and the
formation of iron sand deposit in the Cilacap area as
interpreted from aerial photographs |

DIREKTORAT GEOLOGI
DIREKTORAT JENDERAL PERTAMBANGAN UMUM
DEPARTEMEN PERTAMBANGAN DAN ENERSI

1 9 7 8

JURASSIC BIOSTRATIGRAPHY OF THE SULA ISLANDS, INDONESIA

by

T. Sato ¹⁾, G.E.G. Westermann ²⁾, S.K. Skwarko ³⁾, & F. Hasibuan ⁴⁾

S A R I

Pemetaan terperinci endapan Jura dalam 14 sungai serta lintasan aliran di Kepulauan Sula, Indonesia, dipadukan dengan penanggalan kandungan fosil – terutama amonit – telah memaparkan suatu carta korelasi lokal yang dapat dikorelasikan dengan kolom Jura yang direferensikan sejagat.

Penampang yang kaya fosil Jura, tebalnya boleh jadi kurang dari 1.500 m, mengandung beberapa konglomerat dan batupasir, namun terutama dibangun oleh serpih gampingan dengan atau tanpa konkresi fosil, telah dibagi dalam 5 kesatuan, yang umurnya berkisar antara Thouars Akhir hingga Thiton Akhir. Namun, seluruh Aalen dan Callovian Tengah Atas tidak ditemukan, sedang bukti untuk Bath tetap sedikit.

Penelitian ulang dari lokasi fosil klasik – dan penelitian baru – pada beberapa lokasi menunjukkan, bahwa batupasir Thouars Atas dengan *Hammatoceras* ditindih oleh serpih napalan mikaan tebal berfauna Bayen Awal (ump. *Fontannesia*) dan Akhir (ump. *Caumontisphinctes*). Bukti adanya jenjang Aalenian tidak ditemukan. Batulempung napalan berkongresi, sangat tebal, bagian bawahnya ditandai oleh Fauna Keeuw berumur Callovian Awal seperti *Macrocephalites*, *Oxycerites*, *Kheraicerus*, *Cadomites* dan yang lainnya. Bagian atasnya dicirikan oleh Fauna Wai Galo yang terdiri dari kumpulan Mayaitidae–*Perisphinctes* berumur Oxford awal dan kumpulan Mayaitidae–*Perisphinctes* yang berumur Oxford tengah. Bukti adanya Bath dan Callovian lebih atas tidak ditemukan. Jenjang Kimmeridge – Thiton lempungan dan tebal, secara keseluruhan termasuk ke dalam fasies belemnite–bivalvia seperti *Belemnopsis*, *Inoceramus* dan *Malayomaorica*. Batulempung berumur Thiton Atas ternyata kaya pula akan fauna amonit, di antaranya *Haplophylloceras* dan *Blanfordiceras*.

ABSTRACT

Detailed mapping of Jurassic sediments in 14 river and stream traverses in the Sula Islands, Indonesia, combined with dating by contained fossils – mainly ammonites – has established a local correlation chart that can be correlated with the world reference Jurassic column.

The richly fossiliferous Jurassic section is probably less than 1500 m thick, contains some conglomerate and sandstone, but is mainly made up of calcareous shale, with or without fossiliferous concretions; it has been subdivided into five units, which range in age from late Toarcian to late Tithonian. However, the entire Aalenian and middle–upper Callovian are missing, and evidence for the Bathonian remains poor.

The re-examination of the classic – and examination of some new – fossil localities showed that the upper Toarcian sandstone with *Hammatoceras* is overlain by thick micaceous marly shale with early (e.g. *Fontannesia*) and late (e.g. *Caumontisphinctes*) Bajocian faunas; the lower part of the overlying thick marly claystone with concretions contains the famous early Callovian 'Keeuw fauna' (e.g. *Macrocephalites*, *Oxycerites*, *Kheraicerus*, *Cadomites*); in the upper part the well-known 'Wai Galo fauna' consists of an early Oxfordian Mayaitidae–*Peltomorphites* assemblage, and a middle Oxfordian Mayaitidae–*Perisphinctes* assemblage; there is no new evidence for Bathonian and no evidence for middle–late Callovian. The thick Kimmeridgian–middle Tithonian argillaceous sequence is entirely in the belemnite–bivalve (*Belemnopsis*, *Inoceramus*, *Buchia*, *Malayomaorica*) facies, but the upper Tithonian claystone again bears a rich ammonite (e.g. *Haplophylloceras*, *Blanfordiceras*) fauna.

- 1) Institute of Geoscience, University of Tsukuba, Ibaraki, Japan
- 2) Department of Geology, McMaster University, Hamilton, Ontario, Canada
- 3) Bureau of Mineral Resources, Canberra, A.C.T., Australia
- 4) Geological Survey of Indonesia

INTRODUCTION

The Jurassic sediments in the Sula Islands contain one of the richest and best preserved molluscan fauna known in Indonesia. The discovery of the fauna goes back to Rumphius' records of 1705 (Rumphius Gedenkboek, 1902) which stimulated later geological expeditions such as that of Verbeek in 1899 to the eastern Moluccas (Verbeek, 1908). The first, systematic collecting of fossils was by Boehm in 1900. His important monographs on the Middle and Late Jurassic ammonites, bivalves, belemnites and brachiopods in the Sula Islands (Boehm, 1904a, 1904b, 1907a, 1907b, 1912) were later supplemented with papers on the Early Jurassic and on other faunas by Cloos (1916), Jaworski (1921), Krusinga (1921, 1926), and Stolley (1929). Arkell (1954), Westermann (1956), and Westermann & Getty (1970) have reviewed these faunas.

In every case the fossils were collected without strict stratigraphic control; none of the above works included detailed stratigraphic data. When Wanner (1931) subdivided the Jurassic sequence into eight 'formations', he did so by indirect correlation with the European stages using ammonites and other contained fossils, and on the basis of previous workers' observations of exposures that were usually isolated from each other. Arkell's (1956) comments on the ammonite zonation are also entirely based on published data.

In terms of faunal affinities, the Sula Islands occupy a key position between New Guinea, New Caledonia, New Zealand and Antarctica on the one hand and Southeast Asia on the other. An expedition was therefore planned to re-collect fossils from Boehm's classic sites and other outcrops, and to make as many as possible detailed stratigraphic observations to enable to unravel the local stratigraphic sequence.

The expedition was organized and led by Westermann, included Sato and Skwarko, and Hasibuan. The survey was carried out between 6 and 24 September, 1976 from a 30 m motor-

ship *Damai*, chartered from Bitung in northern Sulawesi.

The expedition was largely financed by the National Research Council of Canada, and the Science and Engineering Research Board, McMaster University. Additional financial aid came from the University of Tsukuba, and Yoshida Foundation, Tokyo. Mr Salman Padmanagara, Director of the Geological Survey of Indonesia (GSI), permitted and supported the expedition; and Mr Rab Sukamto Kartomihardjo, of the mapping division (GSI), provided much information, partly unpublished. The Indonesian Embassy in Ottawa proved most helpful. Dr. Ralph Imlay of the US Geological Survey supplied a report on the Jurassic ammonites collected by the recent joint Indonesia-USA reconnaissance mapping of the islands. The PT Mangole Timber Producer (Mangtip) Company operating along the northern Mangole, through the courtesy of its president, Mr S. Kawahara, made available vehicles, which greatly facilitated the survey. We wish to express sincere thanks to all those persons and organizations for making this expedition possible.

Thanks are also due to Dr J. Thierry of the University of Dijon, France; Professor C.W. Drooger and Dr C.G. Rümke of the University of Utrecht; and Dr J.H. Werner of the University of Amsterdam, Holland, for advice and permission to inspect ammonite collections from many parts of the world, in particular the surviving earlier collections from the Sula Islands, and for making available from their collections Indonesian belemnites for comparative study.

The biostratigraphy of the Sula Islands Jurassic is presented briefly in this paper. Certain conclusions have been reached regarding the associations and the succession of the ammonites. However, the identification of bivalves and belemnites remains preliminary, dependant as they are on their occurrence in the New Zealand Jurassic, the type sections of which are currently being re-examined by G. Stevens. Broad correlation is outside the scope of the present paper; as are the systematic descriptions of all the faunas,

which will be undertaken by the individual contributors at a later stage.

One of the authors (SKS) has received permission to publish this paper from the Director, Bureau of Mineral Resources, Canberra, Australia.

GENERAL AND GEOLOGICAL SETTING

The Sula Islands, which are part of the northern Moluccas island arc, are situated between 124° and 126°E, at about 2°S in the Moluccas Sea, east of Sulawesi. There are three major islands; Taliabu and Mangoli aligned east-west, and Sulabesar north-south (Fig. 1).

Geologically, the islands are made up of basement rocks largely covered by a veneer of essentially flat-lying Jurassic and younger sediments. The basement is made up of granite and metamorphic rocks possibly of Late Palaeozoic and Triassic age, and crops out along the main ridge of Taliabu, on the south coast of Mangole, and in Sulabesar. The Jurassic rocks are more widespread, are less than 1500 m thick, have a basal conglomerate which passes up into sandstone, but mainly consist of claystone and shale (see below). They dip rarely more than 20°, and in places are normally faulted in east-west direction. They are gently folded in an WNW-ESE direction in northern Taliabu, and east-west in northern Mangole. In the central part of the south coast of Taliabu they are gently tilted to the south, and seem to be isolated from all other Jurassic sediments. The passage of Jurassic beds into the overlying Cretaceous sediments has not been observed.

In the past, Brouwer (1921, 1926) subdivided the Jurassic sediments of the Sula Islands into the lower sandy and conglomeratic beds, and the upper clayey and marly beds. The general geology of the islands was summarised by van Bemmelen (1970, p. 380-382). More recently Sukanto (1975a, 1975b) reported on reconnaissance mapping of the islands.

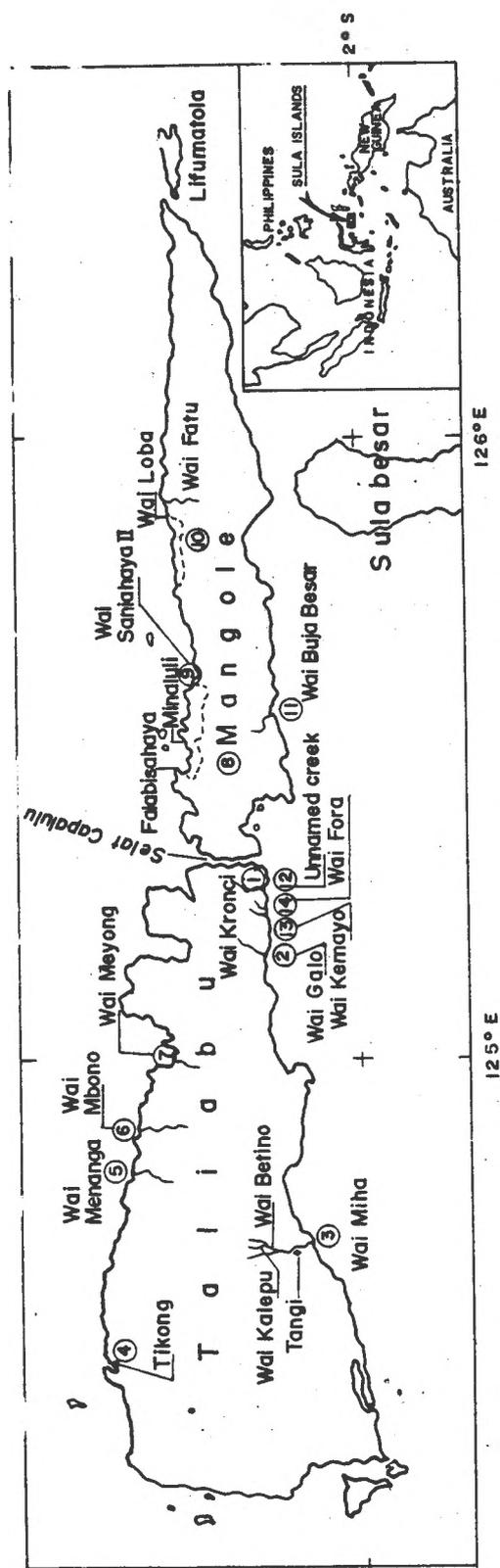


Fig. 1. Location of traverses

TRAVERSES

Fourteen traverses were undertaken, mainly along the stream and river beds which provided the best access inland — and the best exposures. The location of the traverses is shown in Figure 1, and relationship to one another in a correlation chart (Fig. 8). Some traverses encountered few outcrops; others, where outcrops were plentiful, were measured by Sato using the compass-and-pacing method. The Jurassic sediments — except for

some sandy beds — are very fossiliferous. The preliminary identification of ammonites, both in the field and later, were made by Westermann; and of bivalves and belemnites by Skwarko.

1. Wai Kronci (Fig. 2)

Wai Kronci flows from eastern Taliabu into the strait of Tjapalulu (Fig. 2). It is about 5 km south of Wai Lagoi, along which Boehm (1904b, 1907) collected fossils from the Jurassic-Cretaceous boundary. The succession is as follows :

Locality No.	Thickness (m)	Lithology	Fossils
1 A3	>7		<i>Haplophylloceras strigile</i> (Blanf.) <i>Blanfordiceras cf. wallichi</i> (Gray)
1 A1	—		<i>Haplophylloceras strigile</i> (Blanf.) <i>Blanfordiceras cf. wallichi</i> (Gray) <i>Belemnopsis</i> sp.
1 A2	>12	grey marly shale, with hard calcareous concretions	<i>Haplophylloceras strigile</i> (Blanf.) <i>Blanfordiceras cf. wallichi</i> (Gray) δ ? <i>Torquatisphinctes</i> ? sp. <i>Belemnopsis</i> sp.
Relation unknown			
1 C1 } 1 C2	20	silty shale, flaky when weathered, with highly calcareous concretions, and <i>Inoceramus</i> bands	<i>Inoceramus</i> sp. <i>Belemnopsis aucklandica aucklandica</i> (Stevens) <i>B. alfurica</i> (Boehm) <i>Belemnopsis</i> sp.
lack of exposure, 8 m			
1 B1 } 1 B2	18	as above	<i>Inoceramus haasti</i> (Hochstetter) <i>Malayomaorica malayomaorica</i> (Krumbeck) <i>Belemnopsis</i> sp.

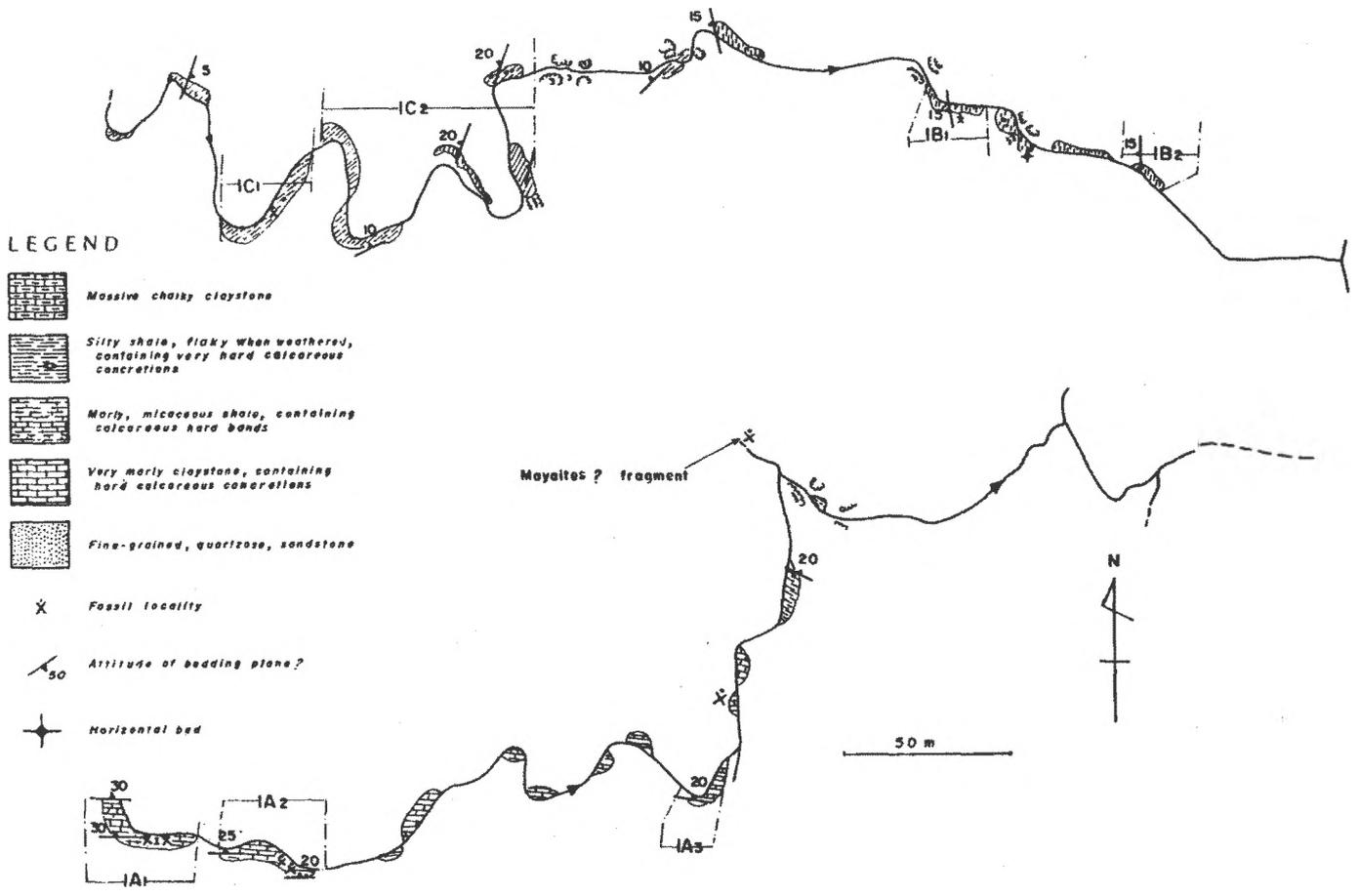


Fig. 2. Wai Kronci traverse

2. *Wai Galo* (Fig. 3)

The famous *Wai Galo*, from which so many of Boehm's type specimens came, enters the sea on the southeast coast of Taliabu (Fig. 2). The exposures are discontinuous, both in the river-

bank and in the river bed itself, the first outcrop – in Jurassic sandstone – being about 1 km from the river mouth. Fossils occur abundantly in the calcareous concretions, but some were also found in the enclosing marly shale. The succession is as follows (see also Fig. 3) :

Locality No.	Thickness (m)	Lithology	Fossils
2 A	> 17	grey marly shale with slumping beds	<i>Buchia</i> sp. nov. B <i>Belemnites</i> indet.
2 B	> 40	silty mudstone, flaky when weathered, with calcareous concretions	<i>Inoceramus</i> sp. <i>Belemnites</i> indet. <i>Inoceramus haasti</i> (Hochstetter) <i>Malayomaorica malayomaorica</i> (Krumbeck) <i>Buchia</i> sp.
lack of exposure			
2 D	25	silty mudstone, flaky when weathered, more marly in lower horizons	<i>Belemnopsis sularum</i> (Boehm) <i>B. aucklandica aucklandica</i> Stevens <i>Inoceramus galoi</i> Boehm ? <i>M. malayomaorica</i> (Krumbeck) <i>Bivalves</i> indet.
2 E	lack of exposure		
2 F	<i>Phylloceras</i> sp. <i>Calliphylloceras</i> ? sp. <i>Perisphinctes (Kranaosphinctes)</i> cf. <i>burui</i> Boehm <i>Idoceras</i> ? sp. <i>Belemnites</i> sp. <i>Inoceramus galoi</i> Boehm <i>I. subhaasti</i> Wandel ?		

2G			<p>[<i>Mayaites (Epimayaites) aff. palmarum</i> (Boehm) <i>Calliphylloceras cf. malayanum</i> (Boehm) <i>Inoceramus sp.</i>] *</p>
2H	> 53	grey marly claystone, with hard calcareous concretions	<p>[<i>Mayaites (Epimayaites) cf. rotangi</i> (Boehm) <i>M. (E.) cf. palmarum</i> <i>Paryphoceras cf. cocosi</i> (Boehm) <i>Inoceramus sp.</i>] *</p>

* Forms in square brackets were float

2 J,L,M			<p><i>Peltoceratoides (Peltomorphites)</i> <i>tjapalului</i> (Boehm) ♀ <i>P. (Parawedekindia) aff.</i> <i>arduennensis</i> (d'Orb.) ♂ <i>Euaspidoceras ? sp.</i> <i>Mayaites (Epimayaites) aff.</i> <i>palmarum</i> to <i>rotangi</i> (Boehm) <i>M. (Paryphoceras ?) cf. sinuatus</i> (Spath) Belemnites indet. Crustacea indet.</p>
2 K			<p><i>Peltoceratoides (Peltomorphites)</i> <i>tjapalului</i> (Boehm) ♀ <i>P. (Parawedekindia) aff. arduennensis</i> (d'Orb.) ♂ Belemnites indet.</p>

lack of exposure

10	massive fine-grained quartzose sandstone, grains well sorted, subrounded
----	---

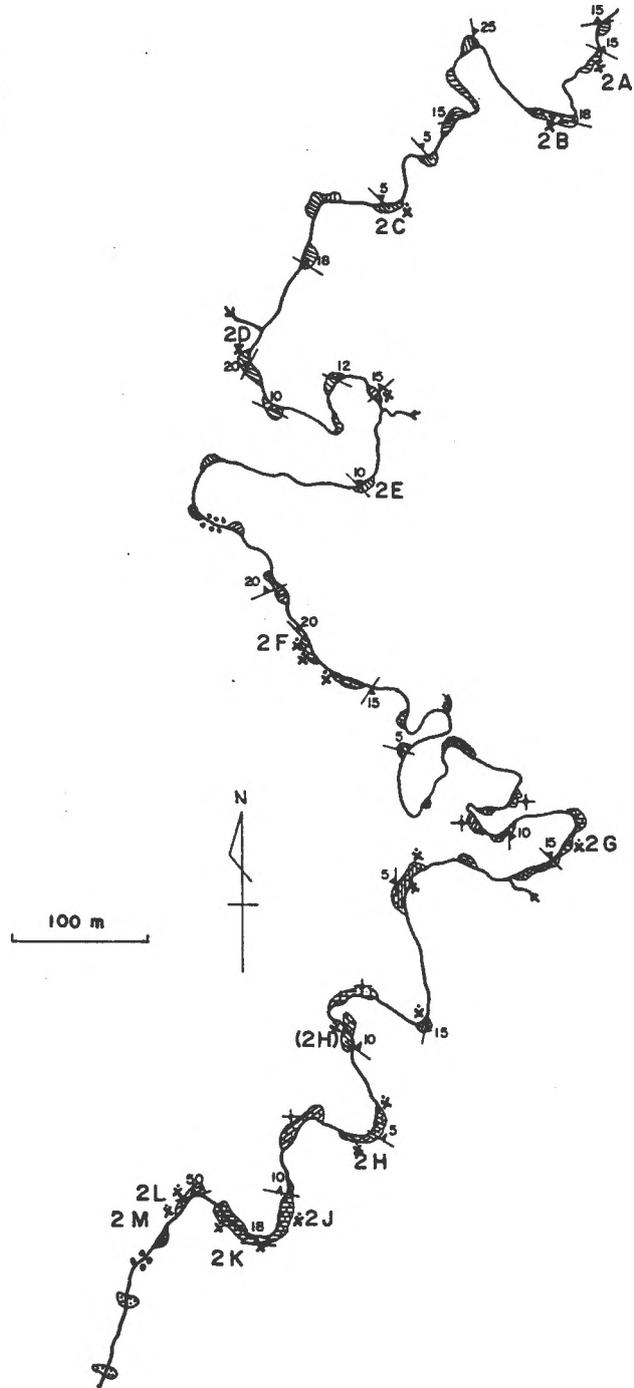


Fig. 3. Wai Galo traverse (for explanation see the legend on Fig. 2)

The following specimens were collected as float in the river-bed :

Mayaites (Epimayaites) cf. rotangi (Boehm)
M. (E.) cf. batavoindicus (Boehm)
M. (E.) cf. palmarum (Boehm)
Paryphoceras cf. sinuatus (Spath)
Prograyiceras cf. bambusae (Boehm)
Perisphinctes (Kranaosphinctes) cf. burui (Boehm)
P. (K.) sularum (Boehm)
Calliphylloceras malayanum (Boehm)

3. Wai Miha and tributaries (Fig. 4)

Wai Miha is a relatively long river which together with its tributaries drains a large part of Taliabu before flowing into the sea. There are only a few exposures along the main river channel but its tributary, Wai Betino, together with its own tributary, Wai Kalepu, were traversed and partly mapped. (Wai Kalepu yielded a rich new early Callovian fossil assemblage near its mouth).

Boehm's (1912) localities of 'Tangi' and 'Keeuw' were on the Wai Miha itself. Keeuw could not be located. Boehm (1912, p. 124) reported it on the western bank of the Betino river at its mouth. Later (p.171), however, he described it as stretching from about 900 m below the mouth of the Betino along the western bank of Wai Miha

to approximately 700 m upstream along the left bank of the Betino, i.e. a total of about 1600 m of outcrop. The recent visit revealed, however, that most of the left bank of Wai Miha is hidden under braided stream deposits, while the small remaining outcrops within 100 m of the mouth of Betino are unfossiliferous. The sporadic exposures along the lower Wai Betino yielded good Callovian ammonite faunas only about 240 to 280 m above the river mouth, and it is therefore assumed that many changes have taken place along the Wai Betino during the last seventy-five years. The current outcrops near the mouth of the Betino appear to be Late Jurassic in age and no evidence for the Bathonian age has been obtained.

Tangi lies in the middle course of the Wai Miha, but the exposures found were discontinuous and isolated. The best outcrop, and one with a modest early Callovian fauna, is 1 km north of Tangi. A gravel bar has backflooded the lower course of the Wai Kempa at Tangi submerging its lower banks and with them the old collecting sites.

The isolated Jurassic outcrops of the whole of this area can be correlated with other sections only by means of fossils. Separate descriptions of the biostratigraphy are given below for Wai Betino, Wai Kalepu, and Wai Miha :

Wai Betino

Locality No.	Thickness (m)	Lithology	Fossils
3 E4	>10	bluish grey silty shale with alternating color banding	<i>Inoceramus</i> sp. <i>Malayomaorica malayomaorica</i> (Krumbeck) <i>Belemnopsis alfurica</i> (Boehm) <i>B. aucklandica aucklandica</i> Stevens
3 E3			<i>Inoceramus galoi</i> Boehm <i>Buchia</i> sp. nov. A <i>M. malayomaorica</i> (Krumbeck) <i>Oxytoma</i> ? sp.

lack of exposure			
3 E ₂	25	marly siltstone, with green thin band at the base	<i>Inoceramus</i> sp.
3 E ₁			<i>Malayomaorica</i> ? sp. <i>Belemnopsis alfurica</i> (Boehm) ? <i>B. aucklandica aucklandica</i> Stevens
3 D	15	marly shale	Macrocephalitidae indet.
3 C	>3	marly shale	Oppeliidae indet. [<i>Ochetoceras</i> ? , <i>Oecotraustes</i> , or <i>Paroecotraustes</i>] Macrocephalitidae ? indet. <i>Bositra</i> sp. Belemnites indet.
relation unknown			
3 A	10 \pm	bluish grey marly shale, with calcareous concretions and septaria	Macrocephalitidae fragment indet. <i>Posidonia</i> sp. <i>Belemnopsis</i> sp.
3 B ₂	9	marly claystone, with calcareous concretions	<i>Holcophylloceras</i> sp. <i>Macrocephalites (Macrocephalites)</i> <i>formosus mantataranus</i> (Boehm) <i>M. (Indocephalites) chrysooliticus</i> (Waagen)
3 B ₁			<i>M. apertus</i> (Spath) Perisphinctid indet. <i>Oxycerites</i> ? cf. <i>marmertensis</i> <i>O.</i> ? cf. <i>subcostarius</i> <i>Bositra</i> sp. <i>Inoceramus</i> sp. Belemnites indet.

Wai Kalepu

Locality No.	Thickness (m)	Lithology	Fossils
3 F ₁	4		<i>Macrocephalites (Macrocephalites) formosus</i> cf. <i>formosus</i> (Sow.) <i>M. (M.) formosus</i> cf. <i>mantataranus</i> (Boehm)
3 F ₂	2	marly shale with hard calcareous concretions	<i>M. (M.) transitorius</i> (Spath) <i>M. (Dolicephalites)</i> cf. <i>subtrapezinus</i> (Waagen) <i>M. (D.)</i> aff. <i>keeuwensis</i> (Boehm) <i>M. (Kamptocephalites)</i> cf. <i>etheridgei</i> (Spath)
3 F ₃	2		<i>M. (K.) cossmanni</i> Pet. <i>Idiocycloceras</i> ? [or <i>Kamptocephalites</i>] cf. <i>bifurcatum</i> Spath <i>Subkossmatia</i> ? cf. <i>intermedia</i> (Spath) <i>Bullatimorphites (Kheraicerus) bullatus</i> (d'Orb.) <i>Cadomites</i> cf. <i>daubenyi</i> (Gemm.) <i>Paroecotraustes</i> ? sp. <i>Oxycerites (Alcidellus ?)</i> sp. Phylloceratid indet. <i>Conodiocoelites</i> sp. nov. aff. <i>keeuwensis</i> (Boehm)

Wai Miha

Locality No.	Thickness (m)	Lithology	Fossils
3 G ₁	15	marly silty shale, flaky when weathered with hard calcareous bands and nodules	<i>Macrocephalites (Kamptocephalites)</i> cf. <i>subkamptus</i> (Spath) <i>Macrocephalites</i> s.l. indet. <i>Idiocycloceras</i> ? sp. <i>Subkossmatia</i> ? sp. <i>Cadomites</i> cf. <i>daubenyi</i> (Gemm.)

Oxytoma ? sp.
Belemnopsis sp. nov. A
Hibolites sp. indet.

3 G ₂	>7	marly shale with hard bands and concretions	Macrocephalitidae ? <i>Bullatimorphites</i> ? sp.
------------------	----	---	--

4. Tikong Quarry

Marly shale containing concretions, is exposed in a 8 – 10 m thick quarry east of the Tikong village on the north coast of Taliabu. Well preserved fossils washed out mainly from the

concretions are of early Callovian age. The stratigraphic relationship of this section to other outcrops is not known. The succession is as follows :

Locality No.	Thickness (m)	Lithology	Fossils
4 A	< 10	marly shale, flaky when weathered, with calcareous concretions	<p><i>Macrocephalites (Dolicephalites) keeuwensis</i> (Boehm) <i>M. (D.)</i> cf. <i>subcompressus</i> (Waagen) <i>M. (Macrocephalites)</i> cf. <i>transitorius</i> (Spath) <i>M. (M.)</i> aff. <i>formosus mantataranus</i> (Boehm) <i>M. (Kamptocephalites) etheridgei</i> (Spath) <i>M. (K.)</i> sp. <i>Procerites</i> ? cf. <i>hodsoni</i> Arkell <i>Gracilisphinctes</i> ? cf. <i>lemoini</i> (Call.) <i>Oxycerites</i> ex gr. <i>rodoensis besairiei</i> Coll. <i>Oecotraustes</i> ? sp. <i>Holcophylloceras</i> sp. <i>Belemnopsis</i> sp. nov. A <i>B.</i> sp. nov. aff. <i>B. rumphii</i> Kruizinga</p>

5. Wai Menanga (Fig. 5)

Wai Menanga flows into the sea in the central north Taliabu about 40 km east of the Tikong quarry. Exposures are 5 km from the river mouth. They are discontinuous, and restricted to the creek-bed itself. The upper Toarcian locality 5 C, separated from the upper Bajocian

5 A and ?lower Callovian 5 B, is about 500 m upstream from the timber company base camp. The stratigraphic thickness of the unexposed part of the sequence between localities 5 C and 5 B is deduced by assuming a constant dip. The succession is as follows:

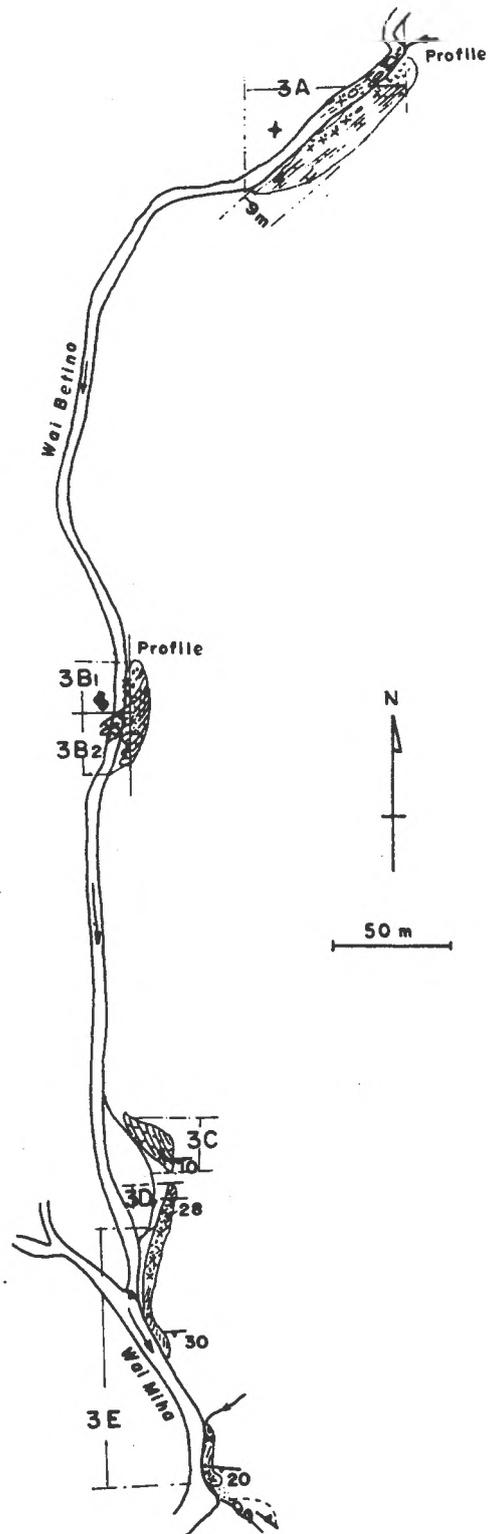


Fig. 4. Wai Betino (tributary of Wai Miha) traverse
(for explanation see legend on Fig. 2)

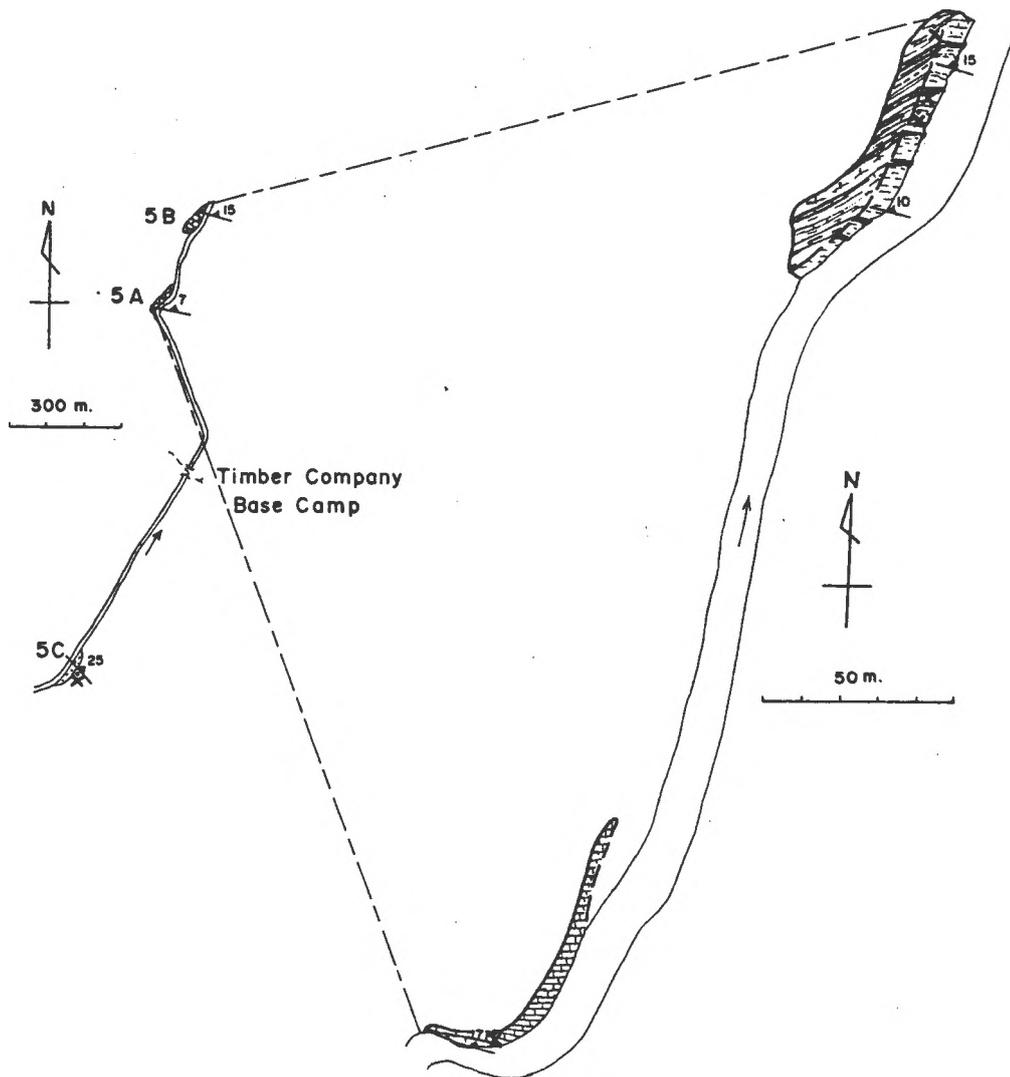


Fig. 5. Wai Menanga traverse (for explanation see legend on Fig. 2)

Locality No.	Thickness (m)	Lithology	Fossils
5 B	> 8	silty shale, with hard silty calcareous bands	<i>Bullatimorphites</i> ? sp. <i>Macrocephalites</i> ? (<i>Kamptocephalites</i> or <i>Pleurocephalites</i> ?) cf. <i>dimerus</i> (Waagen) <i>Holcophylloceras</i> ? sp.
lack of exposure, 25 m			
5 A	> 8	silty, micaceous shale with calcareous concretions	<i>Praetulites</i> cf. <i>kruizingai</i> Westerm.
lack of exposures, ca 100 m			
5 C	> 3	massive, coarse-grained sandstone with fossil banks	<i>Hammatoceras</i> cf. <i>molukkanum</i> Cloos Bivalves indet. Belemnites indet.

6. Wai Mbono (Fig. 6)

Wai Mbono is about 8 km east of Wai Menanga. The first outcrop 6 A, some 4 km from the coast, is a small isolated river bank with ?Oxfordian ammonites. The relatively continuous exposures 6 B (upper Bajocian) and 6 C (lower Bajocian) are about 2 km upstream from 6 A (Fig. 4). The stream channel is full of large

boulders of sandy shale and sandstone. Ammonites in shaly matrix as float between 6 B and 6 C indicate basal Bajocian age, while loose (upper) Toarcian ammonites occur mainly in sandstone boulders strewn upon thick unfossiliferous shales upstream from 6 E. However, they were not traced to outcrop. The succession is as follows :

Locality No.	Thickness (m)	Lithology	Fossils
6 A	5	marly claystone	<i>Paryphoceras</i> ? sp. <i>Calliphylloceras</i> cf. <i>malayanum</i> (Boehm)
relation unknown			
6 B	> 45	silty micaceous shale with hard calcareous sandstone beds and calcareous concretions	<i>Caumontisphinctes</i> sp. <i>Cadomites</i> aff. <i>deslongchampsii</i> (d'Orb.) Sphaeroceratidae ?

Holcophylloceras cf. *mediterraneum*
(Neum.)
Phylloceratidae indet.
Nannolytoceras ?
Belemnites indet.

lack of exposure, 30 m

6 C	>9	marly, silty shale flaky when weathered	<i>Fontannesia</i> sp. * cf. <i>Grammoceras</i> <i>Phymatoceras</i> ? sp. <i>Phylloceras</i> (<i>Macrophylloceras</i>) sp. <i>Ptychophylloceras</i> sp.
-----	----	--	---

* Float between 6 B and 6 C.
Forms in square brackets were float
found upstream from 6 C.

7. *Wai Meyong*

Wai Meyong, east of Wai Mbono, contains only a few isolated outcrops. At one of these about 5 km from the creek mouth, is the contact between the Jurassic basal conglomerate and the underlying irregularly eroded basement granite. The conglomerate is composed of rounded boulders of granite, and rare quartz and black schist up to 3 m in diameter, cemented together by a coarse breccia and coarse sandstone both of granitic composition. It is unfossiliferous, and passes upwards into unfossiliferous sandstone and grit composed of chert and quartzose metamorphic rock grains. The bivalve *Bositra* and belemnites are found in black silty shale about 25 m above the grit.

8. *Falabisahaya – Minaluli (Fig. 7)*

The Falabisahaya village on the north coast of Mangole is the headquarters of the Mangole Timber Company (Mangtip). Logging roads radiate south and southeast from it to the island's central divide, and then north again to the loading port at Minaluli (Fig. 7). They also continue eastwards to near the upper course of Wai Saniahaya II.

The exposures were plotted on a base map at a scale of 1 : 50,000 – of which Figure 7 is a modified version – provided by the Mangtip Company. A very complete Callovian to Turonian section was obtained, but the thicknesses are less accurate than those from the normal stream traverses where compass-and-pacing method was used. The overall sequence for the area was compiled from the following sections.

South from Falabisahaya

Locality No.	Thickness (m)	Lithology	Fossils
8 A	>50	massive white chalky marl	

relation unknown			
8 B	10	black marly claystone with hard calcareous concretions	<i>Ptychophylloceras</i> cf. <i>galoi</i> (Boehm) <i>Prososphinctes</i> ? cf. <i>boehmi</i> (Kruiz.) <i>Aulacosphinctoides</i> ? [or <i>Pachysphinctes</i>?] <i>Inoceramus subhaasti</i> Wandel <i>Buchia</i> sp. <i>Belemnites</i> indet.
Kimm. - (L.) Tith.			

relation unknown			
8 C	>10		<i>Mayaites</i> (<i>Epimayaites</i>) aff. <i>palmarum</i> (Boehm) [<i>sublemoini</i> ? Spath, compressed var.] <i>M. (Paryphoceras) cocosi</i> (Boehm) <i>Perisphinctes</i> (<i>Kranaosphinctes</i> ?) sp. <i>Calliphylloceras</i> cf. <i>malayanum</i> (Boehm) <i>Ptychophylloceras</i> cf. <i>galoi</i> (Boehm) <i>Phylloceras</i> (<i>Macrophylloceras</i>) cf. <i>monsuni</i> Boehm <i>Inoceramus galoi</i> Boehm <i>I. subhaasti</i> ? Wandel <i>Buchia</i> sp. nov. D <i>Belemnopsis</i> sp. nov. B
* Rad. (Pangloss)		M = O + f.	

From Minaluli to near Saniahaya II

Locality No.	Thickness (m)	Lithology	Fossils
8 L	>90	marly shale	<i>Haplophylloceras strigile</i> (Blanf.) <i>Blanfordiceräs</i> cf. <i>wallichi</i> (Gray) <i>Belemnopsis</i> sp. indet.
8 G	150	grey marly shale with hard calcareous concretions, fossil tracks on the surface of concretions	Phylloceratidae indet. Bivalves indet. <i>Belemnopsis uhligi</i> Stevens <i>B. aff. incisa</i> <i>Hibolithes marwicki</i> Stevens subsp?
8 H			<i>Pterolytoceras</i> ? Phylloceratidae juv. Haplocerataceae indet. <i>Belemnopsis</i> sp. nov. C (8H) <i>B. aucklandica aucklandica</i> Stevens (8H)

8 H ₂	>200	marly claystone with calcareous concretions	<i>B. cf. rumphii</i> Kruizinga (8H) <i>Buchia</i> sp. nov. A (8H) <i>Buchia</i> cf. <i>plicata</i> Zittel (8H) <i>Haplophylloceras</i> cf. <i>strigile</i> (Blanf.)
8 H ₂		<u>Up. Tith.</u>	<i>Virgatosphinctes</i> ? sp. <i>Uhligites</i> ? juv. <i>Inoceramus stoliczkai</i> Holdhaus (8H ₂) <i>Belemnopsis uhligi</i> Stevens (8H ₂) <i>B. alfurica</i> (Boehm) (8H ₂)
lack of exposure			
8 I	70	marly claystone with calcareous concretions	<i>Aulacosphinctoides</i> ? sp. Lytoceratidae indet. <i>Belemnopsis uhligi</i> Stevens <i>B. alfurica</i> (Boehm)
		<u>m - up. Tith.</u>	
lack of exposure			
8 K	>50	silty shale, flaky when weathered, with calcareous concretions and <i>Inoceramus</i> bands	Perisphinctid (<i>Perisphinctes</i> s.s. ?) <i>Laevaptychus</i> sp. <i>Inoceramus haasti</i> Hochstetter <i>I. cf. gracilis</i> Holdhaus <i>Buchia</i> sp. nov. A <i>Belemnopsis uhligi</i> Stevens <i>B. aucklandica aucklandica</i> Stevens <i>Belemnopsis</i> sp. nov.
		<u>(m.) Tith.</u>	
relation unknown			
8 F	>85	dark grey marly shale with calcareous concretions	Perisphinctidae indet.
		<u>m - up. Oxf.</u>	
8 E	55?	dark grey marly shale with calcareous concretions and layers	<i>Peltoceratoides</i> (<i>Peltomorphites</i>) <i>tjapalului</i> (Boehm) ♀ <i>P. (Parawedekindia)</i> sp. ♂ <i>Mayaites (Epimayaites)</i> cf. <i>rotangi</i> (Boehm) <i>Phylloceras (Macrophylloceras)</i> cf. <i>monsuni</i> Boehm <i>Inoceramus</i> sp.
		<u>Lo. Oxf.</u>	
lack of exposure			
8 D	>125	black marly shale with calcareous concretions	<i>Macrocephalites (Dolicephalites)</i> cf. <i>keeuwensis</i> Boehm Problematicum

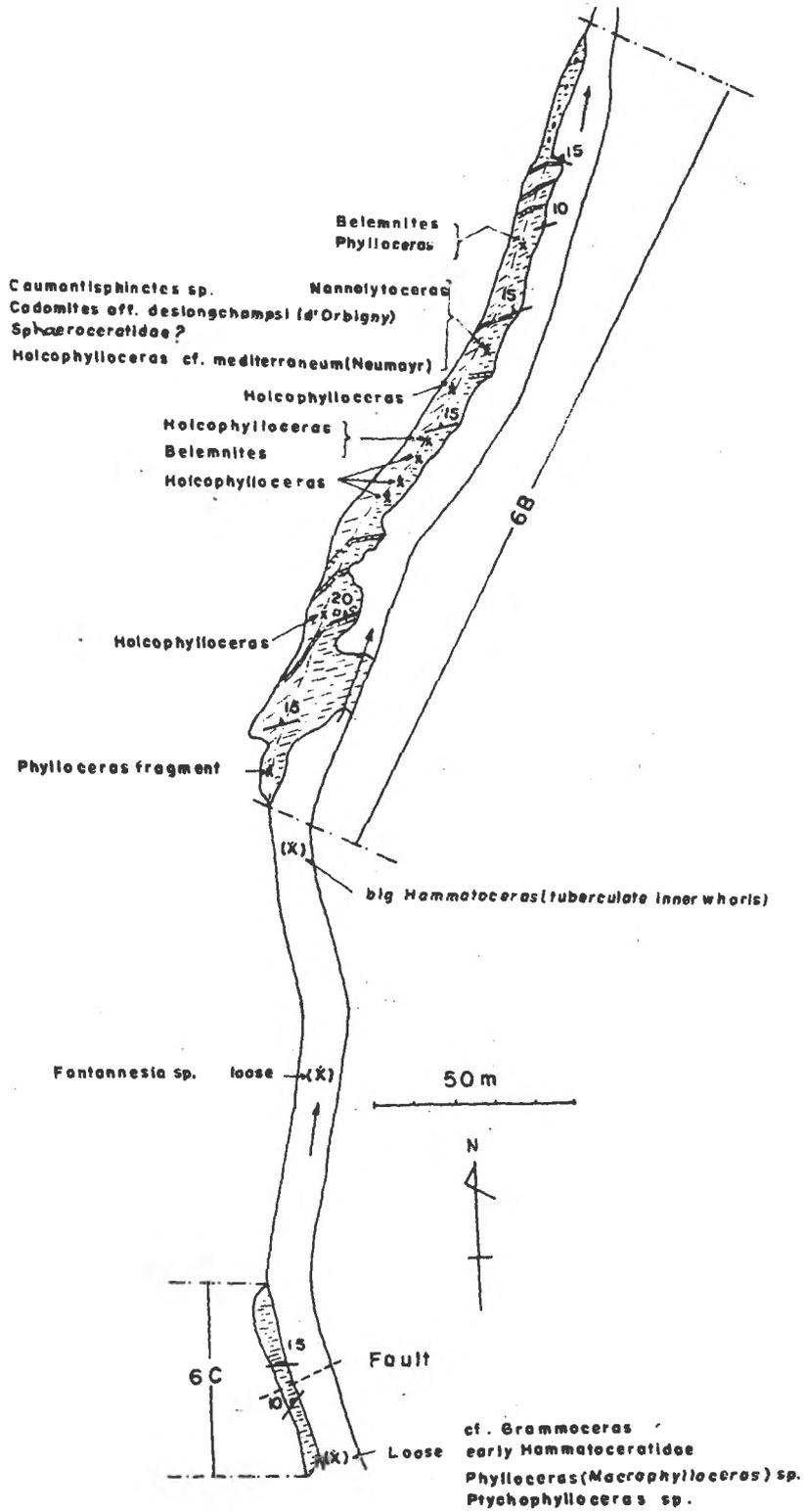


Fig. 6. Wai Mbono traverse (for explanation see legend on Fig. 2)

9. Wai Saniahaya II (Fig. 7)

Wai Saniahaya II is a stream of unknown name about 15 km east of Falabisahaya (Fig. 7), and west of Wai Saniahaya. Its upper reaches adjoin the eastern part of Falabisahaya. The first two localities 9 A and 9 B are about 1 km from the

coast; the next outcrop 9 C is 3 – 4 km farther upstream. The relationship between 9 A – 9 B and 9 C is not known; 9 C and the adjoining 8 E and 8 D are located closely together and are related faunistically and in age. The succession is as follows :

Wai Saniahaya II

Locality No.	Thickness (m)	Lithology	Fossils
9 A	8	black marly shale, with <i>Inoceramus</i> bands	<i>Inoceramus</i> sp. <i>Buchia</i> sp. <i>Malayomaorica malayomorica</i> (Krumbeck) Belemnites indet.
Relation unknown			
	10	black carbonaceous shale	Plant fragment <i>Belemnopsis</i> sp. nov. B <i>Hibolithes brouweri</i> Kruizinga ?
9 B	unknown	marly claystone with hard calcareous concretions	<i>Ptychophylloceras</i> ? sp. <i>Perisphinctes</i> (<i>Kranaosphinctes</i> ?) <i>salarum</i> Boehm <i>Prososphinctes</i> ? cf. <i>boehmi</i> (Kruiz.) <i>Inoceramus galoii</i> Boehm <i>Inoceramus subhaasti</i> Wandel Belemnites indet.
Relation unknown			
9 C	> 10	black marly shale with hard concretions	<i>Perisphinctes</i> s.l. Macrocephalitidae

10. Wai Loba

Wai Loba is a small stream in the central north coast of Mangole (Fig. 2). It is a site of one of the timber company's base camp. A logging road to the east reaches the adjoining Wai Fatoe, with its scattered Jurassic outcrops of deeply weathered and unfossiliferous shale, which make up a disjointed sequence of limited importance.

11. Wai Buja Besar

Wai Buja Besar, west of Buja village on the south coast of Mangole (Fig. 2), has been frequently mentioned by Boehm (1912) and Kruizinga (1926) as a source of float ammonites. A traverse along it has however failed to locate any continuous outcropping fossiliferous sections.

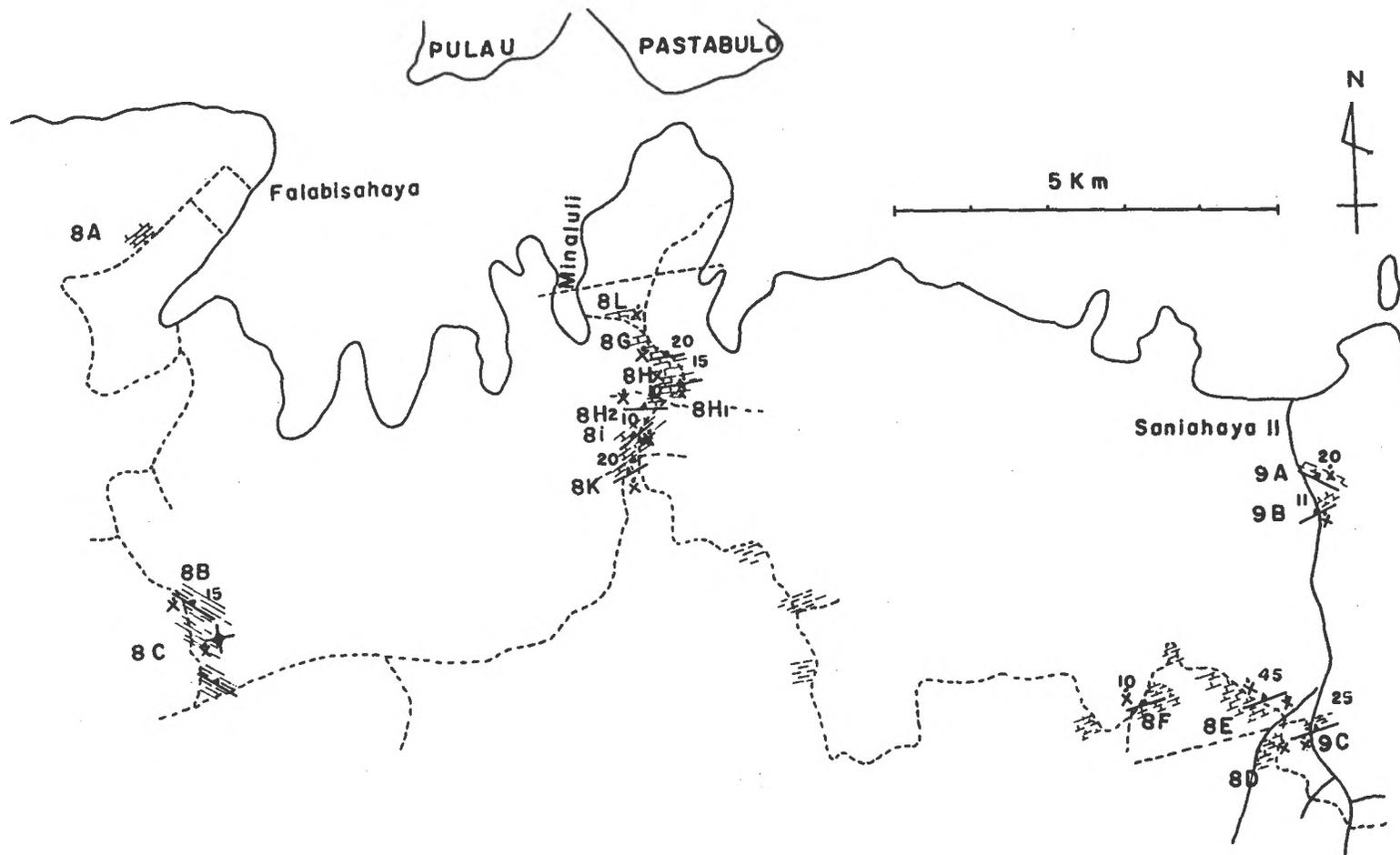


Fig. 7. Falabisahaya – Minaluli and W. Saniahaya II traverses
 (for explanation see legend on Fig. 2)

12-13-14 *Small creeks in southeastern Taliabu*

Several small creeks between Wai Kronci and Wai Galo in southeastern Taliabu (Fig. 2) such as an unnamed creek (12), Wai Kemayo (13) and Wai Fora (14) meander on the flat lowland, their

discontinuous exposures of probably closely related Jurassic strata difficult to correlate. No traverse maps have been prepared for them. Principal lithologies encountered were the dark grey marly shale, and grey silty shale intercalated with a light grey massive fine-grained sandstone.

Section 12 (creek of unknown name)

Locality No.	Thickness (m)	Lithology	Fossils
...	?	boulders of yellow fine grained sandstone	—
Relation unknown			
12	?	dark grey marly shale	<i>Blanfordiceras cf. wallichi</i> (Gray) <i>Haplophylloceras</i> Belemnites indet.

Section 13: Wai Kemayo

13C	?	grey marly clayshale with calcareous concretions	Belemnites indet.
Relation unknown			
13B	?	grey marly clayshale with some concretions	Haploceratidae ? sp. <i>Inoceramus</i> sp. Bivalves indet. Belemnites indet.
Relation unknown			
13A	?	grey marly claystone with concretions	<i>Oxytoma</i> ? sp.

Wai Fora

	?	grey marly shale prominently platy	
Relation unknown			
Section 14			
14A	?	grey silty shale	<i>Inoceramus</i> sp. Bivalves indet. Belemnites indet.

PRELIMINARY RESULTS

a. Stratigraphy

The Jurassic sedimentary succession in the Sula Islands has been subdivided into five units on the basis of age, lithology, and fossil content. This subdivision was made possible by establishing mutual stratigraphic relationships between measured sections and outcrops and by referring them by means of contained fossils to the standard Jurassic column. The five units are as follows:

1. The upper Toarcian (and Aalenian?) sandstone (> 20 m) with basal conglomerate, with equally characteristic molluscs (see below) on the north coast of Taliabu, are easy to distinguish from all the other units.
2. The Bajocian (and Bathonian?) shale (20–120 m), slightly silty, micaceous and marly, and frequently intercalated with hard bands and layers, is on occasion difficult to distinguish from the overlying claystone, except for characteristic ammonites which enable subdivision into the upper and lower parts (see below); it is also limited in distribution to the coast of Taliabu.
3. Callovian and Oxfordian claystone (40–320 m) uniform, marly, and with hard concretions, contains early Callovian and early and middle (+ late) Oxfordian molluscs (see below); it is quite widespread but cannot be further subdivided on purely lithological grounds.

4. The widespread Kimmeridgian–middle Tithonian silty shale (100–150 m) with common mica flakes contains abundant bivalves such as *Inocerami*, belemnites, *Buchias* and *Malayomaorica*, but only rare ammonites.

5. The upper Tithonian marly claystone (150–500 m) with hard concretions is similar to the Callovian–Oxfordian claystone. It seems to be limited in distribution to near the Tjapalulu Strait and can only be distinguished from the older unit by the unusually rich and distinctive ammonite fauna which includes *Haplophylloceras* and *Blanfordiceras*.

The boundary between the Jurassic and the Cretaceous was not examined but may be clearly marked by an abrupt lithological change as suggested by presumably Cretaceous chalky marl (8A) or yellow fine-grained sandstone boulders upstream from 12.

b. Palaeontology

The time ranges of the individual species of ammonites, belemnites and bivalves are currently being studied, and range charts will be published on the completion of detailed palaeontological study. At this stage, the following succession and time–correlation of the principal molluscan assemblages has become apparent (representative locality numbers in parentheses).

Upper Tithonian (1A, 8 H,L, 12) : The rich and diverse ammonite fauna: *Haplophylloceras strigile* (Blanf.), *Blanfordiceras* cf. *wallichi* (Gray), *Virgatosphinctes* ? sp., Haplocerataceae, Phylloceratidae, Lytocerataceae and also *Belemnopsis* sp., *Buchia* cf. *plicata* Zittel and *Inoceramus stoliczkai* Holdhaus. This fauna connects that of the Himalayan Spiti Shales with the more similar ones in New Guinea.

Middle Tithonian - Lower Kimmeridgian (1B, 2 (A?)B-D, 3E, 8B ?, K): The macrofaunas consist almost entirely of bivalves and belemnites, often massed on bedding planes, i.e. *Inoceramus haasti* (Hochstetter), *I.* cf. *gracilis* Holdhaus, late *I. galoi* Boehm, *Buchia* spp., *malayomaorica* (Krumbeck), *Belemnopsis* sp. and a few poorly known perisphinctaceans [*Prososphinctes*? cf. *boehmi* (Kruiz.), *Auulacosphinctoides* ?] inhibiting exact time-correlations. This interesting biofacies remains unexplained.

Middle (+ ? Upper) Oxfordian (2 F-H, 8C): The not very common ammonite fauna is characterized by the approximate association of Mayaitidae, particularly *Mayaites* (*Epi-mayaites*) spp. and *Paryphoceras*, with *Perisphinctes* (*Kranaosphinctes*) spp. ex. gr. *burui* Boehm, as well as *Inoceramus galoi* Boehm, belemnites and phylloceratids. This assemblage (or assemblages) is equivalent to the most commonly described and dated Mayaitidae fauna of the Indo-Pacific faunal province (e.g. Arkell, 1956).

Lower Oxfordian (2 J-M, 6A ?, 8E) : Most of the "Wai Galo assemblage", with the notable exception of the perisphinctids and some rare forms mentioned above belongs to this rich fauna. It is characterized by the association of very similar Mayaitidae as above with *Peltoceratoides* (*Peltomorphites*) *tjapalului* (Boehm) and the apparently corresponding microconch *P.* (*Parawedekindia*) aff. *arduennensis* (d'Orb.), as well as *Calliphylloceras malayanum* (Boehm) and belemnites. The only known other occurrence of this assemblage, here dated as late

early Oxfordian, appears to be Madagascar (Collignon, 1958).

Middle - Upper Callovian : no fossil evidence

Lower Callovian (3B, G, F, 5B): The great host of the "Keeuw assemblage" appears to be of early to basal Callovian age, i.e. the common *Macrocephalites keeuwensis* (Boehm), *M.* cf. *transitorius* (Spath) and *M.* cf. *subcompressus* (Waag.), the rarer *M. formosus mantataranus* (Boehm), *M. etheridgei* (Spath) and *M. apertus* (Spath), *Idiocycloceras*? cf. *bifurcatum* Spath, *Subkossmatia*? cf. *intermedia* (Spath) and, significantly, *Kheraicerus bullatum* (d'Orb.). These are associated, at least in part, with *Oxycerites* spp., *Procerites* cf. *hodsoni* Arkell, *Gracilisphinctes*? sp. and *Cadomites* cf. *daubenyi* (Gemm.) which commonly have been considered to indicate the Bathonian and even the late Bajocian (e.g. Arkell, 1956); finally, there are also some phylloceratids, belemnites and bivalves.

Bathonian : ~~No new fossil evidence.~~ The known mostly single specimens where all found loose in the Keeuw area, Wai Miha, around the turn of the century. These are the *Tulites godohensis* (Boehm) and several *Bullatimorphites sofanum* (Boehm) indicating Middle Bathonian, as first suggested by Arkell (1956), and a fragment in the Utrecht collections resembling *Asphinctites pinguis* (Gross.) (confirmed by C. Mangold, pers. comm.) suggesting Lower Bathonian. The need for caution with respect to the dating of these single specimens found in isolation can, however, not be overemphasised.

Upper Bajocian (6B) : The association of *Caumontisphinctes* sp. and *Cadomites* aff. *deslongchampsii* (d'Orbigny), together with phylloceratids and lytoceratids, is the first good evidence from Indonesia of (early) Late Bajocian. Significantly, the '*Idoceras nihanum*' (Boehm, 1913) from Keeuw also appears to be a *Caumontisphinctes* (confirmed by C. Pavia and the late C. Sturani, 1975 pers. comm.). *

Lower Bajocian (6C) : The only new fossil evidence is the *Fontannesia* sp. found loose

* *Praetulites* cf. *kruizingai* Westermann from locality 5A probably belongs also in this substage.

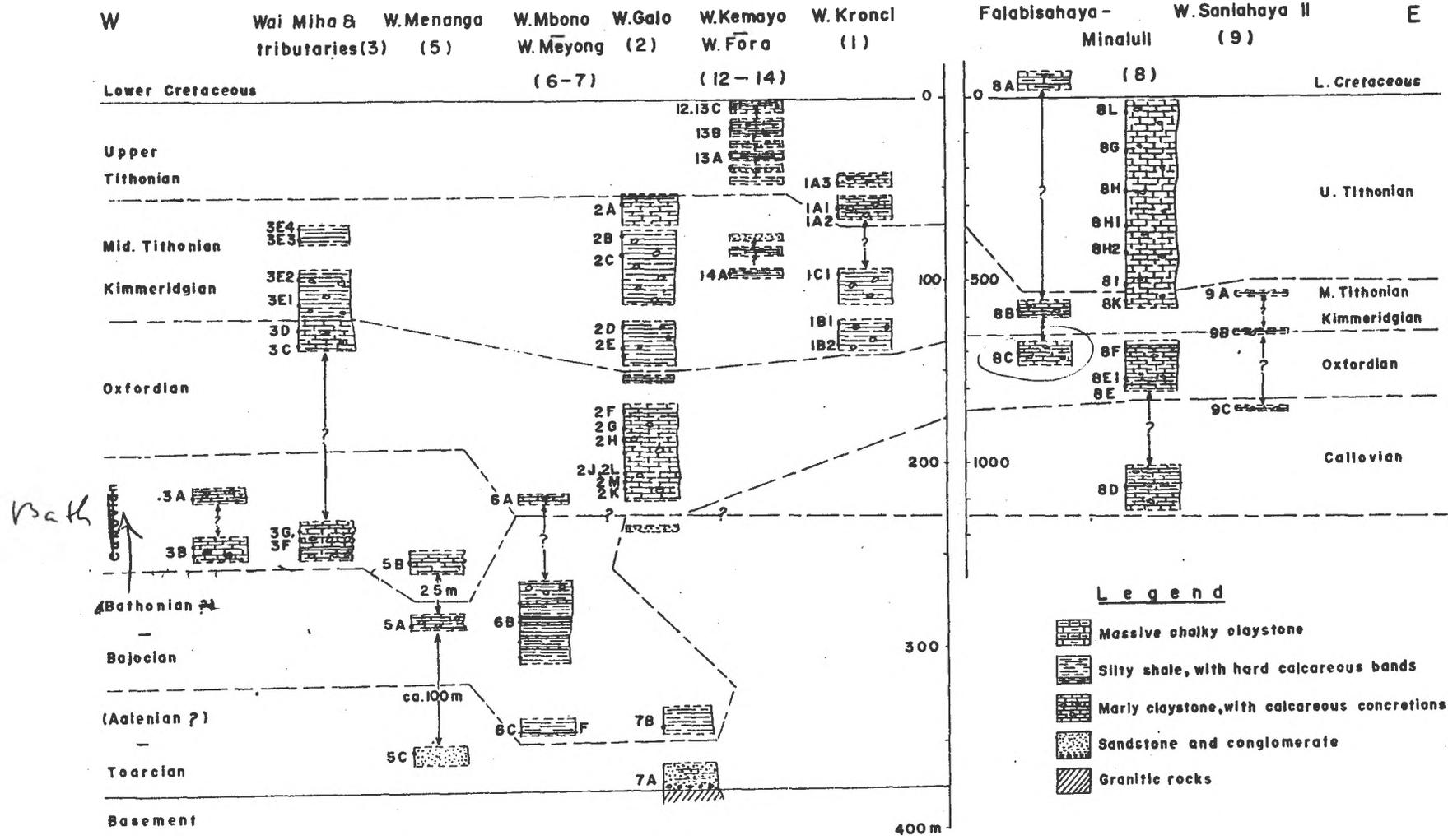


Fig. 8. Correlation chart of the 14 traverses in the Sula Islands

Stage	Lithology	Selected ammonites	Selected bivalves
TITH.	marly clayst. with concretions	<i>Haplophylloceras strigile</i> , <i>Blanfordiceras cf. wallichi</i>	<i>Inoceramus stoliczkai</i>
KIM.	highly silty shale with mica flakes		<i>I. haasti</i> <i>Malayomaorica malayomaorica</i>
OXF.	uniform marly claystone	<i>Epimayaites</i> & <i>Paryphiceras</i> spp. <i>Perisphinctes</i> spp. <i>Peltomorphites</i> & <i>Parawedekindia</i> sp.	<i>I. gaoli</i> <i>I. gracilis</i> <i>I. subhaasti</i>
CAAL.	claystone with hard concretions	<i>Macrocephalites, Dolicephalites</i> & <i>Kamptcephalites</i> spp. <i>Kheraceras bullatum, Cadomites, Oxyerites</i>	
BATH.		[<i>Tulites godohensis, Bullatimorphites sofanum</i>] <i>Praetulites</i> ?	
BAJ.	slightly silty micaceous marly shale hard bands	<i>Caumontisphinctes, Cadomites aff. deslongchampi</i> [<i>Stemmatoceras indicum</i>] [<i>Pseudotoites cf. robiginosus</i>] <i>Fontannesia</i> sp.	
AAL.	?		
TOAR.	sandstone	<i>Hammatoceras cf. moluccanum</i>	

Table 1. Generalised lithology and selected fossils occurrences,
with previous finds in brackets

and confirming Kruizinga's reports ('*Grammoceras kiliani*' and ? '*G. baumbergeri*') suggesting basal Bajocian. Kruizinga also described a specimen (p. 49, pl. 6, figs. 1-2) now identified with *Pseudotoites* cf. *robiginosus* (Crick), indicating a similar age. This assemblage occurs again in Irian Jaya and Western Australia (Westermann and Getty, 1970; Arkell, 1954). The *Stephanoceras* (*Stemmacoceras*) *indicum* (Kruizinga, 1925, pl. 14, fig. 1; perhaps a *Zemistephanus* ?) indicates the late early Bajocian.

Aalenian : No fossil evidence

Upper Toarcian (5C) : The quite rich but difficult to extract fauna includes *Hammatoceras* cf. *molukkanum* Cloos, as figured by Kruizinga (1926, p. 2), belemnites and bivalves.

Despite intensive search, the genus *Irianites* which is widespread throughout eastern Indonesia but has not been found *in situ* (Westermann and Getty, 1970 and in Irian Jaya by Westermann in 1973) has not been found; Kruizinga (1926, p. 13, fig. 2) figured a poor specimen of *I.* cf. *moermanni* (Kruiz.) from Buja Besar. The inspection from Keeuw by Westermann has revealed two poorly preserved specimens in shale matrix, differing from the preservation of the Lower Callovian ammonites. Finally, the extensively described but not illustrated '*Stephanoceras pseudoblagdeni*' Cloos and '*S. pseudohumphriesi*' Cloos from the 'Profil Kempa', i.e. 'Tangi' at the Wai Miha, are now both identified with *Irianites* cf. *moermanni*, macroconch and microconch.

CITED REFERENCES

- Arkell, W.J., 1954, The ammonites and their place in the Bajocian faunas of the world, In W.J. Arkell and P.E. Playford: The Bajocian ammonites of Western Australia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 547-605
- Boehm, G., 1912, Beiträge zur Geologie von Niederländisch-Indien. 4. Unteres Callovien. *Palaeontographica Supplement IV*, p. 121-179, pls. 32-44.
- Boehm, G., 1904a, Beiträge zur Geologie von Niederländisch-Indien, Allgemeine Einleitung, *Palaeontographica Supp. IV*, p. 1-8
- Boehm, G., 1904b, Beiträge zur Geologie von Niederländisch-Indien. 1ste Abt. Die Südküster der Sula Inseln Taliabu und Mangoli. 1. Abschnitt. Grenzschichten zwischen Jura und Kreide, *Palaeontographica Supp. IV*, p. 11-46, 7 pls
- Boehm, G., 1907a, Beiträge zur Geologie von Niederländisch-Indien. 2. Abt. Der Fundpunkt am oberen Lagoi auf Taliabu, *Palaeontographica Supp. IV*, p. 47-58, 1 pl
- Boehm, G., 1907b, Beiträge zur Geologie von Niederländisch-Indien. 3. Oxford des Wai Galo. *Palaeontographica Supp. IV*, p. 61-120, pls 9-31
- Brouwer, H.A., 1921, Geologische onderzoekingen op de Soela-Eilanden. I. *Mijnw. Nederl. Ind., Jaarb.* (1920), Verh. II, p. 71-158, 11 pls., 5 charts
- Boehm, G., 1926, Geologische Onderzoekingen op de Soela-Eilanden. II. *Mijnw. Nederl. Ind., Jaarb.* (1925), Verh. I, p. 3-9
- Cloos, H., 1916, Doggerammoniten aus den Molukken, *Habitatsschrift*, Stuttgart, 50 p.
- Collingnon, M., 1958, Atlas des fossils caractéristiques de Madagascar, *Service géologique Tananarive*. 3 p., 133 pls.
- Jaworski, E., 1921, Ein Beitrag zur Kenntnis des Untersten Dogger von Taliabu (Sula-Inseln), *Mijnw. Nederl. Ind. Jaarb.* (1920), Verh. II, p. 193-205, 1 pl.
- Kruizinga, P., 1921, De Belemniten uit de Jurassische Afzettingen van de Soela-Eilanden, *Mijnw. Nederl. Ind. Jaarb.* (1920), Verh. II, p. 161-189, 6 pls.
- Boehm, G., 1926, Ammoniten en eenige andere fossielen de Jurassische afzettingen der Soela-Eilanden, *Mijnw. Nederl. Ind. Jaarb.* (1925), Verh. I, p. 15-85, 14 pls.
- Rumphius Gedenkboek, 1902, *Koloniaal Museum*, Haarlem
- Stolley, E., 1929, Ueber Ostindische Jura-Belemniten, *Palaeontologie von Timor*, v.16
- Westermann, G., 1970, The Bajocian ammonites of Western Australia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 547-605
- Westermann, G., 1973, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 607-618
- Westermann, G., 1974, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 619-630
- Westermann, G., 1975, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 631-642
- Westermann, G., 1976, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 643-654
- Westermann, G., 1977, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 655-666
- Westermann, G., 1978, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 667-678
- Westermann, G., 1979, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 679-690
- Westermann, G., 1980, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 691-702
- Westermann, G., 1981, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 703-714
- Westermann, G., 1982, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 715-726
- Westermann, G., 1983, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 727-738
- Westermann, G., 1984, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 739-750
- Westermann, G., 1985, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 751-762
- Westermann, G., 1986, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 763-774
- Westermann, G., 1987, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 775-786
- Westermann, G., 1988, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 787-798
- Westermann, G., 1989, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 799-810
- Westermann, G., 1990, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 811-822
- Westermann, G., 1991, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 823-834
- Westermann, G., 1992, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 835-846
- Westermann, G., 1993, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 847-858
- Westermann, G., 1994, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 859-870
- Westermann, G., 1995, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 871-882
- Westermann, G., 1996, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 883-894
- Westermann, G., 1997, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 895-906
- Westermann, G., 1998, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 907-918
- Westermann, G., 1999, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 919-930
- Westermann, G., 2000, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 931-942
- Westermann, G., 2001, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 943-954
- Westermann, G., 2002, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 955-966
- Westermann, G., 2003, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 967-978
- Westermann, G., 2004, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 979-990
- Westermann, G., 2005, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 991-1002
- Westermann, G., 2006, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1003-1014
- Westermann, G., 2007, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1015-1026
- Westermann, G., 2008, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1027-1038
- Westermann, G., 2009, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1039-1050
- Westermann, G., 2010, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1051-1062
- Westermann, G., 2011, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1063-1074
- Westermann, G., 2012, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1075-1086
- Westermann, G., 2013, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1087-1098
- Westermann, G., 2014, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1099-1110
- Westermann, G., 2015, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1111-1122
- Westermann, G., 2016, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1123-1134
- Westermann, G., 2017, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1135-1146
- Westermann, G., 2018, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1147-1158
- Westermann, G., 2019, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1159-1170
- Westermann, G., 2020, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1171-1182
- Westermann, G., 2021, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1183-1194
- Westermann, G., 2022, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1195-1206
- Westermann, G., 2023, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1207-1218
- Westermann, G., 2024, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1219-1230
- Westermann, G., 2025, The Irianites ammonites of eastern Indonesia, *Philosophical Transactions of the Royal Society of London Ser. B, Biological Sciences*, v. 651, n. 237, p. 1231-1242

- Sukamto, Rab, 1975a, Geologi daerah Kepulauan Banggai dan Sula, *Geol. Indon.*, v. 2, n. 3, p. 23–28
- , 1975b, Ujung Pandang, Indonesia, Sheet VIII, scale 1 : 1,000,000, *Geol. Survey of Indon.*
- van Bemmelen, R.W., 1970, *Geology of Indonesia*, 2nd edition, the Hague
- Verbeek, R.D.M., 1908, Molukken—Verslag, Geologische verkenningstochten in het oostelijk gedeelte van den Nederl. Oost-Indischen Archipel., *Mijnw. Nederl. Ind, jaarb.* 37e (1908), p. 106–114
- Wanner, J., 1931, Mesozoikum, *Leidse Geol. Meded., Deel v. 5*, Feestbundel K. Martin
- Westermann, G.E.G., 1956, Monographie der Bajocian – Gattungen *Sphaeroceras* und *Chondroceras* (Ammonoidea), *Beihefte zum Geologischen Jahrbuch*, Heft 24, 195 p., 14 pls.
- , & T.A. Getty, 1970, New Middle Jurassic Ammonitina from New Guinea, *Amer. Paleontol. Bull.*, v. 57, n. 256, p. 227–321, pls. 48–62