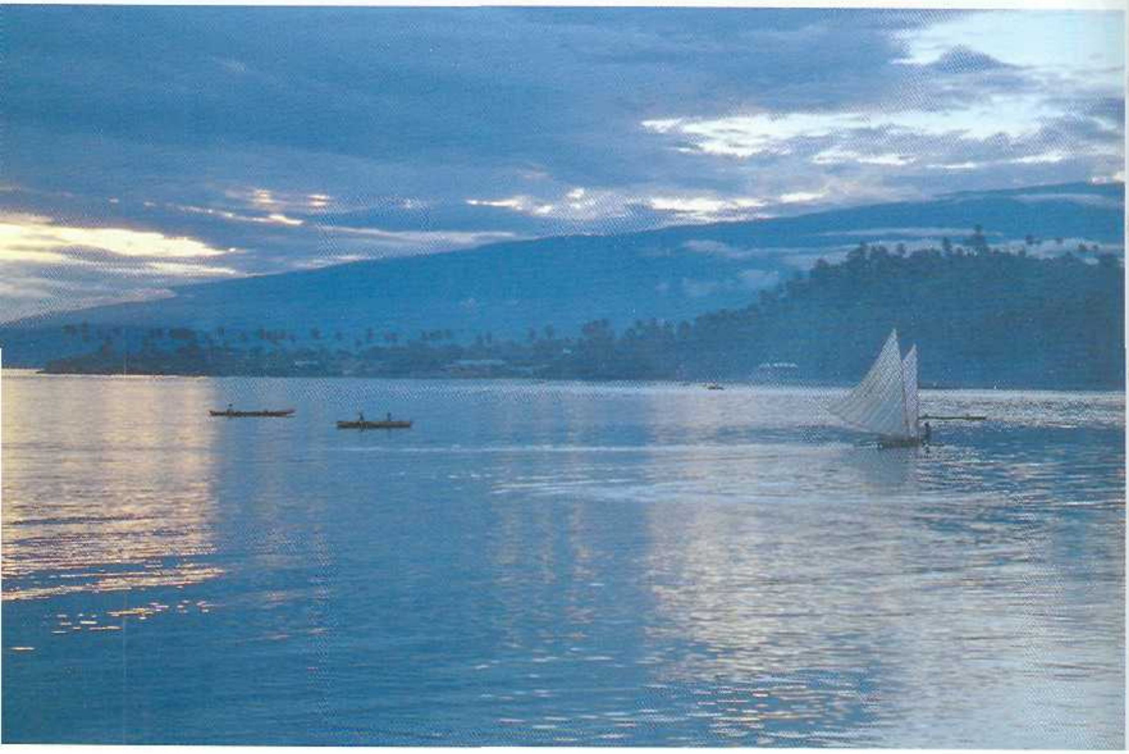
BIRD'S HEAD APPROACHES

MODERN QUATERNARY RESEARCH
IN SOUTHEAST ASIA

15

BIRD'S HEAD APPROACHES
IRIAN JAYA STUDIES – A PROGRAMME FOR INTERDISCIPLINARY RESEARCH

Modern Quaternary Research in Southeast Asia, Volume 15
Edited by Gert-Jan Bartstra



... The light is grey and the dawn wind cool. Low clouds, glistening like snow, drift in front of the mountains. We sail close to the shore on a calm sea, passing palm groves and gardens where maize is laid out to dry. Houses are hidden behind a lattice of clustered coconut trees, and everywhere we smell the smoke of early morning fires...

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Irian Jaya Studies – A Programme for Interdisciplinary Research

Edited by
GERT-JAN BARTSTRA

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It gives me great pleasure to present the fifteenth volume in the series 'Modern Quaternary Research in Southeast Asia'. It is a special volume in the sense that it concerns itself with the Bird's Head, or in Dutch 'de Vogelkop': the distinctively shaped northwestern peninsula of the island of New Guinea. Western New Guinea is a province of Indonesia and is known today as Irian Jaya.

The papers in this volume were collected for ISIR; the abbreviation stands for 'Irian Jaya Studies, a programme for Interdisciplinary Research'. ISIR was set up on 1 January 1993, and is sponsored (as a Priority Programme) by NWO/WOTRO ('Netherlands Organization for Scientific Research'/'Netherlands Foundation for the Advancement of Tropical Research'). It consists of about twenty researchers from both arts and science faculties, scattered throughout Dutch universities and institutes, with the specific goal of promoting and performing research on the Bird's Head. It will be clear that such a set-up is dependent on the cooperation of the Indonesian authorities, and thus LIPI, the 'Indonesian Institute of Sciences', has been involved in the programme from an early stage. Reports on the aims and the progress of the ISIR project are regularly presented in a series of Newsletters, about ten of which have so far appeared. A (first) conference on the Bird's Head, sponsored by ISIR, was held in Leiden in October 1997.

As a result of being involved in the ISIR project myself, as a so-called senior researcher for archaeology, it occurred to me that it would be a good idea to devote a special volume in the series 'Modern Quaternary Research in Southeast Asia' to the island of New Guinea and the surrounding area. One half of the contributions should be formed by papers dealing with past and present research by ISIR members and others on the Bird's Head proper, arranged in the tripartite division of the ISIR scientific ranks: geology, archaeology and botany. The other half of the contributions should contain information about the surrounding areas. This is why the title of this volume is 'Bird's Head Approaches'.

This collection of papers begins with an overview of the geology of the Bird's Head by the ISIR members Dam and Wong, offering a comprehensive and accessible frame of reference. The next paper, Solheim's reminiscences of his Makbon research, has found a place partly because of its historical interest: Solheim was the first to perform archaeological investigations in the Bird's Head in the mid-seventies. Present-day archaeologists will find some noteworthy details in Solheim's account and accompanying illustrations. It is also interesting to note that Solheim's assistant in the field in those bygone days was Goenadi Nitihaminoto, who appears in this volume as the second author of the last paper. The next two contributions, by Jelsma and Pasveer respectively, deal with recent excavations. These authors are junior ISIR researchers in archaeology who have done fieldwork in the Ayamaru region, the southwestern Bird's Head. These papers introduce a lot of new facts as these are the first systematic cave excavations to have been carried out in the Bird's Head interior. Next come three botanical papers by authors involved with ISIR: Vink, drawing on an extensive personal archive of fieldwork experience; Polak, a junior member who recently returned from the Bird's Head with a batch of new data; and last but not least De Vogel, in inner circles known as an ardent orchid hunter.

The subsequent papers deal with the Bird's Head surroundings in a broad sense. Lilley presents us with an update on eastern New Guinea archaeology, followed by Veth and associates who explore the Aru islands. This research, incidentally, is still going on. Keates then reviews the possibility of pre-sapiens hominids having ventured eastward from Java, a topic to which a great deal of attention is being paid at the moment by archaeologists interested in Southeast Asia. I myself present a short history of the cave investigations in southern Sulawesi, a contribution which might be regarded as an introduction to the next paper in line, that by Pasqua and Bulbeck on the Toalean. These papers on the riddles of cave occupation in eastern Indonesia have been included in view of the experiences of Solheim, Jelsma and Pasveer; and also because of the last paper in this volume, by Bellwood et al, which deals with caves in the northern Moluccas. Theirs is a worthy conclusion to this volume, giving the present state of archaeological research in the region.

Bellwood and associates include a section on the linguistic inferences of their archaeological pursuits. This leads me to a brief reflection on the notion of 'interdisciplinary research', something that ISIR feels very strongly about. To be able to work in an 'interdisciplinary' way, a basic supply of facts and figures which may be of service to the researcher is needed. As far as the archaeology of the Bird's Head is concerned, this supply is very meagre indeed. In fact, the unfinished excavations, or rather test pits, dug previously by Solheim and more recently by Jelsma and Pasveer, provide all the material that must support interdisciplinary discussions. Such discussions are probably premature at this stage; neither Solheim, Jelsma nor Pasveer attempt to assess their data in an 'interdisciplinary' way in their respective papers. The archaeologists are collecting basic data concerning the Bird's Head and trying to construct a frame of reference. Any interdisciplinary endeavours must await the results of more urgently needed fieldwork.

Finally, a few technical details. A guiding principle during the editing of this work has been to allow the contributors to determine their own terminology as far as possible. If one wants to write 'Middle Holocene' and another 'mid-Holocene', then this has been left unchanged. The same holds true for the spelling of certain local geographical names. After discussion with the publisher, it has also been decided not to print emphasized words or so-called 'foreign' words either in bold or italics (with the exception of Latin floral and faunal designations). Too many difficulties were encountered in determining which words are really 'foreign', and which have already become current in everyday English. In this volume 'foreign' words or names, if necessary, have been placed within inverted commas or are explained.

The caption to the frontispiece is a (loose) translation of a few lines from a description (in Dutch) of a journey by proa in the northern Moluccas by the writer Beb Vuyk. The photograph itself shows a typical approach to one of the many isles between Halmaheira and the Bird's Head: a very ancient seafarer's route.

Many institutions and people assisted in the genesis and subsequent growth of this volume. In the first place I would like to mention WOTRO and ISIR; for the abbreviations I refer to the first lines of this Preface. In particular I would like to express my appreciation for the assistance afforded me by several people in these organizations: Prof. W.A.L. Stokhof (the initiator of ISIR; chairperson of the WOTRO-ISIR Steering Committee), Dr R.R. van Kessel-Hagesteyn (WOTRO), Dr J. Miedema and Drs. M.E. Bakker (ISIR). Their endeavours made it possible to include some colour plates in this volume. Furthermore, I would like to thank L. Tol, A.J. Tol-Bouwman and J.H. Zwier, of the Department of Archaeology at the University of Groningen for their help with the typing and the drawing of the figures. Dr J. Harvey deserves praise for the polishing of the various texts into correct English, and the publisher A.A. Balkema and his staff for their care in the production process.

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The environmental and geologic setting of the Bird's Head, Irian Jaya

1 INTRODUCTION

This review describes the regional environmental setting of the Bird's Head peninsula, focusing on climate, geology, geomorphology, soils, and on regional environmental developments associated with changes from glacial to interglacial conditions during the Late Quaternary. The tectonic development of the area is reviewed as it clarifies the present position of the peninsula in the Eastern Indonesian Archipelago, and the relation of the Bird's Head to mainland New Guinea and the Australian continent. The regional geology and morphology are briefly described in support of reports presenting results of ongoing archaeological and botanical research (this volume). Quaternary environmental change had a profound effect on palaeogeography (sea-level changes), vegetation and climate, and landform developments. Data from Eastern Indonesia, Papua New Guinea and the northeastern Australian region are synthesized and the most pertinent developments for the Bird's Head are discussed.

2 REGIONAL GEOGRAPHIC SETTING

The Bird's Head or Kepala Burung in Bahasa Indonesia (Jazirah Doberai is sometimes also found on maps), is the westernmost large peninsula of the island of New Guinea (see Figs 1 and 2). The area is located just south of the equator from about 0° to 2°20′ southern latitude and between 130° and 134°20′ eastern longitude. A narrow and mountainous 'neck' connects the Bird's Head to mainland New Guinea, and is bordered to the east by Cendrawasih Bay (>1000 m deep). The northern coast of the Bird's Head descends steeply to the Pacific Ocean with depths of over 4000 m. To the west lies the Halmahera Sea with several

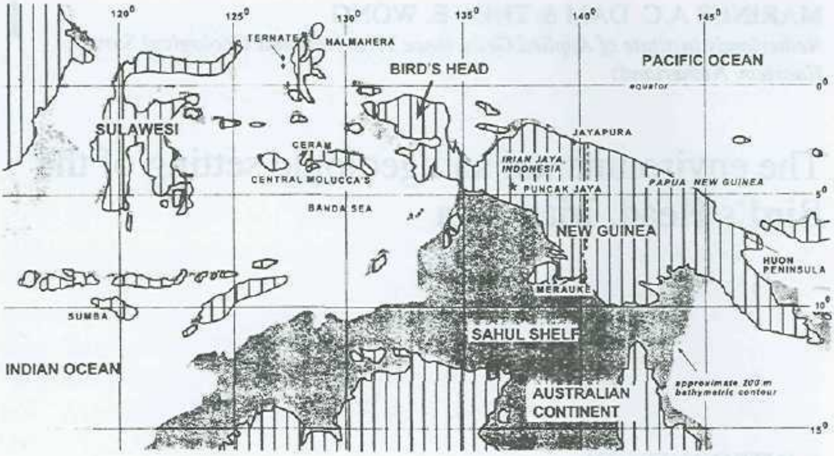


Figure 1. Pertinent geographic features in the eastern Indonesia-New Guinea region, surrounding the Bird's Head. In grey shading the exposed continental shelf areas during periods with low sea levels. At those times, the Bird's Head formed a remote promontory of the Australian continental mass.

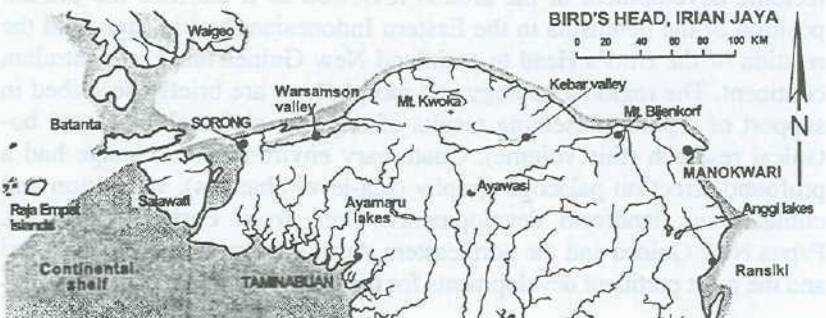


Figure 2. The Bird's Head peninsula.

small islands (the Raja Empat group, Misool and Obi islands). The shallow MacCluer Gulf and Bintuni Bay form part of the continental shelf that borders the southern shores of the Bird's Head. Further to the southwest the island of Ceram and other islands of the central Moluccas are found. The shallow seas of the extensive Sahul continental shelf extend from the southern shores of New Guinea up to the northeastern tip of mainland Australia, some 1000 km to the south.

Administratively, the Bird's Head forms part of the Indonesian province of Irian Jaya. It consists of two administrative regions or kabupatens; Sorong and Manokwari. This includes the large islands Waigeo, Batanta and Salawati, and the smaller Raja Empat islands west of the Bird's Head proper, and the islands off the eastern coast in Cendrawasih Bay. Sorong, Manokwari, Ransiki, Taminabuan, and Inanwatan are the larger settlements, but most indigenous Irianese people live in small villages scattered throughout the area (see Fig. 2).

3 MAP, AERIAL PHOTO AND SATELLITE IMAGERY COVERAGE

The extent of topographic map coverage for the Bird's Head is variable; a number of 1:100,000 scale maps were first compiled by the Netherlands Indies Topographic Service just before World War II. These maps were partly based on aerial photographs taken for the Netherlands New Guinea Petroleum Company. The Japanese army also produced a limited number of 1:100,000 maps. In the period 1942-1945 the US Air Force took aerial photographs over much of Irian Jaya which formed the basis for a series of U.S. Army maps at scales of 1:20,000 and 1:63,360. In the 1950s, KLM/Aerocarto from the Netherlands produced very useful aerial photographs of most of the Bird's Head at scales of 1:20,000 and 1:40,000. Between 1976 and 1979 the Royal Australian Air Force photographed most of the Bird's Head at a scale of 1:100,000. Recently, this material is being used for the compilation of 1:100,000 scale topographic maps. Some of these maps are available at BAKOSURTANAL, the national mapping and survey organization of Indonesia. A joint Indonesian-Australian geological mapping project (1978-1982) produced excellent 1:250,000 scale regional geological and geophysical maps with reports of the western part of Irian Jaya, including the Bird's Head. Most of the geological information presented here is based on these maps.

The Bird's Head is also covered by various satellite imagery. In the optical imagery range generally a considerable part of the land area surface is concealed by clouds. Most useful for general, geological, geographical, or vegetation studies are SPOT or LANDSAT TM scenes with a high spatial resolution. Although each scene covers an area of some 10,000 km^2 or more, it should be noted that the whole of the Bird's Head involves a large number of images (multi-temporal, and images need to be processed and/or fused to overcome cloud cover problems). The area is also covered by recent satellite radar imagery (Radarsat, ERS or

J-ERS scenes) which give a good impression of the topography and structural geology and do not have the disadvantage of (partial) cloud cover. However, these images lack the visual impression of the earth's surface colours.

4 CLIMATE AND WEATHER

The Bird's Head region has a wet tropical climate (Köppen *Af*). The position of the Bird's Head bordering the Pacific Ocean close to the equator and its relative proximity to the Australian continent determine regional climate properties. Thus, the weather patterns in the area relate to the Australian-Asian monsoon circulation and the movement of the Intertropical Convergence Zone (ITCZ) with the seasons (Nieuwolt 1977). Due to the scarcity of weather stations in the region and the lack of long records only general information on weather patterns is available, although locally some simple recordings give a reasonable impression. Table 1 presents rainfall data for several locations in the region. From November to March the northwest monsoon influences the weather, with increased rainfall and large waves along the northern coast. During this period the position of the ITCZ is roughly parallel to the equator at about

Table 1. Selected rainfall data for the Bird's Head, Irian Jaya and Ternate. For locations, see Figures 1 and 2 (Source: Berlage 1949).

Location	Period of observation							Annual Average
		Jan.	Feb.	March	Apr.	May	Jun.	
Manokwari	1900-1941	305	239	335	283	197	184	2391 mm
Sorong	1905-1941	183	167	202	243	315	341	2850 mm
Inanwatan	1914-1941	347	250	357	360	306	228	2821 mm
Momi-Ransiki	1924-1941	146	138	129	136	103	122	1287 mm
Jayapura	1917-1941	318	297	284	230	202	155	2523 mm
Merauke	1902-1941	261	229	254	184	125	44	1481 mm
Ternate	1879-1941	210	184	194	235	260	210	2211 mm
		Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	
Manokwari	1900-1941	137	141	126	119	164	261	2391 mm
Sorong	1905-1941	333	246	261	205	176	178	2850 mm
Inanwatan	1914-1941	149	107	143	141	152	281	2821 mm
Momi-Ransiki	1924-1941	110	100	94	89	103	117	1287 mm
Jayapura	1917-1941	169	166	136	161	188	217	2523 mm
Merauke	1902-1941	33	19	27	41	77	187	1481 mm
Ternate	1879-1941	135	104	112	135	202	230	2211 mm

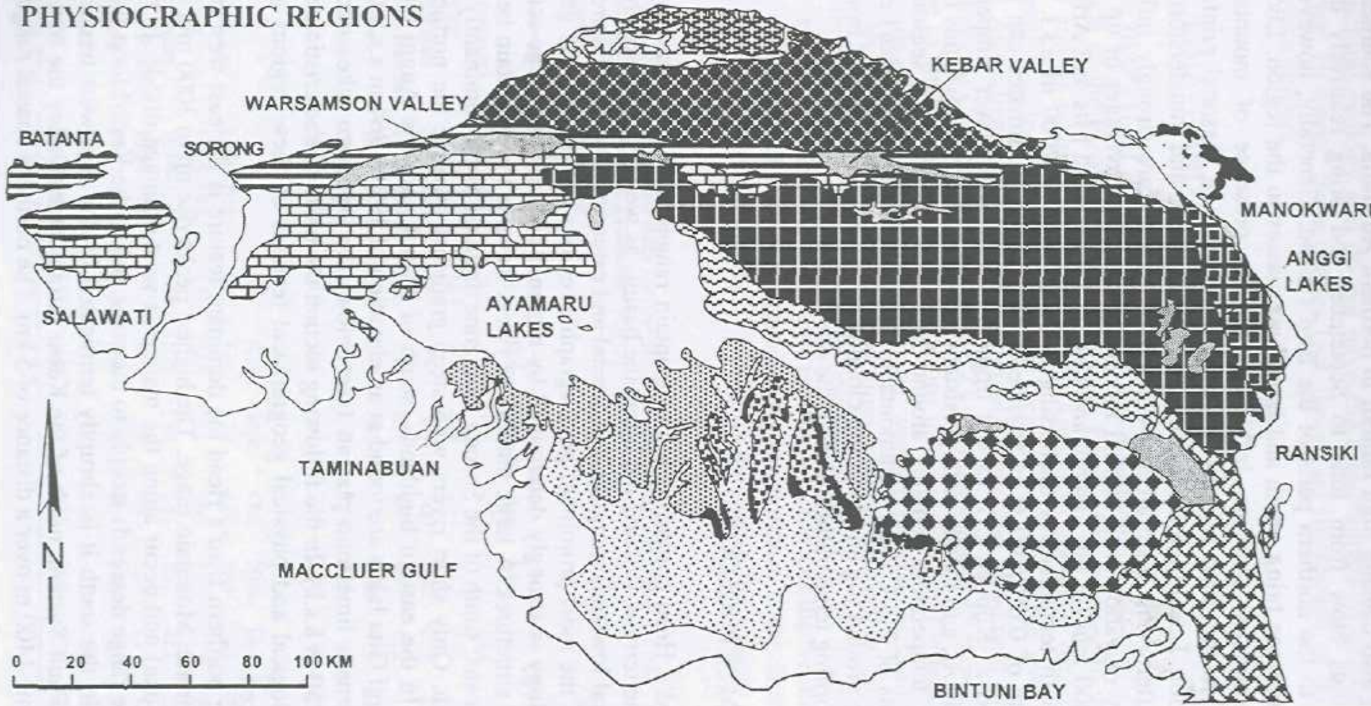
10-12°S, also causing high rainfall in northern Australia. The southeast trade winds blow from June to September and bring relatively dry weather to the northern parts of the Bird's Head. Generally, however, both monsoons bring warm and humid air masses to the region. Local wind circulation patterns, influenced by the presence of mountain ranges, are the main reasons for large differences in seasonal rainfall distribution. Local high insolation often leads to rain- and thunderstorms in the afternoons. Rainfall and temperature figures are strongly influenced by elevation with rainfall increasing to annual averages of up to 3500-4000 mm (in the Tamrau and Central Bird's Head Mts and Arfak range) with temperatures decreasing to some 16°C at 2000 m a.s.l. (a lapse rate of 0.6°C/100 m is assumed). The mountain climates can be classified as Köppen *CGf* (a wet tropical climate with lower temperatures than *Af*, and locally with persistent cloudiness). In the lowlands the daytime temperature remains around 27°C year-round, with seasonal variations of 2-3°C. The intramontane valleys (Warsamson, Kebar) experience ground fog and morning cloudiness, as well as somewhat lower early morning temperatures during the dry season.

5 GEOMORPHOLOGY

The Bird's Head comprises high mountain ranges, extensive karstified limestone terrain, isolated intramontane basins, as well as large stretches of alluvial lowlands merging into coastal and estuarine swamps. Figure 3 presents the most prominent physiographic regions. In general, the geomorphology is strongly determined by regional geology and large-scale tectonic structures. A large number of rivers traverse the mountain belts and plateaus; south of the Sorong fault zone drainage is predominantly to the south. Only short rivers with steep gradients traverse the northern ranges. In the eastern highlands, south of Manokwari, the Anggi Gigi and Anggi Gita lakes are found at an elevation of 1921-1864 m a.s.l. On the Ayamaru limestone plateau (see below) the Ayamaru lakes occur (about 250 m a.s.l.). In the following section the most characteristic geomorphological and physical geographical features of these regions are introduced.

In the northern Bird's Head the dominant feature is the east-west oriented Tamrau Mountain range. The highest peaks rise up to 3000 m a.s.l. (Mt Kwoka) and occur along the main east-west drainage divide. In the north the range descends steeply to the coast and to the Koor/Moon river basins. In the south it is abruptly terminated by the east-west trending Sorong Fault System; north of the Kebar intramontane valley the terrain rises some 1400 m over a distance of 5 km. The northern coastal range is

BIRD'S HEAD PHYSIOGRAPHIC REGIONS



formed by the Tosem Mountains. It forms a small, rugged massif with elevations up to 1400 m a.s.l., with gentle northward slopes but cliffs and steep slopes form the southern side.

The Sorong Fault System is a major geological structure in the northern Bird's Head. It is interpreted as the boundary between the northern Pacific Ocean plate and the southern Australian continental plate (see below). The Tohkiki mountains form a narrow east-west trending range of about 150 km long within the fault zone. In accordance with the regional geology it is a rugged and chaotic terrain with short, steep ridges and narrow valleys. Streams are characterized by steep gradients and numerous waterfalls. Within the Sorong fault zone numerous intramontane basins occur, such as the Kebar basin (40×8 km) and the elongate Warsamson basin (10×70 km). Comparable in nature to the Sorong Fault System is the Ransiki fault zone, although this structure has affected the regional morphology and topography far less. It stretches from the eastern extension of the Sorong Fault System in a southeastern direction up to Ransiki on the coast of Cendrawasih Bay. The fault forms the boundary between the Central Bird's Head and Arfak Mountains, and is expressed as a narrow zone with disturbed topography, predominant SE-NW lineaments, cut-off drainage systems and narrow strike-slip valleys and basins.

The Central Bird's Head Mountains largely coincide with the presence of metamorphic rocks of the Kemum Formation (see below and Fig. 5). In the western part elevations of up to some 800 m prevail, with steep, straight slopes and a uniform morphology. The highest peaks rise up to 2800 m a.s.l. in the east where the relief is more rugged. In the

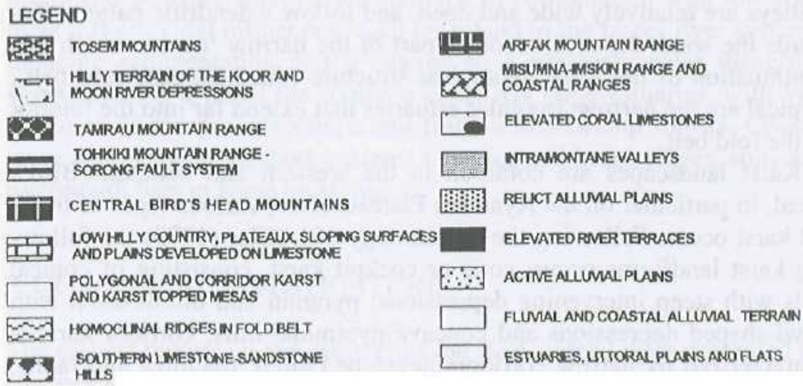


Figure 3. Physiographic regions of the Bird's Head (see text for explanation).

Aifat river basin the summit level of the ridges appears to form a planar surface at an elevation of 1000-1400 m a.s.l. The terrain is characterized by a uniform but rugged ridge and V-valley morphology. Dome-shaped mountains and hills with steep, straight slopes occur. Locally, the monotonous morphology is interrupted by gently sloping surfaces and plateaus. A structurally-controlled, dendritic drainage pattern has developed and the streams usually have low-gradient, winding courses. Locally, braided river systems occur.

Arfak plain forms a structural low on the northeastern side of the Sorong fault zone. Alluvial fans with braided rivers form a zone of low relief gradually descending to the northern coast. In some areas along the mountain front terraces have formed as a result of tectonic uplift. In the northwestern corner of Arfak plain the volcanic neck known as Mt Bijenkorf (577 m) forms a distinct landmark. Pliocene and Quaternary uplifted reef limestones form the northeastern corner of the Bird's Head in the vicinity of Manokwari.

The eastern portion of the Bird's Head is formed by the Arfak Mountains. This mountain range, of which the highest summits reach over 2300 m in altitude, are characterized by high local relief. Steep, V-shaped valley systems separate high ridges with sharp crests and river systems often form waterfalls while draining through steep gorges. Towards the coast the mountains grade into a series of hills. Locally, steep cliffs occur along Cendrawasih Bay coast. Most rivers form alluvial fans upon entering the narrow coastal zone.

Towards the 'neck' of the Bird's Head the Misumna-Imskin Range is characterized by structurally-controlled ridges and valleys. Tectonic pressure has resulted in the formation of folds, with oriented ridges and valleys. The relief is more rounded and elevations reach 700-900 m. Valleys are relatively wide and open, and follow a dendritic pattern. Towards the south the area becomes part of the narrow 'neck', which is a continuation of the same geological structure (the Lengguru fold belt). Typical are the narrow, irregular estuaries that extend far into the interior of the fold belt.

Karst landscapes are common in the western and southern Bird's Head, in particular on the Ayamaru Plateau. Here, various types of tropical karst occur. Following the terminology of Löffler (1977) the following karst landforms occur; cone or cockpit karst, consisting of conical hills with steep intervening depressions; pyramid and doline karst with bowl-shaped depressions and concave pyramidal hills; corridor karst is characterized by narrow corridors developed along fractures and faults, but lacking an integrated drainage system. The karst-topped mesas in the northwestern part of the Ayamaru Plateau are characteristic steep-sided, flat-topped hills formed on the exposed reef complexes in the Miocene

Kais limestone formation. Major rivers form deep, narrow gorges where they cut through the limestone. In the karst landscape the drainage pattern is usually intermittent or partly subterranean. The limestone terrain without distinct karst features is indicated separately in Figure 3.

6 THE LOWLANDS

The alluvial lowlands along MacCluer Gulf and Bintuni Bay are geologically very young. Most of these plains have developed during the last few thousand years and are presently still active centers of deposition. They were formed as a result of the regional trend in sea level change in conjunction with varying sediment supply from the hinterland. The off-shore marine environment is characterized by very low-gradient continental shelfs, which were exposed during periods of low sea levels (see below).

In the coastal lowlands fluvial and estuarine/marine depositional processes have determined the morphology. Adjacent to the southern margin of the limestone plateau and Central Bird's Head mountains alluvial fans and plains form extensive, gently sloping surfaces of low relief, gradually merging into flat coastal plains. Relict alluvial fans are mainly found in the southeast of the Bird's Head and form low, tongue-shaped plateaus that are interrupted by vertically incised river valleys. Downstream, meandering rivers have built up extensive alluvial plains. Coarser-grained (sand and gravel) stream deposits form a framework of amalgamated bars and channels, while in between the larger river systems floodbasins receive finer-grained sediment through overbank deposition. Peat formation can occur in some of the wetter floodplains due to prolonged flooding and/or poor drainage in combination with low sediment inflow. Tidal influences reach far inland in the larger river systems, inducing sedimentation and a change to a brackish water mangrove vegetation. As a result the southern coast has large estuaries, with vast expanses of mangrove swamps and fresh water swamp forests. Coastal wave action and alongshore currents have formed beach ridges, spits and rivermouth bars in some locations.

7 GEOLOGICAL INVESTIGATIONS

The earliest reports on the geology of the Bird's Head were presented by Verbeek (1908), Hirschi (1908), Wichmann (1917), Brouwer (1917), and Rutten (1923). The first geological map (scale 1:500,000) of this area was composed by Loth (1924). This map was based on data collected by the *Kantoor voor het Mijnwezen in Nederlandsch-Indië* (Mining Office in the Dutch Indies) in 1920. Using information from the same office, Zwierzycki (1932) composed a geological composition map (scale 1:1,000,000). Van Bemmelen (1939) presented a four-fold geotectonic division of the Bird's Head. Subsequent geological research was performed by the *Technische Hogeschool* (Technical University) Delft, the Netherlands (Bemelmans 1956; Visser 1956; Hermans 1959; Kaptein 1960) and the *Kantoor voor het Mijnwezen in Nederlands Nieuw-Guinea* (Mining Office in Dutch New Guinea) (Schippers & de Valk 1954; Molengraaff 1957a,b; Soutendam 1957a,b; Verstappen 1959, 1960; Valk 1962). From 1935 to 1960 the *N.V. Nederlandsche Nieuw Guinea Petroleum Maatschappij* explored for oil in almost all the younger sedimentary regions of Irian Jaya including the Bird's Head. This exploration also encompassed seismic and gravimetric surveys. The final report was presented by Visser & Hermes (1962). This report included a geological map (scale 1:1,500,000) of the entire Irian Jaya area. During the period 1959-1962 the Foundation Geological Investigation Netherlands New Guinea carried out field investigations in the north-eastern part of the Bird's Head. The results were published by d'Audretsch et al. (1966).

Systematic geological mapping of the Bird's Head was continued in 1976 by the Geological Survey of Indonesia (the forerunner of the Geological Research and Development Centre) in conjunction with the Australian Bureau of Mineral Resources (Pieters et al. 1979). These organizations cooperated in the Irian Jaya Geological Mapping Project (1978-1982) and produced various geological maps (Bird's Head map sheets scale 1:250,000, with explanatory texts: Pigram & Sukanta 1989; Pieters et al. 1989; Amri et al. 1990; Robinson et al. 1990). A scale 1:1,000,000 2-sheet map of the whole of Irian Jaya was published by Dow et al. (1986). In the context of this cooperation various papers were published dealing with specific topics (e.g. Pieters 1982; Dow & Sukamto 1984).

8 GEOLOGICAL SETTING

The island of New Guinea is part of the northern margin of the Australian continental block and the southern part of the Pacific Plate (see Fig. 4). The plates are separated from each other by major, largely E-W trending, fault zones (the Yapen fault zone in eastern Irian Jaya and the Sorong fault zone in the Bird's Head). Geologically, a subdivision into three provinces can be made each characterized by their own specific stratigraphic, tectonic and magmatic history (Dow 1977). From north to south these provinces are:

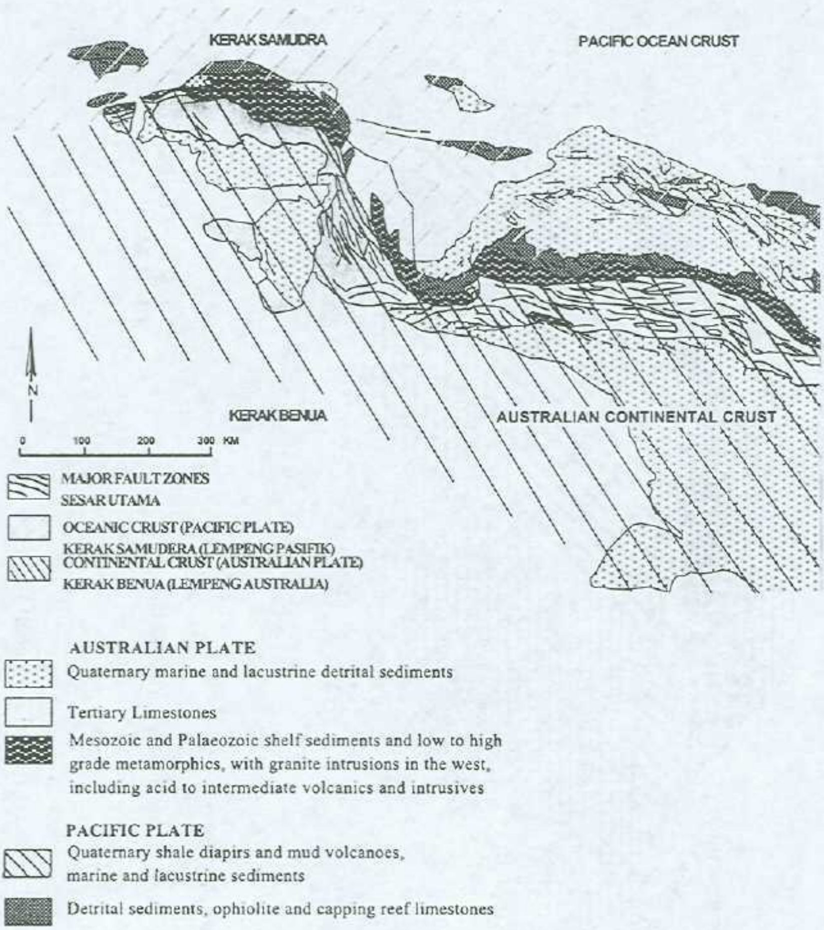


Figure 4. Regional tectonic setting (after Dow et al. 1986). Volcanic Arc and Ophiolite lithologies with a Pacific Plate affinity occur along the northern coast of the Bird's Head and north of the main mountain range of the Irian Jaya mainland. The Mobile Belt lithologies form the northern rim of the east-west trending main mountain range and the northern and northeastern margin of the central Bird's Head mountains. Platform sediments are found in the southern, Australian continental part of Irian Jaya and the southern and southwestern part of the Bird's Head.

1. An outer zone of Ophiolite and Volcanic Arc lithologies belonging to the Pacific Plate. The lithologies consist of relatively undisturbed Mesozoic and Tertiary ultramafics, gabbro and basalt representing upper mantle and oceanic crust, locally overlain by Late Mesozoic or Tertiary rocks;

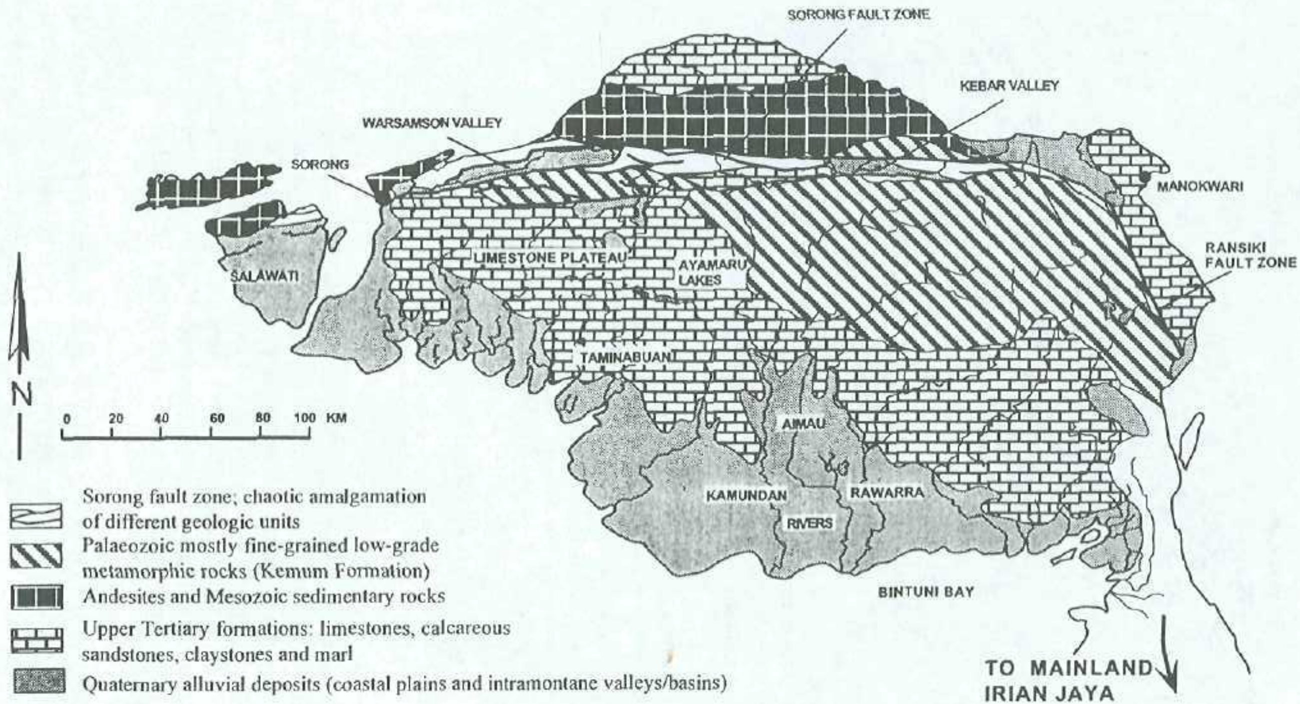


Figure 5. Generalized geology of the Bird's Head (based on Dow et al. 1986).

2. A Mobile Belt, comprising an arcuate belt of Cretaceous to Late Eocene sediments, metasediments and metavolcanics, folded and metamorphosed during the major orogeny (the Melanesian orogeny, cf. Simandjuntak & Barber 1996) which lasted until the Middle Miocene;

3. The Platform, an almost continuous sequence of predominantly marine sediments ranging in age from Late Carboniferous to Holocene, underlain by stable continental crust of the Australian block.

The Bird's Head comprises Palaeozoic low-grade metamorphic rocks (metasediments) intruded by granites of Carboniferous and Permian age, unconformably overlain by subhorizontal, Late Carboniferous to Middle Miocene, platform sediments (see Fig. 5). The Sorong fault zone, first described by Visser & Hermes (1962), has a width of several kilometers and consists of a large variety of lithologies with both oceanic and continental characteristics. Pieters et al. (1989) described this area as made up of a melange of fault-bounded, both locally derived and exotic rock fragments with dimensions ranging from a few centimeters to 10 km These fragments have widely differing compositions, ages, tectonic styles, and origins. Some of these fragments are relatively coherent, mappable at 1:250,000 scale and clearly derived from adjacent geological provinces. Towards the south-east the Sorong fault zone links up with the north-northwest trending Ransiki Fault System (see Fig. 5).

9 STRATIGRAPHY

The platform sediments cover a large part of the Bird's Head (see Fig. 5). There is a distinct unconformity between the metamorphic Siluro-Devonian basement and the nearly complete section of Upper Carboniferous to Holocene platform sediments. The metasediments, belonging to the Kemum Formation, consist of shale, slate, metagreywacke, quartzite, schist, minor metaconglomerates, and metalimestones usually with graded bedding and cross-lamination. Locally, graptolites and ostracods have been recorded in the shale. In some places, higher grade metamorphic rocks occur, characterized by biotite, andalusite, sillimanite, and garnet porphyroblasts which formed during a phase of thermal metamorphism in connection with the emplacement of granitic batholiths and pegmatite veins during the Late Permian to Early Triassic (cf. Pieters 1982).

The oldest unit of the platform sediments is the Aimau Formation of Late Carboniferous to Early Permian age. It consists of sandstone, limestone, shale, and basal reddish conglomerate. This formation is conformably overlain by the Aifat Mudstone of Early Permian age, which in turn is conformably overlain by carbonaceous sediments of the Ainim

Formation. These three formations constitute the Aifam Group (Pieters et al. 1989). This group contains a varied fauna of brachiopods, corals, fusulinids, bryozoans, crinoid stems, and molluscs while plant remains have also been recorded. Locally, the Ainim Formation may be absent due to erosion. In places the other two formations have also been eroded and the Kemum Formation is directly overlain by red fine to coarse-grained clastics and dolomitic limestones of the Tipuma Formation (Triassic to Early Jurassic). Early Jurassic-Late Cretaceous sediments generally occur in the subsurface as is revealed by various drillings. They consist of shales, calcareous sandstones and claystones. This section (lithologies grouped in various units e.g. Fageo Group, Facet Limestone and Jass Formation) contains a rich fauna of ammonites, belemnites and foraminifera. It is overlain by a thick unit of stable shelf, reef and fore-reef and minor basinal limestones. The complete calcareous section, ranging in age from Palaeocene to Middle Miocene, is developed in the subsurface of the Salawati Basin in the southwestern part of the Bird's Head. All these different lithologies, varying from fine- to coarse-grained detrital, phanitic and biolithic limestones have been grouped in the New Guinea Super Group. In the central part of the Bird's Head the Mesozoic rocks are unconformably overlain by Eocene reef and fore reef limestones. The main reef builders were algae and bryozoa. The Eocene limestone is covered by Oligocene and Early Miocene paralic sandstone, shale and conglomerates with plant imprints and coal films. Late Palaeozoic, Mesozoic and Early Tertiary sediments may be eroded locally and can be covered by a very extensive Mid-Late Miocene carbonate sheet which extends east along the central range. In adjacent basins around the Mid-Late Miocene platform continental, deltaic and shallow marine fine and coarse clastics of Late Miocene, Pliocene and Quaternary age occur. North of the Sorong fault zone is a sliver of Early Palaeozoic basement overlain unconformably by remnants of the Late Palaeozoic, Mesozoic and Early Tertiary cover. These sediments are overlain by a sheet of mid-Miocene andesite and dacite pyroclastics, lava, volcanically derived sediments, and limestone. Late Miocene, Pliocene and Pleistocene clastics are draped around former landmasses.

10 REGIONAL TECTONICS

Generally, the Sorong fault zone has been interpreted as a regional left-lateral strike-slip fault, forming a decoupling zone between the Australia-India plate and the Pacific plate (Visser & Hermes 1962; Tjia 1973; Hamilton 1979; Pieters et al. 1982). Dow & Sukamto (1984) suggest that the displacements along the Sorong fault since the Middle Miocene amount to at least 370 km. It has been remarked by Puntodewo et al. (1994), however, that the Sorong fault in the Bird's Head at present does not form the main boundary between the Australia and the Pacific Plates because GPS sites on opposite sides of the fault show little relative motion. As far as the relative position of the Bird's Head is concerned, various authors e.g. Visser & Hermes (1962), Hermes (1968), Robinson & Ratman (1978), Hamilton (1979), Norvick (1979), suggest large northeastward movements or clockwise rotation of the Bird's Head relative to the Australian continental block. Pigram & Panggabean (1983), and Pigram et al. (1985) present a contrasting view in which the Bird's Head constitutes an apart microcontinent that has been rafted to its current position. Dow & Sukamto (1984) postulate that the Bird's Head remained an integral part of the Australian continent since the start of the movements in the latest Miocene. Its protrusion into the Pacific Plate has resulted largely from differentiated shortening along the northern edge of the Australian continent. Hall (1996) suggests that the Bird's Head, the Sula Platform and Tukang Besi Platform were part of a single large microcontinent. These units moved to their present location after slicing off fragments from this microcontinent at different times and each was attached to the Philippine Sea Plate for a few million years before collision. Prior to this time, at the end of the Oligocene, the Bird's Head was a single block that was formed by separation from Australia during the Mesozoic.

11 SOILS

Reynders (1961) presents a useful overview of soil survey activities in Irian Jaya covering most of the early work in the Dutch period. During the initial exploration of the Bird's Head several semi-detailed surveys were conducted in small, mostly coastal areas. Reports by Wentholt (1934, 1935), Van Es (1948), Van der Voort & Wentholt (1932), and Reynders (1961: also for complete references) present qualitative information on regional morphology and vegetation, soil type and agricultural potential. For a more comprehensive discussion on soil information for the island of New Guinea reference is made to the work by Haantjens et al. (1967) comprising a map and report on the major soil groups in the area. Wood (1982) presents a more recent review of data on New Guinea soils and remarks that only limited information is available on Irian Jaya soils. Useful references include Schroo (1963a,b, 1964), Haantjens (1970), Haantjens & Bleeker (1970), and FAO-UNESCO (1974).

Based on the maps published earlier by Haantjens et al. (1967), Haantjens (1970) and Bleeker (1974), Wood (1982) discusses the major groupings of soil types. Some groups consist of associations of widely varying soil types. The soil types are strongly associated with the geology and geomorphology of the area. In the Bird's Head the following soil associations (following the FAO system for soil classification (FAO-UNESCO 1974) are widely distributed.

– Rankers and Regosols: Shallow soils developed in a thin layer of stony parent material, directly overlying bedrock. This association occurs on rugged mountains with steep slopes. Soil profiles are generally shallow due to the instability of the slopes and soil creep. Lithosols (very shallow, stony soils) occur on the steepest slopes. On more acidic parent material podzolic soils can also occur.

– Rendzinas and limestone soils. Soils on limestone. On steeper slopes shallow, stony Rendzinas are dominant, while deeper red and brown calcareous soils are more common on old surfaces and on more stable slopes. Karst features are common in all these soils.

– Latosols and brown soils. This association includes a wide variety of soil types occurring in hilly and mountainous country (0-2500 m). Included are Lithosols and Regosols on steeper terrain. Moderately fertile Brown Forest soils occur on more gentle, stable slopes. Brown Podzolic Soils occur at higher elevations on acidic parent material. Deep weathering under high temperature and rainfall conditions at lower elevations produces Latosols.

– Latosols. Mainly moderately fertile soils (Ultisols) on weathered Pleistocene alluvial sediments which form flat to undulating plains between 0-100 m elevation. Most soils are acid with loamy topsoils and clayey subsoils due to eluviation caused by moderate to good internal drainage.

– Poorly drained alluvial soils. These occur on poorly drained, level floodplains and on Holocene alluvial terrain (0-150 m). Soils are fine-textured and poor drainage causes gley features. During the wet season prolonged inundation may occur. In the dry season deep cracks develop due to the presence of expanding clays. Organic peat soils occur locally in swamps.

– Mangrove soils. Fine-textured, poorly drained, saline soils developed in marine sands, mud and peat. They are widespread in tidal mangrove plains in the coastal lowlands.

12 QUATERNARY ENVIRONMENTAL CHANGE IN THE BIRD'S HEAD REGION

During the Quaternary period, covering approximately the last 2.4 million years, Southeast Asia and also the Bird's Head region experienced significant geologic, geographic and climatic changes in conjunction with the global glacial-interglacial cycles. For the southeast Asian equatorial region these environmental changes essentially comprise; temperature changes of 2-4°C at sea level (disputed) and possibly up to 6-8°C in the highlands, glaciation of the highest mountain ranges, regional precipitation decreases of up to 30%, as well as marked vegetation changes and sea level fluctuations in the order of 100-125 m with associated changes in the coastal configuration. Major geologic developments (vertical and horizontal plate motions, volcanism, coastal accretion) have taken place, in particular in the tectonically dynamic eastern Indonesian region. To date, indications for major environmental change in the region do not derive from research in the Bird's Head, but from locations in Eastern Indonesia, Central Irian Jaya, Papua New Guinea, and northeastern Australia. Below, the pertinent phenomena of Quaternary environmental change inferred for the Bird's Head region are summarized.

13 SEA LEVEL CHANGE

The effect of global sea level lowering (in the order of 100-125 m below the present level) on the islands, peninsula's and lowlands in the Bird's Head area has been considerable. Evidence for sea level change in the region comes from uplifted coral terraces and their inferred link with past sea levels (Chappell 1982; Aharon & Chappell 1986; Pirazzoli et al. 1993; Bard et al. 1996). The sea level curve obtained by Aharon & Chappell (1986) from the marine terrace sequence at the Huon peninsula (eastern Papua New Guinea) provides a reliable indication of sea level fluctuations over the past 300 Ka (see Fig. 6).

Studies of the shallow seas and sediments on the Sahul and Sunda continental shelfs also provide useful information on the timing of major sea level fluctuations in the area (Van Andel et al. 1967; Torgersen et al. 1988; Aleva 1973; Geyh et al. 1979). Since the peak of the last glacial (22,000-18,000 yr BP), sea level has risen rapidly, with rates of up to 30 mm/yr (Fairbanks 1989; Bard et al. 1990). In particular in areas with low relief like the southern Bird's Head, this rate of transgression must have caused major coastline changes. Regional data for sea level low stands at the beginning of the Holocene indicate sea-level was –20 to –15 m at around 8000 yr BP, and flooding of the shallow MacCluer Gulf and Bintuni Bay (about –20 m) only took place after approximately 8500 yr BP. Prior to this, the expanded river systems drained across the exposed shelfs and sedimentation took place in distal positions at the edge of the continental shelf, now submerged beneath the sea. Coastline changes along the northern and eastern coast were less extensive, largely due to

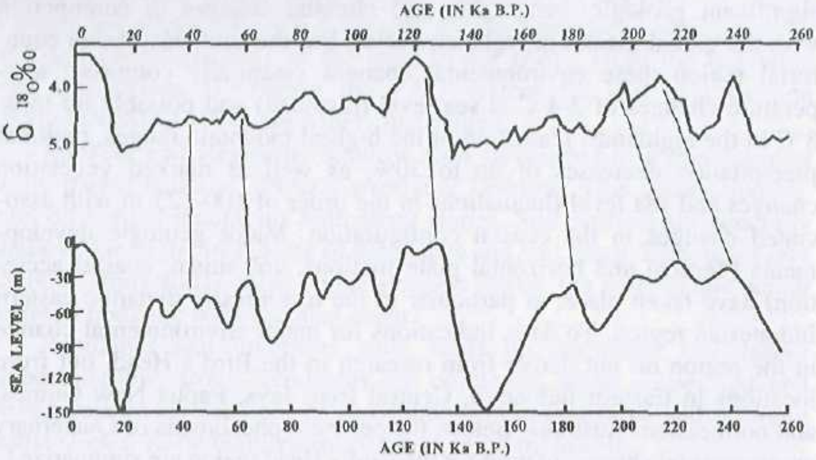


Figure 6. Late Quaternary sea level and associated oxygen-isotope record derived from coral terraces at the Huon peninsula, Papua New Guinea (after Aharon & Chappel 1986). The Huon terraces sea level curve is one of the few long, continuous records from the region. A reconstruction of absolute sea level positions could be made after careful analysis of spasmodic uplifts of the land. Throughout the Indonesian region, active uplift/subsidence interacts with global, eustatic sea level fluctuations. The resulting net effect can only be reconstructed with meticulous dating and ample consideration of the regional geology (copyright: Elsevier Science).

the steep offshore profiles and narrow zone of lowlands adjacent to the uplands. Major rivers incised deep valleys in their coastal reaches to accommodate the steeper gradients.

Brief increases in the rate of sea level rise resulted in temporarily increased accumulation of fine sediment in the shallow coastal waters. This is probably the cause of the widening of the coastal mangrove vegetation belt (see also below). The present extensive mangrove belt along MacCluer Gulf and Bintuni Bay originated during the second half of the Holocene, when sea levels stabilized and the coastal lowlands started to expand seawards. Thom & Chappell (1975), Geyh et al. (1979), Chappell (1982), and Tjia (1990) infer sea levels several meters higher then present around 6-5000 yrs ago (see Fig. 7). A minor regression during the last 5-4000 yrs may have contributed to the rapid expansion of New Guinea coastal lowlands, but reliable data for Holocene sea level change from sites within the area are not available.

The glacial period palaeogeography in the New Guinea region, with lowered sea levels, was significantly different from the present day settings (see Fig. 1). The land area of the Bird's Head peninsula increased substantially, whereas the distance to the surrounding islands (Halma-

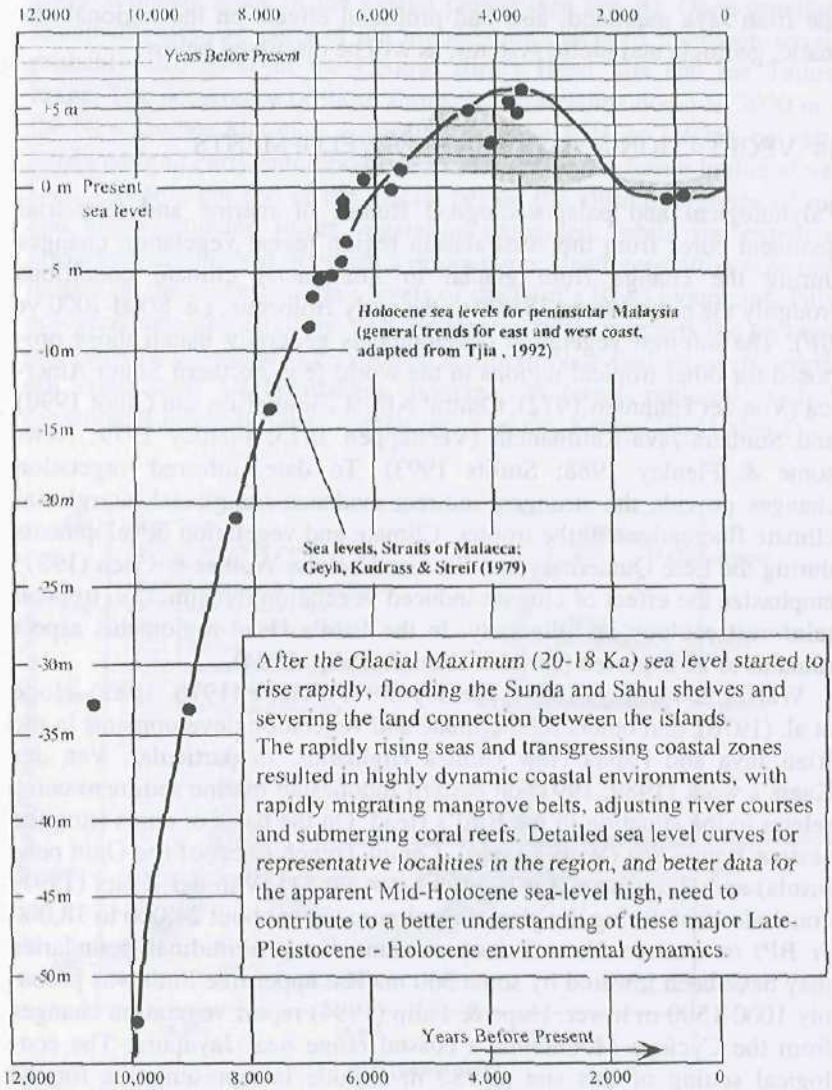


Figure 7. Sea level during the Late Quaternary (adapted from Geyh *et al.* 1979; Tjia 1992).

hera, Ceram, Biak and Yapen) was far less. Cendrawasih Bay was a semi-enclosed, poorly ventilated bay. For the migration of plant and animal species, and possibly also the early human inhabitants of the region, this Late Quaternary palaeogeography was of great significance. In particular the exposure of the immense Sahul continental shelf, south of the Irian Jaya mainland, also had profound effects on the regional climatic, geologic and biotic systems, as will be discussed below.

14 VEGETATION AND CLIMATE DEVELOPMENTS

Palynological and palaeoecological studies of marine and terrestrial sediment cores from the Australasian region reveal vegetation changes during the change from glacial to interglacial climate conditions (roughly the period from 25,000 to the early Holocene, i.e. 8000-7000 yr BP). The inferred vegetation developments generally match those proposed for other tropical regions in the world (e.g. northern South America (Van der Hammen 1972), Central Africa (Bonnefille and Guiot 1990) and Sumatra-Java-Kalimantan (Verstappen 1975; Flenley 1979; Newsome & Flenley 1988; Stuijts 1993). To date, inferred vegetation changes provide the strongest indirect evidence for glacial-interglacial climate fluctuations in the tropics. Climate and vegetation developments during the Late Quaternary are discussed below. Walker & Chen (1987) emphasize the effect of climate-induced vegetation dynamics on tropical rainforest ecology and diversity. In the Bird's Head region this aspect remains to be explored (see also Hope & Tulip, 1994).

Walker & Flenley (1979), Flenley (1979), Hope (1976, 1989), Hope et al. (1976), and others infer climate and vegetation developments in the Irian Jaya and Papua New Guinea Highlands. In particular, Van der Kaars's work (1989, 1991) on eastern Indonesian marine sediment cores relates to the situation in the Bird's Head. On the basis of cores from the eastern Banda Sea (Weber Deep), Ceram Trench (west of the Onin peninsula) and Halmahera (for locations, see Fig. 1), Van der Kaars (1991) concludes that during the glacial maximum (from about 24,000 to 18,000 yr BP) in western New Guinea montane forest altitudinal boundaries may have been lowered by some 500 m. The upper tree limit was probably 1000-1500 m lower. Hope & Tulip (1994) report vegetation changes from the Cyclops Mountains, a coastal range near Jayapura. The ecological setting of this site at 780 m altitude is representative for the northern, mountainous part of the Bird's Head. The palynological record suggests increases in high altitude forest taxa in the period 25,000-10,500 yr BP, with an inferred temperature change of 3-4°C cooling. Nevertheless, montane forests are continuously present at the site, supporting the assumed long-term stability of the montane tropical rainforest. In response to globally warmer and wetter climates a change in vegetation to lower altitude forests commenced around 10,500 BP and was only completed around 7000 BP.

In the central New Guinea Mountains the forest upper limit was below

2500 m during much of the glacial period (see Fig. 8). Open grassland occupied extensive parts of the highest non-glaciated mountain terrain, probably also those of the Central Bird's Head Mts and the Tamrau range. The occurrence of these shrub-rich grasslands down to 3000 m in the New Guinea Mts may, according to Hope & Hope (1976), be partly attributable to early anthropogenic influences in the fertile highland valleys. Towards the end of the glacial period the altitudinal range of mid and upper montane forest vegetation expanded, while the extent of grasslands diminished. Remnants of open grassland vegetation now only remain on the highest summit levels of the Bird's Head mountains. Palynological data discussed by Van der Kaars (1991) suggests the presence of extensive grassland vegetation in southern New Guinea or the northern Sahul Shelf. On Halmahera, montane oak forests replaced much of the tropical lowland forest vegetation. Van der Kaars (1991) also infers

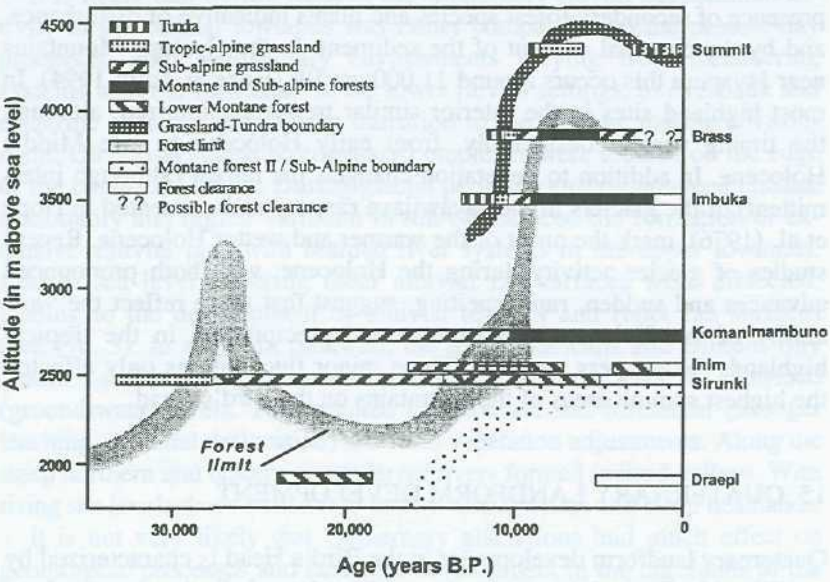


Figure 8. Summary diagram showing Late Quaternary vegetational changes in the New Guinea Highlands (after Flenley 1979). More pronounced than in other mountain regions in the archipelago, the montane vegetation in the New Guinea Mts was lowered as a result of decreased Glacial period temperatures. The diagram indicates that the forest upper limit was below 2500 m (apart from a brief upward excursion). The rise of the forest upper limit only occurred at about 9000 BP, at the beginning of the Holocene Interglacial period. The vegetation adjustments can be explained by lower overall temperatures, probably in combination with drier conditions and possibly a steeper lapse rate.

the presence of a large mangrove belt off western New Guinea prior to 12,000 BP, possibly as a result of the large expanse of swampy, exposed continental shelf. Possibly, the change from a vegetation zoning with initially an extremely wide mangrove belt to a restricted mangrove fringe with widespread freshwater (peat) forests on the landward side came about due to continued sedimentation under a stable or falling sea level during the Middle to Late Holocene. The onset of the Holocene shows an expansion of the tropical lowland forest (retreat of the montane forest to higher altitudes) and increased importance of ferns on Halmahera and western New Guinea (suggestive of a year-round wet climate). The rapid expansion of shallow, warmer waters in the seas surrounding the Bird's Head clearly had a humidifying effect on the climate, with consequences for the vegetation composition.

During the Holocene much of the vegetation dynamics and response to climatic change is obscured by anthropogenic disturbance of the forest vegetation. It can be observed in palynological records as the dominant presence of secondary forest species and plants indicative of disturbance, and by the charcoal content of the sediment. In the Cyclops Mountains near Jayapura this occurs around 11,000 yrs BP (Hope & Tulip 1994). In most highland sites in the interior similar trends are inferred, although the timing varies considerably, from early Holocene to late Middle Holocene. In addition to vegetation changes, the retreat (although intermittent) of the glaciers in the Jayawijaya ranges, as documented in Hope et al. (1976), mark the onset of the warmer and wetter Holocene. Recent studies of glacier activity during the Holocene, with both pronounced advances and sudden, rapid melting, suggest that these reflect the variability of the Holocene temperature and precipitation in the tropical highlands (Hope, pers. comm.). These minor fluctutations only affected the highest summit areas of the mountains on the Bird's Head.

15 QUATERNARY LANDFORM DEVELOPMENT

Quaternary landform development in the Bird's Head is characterized by considerable vertical movements as well as lateral displacements along the major Sorong and Ransiki faults. Evidence for this comes from geological mapping and geomorphological studies.

The presence of raised coral reefs along the northern and eastern coasts of the Bird's Head (Ratman & Robinson 1981; Pieters et al. 1989) is indicative of tectonic uplift. These reef terraces could facilitate analysis of tectonic and sealevel movements, for instance by correlation with the Huon terrace sequence (Aharon & Chappell 1986), or other marine terrace records in the region (e.g. Sumba: Pirazzolli et al. 1993, Timor:

Vita-Finzi & Hidayat 1991, and eastern Sulawesi: Sumosusastro et al. 1989). However, since the tectonic setting of the Bird's Head is still poorly understood (see above), this remains a complicated task.

According to Pigram & Sukanta (1989), uplift and tilting of the southern margin of the Central Bird's Head Mountains continued during the Quaternary, causing entrenchment of the middle reaches of the larger rivers and the formation of deep, narrow gorges in the limestone. Further downstream, terraces formed along the Kamundan, Aimau and Rawarra rivers, a process which is continuing today. Also, as a result of the most recent vertical and lateral movements, relatively young intramontane basins formed, which are presently being filled in with sediments from interrupted drainage systems. Ponded-up lakes once occupied several of these basins, e.g. Kebar and Warsamson basin sedimentary fill consists partly of fine-grained organic swamp and lacustrine deposits (Pieters et al. 1989; Amri et al. 1990).

It is likely that during most of the Quaternary fluvial depositional activity in the coastal lowlands was rather comparable to the present-day processes, with sedimentary environments varying from meandering systems with bar formation in the lower fluvial settings, to overbank and estuarine sedimentation in the transition to the shallow marine environment. Obviously, these sedimentary complexes were located on the edge of the continental shelf. During glacial periods more pronounced climate seasonality and higher variation in run-off induced the formation of extensive alluvial fans with braided river systems in the upper lowlands. Due to sea level lowering older alluvial fan surfaces were dissected, leading to the development of alluvial terraces and relict fan surfaces (see Fig. 3). In southern Salawati, the MacCluer Gulf and Bintuni Bay coastal sedimentary environments were affected due to lowered (ground)water levels. This resulted in increased soil formation (stronger leaching, seasonal desiccation) and local vegetation adjustments. Along the steep northern and eastern coasts larger rivers formed incised valleys. With rising sea levels these turned into narrow embayments and steep headlands.

It is not very likely that Quaternary glaciations had much effect on geomorphic processes and landform development in the highlands of the Bird's Head. Although depression of vegetation belts and geomorphic process zones occurred, this did not result in significant changes in morphologic development. There is also no evidence from New Guinea that deglaciation (from 15,000-9000 yrs BP) caused large scale erosional-depositional activity (Löffler 1977). Only in the Early Holocene do anthropogenic influences (deforestation, burning activities) cause increased erosion and valley-floor sedimentation due to slope instability. However, these minor modifications do not obscure the fact that in a large part of the Bird's Head very young tectonic processes have been responsible for the present landforms.

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2

Preliminary report on Makbon archaeology, the Bird's Head, Irian Jaya

1 INTRODUCTION

My wife and I have spent major portions of two years in Irian Jaya, Indonesia, doing archaeological field work and working on the collections that resulted. The first year was during my sabbatical leave of 1975-1976 from the University of Hawaii at Manoa, when we made an archaeological survey of coastal areas and short excavations. This was a joint program of the University of Hawaii, the National Research Centre of Archaeology in Indonesia, and the Institute of Anthropology of the Cenderawasih University, Irian Jaya. This program was supported by the Ford Foundation through their Southeast Asia Research Fellowship Program and their Indonesian office of the Ford Foundation. The second period was primarily in 1990, supported by a Regional Fulbright Research Grant from the United States Information Agency for archaeological research in Irian Jaya and the northern Moluccas. I thank these several organizations for their support.

2 FIRST YEAR'S WORK

The first year we had two seasons working in the field and two periods working on the resulting collections in the Anthropology Museum at Cenderawasih University, near Jayapura, the capital of Irian Jaya. I would like to thank Dr Rubini, the Rector of Cenderawasih University at that time and Dr Suharno, the Director of the Institute of Anthropology, for the laboratory and staff facilities they made available. Also Mr Coates, for the assistance of Freeport Indonesia, Inc. in the first portion of our Irian Jaya program.

The purpose of the research was to find archaeological evidence of the movement of the Austronesian peoples from eastern Indonesia and the southern Philippines out into Melanesia. As virtually no organized archaeological research had been done in Irian Jaya before our program we had nothing to go on from previous research. From experience of surveying in the Philippines I knew that the easiest archaeological sites to locate were cave sites. Caves were often used by Austronesian peoples living in coastal areas for burial of for temporary shelter. The most logical coastal areas in which to look for cave sites are areas with limestone formations, which are easy to spot from geological maps.

Our first survey program included myself, my wife Ludy and stepson Edwin, Johsz Mansoben from the Institute of Anthropology, Cenderawasih University, and Goenadi Nitihaminoto of the Indonesian National Research Centre of Archaeology. After surveying on several Islands in the Cenderawasih Bay we moved to Sorong, at the western tip of the Bird's Head. From here we surveyed on several islands to the west of Sorong and south to the Bomberai peninsula and the area around Kaimana.

While in Sorong we were able to arrange transportation through an uncle of Mansoben's to visit Makbon, a small village or kampong to the east of Sorong on the north coast of the Bird's Head. While there was no limestone indicated there on the sketchy geological map that we had with us, it was in the only protected bay along the whole north coast (the Dore Hum Bay), and so would have been a likely stopping place for any maritime movement to the east or west along that coast (see Fig. 1).

When we arrived at Makbon, I was having a malaria attack, so we sent Johsz and Goenadi to check with the local people for sites in their area and we said we would return to pick them up after they had one full day of surveying. When we picked them up we found from their report that there was a single, large limestone formation only a few kilometers to the west of Makbon, which had not been indicated on our geological map. They had made surface collections of potsherds from two small caves in this formation. Some of these sherds were decorated with patterns similar to that of the Sa-Hyunh-Kalanay Pottery Tradition found on many islands in the southern Philippines and in northcentral Indonesia which in turn is related to the so-called Lapita Pottery of Melanesia, Fiji, Tonga, and Samoa. This Lapita Pottery is considered to be that of the ancestors of the Polynesians. While we did not find typical Lapita pottery anywhere during our Irian Jaya survey, this was one of the few sites with pottery having similar patterns of decoration. We therefore decided that on our second program in Irian Jaya we would make major tests at these sites. Several preliminary publications resulted from this first year's research (Solheim 1978, 1979, 1985; Solheim & Ap 1977; Solheim & Mansoben 1977).

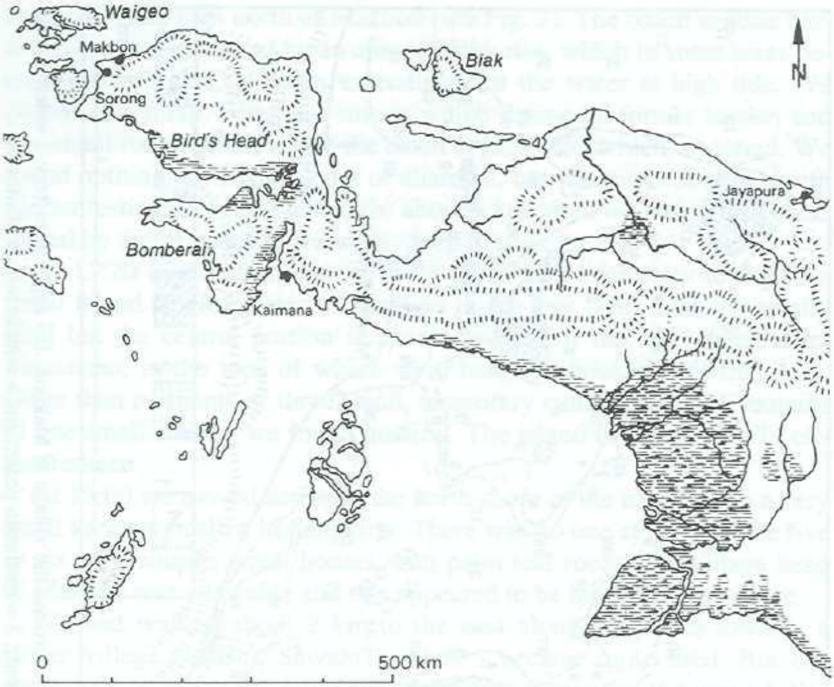

Figure 1. Map of Irian Jaya, with names referred to in the text.

3 SECOND YEAR'S PROGRESS

For the second year's program my wife and I returned to Cenderawasih University on the 6th of July 1990 to work on the collections in the lab of the Anthropology Museum. On the 10th of September we went to Sorong again, this time with Naffi Sanggansfa, the head of the Anthropology Department at Cenderawasih University.

On the 15th of September we went to Makbon. I would like to thank here the Bupati of Sorong for loaning us a good sized boat to take us to Makbon without charge. I would also like to thank the Camat of Makbon for granting us the use of a government house next to his office for our headquarters, free of charge. I shall now continue from my daily log in those days, supplemented here and there with recollections:

– *16 Sept.* Makbon appears to be primarily a Christian kampong and no work is done here on Sundays, so we could not find a guide to take us to the caves this day. At 8:00 Naffi and I started walking along the beach

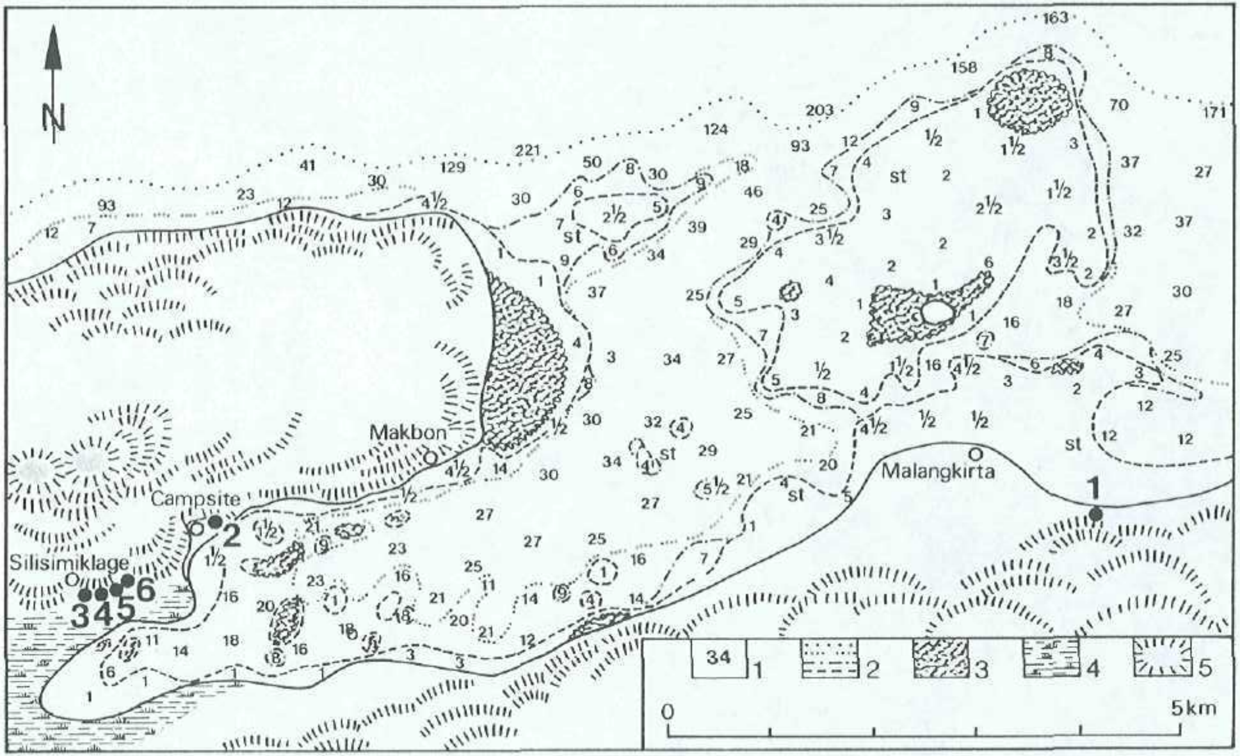

Figure 2. Map of the Dore Hum Bay and the research area around the village of Makbon. 1 = depth in meters; 2 = depth contour lines; 3 = reefs and shoals; 4 = larger mangrove swamps; 5 = mountain peaks; and • = archaeological sites.

to the east and then north of Makbon (see Fig. 2). The beach is quite narrow there and is backed by an abrupt rocky rise, which in some areas becomes a true cliff, at times extending into the water at high tide. We passed one small, perennial stream which drained a former lagoon and one small rock shelter, above the reach of high tide, which we tested. We found nothing but small pieces of charcoal, but felt this would be worth further testing. We had walked for about 3 km when we had to turn back, forced by a cliff based in water too deep to walk by.

At 13:20 in the afternoon we were taken by motor prow to the very small island of Hum, east of Makbon in the bay. This island is totally sand but the central portion is covered with star tree and much taller *Casuarina*, in the tops of which were hanging thousands of fruit bats. Other than remnants of three small, temporary camps each with remains of one small shelter, we found nothing. The island is about 1 km in circumference.

At 15:00 we moved across to the north shore of the mainland to a very small kampong called Malangkirta. There was no one at home in the five or six very simple, small houses with palm leaf roofs. The village head of Makbon was our guide and this appeared to be his old home village.

We had walked about 2 km to the east along the beach towards a newer village (Sausut, Sawalu?), when I became quite tired. But our guide told us that a bit further on there was pottery in the ground. We reached this spot (Site 1) after out path went through a small bamboo thicket, which must indicate a former kampong. There were no other indications besides the pottery cache which was at the base of a small rock outcrop, just above the beach. The pottery, just below the surface scatter of leaves and vines, was all porcelain and one glass plate plus a few small, late type beads. The porcelain was all similar to what we had collected at other sites in the Cenderawasih Bay and on the island of Waigeo to the west (early 19th century), several with Maastricht stamps on the base. We were back at Makbon at 18:00, and very tired.

– *17 Sept.* At 8:00 we left by prow southwest along the north shore of the bay from Makbon (see Fig. 2). In about twenty minutes we entered a small opening in the mangrove clad coast and unloaded all of our baggage. At 8:40 we had located a good camping spot next to a small, fresh water stream, and started building a shelter for seven of us (including three locally hired workmen) to live in. This didn't have to be too good, as it hadn't rained in over three months.

About 30 m east of our camping spot a ragged cliff stretches upwards about 100 m. This day the owner of the boat and one of his helpers led Naffi and me up the cliff, in many areas climbing hand over hand using vines and small trees growing among the boulders. Near the top we came to a small rock shelter (Site 2) in which there was a large Chinese blue on white jar which, before it had been slightly damaged, was undoubtedly an important item in bride price. Our guide informed us that there were several such hidden collections in this cliff, some of which had been damaged during the Second World War, but others which were still valued bride price items. We collected several broken porcelain plates and bowls from this site.

After a nap (I was exhausted from the climb) and some lunch, Naffi and I and a guide headed west on a narrow path and in ten minutes we came to the eastern end of the large limestone formation reported upon by Johsz and Goenadi during our first year's research, and called Silisimiklage. Our guide knew of no caves here.

We never made a detailed map of Silisimiklage, unfortunately. The whole formation is about 300 m long and roughly lenticular in formation. When after a long walk we rounded the western end (farthest away from our camp), which I did only at this particular day, my recollection is that it was much more of an unbroken cliff than the eastern end, not coming to a definite point but not as wide as the majority of the formation. I remember that the base of the western end was considerably hidden by brush and with fallen boulders, and was difficult to reach. There was one spot that might have had a cave, but I could not check it out at that time.

As we moved back on the bay side of Silisimiklage we found mangrove swamp right up to the outcrop, with high tide coming practically to the base. When we had gone about a 100 m along the base we saw what we thought might be a cave about 3 or 4 m up the side. When we checked this it was not a cave, but we found that the soil was virtually covered with quantities of earthenware sherds (Site 3). We found that the southern side of Silisimiklage was like this all the rest of the way back to the eastern end. We made a small surface collection at a stop on our way back (Site 4) and found there nice pottery with well done incised decoration and a few carved-paddle impressed sherds, as well as lots of shell, but no metal or high fired pottery. The pottery extended back up through a crevasse to the top of the limestone hill. We felt it was likely that the sherds had washed down from above as there was no good reason for in situ deposit on such a steep slope. At the eastern end of the formation, about 3 to 4 m above high tide, we found a small, relatively level area where there had been recent camps (Site 6). We returned to our camp about 16:15 and around 19:00 a light rain started with heavy thunder and lightning in the distance.

– *18 Sept.* The tide was up this morning and as the path crossed a moderate sized second stream a short way from our camp we had to wait until 9:00 before we could leave without getting soaked to above the knees. But as I was going to take a video of our walk to the limestone formation and of Site 6 before and during intended cleaning, we had to wait anyway, for there was condensation inside the camera and it had to dry out.

Site 6 is the small level area at the eastern end of Silisimiklage (see Fig. 2). This area is about 5 by 4 m^2, sloping gradually to the east, with a somewhat steeper gradient for about 2 m to slightly above high tide level. The area was heavily covered with brush and vines before we started clearing it. After preliminary clearing we could see a fireplace at the base of the abrupt rise to the top of the ridge. While two of our workmen continued clearing the area, three of us made a path to the top of the ridge and farther along the top. The latter appeared to be flat and level, about 4 to 6 m wide and over a 100 m long before reaching the break of the northern face of the cliff.

About 20 m in from the eastern end of the limestone complex we cleared a small area on the top and made a test pit (Site 5). Going down just below the surface was a fire area with fired clay and charcoal, but no sherds evident. While there must have been occupants using the level areas it looks like the garbage and broken pottery was swept on to the steep southern side. Later we heard from several people living in Makbon, with no dating suggested, that formerly only women lived on Silisimiklage and it was said that they were expert at black magic so no men dared to approach it. After checking the top of the ridge near our test pit, we made a surface collection at Site 5.

We returned to camp shortly after 12:00 for lunch and remained there that afternoon to wash our collections, and to build drying tables. Besides the pottery we recovered two possible stone pottery anvils, so it appeared that pottery was being made on top of the ridge.

– *19 Sept.* A steady rain started about midnight and many leaks developed in the roof of our shelter. Ludy and most of the crew stayed at camp to make a better roof for our 'home', while Naffi and I and two helpers went back to Site 6 to prepare it for excavation and mapping. We placed a datum on the limestone just above the mentioned fireplace. Using a Brunton compass we set up a 1 m grid system, extending 5 m to the east, labeled 1-5, and 4 m to the north, labeled B-F. This covered most of the relatively even area of Site 6. We started down 15 cm in square B-2, finding bits of charcoal and very hard clay. This clay, though not fired, suggested fires outside the fireplace or coals raked out over this area. A brief look at the steeper slopes outside our excavation area suggested more sherds on the slope than on the even surface, further suggesting periodic cleaning of the area like seen on the top of the ridge, near Site 5.

– *20 Sept.* To-day we were visited by a three man police patrol at 7:30, just as we were preparing to leave for Site 6. The police went with us and joined in the excavation, proceeding carefully as instructed. They were very helpful, working all day and accepting no pay, only joining us in a light lunch. We discovered later that the Bupati had sent them to look after us as there was a wanted man somewhere in the general area. At the base of the 2 m or so slope at the edges of the site, the ground leveled out again in all directions. Three of our workmen were kept busy clearing the underbrush to the east of the site and down the north slope back about 5 m, leaving the south side overgrown to the mangrove swamp. Excavating in three squares we continued to find extremely hard clay, with the deposit not nearly as rich in potsherds as it appeared on the north slope. From about 9:30 I started clearing the soft surface of this north slope.

We returned to the camp for lunch. After lunch the workmen washed sherds, while Naffi and I returned to Site 6 to map. It was difficult mapping though, as Site 6 is on a relatively flat end of the limestone ridge with limestone of unusual shapes protruding above the surface at different heights and levels around the egde and down the sides.

– *21 Sept.* After the morning condensation had cleared from the video camera I made a further tape of Site 6 and its south side, before having this cleared of brush and the lower vines. Naffi and Ludy continued in their squares, only making it down to a bit over 20 cm as the heavy clay is so hard. I stopped working on the north side as I had cleared out all of the soft pockets rich with sherds, that I had found there. I considered these as surface deposit and made no deeper excavation on the sides. I worked next on the eastern slope and it was the same as the north side, with soft pockets that were rich with sherds, protected by limestone rocks. I worked towards the south side, which was now being cleared. This side was somewhat rougher, with larger and more limestone rocks, and if anything this area was richer than the other two sides. At the south side of the eastern slope I came across another fire area with red soil in small hard lumps.

We had lunch brought to the site at 13:00 and continued working until about 15:30 when gathering clouds suggested coming rain. We were back at camp in 10 minutes, rushing to get atap on the roof over the workers portion of the platform when the rain started. Major leaks developed over much of the area, making rather a mess. To add to this discomfort there were may tiny, black, flying insects that bit. We moved the cooking fire under the corner of the roof as rain continued heavy until about 18:00, followed by a couple of light showers.

– *22 Sept.* We departed camp at 8:30. I continued on the east end of Site 6, excavating at the base of the formation among the rocks. I finished up this area after lunch, having worked in a very rich small pocket of sherds about 30 cm^2. Naffi worked on B-3, Ludy completed a small area of B-4 to 15 cm and started at B-6, and the police lieutenant, who had returned voluntarily by himself, worked in B-5. The workers cleared the south side finding about as much surface pottery as on other sides. We returned to camp at 15:45, bagged the dry sherds and washed the new collections.

– *23 Sept.* Sunday, spent most of the morning in camp washing sherds and arranging them on the drying table. Late in the morning a local man brought a large, approximately eighty kilos, young boar, for which we paid, though he had asked nothing. We sent considerable gifts of pork to the head of the school in Makbon (who had given us a large bunch of cooking bananas) and the Camat.

Shortly after noon Naffi and I and two small boys (who had joined us in the mean time) went to Site 3, towards the far western end of Silisimiklage. We worked in the so-called Main and Lower Site, the Lower with an area of about 2 m and the Main perhaps 3 to 4 m (see Pl. 1). In some areas the Lower and Main Site 3 are almost shell middens with mostly bivalves, but considerable variety. The areas are extremely rich in both quantity and quality of the pottery. Much of this has incised decoration (see Plates 2-5), and on one wide rim what looks like an inscription rather than simple decoration. There is an entrance to a small cave just to the west side of Main Site 3. This has a vertical entrance and we left it for later examination. It would appear that all, or most, of the material (we brought back eleven bags from Site 3) has washed down from above through a crevasse in the rock, wide enough for a man to climb through sideways. We have looked only very briefly at the small area immediately above the crevasse which we also consider a part of Site 3. It would also appear to be rich and probably not the ultimate origin of this richness.

We left the site at about 16:50. Rain started shortly after 17:00 and showered off and on. By 21:00 it was raining hard and steady for the first half of the night.

– *24 Sept.* We left camp at 8:25 going directly to Site 3 again, to check out the cave. The entrance is vertical, but once you are on the floor at the entrance the cave extends to the north. I was unable to go into the cave because of the rather narrow, vertical entrance. An opening, too small for an entrance, in the ceiling admits a little light. The cave has stalagtites and stalagmites, and at the time of our visit the floor was strewn with a considerable number of potsherds. We had the impression that the quality of the pottery was better and the variety of decoration from Site 3 was greater than that from Site 6.

Showers started about 15:00 forcing us to leave at 15:20. This gradually intensified until by about 18:00 it was raining again. We will therefore close down tomorrow and move back to Makbon.

– *25 Sept.* We expected the motorized prow to pick us up in the afternoon, but, instead, it arrived at 6:30 in the morning already, as it was going on to Sorong. We pulled together as much of our baggage as we could quickly, plus all the bags of the collections, and the boat was able to leave with these at 8:10. We stayed behind. Naffi and I and one boy went to Site 3 once more to take some last pictures. The light was not good, however, and the flash gun was not working well. We also collected more sherds, not only at Site 3, but at Site 4 as well.

We closed down about 13:00, as we were getting too many bags from Sites 3 and 4. Near the surface at Site 4 I recovered a heavy iron artifact that looked like a straight razor. It was not badly rusted and, to my knowledge, is the only piece of metal we found at any of the sites on the south side of Silisimiklage. Site 3 and 4 have proven to be incredibly rich in pottery.

Back at the camp, starting about 14:00 three boys and two workmen walked a big load of baggage to Makbon and were back to camp shortly after 15:00. At 15:25 we all left with the rest of the baggage and reached Makbon at 16:05. While it was mostly a level walk on a narrow trail through the jungle, Ludy and I were worn out.

– *26-27 Sept.* These days were spent exploring a bit along the coast towards the open sea to the north and excavating a bit in the kampong of Makbon itself, while Ludy oversaw the washing and drying of the pottery (see Pl. 6). We found nothing more along the beach as we were stopped by the deep water in the same place where we had been stopped the first day. In the evening a local man brought a bucket of sherds that he had dug up near his house. The next morning we went to this house, about a 100 m inland from we were staying. With permission to excavate in his yard we put in a 1 m^2 test pit. There were numerous sherds, quite similar to the simpler pottery from Silisimiklage. This was recovered from the about 5 to 10 cm thick, black topsoil. Below this was clean sand, with no artifacts. We found that similar sherds could be found in several areas in the kampong, but always only in the black topsoil.

That night we had a talk with several of the older local people and they said that no one in the kampong had ever made pottery. They further told us that many of the local people had somewhat distant relatives at the island of Biak, to the east. They said that there had been no contact with these relatives for over a hundred years, but that before that they were often in contact by boat along the north coast of the Bird's Head. They further told us that the bride price pottery we had seen was brought in from Biak, and not from the west. All this information needs to be checked as all of it came from translation and we had no time to verify it in talking to several different informants using translators that were better acquainted with the local somewhat variant Biak dialect.

– *28 Sept.* We started packing for return to Sorong and were ready to

Plate 1. Lower area of Site 3 at Silisimiklage. In the left background is the Main area.

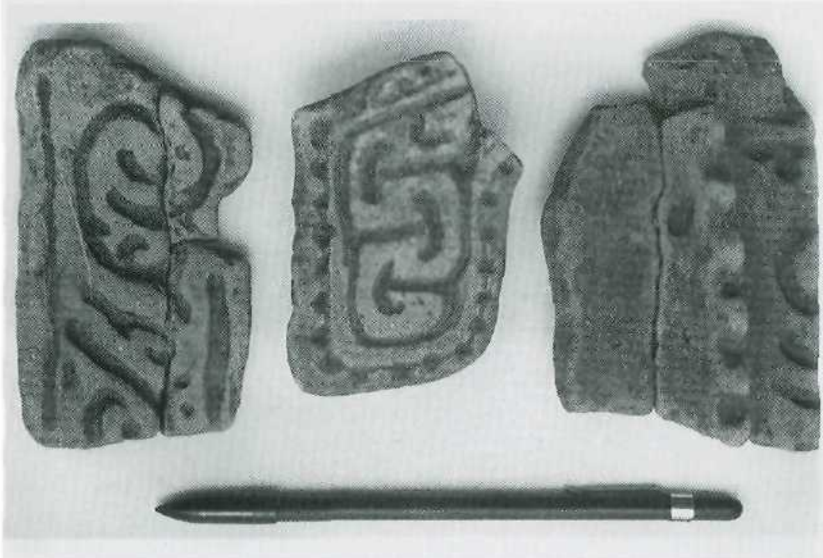

Plate 2. Thick fired earthenware carved in deep relief from Site 3, with varying patterns of decoration.

Plate 3. Pottery carved in low relief from Site 3: rim sherds from both deep and shallow bowls.

Plate 4. Pottery carved in low relief from Site 3: a partially restored vessel with a vertical, plain rim.

Plate 5. Inside view of the vessel above, showing impressions from an anvil (in paddle-and-anvil forming) and finished edge of top half which joined with finished edge of the (possibly rounded) bottom.

Plate 6. Drying sherds from Silisimiklage at Makbon.

go at 10:00. At 10:30 we received word from the office of the Bupati in Sorong that the boat would be unable to pick us up today and possibly not tomorrow either. The Camat in Makbon offered us therefore the use of his large boat and we accepted. At first he said it could not go until tomorrow morning but at our request to go to-day he agreed we could leave at 12:30. The regular driver was sick, so his two young assistants were to bring us to Sorong. It was a large boat, well over 2 m wide and with a solid wooden cabin. With a southsouthwest wind it was a smooth passage along the north shore of the Bird's Head. We rounded the point by Crocodile Island (Pulau Buaya) about 15:10 and headed into the wind and moderate waves. When we turned the corner by Doom Island to head east into Sorong we were roughly parallel with the waves and it got rougher. We finally reached Sorong and our hotel at 17:30.

4 EPILOGUE

The next three weeks were spent in Sorong cleaning, reconstructing, describing and cataloguing the collections from Silisimiklage. We found a mixup of bags from the first day in the field, noted because a partial human face (modeled brown earthenware) which we had recovered at Site 3 had been labeled as Site 6. This appeared to be the only mislabeled bag, fortunately.

On the 3rd of October Naffi returned to Cenderawasih University, hand-carrying the reconstructed porcelain. He also took with him several small animal effigy figures of baked clay, that we had found. Regarding the pottery, there was a great variety of decoration present: incising with interlocking scrolls (somewhat similar to elements of the Lapita pottery of Oceania and the Sa-Huynh-Kalanay pottery of Southeast Asia); carved-paddle impressed; carved in low relief (see Pl. 3), including one considerably restored vessel that appears to have been formed by paddle-and-anvil and made in two pieces and then joined together (see Plates 4 and 5); and unique ceramics carved in deep relief (see Pl. 2). The usual form of these latter had right angles between sides and apparent bottom. In some cases the sherds do not suggest containers, as their smoothed edges indicate that they had neither tops nor bottoms, but were flat. Rather unusual horizontal handles were also recovered.

The harvest from Site 3 appeared very rich indeed. I decided to describe and catalogue only decorated and unusual pottery from this site. We packed one large basket with decorated sherds to take to Jakarta for further reconstruction. We could confirm that at least some of the sherds recovered from the cave had dropped through the opening in the ceiling, as we were able to fit several of these sherds with sherds recovered from

Upper Site 3 and from the crevasse. However, we did not come close to completing and cataloguing all of the collections from Site 3. Apart from the basket in Jakarta, the materials have all been brought to Cenderawasih University at Jayapura, where they have been stored. There is thus much left to be done and, hopefully, I will be able to return to Cenderawasih University one day to really complete our Makbon researches.

NOTE

The research in Makbon has been pretty well documented by photo and video. As in the context of this paper only a fraction of the available material could be published, the author invites anyone interested to contact him for further information.

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3

Room with a view. An excavation in Toé cave, Ayamaru district, Bird's Head, Irian Jaya

1 INTRODUCTION

The intensity of archaeological research in the different regions of New Guinea and Australia varies significantly. Very little is known about the prehistory of Irian Jaya, the western part of New Guinea, particularly about the Bird's Head peninsula. This area, however, is of great archaeological potential because it is likely to have been one of the landing points for the first settlers that crossed the seas between Asia and Sahul (the Pleistocene landmass that comprised present-day Irian Jaya, Papua New Guinea and Australia) during the Pleistocene Epoch (Birdsell 1977). Goenadi Nitihaminoto of the 'Balai Arkeologi' in Yogyakarta and Wilhelm G. Solheim II of the University of Hawaii conducted archaeological survey work and excavations in the coastal region of the Bird's Head peninsula (Solheim & Mansoben 1977; Solheim, this volume). In the interior of the peninsula no archaeological fieldwork was carried out until recently.

Within the framework of the ISIR project ('Irian Jaya Studies, a Programme for Interdisciplinary Research', see Preface this volume), an archaeological study focused on the Ayamaru district (central Bird's Head) is currently being conducted by the Department of Archaeology at the University of Groningen in the Netherlands. The three main research objectives of this study are the following:

1. To discover prehistoric sites, preferably with good preservation of organic materials (such as bones and wood), by means of an archaeological survey.

2. To excavate and analyze a few of these sites in order to reconstruct as much as possible of the behaviour of the prehistoric inhabitants.

3. To establish the genetic relationships between excavated human remains (if found) of prehistoric population(s) and the modern popula-

tion of the area. This will be done by means of comparisons between prehistoric DNA sequences from archaeological samples, and modern DNA sequences from blood samples. This is an attempt to trace pre- and protohistoric migrations.

In the period June-August 1995 an archaeological field survey and two excavations were carried out in the Ayamaru district. Some aspects of the survey and a description of the excavation of one of the sites, Toé cave, are presented in this report. Most attention is directed to the preliminary results of the Toé cave data analyses. Research concerning the third objective will be described in a later publication.

2 THE SURVEY AREA AND THE TOÉ CAVE

The Ayamaru district consists of a 'Kais' limestone plateau (Visser & Hermes 1962) with cone-shaped karst hills (see Pl. 1) (Löffler 1982). The typical karst features are created under the influence of tropical erosion (Jennings 1985). An annual rainfall of almost 5 m a year (Berlage 1949: 160; an average annual rainfall of 4849 mm was measured in Aitinjo during the period 1936-1941), lack of drainage, and high temperatures makes the Miocene limestone rock dissolve quickly. Therefore caves and rock shelters are relatively abundant in the Ayamaru district. Toé cave is part of one of the conic karst hills (see Pl. 1), located on a peninsula which stretches into the most western of the Ayamaru lakes (see Fig. 1 and Pl. 2). It lies near the hamlets of Kartapura and Men (Semoe) at a latitude of 1°17′5.6″ south and a longitude of 132°13′6.1″ east, on the south side of the lake. Toé cave has five entrances, of which the south-east entrance proved to contain remains of a prehistoric habitation site. This entrance lies approximately 12 m above the present lake level and has a good view of the lake and the 'mainland'.

3 METHODS

3.1 *The survey*

The archaeological survey was aimed at the discovery and sampling of cave localities. Caves would have provided shelter for (prehistoric) people and are therefore good localities to live in. In addition to being living areas, caves could also have been used as burial sites (McWilliam 1936). Another reason for selecting caves as survey targets is the fact that these locations can be relatively stable containers for archaeological material. In general, most prehistoric open-air sites dating from the Pleistocene

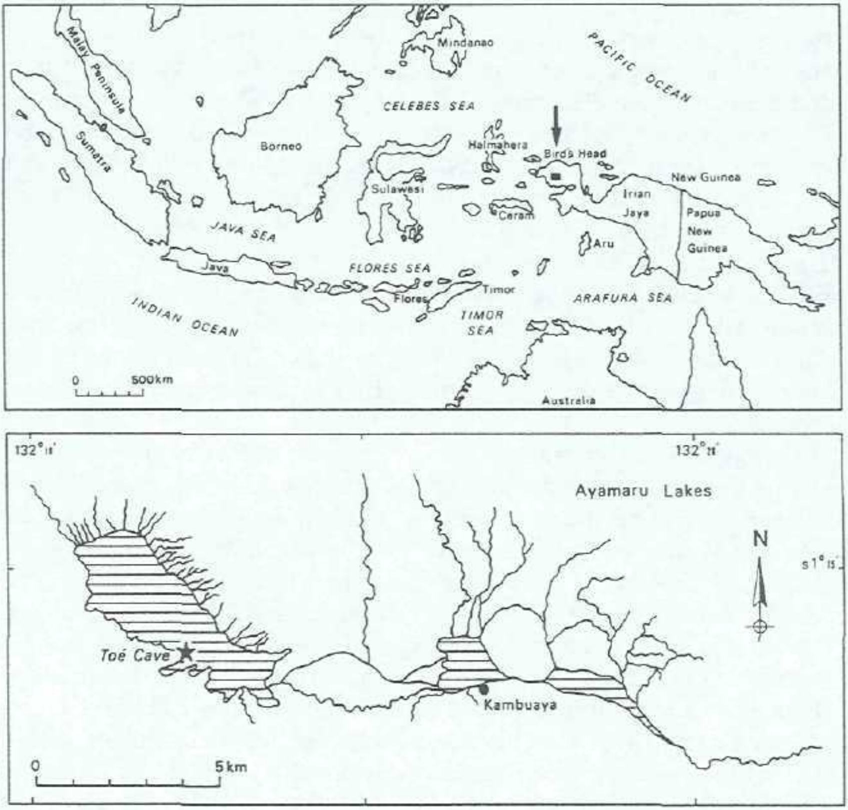


Figure 1. The location of the Bird's Head, the survey area and Toé cave (drawings by Hans Zwier).

Epoch have been disturbed or irretrievably buried because of erosional effects (Strauss 1979). In limestone areas, particularly in karst formations where extensive erosion takes place, the discovery of undisturbed archaeological sites, whether of Pleistocene or Holocene age, is problematical. The large amounts of rain dissolve the limestone bedrock so that little deposition of sediment takes place. The remains of open-air sites are often washed away within a few days and leave no archaeologically recognizable traces. In caves the situation is different. Deposition of sediment takes place (mainly from the ceiling) and the eroding effects of rain are less severe than in the open air. As far as archaeological research is concerned caves are preferable to open-air sites. The reason for selecting a karst formation as a survey area is the fact that numerous caves may be expected in these areas.

In order to detect areas with a high density of limestone caves and rock shelters, aerial photographs of the Bird's Head peninsula were studied (these photographs were taken in the late 1950s and early 1960s and are part of the collection of the Topographical Service in Emmen, the Netherlands). On these photographs dolines and skylights may be discerned. These features are caused by the collapse of cave ceilings and are an indication of the presence of caves. As a result of this aerial photograph study the Ayamaru district was selected as a prime survey area. The abundance of caves and the presence of the three large lakes (see Fig. 1), which provide the possibility to obtain food from two different ecological zones, make the area a favourable dwelling place. The suitability of the Ayamaru lakes region for habitation is demonstrated by the high population densities present there, from historical times down to the present day.

In May 1994 a reconnaissance trip was made to the Ayamaru district. During this visit the geomorphology of the area was studied and a large number of local people were questioned about the presence of caves in their neighbourhood. Apart from the locations of caves, the people were also asked about their knowledge concerning habitation of these sites during historic times. It is known, for example, that during the European Palaeolithic some caves were consistently used, whereas others do not contain any archaeological remains at all (Strauss 1979). Information about the historical utilization of caves and rock shelters can thus be useful since some caves may have been occupied for thousands of years. Galis (1964) reported the presence of historically inhabited caves in the Ayamaru district.

Guided by schoolteacher Elimas Kambuaya (see Pl. 3), fifteen caves around the Ayamaru lakes were located and sampled. For determining the archaeological potential of a cave two criteria were used. The first criterion is the thickness of the sediment layers that are present. The second is the occurrence and depth of archaeological material in those cave deposits. In order to measure the amount of sediment in the caves and to take samples of this material, corings were made with an 'Edelman drill'. The sediment brought up was sieved and the residue screened for fragments of charcoal, bone, shells, pottery, ochre, and stone flakes, which are indications of former human activity. This sieving was done with a 2 mm mesh screening net in a water tank.

Seven of the sampled caves proved to have archaeological potential. Two of those sites, Toé cave and Kria cave (see Pasveer, this volume), could be subjected to further study. At these localities small-scale excavations were conducted. Five people were involved in the survey team, which operated for approximately two weeks.

3.2 *The excavation*

One of the reasons for excavating Toé cave was a thick (1.3 m) layer of artifact and ecofact-bearing sediment that was found in one of the cave's entrances. From the archaeological record it is known that most of the occupation layers in caves are located in cave mouths, the area that was sunlit (Strauss 1979). The location of Toé cave, which has a good view of one of the Ayamaru lakes, which provided fresh water, fish, and all kinds of water fowl, must have been favourable for its inhabitants. This was another reason to expect rich archaeological deposits. An area of 3 m^2 was excavated until the bedrock was reached. The site was divided into units of 1×1 m^2. The soil was removed in 5 cm spits using small trowels. The locations of stone artifacts and natural stones were recorded in three dimensions. At each 5 cm level a drawing was made of the features, artifacts and stones encountered. From all levels samples for sieving (2 mm mesh) were taken to retrieve small ecofacts such as fish bones. The backdirt of each level was investigated by a second person who picked out any items had been missed by the excavator. Sieving of all soil was not possible because of the difficulties of obtaining water (the site lies 12 m above the lake) and the fact that all the backdirt had to be put back into the pits. This refill was needed to protect the unexcavated section of the site against excessive future erosion. Also, samples for pollen analysis and ^{14}C dating were taken from each level. In order to facilitate the study of the stratigraphy of the site, a profile print was made by means of a layer of latex sprayed on a profile wall and supported by a nylon fabric (Orliac 1975). After drying, this print was studied in the open air, where light conditions are better than in the cave. Approximately 4 m^3 of soil were excavated by a crew of five taking approximately one month.

3.3 *Analyses of the data*

^{14}C datings on bone and charcoal were conducted by the AMS (Accelerated Mass Spectrometry) facility of the University of Oxford. These dates are in years BP, uncallibrated years before 1950. Faunal vertebrate analysis was conducted by comparing the excavated bones to the New Guinea skeletal collections of the Western Australian Museum in Perth, the Australian Museum in Sydney, and the 'Natuurhistorisch Museum' in Leiden, the Netherlands. Remains of mollusc shells were determined using the New Guinea shell collection of the 'Zoölogisch Museum' in Amsterdam, the Netherlands (Van Benthem Jutting 1963a,b, 1964, 1965). Excavated bone, eggshell, mollusc shell fragments, stone artifacts, and pieces of ochre were cleaned with water, weighed and counted. Their amounts were quantified by volume as well, using glass grade tubes. Bone and stone volumes per level were corrected for the presence of large rocks in the excavated squares. If, for example, 50% (calculated from the drawings) of a square was occupied by a large rock, the excavated bone volume was corrected by multiplying it by 100/50 = 2. Measurements of stone flakes were taken according to the method described by Bordes (1988: 17) and Schäfer (1993: 55-65) (among others). Stone tools were classified according to Bordes (1988). Seriations were carried out with the ROZOY NUMERICAL ORDINATION AND SERIATION PACKAGE. Calculations and graphs were made with QUATTRO PRO (5.0). Drawings were made or modified with WP-PRESENTATIONS (2.0). The principal component analyses were conducted using the FACTOR procedure of the SPSS/PC+ (4.01) package.

4 RESULTS

4.1 *Stratigraphy and dating*

The excavation revealed a large number of artifacts and a great deal of food remains; the latter represented by bones, mollusc shells, and egg-shells. These materials were found intermixed with high quantities of burnt rocks, indicating the former presence of fireplaces. Undisturbed fireplaces or other recognizable features such as graves were not found. The stratigraphy showed a gradual change in colour, from dark grey in the top layers to a lighter grey in the middle section and an orange brown-colour near the bedrock. Distinct stratigraphical layers could not be identified, nor any signs of disturbances in the stratigraphy. The thickness and depth of the sediment layers and the levels of the present floor and the bedrock may be seen in Figure 3, which represents a section through the cave sediments along the west-east transect indicated in Figure 2.

The thickness of the deposits through the cave varies substantially. The sediment in the cave's entrance is 1.3 m thick; only 10 cm of deposit was found in the back of this cave arm, which is connected to chambers on lower levels. The slope of the cave floor ranges from 15 to 25°, indicating that there must have been a large run-off of sediment towards the lower cave corridors.

Four ^{14}C dates have been provided (see Table 1). Below the level (35-40 cm) where 2930 BP year-old bone was found, charcoal samples of significantly younger dates were excavated. If these dates are correct the stratigraphy cannot be considered as a single, vertical, chronological sequence. In that case some form of erosion must have taken place, possibly sink action or animal activity. To what extent the total sequence is

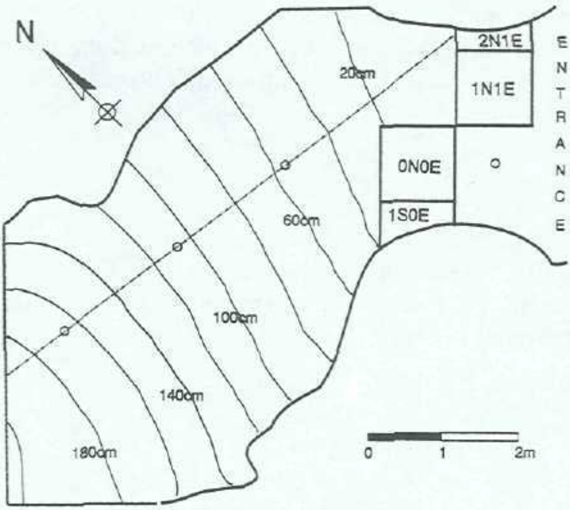


Figure 2. Plan of Toé cave showing excavated squares, contour lines (20 cm intervals below the entrance floor level) and coring locations (indicated by circles) along a transect line (see Fig. 3).

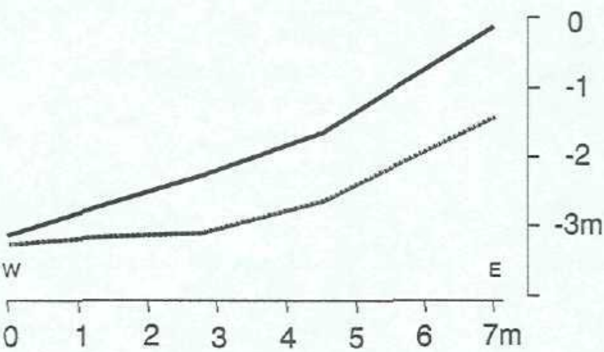


Figure 3. West-east transect indicated in Figure 2, showing the level of the bedrock (dotted line) and the surface (solid line) in Toé cave.

Table 1. Uncallibrated ^{14}C dates Toé cave.

Depth	Reference	Date	Sigma	Material
35-40 cm	OxA 6201	2930 BP	± 65 years	Animal bone
45-50 cm	OxA 6223	220 BP	± 70 years	Charcoal
60-65 cm	OxA 6224	111 BP	± 55 years	Charcoal
65-70 cm	OxA 6064	240 BP	± 40 years	Charcoal

disturbed by erosion could not be established with ^{14}C dating. In the lower levels of the sequence charcoal has not been found, and the bone samples collected from these levels do not contain enough organic material for reliable AMS ^{14}C dating.

4.2 *Faunal analysis*

Approximately 7000 pieces of animal and human bone have been recovered, of which the majority came from the lower levels (see Fig. 8). A seriation of the presence of vertebrate species (remains of bones and teeth) in each level is presented in Figure 4.

Vertebrate species presented in Figure 4:

1. *Homo sapiens*	Human
2. Boidae indet.	pythons
3. *Zaglossus bruijnii*	Long-beaked Echidna
4. *Spilocuscus* sp. indet.	spotted cuscuses
5. *Dorcopsis* sp. indet.	forest wallabies
6. small-sized Muridae	small-sized rodents
7. Macropodidae indet.	kangaroos / wallabies
8. *Dorcopsis muelleri*	Brown Forest Wallaby
9. *Phalanger* sp. indet.	cuscuses
10. *Casuarius* sp. indet.	cassowaries
11. *Spilocuscus maculatus*	Common Spotted Cuscus
12. *Dendrolagus* sp. indet.	tree kangaroos
13. Peroryctidae indet.	bandicoots
14. Agamidae indet.	dragon lizards
15. *Pogonomelomys* spp.	tree mice
16. *Dendrolagus inustus*	Grizzled Tree kangaroo
17. medium-sized Muridae	medium-sized rodents
18. *Phalanger gymnotis*	Ground Cuscus
19. Aves indet.	birds
20. *Pseudocheirops* spp.	ringtail possums
21. Muridae indet.	unidentified rodents
22. *Varanus* spp. indet.	monitor lizards
23. *Myoictis* sp.cf. *M.melas*	Three-striped Dasyure
24. *Rattus praetor*	Large Spiny Rat
25. *Spilocuscus rufoniger*	Black Spotted Cuscus
26. *Tiliqua* sp.cf. *T.gigas*	Blue Tongue Skink
27. *Pseudocheirulus* spp.	ringtail possums
28. *Dorcopsulus* spp.	lesser forest wallabies
29. *Mallomys* sp.cf. *M.aroaensis*	De Vis' Woolly-rat
30. *Dendrolagus* sp.cf. *D.goodfellowi*	Goodfellow's Tree kangaroo

31. *Phalanger* sp.cf. *P.intercastellanus*	Southern Common Cuscus
32. *Dasyurus albopunctatus*	New Guinea Quoll
33. *Phalanger* sp.cf. *P.orientalis*	Northern Common Cuscus
34. *Echymipera rufescens*	Long-nosed Echymipera
35. *Dactylopsila* spp.	striped possums
36. *Pteropodidae* indet.	fruit bats / flying foxes
37. *Echymipera kalubu*	Common Echymipera
38. *Pseudocheirulus schlegeli*	Arfak Ringtail
39. *Uromys caudimaculatus*	Mottled-tailed Giant rat
40. *Dactylopsila palpator*	Long-fingered Triok
41. large-sized Muridae	large-sized rodents
42. *Microperoryctes* sp.cf. *M.longicauda*	Striped Bandicoot
43. Phalanger vestitus	Stein's Cuscus
44. Xenuromys barbatus	Rock-dwelling Giant rat

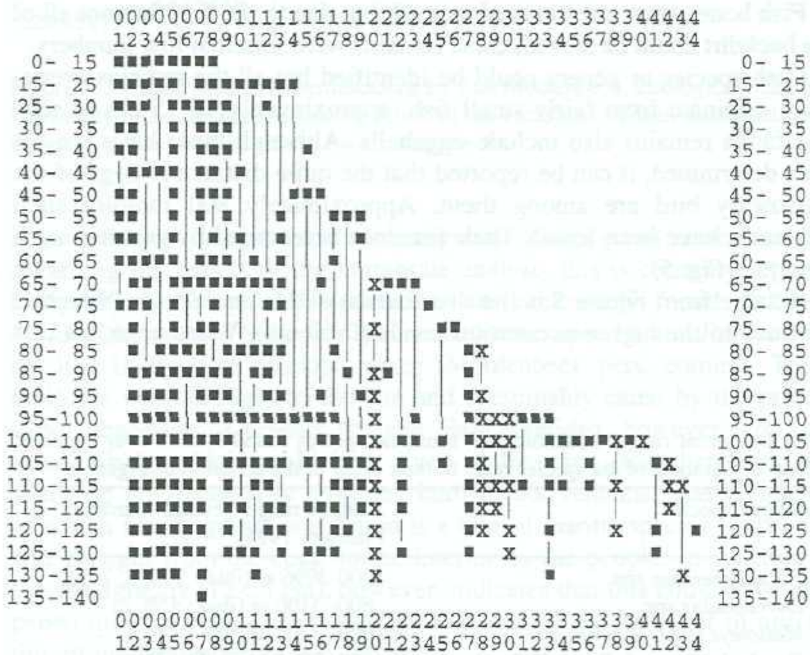


Figure 4. Vertebrate species (determinations were made by Ken Aplin, Western Australian Museum & Juliëtte Pasveer, Departement of Archaeology, University of Groningen) in each level of all the excavated squares combined. Levels are in cm below the surface. ▪ = species present, X = montane species present.

As is clear from Figure 4, vertebrate species confined today to montane regions have only been found in the lower levels (below 65 cm) of the sequence. The current altitudes where these species occur range from 680 to 3996 m (see Table 2). Altitudes above 600 m are not present within 30 km of Toé cave. Therefore the spatial distribution of these vertebrate species must have been different at the time these lower layers were formed. This was probably determined by the former presence of (today's) mountainous vegetation types in lowland areas. A decrease of a few degrees centigrade in the average temperature, which was the case in New Guinea during the Pleistocene Epoch (Nix & Kalma 1972), could have caused such differences.

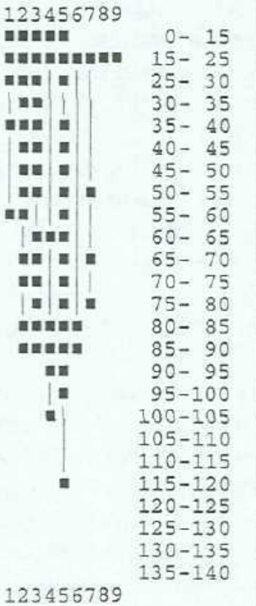
The only species of which the occurrence is restricted to the higher levels (0-75 cm) of Toé cave is *Homo sapiens*, of which five bone fragments and nine teeth have been found. These remains were not in anatomical position and the bones had tooth marks on them. Due to the state of preservation the presence or absence of stone tool cut-marks could not be established. Therefore it is uncertain whether the human bones represent animal or human food remains.

Fish bones were encountered as well, but due to the fact that not all of the backdirt could be sieved, these remains were found in low numbers. No fish species or genera could be identified but all the remains (vertebrae) originate from fairly small fish, approximately 10-15 cm in size. The fauna remains also include eggshells. Although these have not yet been determined, it can be reported that the quite distinctive eggs of the Cassowary bird are among them. Approximately 800 mollusc shell fragments have been found. Their presence is recorded by genus in each level (see Fig. 5).

Notable from Figure 5 is the distribution of *Melanoides* sp., which is confined to the higher excavation levels (0-60 cm). Whether or not this

Table 2. Current ranges in altitudes of montane species found in the lower levels of Toé cave. Numbers of the species refer to their order in the seriation of Figure 4.

Vertebrate species	Altitude range (several sources in Flannery 1995)
20. *Pseudocheirops* spp.	1000-3996 m (ibid.: 214, 6, 7, 9)
28. *Dorcopsulus* spp.	800- 3100 m (ibid.: 150, 2)
29. *Mallomys* sp.cf. *M.aroaensis*	1000- 2700 m (ibid.: 284)
30. *Dendrolagus* sp.cf. *D.goodfellowi*	680- 2865 m (ibid.: 130)
38. *Pseudocheirulus schlegeli*	750- 1900 m (ibid.: 230)
40. *Dactylopsila palpator*	1200- 2950 m (ibid.: 201)
42. *Microperoryctes* sp.cf. *M.longicauda*	1000- 3950 m (ibid.: 114)
43. *Phalanger vestitus*	1200- 2200 m (ibid.: 180)



1. *Melanoides* sp.
2. *Batissa sp.*
3. *Polymesoda* sp.
4. *Cyclotus* sp.
5. *Hyridella* sp.
6. *Leptopoma* sp.
7. *Bellamya* sp.
8. *Voluta* sp.cf. *V. melo*
9. Helicarionidae indet.

Figure 5. Mollusc species (determinations by Rob Moolenbeek, Zoological Museum, University of Amsterdam) in each level of all the excavated squares combined. Levels are in cm below the surface, ■ = species present.

is caused by a changing spatial distribution of this genus is unclear, but regarding the results of the vertebrate analysis this is certainly a possibility. *Hyridella* sp. and *Batissa* sp. are exclusively found in lakes, *Melanoides* sp. and *Bellamya* sp. are freshwater species, and *Polymesoda* sp. live in fresh to brackish water (Moolenbeek pers. comm.). These molluscs were brought to the site and presumably eaten by the prehistoric inhabitants. *Cyclotus* sp. and Helicarionidae, however, are land snails (ibid.) which could have lived in the cave, and therefore their shells do not necessarily represent human food remains. The *Voluta* sp. of which one fragment was found is a typical marine species (ibid.) and was brought from the coast to the interior by the people. Its position in the stratigraphy (15-25 cm), however, indicates that this could have happened quite recently. From levels lower than 25 cm no proof of utilization of marine resources was found.

The excavated bone fragments proved to be in different states of fossilization. Generally the rate of fossilization is correlated with time. Therefore it might be expected that in an undisturbed stratigraphic sequence the rate of fossilization increases with depth. The deeper the bones are found the more fossilized they will be and the higher specific densities they will have. In order to check whether the stratigraphy had been affected by significant erosion, the rate of fossilization in each level was established. For measuring these rates the average specific densities of the bones from each excavated level were calculated.

From Figure 6 it is obvious that there is a wide spread in the observed specific densities of the excavated bone samples. The measured values range from 1.62 to 2.11 kg/litre (the outlier at –75 cm is excluded). Taking the lowest density as a standard, the increase in weight per volume due to fossilization is as high as 30.2%. This suggests that weight is not a good variable for the quantification of faunal remains, at least not for the analysis of cave excavations.

The second observation to be made from Figure 6 is that there are two different gradients of fossilization. Bones in levels 35-60 cm and 85-135 cm below the surface have specific densities which increase with depth. It seems that two different stratigraphic sequences are present in Toé cave, with a mixed or reversed layer (65-80 cm) separating them. Because of the fact that the rates of fossilization immediately below and immediately above this disturbance are not comparable, it is unlikely that we are dealing with a disturbed single cave sequence.

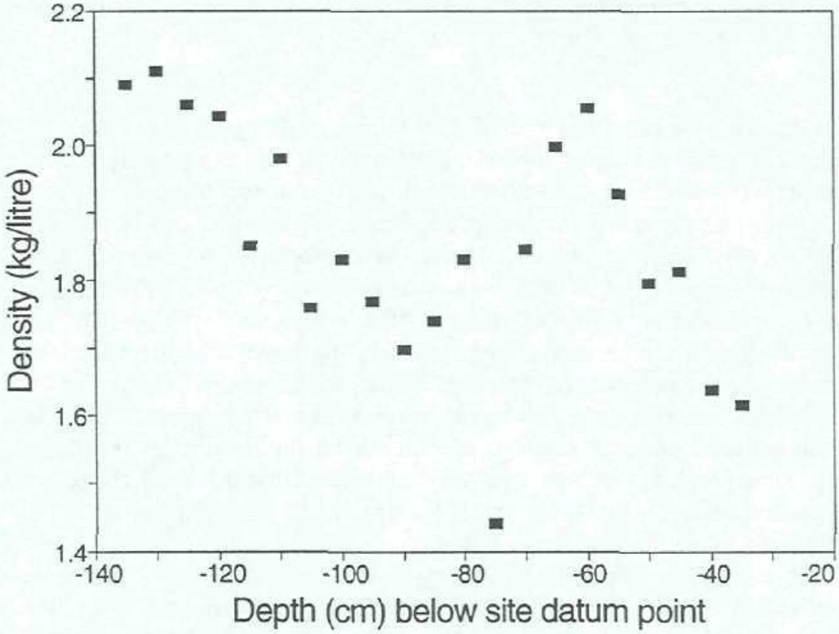


Figure 6. Specific densities of bones in square 1S0E.

A further indication for the presence of two separate sequences is a significant difference between the average sizes of the bone fragments excavated from the lower and upper levels. Figure 7 shows that the average bone fragment sizes in the levels 70-135 cm below the surface are larger than those from the higher levels. The Mann Whitney-U test (Siegel 1956) shows that this difference is statistically significant ($n1 = 7$, rank sum $1 = 28$, $n2 = 14$, rank sum $2 = 203$, $U = 0$, $p < 0.001$). Erosion might have been the cause of this difference. If two different stratigraphical sequences are present it is likely that the upper sequence is superimposed on the lower one. This may have been the result of sink action (Glover 1979), such as the collapse of a ceiling that had been the (living) floor of a former higher level in the cave. In that case the bones would have fallen down amidst numerous fragments of rock, which would have broken the bones into smaller pieces. The difference in average bone sizes might also have a cultural cause. Possibly the inhabitants who lived during the build-up of the upper layers broke the bones into smaller pieces for the extraction of marrow, whereas this was not practised by the inhabitants that helped to create the lower sequence. Also, the role of scavenging carnivores must be taken into account. Intensive occupation of a living floor results in a lot of bone fragmentation as well.

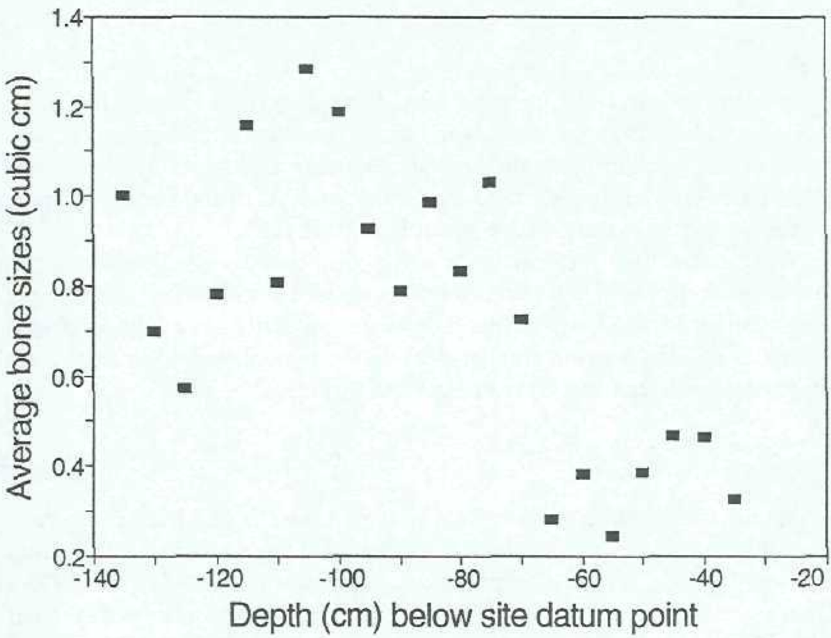


Figure 7. Average sizes of bone fragments in square 1S0E.

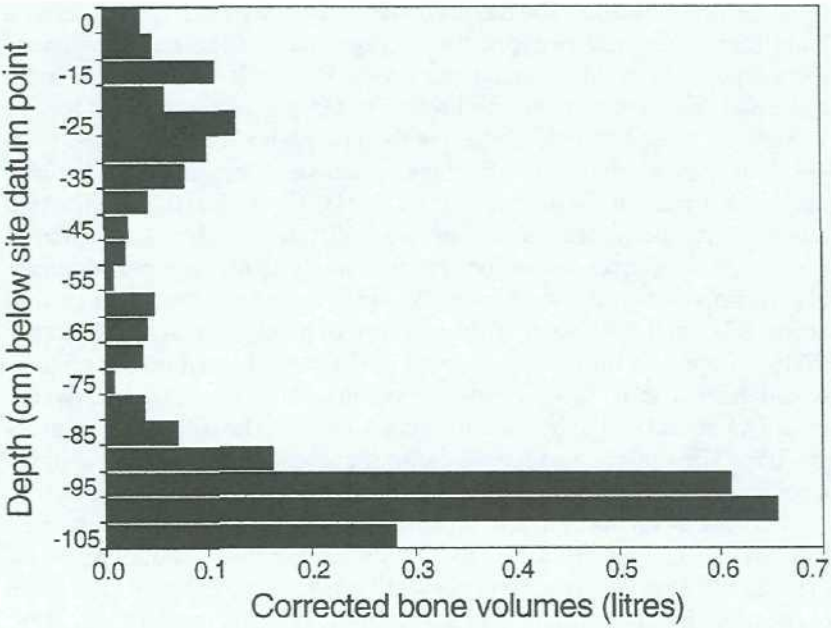


Figure 8. Bone volumes in square 2N1E corrected for fluctuations in excavated layer volumes.

The more people walk on the mixed bone and stone debris, the more bones will break. The variations in size of the hunted animals might also have contributed to these differences. Whether this has played any significant role will be established by further analysis of the faunal remains. Several other explanations are possible as well.

Also indicating the existence of two different stratigraphical sequences are the amounts of recovered bone (see Fig.8). Most of the bone originates from the lower levels. The largest quantities are found below a depth of 85 cm. A much smaller peak in the bone distribution histogram lies between 10 cm and 40 cm below the surface.

4.3 *Artifact analysis*

Stone artifacts from archaeological sites in Australia and Melanesia have been analyzed in a number of ways. These studies have not yet resulted in satisfactory regional typological frameworks (Holdaway 1995). Therefore the stone tools of Toé cave have in an exploratory way been classified according to the typology of Bordes (1988), which is one of the best known. For some this classification might be too specific and

Plate 1. Karst formation in the Ayamaru district.

Plate 2. Lake Ayamaru from the air.

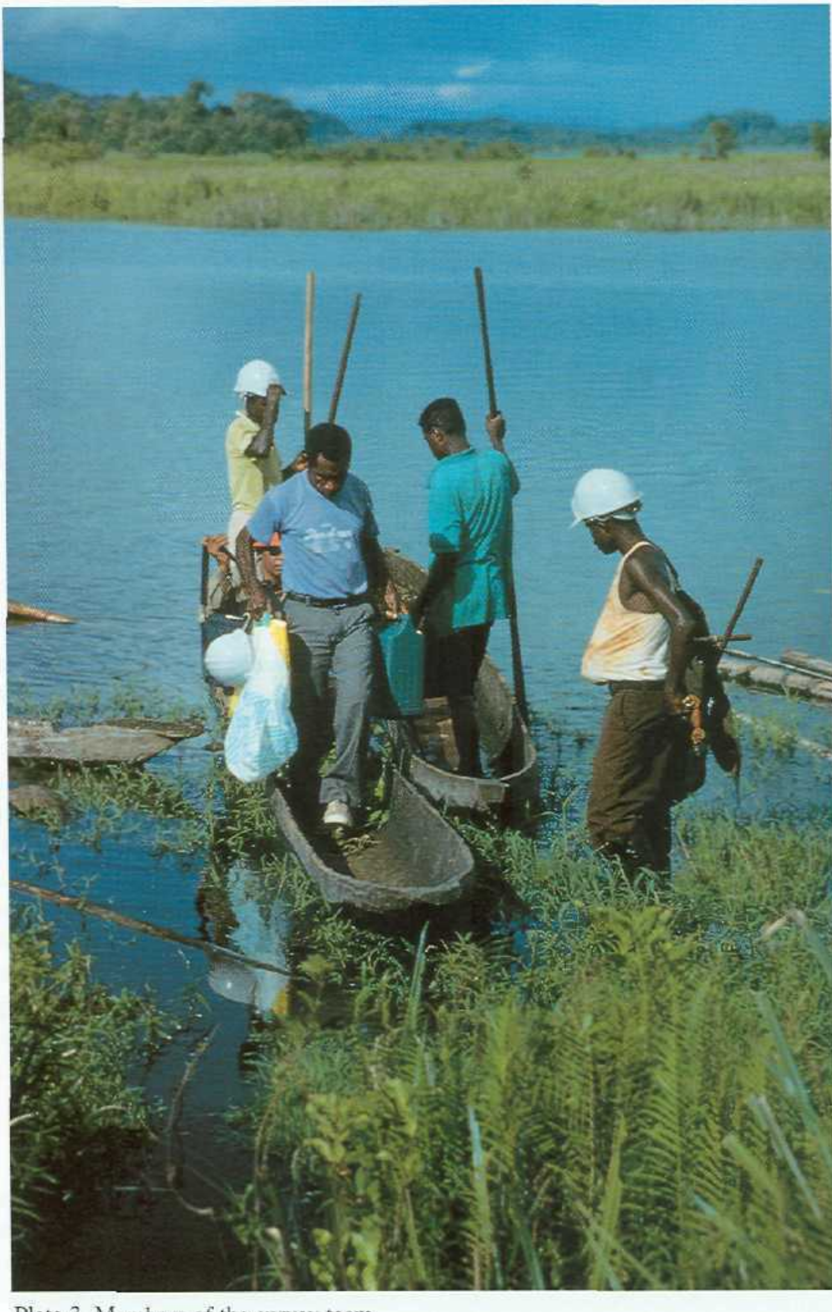


Plate 3. Members of the survey team.

too Eurocentric (as evidenced, for example, by a designation such as 'Pointe Moustérienne', see Fig. 9: No. 7), but interested readers may recombine the data published here into their own type groups.

In all the excavated levels, but especially between 45-60 cm below the surface, stone tools including retouched flakes have been found. The raw material is predominantly chert. Examples of the main tool types are illustrated in Figure 9. The 146 excavated stone artifacts were classified into 23 types. The waste material consists of 1377 flakes and blades, plus 15 core fragments. The great majority of the stone tools were made using the hard percussion technique, i.e. they were hammered into the desired shape with other stones, so-called hammer stones, of which one was found. The soft percussion technique, where wood or bone hammers are used, was practised rarely. Striking platforms are found to be hardly prepared and are usually cortical or plain, consisting of a negative bulb. Facetted and dihedral striking platforms are rare (see Fig. 9: No. 2). The industry is predominantly flake based, although a few core-based tools were discovered (see Fig. 9: No. 8). Nosed scrapers ('Grattoir à museau/caréné', see Fig. 9: Nos 1, 2 and 4) are the most abundant tool type.

In an attempt to trace functional and/or cultural differences between the apparent upper and lower sequences, the frequencies of the tool types were calculated for the upper (0-60 cm) the lower (80-140 cm) and the intermediate (60-80 cm) levels (see Table 3).

Unfortunately only six stone tools and two retouched flakes ('Eclat retouchée') have been found in the 80-140 cm levels. This makes a meaningful statistical comparison between the upper (0-60 cm) and lower (80-140 cm) levels impossible.

In a limestone matrix, as is the case in Toé cave, chert and flint materials tend to decalcify. This process causes a decrease in weight of stone artifacts from cave deposits. Because this effect is correlated with time, the specific densities of the excavated tools and flakes may be used to detect 'anomalies' in the stratigraphy. This analysis is comparable to that of the bones (see Fig. 6), although the specific densities of bone increase, wheras those of stone decrease with time. As with the bone densities, it is obvious (see Fig. 10) that there is a substantial amount of variation in the specific densities of stone artifacts, which range from 1.63 to 2.32 kg/liter (the outlier of 1.3 was excluded). Taking the highest density as a standard it was calculated that the stone artifacts had lost up to 29.7% of their original weight. This variability suggests that weight is not a reliable variable for the quantification of stone artifacts originating from limestone deposits.

Only with regard to the levels 80-115 cm does Figure 10 provide the expected mirror image of the pattern observed in Figure 6. The Spear

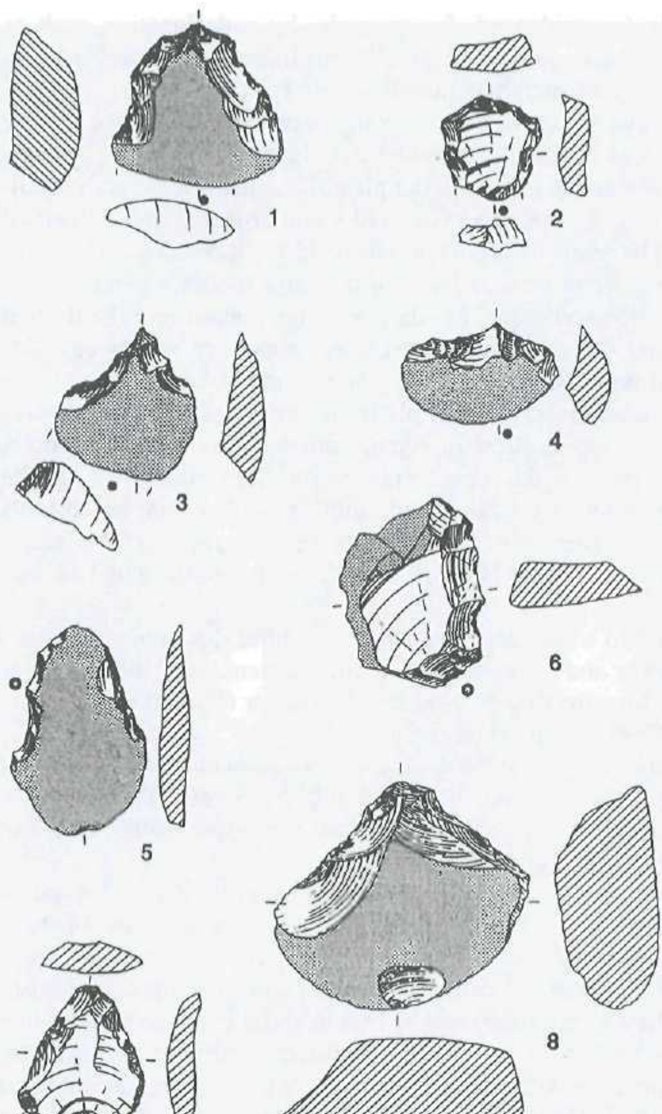


Figure 9. Stone tools from Toé cave: 1, 2 and 4) Grattoir à museau/caréné, 3) Perçoir, 5) Racloir double droit concave, 6) Denticulé, 7) Pointe Moustérienne, 8) Chopper. Legend: Filled circle = bulb of percussion present, open circle = bulb of percussion absent, dotted areas indicate cortex (drawings by Marcel Niekus).

Table 3. Frequency distributions of tool types (Bordes 1988) in three vertical sections.

	0-60 cm	60-80 cm	80-140 cm	Total
Racloir simple droit	3	1	–	4
Racloir simple droit (dominant)	1	–	–	1
Racloir simple convexe	9	5	2	16
Racloir simple concave	5	5	–	10
Racloir transversal droit	3	2	–	5
Racloir transversal convexe	–	1	–	1
Racloir double biconvexe	1	1	–	2
Racloir double biconcave	–	1	–	1
Racloir double droit convexe	3	–	–	3
Racloir double droit concave	–	1	–	1
Racloir double convexe concave	1	1	–	2
Racloir convergent convexe	1	–	–	1
Racloir déjeté	1	–	–	1
Pointe Moustérienne	1	–	–	1
Denticulé	10	8	1	19
Denticulé transversal	–	1	–	1
Grattoir à museau/caréné	24	7	1	32
Perçoir	2	1	1	4
Couteau à dos naturel	5	2	–	7
Couteau à dos atypique	2	–	–	2
Eclat retouchée	15	11	2	28
Chopper	1	–	–	1
Chopping tool	1	1	1	3
Total	89	49	8	146

man Rank Correlation test (Siegel 1956) does not show a statistically significant correlation between depth and specific density through all the levels ($Rs = -0.379$, $0.100 > p > 0.050$). The fact that no decalcification gradient can be observed in the upper (15-70 cm) levels, whereas this effect was found for the bone material, could have been caused by differences in reaction to sink activity by the two kinds of material.

If the stone artifacts are expressed in volumes per level, another difference between the upper and lower levels may be traced (see Fig. 11). The highest quantity of stone artifacts occur in the layers of the postulated upper sequence. Whether Figure 11 reflects a bi-modal or unimodal (with a disturbance in the 70-80 cm levels) distribution of the stone material is as yet unclear. The observed pattern does not resemble that of the bone volumes distribution (see Fig. 8).

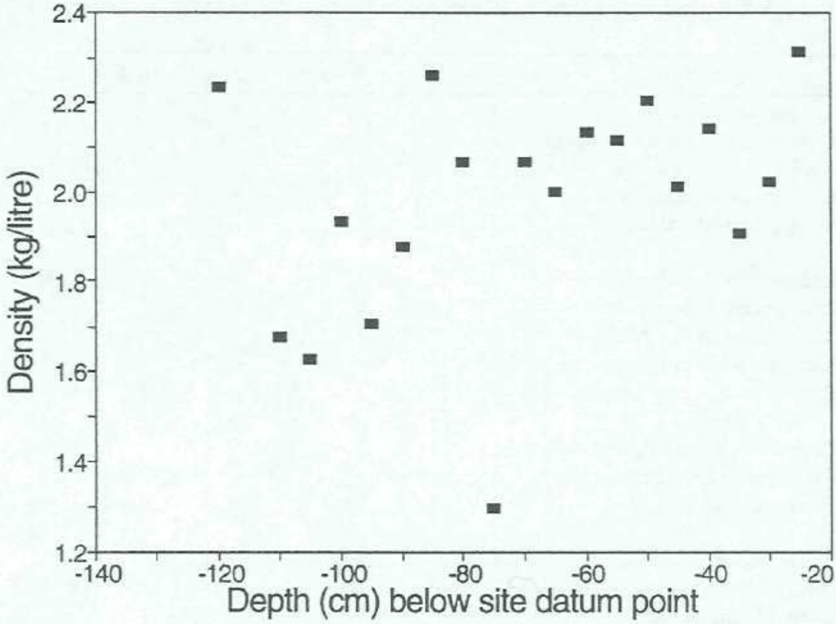


Figure 10. Specific densities of stone artifacts in square 1S0E.

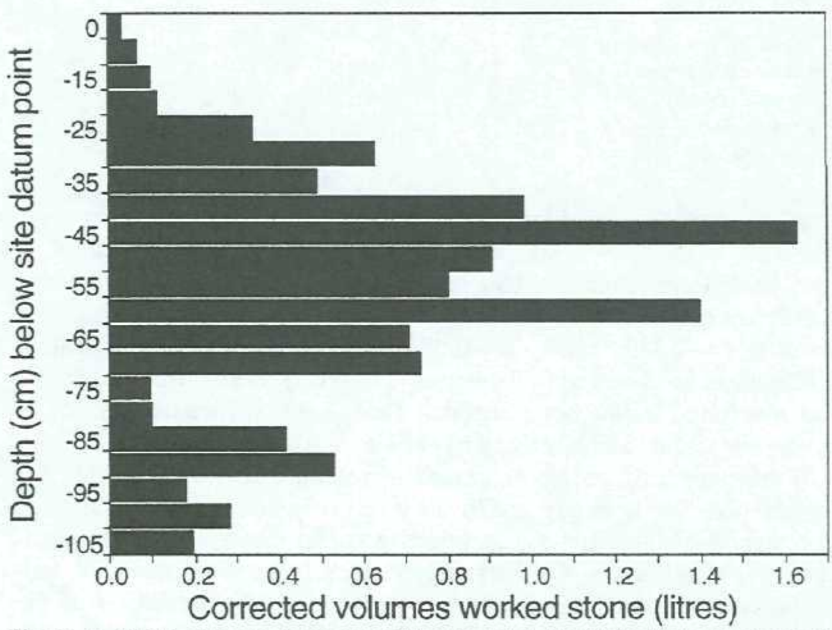


Figure 11. Stone volumes in square 2N1E corrected for fluctuations in excavated layer volumes.

Table 4 Factor score coefficient matrix.

	Factor 1 Size	Factor 2 Shape
Length	0.307	–0.071
Width	0.219	0.222
Thickness	0.265	0.154
Percussion angle	0.058	0.253
Width/length	–0 131	0.414
Thickness/length	–0 005	0 405
Percussion angle/length	–0 285	0.203

Stone waste material is represented by 1377 flakes, of which 795 were found between 0-60 cm, 351 in the levels 60-80 cm and the remaining 231 between 80-140 cm. In an attempt to discover whether different tool manufacturing techniques were practised, the dimensions of the flakes were analyzed statistically. Five measurements were taken of 466 unbroken flakes. The five dimensions and three ratios that were calculated from these may be found in Table 4. After standardizing the measurements to z-scores (the data were not transformed, Baxter 1994: 45) a principal component analysis was carried out. This technique is used to reduce a 'large' number of inter-correlated variables (measurements) to two or three components which cover most of the variation present in the data. Two principal components (called factors by SPSS) were selected covering 46.1 + 27.3 = 73.4% of the total variation in the measurements. The first factor has high coefficients for length, width and thickness, and therefore represents the size of the flakes. The second factor represents the shape of the flakes, as it shows high coefficients for the weight/length and thickness/length ratios (see Table 4).

The distribution of these 'size' and 'shape' scores through the excavated levels showed (no figure published) no correlation amongst Factor 2 (which represents the shape of the flakes) and depth. In the distribution of high Factor 1 scores (large flakes) however, a slight patterning may be observed. The distribution of large flakes appears to be confined to the 35-70 cm levels (see Fig. 12). Large flakes were not deposited in the lower sequence, suggesting a difference in the tool manufacturing techniques practised by the inhabitants during the formation of the lower and upper sequences.

4.4 *Other excavated materials*

Three pieces of undecorated pottery have been found in Toé cave (total weight 13.3 g). This material originates from the level 5-15 cm below

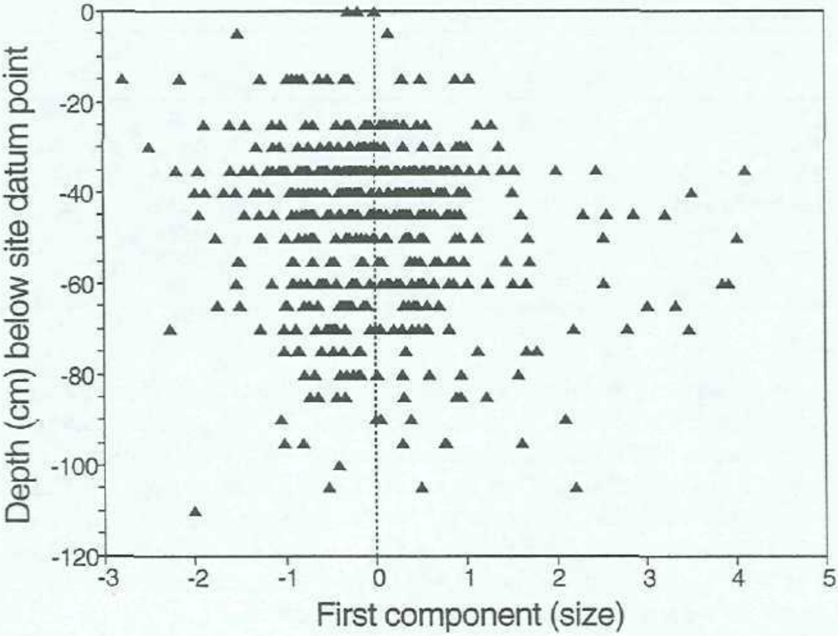


Figure 12. First principal component (size) scores of stone flakes in each level of all squares combined.

the surface. Lower in the sequence no pottery was encountered. Notable is the presence of two so-called 'Muduk' bone points (McCarthy 1940) of approximately 2.5 cm in length and pointed at both ends (bi-points). These points, which were found in the 50-55 cm and 55-60 cm levels, were probably used as barbs on a spear or arrow for fishing purposes (ibid.). Red and yellow ochre was found in large quantities: 131 pieces were recorded. The highest quantities, in both frequency and weight, were excavated in the 80-140 cm levels. The soil samples taken for pollen analysis proved to contain no pollen. This is usually the case in limestone sediments (Bottema, pers. comm.).

5 DISCUSSION

5.1 *Two different occupation sequences*

From the results of the archaeological and statistical analyses the presence of two different sequences at Toé cave is concluded. The arguments that lead to this conclusion are the following:

1. The presence of the 2930 BP ^{14}C date above the three younger ones (see Table 1).

2. The confinement of montane vertebrate species to the lower levels (see Fig. 4).

3. The two distinct fossilization sequences in the bone material (see Fig. 6).

4. A significant difference between the average sizes of bone fragments originating from the upper and lower layers (see Fig. 7).

5. The absence of large flakes in the lower levels (see Fig. 12).

6. The differences between the upper and lower levels regarding the stone and bone quantities which have been recovered (see Figs 8 and 11).

If the ^{14}C date of 2930 BP is accepted, one might conclude that the upper levels of the excavated soil are the remnants of a former higher floor in the cave, which was at least inhabited approximately 3000 years ago (see Table 1). As a result of a collapse of this floor (ceiling), its archaeological deposits were superimposed on a lower sequence. If the charcoal samples dated to 155-220 BP (see Table 1) were part of the lower sequence, then the collapse of the ceiling happened not more than about 200 years ago. This is another example of the fact that archaeological deposits in caves are seriously affected by eroding processes (Glover 1979, Strauss 1979) although not as vigorously as those of open-air sites.

5.2 *The lower levels, 80(60)-140 cm: a Pleistocene sequence*

Gradual cooling of oceanic and atmospheric circulations during the Pleistocene caused the development of giant ice sheets at high latitudes. In the tropics this only occurred at high altitudes. These changes had global effects and also influenced the climate in (present-day) Irian Jaya. During the glacial maxima and consequent low sea levels, colder and dryer air masses must have determined the New Guinea climate (Nix & Kalma 1972). In about 20,000 BP the average lowland temperature would have been 3.5°C lower than it is now. Rainfall would have been about half the amount today, and evaporation would have been only 80% of the current amount (ibid.). Löffler (1970) established that the considerable lowering of the snow line in the alpine region of New Guinea during the Pleistocene must have been caused by a decrease of 5-6°C in the local temperature. This corresponds with the 3-4°C decrease in lowland temperature calculated by Nix & Kalma (1972). Hope and Hope (1976) suggest that what is now lowland rainforest was broadleaf open forest in 20,000-14,000 BP (Pollen analysis from Bird's Head localities has not yet taken place. For a general discussion about climatic change, see Kershaw 1995). The circumstances would not only have caused a different vegetation, but must have had an effect on the distribution of animal species as well. Not much is known about these changes, in fact hardly any Pleistocene fauna has been recovered from Irian Jaya (Hope et al. 1993).

Because it is unlikely that the montane species discovered in the lower levels of Toé cave were hunted and subsequently transported over distances of 30 km or more, where they are found today, it may be concluded that people lived in Toé cave during the Pleistocene Epoch. They used a wide variety of resources from the lake and the surrounding forest such as fish, shellfish, (tree) kangaroos, cuscuses, birds and their eggs. Remains of the plants, nuts and fruits they ate have not survived the ages. The people lit fires in the cave, presumably to cook their food, to keep dry, and to provide light. Red and yellow ochre was probably used for painting purposes. Whether this material was also used to make cave paintings is unknown. Paintings have not been found on the cave walls, although these were inspected thoroughly. Ochre may also have been used for the conservation of organic materials such as hides (Semenov 1964: 5). How many people lived in the cave simultaneously is quite uncertain, but considering the size of the cave these numbers could not have been high. When exactly this Pleistocene occupation took place is currently being investigated. Attempts are being made to date the lower sequence by means of the electron spin resonance technique. Present-day Papua New Guinea is known to have been inhabited by people as early as 40,000 BP (Groube et al. 1986).

5.3 *The upper levels, 0-60(80) cm: a Holocene sequence*

In comparison with the lower sequence, many artifacts were found in the upper levels. Unfortunately these have been subject to sink action or other kinds of erosion and locations of the artifacts in the stratigraphy do not reflect where the people used or discarded them. Therefore a spatial analysis of their horizontal distribution to detect specific activity areas is not meaningful.

People lived in Toé cave in around 2930 BP and did not have as many vertebrate game species available to them as their Pleistocene predecessors (*Homo sapiens* bones are confined to the upper sequence). They did use a great variety of stone tools (see Table 3), and bone tools in the form of 'Muduk' points. This hints at the role of fishing in their subsistence, which is not surprising this close to a lake.

5.4 *Further research*

Considering the effects of eroding processes, which preclude a meaningful spatial analysis of the collected data, further excavations in Toé cave are not expected to reveal much new information. Future research must therefore be focused on the location and sampling of other prehistorically inhabited caves in the Ayamaru district. The survey that has been conducted shows that there are many archaeological opportunities in this area. Prehistoric caves with high archaeological potential will have to be excavated completely, using proper methods. The significance of a thorough pilot study of cave stratigraphies has been underlined by the analyses of the Toé cave data.

In order to correctly interpret the archaeological data from sites around the Ayamaru lakes within a better ecological framework, an extensive study of the vegetation history needs to be conducted. Therefore pollen analysis from a number of samples from these lakes is needed. Hopefully, these goals will be met in the not-too-distant future.

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4

Kria cave: An 8000-year occupation sequence from the Bird's Head of Irian Jaya

1 INTRODUCTION

Over the last ten to fifteen years evidence has been found of long human occupation in New Guinea (e.g. Groube et al. 1986). Archaeological research in the New Guinea region has been carried out mainly in the eastern half of the island, Papua New Guinea, and Indonesia's province of Irian Jaya has, in this respect, been neglected. The Bird's Head (or Doberai) peninsula is likely to have been part of one of the major migration routes of the first settlers of New Guinea (Birdsell 1977, Bellwood 1996), yet its prehistory remains completely unknown. Archaeological sites were discovered by Solheim in 1992 along the north coast of the peninsula (see Solheim, this volume). The archaeological part of the ISIR (Irian Jaya Studies: a programme for Interdisciplinary Research) project focused on the discovery and investigation of additional sites to fill the gaps in our knowledge of the prehistory of the area. Fieldwork was undertaken in the interior of the Bird's Head in 1995, and test excavations were carried out in two of the discovered sites: Kria cave and Toé cave (see Jelsma, this volume). This paper reports the results of the survey and gives a preliminary account of the stratigraphy, dating and archaeological remains from Kria cave.

2 THE FIELDWORK

2.1 *The survey design*

The recovery of organic remains was of high priority in the selection of a field area, both for the dating and investigation of prehistoric remains. In the New Guinea region radiocarbon dating represents the most important means of establishing archaeological chronology. Relative dating based on typochronology is of extremely limited use. In spite of major changes that have occurred in economies over time, the basic Melanesian stone tool kit has changed little in morphology over long periods of time (Golson 1977, White 1972). The earliest use of pottery in the region may be at about 3500 BP in Halmahera (Bellwood 1993). In Papua New Guinea, pottery has been used in certain coastal areas for at least 2000 years, with more recent usage in other coastal regions and the highlands (Watson 1979, White & O'Connell 1982). The use of pottery in the Bird's Head thus may date only to the last few thousand years. Other, perishable items of material culture are likely to have changed more frequently (Peterson 1971), but these are rarely preserved. The dates of introduction of various domestic animals (pigs, dogs) could prove useful chronological markers, but these are not yet well established. Recovery of organic remains is also crucial for the analysis of prehistoric economies. Previous studies of faunal remains have shown signs of changes related both to climatic changes and human land use (Aplin 1981, Hope et al. 1993, Mountain 1993).

2.2 *The field area*

The natural vegetation of the Bird's Head is tropical rainforest, which produces an acid humic soil with devastating properties. In general in such tropical regions, well-preserved organic materials may only be expected in the sheltered environments of limestone caves. Caves are usually found in areas where karst processes are taking place (Jennings 1985). A large karst area is present in the Ayamaru area, located more or less centrally on the Bird's Head (see Fig. 1). The Ayamaru lakes, comprising three connected lakes, are surrounded by low, rounded hills, typical of a sinus karst. The lakes are shallow, with dense, low aquatic vegetation (see Pl. 1). The hills are covered with low rainforest, interspersed with active and abandoned gardens.

The area has a long history of colonial contacts and is now relatively densely populated. The present-day economy consists of horticulture, fishing and occasional hunting. Sago palms are present in limited numbers; however, the production of sago has not been observed in the area.

Many places in Papua New Guinea show evidence of prehistoric occupation in caves, and ethnological sources (e.g. Gorecki 1979) also document the use of caves for mortuary practices and other activities. Although such literature is limited for the western part of New Guinea, some ethnographies report the existence and use of caves in certain areas, such as the Mejprat area in the Ayamaru lake district (Elmberg 1955, 1965).

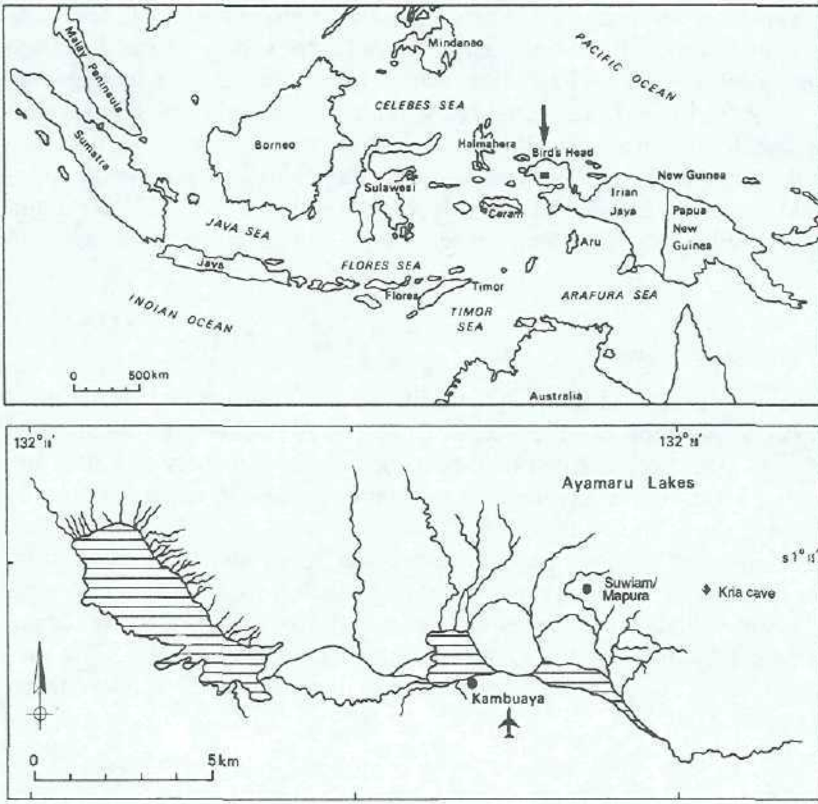


Figure 1. The Ayamaru area and the location of the site.

2.3 *Survey results*

Examination of maps and aerial photographs confirmed the presence of a large karst area near the Ayamaru lakes. Caves were located with the assistance of local villagers, who also provided information about the traditional usage of specific caves. This process was considerably facilitated by the local schoolteacher Elimas Kambuaya, who established the location of the caves, their owners and their accessibility. In some cases, permission was not given to enter a cave. For example, one cave had been the place of exile for people affected by leprosy and it was feared that the souls of the deceased, together with the disease itself, was still in there. Where permission was granted, the cave, its position and that of its entrances was described, and a record was made of the surrounding natural environment. The thickness and contents of the deposit were estimated by means of augering with an 'Edelman' drill, generally at or near the entrance of the cave. The area turned out to have high archaeological potential: although the time and possibilities for surveying the Ayamaru area were limited because of a lack of local transport, we managed to visit fifteen caves or rock shelters, seven of which were found to contain archaeological material. Three sites were located within 2 km of the lakes; one site lay on the margin, two on a peninsula, and one on an island in one of the lakes. Eventually, based on richness of the deposit and accessibility, two sites were selected for test excavation: Toé cave and Kria cave.

2.4 *Kria cave and its location*

Kria cave is located inside a low hill, about 2 km northeast of the most easterly lake, and ca. 3 km east of the village of Suwiam/Mapura (see Fig. 1). The cave has two entrances facing approximately east and one facing west. From any one of the entrances the daylight coming in through the other two is visible.

In the large hall behind the entrances large rocks have fallen down from the ceiling and many stalactites and stalagmites have formed over the years. The atmosphere in the cave is very humid. The location of the cave, as determined by means of a Global Positioning System, is 01°15′7″S and 132°20′1″E. The excavated entrance lies approximately 325 m above mean sea level.

2.5 *The excavation*

The east-northeast entrance (see Pl. 2) appeared to have the deepest and richest deposit. The grey, loamy soil in the cores contained a great deal of organic material, together with shell fragments and pieces of bone, and some stone flakes. With 105 cm of sediment indicated by coring (on excavation this turned out to be over 2 m), it was obvious that this entrance had been the main focus of occupation of the cave.

The excavated entrance has the shape of a rock shelter (see Pl. 3), and has passages into the cave in the back wall. Two test pits, each of 1 m^2, were made: one more or less central (1N1E), and one near the back wall of the rock shelter (0N0E) (see Fig. 2). These locations represent the optimal conditions for excavation: the northern part of the surface is covered with large, immovable rocks; the southern wall is formed by a very low-hanging, tilted ceiling and the regular dripping of rainwater has produced a pothole in the surface; and in front of the shelter, the surface, covered by trees, slopes away steeply and has probably been subjected to considerable erosion.

The test pits were excavated in 5 cm levels because natural layers were not obvious during excavation. A latex peel, following the method described by Orliac (1975), was made of the stratigraphical profile in one of the pits (see Fig. 2). The excavation reached a depth of approximately 170 cm below the surface in square 1N1E and 195 cm in square 0N0E. Unfortunately, because of limited time, the bedrock was not reached; coring at the base of the test pits indicated that the bedrock lies at 190 cm and 235 cm respectively.

All measurements of depth are related to a fixed point approximately 25 cm above the surface at the back of the rock shelter. The surface rises slightly towards the entrance, but is roughly horizontal at the location of the excavation squares. All measurements of depth are converted into centimeters below the surface of each square. The three-dimensional location of all stone tools, pieces of ochre and charcoal, human bones, and exceptional finds, such as large animal bones or large shells, was recorded. Horizontal measurements were recorded in centimeters from the southwestern corner of square 0N0E. The remaining finds were selected from the excavated soil by hand because the soil was damp and rich in clay and no appropriate wet-sieving facility was available. This method appeared to be adequate, because even very small fragments of eggshell or charcoal were recovered. As a check on the 'manual' method, a sample of the excavated soil from every level was sieved in a net with a mesh width of 2 mm. These samples pro-

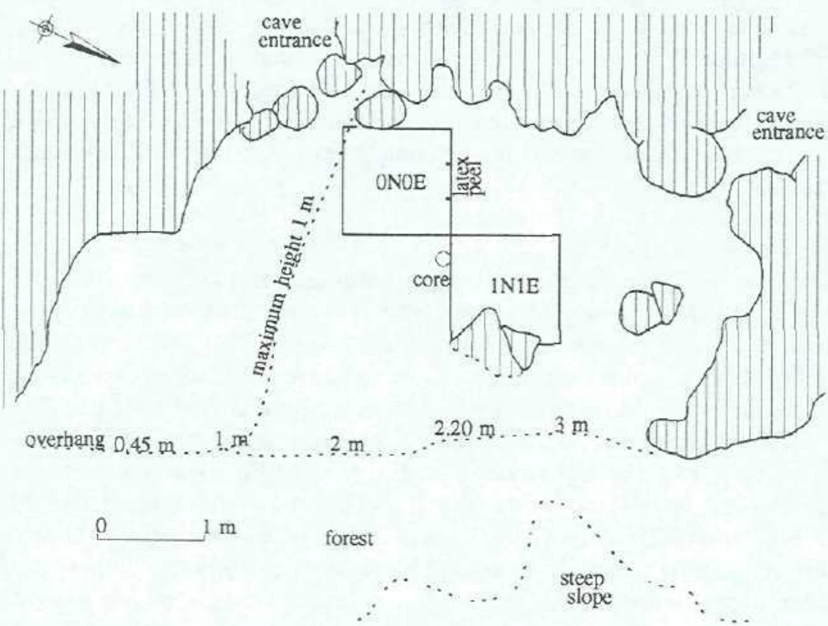


Figure 2. Map of the cave entrance and the excavated squares.

vided finds of the same kind, but smaller than those detected by hand. This control system turned out to be essential for finding fish bones, all of which were very small, and which would otherwise have been under-represented.

3 EXCAVATION RESULTS

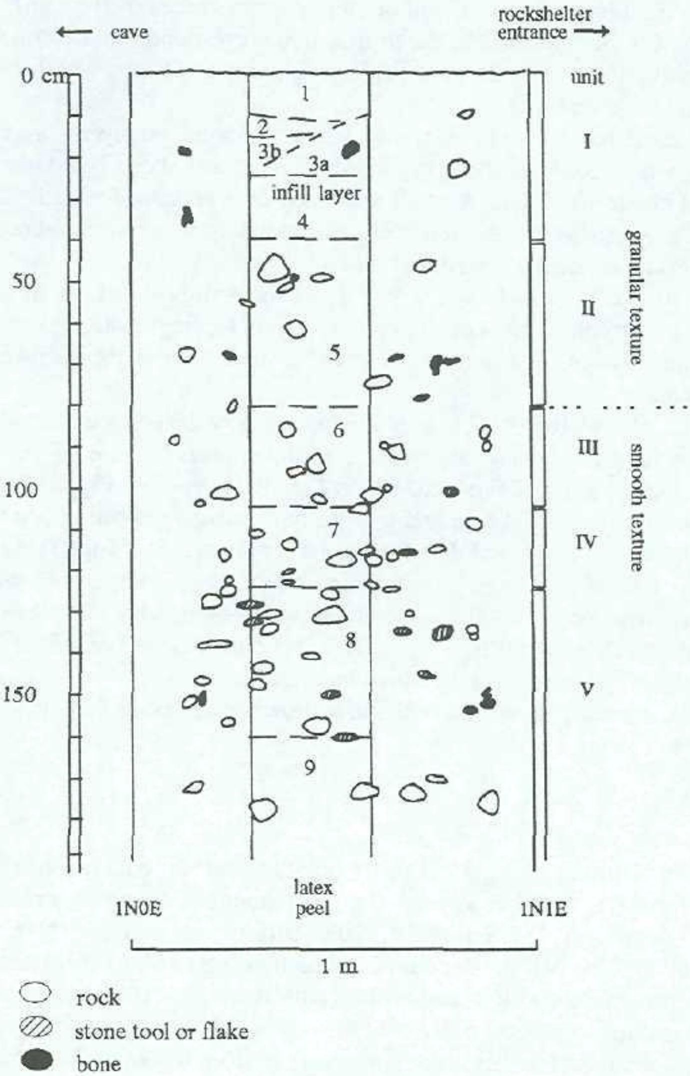
Among the finds discovered in Kria Cave are mammal bones, including human, bones of birds and eggshell fragments, fish and reptile bones, crab claws, molluscan shell fragments, ochre, charcoal, stone and bone artefacts. Pottery is represented by only four sherds from the top levels. A brief description of these finds is given here in Section 3.3; a more detailed analysis of the finds will be presented in future publications. In this paper I will describe the stratigraphy of the deposit, the distribution of the various archaeological remains through the profile, the correlation between the excavated squares, and the dating of the site.

3.1 *The stratigraphy*

No obvious natural strata were recognised during excavation of the deposit in Kria cave. The following account is based on careful study of the latex peel, horizontal drawings made of each level, and on the quantitative analysis of the vertical distribution and the state of preservation of the cultural remains throughout the deposit. Because only a single radiocarbon date is currently available, the interpretation of the sequence should be considered preliminary. The depth in centimeters is provided as a rough indication of the major boundaries rather than as a strict segregation.

3.1.1 *The latex peel*

The latex peel was made of part of the northern wall in square 0N0E (see Fig. 2): a central section of 30 cm width, covering the total length of the profile down to the lowest excavated levels (see Fig. 3). Held in proper light, which was not possible in situ, some different textures and shades of colour are visible. The upper 10-12 cm are light grey (Layer 1 of Fig. 3). This is underlain on the western side (towards the back wall of the cave) by a thin, slightly darker layer (Layer 2 of Fig. 3) a few centimeters thick. Layers 1 and 2 give way to a light brown-grey layer (Layer 3a of Fig. 3) which continues until some 25 cm below the surface. A projecting piece of human bone at ca. 15 cm depth corresponds with a concentration of human bones in this square. Underlying Layer 2 is a small layer or feature (this is not clear from the narrow peel), which reaches a maximum thickness of 7 cm on the western side (Layer 3b of Fig. 3).



1 light grey
2 grey
3a light brown-grey: (human) bone
3b light brown-grey: (human?) bone, charcoal
4 grey-brown: charcoal, shell
5 light grey-brown: bone, stone flakes
6 brown-grey
7 brown-grey: bone
8 yellow-brown: stone flake, burnt bone, red ochre
9 darker yellow-brown: burnt bone

Figure 3. The profile in square 0N0E (facing approximately south) including the analysed latex peel.

This layer is light brown-grey in colour and contains pieces of (human?) bone and a speck of charcoal. In depth this also corresponds to the concentration of human bones, like the projecting piece at 15 cm, which is located outside this feature.

Below 25 cm depth, the soil grades into a darker grey-brown layer (Layer 4 of Fig. 3), which contains some specks of charcoal and shell. This layer extends until about 40-45 cm. A small specimen of a *Melanoides* shell is attached to the west side of the latex peel, corresponding to a concentration of shells at this level noted during excavation.

Between 40 and 80 cm (Layer 5 of Fig. 3) the sediment returns to a lighter grey-brown colour, but contains projecting rocks, fragments of bone and small stone flakes. The soil has a granular texture from the surface down to 80 cm.

Between ca. 80 and 105 cm (Layer 6 of Fig. 3) below the surface the soil is brown-grey in colour, has a smooth texture, and appears to have no projecting finds but some rocks. From ca. 105 to 125 cm (Layer 7 of Fig. 3) the soil is similar to Layer 6 in colour and texture, but contains projecting bone fragments. Below this depth and down to ca. 160 cm (Layer 8 of Fig. 3) the sediment is yellow-brown, smooth in texture, and contains a large projecting stone flake, fragments of burnt bone and a piece of red ochre. The lowest part of the peel (Layer 9 of Fig. 3, 160-190 cm) is a darker yellow-brown colour with projecting fragments of burnt bone.

Coring of the unexcavated sediment showed bedrock to be at 235 cm in this square.

3.2 *Dating*

At the time of writing (spring 1997) only one radiocarbon date has been obtained for the site. It is based on a single fragment of charcoal, excavated at a depth of 155 cm below the surface in square 1N1E: OxA-6043 6900 ± 80 BP. After calibration (according to Van der Plicht 1993), this corresponds with a date either (with two s.d.) between 5942-5912 cal BC or between 5882-5597 cal BC. Below this level, insufficient charcoal was obtained for dating. A bone sample from the same level in square 0N0E contained insufficient collagen for dating. This means that occupation of the site started at least some 8000 years ago, since the lowest excavated levels in this square at 170 cm depth still contained bone fragments and flakes, and bedrock lay even deeper at 190 cm.

3.3 *The major find categories*

The pattern of occurrence of each of the major find categories through the sequence in each square is shown in Figure 4. Most of the find cate-

	0N0E		1N1E
1 : Pottery	n= 4	1 : Pottery	-
2 : Human bone	762 g	2 : Human bone	27 g
3 : Animal bone	6390 g	3 : Animal bone	6410 g
4 : Shell	250 g	4 : Shell	478 g
5 : Flakes	2680 g	5 : Flakes	2050 g
6 : Eggshell	24 g	6 : Eggshell	33 g
7 : Bipoints	n=40	7 : Bipoints	n=46
8 : Stone tools	n=18	8 : Stone tools	n=20

Figure 4. Kria, presence of materials through the deposit in square 0N0E and 1N1E.

gories are present in relatively low quantities. Animal bone and stone flakes comprise the bulk of the total excavated material, with lesser quantities of shell and other faunal and cultural remains. The quantities of bone, stone and shell fluctuate markedly through the sequence and will be described in detail. For the other materials, only their pattern of occurrence through the sequence is discussed.

3.3.1 *The faunal remains*

The total quantity of animal bone is approximately 12,800 g. The bulk of the bones (estimated to be between 80 and 90%) come from forest wallabies (*Dorcopsis* spp.). Other species present include tree kangaroos (*Dendrolagus* spp.), cuscuses (*Spilocuscus* spp. and *Phalanger* spp.), echidna (*Zaglossus bruijnii*), possums (*Dactylopsila* spp. and *Petaurus* sp.), ringtail possums (*Pseudocheirulus* sp.), bandicoots (*Echymipera* spp.), rodents, birds (including *Casuarius*), snakes, lizards, and both megachiropteran and microchiropteran bats. A few pig bone fragments were present in one of the uppermost levels. The human skeletal remains (ca. 790 g) are concentrated in the upper levels of square 0N0E. They clearly belong to more than one individual but the circumstances of interment are not yet clear. Eggshell fragments are present in most levels through the deposit; the total weight amounts to 57 g. The total quantity of molluscan shell fragments is 729 g. These have not been identified in detail yet, but the majority are from a fresh water species of *Melanoides* (Moolenbeek, pers. comm.). These are concentrated in the upper levels.

3.3.2 *The cultural material*

Stone flakes amount to ca. 4730 g; in addition to these, there are 38 pieces which show evidence of secondary retouch, along with several cores and hammerstones. The majority of the flaked stones are made of a relatively light, brittle chert (the kind of chert has not been indentified yet; further details will be described in a future publication). Many pieces show a softer, pale cortex, suggesting the use of moderate to large nodules of chert, probably derived from local sources in the limestone. A small proportion of the stone artefacts are manufactured from a harder, red silicious material of an as yet undetermined nature and source.

The retouched implements do not include any obvious formal 'types', and in this respect the collection appears to be similar to other stone tool assemblages from Papua New Guinea (White 1972, White & O'Connell 1982). No specimens show the high polish produced as a consequence of sago manufacture with a 'sago chopper' of the kind described by Rhoads (1980). No edge-ground implements or obvious flakes or fragments derived from such implements were recovered. For the present analysis the stone artefacts were divided into simple flakes and 'tools', i.e. retouched flakes and hammerstones.

A total of 92 bone points, or fragments thereof, were found. Most of these are between 2 and 4 cm long, with occasional examples over 5 cm. Twenty of these are worked at both ends (i.e. bipoints), while the remainder could be unipoints, or damaged or incomplete bipoints.

Three of the four pottery sherds are undecorated; one is decorated with cross lines. Only one undecorated piece comes from the rim of a pot, the others are body sherds. They have not yet been compared to existing pottery traditions.

The fragments of red and yellow ochre and charcoal are still in the process of being analysed. Rock paintings were not observed in Kria cave or any other cave visited, although the presence of mossy growth obscures many surfaces. Among the charcoal fragments are some pieces that resemble fruits or nuts; these are currently being examined.

3.4 *Vertical distribution of finds*

As shown in Figure 4, only animal bone and shell occur in practically all levels of the deposit. Flakes, eggshell, bipoints and stone tools are mainly found below 35 cm in square 0N0E, and below 20 cm in square 1N1E, with a single specimen each of eggshell and stone flake, and a disputable bone point fragment above that level in square 0N0E. Human bone and pottery, on the other hand, are mainly present in the upper levels. As will be shown in the quantified distributions below, this applies also to the occurrence of shell.

The vertical distributions of animal bone, stone flakes and molluscan shell are illustrated in Figure 5. The quantity of animal bones in square 1N1E is high between 30 and 55 cm and again below 105 cm, with lower quantities between 55 and 105 cm depth. Lower values are seen again at 125-135 cm depth. The animal bone material in square 0N0E shows a stronger bimodality, with peak values at 60-80 cm and again below 120 cm, and low quantities above 60 cm, between [illegible] d at 150-155 cm depth. A small peak occurs at 110-115 cm in square 0N0E.

The pattern of distribution of stone flakes in both squares does not correspond with that of animal bone. In square 0N0E the quantity of stone flakes shows an overall increase towards the base of the excavated deposit, interrupted by a fall in values between 80 and 110 cm. In square 1N1E, it fluctuates greatly but with a decrease in the lower half of the deposit. In neither square is there a bimodality of the kind seen in the distribution of animal bone.

Molluscan shell fragments are present in relatively large quantities in the upper levels of the deposit in square 1N1E, but only occasionally and in low

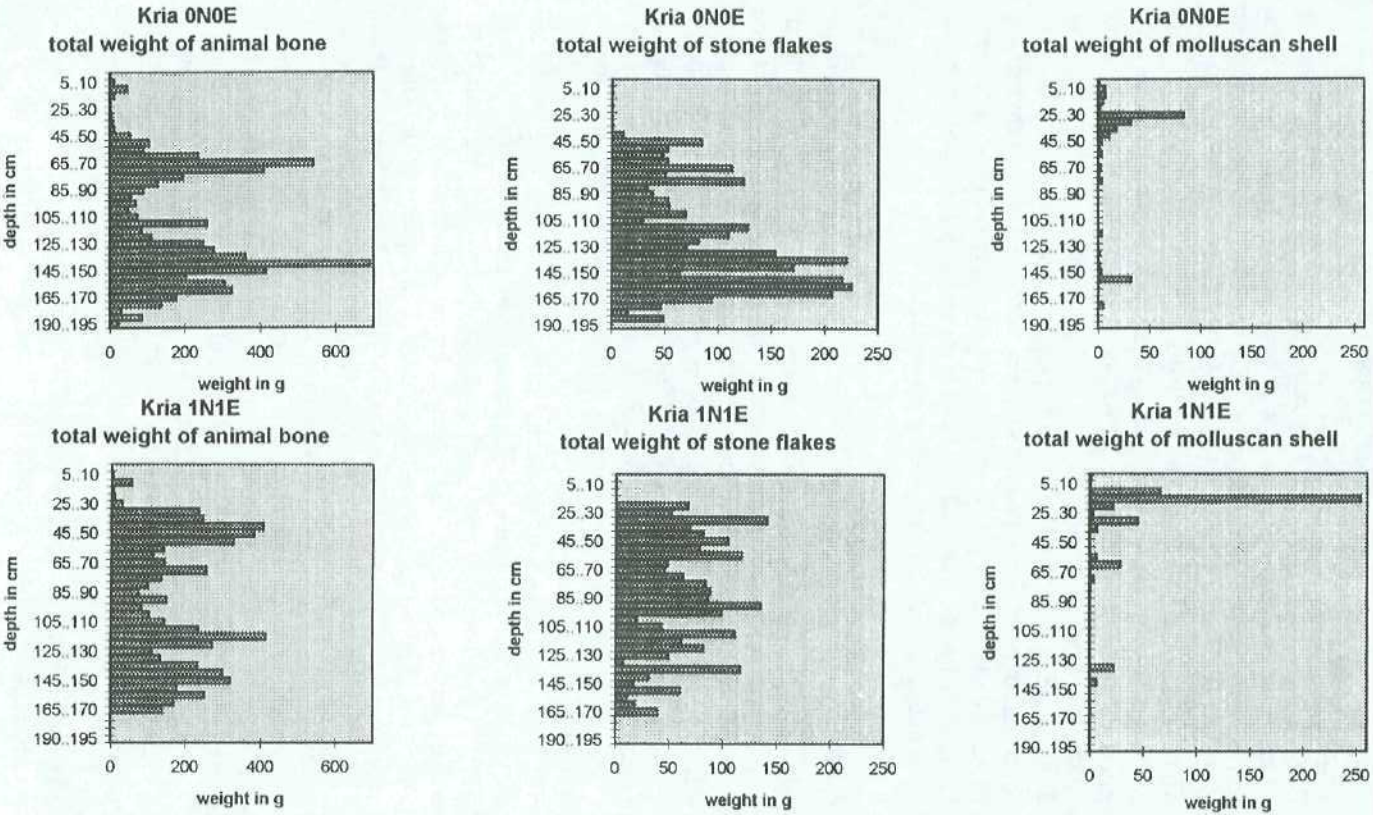


Figure 5. Distributions of animal bone, stone flakes and molluscan shell in both squares.

quantities below ca. 35 cm. The same applies to square 0N0E, where the bulk of shell fragments occurs above ca. 55 cm, with a maximum at 25 cm. However, in this square there is also a sharp peak at 150-155 cm. The pattern of distribution of molluscan shell contrasts markedly with that of both animal bones and stone flakes.

The upper levels of the sequence, from the surface down to ca. 40 cm in 0N0E, and to ca. 35 cm in 1N1E, are clearly distinguished from the levels below. Only in the upper levels does pottery occur, together with large amounts of shell and human bones. Also pig bones are only present in this part of the sequence. Flakes, stone tools, bipoints, eggshells, and animal bone are absent in these upper levels, or occur in minor quantities only.

The distributions of the material found in square 0N0E correspond well with the projecting finds and sedimentary layers observed in the latex peel. Combining the evidence from both sources, five units may be distinguished (see also Fig. 3):

– *Unit I.* From the surface down to about 40-45 cm, a light grey to grey-brown granular sediment, characterised by the presence of pottery, human bones and a concentration of shell fragments (predominantly *Melanoides* sp).

– *Unit II.* Between 40-45 and 80 cm, a light grey-brown granular sediment with abundant animal bones, stone flakes and tools, eggshell fragments and bone points.

– *Unit III.* Between 80 and 105 cm, a brown-grey smooth-textured sediment with only minor quantities of finds.

– *Unit IV.* Between 105 and 125 cm, a brown-grey, smooth-textured sediment with abundant animal bone, stone flakes and tools, bone points and eggshell.

– *Unit V.* Between 125 cm and the lowest levels, a yellow-brown, smooth-textured sediment with abundant animal bones, stone flakes and tools, bone points and eggshell.

3.5 *Correlation between squares*

The vertical distribution of animal bones in each square is compared in Figure 6a. Apart from a near perfect fit in the uppermost 25 cm, the patterns of distribution show little obvious correspondence. However, by shifting the 1N1E sequence downwards by 20 cm (see Fig. 6b), the two sequences attain a very good alignment of peaks and lowpoints. A similar result is obtained by comparing the quantities of stone artefacts, in both original and 'shifted' positions (see Figs 6c and d). This result suggests that, at least for the greater parts of their history, the cave sediments accumulated with a downward slope of some 10° away from the entrance. This is of course consistent with the observed difference in

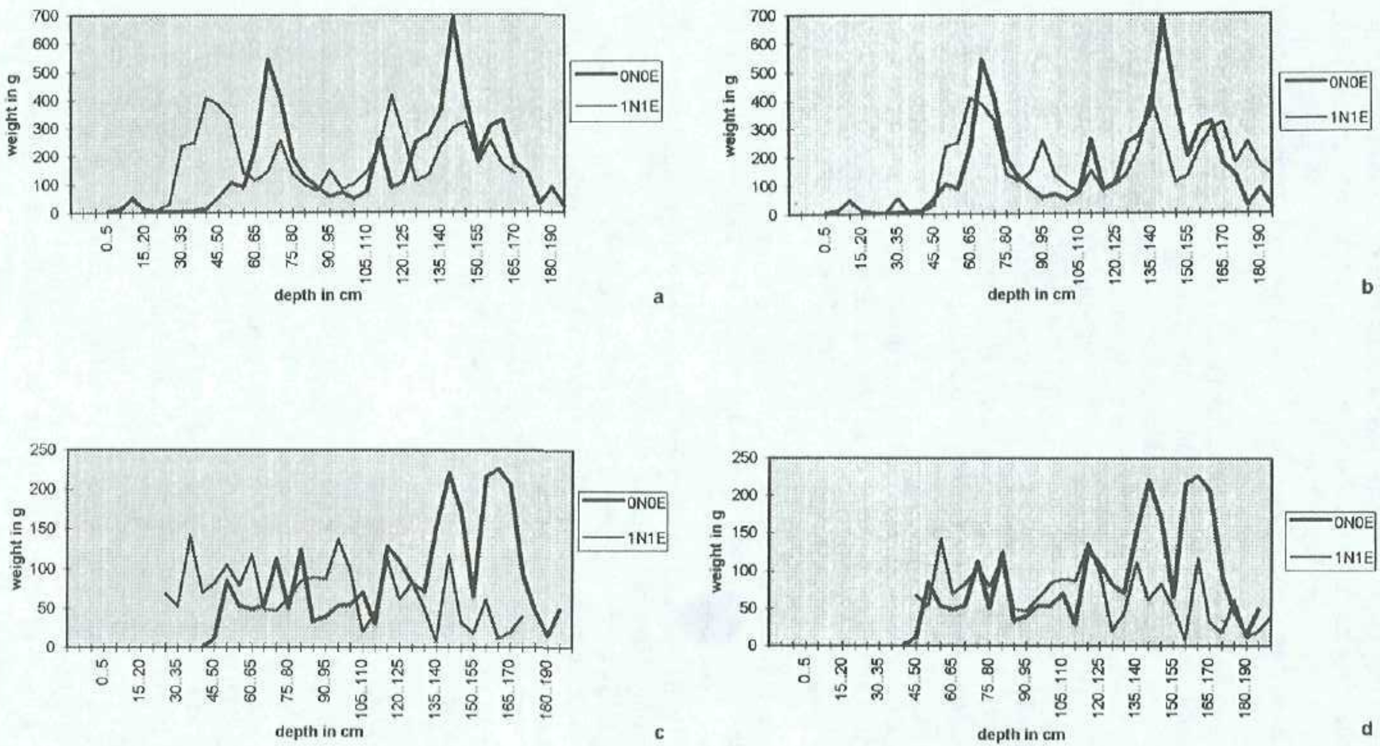


Figure 6. Animal bone and stone flake distributions. a and c) Original distribution, b and d) Distribution in 1N1E shifted 20 cm downwards.

depth to bedrock in the two squares, being 235 cm in 0N0E and 190 cm in 1N1E. Infilling at the rear of the cave, thereby levelling the surface of the deposit in the area of the two squares, evidently occurred during the period of accumulation of Unit I, perhaps through deposition of the relatively shell-rich Layer 4 in 0N0E, corresponding to the observed peak in shell quantities in the 15-20 cm level in 1N1E.

The very good correspondence in the vertical distribution of both animal bones and stone flakes between the two squares, once allowance is made for the slight dip in the bulk of the sediments below Layer 4 in 0N0E, further indicates that the excavated part of the deposit has not been subject to significant local disturbance through human activities or through natural processes such as water erosion or slumping.

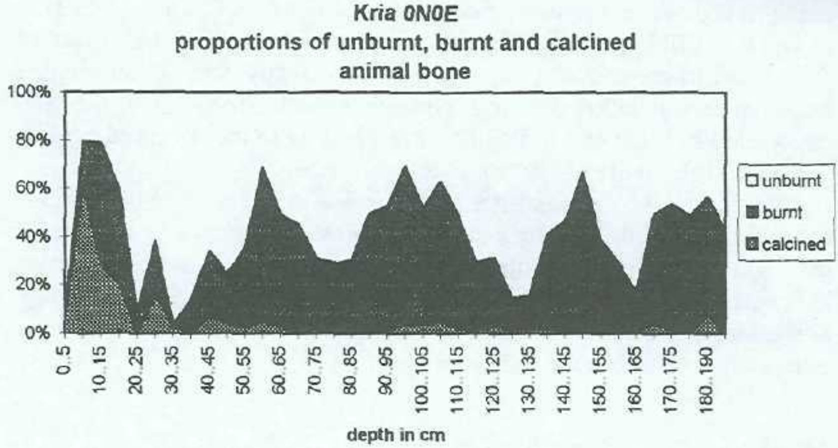
3.6 *Horizontal distribution of finds*

Because only 2 m^2 of the cave entrance have been excavated, only very limited evidence of the horizontal distribution of materials is available. In the upper levels, human bones occurred in both squares, but predominantly in 0N0E at the rear of the cave. The dispersion of the bones continues into the adjacent squares, and the bones did not lie in anatomical position. The significance of this distribution is not clear.

In contrast, the densest concentration of molluscan shell was found in the upper levels of 1N1E, with lower densities spread through a greater vertical range in 0N0E. As noted above, this corresponds to Layer 4 of the latex peel (see Fig. 3), and may represent an 'infill' unit which effectively levelled the cave floor.

Although the total quantity of animal bone recovered from each square is very similar, there are remarkable differences in the proportion of burnt and unburnt material (see Fig. 7). In square 1N1E, 70 to 95% of the material is unburnt, and the quantity of burnt material is fairly constant through the deposit. In square 0N0E, the proportion of burnt bone fluctuates between 20 and 70%. Square 0N0E also contains relatively more calcined bone than 1N1E. As will be demonstrated below, this pattern is unlikely to reflect any marked difference in the preservation of unburnt versus burnt bone between the squares. A reasonable explanation in terms of human behaviour concerns the likely location of the fireplace: near the back wall of the rock shelter, where square 0N0E yielded much more burnt and calcined bone, and away from the drip line, where square 1N1E contained relatively more unburnt bone.

Stone tools, bone points, and eggshell occur in roughly equal quantities in both squares. Pottery was found exclusively in 0N0E. The quantity of stone flakes is also roughly the same between the two squares, other than in



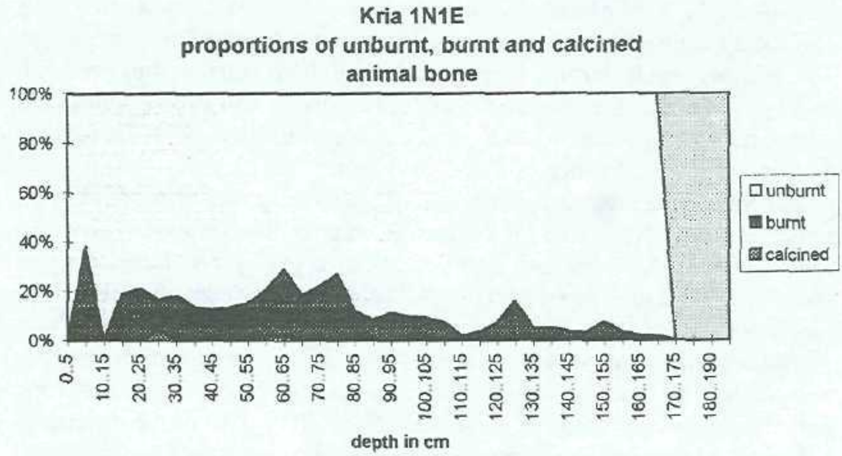


Figure 7. Proportions of burnt and unburnt animal bone in both squares.

Unit V, where square 0N0E produced significantly greater quantities of stone flakes at each equivalent level.

3.7 *Preservational state of the animal bone and stone material*

Fluctuations in the quantity of archaeological material through the deposit may reflect changes in the intensity of the use of the site, provided that the effects of soil condition and other agents on the material can be accounted for. Soil conditions may obviously affect the total amount of material, and not only organic materials are subject to deterioration but lithic material may also be affected (Hiscock 1990).

3.7.1 *Preservation of animal bone*

The preservational state of animal bones was assessed using three different methods: (1) visible inspection for signs of post-depositional damage, in particular to the unburnt material, (2) calculation of the density of the total animal bone sample for each level, and (3) examination of changes in the proportion of unburnt to burnt fractions in each sample.

1) *Visible criteria of damage*

Each sample was scored for three different kinds of damage: fine surface damage probably caused by plant roots, toothmarks indicative of animal scavenging, and general erosion of the bone tissue, presumably caused by water solution and microbial breakdown. Bone fragments are more resistant to erosion if they are burnt, and are probably less likely to be affected by scavenging; therefore, the bone condition as described here is based on the appearance of the unburnt fragments.

Root damage is relatively minor in most samples. It is most noticeable in remains from square 1N1E at the front of the rock shelter and especially in units I and IV and the top of Unit V. Square 0N0E shows less root damage in Unit I remains but some within the top of Unit II and within Unit IV.

Signs of animal scavenging are fairly randomly distributed through each sequence, except that the lower levels of Unit IV show fewer toothmarks in both squares. The remains from square 1N1E show a somewhat higher incidence of toothmarks. From the size and nature of the toothmarks, the most likely scavenger of bones in the Kria site was a dasyurid marsupial, perhaps *Dasyurus albopunctatus* or *Myoictis melas* (Aplin, pers. comm.); the latter is recorded by Flannery (1995) as scavenging in villages within Papua New Guinea.

The degree of general erosion of the unburnt bones shows more marked variation through the deposit. In square 0N0E the unburnt bone is quite badly eroded throughout Units II and III, but shows little sign of erosion in the lower units. In square 1N1E erosion is particularly marked in Units I and II and variably so in Units IV and V. Bone from Unit III appears less eroded. The situation in this square is thus less clear than in square 0N0E.

2) *Bone density*

The density (weight/volume) has been used as a measure of preservation of animal bone and stone flakes. Bones that are badly preserved might be expected to have a low density due to removal of both organic and inorganic matrix. If there is a tendency in certain levels for the bone to be more poorly preserved than in other levels, this might be evident in changes in bone density.

The total amount of animal bone material per level was weighed on an electronic balance; the volume of the material weighing more than 10 g per level was then determined in a glass measuring-jug filled with water. The results for both squares are presented in Figure 8. In square 1N1E there is some variation in bone density, but no specific trend through the sequence. In square 0N0E, however, bone density appears to increase slightly towards the bedrock. It seems reasonable to ascribe this to the observed lesser degree of erosion of the bones in the lower levels of this square. However, it might also be explained in part by the presence on some bones of carbonate encrustation, which may have biased the density of these fragments. (Al-

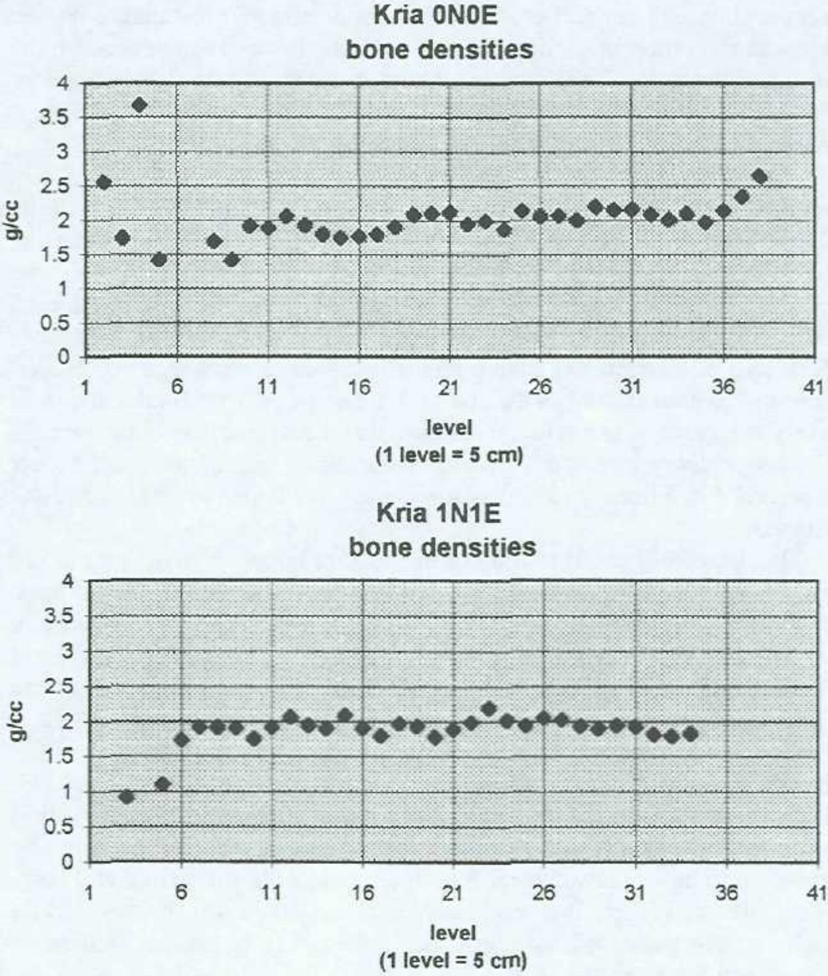


Figure 8. Animal bone densities through the deposit.

though the majority of the bones were cleaned sufficiently, the crust was in some cases too thick and strongly attached to be removed.) Carbonate encrustation was most pronounced in square 0N0E and in the lower half of the deposit, and it may also be that this has served to protect the bone from erosion at these levels.

Burning of bone material alters its chemical composition, making it not only more resistant to deterioration (Aplin 1981) but also denser than unburnt bone. As seen by a comparison of Figures 7 and 8, the variable proportions of burnt bone to unburnt bone through the deposit in square 0N0E do not appear to be matched by corresponding changes in bone densities in this square.

The marked fluctuations in bone density values in 0N0E above 45 cm and the low values in the upper level of 1N1E may be related to preservational circumstances. However, it might also reflect the presence in these samples of unrecognised fragments of human bone, which are generally less dense than animal bone. The samples from these levels are very small and the fluctuations may not be significant.

3) *Burning proportion*

The changing proportions of unburnt to burnt and calcined bone may be also indicative of post-depositional alteration of bone distributions. This is because unburnt bone is more susceptible to biochemical breakdown than burnt bone, from which much of the organic component has been removed during incineration, and particularly so when compared to calcined bone which has lost all of its original organic component. Over time, the expectation is, therefore, that the proportion of unburnt bone will decrease, as it is preferentially destroyed by microbial and chemical processes. However, this may obviously be complicated by aspects of soil chemistry and by variations in the proportions of unburnt to burnt bone in the original assemblages, due to differences in human behaviour.

As shown in Figure 7, the proportion of unburnt bone shows a slight overall increase with depth in square 1N1E, interrupted by lower values between 60-80 cm. Square 0N0E, in contrast, shows a series of major fluctuations in the proportions of unburnt to burnt bone, with peak values of unburnt bone at 20-35 cm, 70-80 cm, 115-135 cm, and 160 cm. These fluctuations are clearly not random, but show no obvious correlation with peaks in bone density or the visible criteria of scavenging or surface erosion of the bone.

For the present, it is therefore concluded that the variations in the proportion of unburnt to burnt bone are a primary feature of the sequence, caused either by variations in sedimentation rate (slower deposition rates perhaps leading to more frequent burning of bone beneath fireplaces), or by changing patterns of human behaviour (e.g. shifting location of fireplaces across the rear of the shelter).

3.8 *Preservation of stone flakes*

The density of the stone flakes in Kria was also estimated by the same method used for the animal bones. In both squares the stone flake density shows some variations but with no overall trend. These variations may reflect other factors such as a variable representation of softer cortex or of burnt chert (which is likely to have a slightly higher density). The stone material will be studied in detail at a later stage. For the present, it is not possible to attribute the changes in density to variable preservational conditions through the deposit.

4 DISCUSSION AND CONCLUSION

The excavation in Kria cave has revealed traces of human occupation in the Bird's Head which date back to at least 8000 years ago. Together with other sites reported in this volume, this provides the first securely dated evidence of prehistoric occupation of this poorly known region of Irian Jaya. Considering the much older evidence for human occupation of the eastern half of New Guinea (e.g. Groube et al. 1986), it is likely that humans were present in the Bird's Head during Late Pleistocene times (Bowdler 1993); Toé cave (see Jelsma, this volume), some 7 km away from Kria, also hints at an early human presence in the Ayamaru lakes area.

Preliminary analysis of the sedimentary and cultural sequences has revealed some significant changes through time in the use of Kria cave. The most dramatic contrast within the sequence is between an upper unit (Unit I) which contains pottery, human bones and a concentration of freshwater shells, and a lower sequence with abundant stone artefacts and animal bones, dominated by the remains of forest wallabies (*Dorcopsis* sp.). The only evidence of domestic animals, a few fragments of pig bone, also comes from the upper unit. Well-formed bone points are present in moderate numbers throughout the lower sequence but are absent from Unit I.

Within the lower sequence, two major concentrations of cultural and faunal material are separated by a unit containing considerably less material (Unit III). Additional radiocarbon dating is currently being undertaken to determine whether these changes represent variations in the level of human activity at the site or variations in sedimentation rate.

An abrupt change in the texture of the cave sediment, from smooth to granular, occurs at the boundary between Units II (with dense cultural mate-

Plate 1. View from Lake Ayamaru on Toé peninsula.

Plate 2. Kria cave: The east-northeast entrance.

Plate 3. The excavation area in Kria.

Plate 4. Excavating in Kria.

rial) and III (sparse cultural material). Gillieson & Mountain (1983) and Gillieson et al. (1986) have reported a potentially comparable change in texture within limestone cave sediments in Papua New Guinea. In these sites, the granular sediments are attributed to erosion of shallow limestone soils as a result of human disturbance. Further work will be required before any such interpretation can be extended to the Kria cave sediments.

The two excavation pits show marked differences in quantity and fluctuations of burnt and unburnt bone fragments. These differences are probably due to the general location of the fireplace against the back wall of the cave. Other horizontal features have been recognised in the top levels: a small shell 'midden' and a concentration of human bones.

The presence of a number of distinct units within the Kria cave sequence clearly signifies some changes in the nature of the prehistoric occupation of the cave itself. Whether these changes relate to more widespread changes in the prehistoric culture or economy within the region is currently unknown. Additional sites in the Bird's Head need to be excavated and analysed in the future, and more extensive comparisons made with the archaeological record of eastern New Guinea and the adjacent areas of Indonesia. This latter process must await completion of the ongoing analyses of the cultural and faunal remains from Kria cave.

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5

Notes on some lowland rainforests of the Bird's Head peninsula, Irian Jaya

1 INTRODUCTION

Descriptions of the Irian Jaya lowland rainforest are almost exclusively hidden in typewritten or mimeographed internal reports of forest surveys made by the 'Dienst van het Boswezen' (Forestry Service), in Dutch, and with a very limited distribution. Therefore, it is worthwhile to pay attention to a number of reports relating to the surveys made in the Bird's Head peninsula between 1936 and 1962. Some reports are not available because they were not mimeographed and distributed, and some surveys did not reach the report stage and their results are inaccessible.

2 METHODS

Koorders introduced a survey system using permanent plots of several hectares each. He started in Java in 1888 with several dozen plots and his method was followed in surveys in other islands of the Netherlands Indies.

The advantage of this method is that the plots can be revisited in different seasons and herbarium material can be taken repeatedly from the numbered trees, thereby covering both flowering and fruiting stages. Knowledge of the forest trees increased overwhelmingly and this new knowledge was used by Koorders (see De Wit 1949) and many subsequent taxonomists.

The disadvantage of this method is that in large tracts of forest the information is still very local and gathering it is very time consuming. Therefore another method was devised to obtain more general information about the standing stock in a (comparatively) shorter time: the strip survey.

In this method a straight line, sometimes several kilometers long, is laid out and measured; terrain and soil conditions are noted. For either up to 5 or up to 10 m on each side of this line the trees above a certain diameter are named and measured; records are usually restarted after every 100 m. The trees are named by a local tree expert whose naming has been tested several times for consistency by going back along a strip and repeating the naming. The diameter is measured at breast height or above buttresses (both indicated as 'd.b.h.'); the length of the bole is measured from its base or above buttresses to the first large branch. For marginal trees the distance of the centre of the bole to the survey line is decisive for inclusion in the survey.

The measured trees are grouped in diameter classes; e.g. Class 6 comprises trees with diameters of 55-64 cm. Usually Class 4 (35-44 cm) was used as the lower limit in the surveys; trees with diameters of at least 50 cm were considered to be merchantable.

In West New Guinea a strip width of 10 m (5 m on either side of the measured line) was used. Each km of strip resulted in a 'plot' of 1 ha, but information was listed for every 100 m of strip, covering 0.1 ha. Parallel strips laid out every km resulted in an inventory of 1% of the forest stand.

A variation on the theme is the use of square plots each of 1 ha (100 × 100 m) laid out with the help of a grid of squares of 1 × 1 km, also resulting in a 1% inventory.

In the West Warsamson valley a mixed type was used: a main strip lengthwise through the valley, and square plots at each end of the shorter cross-lines through the width of the valley.

The use of vernacular names is the crux of the system. Good native tree experts are therefore of vital importance, but sometimes hard to find. To solve this problem, two such men were permanently attached to the inventory teams based at Manokwari: Jacob Ainyussi (Manikiong language) and Marinus Rumawak (Biak language); they worked also very satisfactorily outside their area of origin.

The contents of a vernacular name are, of course, not always congruent with those of a botanical name. The Manikiong name *bettiaan* is used exclusively for *Homalium foetidum*, but *sekka* is used for both *Intsia bijuga* and *I. palembanica*. Of the family Myristicaceae *Horsfieldia sylvestris* has the separate name *bomsij*; the other species of the genera *Horsfieldia* and *Myristica* are divided over *betelehoi* and *sebohonggwa*, but not along botanical generic lines (Anonymous 1958). In other languages the groupings may be different.

As the purpose of the inventory is to gain an insight in the standing stock of timber, these groupings are not too inconvenient for the forestry service as they are often convertable to trade groupings. However, ecological information, such as the differences in habitat preferences between the *Intsia* species, may be lost.

Herbarium collections have been made to relate the vernacular names to botanical ones. The number of collections made to identify or verify a vernacular name was related to the frequency of the vernacular name; the total number of collections, that could be made, was also dependant on the time schedule of the inventory, the personnel available, and the quality of the vernacular naming. In general, the commercially less important species with frequencies far below 1% tended to remain uncollected. Further, economies could be made on the collecting of common well-known species if the naming was done by Ainyussi or Rumawak. From a botanical point of view, all this is regrettable; on the other hand, the grouping of several taxa under one vernacular name increased the number of species that was obtained.

In the calculation of volumes, the form factor 0.7 was used. The result of an inventory was:

– A fairly detailed topographical map;

– A summary of the stand of trees over 35 cm in diameter, by vernacular name, specified in diameter classes and volume;

– Data indicating large-scale differences in forest composition;

– Botanical collections for the 'translation' of vernacular names into Latin names or species groups.

Nevertheless, the non-commercial results are somewhat meagre. Except for the most common species the information about variability and ecology is either haphazard or entirely lacking. Therefore, the interpretation of the results of the inventories has to rely on the more common species and on observations made and published by foresters. And, although publication of field observations is – for botanical collectors and foresters alike – a weak side, much may be gleaned from the reports made by Kostermans, Zieck, and other good foresters.

3 SOME HISTORY

Before the Second World War the exploration for oil was centred near the small village of Babo on the southern side of the Bintuni Bay. For this exploration the (at that time very modern) technique of aerial photography was used. In 1935 started an operation to photograph ten million hectares of West New Guinea. The government received copies of the photographs and Forestry was quick to use this new opportunity. Ir Z. Salverda was appointed to explore the possibilities of aerial photography in forest surveys (Kint 1954). The availability of photographs dictated the location of his study areas: on both sides of the MacCluer

Gulf (Teluk Berau) – Bintuni Bay, and on the south coast east of Fakfak, so that his terrestrial explorations (Salverda 1938) had to cover a large tract of land. On the Bird's Head he visited the area Teminabuan-Ayamaru and the banks of the Kamundan river. (= southern Aifat r.).

In 1939 Ir L.J. Van Dijk explored in a simalar way the forests of the Geelvink Bay islands Biak, Japen, and Meos Num (Van Dijk 1939).

The survey by E. Lundquist in 1941 should provide definite facts about the possibilities of forest exploitation in the areas already reconnoitered by Salverda. His findings were disappointing (Lundquist 1942). The best forests he found in the southern Bird's Head were those along the upper Tisa and Muturi rivers at low altitude (see Table 1).

The listed species provide slightly less than half of the standing volume, the remainder being made up by the other 50 to 60 species.

After the war the inventarisation of virgin forests was resumed. The focus was changed to the east coast of the Bird's Head. Prewar there had already been trials in agricultural development in the deltas of the Waren, Momi, and Ransiki rivers and near Cape Oransbari, and further development plans also included the timber resources. In 1948 forest officer H. Weygers and forest botanist Dr A.J.G.H. Kostermans performed a 2% inventory of 4,258 ha of forested terrain (Anonymous n.d.) in what became known as the Momi-Ransiki area.

From 1950 onwards further surveys were planned and executed under the direction of Ir J.F.U. Zieck, head of the planological section of the Forestry Service in Hollandia (Jayapura), later in Manokwari.

Table 1. Frequency of the most important tree species with diameter 35 cm and over in the complex 'Tisa-Muturi' (in the tables the names of some taxa have been italicised to facilitate comparisons).

	Tisa R.	Muturi R.
Strip length in km	7.7	6.85
Total number trees	260	218
Trees per ha	33.8	31.8
Pometia pinnata	23.8%	15.6%
Intsia	11.9%	11.5%
Pentaspadon	6.5%	–
Pometia a/c	3.5%	4.1%
Octomeles sumatrana	1.5%	2.6%

The subspecific taxonomy of *Pometia* is complicated. Locally, three forms are more or less distinct in morphology and ecology, but their circumscription is a source of disagreement (Jacobs 1994: 702); for the most recent discussion see Damas (1993). In the forestry reports the large-leaved form is called *Pometia pinnata*, the small-leaved forms are called *P. acuminata* and *P. coriacea*, in this paper collectively indicated as *P. a/c*.

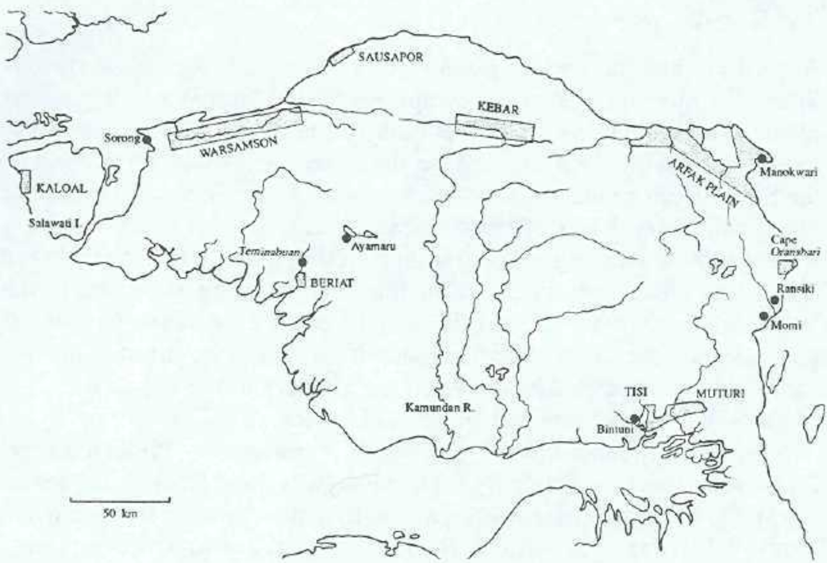

Figure 1. Map of the Bird's Head peninsula with some of the forest areas inventoried by the Forestry Service.

For the Bird's Head peninsula, it was thought that the economic activities would develop at Sorong and Manokwari and therefore attention was focused on the north and east coasts. The larger survey projects were from west to east: Kaloal on Salawati I., Warsamson valley, Sausapor, the deltas of the Wariki, Warjori, Prafi, and Pami rivers, the hills around Manokwari, and from there to the south: Cape Oransbari. To these were added some surveys in the Kebar valley, at higher altitudes, of interest because of the occurrences of valuable conifers (*Araucaria cunninghamii* and *Agathis labillardieri*). Several reconnaissences were made outside these areas, e.g. around the Anggi Lakes, often in search of the resin (copal) producer Agathis, at that time a source of income for the local population.

4 THE LOWLAND-DRYLAND FOREST ON ALLUVIUM

The virgin forests that first attract the attention of the Forestry Service are of course those that have a valuable stand of timber on flat terrain in an accessible area. In the Bird's Head these are mainly found on the better drained parts of the alluvial flats near the coast.

4.1 Sidei-Wariki

A good exemple of lowland rainforest on alluvium is the area known as Sidei-Wariki, composed of the complexes 'Sidei' and 'Wariki'. It is part of the 'Arfak Plain', situated between the northern foot of the Arfak mountains and the Pacific Ocean, on the eastern part of the north coast of the Bird's Head peninsula, about 65 km west of Manokwari. This coastal plain, built from debris of the Arfak mountains, is locally 15 to 20 km wide, gently undulating, sloping from c. 100 m altitude to sea-level, and drained by small streams that sometimes vanish in marshy land. In the west it is bordered by the Kasi river, in the east by the Waramoi that debouches into the large Waryori about 4 km from the coast. The two complexes are separated by the Wariki, a tributary of the Kasi river.

The soil is sandy loam with gravel and boulders.

Near the confluence of the Kasi and the Wariki bulges 369 m high and 2 km wide the 'Bijenkorfberg', known locally as Bon Simufui (Staal 1913). On its eastern base it is separated by a marshy strip from an overgrown WWII Japanese airfield. Behind the coast are stretches with secondary growth. Cape Sidei pushes 3 km out into the ocean. It is 4 km wide, fringed by coral reefs, and has an excentric 50 m high hill.

The survey was conducted by making parallel strips 500 m apart, perpendicular to a nearly N-S line in each of the two complexes. Thus a 2% inventory was performed with 193 km of survey strip in which a total of 9,855 trees of diameter Class 4 and over was measured and named. The more common species are listed in Table 2 (from Luitjes 1960: updated).

Table 2. Frequency of the more common tree species with diameter 35 cm and over in the complex 'Sidei-Wariki'.

No.			Sidei	Wariki
	Area in ha		8000	1900
	Survey strip in km		155.2	38
	Percentage inventory		2.0	2.0
	Number of trees		7881	1974
	Trees per ha		50.8	51.2
	Vernacular: Manikiong language			
1.	Ihi	*Pometia pinnata*	12.5%	39.6%
2.	Kossijt	*Teysmanniodendron bogoriense*	6.5%	6.0%
3.	Sekka	*Intsia (bijuga + palembanica)*	5.6%	1.6%
4.	Bobohoefeka	Gironniera	4.4%	–
5.	Kottij	*Pometia acuminata/coriacea*	4.3%	0.5%
6.	Komkwa	*Pimelodendron amboinicum*	4.2%	5.6%
7.	Sbijdjakka	Litsea spec. div.	3.9%	2.3%
8.	Iegboei	Artocarpus altilis	2.4%	1.5%

Table 2. Continued.

9.	Bomsij	Myristicaceae	2.2%	2.8%
10.	Merek	Chisocheton	2.2%	1.6%
11.	Bowwie	Haplolobus	2.2%	–
12.	Sehiega	Celtis	2.1%	1.4%
13.	Seraka	Chisocheton + Dysoxylum	2.0%	7.9%
14.	Seriega	Syzygium	1.8%	–
15.	Bettiaan	*Homalium foetidum*	1.6%	0.6%
16.	Herrib	Aglaia + Dysoxylum	1.3%	1.5%
17.	Djakarra	*Alstonia scholaris*	1.3%	–
18.	Senai	Dracontomelum dao	0.9%	1.4%
19.	Majongga	Dillenia papuana	1.1%	–
20.	Menait	Planchonella	1.1%	3.2%
21.	Starka	*Octomeles sumatrana*		1.4%
22.	Sagotoob	Hernandia ovigera		1.3%
23.	Soetiet	Spondias dulcis		1.0%
24.	Sagowgwo	(mixture)		1.5%
(10 + 13 + 16 =		Meliaceae	5.5%	11.0%)

Of this list No. 8 *Artocarpus altilis* and No. 21 *Octomeles sumatrana* are pioneers on riverbanks, that survive in closed forest; the latter can reach large dimensions and is than emergent over the forest canopy (Paijmans 1976: 59).

This type of forest can be characterized by: *Intsia – Pometia – Teysmanniodendron – Pimelodendron*, usually accompanied by *Homalium* and *Celtis*. Meliaceae, Myristicaceae, and Burseraceae are also prominent, but nothing can be said about their presence on the species level as the grouping of species under the vernacular names is (very) wide.

Within an area of nearly 9000 ha there is, of course, variation in ecology. Such a variation is not apparent in the reports, but it is possible to make a rough comparison between Sidei and Wariki using Zieck's notes on differences in ecology of the constituent species. In his Warsamson report (Zieck 1960c) he differentiates:

a) Preferring well-drained sites: *Pometia acuminata, Koordersiodendron pinnatum, Vatica rassak, Alstonia scholaris* (added from 'Tafelberg' report, Zieck 1960a), *Artocarpus altilis, Pimelodendron amboinicum, Pterygota horsfieldii; Palaquium, Planchonella, Aglaia, Diospyros.*

b) Preferring wetter sites: *Pometia pinnata, Homalium foetidum, Intsia, Teysmanniodendron bogoriense, Pterocymbium beccarii, Octomeles sumatrana, Pericopsis mooniana, Inocarpus fagiferus, Elmerrillia tsiampacca; Buchanania, Celtis, Lagerstroemia, Terminalia.*

Comparing this enumeration with Table 1 we find:

	Sidei	Wariki
a) Preferring well-drained sites:		
5, 6, 8, 17, 20	13.3%	10.8%

b) Preferring wetter sites:

1, 2, 3, 12, 15, 21 28.7% 50.6%

It must be admitted that this comparison is not based on resarch, but on field experience (moreover, mostly acquired outside Sidei-Wariki). Nevertheless, the difference between the two complexes in category 'b' is large enough to give an indication of ecological inequality. From Table 1 it follows that this difference is largely due to the disparity of the frequencies of the *Pometia's* and less so in that of (the two species of)

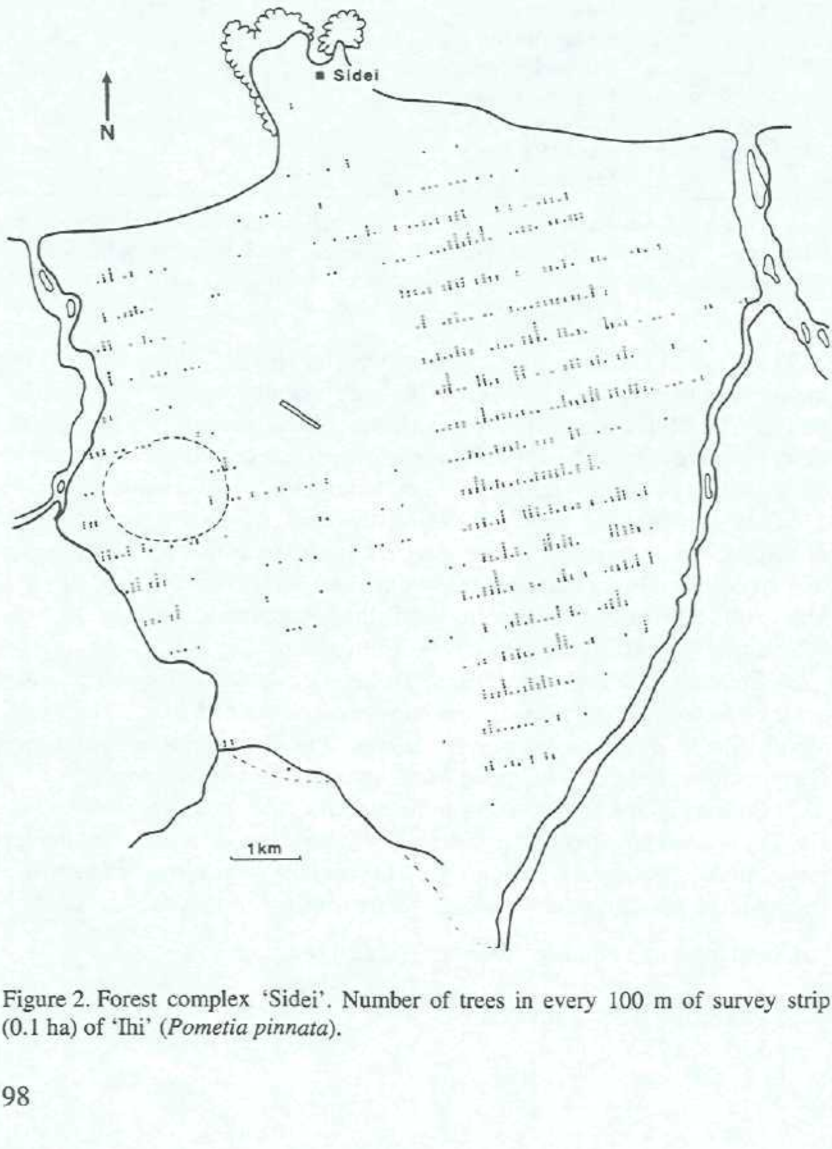

Figure 2. Forest complex 'Sidei'. Number of trees in every 100 m of survey strip (0.1 ha) of 'Ihi' (*Pometia pinnata*).

Intsia; No. 2 *Teysmanniodendron* and No. 6 *Pimelodendron* do not join this tendency.

The dissimilar ecological preferences of the *Pometia's* may be visualized by mapping the individual trees as has been done for the Sidei complex in Figures 2 and 3. On these maps the better drained areas are in the West the 'Bijenkorfberg' and in the centre the north-south running strip raised 40-50 m above the surroundings which was picked by the Japanese for the construction of their airstrip.

From these maps it is clear that *Pometia pinnata* avoids the raised areas

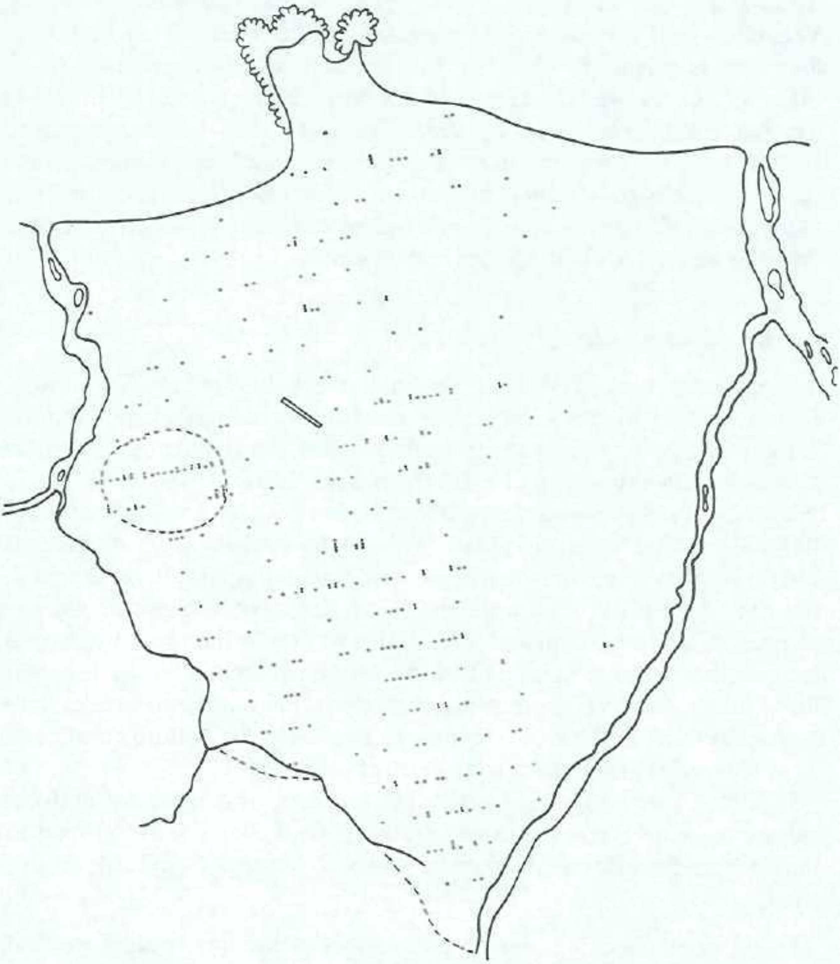

Figure 3. Forest complex 'Sidei'. Number of trees in every 100 m of survey strip (0.1 ha) of 'Kottij' (*Pometia acuminata* and *P. coriacea*).

that are, however, preferred by *Pometia acuminata/coriacea*; the top area of the 'Bijenkorfberg' and the vicinity of the airstrip have no old forest.

4.2 *Kebar valley*

The Kebar valley lies in between the Arfak Plain and the Warsamson valley, on the south side of the Tamrau Mts, but at a higher elevation: at 550-600 m altitude. The mountain slopes around the valley are clad with various types of (sub)montane forest in which the emergent giants of *Araucaria* contribute to the scenic values of the valley (e.g. Faber & Versteegh 1961). What presently remains of the forest on the bottom of the valley is, however, 'almost a complete copy of the forest in the Arfak Plain' (Zieck 1954). The results of the strip survey are not available to me, but the picture given by Zieck is quite clear: *Intsia bijuga* and *I. palembanica* are rather common as are *Pometia a/c* and *P. pinnata* and large specimens of *Alstonia*; further are represented: *Spondias, Cananga, Mangifera, Cinnamomum, Octomeles, Bischofia, Kleinhovia, Celtis, Pterocarpus,* and lowland species of *Lithocarpus.*

4.3 *Warsamson valley*

A comparable type of forest is found in the valley of the Warsamson. This river rises in the Tamrau Mts and flows westwards following the Sorong fault zone. After leaving the mountains, the river runs through an east-west valley between the southern karst hills of about 600 m in height and a steep coastal range about 10 km wide and with summits of 400-600 m. The valley is about 80 by 7 to 10 km, at an altitude of 60-100 m, flatter and marshier in the east, undulating to hilly in the west. The river itself is 40-80 m wide and 2-8 m deep, but at high tide the water rises an additonal 5 m and then floods forests in flat areas by several decimeters. As the western end of the valley is blocked by the hills behind Sorong, the river there turns abruptly to the north and breaks with low rapids through the coastal range. In the valley the bottom consists of clays or (sandy) loam with varying gravel contents.

In such a long and varied valley the forest is, of course, not uniform and the totals of the inventories (Zieck 1960c, Faber c.s. 1962) tend to homogenize the effects of drainage and soil patterns (see Table 3: updated).

Using again Zieck's notes on preferences of the tree species we find values similar to those of 'Sidei':

Table 3. Frequency of the more common tree species with diameter 35 cm and over in the complex 'Warsamson'.

No.		West part	Main part
	Area in ha	1600	31,000
	Survey strip in km	8.4	123.6
	Plots in ha	13.5	–
	Percentage inventory	0.5	0.4
	Number of trees	1470	9515
	Trees per ha	67.1	77.0
1.	*Pometia pinnata*	12.0%	8.1%
2.	*Intsia palembanica*	6.5%	4.7%
3.	(mixture)	4.4%	0.9%
4.	*Pimelodendron amboinicum*	3.9%	2.8%
5.	*Teysmanniodendron bogoriense*	3.5%	6.3%
6.	Pericopsis mooniana*	3.4%	2.5%
7.	*Homalium foetidum*	3.3%	3.6%
8.	Celtis	3.1%	1.3%
9.	Meliaceae	3.1%	2.3%
10.	*Pometia a/c*	3.1%	2.3%
11.	*Artocarpus altilis*	2.9%	1.7%
18.	*Alstonia scholaris*	1.4%	0.7%
19.	*Octomeles sumatrana*	1.4%	0.6%
20.	Vatica rassak	1.2%	6.4%
25.	*Koordersiodendron pinnatum*	1.0%	<0.2%

*Pericopsis here reaches the eastern boundary of its distribution range.
The participation of No. 7 *Homalium foetidum* in the composition of this type of forest is here more distinct than in Sidei-Wanki.

	West part	Main part
a) Preferring well-drained sites:		
4, 10, 11, 18, 20, 25	13.5%	14.0%
b) Preferring wetter sites:		
1, 2, 5, 7, 8, 19	29.8%	24.6%

In the main part of the valley the dipterocarp No. 20. *Vatica rassak* is second in number of individuals after *Pometia pinnata*. Zieck (1960c) classified it with species preferring good drainage. And, indeed, in the main part of the Warsamson valley 'damar hiru' occurs mainly at the western end, and elsewhere distinctly more frequently north of the river to than the south side, that is, on more hilly or, respectively, more gravelly terrain. According to Van Petersen (1961) *Vatica* is also frequent in the coastal mountains.

4.4 *Momi-Ransiki*

This brings us to the 1948 Momi-Ransiki survey (Anonymous n.d.). In the river deltas here the *Intsia-Pometia-Teysmanniodendron-Pimelodendron* forest was also present, in several varieties. However, 'complex Ib' deviates because of its high content of *Vatica* (see Table 4: updated). This forest was growing on a gently sloping spur of the foothills of the Arfak Mts, adjoining the valley, at an altude of only 30 to 70 m. The subsoil probably consists of deeply weathered limestone with a high porosity; even during high rainfall the creeks remain empty.

The highest density of *Vatica* reached in one of the survey strips was 74.5%. The good drainage of this *Vatica* habitat agrees with the findings in the Warsamson valley. However, Salverda (1938: 109c; 1939: map to Afb. I) maps 'marshland forest with *Vatica rassak* usually numerous' in the Bomberai peninsula. This fits with Ashton's note on the ecology of *Vatica rassak*: 'River-banks in Borneo, elsewhere also on hills to 400 m, locally abundant'. For the upper Fly river area in Papua New Guinea, Paijmans (1971) describes both situations: *Vatica* nearly always present in the Mixed Swamp Forest, but also the most common tree in all layers in a dense thin-stemmed variety of Closed Rain Forest on steep slopes below 100 m altitude.

The conclusion therefore must be that the reason behind the local abundance of this species is not to be sought in the local drainage pattern.

Kostermans (Anonymous n.d.: 165) compares the Momi *Vatica* stand with a forest in Papua New Guinea described by Lane-Poole (1925: 15).

Table 4. Frequency of the more common tree species with diameter 35 cm and over in complex Ib of the 'Momi-Ransiki' survey.

No.			Momi – Ransiki
	Area in ha		215
	Survey strip in km		4.3
	Percentage inventory		2.0
	Number of trees		265
	Trees per ha		61.6
	Vernacular: Manikiong language		
1.	Keska	*Vatica rassak*	34.6%
2.	Sekka	*Intsia palembanica*	12.1%
3.	Kossydzj	*Teysmanniodendron bogoriense*	7.5%
4.	Djakarra	*Alstonia scholaris*	3.6%
5.	Senai	*Pometia tomentosa*	2.6%
6.	Sie-ieka	Pterocarpus indicus	2.6%
7.	Komkwa	*Pimelodendron amboinicum*	2.3%
8.	Ihi	*Pometia pinnata*	1.6%

In this forest *Anisoptera thurifera* is the most important tree making up 24.6% of the stand. *Anisoptera* belongs to the same family as *Vatica* and *Hopea* (Dipterocarpaceae) and is known to 'regenerate profusely in secondary forest' (Ashton 1982: 334).

Johns (1986) lists the local forest dominants *Anisoptera, Hopea, Intsia, Pterocarpus, Pometia, Albizia*, etc. as (probably) not regenerating in the closed forests but only when much light is available. 'While many of these species do successfully regenerate in rainforest gaps, their domination of the rainforest canopy suggests that extensive historical disturbance occurred allowing widespread regeneration of these 'secondary' species.' For areas outside New Guinea other species are described to show the same behaviour.

But *Vatica rassak* does not fit this picture either. Both Kostermans (l.c.) and Paijmans (1976: 69) describe the *Vatica* forest as tall slender forest with seedlings and saplings dense on the forest floor! So *Vatica* has a different strategy. If disturbance of the forest was the original cause of the present dominance of this species, than *Vatica* is perpetuating this situation by recruitment from its abundant regeneration. Other taxa promoted by disturbance, like *Intsia*, do not regenerate in the shadow of closed forest and therefore will in time die out.

4.5 *Forest disturbence*

The latter situation is reflected by the diameter class distribution which is assumed to reflect the (unknown) age class distribution. Table 5 also incorporates the results from the complex 'Sausapor' (Zieck 1960b) and from the combined smaller complexes in the hilly limestone areas around Manokwari collectively known as the 'Baaien areaal' (Zieck 1959).

Species that have a permanent position in the forest composition retain that position by producing enough regeneration to compensate for the losses in the higher age classes. In this case every class contains more individuals than the one higher up. However, in every complex listed in Table 5 the maximum number of individuals is not in the lower but in the higher diameter (age) classes and future losses in these classes will not be compensated. The strong participation of *Intsia* in the forest composition is thus a temporary one. *Homalium* follows the same pattern; *Pometia, Pimelodendron* and *Teysmanniodendron* have (above 35 cm diameter) a normal distribution pattern.

The seeds of *Intsia* need light for their germination (Vink 1994). *Intsia's* widespread occurrence with a good percentage of the total number of trees indicates that there was once a time when the forest was very open, that is, strongly disturbed. Moreover, many of the species, in these forests associated with *Intsia*, are listed by Womersley & McAdam

Table 5. Diameter class distribution of *Intsia (bijuga + palembanica)* in the north of the Bird's Head Peninsula.

Complex	ha	n	Diameter class																
			4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Warsamson (M)	31,000	459	46	49	48	68	83	68	42	25	9	5	3	1	1	1	–	–	–
Warsamson (W)	1,600	96	8	17	13	15	15	13	8	4	–	2	–	–	–	–	–	–	1
Sausapor	1,000	44	3	5	7	9	5	9	1	3	1	–	–	1	–	–	–	–	–
Wariki	1,900	31	3	3	4	6	1	7	1	1	2	3	–	–	–	–	–	–	–
Sidei	8,000	439	58	55	86	76	59	28	37	20	14	–	5	–	1	–	–	–	–
Manokwari area	5,800	217	24	40	35	40	31	25	11	6	21	1	–	–	2	–	–	–	–
Totals	49,300	1286	142	169	203	214	194	150	100	59	28	11	8	2	4	1	–	–	1
Percentages (%)		99.9	11.0	13.1	15.8	16.6	15.1	11.7	7.8	4.6	2.2	0.9	0.6	0.2	0.3	0.1	–	–	0.1

(1957) as members of 'the subclimax *Pometia* type of forest'. And *Pometia* itself, strongly represented in the forests under consideration, 'tends to be more frequent in sub-climax lowland communities' (Paijmans 1970: 99) and 'sometimes comes up gregariously after felling of the forest' (Whitmore 1969: 268).

For the disturbance of a vast stretch of flat land like that in Table 5 only fires resulting from serious droughts can be taken into account. Ideas about the occurrence of fire in 'virgin' rainforests are gradually changing. 'Fire is, in contrast to previous views, being recognized as an ecological factor in primeval rainforests' (Bruenig 1996).

In the series of regional droughts important ones are e.g.: 1877-1878, 1888, 1891, 1902, 1914-1915, 1940, 1982-1983, 1991 (Braak n.d.; Bruenig 1996; Johns 1986; Schulte & Schöne 1996). New Guinea was only rarely visited in earlier days and reports concerning the effects of pre-WWII droughts are scarce. Braak (n.d.: 409, 410) mentions for 1914: 'The Captain of H.M.S.S. 'Zwaan' reports that even far out of the north coasts of New Guinea and Ceram a distinct smell of fires was observed' and 'Along the coasts of Borneo, in Banka Straits, and north of Ceram and New Guinea the smoke, originating from forest- and garden-fires, intensified the density of the offshore haze.'

In Sidei *Intsia* has the highest number of trees in diameter Class 6, but in the Warsamson valley in Class 8. If this inequality is not the result of a difference in the rate of increment because of variation in ecological conditions, it could indicate a difference in the date of the destructive fires along the New Guinea north coast.

From a forester's point of view such a vegetational history has the advantage that the frequency of the valuable *Intsia* (merbau) is strongly increased and that most of its standing timber volume is now available in merchandizable log sizes.

5 THE LOWLAND-DRYLAND FOREST ON POOR SOIL

Apart from the dryland forest on alluvium, there are many other types of forest in the Bird's Head peninsula. Descriptions of these forests are, however, scanty to non-existent.

Drainage pattern, altitude, and soil type are the most important factors determining the composition of a forest. The influence of the substrate is clearly shown by a type of *Agathis* forest that occurs on poor soils such as sand. It is broadly comparable to 'heath' forest on the extensive sandy flats in southern Borneo.

5.1 *Beriat*

In our study area such forests are found in the south of the Bird's Head, where sandstones – underlying limestones and alluvial flats – form small outcrops, providing sandy soils at a low altitude. As a terrestrial check of an aerial photo interpretation, a small survey was made on the eastern side of the Kaibus river, south of Teminabuan, near Beriat. Of the four types of forest distinguished, 'Type 3' is of interest here as it grows on a very poor soil: white sand interspersed with loam. Its composition is quite different from that of the forests on the alluvial flats (see Table 6; from Kalkman 1958: updated). It should be noted that in this table the large emergent trees of *Agathis* are strongly underrepresented, probably because of long-term exploitation by tapping the resin as well as removal of seedlings for plantation. Vink reports in 1932 already: 'The few damar complexes in the Teminabuan district have in earlier years almost completely been killed by tapping' (Vink 1932: 34).

Table 6. Frequency of the more common tree species with diameter 35 cm and over in Forest Type 3 of the 'Beriat' survey.

No.			Beriat
	Survey strip in km		4.5
	Survey plot in ha		1
	Number of trees		287
	Trees per ha		53
	Vernacular: Tehid language		
1	Megoengoen	Hopea iriana + H.nodosa	16%
2	Ndok	Ctenolophon parvifolius	10%
3	Damoer	Anisoptera thurifera	8%
4	Sokar	*Vatica rassak*	8%
5	Kiejerie	Gluta papuana	8%
6	Kedindin, Mammoek, Meng-genah, Wohhin, Wohokin	Eugenia spec. div.	8%
7	Kofetok	Metrosideros spec.	4%
8	Kariejef	Metrosideros spec.	2%
9	Sejan	Xanthophyllum suberosum	2%
10	Kasin	Dysoxylum inopinatum	2%
11	Towoer	Calophyllum spec.	2%
12	Kierna	Agathis labillardieri	1%
13	Kefat	Metrosideros petiolata	1%
14	Piejawerie	Tristania ferruginea	1%
15	Orofook, Savonggee	Canarium + Haplolobus	1%
16	Barang, Kediwoh	Litsea spec. div.	1%
17	Troenggoef	Palaquium ridleyi	1%
	(1 + 3 + 4 =	Dipterocarpaceae	32%)
	(6 + 7 + 8 + 13 + 14 =	Myrtaceae	16%)

Vatica rassak is the only element in common with the forest on the alluvial flats. Its high percentage, and that of *Anisoptera*, might be related to the disturbance mentioned by A.L. Vink.

Wherever in New Guinea the distributional areas of *Agathis* and *Ctenolophon* overlap, *Ctenolophon* is accompanied by *Agathis*; the reverse is not certain as many *Agathis* complexes have not been inventoried for other species.

In the *Intsia-Pometia* forest the family Meliaceae is rather prominent, in this forest it is the family Myrtaceae that plays a distinctive role.

Also collected in this forest are: *Ixonanthes petiolaris* (Keseroeok or Koesirioek; Tehid language), *Maranthes corymbosa* (Kondoe), *Atuna racemosa* (Andekakait), and the conifer *Nageia wallichiana* (*Podocarpus blumei*) (Moengkas); these occur with higher percentages in other *Agathis* forests (e.g. on Japen island). Not represented in the limited collections are elements known from other *Agathis* forests such as the pithcher plant *Nepenthes* and the ant-plants *Hydnophytum* and *Lecanopteris carnosa* (the latter is a fern).

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6

Initial results of a botanical species richness study in the Ayawasi area, Irian Jaya

1 INTRODUCTION

As part of the ISIR programme, Botany subprogramme, a study has been carried out in the Ayawasi area of Irian Jaya to investigate the species composition of primary and secondary forests in that area, and its relation to soil and geological substratum.

The flora of the island of New Guinea, comprising both Papua New Guinea and the Indonesian province of Irian Jaya, is probably one of the least known of the Malesian region, although it holds a phytogeographically strategic position between Malesia and Australia (Stevens 1989). The collection density for the island as a whole is low, and even lower for the Bird's Head peninsula, which has certainly not received much attention from botanists. A considerable part of the botanical collecting in New Guinea was concentrated on the high mountains. Furthermore, many of the inventories which have been carried out in the lowlands have been focused on large diameter trees in relatively easily accessible areas with forest with high timber volumes. The fieldwork area around Ayawasi is characterised by a rather inaccessible, karst-dominated landscape, often with a relatively thin-stemmed vegetation (see Pl. 3). It should therefore be no surprise that the vegetation which occurs in this landscape has hardly been sampled by collectors (examples are Kalkman and Versteegh, see discussion), and certainly not in such a way that the relationship between species composition and the underlying substrate was investigated.

2 FIELDWORK AREA

The village of Ayawasi is located at 1°10′S 132°27′E in the centre of the Bird's Head peninsula ('Vogelkop') of Irian Jaya, at 450 m above sea level (see Pl. 1). It lies in the valley of the Netayn river, a tributary of the upper Ayfat river. As stated above the area is dominated by karst features.

Two types of karst occur in this area: the cone karst and the pyramid and doline karst, both characterised by a dominance of hills separated by enclosed depressions. The hills are rather low, c. 50-100 m. The limestone formations in the area are part of the karst-dominated Ayamaru Plateau and belong to the Kais Limestone formation (Pigram & Sukanta 1989), a barrier reef complex dating from the Miocene.

In the forest, solution holes in the soil are frequently encountered, usually to c. 1 m in diameter and c. 1-4 m deep, at the bottom of which running water can be seen, particularly after rainfall. The soils in the area vary from pure white sand to brownish sand to clay soils. In some places in the valley the limestone is found so close to the surface that temporary flooding occurs after rainfall. In most places, however, the soil is deeper and no such flooding occurs. On the limestone hills the litter / humus often lies directly over the limestone rocks and is mixed with small rock pieces, or there may be a layer of white clay in between.

In the Ayawasi area rainfall amounts to c. 5500-6000 mm/year, and is among the highest in Irian Jaya. Only the eastern part of the central mountain range receives comparable amounts of rainfall (Ridder 1995). Rainfall is highest in the months of May (c. 650 mm) and June (c. 600 mm) and lowest in January and December (c. 300 mm). This high rainfall is probably mainly correlated to wind directions in combination with the location of this area, on the southern transition zone from the coastal area to the central mountain range where the land starts to rise considerably (see Braak 1954).

Temperatures range from 25-30°C, and may drop to c. 20°C during the night and early morning.

The people of Ayawasi belong to the Maybrat tribe. The village is primarily an agricultural community, and the people practice shifting cultivation of cassava, taro and sweet potato. In times of 'scarcity' during the transition from one garden to another, sago is harvested from (planted) trees. Apart from the cultivated plants in the 'gardens' in the surrounding forest area, many plants from the wild are also used (see Schoorl 1979). Further, the people raise pigs and they go hunting (pigs, deer, birds) to obtain meat.

3 METHODS

Plots of 0.1 ha (20×50 m) were laid out in primary and secondary forest in the slightly undulating terrain in the Netayn River valley, on sand as well as on clay, and on top of the limestone hills. Initially, selection was intended to be done with the help of aerial photographs, but it turned out that the area was so complicated (extensive limestone hill complexes) that exact location in the fields was impossible without spending an unacceptably large amount of time on it.

In a homogenous part of the vegetation the limits of the plot were determined, marked, and measured. The same was done for subplots (10 per plot, each 10×10 m). The vegetation was sampled per subplot for plants with a diameter at breast height (dbh) of 10 cm and over, and encompassed the following steps: label the plant, note down label number and (if applicable) collection number, local name, measure dbh, note down life form, collect reference material. The reference material was collected with the help of tree climbers and by using a branch cutter on an extendable carbon fibre pole. From flowering and/or fruiting plants more extensive collections were made for sending to specialists for identification. The large amount of rainfall (see above) caused serious complications in obtaining the reference specimens since the tree bark was often too slippery to climb the trees.

Soil samples (from a depth of 0-20 cm and 70-80 cm) were taken at random from 5 places in the plot. The 5 samples of a layer were mixed and from this mixture the actual sample for analysis was taken.

Most of the plots were revisited at a later stage in order to collect plants not collected during the first visiting stage, and at the same time to collect fertile material from plants which were not flowering or fruiting during the initial survey. Species or species groups (in the case of difficult and/or species-rich groups such as Lauraceae, Syzygium, Garcinia) for which no fertile collections could be obtained from the plots, were searched for outside the plots in order to obtain as much reference material as possible to support the identification of species growing in the plots.

4 RESULTS

4.1 *Non-floristic data*

In total, 22 plots of 0.1 ha were established. In these plots 1945 plants were labelled and measured, and c. 1700 (87%) were collected.

Three major forest types can be distinguished: primary mixed forest, secondary mixed forest, both in the relatively flat areas, and limestone hill forest.

For the primary forest the density varied from 72-101 individuals per plot, with an average of 81. In the secondary forest the density varied from

75-89 individuals per plot, with an average of 81. In limestone hill forest the range was 96-139 individuals per plot, with an average of 114.

Tree diameter varied from 10 cm (lower limit in this study) to 145 cm. Average diameter for all measured individuals was 19 cm. For the primary forest in the relatively flat areas the diameter varied from 10-145 cm, with an average diameter of 20 cm. For the secondary forest the diameter range was 10-48 cm, with an average of 16 cm. In limestone hill forest the range was 10-42 cm, with an average of 15 cm.

The number of individuals with a diameter of 30 cm and over, a limit often used in forestry-oriented studies, was only 167 (9%). In the plots on the limestone hills there are only 14 trees (2%) with a diameter of at least 30 cm.

The distribution of the individuals over the different diameter classes is shown in Table 1. The data have been split up into the 3 forest types mentioned above. This division into 3 types is preliminary. In a later phase of the research the computer-aided vegetation analysis will yield a vegetation classification based on the species composition and other parameters of the plots.

4.2 *Floristic data*

4.2.1 *General*

Of all individuals, the majority (1891) were dicotyledonous trees. The

Table 1. Distribution of individuals over dbh classes (in cm) for all plot individuals and for the 3 major forest types, in absolute numbers and in% of the total number of individuals.

	All plots		Prim. forest		Sec. forest		Limestone hill forest	
Dbh	Nr	%	Nr	%	Nr	%	Nr	%
10-19	1432	74	624	65	325	80	483	85
20-29	345	18	207	21	65	16	73	13
30-39	98	5	72	7	13	3	13	2
40-49	39	2	34	4	4	1	1	–
50-59	13	1	13	1	–	–	–	–
60-69	6	–	6	1	–	–	–	–
70-79	4	–	4	–	–	–	–	–
80-89	3	–	3	–	–	–	–	–
90-99	1	–	1	–	–	–	–	–
≥ 100	3	–	3	–	–	–	–	–
Total	1944		967		407		570	

Note: The total number of individuals is 1944 as for 1 tree no diameter data are available.

other groups are (number of individuals in parentheses): gymnospermous trees (10), monocotyledonous trees (17), lianas (14), and tree ferns (13). In all, c. 300 species, belonging to c. 56 families in c. 110 genera were found.

It has to be noted here that the identification of the reference specimens is still in progress. After that process has been finished more detailed information can be given on the taxa involved, and more extensive comparisons can be made with the results of other studies. Although collections could not be made from all trees in the plots reference, and some material still has to arrive at the Rijksherbarium in Leiden, it is expected that this will not significantly change the (interpretation of) the results.

4.2.2 *Families*

Of c. 5% of the individuals no family name is available yet. Most families are represented by very few species and genera only, as is demonstrated below.

30 Families are represented by 1 genus only (of which 18 families are represented by 1 species), 12 families are represented by 2 genera; and 14 families by 3 or more genera. Families with the most genera are Euphorbiaceae (*Antidesma*, *Endospermum*, *Glochidion*, *Homalanthus*, *Macaranga*, *Mallotus*, *Pimelodendron*, probably more), and Myrtaceae (*Decaspermum*, *Octamyrtus*, *Rhodamnia*, *Syzygium*, *Tristaniopsis*, maybe *Eucalyptopsis*). After further identification of the reference collections, more families, e.g. Lauraceae and Rubiaceae, may be represented by a similar number of genera.

There are 21 families which are represented by at least 1% of the total number of collected individuals in all plots, and these families together form c. 95% of the total number of individuals. Of these 21 families, the 8 best represented families account for c. 65% of the individuals. These 8 families are: Myrtaceae (c. 16%), Burseraceae (c. 10%), Lauraceae (c. 8%), Elaeocarpaceae (7%), Euphorbiaceae (c. 8%), Guttiferae (6%), Fagaceae (5%), and Myristicaceae (5%).

At the other end of the range there are 11 families which are represented by 1 or 2 individuals only, as shown in Table 2.

Table 2. Families represented by 1 or 2 individuals only in the plots, number of individuals in parentheses.

Family	Genus/species
Capparidaceae	Crataeva religiosa (1)
Compositae	Vernonia arborea (2)
Ericaceae	Vaccinium sp. (1)
Himantandraceae	Galbulimima belgraveana (2)

Table 2. Continued.

Lecythidaceae	Barringtonia sp. (1)
Liliaceae	Dracaena sp. (1)
Lythraceae	Lagerstroemia sp. (1)
Symploccaceae	Symploccos sp. (1)
Urticaeae ?	Genus ? (1)
Vitaceae	cf. Cissus (1)
Thymelaeaceae	Aquilaria sp. (1), Wikstroemia sp. (1)

The total number of families per plot varied from 14-23. The number of dominant families per plot (5% of individuals in a particular plot) varied from 4-8. In total there are 28 families which are dominant in at least one of the plots. The families dominant in the largest number of plots are (number of plots in parentheses): Burseraceae (18), Myrtaceae (15), Elaeocarpaceae (12), Lauraceae (12), and Euphorbiaceae (9).

4.2.3 *Genera*

Of the c. 110 genera, there are 83 which are represented by 1 species only. Another 19 genera are represented by 2 species only, and 16 genera by 3 or more species. Most rich in species are the following genera (family and number of species in parentheses): *Canarium* (Burseraceae; c. 10), *Elaeocarpus* (Elaeocarpaceae; c. 7), *Garcinia* (Guttiferae; c. 10), *Ficus* (Moraceae; c. 10), *Syzygium* (Myrtaceae; c. 30?).

There are 21 genera of which the individuals form at least 1% of all collected individuals in the plots. These genera are: *Anisoptera* (Dipterocarpaceae), *Calophyllum* (Guttiferae), *Campnosperma* (Anacardiaceae), *Canarium* (Burseraceae), *Chionanthus* (Oleaceae), *Elaeocarpus* (Elaeocarpaceae), *Engelhardia* (Juglandaceae), *Garcinia* (Guttiferae), *Glochidion* (Euphorbiaceae), *Gymnacranthera* (Myristicaceae), *Homalanthus* (Euphorbiaceae), *Horsfieldia* (Myristicaceae), *Litsea* (Lauraceae), *Lithocarpus* (Fagaceae), *Macaranga* (Euphorbiaceae), *Melicope* (Rutaceae), *Pometia* (Sapindaceae), *Prunus* (Rosaceae), *Sloanea* (Elaeocarpaceae), *Syzygium* (Myrtaceae), *Tristaniopsis* (Myrtaceae).

4.2.4 *Species*

Because the identification process is still in progress, the amount of information that can be given at a species level is (still) limited.

The number of species per plot is at present estimated to vary from c. 20-50, with an average of c. 35. In general the number of species is higher in plots in the primary forest in the relatively flat areas (c. 30-50 species, average c. 40) than in the plots in the forest on the limestone hills (c. 25-40 species, average c. 30).

There are 14 species which each account for at least 1% of all collected individuals. Highest numbers of individuals are found for some species which play a dominant role in the vegetation on the limestone hills, e.g. *Anisoptera thurifera, Campnosperma montanum*, and *Tristaniopsis* sp. ('smi'). *Anisoptera thurifera* is the most frequent species when looking at all limestone plots, with 70 individuals corresponding to 12% of all individuals. Most frequent when considering the limestone hill plots separately is an unidentified species of *Garcinia*, with 35% of the individuals in one of the limestone hill plots. The names of the 14 most frequent species are listed below. If no identification is available yet, the species is temporarily indicated by its local name. For family names see under 'Genera'.

Anisoptera thurifera ssp. *polyandra, Campnosperma montanum, Canarium* sp. ('atie kof'), *Chionanthus* sp. ('faket poh'), *Engelhardia rigida, Garcinia* sp. ('moto' of limestone hills), *Glochidion* cf. *lanceilimbum* ('ais ati'), *Gymnacranthera farquhariana* var. *zippeliana*, cf. *Litsea* sp. ('upoh'), *Lithocarpus* sp. ('mrie poh' and 'non-white mrie poh'), *Sloanea aberrans* ('hapon'), *Syzygium* sp. ('sayoh asem'), and *Tristaniopsis* sp. ('smi').

Elaeocarpus sp. ('tamu'), might be added to this list, along with *Macaranga* sp. ('siah ati'), and additional species of *Syzygium*, but it has not yet been confirmed whether there are at least 19 individuals (1% limit) of a single species in these three genera.

Among the species which are represented by only a very few individuals, an interesting one was a representative of the genus *Dubouzetia*, probably *D.galorei*, a species only known from eastern New Guinea. The genus is well-represented in New Caledonia and Papua New Guinea. From Irian Jaya this genus was hitherto only known from two specimens, one from the Angi lakes area near Manokwari, belonging to the montane *D.elegans* var. *Novoguineensis*, and one from near Lake Habbema, belonging to *D.dentata*, which may represent the same species (Coode, 1981). The tree is not uncommon in the Ayawasi area, and well-known by the local population for its very hard wood (its local name 'ara fra' means 'stone tree', referring to the hardness of the wood).

4.2.5 *The plots on limestone hills*

The limestone hills are the most conspicuous element of the landscape in the fieldwork area and will be dealt with in more detail here. The forest on the hills is very different in species composition from the forest in the adjacent lower areas. The hills are c. 50-100 m high, have steep slopes and a flat top, and often form ridges enclosing depressions, creating the already-mentioned pyramid and doline karst. In general, the vegetation on the hills is low, i.e. c. 10-15 m, and the trees have small diameters (see Plates 2 and 3). Leaves are in general small and hard compared to the leaves of the trees in the forest in the lower areas. Furthermore, usually only a few species form a large part of the number of individuals.

No quantitative studies have been published on this type of forest in Irian Jaya. The preliminary results of the present study are given below.

In the 5 plots a total of 570 plants were labelled. Of these plants 563 are dicotyledonous trees, 4 gymnospermous trees (Podocarpaceae), 1 monocotyledonous tree (Palmae), and 2 lianas. The number of plants per plot varied from 96-139 (average 114).

In total 26 families are represented, whereas per plot 16-19 families were found. Per plot 4-8 families dominate the vegetation, here defined as accounting for at least 5% of the individuals in a plot. In total there are 12 different families that are dominant in at least one of the plots. These families are: Anacardiaceae (5%), Burseraceae (11%), Casuarinaceae, Dipterocarpaceae (12%), Fagaceae, Guttiferae (12%), Juglandaceae, Lauraceae, Myristicaceae, Myrtaceae (21%), Rubiaceae, Sapotaceae. For the five families which also account for at least 5% of all individuals in the plots, the exact percentage has been indicated in parentheses. Together they account for 62% of the individuals in the plots.

The number of species occurring in limestone hill plots is estimated at 80. Some species groups have not been dealt with yet, so this number may still change after further study of the reference material. Per plot there are c. 25-40 species, of which 3-8 are dominant species (same 5% limit as above). For all plots together there are 12 such dominant species, 5 of which also account for at least 5% of all individuals in the limestone plots. These 5 species account for 47% of the total number of individuals. The dominant species are (percentage of individuals in parentheses for the five species just mentioned): *Anisoptera thurifera* subsp. *polyandra* (Dipterocarpaceae: 12%), cf. *Baccaurea* sp. 'kon sawia' (Euphorbiaceae), *Campnosperma montanum* (Anacardiaceae: 5%), cf. *Canarium* sp. (Burseraceae: 10%), *Engelhardia rigida* (Juglandaceae), *Garcinia* sp. (Guttiferae: 9%), *Gymnacranthera farquhariana* var. *zippeliana* (Myristicaceae), *Gymnostoma sumatrana* (Casaurinaceae), *Lithocarpus* sp. (Fagaceae), *Neonauclea vinkiorum* (Rubiaceae), *Tristaniopsis* sp. 'aif' (Myrtaceae), *Tristaniopsis* sp. 'smi' (Myrtaceae: 10%). Maybe after further analysis a species of *Calophyllum* (Guttiferae) will also be added, as well as 1 or more species of *Syzygium* (Myrtaceae).

There are only a very few species present common to all three vegetation types: *Engelhardia rigida* (Juglandaceae; more common on limestone hills), *Gymnacranthera farquhariana* (Myristicaceae; much more common in mixed forest), and maybe *Lithocarpus* sp. 'mrie poh' (Fagaceae).

5 DISCUSSION

The studies to which the present one may be compared are few, and the

a

b

Plate 1a) The village of Ayawasi in the western Ayfat region. b) The canopy of the forest in one of the research plots on a limestone hill, with *Gymnostoma sumatrana* (Casuarinaceae).

Plate 2. A look inside the relatively thin-stemmed forest in a research plot on a limestone hill.

extent to which meaningful comparisons may be made is limited. The information provided by Paymans (1976) may serve as a general reference. Only a few studies have been carried out in New Guinea using a plot-based inventory of plants with a diameter of 10 cm or more. These include the study by Valkenburg (1987) in the mid-montane forests at 1600-2400 m on Mt Missim and Mt Kindi in the province of Morobe in eastern Papua New Guinea, and the study by Paijmans (1970) in 'hill slope forest' and 'plateau forest' at 825-1125 m and 600-700 m, respectively, in the Hydrographers and Sibium ranges and on the Managalase volcanic plateau in eastern Papua New Guinea. Valkenburg studied 10 plots of 0.02 ha with subplots of 2 × 2 m, and Paijmans studied 4 plots of 0.8 ha with subplots of 20 × 20 m. Only the latter study is used for comparison here, since the area where Valkenburg (1987) carried out his study is too different from the Ayawasi area.

A limitation for the comparison with Paijmans's (1970) study is that the 10 cm diameter classes used in the present study do not correspond with the 30 cm girth classes which Paijmans used. The small difference (3%) between the minimum diameter limit used in both studies, 10 cm and 9.7 cm (equivalent to a girth of 1 foot), respectively, is regarded as negligible. Considering these facts, comparison is only possible for the total stem density of plants with a diameter of at least 10 cm, which in this study is 720-1390 (average 880) stems per hectare, higher than any of the values given by Paijmans (1970), which range between 430 and 691. It is most likely that soil conditions are responsible for the high stem density in the study area, but human influence may play a role too. The number of species per 0.1 ha (deduced from Fig. 2.4 in Paijmans 1970) varies from c. 25-45, which is in the same order as that found in the present study. The Meliaceae and Moraceae which are listed among the families with most individuals and species by Paijmans (1970) are absent in the first category in the present study. Since no detailed floristic information is provided by Paijmans a more detailed comparison is not possible.

The areas nearest to the Ayawasi area where a survey has been carried out is near Beriat (Kalkman 1958), c. 70 km SW of Ayawasi at an altitude of 50 m above sea level on relict alluvial plains of Quaternary origin (Pigram & Sukanta 1989), and in the Ayamaru area (Versteegh 1958), c. 40 km SW of Ayawasi on the karst-dominated Ayamaru plateau. Both areas are situated S to SW of the Ayamaru lakes. The latter, however, concerns a brief, non-quantitative survey report and mainly gives identifications at genus level. As far as may be concluded from these data, there is a fair floristic similarity between the Ayamaru site and the Ayawasi site for the limestone forest (termed 'dwarfed forest' by Versteegh 1958). The primary forest as described by Versteegh apparently contains a mixture of genera from primary forest and limestone hill forest in the Ayawasi area. It should be noted that the Ayamaru area is populated more densely and for a longer period than the Ayawasi area.

In the Beriat study a lower diameter limit of 40 cm was used. In the present study only 4% of the measured individuals had a diameter of 40 cm or more. Some of the species mentioned by Kalkman (1958) for his forest type 3, which seems to most closely resemble the Ayawasi forest, also occurs in the plots of the present study, but not in the combination mentioned by Kalkman (1958). Some species are restricted to the limestone plots, e.g. *Anisoptera thurifera*, and others are restricted to the forest in the lower areas, e.g. *Agathis labillardieri*. The dominant *Hopea* species mentioned by Kalkman (1958) were only very infrequently encountered near Ayawasi, and the second most dominant species, *Ctenolophon parvifolius* (Linaceae), is not known from the Ayawasi area at all.

Some of the dominant species in the plots on the limestone hills are in the Ayawasi area or in other areas also known from other kinds of vegetation, see, for example, the remark on *Anisoptera thurifera* above. That species (see Johns 1986), as well as *Engelhardia rigida*, is known from other studies and observations to be a pioneer. It therefore seems not unlikely that the vegetation on the limestone hills is of secondary origin. The dominant role of *Anisoptera* in all limestone plots and similar observations outside the plots in other places in the area, may indicate that a certain time ago the forest on these hills was destroyed on a large scale, probably by fire. The relatively large amount of litter, and the relatively dry state of the vegetation due to the exposure and the influence of the limestone substrate on the hydrological system, certainly makes the vegetation susceptible to destruction by fire. In his report on the survey of the Ayamaru area, Versteegh (1958) also suggests that it is not unlikely that the forest he found on the slopes and tops of the limestone hills is the result of burning of the primary forest in the past. Perhaps the frequency of fires (both natural and started by man) is high enough to allow the observed vegetation type to be widespread over large areas. However, it has to be noted that no charcoal fragments were found in the soil samples from the limestone hills, and that *Anisoptera thurifera* was only observed on the limestone hills, not in the secondary vegetation on the relatively flat terrain. It would be interesting to find out whether there is a forest type on limestone hills in (almost) unpopulated areas that represents a further step in a climax series.

According to Versteegh (1958) the species involved are often also found in larger sizes in the primary forest in the hilly terrain in the Ayamaru area. Some of the dominant species in the plots on the limestone hills are indeed found in both forest types (see section of results on limestone hill plots), but in general there is hardly any overlap in species composition.

NOTE

Nomenclature for families and genera in this publication follows Van Steenis (1987).

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7

New Guinea: An orchid paradise

1 INTRODUCTION

With nearly 900,000 km^2 of land mass, New Guinea is the second largest island in the world. The geological history of the island is very complex. New Guinea is composed of many pieces of tectonic plate of various sizes, which collided at different moments in the past. These land masses are supposed to have carried a variety of plants from different derivation, the ancestors of the present species.

Two factors have been of major importance for the origin of the wealth of species which is now present on the island. Firstly, the climate of New Guinea has over the course of time been very favourable for the development of a rich flora. High rainfall, evenly distributed over the year, is essential for the presence of mixed tropical rainforest and montane elfin forest which belong to the most species-rich vegetation types in the world, and since the Oligocene some 26 million years ago, these forest types have probably always been present on the island. Under favourable circumstances these were distributed over vast areas, and shrank under adverse situations during dryer periods to remnants in local pockets. Under ever-wet conditions in the rainforest, with its many different niches, the flora has the possibility to differentiate with few restrictions, because factors like drought do not then play a limiting role.

Secondly, in New Guinea the variation in edaphic factors, that is, the factors depending on soil and topography, is enormous. The origin of the different bedrocks varies widely from alluvial deposits to metamorphic rock, dating back to various geological eras, and this mother material directly influences the composition of the mineral content of the soils which are derived from them. Together with a wide altitudinal range, a rugged topography in many places, and active tectonics in the area this leads to a large variety of different forests and other vegetation types, with a matching high number of plant species.

2 PLANT WEALTH

An estimate of the number of plant species present in New Guinea is not easy to give. Many plant families which occur in the area have never been revised. As a consequence, many described species will later be recognized as conspecific with others and need then to be reduced to synonymy. Conversely, an unknown number of species new to science may have been collected already but are still undescribed, and others remain to be detected in the field. And on top of all this the species concept of the revising taxonomist may play a role in the number of species recognized.

De Wilde (1995) revised the New Guinea species of the nutmeg genus *Myristica* for Flora Malesiana only 17 years after the last revision, which recognized 38 species and 8 varieties. He discovered and used several new characters and had many new collections at his disposal, and was forced to recognise 57 new species and 31 varieties and subspecies. Vermeulen (1993) revised the species of 5 sections of the monster-sized orchid genus *Bulbophyllum* (about 1200 species). Of the 99 New Guinean species of these sections, 46 appeared to be new to science, which is almost 50% of the total.

Reduction in species number may also occur. The genus *Drymis* (*Winteraceae*) has a very complex variation pattern and at the time of revision the density of collecting was very uneven. Vink (1970), after meticulous comparison of hundreds of specimens of the genus, decided to reduce all 34 described species to one species only: *Drymis piperita*. He was forced to do this because he could not find discontinuities in characters, and thus was unable to define taxa and to construct identification keys.

A guess, even an educated one, at the number of plant species in New Guinea is consequently bound to be far from the true number. Nevertheless, some attempts have been made. The estimate for Flora Malesiana (including Malaysia, Indonesia, Brunei, the Philippines, and Papua New Guinea) is 46,000 species, which leaves the flora for the whole of New Guinea at about 20,000. But there are also botanists with experience in New Guinea who are inclined to estimate the flora of the island at almost double that amount. They take into consideration the fact that, although there have been many plant-collecting trips in New Guinea, the collecting density is still very low.

3 PLANT COLLECTIONS IN NEW GUINEA

In 1988 the total number of vascular plant specimens collected in New Guinea was estimated to be about 450,000. With continuing botanical activities it is fair to assume that by now 500,000 collections are present. This gives an average collecting density of 55 plants per 100 km^2. A rule of thumb, based on long-standing experience with flora work in the Malesian area, suggests that the flora of a moderately sized area is reasonably well known when the collecting density is over 100. But then these collections should be distributed evenly over the various habitats and vegetation types, and over the area itself as well, and that is certainly not the case.

Papua New Guinea (PNG) is botanically much better known than Irian Jaya. In colonial times a number of major botanical expeditions were made in Papua (British) and German New Guinea. Later, the PNG national herbarium in Lae (LAE) was very active and initiated a collection series for which many botanists collected. This NGF (New Guinea Forestry) series began in 1940 and its name was changed into the LAE series at number 50.001. This latter series continued after the country became independent, and at present comprises almost 80,000 collections. The total number of collections in PNG must now be over 400,000.

In Irian Jaya several major general exploration expeditions were made in the colonial period. Botanists often participated in these activities, but botanical fieldwork was by no means as intensive as in PNG. Since 1960 virtually no major collecting activities have taken place, with the exception of 1995/1996. In 1950 the number of collections made in Irian Jaya was estimated at about 40,000. The number of subsequent BW (= 'boswezen', = forestry) collections after that date amount to almost 15,000, those of separate collectors to about 3500. In very recent times an unknown but rather limited number of plant collections have been made by Herbarium Manokwari and Herbarium Bogoriense. In a cooperation between the latter two institutions and the Royal Botanic Gardens in Kew, a major inventory was set up in the Northeast part of the Bird's Head, resulting in some 3000 collections (Johns pers. comm.). Another recent large-scale botanical activity has been a cooperation project between the two Indonesian institutions and Rijksherbarium/Hortus Botanicus in Leiden under ISIR, in the central part of the Bird's Head, which had as a spinoff a total of over 3800 plant collections, consisting of more than 2300 fertile collections and some 1500 sterile vouchers for a vegetation study.

The collecting density of plants in New Guinea not only varies from area to area, there is also a big difference in attention paid to the various habitats. Professional botanists have been (and still are) focused on the high mountains where the subalpine and alpine areas in particular have been explored and subjected to collecting activities: in former times in the wake of large-scale exploration expeditions, in recent times because of a relatively easy access by road, plane or helicopter. Open, low vegetation is more attractive to human beings than dense forests, even botanists. The latter often come from temperate regions in Europe and America, and enjoy encountering many familiar flora elements in high altitude areas because these belong to the same families and genera as those in their native countries. And, in addition, they appreciate the cool climate of higher altitudes. Consequently, the plants of high altitude vegetations are much better collected than those of the lowland forests, and of the latter those of the marsh and peat forests are particularly underrepresented in the herbaria.

In former times expeditions into the interior in which botanists participated were major and dangerous undertakings of many months or even years. In recent times opportunities for long periods of fieldwork are rare. Due to the limited infrastructure there is in New Guinea some duplication in collections because a tendency exists among contemporary collectors to collect at the same site. Holiday resorts and other places with overnight accommodation are popular because they are relatively easy to access, and facilities are present for preserving collected specimens. In regularly visited areas it is common for conspicuous plants to be collected over and over again. Roads leading inland, or airstrips, similarly attract collectors, at least when patches of forest remain within easy reach.

Expeditions in former times covered a lot of ground. Recent botanists have in general a much more limited reach, whether they collect from a road or move one or more day-marches into the forest to make a collecting camp. When flowering is fair to good a botanist can spend days collecting in a very limited area. And when he follows a trail he never wanders far from it to collect, because for one thing he does not want to get lost, and the sighting of flowering or fruiting trees in a forest is never far away. The collecting areas of botanists are normally indicated as dots on maps. Such dots, which because of the scale of the map often cover large areas of many square kilometers, consist in general of a few transects of at most a few kilometers long, along which plants no further than 50 m from the transect were spotted and collected. When this is taken into consideration it is clear that much less than 5% of the total surface area of New Guinea has ever been visited by a botanist.

The fact that most recent field trips are of limited duration also has an influence on the species content of the collections. Plants often have a limited flowering or fruiting period, and botanists take only fertile collections because these are essential for identification. Consequently, in a given period a large number of species will be missed at a site because they are only found in a vegetative state. In species rich vegetation types in particular, a collecting trip at a different time of the year will bring in a high

a

b

c

d

Plate 1a) *Dendrobium polysema* Schltr. b) *Dendrobium petiolatum* Schltr. c) *Bulbophyllum bisepalum* Schltr.(aff.). d) *Bulbophyllum nasica* Schltr.

a

b

Plate 2a) *Bulbophyllum graveolens* (Bailey) J.J. Smith. b) *Bulbophyllum ustusfortifer* J.J. Verm.

percentage of different species. And then there is the fact that a collector has only a limited collecting capacity. In a good flowering or fruiting period the average result of an experienced plant collector is in the order of about 500 collections a month, a mixture of trees, shrubs, lianas, herbs, epiphytes, etc. Even with experienced helpers this capacity can scarcely be enlarged because notes have to be made of every collection, and the specimens must be preserved before collecting is resumed the next day. Most collecting trips, especially more recent ones, last only two months or less in the field. Considering that in an average area a few thousand species occur, and that duplication of collections cannot be avoided, it is clear that many species will remain uncollected.

It is evident that the fantastically rich diversity of plants in New Guinea has so far been inadequately inventoried, despite the efforts of so many devoted botanists. This is proven by the very high number of species which are so far known only by the type collection on which they are described. If this is true for plants in general, there are certain plant families where additional difficulties make that they are more underrepresented in collections than others. One of these is the orchid family. With about 2800 described species in New Guinea including over 100 described varieties or subspecies, of which about 500 are synonyms, this is the largest plant family in the area. It is estimated that a few hundred species still remain to be discovered; the actual number of species is probably around 2500.

4 ORCHIDS AND ORCHID-COLLECTING IN NEW GUINEA

Orchids are very common tropical plants, renowned for the spectacular beauty of their large-sized, often bizarrely shaped flowers, and their fantastic methods of pollination. At least, that is how they are known to most non-botanists. These characteristics, often not in combination, are partly true for a limited number of genera and species which are widely cultivated and much written about in popular publications. In reality, the majority of orchids have small to moderately sized flowers in which the interesting features only become apparent when observed under magnification. In the field one finds in general an average of only 2% to 5% of the species in flower, and for more than 98% of the species the pollination has never been observed. For New Guinea orchids virtually no pollination studies have been done. New Guinea orchids are in general very poorly known: about one quarter of the 2500 species is known from one to three specimens only.

In addition to the rather small size of many orchid flowers it is also their way of life which makes them rather inconspicuous in their natural habitat, especially in the forest. In the tropics about one quarter of all species is terrestrial, rooting in the soil, and these are in general rather easy to detect once one is familiar with what they look like. But terrestrial orchids do not often occur in large quantities, in contrast to many of the remaining 75% of the species which are epiphytes. Epiphytes live on the trunks, branches and twigs of trees and shrubs, often high in the canopy, and can in many cases only be detected by binoculars. A tree-climber, personal tree-climbing skills, or special equipment are required to collect epiphytic specimens, or else one needs to cut down the tree on which the orchids grow, an act which even a professional botanical collector will seldom perform to obtain only a few epiphytes. In practice most collected epiphytic orchids are encountered on and taken from uprooted trees, fallen branches or shed pieces of bark on the forest floor.

In logging concessions large collections of orchids can be made, but in practice this is seldom done because access to these areas is in general prohibited to all. This is very unfortunate. All orchid specimens which come down from the canopy will die as they cannot survive on the forest floor. Every year vast quantities of orchids are lost in this way. The forest vegetation in Irian Jaya has been largely untouched until recent decades. The present opening-up of areas with the accompanying cutting-down of forests for various goals such as road building, transmigration, logging, etc. will lead to a large-scale destruction of orchid populations and over the course of time to the loss of a very large number of orchid species. Suggestions by orchid growers that profits could be made by the country of origin by collecting and selling these plants in bulk to save them unfortunately has not yet led to action in this direction.

One reason why orchids are rather underrepresented in plant collections is that most professional plant collectors are specialists. Their interest is in one or a few plant families on which they focus most of their attention. They simply do not have enough time left to search for orchids, and their search pattern is different. As a result all plant groups not belonging to their direct interest are underrepresented in their collections, even when they do general collecting. Foresters in former Dutch New Guinea before 1960 had orders not to collect orchids. Their task was to make inventories of forests and the composition thereof, and because there were only few of them, responsible for covering a vast area with a wealth of tree species which make up the frame of the forest, there was no working time left to spend on frivolities like orchids. Fortunately several of them could not resist the attraction of these plants and brought in most interesting collections from remote areas which are difficult to access. For many such areas these are the only collections ever made, and orchidology owes them a tribute for all the work they did.

An experienced orchidologist (professional or amateur) may find dozens of species where others only see a few, because of familiarity with the special niches where certain species live. In New Guinea most orchids were collected by general plant collectors and foresters. The most important orchid experts who before the Second World War did prolonged fieldwork in New Guinea were Rudolf Schlechter and Cedric Carr. They brought together gigantic collections of orchids. More recent important collectors were Father Norman Cruttwell, Tom Reeve and Peter Jongejan who gathered and grew hundreds of live orchids from which many new species were described. All these plant collectors worked in eastern New Guinea.

5 PROFESSIONAL APPROACH TO INCREASE THE KNOWLEDGE ABOUT NEW GUINEA ORCHIDS

Because of the low percentage of orchids in flower at a given time (as said above, in general only 2 to 5% of all species present in a certain area are bearing flowers), a botanist making an inventory is bound to miss some 95% of the species in an area because sterile specimens cannot be named. Expeditions are expensive undertakings, and for Irian Jaya the money investment for field inventories is considerably higher than for other areas. Special inventories for orchids in Irian are thus very inefficient when only herbarium is collected, because such a high percentage of the species in the area is missed. It is, however, possible with simple techniques to raise the number of identifiable orchids to a much higher level, even over 50%.

Orchids, especially the epiphytic ones, are adapted to life in an environment with quite adverse conditions. They can withstand water stress because they regularly undergo this in the habitat they live in. They possess a thick cuticula, or water storing tissue, or both, and most are not adversely affected in their health when their roots die off or are damaged. These characteristics mean that it is easy to keep most species in good condition during several weeks of transport. Orchids, in this respect, travel much better than most other plants, and during fieldwork periods of a month or longer only very few plants are lost. This is of fundamental importance for the increase in the knowledge of Irian Jaya orchids. It is possible to make collections of live orchids, cultivate the plants till they flower, and then gather information on their identity, as well as obtain perfect material for descriptions and illustrations. And, in addition, high quality colour photographs can then be made under controlled conditions. Each identification acquired this way increases the knowledge on the distribution of that particular taxon.

An orchid-rich area like New Guinea should have several representative live orchid collections, with duplicate collections in sister Botanic Gardens to prevent loss by accident. There are few live orchid collections in PNG and Irian Jaya, maintained by various District offices, Forestry institutions and local orchid amateurs. These are mainly display gardens with large and showy plants, exept two in PNG which stock a wide variety of species. Since there are no more orchid specialists working in New Guinea there is, unfortunately, no increase in orchid knowledge to be gained from these, because there are no initiatives to preserve specimens as vouchers for identification, or to describe species.

The gardens outside New Guinea which have always been of major importance to the taxonomy of the orchids of the area are the Kebun Raya Bogor and the Hortus Botanicus Leiden for Irian Jaya, and Port Moresby Botanic Gardens, Royal Botanic Gardens Kew, and Edinburgh Botanic Garden for Papua New Guinea. Botanic Gardens, in the tropics as well as in temperate regions, in cooperation with botanical institutions or herbaria or not, have increased the knowledge of tropical orchids enormously. But nowadays it is very difficult for the European Botanic Gardens to obtain live orchids of wild origin from New Guinea, and their collections from this area are decreasing in importance. It is fortunate that in the Kebun Raya Bogor extensive collections of Irian Jaya orchids are present, and that recently three people have been assigned to work on orchids, and collecting of spirit samples from the plants cultivated there has begun.

Increase of knowledge from live orchid collections in Botanic Gardens works only when there is a person actively dealing with the taxonomy of the Orchidaceae, because the mere possession of a collection of live orchids in itself will not increase orchid knowledge. For that purpose observations are required which must be noted down in a systematic way, and made available to the scientific and amateur community through publication. Amateur orchid growers have in the past also greatly contributed by supplying cuttings of specimens they had collected in the field to orchid scientists, enriching in this way the collections of botanic gardens and herbaria. But in many countries this is past tense. Unfortunately, there is a tendency in several tropical countries to prevent all export of live orchids, not only for horticultural goals but also for scientific purposes, even if these countries have no specialists working on the taxonomy of the orchid family. In the light of the vast and rapid destruction of the prime orchid habitats, the tropical rainforest and the montane forest, the result can only be that biodiversity information will be lost forever, which is contrary to the intention of these measures which are, with the best motives, designed to prevent losing the species. It is sad that orchid taxonomy is seriously hampered in this way, and that increase of orchid knowledge is thereby considerably slowed down.

6 PRESENT LACK OF AVAILABLE INFORMATION ON NEW GUINEA ORCHIDS

Scientific information about the great majority of the orchid species of New Guinea is difficult to obtain, because this is hidden and scattered in scientific journals and books which are published in a large variety of countries throughout the world. Unfortunately most of the existing taxonomic works on New Guinea orchids are long out of print, and only extant in specialised botanical institutions and some private collections. In Indonesia only one almost complete set of orchid literature covering the New Guinea orchids is present, in the Herbarium Bogoriense. Virtually no orchid literature is available in Irian Jaya itself, it is not known to me what the situation in PNG is. Old archives, in the tropics as well as in temperate regions, contain a wealth of published and unpublished data on New Guinea orchids; old books often include watercolour paintings of a very high scientific and aesthetic standard. In practice this information is almost inaccessible to most people interested in orchids.

The large majority of the New Guinea orchids were described in the last few decades of the last and the first few decades of the present century. Many species were illustrated by line drawings or lithos. Only five persons published most of these: Schlechter (1905-1924) and Kraenzlin (1886-1911) in Germany, Smith (1907-1937) in Indonesia and the Netherlands, Rolfe (1889-1907) and Ridley (1886-1916) in England. The first three published in German, the others in English, but the descriptions of their new species were all in Latin. These publications are all out of print. Schlechter's major opus *Die Orchidaceen von Deutsch-Neu-Guinea* was reissued in 1982. Unfortunately only the general information in this book was translated into English but the descriptions of the c. 1500 species he treated are still in Latin. It is estimated that an adequate English description exists of only some 500 species of New Guinea orchids.

Recent general publications on the orchids of New Guinea in English are very few, since 1970 only five, and a further one is in Dutch. These either describe a limited number of species, or deal in other ways with New Guinea orchids. The orchids treated are from a specific altitudinal zone (O'Byrne 1994; Van Royen 1982), or from a restricted geographical area (O'Byrne 1994; Van Bodegom 1973; Howcroft 1984; Millar 1978). Howcroft (1984) provides only a synopsis of the higher taxa of the orchids, with species lists and keys to a limited number of species (series aborted at an early stage). Schuiteman (1995) published a (long overdue) new identification key to all 133 orchid genera in New Guinea. These recent works, even together, give only a very incomplete understanding of New Guinea orchids. Additional English descriptions of New Guinea orchids may be found in a number of recent or older publications which give taxonomic accounts of groups of orchids on a monographic or regional basis, but these cover only a small percentage of all New Guinea orchids (e.g. Cribb 1984, 1986; Reeve & Woods 1990; Van Royen 1983; Vermeulen 1993).

7 APPROACH TO IMPROVE AVAILABILITY OF INFORMATION ON NEW GUINEA ORCHIDS

A vast amount of information is available on the orchids of New Guinea, but it scattered, not easily available, and not present in a uniform format. What is needed is a work in which all this information is brought together in a standardised format, illustrated by colour slides and drawings for all species. With some effort, the available information can be standardised and published together in a medium which gives easy access to the data: CD-ROM.

Modem multimedia software for data storage and retrieval that has the capacity to hold large quantities of information is ideally suited to low-cost publication of descriptions, illustrations in colour and black and white, literature, identification keys, and all other information available for this fascinating group of plants. A multimedia database system, Linnaeus II, has been specially designed for biodiversity documentation and species identification by ETI, the Expert Centre for Taxonimic Identification. This system is well designed, and a number of biodiversity databases are already available using this system in the World Biodiversity Database, CD-ROM series. Among these are Birds of Europe (in several languages), Lobsters of the World, Sea Cucumbers of Australia, UNESCO's Fishes of the Northeastern Atlantic and the Mediteranean, and others. A large number of databases in all kinds of biological disciplines are in preparation using Linnaeus II, including a project on the Legumes of Flora Malesiana at the Rijksherbarium/Hortus Botanicus in Leiden.

A pilot project, organised and funded by the Rijksherbarium/Hortus Botanicus and implemented by André Schuiteman and the present author, has produced a demonstration CD-ROM containing a working model of an Orchid Information System as described above.

The demo CD-ROM includes a sample treatment of one small genus, two monotypic genera, and a selection of species from other genera, covering a total of 48 species, all with genus and species descriptions. An interactive multi-entry key to these species is provided, as well as a glossary and many other features. A total of 200 illustrations in colour and in black and white are included, all edited to reduce their size and to improve the image. This demo indicates the great potential and power of the system. The total size of the demo programme is 8.5 megabytes. It is intended to produce a programme on disk containing all 2500 New Guinea orchid species along the same lines, lavishly illustrated with colour photographs (see Plates 1 and 2) and pencil and line drawings. A CD-ROM disk can currently store 650 megabytes, which means that all New Guinea orchids will fit easily on one disk.

Attempts are now being made to acquire funds to start work on including all New Guinea species of orchids on one CD-ROM. This is the only medium on which all 2500 New Guinea orchid species can be published and which will at the same time remain moderately priced.

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8

East of Irian: Archaeology in Papua New Guinea

1 INTRODUCTION

Professional archaeology began less than three decades ago in what was then the Australian-administered Territory of Papua and New Guinea (see Fig. 1). (Following convention, 'New Guinea' here refers to the whole island, while 'Papua New Guinea' refers to the state of that name which was established in 1975 and encompasses the eastern half of the island as well as some nearby archipelagoes. The term 'highlands' denotes those areas of the central ranges of New Guinea above 1000 m a.s.l. and should not be confused with the area encompassed by the Papua New Guinea administrative provinces of Enga, Simbu, Southern Highlands, Western Highlands and Eastern Highlands.) In 1959, Sue Bulmer completed a program of survey and excavation in the Western Highlands, excavating the Pleistocene sites of Yuku and Kiowa. The growth of our knowledge of Papua New Guinea's prehistory since then has been spectacular in relative terms, but because archaeological research in the country has been conducted on such a limited scale it is still only possible to sketch an outline of the nation's human past.

Small scale it may have been, but there has been very much more archaeological work done in Papua New Guinea than in Irian Jaya, and results and perspectives from eastern New Guinea, as well as from the Indonesian archipelagoes to the west and Australia to the south, will inform students of Irian Jayan prehistory as detailed research there gets underway. With this fact in mind, this paper presents an updated summary of my review of research in Papua New Guinea to 1990 (Lilley 1992; see also Golson 1996; Lilley 1994), with an eye to matters which could profitably be pursued in western New Guinea.

Figure 1. Major archaeological sites in Papua New Guinea.

Despite recent controversial claims for dates of human occupation from 50,000 to more than 100,000 years ago in northern Australia (e.g. Fullager et al. 1996; Roberts et al. 1990; cf. Allen & Holdaway 1995; Hiscock 1990; Morwood 1996), the unambiguously demonstrated antiquity of human occupation in New Guinea has increased in much the same way as it has in Australia over the three decades and since the mid-1980s has stood at around 40,000 BP on the basis of Groube's dates from the Huon Peninsula on the northeastern corner of the island (Groube et al. 1986). Crucially, an antiquity of this order is supported by Irwin et al.'s (1996) date of 30,000 BP for initial use of Gebe Island, which lies to the west of the Bird's Head on a logical colonizing route to New Guinea (see below). At that time of much-lowered sea levels, New Guinea was joined to Australia to form the northern edge of the continent of Sahul, separated from an extended Asian mainland known as Sunda by the archipelagoes of Wallacea (Chappell 1976). There is good reason to believe that colonization was purposeful, not accidental (Gosden 1993; Irwin 1991), with water-borne founding groups island-hopping through northern Wallacea to western Irian Jaya in the same period that other people moved through Bali and Timor to northwestern Australia (Birdsell 1977).

As in southern Sahul, New Guinea's first human colonists were the only placental mammals other than rats and bats to cross Wallacea independently, and so would have met with an unfamiliar terrestrial mammal fauna dominated by marsupials, including a number of now-extinct 'giant' species. Further, from 60,000 to 30,000 BP, north coast temperatures fluctuated between 3-6°C below present (Aharon 1983a), which probably coincided with a marked lowering of the highland tree line prior to 34,000 BP (Hope 1983). The first immigrants may not have been much affected by these variations in terrestrial fauna or changes in upland vegetation, as their ocean-crossing capacities suggest they were coastally-oriented (Bowdler 1977). Nor, at least in coastal northern New Guinea, should other environmental factors have necessitated significant adaptive shifts, as the environments of the region were similar to those in Wallacea and Sunda (Van Balgooy 1976). In southern New Guinea the situation may well have differed, as drier environments like those found today in northern Australia penetrated some distance into the region, as evidenced, for example, by relict savannah in the Port Moresby area (Nix & Kalma 1972).

We do not yet know how long it took for people to move into New Guinea's rugged interior. Exploration may have begun with initial colonization, following routes of least resistance such as major rivers, but progress need not have been rapid. Indeed, penetration of the highlands could have taken upwards of 10,000 years, for while the oldest known lowland site dates back some 40,000 years (Groube et al. 1986), the earliest indications of human activity in the uplands date to 25,000-30,000 BP (Gillieson & Mountain 1983; Hope 1982; White et al. 1970), with the more certain archaeological evidence at the more recent end of the range (Haberle 1993). This disparity may reflect the time it took for coastal people to adjust to upland conditions, but may just be a function of patterns of research and so it is important to emphasize that available data do not preclude earlier activity in the highlands. In fact, recent discoveries in the islands east of New Guinea show the earliest colonists to have been highly adaptable and almost certainly capable of moving into the highlands very soon after they reached the mainland coast (e.g. Allen 1993).

The Bismarck Archipelago and nearby islands were settled very soon after the mainland, and perhaps simultaneously in archaeological time. Before 1980, when an expedition of Specht's (Specht et al. 1981, 1983) dated Misisil on New Britain to the terminal Pleistocene, such ancient occupation east of New Guinea was only conjectured on the basis of Downie & White's (1978) Early Holocene dates from Balof on New Ireland. Subsequent studies have more than trebled that time-depth, most recently from sites around Yombon, near Misisil on New Britain, where Pavlides (Pavlides & Gosden 1994) has sites dated up to 35,000 BP. Matenkupkum and Buang Merabek on New Ireland date to about 33,000 and 32,000 BP respectively, while two other New Ireland sites, Balof 2 and Panikiwuk, date to 14,000-15,000 BP and a third, Matenbek, to 20,000 BP (Allen et al. 1989). Some 30,000 years of human occupation is also indicated in the Solomon Islands on the basis of dates from Kilu on Buka (Wickler & Spriggs 1988), while Pamwak, on Manus, may be of the same order of antiquity, though its lowest levels have not yet been dated (Fredericksen et al. 1993).

These latter data are profoundly important as a gauge of early capacities for open-ocean voyaging and remote island adaptation (e.g. Irwin 1991). As several commentators point out (e.g. Allen 1993; Groube 1989; Pavlides & Gosden 1994; Spriggs 1993, 1996), these and other new findings indicate that received popular and scientific models and their often Eurocentric theoretical underpinnings regarding the Pleistocene and cultural-evolutionary patterns are proving increasingly inadequate in the description and explanation of prehistoric change in Australasia and Near Oceania. We have had to look to our models of how this wider region was colonized, and how rapidly. We have had to pay particular attention to the nature of the cultural adaptations of this broader region's first peoples and especially their abilities to cross open seas out of sight of land and render difficult environments such as rainforests and biotically depauperate remote islands habitable by moving resources around the landscape and otherwise manipulating natural physical and biotic patterns. Archaeological data from New Guinea bearing on such questions are changing wider views of the cultural capacities of people in the remote past, just as Early Holocene sites in the highlands have helped change perceptions about the origins of agriculture and Late Holocene finds on the coasts and islands have influenced ideas about the nature of prehistoric trade and exchange. The challenges to Old World orthodoxy emanating from Papua New Guinea will undoubtedly be bolstered by results from Irian Jaya, which should prove a critical testing ground for such ideas.

The rest of the paper discusses the highlands and coasts and islands separately.

3 THE HIGHLANDS

Owing to its significant Gondwanaland inheritance, highlands vegetation differs from the more Malesian flora of the lowlands (Van Balgooy 1976) and, from the time that the oldest known sites were first occupied until about 9000 years ago, varied considerably because of climatic fluctuations (Hope 1983; Hope et al. 1983). During the last glacial maximum, temperatures were 3-7°C below present, a considerable area was glaciated and the tree line up to 1700 m below present. The climate improved from about 15,000 BP and by 9000 years ago the glaciers had all but disappeared.

While movement from the lowlands into high altitude areas would have seen changes in subsistence and settlement patterns and other aspects of human culture, we know little more now about the actual nature of such shifts than we did following the pioneering work of Bulmer (1966), Cole (Watson & Cole 1977) and White (1972; White et al. 1970). Similarly, we still do not know much of the ways in which people adjusted to subsequent environmental variation. Work at Kosipe (White et al. 1970) and Nombe (Gillieson & Mountain 1983; Mountain 1993, 1986), the two most ancient archaeological sites known in the highlands, indicates amongst other things that early stone artefact assemblages included distinctive waisted tools (the term 'waisted' refers to notching on the sides of the tool to produce a rough hourglass shape which can be secured to a handle). Finds at Nombe also indicate that people may have hunted some of the now-extinct marsupials with which they co-existed until about 10,000 BP, such as the 'giant' wallaby *Protemnodon* and the dog-like *Thylacinus*, though the thylacine may in fact have been the predator. In addition, there is one pig (*Sus scrofa*) tooth from Nombe which may derive from Pleistocene sediments, though the excavator believes it not to be in primary depositional context, a view recently strengthened by AMS dating of the actual tooth to a very late date (Mountain, Department of Anthropology and Archaeology, ANU, pers. comm.; see also Golson 1996: 170).

Other early sites, such as Manim (Christensen 1975), Wānlek, Yuku and Kiowa (Bulmer 1966, 1977), Batari and Kafiavana (White 1972) and NFX (Watson & Cole 1977), were first occupied between about 18,000 and 10,000 BP. Aside from pandanus-nut processing at Manim, these sites have yielded broadly similar evidence for intermittent hunting in mid-montane areas. In addition, marine shells dated to about 10,000 BP in Kafiavana provide evidence for early lowlands-highlands interaction, while Bulmer claims to have found 10,000-year-old fragments of pig bone in both Yuku and Kiowa. These two sites also contain waisted tools similar to those mentioned above.

The waisted stone tools from Kosipe, Yuku and other sites have been a focus of scholarly debate since Golson proposed that they and similar tools in Australia reflected the introduction of a technological tradition of Asian origin by Sahul's first inhabitants (e.g. Allen 1993; Golson 1971; Groube 1986, 1989; Lampert 1983), but despite two decades and more of study, a definitive resolution of the questions they raise seems a distant prospect. The same has to be said about the tenuous evidence for the Pleistocene presence of pigs in the highlands. Pleistocene – or, indeed, Early Holocene – evidence for *Sus* is becoming increasingly uncertain, but like the distribution of waisted blades, would, if proven, have major implications for issues of Pleistocene cultural variation, population movement and interaction patterns between highlands and lowlands and between eastern New Guinea and points west (e.g. Lilley 1992: 155-56). Such questions will undoubtedly have a central place in archaeological enquiries in Irian Jaya, owing to its geographically central location in the wider region of interest.

The nature and intensity of activity in the highlands changed significantly in the Holocene. The clearest indication of this is in the emergence of horticulture in and around swamps in the Wahgi Valley by 9000 BP, a date as early as any associated with the beginnings of agriculture in other parts of the world (but see mention below of Spriggs's position). The most comprehensive record of developments is found at the Kuk site near Mt Hagen, where extensive excavation has exposed evidence for a discontinuous sequence of six phases of swamp drainage and gardening (for detailed discussion see Bayliss-Smith & Golson 1992; Golson 1977, 1982; Golson & Gardner 1990):

– *Phase* 1: 9000 BP;
– *Phase* 2: 6000-5500 BP;
– *Phase* 3: 4000-2500 BP;
– *Phase* 4: 2000-1200 BP;
– *Phase* 5: 400-250 BP;
– *Phase* 6: 250-100 BP.

The two related sets of major changes through time which occur in the Kuk sequence can be summarized as follows. First, the drainage works become more complex, massive and, up to Phase 5, more extensive. Phases 1-3 have unco-ordinated arrangements of drains and gutters, while Phases 4-6 feature networks of major drains, large tributary channels and relatively tight grids of gutters, with the Phase 5 system draining upwards of 200 ha of swamp.

Second, it is thought that the changes in the drainage works relate to changes in crops and cultivation methods. The simple early drains may indicate mixed cropping of plants with differing soil and moisture requirements. In Phase 1, cultigens were probably indigenous greens and perhaps *Australimusa* bananas, while in Phases 2 and 3 people may have been growing indigenous and Southeast Asian tubers such as taro (*Colocasia esculenta*) and *Dioscorea* yams (Yen 1982, 1990, 1991). The co-ordinated drainage systems of more recent phases indicate intensive mono-cropping of taro in Phases 4 and 5 and the South American sweet potato (*Ipomea batatas*) in Phase 6. Though its introduction via Polynesia up to 1200 years ago is occasionally entertained, sweet potato is generally thought to have come to New Guinea from eastern Indonesia in the sixteenth century, after having been brought to mainland Southeast Asia by early Portuguese explorers (Yen 1974).

Questions of why people came and went from the swamps have not yet to been answered entirely to the satisfaction of Golson and his colleagues, owing to the intractability of much of the evidence and the complexity of the issues involved. This is not to say, though, that considerable progress has not been made in the interpretation of the Kuk data. It is proposed that different processes were responsible for shifts in the focus of activity during Phases 1-3 on one hand and Phases 4-6 on the other. Correlations between the archaeological, geological and palynological records in the three early phases indicate swamp horticulture was an adjunct to dry-land slash and burn farming, taken up when the latter failed to deliver sufficient food and abandoned when techniques were developed to restore its productive capacity.

Similar arguments have been offered in explanation of the beginning and especially the end of Phase 4, but in the second of his three major papers on the matter, Golson (1982) argued there may be more to the relatively sophisticated later drainage systems than suggested by correlations between archaeological and other physical data. He hypothesized that the establishment of permanent grasslands by the end of Phase 3 some 2500 years ago would have reduced the availability of both wild protein sources and natural pig fodder and thus necessitated an intensification of pig husbandry to supply protein and of gardening to feed the pigs. In these circumstances it could have been of benefit to those communities (and politically ambitious individuals) with access to swamps to construct efficient drainage systems and take advantage of the rich soil they made available. He and his recent collaborators have since stepped back from this idea (Bayliss-Smith & Golson 1992; Golson & Gardner 1990), but still believe Phase 4 was a vital one. Indeed, they see it as 'the seedbed for the distinctive Central Highlands societies which, much later, adopted the sweet potato with such dramatic consequences for population, landscape and society' (Bayliss-Smith & Golson 1992: 18).

Studies elsewhere in the highlands and highlands fringe show that the developments evidenced at Kuk are neither unique nor the only sort of changes that occurred during the period in question. At least half-a-dozen other swamps in the Mt Hagen region contain equivalents of one or more of the Kuk phases (Golson 1982: 120-121; Dr J. Muke, Department of Anthropology and Sociology, UPNG, pers. comm. 1995). Further afield, indications of swamp cultivation and forest clearance, dating back to about 5000 BP and more than 3500 BP respectively, have been found at Ruti Flats, a low altitude river valley below Mt. Hagen (Gorecki & Gillieson 1989; also Gillieson et al. 1985), while agricultural features more than 3000 years old are present at Yonki in the Arona Valley area on the eastern edge of the highlands (Golson 1989, 1996; Sullivan et al. 1986; Swadling 1973). There is evidence from sites in the Manim Valley that people may have begun to curate pandanus from about 9000 BP and, between 4500 and 2000 BP, began hunting at progressively higher altitudes, possibly because horticultural activities destroyed game habitats at lower elevations (Christensen 1975). Finally, John Burton (1984) has found that the organized quarrying and intra-highlands movement of highly-valued axe stone from sites still used at the time of European contact arose at some time between 2500 and 1500 BP.

4 THE COASTS AND ISLANDS

As highland glaciers began to retreat about 15,000 years ago, rising seas started to flood the Arafura and Torres Plains which had been exposed by lowered sea levels. By 10,000 BP only a narrow isthmus remained to link Papua and Cape York and by 8000 years ago northern Sahul had become the island of New Guinea (Chappell 1976). As in the highlands, lowland climates have varied little since about 9000 BP (Aharon 1983b; Garrett-Jones 1979), but coastal areas were affected by rising seas until about 6000 years ago.

The early prehistory of the mainland coast is almost completely unknown. There are as yet no detailed reports concerning the 40,000 year old Jo's Creek site in northeast New Guinea (Groube et al. 1986), which until mid-1994 was the only published mainland coastal site from the period in question, and no published details at all regarding cultural material in the 14,000-35,000 year old deposits in Lachitu Cave on the north coast near the Irian Jaya border (Gorecki et al. 1991; Smith & Sharp 1993: 40). Most finds from Jo's Creek are waisted stone tools broadly similar to those found in the highlands sites discussed earlier. In a convincing paper, Groube (1989) suggests they may have been used for forest clearance, thus initiating a long-term trend of change which culminated in the emergence of horticulture of the sort described by Golson in the highlands. Spriggs (1996), on the other hand, finds Groube's and Golson's perspectives on the local origins of agriculture unconvincing, preferring instead to argue that the advent of 'full-scale agriculture', as opposed to 'wild food production', was the result of intrusion from Asia of the Austonesian-speaking manufacturers of Lapita pottery, discussed below.

Study of the early material from the islands is still in its early stages, but three extremely interesting patterns are emerging (Allen et al. 1989; Fredericksen et al. 1993; Gosden 1993). The first is that obsidian from the north coast of New Britain first appears in New Ireland around 20,000 BP, having been moved some 350 km from source. The second is that several species of mainland wild animals were introduced to the archipelago, one as early as 20,000 BP and several others over the last 10,000-15,000 years. Though the animals were not necessarily tame, let alone domesticated, the implications of this sort of environmental manipulation for our understanding of Pleistocene cultural patterns are profound. The data are certainly sounder in my view than those behind debates about Pleistocene animal husbandry in Europe (e.g. Bahn 1978; cf. R. White 1989). The third emergent pattern is that cultural deposition ceases at some sites and either begins or changes in nature at others in the period 7000 to 10,000 BP. This last may relate to the spread of horticulture from the mainland and/or local developments in silviculture/horticulture (Yen 1990; Fredericksen et al. 1993; Wickler & Spriggs 1988; but cf. Spriggs 1996).

The various hypotheses and speculations concerning more recent coastal prehistory focus largely on the nature and effects of the movement through island Melanesia to Polynesia some 3500 years ago of

Southeast Asian speakers of Austronesian languages related to those of Indonesia, the Philippines and, ultimately, Taiwan. This phenomenon is marked in the archaeological record by the first appearance of pottery in island Melanesia, in the form of an elaborately-decorated ware known as Lapita. Sites containing classic Lapita pottery are found from the Bismarck Archipelago east to Samoa and Tonga in Polynesia and date to between 3500 and 2000 BP (Allen & Gosden 1991; Spriggs 1990). While most clearly linked by striking similarities in their pottery assemblages, the sites evince other indications that they were created by interacting and probably culturally-related people (e.g. Spriggs 1993: 192-193). Pawley & Green (1973) detail the links between Lapita and Oceanic Austronesian languages indicating that the distribution of both resulted from population movement rather than diffusion, at least east of the Solomon Islands.

While there is little doubt that the Lapita phenomenon reflects the movement from Melanesia to Polynesia of the descendants of Southeast Asian and Melanesian people, there is debate concerning the dynamics of their spread through Papua New Guinea in particular (e.g. Allen 1984a; Spriggs 1993, 1996). Lapita sites are known throughout the Bismarck Archipelago but only two Lapita sherds have been found on the New Guinea mainland or its immediately offshore islands (Terrell & Welsch, 1997: 557-558), which strongly implies that the colonists skirted at least the eastern part of New Guinea altogether.

Plainly, investigations on the north coast of Irian Jaya are crucial to resolving this and other questions concerning Lapita-period archaeology in Melanesia. Of interest in this regard is the discovery in the Sepik region close to Irian Jaya of pottery stylistically unrelated to, and, it is claimed, up to 2000 years older than Lapita pottery from the islands. Though the scholars who made the first such find have now implicitly retracted their claims in the light of inconsistent radiocarbon determinations (Swadling et al. 1989, 1991), one of those who made the second find has recently confirmed his belief that his results are sound (Gorecki 1996; Gorecki et al. 1991). It is worth remembering, too, that Bulmer (1985) claims to have found a sherd in deposits older than 4500 years at the open site of Wãnlek, in the uplands above the Sepik-Ramu basin. It will be fascinating to learn whether these assertions can be sustained in the light of results from Irian Jaya, as well as from other parts of Papua New Guinea. Results from Gebe, raised earlier (Irwin et al. 1996), not to mention other parts of island Southeast Asia, suggest a maximum antiquity for ceramics in Melanesia of 3500-4000 years.

Until the discovery of Pamwak in 1989 (Fredericksen et al. 1993), finds of aceramic mid-Holocene occupation suggested the Admiralty Islands were settled only shortly before the emergence of Lapita (Kennedy

1983). While the implications for Lapita settlement patterns of the Pamwak finds have yet to be explored in detail, their broader implications have been raised (Spriggs 1993) in the debate on cultural continuities between pre-Lapita and Lapita times which gave the Lapita Homeland Project most of its impetus.

To back-track a little, although it is clear that the Lapita potters who moved from the Bismarck Archipelago to Fiji, Tonga and Samoa laid the foundations of later Polynesian society, there is much less certainty regarding their cultural impact in Melanesia. The received, migrationist, view (e.g. Shutler & Marck 1975; Spriggs 1996) is that many characteristic features of modern coastal and island cultures in Melanesia stem from contact between existing communities and Southeast Asian people who, in addition to introducing pottery and Austronesian languages, brought with them cultural innovations including 'full-blown' agriculture, efficient ocean-going watercraft which enabled long-distance interaction, and perhaps a weak hierarchical sociopolitical order, as they migrated rapidly through the region.

A second, indigenist, proposition which has gained some acceptance is that the ethnographically-known cultures of coastal and islands regions are the products of very long-term trajectories of change (e.g. Allen 1984a; White et al. 1978). Supporters of this alternative generally acknowledge that people of Southeast Asian origin introduced pottery technology, Austronesian languages and possibly certain sociopolitical institutions to Melanesia (for the last see Lilley 1985; cf. Gosden 1989: 52-53). They argue, though, that the evidence of the early islands sites shows ocean travel has an extraordinarily long history in the region, that data from Kuk and the early islands sites suggest that silviculture/horticulture may have been established in the Bismarck Archipelago by the Early Holocene and that the New Britain obsidian in Pleistocene sites far distant from its sources shows that long-distance interaction networks were developed well before the Austronesian expansion into Melanesia.

Opposing indigenist views, Spriggs (1993) notes that Pamwak, amongst other sites, may have been abandoned well before Lapita appeared, while the very few sites with continuous deposition from pre-Lapita to Lapita times, such as Bitokara Mission at Talasea on New Britain (Torrence 1993), exhibit definite cultural discontinuities. He argues (1993: 191) such problems give lie to indigenist claims that questions of the articulation of the Lapita phenomenon with existing cultural systems are all but solved. Although both parties have shifted ground in recent years, new data have forced the indigenists to compromise their original claims while further emboldening migrationists such as Spriggs (if that were possible) and causing others, such as me, who adopt less polemical stances, to adapt their arguments and models (e.g. compare Lilley 1990, 1996).

The more recent of the two papers just cited proposes an anthropological trade-diaspora model for Lapita origins, based on the African researches of Cohen (1969, 1971). I will grasp here a nettle I avoided there, to foreshadow a two-part hypothesis I will develop in more detail elsewhere. First, I think the motivation for initial penetration of island Melanesia by Southeast Asian 'scouts' (Anthony 1990) prior to migration on a larger scale was disruption of critical obsidian distribution networks by the cataclysmic eruption of Witori, a volcano near New Britain's principal obsidian source areas, at a time when Swadling (1995) believes there was growing southeast Asian interest in northwest Melanesia. Second, I think that the appearance of Lapita pottery in the Bismarcks shortly after the eruption had nothing to do with trade with existing local populations and everything to do with the maintenance of identity amongst the dispersed communities of a diaspora.

The first suggestion advances discussion by a number of scholars regarding the impact of volcanism on access to obsidian sources (e.g. Ambrose et al. 1981; Summerhayes & Hotchkis 1992: 132; cf. Pavlides 1996). The second notion flows logically from recent findings regarding patterns of production and movement of Lapita ceramics (e.g. Dickinson et al. 1996; cf. Green 1992: 17, 1996: 126) and sits well with the diaspora model, as well as influential readings of the 'function of style' (e.g. Wobst 1977; see also Hegmon 1992). A more detailed formulation of this hypothesis will account for the arguments of Torrence (e.g. 1992, 1994) and White (1996, 1997) regarding long-term cultural continuities in the Bismarcks and relationships between the distribution of obsidian and Lapita ceramics in the region. Paradoxically, I think these arguments support rather than undermine my proposals even though they are intended to bolster an indigenist rather than a migrationist position. The hypothesis may also require refinement in the light of critical appraisals of such models by scholars such as Lightfoot & Martinez (1995). I should stress that my proposals concern the very earliest days of Lapita and not what may have developed even slightly later in the Bismarcks and elsewhere.

The last two decades have seen investigations of post-Lapita developments in the Vitiaz Strait (Lilley 1987, 1988a), West New Britain (Gosden 1989, 1991; Lilley 1991; Specht et al. 1981, 1983), the Massim (Egloff 1979; Irwin 1983; Lauer 1974) and along the Papuan south coast (Allen 1977a, b; Bulmer 1978; Frankel et al. 1994; Irwin 1985; Rhoads 1980; Vanderwal 1973). The dominant focus has been the development of ethnographically-documented long-distance trading systems such as the hiri, kula and Vitiaz Strait network, long thought to derive in some way from the extensive interaction systems of Lapita times (e.g. Harding 1967; cf. Ambrose 1978).

The locality-specific models developed to describe and explain changes in these systems remain the subjects of debate and there is some question as to whether any of them can be generalized in order to explain developments in other areas. Only one general model expressly formulated to account for common characteristics in the developmental trajectories of the systems has been formulated to date (Allen 1984b). Drawing heavily on his arguments concerning Motupore, Allen's scenario begins with an areally extensive but organizationally simple system which, through a series of systemic collapses, splits into an increasing number of more localized but organizationally more complex systems. He equates the initial system with a Lapita interaction network, intermediate states with the breakdown of that network and the most localized and complex networks with ethnographic systems.

Irwin (1980, 1983) takes issue with such ideas on the grounds that a formal model like Allen's cannot accommodate the variability in the southern Papuan cases he has investigated. He views the causal variables isolated in his Mailu work as expressions of broad themes such as colonization, local diversification, the development of local and long-distance interaction spheres and the emergence of central places within them, and the relationship between technology and the socioeconomic context of production. He thinks that other trading systems which are broadly similar to and contemporaneous with Mailu may have been variations of the same or similar themes.

I examined some of the possibilities raised by Allen, Irwin and others in my studies (1986, 1987, 1988 a, b, 1991) of the development of the Siassi trading system and related networks in the Vitiaz Strait-West New Britain area. Like the systems on the Papuan coast and in the Massim, the ethnographically-documented form of the Siassi network developed only within the last few hundred years. It can best be understood as the most recent of a discontinuous series of trade or interaction systems which date back to Lapita times and varied considerably in configuration, content and intensity. Its evolution is linked with developments in northwest New Britain and emergent regional patterns of change suggest that Allen's model can be applied to the region with only minimal modification (but cf. Green 1996: 126).

It should be pointed out that while the dispersal of Austronesian-speakers was undoubtedly the last major episode of population movement from Southeast Asia to Melanesia, there is some evidence for continuing east-west interaction. In addition to finds of New Britain obsidian in Malaysia (Bellwood & Koon 1989) and Southeast Asian bronze artefacts in Irian Jaya and Manus (Ambrose 1988; de Bruyn 1959;

Elmberg 1959), there are similarities between art motifs and ceramics in Southeast Asia and those in both the Admiralty Islands and the Massim (Badner 1974; Egloff 1979; Golson 1971; Kennedy 1982). These and other possible links notwithstanding, there is no indication that late prehistoric developments in Southeast Asian had any great impact in Papua New Guinea, which has always surprised me (see also Bowdler 1993: 133-134), given the nature and extent of the changes in question (e.g. Bellwood 1985: 271 ff). Swadling's (1995) fascinating recent work on trade in Bird of Paradise plumes implies there may be more to be investigated than presently meets the eye, though this seems to me to be more likely in Irian Jaya than it is in Papua New Guinea, despite her conjectural connections with the Bismarck Archipelago.

5 CONCLUSION

Archaeological research over the last three decades has resulted in a number of significant and sometimes surprising discoveries concerning Melanesia's human past, especially in Papua New Guinea. It is still not possible, though, to write an integrated prehistory of any major part of the region, a problem made worse because the almost complete lack of research in Irian Jaya. It is there where critical evidence regarding initial colonization of the island as a whole and the highlands in particular will be found, where debate regarding the origins of Melanesian horticulture and pig husbandry can be advanced, and where research must be done to resolve questions of profound importance to our understanding of mid- to Late Holocene developments in coastal and island regions.

There is danger in holding Irian Jaya up as a critical testing ground in this way, of course, though not because it might lead to disappointment if the results we expect to find do not materialize. Rather, the danger lies in pre-determining too rigidly the questions that should be pursued in western New Guinea on the basis of what has been found (or not found) on the island's eastern half or adjacent archipelagoes, for this could blind us to unique features of Irian Jayan prehistory. Thus while observations in Papua New Guinea can serve as pointers to those interested in the archaeology of Irian Jaya, it should be kept in mind that the culture-historical and theoretical models based upon those observations are still evolving and should not be seen as standards with which to conform without critical reflection. This habit is inappropriate enough in Papua New Guinea itself without extending its application elsewhere (e.g. Ballard 1989; Golson 1996: 159-160).

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9

Bridging Sunda and Sahul: The archaeological significance of the Aru Islands, southern Moluccas

The productions of the Aru Islands offer the strongest evidence that at no very distant epoch they formed a part of New Guinea...having been separated by the subsidence of the great plain which formerly connected them with it.
Lord Alfred Wallace 1869: 373-374

1 THE MARITIME COLONIZATION OF SAHUL BY *HOMO SAPIENS SAPIENS*

The earliest evidence in the world for purposeful ocean voyaging comes from numerous Pleistocene-aged cultural deposits located within the Wallacean islands and Sahulland. It is assumed that these sites were produced by anatomically modern humans (Bowdler 1993; Davidson & Noble 1992). Despite claims for *H.erectus* in Sulawesi, Luzon, Timor and Flores, the age and contemporaneity of fossil and artefact assemblages remains unresolved (Allen 1991; Bartstra et al.1994; Keates & Bartstra 1994; Maringer & Verhoeven 1970; Morwood et al. 1997).

That these early maritime colonists from Southeast Asia utilized competent watercraft should be beyond dispute given the combination of early dates greater than 30,000 BP and degree of radiation to destinations such as Sulawesi, northern Australia and island Melanesia (Allen et al. 1988; Glover 1981; O'Connor 1995; Roberts et al. 1990). The settlement of Manus, an island in the Admiralties located 200 km from the nearest land, before 13,000 BP (Fredericksen et al. 1993), suggests some degree of sophistication in boat technology. It can be further argued that such technology would be rooted within a broad spectrum maritime economy which incorporated hinterland resources, as different landfalls were encountered.

The Aru Islands were connected to Greater Australia until approximately 8000 years ago, when they were separated by rising sea levels. While now forming part of the Indonesian province of Maluku (the Moluccas), for a long time they comprised an elevated land mass on the edge of the Sahul continent (see Fig. 1).

The presence on Aru of numerous marsupials and the cassowary attest to this shared history. Indeed the biogeographical significance of the Aru Islands has long been highlighted by naturalists such as Wallace (e.g. Ride 1972; Wallace 1869). While the waters to the east of the Aru Islands are relatively shallow, reflecting the previous landbridge with Irian and northwest Australia, the continental shelf to the west slopes steeply away with the 100 m isobath located as little as 10 km away. Due to their optimal position, the Aru Islands have the potential to register a multitude of maritime colonizing events through time.

Aru was part of a continuous landbridge to both Australia and New Guinea for at least the first 40,000 years of occupation of Sahul by *H.sapiens sapiens*. It is only by approximately 12,000 years ago that rising sea levels begin to encircle the island group, separating it from Australia, and possibly as late as 8000 to 9000 years ago that it was completely separated from New Guinea.

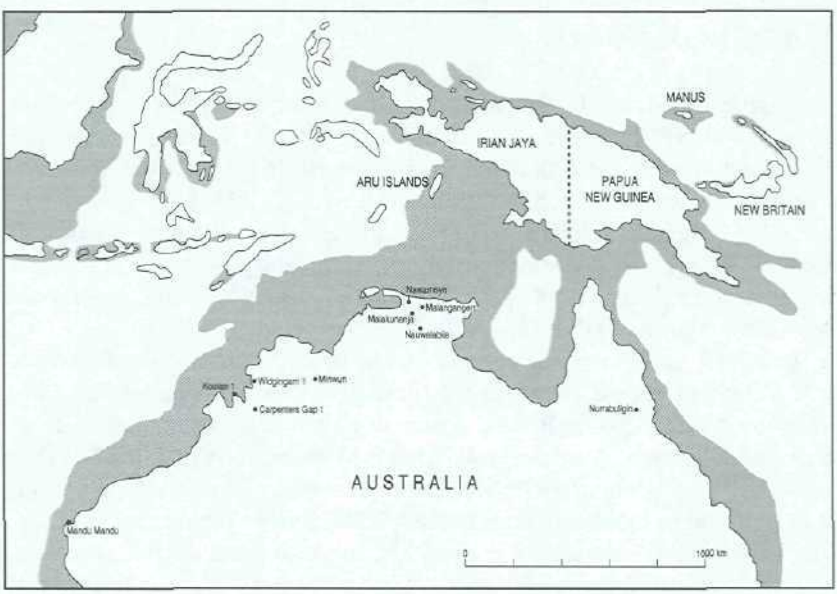

Figure 1. Location of key sites in Northern Australia, showing relative location of the Aru Islands.

2 THE ARU ISLANDS LOCATED ON A KEY COLONIZATION ROUTE

The Aru Islands and their now-inundated Pleistocene coastal plains are located on two of the major colonizing routes into Sahul, as proposed by Birdsell (1977: 122). Five possible colonizing scenarios were proposed in this seminal paper (see Fig. 2). The first route of interest passes through Maluku via Buru, Seram and finally the Kei Islands with a landfall directly on the Aru uplands. The second route passes along the Lesser Sundas to Timor then via Maluku through Wetar, Babar and Tanimbar with landfall on the Pleistocene coastline immediately southwest of the Aru group, perhaps within 100 km. The Aru Islands would have represented the only elevated land mass within a radius of approximately 500 km. The key point is that branches of both the postulated primary northern and southern colonizing routes pass through, or close to, the Aru Islands. This feature combined with the fact that they are positioned right on the edge of the Sahul Shelf make them prime targets for investigating initial and subsequent maritime colonizations.

The Aru Islands also have the advantage of being composed in part of limestone, with a substantial belt of karst located near the central western coast (see Fig. 1). Rockshelters and caves occur in the karst and the alkaline environment has the potential to provide excellent faunal and botanical preservation. In fact, the oldest radiocarbon dates for occupation of Australia, in the order of 40,000 BP, now come from a limestone cave located in the Kimberley Region of north-west Australia (O'Connor 1995). Another unique feature of Aru is the presence of substantial channels connecting the west and east coasts. These sungai not only connect major littoral zones, they also penetrate deep into the interior thereby providing easy access by watercraft to uplands and dense rainforest. The tidal channels have been formed either by jointing or by previous drainage (cf. Fairbridge 1966; Verstappen 1959).

3 AN OVERVIEW OF RESEARCH QUESTIONS IN MALUKU PREHISTORY

A number of authors have recently identified archaeological research questions for Maluku (Bellwood et al. 1993; Spriggs, in press). These may be summarized as:

1. The timing and source of Pleistocene settlement,
2. The nature of Austronesian settlement.
3. Papuan and Austronesian contact over the last 4000 years, and
4. The history of the spice trade with China, India and the West.

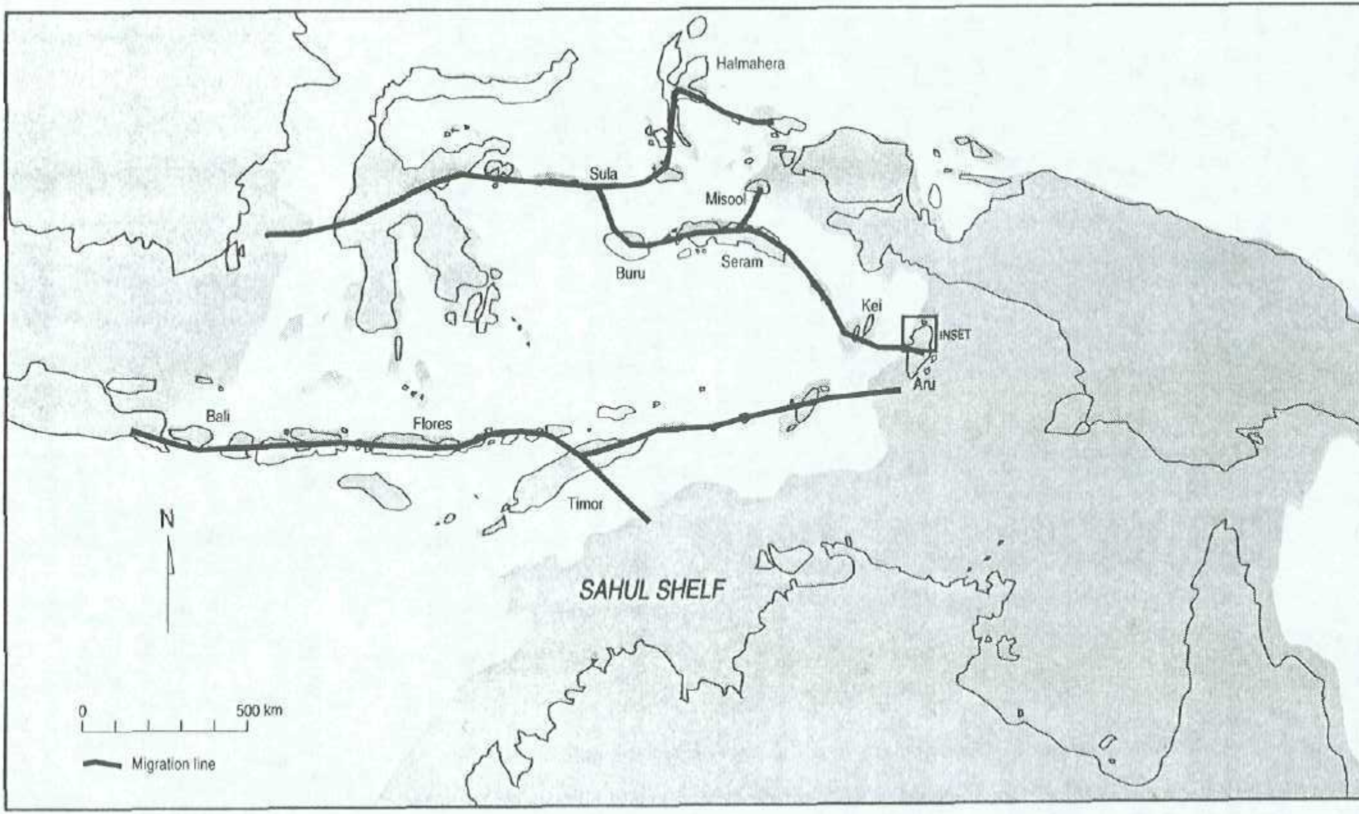

Figure 2. Alternate migration routes into Sahul showing the location of the Aru Islands. Extended landmass shaded to –150 m contour (after Birdsell 1977).

A number of salient points can be made at this stage to guide research on Aru:

Given that the Aru Islands lie along branches of both the major colonizing routes proposed by Birdsell (1977), and given the antiquity of thermoluminescence and radiocarbon dates available from Melanesia and Australia (Smith & Sharp 1993), a 55,000 year history for Aru is likely.

The widespread evidence for 'hunter-horticulturalism' (after Guddemi 1992) in New Guinea and Island Melanesia from at least 20,000 years ago is likely to be shared by Aru as it is within the range of a variety of important food plants, including sago. Hunter-horticulturalism describes an economy incorporating low intensity gardening and tree cropping, deliberate movement of plants and animals across water gaps to more impoverished environments and long-distance exchange of valued items (Spriggs 1996).

The dates for Island Southeast Asian Neolithic culture associated with agriculture and the spread of Austronesian languages suggest an age of 4500-4000 BP as likely for Neolithic settlement in the Aru group (Bellwood 1985; Spriggs 1989). Assemblages of Neolithic type pottery and domestic animals such as the (hybrid) pig, dog and chicken are to be expected.

The antiquity of the spice trade might be much older than the appearance of metal and Dongson bronze drums in Maluku and the Bird's Head which, along with references in Chinese and Classical sources, are usually taken to mark its beginning about 200 BC (Swadling 1996: 22, 51-61). Dates of 3710-3550 BP have been claimed for cloves recovered from the ancient city of Terqa on the Middle Euphrates (Bucellati & Kelly-Bucellati 1977, 1977-1978). The significance of these dates is that they are from a period soon after Austronesian expansion. Spriggs (in press) has speculated that in fact part of the reason for Austronesian expansion may have to do with the extension of trading networks already operating on an (Old) World scale. At this time the Austronesian sphere ran north through the Philippines, Taiwan and into South China.

The identification of the Terqa find as cloves has, however, been disputed by other scholars (C. Lamberg-Karlovsky, pers. comm. 1996). As Swadling notes (1996: 22), written sources relating to cloves do not begin until some 1500 to 1700 years later.

Whether the spice trade began nearly 4000 or 2000 years ago, the archaeology of the Portuguese and Dutch colonial period must be seen as an appropriation of a much earlier global trading system. To spices, Swadling would add Birds of Paradise plumes as an early and significant component of this trading system. Aru was a probable early supplier of such plumes (Swadling 1996: 62).

4 SHARED HISTORY BETWEEN ISLAND SOUTHEAST ASIA AND SAHUL: THE AUSTRALIAN PERSPECTIVE

4.1 *The earliest dated occupation in northern Australia*

The date for initial occupation of Sahul is still unresolved and the search for the elusive oldest sites continues. Unlike the northwest coast of Aru, the majority of the north and northwest coastline of Sahul is broad and shallow (see Fig. 3). The most recent research into sea level changes in

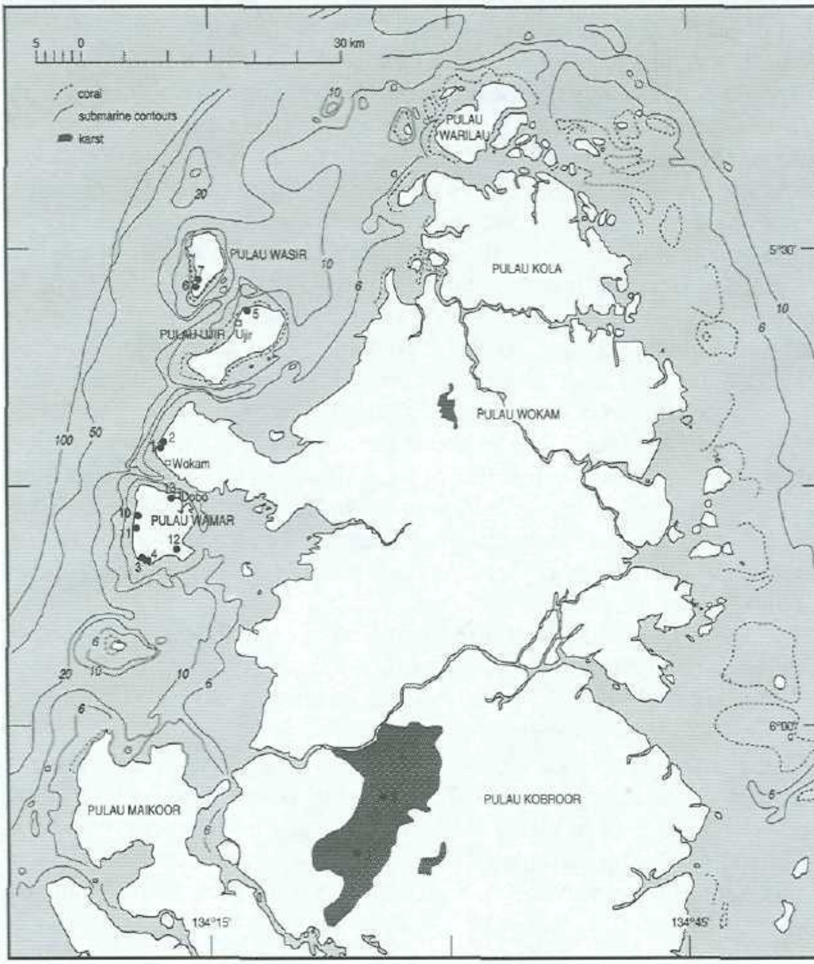

Figure 3. Northern portion of the Aru Islands showing location of key sites mentioned in text.

the Australian region indicates that between 40,000 and 70,000 BP the sea level has been between -50 and -90 m below its present position (Chappell 1994).

This means that the earliest evidence for colonization will now be submerged and the earliest date for colonization probably unknowable. For example, the archaeological sites of Nauwalabila and Malakunanja, currently the oldest sites in Australia (see Fig. 3), are located approximately 120 and 60 km respectively from the present coastline and would have been up to 200-300 km inland at time of their initial occupation.

Most Australian researchers place the date for initial occupation sometime between 40,000 and 70,000 years ago, the difference of opinion arising from the dates obtained using the radiocarbon versus the optical luminescence (OSL) and thermoluminescence (TL) dating techniques. Many sites and complexes in Australia now demonstrate definite dated evidence for human occupation in the order of 35-40,000 years ago. Dates of between 53,000 and 60,000 BP have been obtained using thermoluminescence and optical luminescence dating of sediments (Roberts et al. 1994a, b), while the earliest radiocarbon dates are still in the order of 40,000 BP. However there are firm reasons to believe that the radiocarbon technique reaches an effective barrier at c. 40,000 BP (Chappell et al. 1996), and while some members of the archaeological community believe that the current TL and OSL dates need further substantiation (Allen 1994; Allen & Holdaway 1995: 106; Hiscock 1990), the date of 50,000-60,000 is widely accepted for arrival of humans in Australia. The resolution of these dating problems will obviously determine the rate at which new adaptations are seen to take place.

4.2 *The nature of Pleistocene subsistence in northern Australia*

Due to poor preservation conditions, there are few Pleistocene sites with faunal remains, and so assessing the nature of the subsistence base is often difficult. Those that do preserve faunal material to their Pleistocene levels, however, evidence a broad-based economy that incorporated both marine and terrestrial components. The Kimberley sites Koolan Shelter 2, Widgingarri Shelter 1 and Carpenter's Gap I (see Fig. 3) all preserve fauna to levels dated to 30-40,000 BP (O'Connor 1990, 1995). The faunal remains in all three sites indicate that the economy was terrestrially focussed and broad-based, as they include small, medium and large macropods, possum, bandicoot, freshwater turtle, reptiles, rodents, and bird eggs.

As all three sites were located well inland relative to the position of the coast the lack of marine focus is not unexpected. Small fragments of pearl shell, baler shell and worked sea urchin spine indicate that contact with the coast was maintained, at a time when the sea was some 200 km distant. In view of the distance, however, it seems extremely unlikely that such contact was direct, and it is more likely that the shell was being traded inland 'down the line' in much the same way as it is today (Akerman 1973). Nurrabullgin Cave in Cape York also preserves humanly-derived faunal material in the Pleistocene unit (David 1993). Like the Kimberley sites it contains a broad range of small to medium sized macropods, rodents and reptiles.

Mandu Mandu Rockshelter at Northwest Cape (see Fig. 3) is a site on the northwest Australian coast that might be expected to provide a window into coastal land use in the Pleistocene. This region is unique in Australia as the continental shelf comes close to the present coastline and all phases of human occupation of the coast would never have been over 10 km distant from its present position. North West Cape has a Pleistocene unit falling between the dates of 19,000 and 35,000 BP associated with faunal remains. Small quantities of marine shell, other marine fauna and small terrestrial species are represented in this unit (Morse 1988). In general the picture is one of a generalized subsistence base utilizing both the marine environment and the immediate hinterland surrounding the site. Morse (1993) has also recovered a shell necklace from the lowest Pleistocene levels.

While Lourandos (1985: 392) has argued that some eastern Australian shelters show 'a trend from less complex early economies (based on a restricted range of resources) towards an expansion (with broad-based marine, estuarine and terrestrial resources) in the last few thousand years', this supposed trend is not found in the faunal data presently available in the early northern Australian sites.

4.3 *The early stone tool assemblages: Southeast Asia and northern Australia*

The earliest Australian stone tool industry has been called the Australian Core Tool and Scraper Tradition (White & O'Connell 1982: 65). Despite this label, large cores, scrapers and pebble tools are notably poorly represented in northern Australian assemblages and arguably in the earliest Australian assemblages generally (cf. Barton 1979: 67-8; David 1993; Davidson 1935: 159; Dortch 1977: 121; Flood 1967: 25a, 27-9; McCarthy & Setzler 1960: 275; O'Connor 1990).

The northern Australian Pleistocene assemblages are comprised almost entirely of small unretouched and retouched flakes. The only distinctive component of these assemblages is the edge-ground axe or hatchet, or flakes from these tools, which appear in the earliest levels of most sites.

Nawamoyn and Malangangerr rockshelters in western Arnhem Land in the Northern Territory exemplify this trend (see Fig. 1) (Schrire 1982). At Nawamoyn 2361 flaked stone artefacts were recovered from the deposit, of which 109 (4.6%) are implements and 2252 are unretouched flakes (95.4%). With the exception of the edge-ground axes, the implements are almost exclusively made on flakes. Pebbles were recovered but all had signs of wear indicative of their use as hammerstones. Only one had been flaked (Schrire 1982: 136-138). Most of the unretouched flakes are less than 2 cm in length (Schrire 1982: 129-30).

At Widgingarri Shelter 1, Koolan Shelter 2 and Carpenter's Gap Shelter I in the Kimberley region (see Fig. 3), the lithic assemblages consist almost exclusively of flakes, broken flakes and debris. Retouched tools comprise amorphous retouched and utilized flakes, most of extremely small size (maximum dimensions of less than 2 cm) (O'Connor 1990; see also Dortch 1977: 121). Widgingarri 1 also contains characteristic flakes from edge-ground hatchets. These appear in the lowest levels below the date of 28,000 BP. Pebble tools are entirely absent (O'Connor 1990).

Looking to the northeast we find the picture is much the same. Nurrabullgin Cave in Cape York has a lower unit dating to greater than 37,170 BP. The assemblage is typified by small unretouched flakes and other debitage made on porphyritic rhyolite. Large pebble-based implements are absent (David 1993).

From this overview we can safely say that the early northern Australian assemblages are flake and flake tool dominated, largely lacking even the emphasis on core tools and specialized scrapers claimed for southern Australia. We can, however, see definite connections between the pre-Hoabinhian industries from mainland Southeast Asia and those of northern Australia. The principal discordant feature between the pre-Hoabinhian Southeast Asian assemblages and those in northern Australia is the presence of edge-ground axes in the latter.

Early interpretations of the patterning of Southeast Asian stone assemblages describe two major archaeological traditions in the area from central China to island Southeast Asia during the Late Pleistocene (Bellwood 1985). The chopper pebble tool tradition was believed to have been the earliest tool type used in mainland Southeast Asia pre-dating the appearance of modern *H.sapiens* (although the evidence for this is extremely tenuous). A flake tool tradition subsequently evolved in South China and replaced the pebble chopper tradition, spreading to island Southeast Asia via the exposed Sunda Shelf but by-passing present day mainland South east Asia (Glover 1973).

The important issue here is that a pebble tool tradition is seen to have persisted in mainland Southeast Asia from the Pleistocene and into the Holocene, experiencing only minor modifications through time. The longevity of the pebble chopper tool suite in mainland Southeast Asia has been argued to demonstrate its success as a generalized tool suite which would have been augmented by other tools made of perishable materials.

In an innovative review of Southeast Asian assemblages Anderson (1990) has challenged earlier interpretations of the Southeast Asian prehistoric record. On the basis of the Lang Rongrien Rockshelter sequence (Anderson 1987, 1988), he (1990) argues that flake tool industries, not pebble tool industries, characterize the Upper Pleistocene of Southeast Asia. The pebble tool industries are, he suggests, merely recent interlopers into what is essentially a flake and flake tool tradition.

Assemblages with Hoabinhian characteristics are restricted in time and space. They generally do not occur in island Southeast Asia (apart from Sumatra) and where they do occur in mainland Southeast Asia they are preceded by an earlier flake dominated industry consisting of small retouched and unretouched flakes, much like those in northern Australia. The Hoabinhian is therefore clearly unrelated to the putative earlier pebble tool industries but is rather a later specialization.

If we look afresh at the Australian picture we see a similar trend to that outlined by Anderson for mainland Southeast Asia and common to island Southeast Asia. The archaeological record of Australia in the Pleistocene may also be seen to demonstrate a period of continuity characterized by generalized flake tool assemblages.

In northern Australia as in island Southeast Asia there is a basic continuity in the flake tool industries, with the addition of some later specialized forms and regional variants in the terminal Late Pleistocene. The Hoabinhian is possibly merely one such response, just as the core tool and scraper is in southern Australia, possibly axes in northern Australia and thumbnail scrapers in Tasmania.

In the Upper Pleistocene we have a generalized industry which is predominantly flake-based and can be readily adapted to different raw materials and environments. The earliest Upper Pleistocene assemblages associated with *H.sapiens sapiens* in island Southeast Asia, mainland Southeast Asia and northern and southern Australia can be seen to encapsulate this generalized colonizing strategy. The later terminal Pleistocene/Holocene industries in Australia, island Southeast Asia and mainland Southeast Asia begin to show differentiation and unique responses to increasingly diversified environments.

5 RESULTS OF THE 1995 RECONNAISSANCE SURVEY OF ARU

Initial reconnaissance surveys were focussed on the northwest islands as these lay closest to the edge of the Continental Shelf and were therefore more likely to provide stratified sites with the oldest and most continuous occupation sequences. These islands comprised Kobroor, Wamar, Wokam, Ujir and Wasir (see Fig. 1). A considerable amount of time was spent liaising with kepala desa (village leaders) and communities towards a thorough explanation of our long-term objectives and in order to identify any known sites. During interviews it became obvious that the general term for cave, goa, might include a range of caves and shelters many of which simply held birds nests or bat colonies.

The term lia or liang was held to more accurately represent an occupation site or a cave connected with religious custom, or adat. After travelling to islands from the capital Dobo, the general strategy was to carry out formal discussions and interviews, address adat issues and then carry out systematic surveys and site inspections with community representatives.

It should be noted here that most of the limestone formations surveyed on the islands were found to be unsuitable for cave/rockshelter formation and if these latter were located, they were either post-transgression sea caves of recent origin or contained running water and thus were unsuitable for human occupation. Our initial strategy to target cave sites on the northwestern islands closest to the edge of the Continental shelf in the hope of finding evidence of early occupation thus proved unsuccessful. Suitable caves in this part of Aru appear to be restricted to the karst formation (see Fig. 3).

A total of 13 sites were recorded on the five islands. These included two substantial caves with cultural deposits, three further caves of primarily religious significance containing Chinese and Dutch porcelain, five midden complexes, at least three of them with associated pottery, a substantial 'Islamic' settlement with an associated shipwreck, and an early Dutch fort (originally built c.1650 AD) and nearby stone church. These sites have the potential to address the key research areas as outlined above.

6 CAVE/ROCKSHELTER SITES

6.1 *Liang Lemdubu (Site 9)*

This is a very large and elevated cave on Pulau Kobroor located within karst limestone and surrounded by dense rainforest. It appears to be comprised of an ancient subterranean river channel which is now truncated (thereby providing an entrance at each end) and representing a high point within the local landscape.

The cave may be approached by boating to the upper reaches of Sungai Papakula, and then by a three hour walk through rainforest. The cave has adat significance as a source of sacred water which drips from the roof, and is still periodically visited by hunting parties. Its maximum dimensions are approximately 30 m in length, 9 m in width by 4 m in height.

The cave contains substantial sedimentary deposits with surface expressions, and some erosional exposures of fauna (including macropod), mangrove shellfish (*Geloina* sp. and *Anadara* sp.), low-fired earthenware pottery as well as Chinese and Dutch bowls and plates into which the sacred water drips. This site has the greatest potential to yield a long cultural sequence.

6.2 *Liang Lisaibam (Site 8)*

This cave also on Pulau Kobroor is a smaller version of Lemdubu. It is located only 300 m from the nearest sungai and has maximum measurements of approximately 15 m in length, 5 m in width and 2 m in height. It has well developed middens at its entrances containing the mangrove shellfish *Geloina* sp., *Terebralia* sp. and *Anadara* sp., as well as earthenware pottery and Chinese porcelain sherds. The most remarkable feature of the cave is the plethora of engravings on most of its surfaces. Motifs include abstract geometrics, anthropomorphs and stylized feet/hands, naturalistic representations including marine craft (specifically perahu) and what appears to be writing in Arabic script.

6.3 *Liang di Karkur, Liang Belnarnar and Liang Batul Bakar (Sites 4, 6 and 7)*

All three of these caves/rockshelters are associated with adat ceremonies and contain either burials, Chinese and/or Dutch porcelain or engravings above their entrances in Arabic script. They contain limited occupation deposits, and because of this and their adat significance will not be excavated.

6.4 *Discussion of cave sites*

The two caves in the karst limestone provide excellent sample points for describing occupation both adjacent to and considerably removed from the channels or sungai. The presence of mangrove shellfish at the interior cave is particularly of interest given the early observation by Wallace (1869: 343) that 'Those who live on the coast have plenty of fish; but when inland...[they] go to the sea occasionally, and then bring home cockles and other shell-fish by the boatload'.

He noted further that the diet of the interior groups was largely based on plants and comments 'Now and then they get wild pig or kangaroo, but too rarely to form anything like a regular part of their diet, which is essentially vegetable...e.g. plantains, yams, sweet potatoes and raw sago; sugar cane, betel nuts, gambir and tobacco' (Wallace 1869: 343).

During times of lower sea levels when Aru was joined to New Guinea and Australia the sites of Lemdubu and Lisaibam may have been located as much as 40 km inland from the Pleistocene coastline. The role of the sungai is significant at this time as they would have represented drainage systems and routes of access into the interior. It is worth noting that many faunal species of economic importance are found in the interior. Wallace (1869: 333) notes 'To the mainland many of the birds and murids of the country are altogether confined; the Birds of Paradise, the black cockatoo, the great brush turkey, and the cassowary are not found on the detached islands'.

Of equal interest is the fact that Liang Lemdubu is located within dense rainforest in an area receiving over 5000 mm per annum. It has been argued by Bailey et al. (1989) that globally there is no firm evidence for systematic exploitation and occupation of rainforest systems in the Pleistocene. More recently, this view has been contradicted by evidence from the interior of New Britain in island Melanesia that human occupation of rainforest environments in this region goes back to at least 35,000 BP (Pavlides & Gosden 1994). Bellwood et al.(1993) have promising evidence from Halmahera for such an adaptation in the Early Holocene. It will be interesting to see if Liang Lemdubu shows a similar pattern of early inland rainforest occupation.

7 OPEN MIDDEN SITES WITH ASSOCIATED POTTERY

Such sites were observed to be common on Wamar Island in coastal and near coastal situations. Construction of the Dobo to Durjela vehicle track disturbed several middens near the village of Wangil (Site 10). Examination of areas where sand is currently being quarried on a small-scale near Wangil revealed red-slipped pottery sherds, some of complex vessel form, in a shell midden layer containing *Anadara* sp. and *Telescopium* sp., as well as turtle and large fish bones. On the surface of adjacent fields a sherd from a Chinese tempayan or water jar and a piece of metal were found. It is not at all certain whether they are associated with the main midden deposit.

Shell midden mounds were observed among the houses of Durjela village and appeared to predate the current village (Site 11). South of Durjela on a walking track close to the shoreline we visited an old village site in a cassava garden, called Karkur (Site 3). The site was marked by marine shell, earthenware pottery, some red-slipped, a stoneware tempayan sherd and an iron knife. The site probably dates to the last few centuries. The site is 200 m north of Liang di Karkur.

Near the south coast of Wamar, along a vehicle track to the Pertamina oil complex and along a secondary vehicle track from it to Dibelakang Wamar village, were observed multiple shell midden exposures associated with fossil beach ridge systems (general site number, Site 12). Clearly there has been significant coastal progradation over time in this area. The area would repay further study as having the potential to provide a sequence of sites associated with beach deposits of different ages postdating sea-level stabilization.

Within the town of Dobo itself, there are scattered shell midden deposits exposed in the main football field adjacent to the Fany Hotel near the beachside memorial to the Battle of the Aru Sea. No pottery was observed in the exposed areas at this site (Site 13).

Bad weather prevented more detailed examination of the Wangil and Durjela middens, and only passing observations were made of the other surface sites. These sites have the potential to illuminate the last 4000 years or so of Aru prehistory, but may turn out to be quite recent in age. The red-slipped pottery, at least superficially, resembles that known from Early Neolithic contexts in the Philippines and Eastern Indonesia (Bellwood 1985: Chapter 7).

8 'ISLAMIC' SETTLEMENT, UJIR (SITE 5)

In secondary forest adjacent to the present village of Ujir on Ujir Island are the remains of a remarkable settlement site, consisting of structures made of coral blocks, some of more than 2 m wall height, which are plastered. The plaster bears non-figurative designs in relief. The structures are generally only a few meters square and some did not have any obvious entrance doorways. They had small windows, some of semi-circular form with designs surrounding them on both the inside and outside. It is possible that these structures were entered via the roof.

Although described locally as a 'Portuguese Fort', the style of the structures and the non-figurative art would suggest an Islamic inspiration. It is possibly the site of a Malay or Macassan trading post. Historical research may reveal more about the origins of this substantial settlement. It is called Mai Abil, meaning 'deep river' and there is a substantial sheltered harbour adjacent to the site. The site warrants further investigation. It is used as a source of stone by local villagers and so is under active threat at present.

The traditional site of Ujir village is said to be nearby, with a mosque site that is on the harbour shore. A cannon is presently located near the present mosque in Ujir village and a cannonball and anchor are said to be found on the other side of the harbour from the village.

9 DUTCH FORT AND CHURCH, WOKAM (SITES 1 AND 2)

The first fort on the site was built sometime after 1650 AD. It is known locally as Kota Lama Wokam (Wokam old village). It is under the custodianship of the Education Department and is occasionally visited by tourists. The fort is adjacent to the beach and commands the entrance to the channel between Wokam and Wamar Islands. The coral block walls are in generally good condition, and measure approximately 50 by 35 m with the longest axis parallel to the beach. There are remains of corner bastions, and attached to the west, sea-facing wall is a rectangular blockhouse.

Among the internal structures are a stone-walled building in the southern half of the fort with five internal rooms and with its external walls well-preserved. Foundations of another stone building are also visible in the southern half of the fort. In the northeast corner is a stone-lined well. Coconuts have been planted within the walls. There is an entrance on the sea side immediately south of the blockhouse and a blocked larger entrance opposite it in the east, inland side with door slots preserved. Porcelain and bottle glass sherds are found inside the fort and there are dumps of porcelain and bottle glass outside the fort to the east, and between the fort and the church.

South of the fort are the remains of a stone church, with its walls remaining to the full height. The church has three windows on each side and a small door to the seaward side as well as a larger one at the inland, eastern end. The present site of Wokam village is immediately south of the church site. Valentijn (1862 [1722]: III: 36-8) described Wokam as the main village in the Aru Islands and noted that around 1700 AD there were a sergeant, a corporal and 10 or 12 soldiers stationed in the fort.

10 CONCLUSIONS AND FUTURE PLANS

This first reconnaissance survey has located a total of 13 significant sites which have the potential to address the key research questions identified for Maluku. Sites are likely to yield occupational sequences dating from the terminal Pleistocene through to the present. Given the unique location of the Aru group, investigations will most certainly provide valuable insights into the genesis and evolution of maritime societies from the earliest colonists to the Austronesians and then later regional powers. We have received an Australian Research Council Grant to conduct major field seasons on Aru from 1996 to 1998. This work will be carried out in conjunction with the National Research Center of Archaeology (Jakarta), and with the 'Universitas Pattimura' as the host institution.

Our work on the islands of the north-west, closest to the edge of the continental shelf, has indicated that prospective caves and rockshelters do not exist in this part of Aru. Suitable sites were only located within the interior limestone karst country, and even there they were uncommon. It is clear that survey needs to be widened to all parts of Aru.

A range of sources and observations made during the 1995 survey indicate there is a gradient in rainfall and vegetation assemblages from north to south through the island group. It is likely that the more open savannah country of the south will have hosted a different fauna and offered different dietary choices. We will aim to locate and excavate sites which form a transect through the various environmental zones. There is also a need for palynological studies to examine climate history and characterize the impact of humans on vegetation. Coring for prospective palynology is planned for the 1997/1998 field season in Aru. A number of interior swamps have been identified both within the rainforest covered limestone karst of the northern portion of the islands and within the open woodland systems of the southern section. Some of these should be suitable for a remote area coring operation (G. Hope, pers. comm).

We expect the cave sites to contain cultural sequences with dietary shellfish back to the earlier levels. They should have a sequence with mangrove shells dating back to the flooding of the sungai, perhaps 6-8000 years ago, and riverine species present before this date. There should be changes in terrestrial fauna both before, and after, the islandization of Aru. The appearance of pig, dog and chicken in Neolithic assemblages will have later been supplemented by deer, perhaps by about 2000 years ago.

Two excavations were carried out in the Liang Lemdubu in October of 1996. The densest concentrations of cultural materials on the extensive sediment floor of the cave are located near both of the driplines. Material includes shell midden, including the mangrove species *Geloina* sp., *Anadara* sp. and *Terebralia* sp. Plain earthenware was also present, although in low numbers. Terrestrial fauna noted on the surface included deer, pig, kangaroo and possibly cuscus. A low density of stone artefacts were recorded, although it became clear that many of the large *Geloina* valves had been retouched/utilized and had therefore probably also served as artefacts.

Our initial assessment was that the deposits immediately inside the driplines at both ends of the cave were likely to be the deepest and the least disturbed by water action, roots and major roof falls events. Our method was to excavate in 5 cm spits, wet-sieving all materials through fine mesh (1.5 mm), record volumes of recovered materials and to sort all cultural residues. Initially a 1×1 m test-pit (Test-pit 1) was dug at the west end of the cave. This reached bedrock at approximately 50 cm below surface level. The test-pit revealed a homogeneous loose grey-brown sediment which changed to an orange-brown mottled clay immediately above bedrock. The Upper Unit contained charcoal, terrestrial fauna, earthenware, marine shellfish, a fragment of metal and stone artefacts. The Middle Unit lost the shellfish but contained terrestrial fauna, stone artefacts and minimal charcoal while the Lower Unit comprised a sparse assemblage of fauna and the occasional stone artefact. From this first test-pit it became apparent that the deposits of Lemdubu contain a phenomenal quantity of terrestrial fauna, reflecting resources from a wide range of habitats within the rainforest system.

Test-pit 2 was located near a massive in situ boulder at a mounded portion of the deposit at the eastern end of the shelter. To some extent this excavation represented an expanded version of Test-pit 1. The excavation of 1 × 1 m reached sterile deposits at >160 cm below surface level and contained a remarkable quantity and range of terrestrial fauna. For example, Spits 24 and 25 each yielded 14 medium-sized bags of bones. Much of this material is in a good state of preservation and includes a substantial amount of cranial material and teeth which may be used to identify species and possibly indicate the existance of now extinct species. As expected, a major marsupial component was seen through the presence of small to medium sized wallabies (macropods), cuscus (phalanger), bandicoot and native cat (dasyurids). Lizards, snake, cassowary (both bone and shell) and dog are also present. The faunal assemblages represent the most extensive and dense ever experienced by the researchers in the Indo-Pacific region.

Dating the deep deposits of Test-pit 2 will be facilitated by the presence of charcoal and marine shellfish down to Spit 7, the occasional occurrence of marine shell or charcoal through to Spit 25 and two flowstone features which occur between Spits 27 and 30. Fauna appears to have been discarded due to human agency down to Spits 28/29. The minimal faunal remains from basal Spits 30 and 31 is assumed to be due to natural agencies. The lowest stone artefact was recovered from Spit 29 and this is bracketed by the lower flowstone layer.

While it is impossible to meaningfully estimate the age of the deposit, the fact that marine shellfish are effectively lost by Spit 8 (ca. 6500 BP?) and that geological features (two separate flowstone layers) bracket the base of the deposit and that the faunal assemblage is extremely dense, does suggest a Pleistocene antiquity for the site. Key samples of marine shellfish and charcoal have been submitted for AMS dating, following removal of modern organics using novel techniques at the Australian National University (J. Head, pers. comm.).

The excavations have also yielded sizeable assemblages of stone artefacts which may also be reliably dated through time. There appear to be long-term continuities in the technology of artefact production, in that the industries are essentially percussion flake based, with the modified component represented simply by retouched/utilized flakes. There are no grounds to argue for specialized scraper categories or the later appearance of a small tool component, and certainly no indication of the Hoabinhian. There do appear to be consistent changes in the dominant lithologies used through time, however, with silicified calcretes, cherts, silcretes, chalcedonies and even possibly obsidian, all making an appearance. The flaked stone technology is therefore very similar to key Pleistocene sites excavated from Northern Australia (cf. papers in Veth & Hiscock 1996).

Our field observations suggest that Liang Lemdubu is a most significant site for understanding the shared history of northern Australasia and island Southeast Asia. It will likely provide early dates for the systematic exploitation of rainforest ecosystems (see also Pavlides & Gosden 1994), show shared material cultural attributes with early sites in northern Australia and witness the deliberate use of hinterland resources by coastally adapted peoples.

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10

A discussion of the evidence for early hominids on Java and Flores

1 INTRODUCTION

In the past few years new dates have been published on the antiquity of the earliest hominids in island Southeast Asia. The revised chronology suggests that Java, Indonesia, was first colonized at about 1.81 or 1.66 million years ago (Swisher et al. 1994; Swisher 1994). This would mean that early hominids migrated from Africa to Southeast Asia up to 800,000 years earlier than to other regions in the Far East. It has also been proposed that stone artefacts discovered on the island of Flores, Nusatenggara (Lesser Sunda Islands), Indonesia, demonstrate occupation by *Homo erectus* in the early Middle Pleistocene (Van den Bergh et al. 1996a). The presumed age context of the Flores artefacts and early hominid sea-travel seems to call for a radically new view of early hominid capabilities and capacities not only in island Southeast Asia, but also in other Palaeolithic regions.

This article will address the evidence put forward for the earliest proposed hominid occupation of island Southeast Asia, and specifically of the island of Flores, with an examination of the various data presented and associated.

2 JAVA

2.1 *Context and chronology of early hominids in Java*

New radiometric dating has produced mean ages of 1.81 ± 0.04 million years for *Homo erectus* at Mojokerto (Perning 1 hominid) in East Java and 1.66 ± 0.04 million years at Sangiran (S27 and S31 '*Meganthropus*' sp. hominids) in Central Java by Swisher et al. (1994; see Fig. 1). Prev-

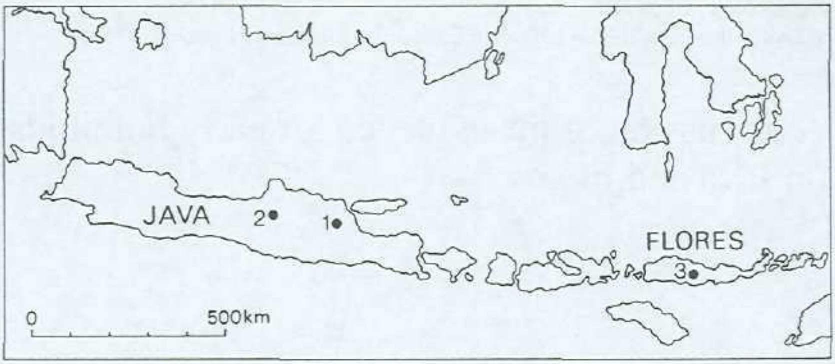

Figure 1. The location of 1. Mojokerto, 2. Sangiran in Java and 3. Mata Menge in Flores, Indonesia.

ious to the new dates, the chronological evidence indicated that the earliest hominids, i.e. *Homo erectus*, first colonized the Far East at approximately 1 million years ago (e.g. Pope 1983, 1988a; Matsu'ura 1982; and see below) based on multidisciplinary studies of Pleistocene deposits in Central and East Java (e.g. Watanabe & Kadar 1985; see below). The new dates were obtained by $^{40}Ar/^{39}Ar$ laser-incremental heating analyses of hornblende from pumice tuffs (Swisher et al. 1994). The Mojokerto dating samples derive from the stratum thought to have been the parent layer of the hominid and also from volcanic clay layers occurring within the 'conglomeratic volcanic sandstone' of this stratum (Swisher et al. 1994: 1119). The pumice from the hominid layer is comparable to that found in the Mojokerto cranium; pumice from the cranium could not be used for dating (Swisher et al. 1994). At Sangiran the samples were collected from 2 m above the hominid stratum from a 'pumice-rich layer' (Swisher et al. 1994: 1120). Both the Mojokerto and the Sangiran strata are assigned to the Pucangan Formation (Swisher et al. 1994). Swisher et al. (1994: 1119) assert that their mineral samples were selected from '...volcanic units in direct association with the hominid find sites, thus avoiding circuitous age guesses based on regional lithologic correlations'.

The first assertion of 'direct association' has been criticized because of the questionable stratigraphic provenance of the samples used (De Vos & Sondaar 1994). There is also the possibility of redeposition of the conglomeratic volcanic sandstone of the Mojokerto sample (De Vos & Sondaar 1994). It has also been stated that 'The matrix from which the dated crystals [of the supposed Perning 1 hominid locality] were taken is time-transgressive and Eocene foraminifera are present in the matrix'

(Pope 1996). Geomorphological and biostratigraphic analyses have often shown that reworking and redeposition of sediments in Javanese deposits can produce inaccurate chronologies (e.g. Bartstra 1983a, 1985; Pope 1988a).

Thus, the most serious problem with the new dates seems to be that the dated sediments may bear no relationship to the age of the hominid fossils. It has been pointed out previously that it remains uncertain which deposit the Mojokerto hominid derives from (e.g. De Vos 1985; Pope 1983, 1988a), and no consensus has been reached with regard to the locality or layer of the Mojokerto hominid. Sartono (1985) favours a (Middle Pleistocene) Kabuh derivation for Mojokerto (see also Sartono et al. 1981). The S27 '*Meganthropus*' hominid fossil derives from the Pucangan Formation according to Jacob (1980), while Sartono et al. (1981) place S27 and S31 in the younger Kabuh Formation. The palaeomagnetic stratigraphy of Hyodo et al. (1992, 1993) places Mojokerto and the Pucangan Formation in the Jaramillo Event and Sangiran to within and above the Jaramillo, and thus younger than 0.990 million years ago (according to the most recent palaeomagnetic scale, Valet & Meynadier 1993). Bartstra (pers. comm.), based on years of fieldwork, has expressed doubt regarding the interpretive value of chronological identification of palaeomagnetic events in Java.

The Swisher et al. (1994) chronology does not agree with the fission-track dates of Suzuki et al. (1985) and the palaeomagnetic stratigraphy of Hyodo et al. (1992, 1993) which correlate and suggest an age context of below 1 million years ago (De Vos & Sondaar 1994). It also conflicts with the proposed age by Van den Bergh et al. (1996b) for the earliest Javanese at 0.900-1.200 million years ago.

The second assertion argues that only 'regional lithologic correlations' have been available for dating the Mojokerto and Sangiran localities before Swisher et al.'s (1994) work. This ignores geological, faunal, including foraminiferal, and fluorine analyses and fission-track and palaeomagnetic dating conducted in Java during the past decades and consistency overall in dating results (e.g. Watanabe & Kadar 1985; Pope 1988a; De Vos & Sondaar 1994).

Apart from the rejection of previous work, acceptance of the new dates for Mojokerto and Sangiran would have several other implications. They would indicate that during this time period the Sunda Shelf was dry land providing an opportunity for hominids to colonize Java. Maximum exposure of the Sunda Shelf (i.e. lowest sea-levels) during the Late Pliocene and Early to Middle Pleistocene according to micro-palaeontological and deep-sea core oxygen-isotope analyses occurred at c. 3, c. 1.250, c. 0.900-0.800 million years ago, and from c. 0.650-0.450 million years ago (Berggren & Van Couvering

1979). Low sea-level conditions are also thought to have occurred at about 2.5 million years ago (Sémah & Sémah 1991). These dates suggest that Pleistocene Java was not accessible to hominid migration between c. 2.5 and 1.250 million years ago which on this basis would invalidate the new dates. Non-hominid species may have been able to cross the water-barrier (Pope 1988a; Shutler & Braches 1988). The new dates would furthermore suggest that the earliest Far Eastern hominids colonized Southeast Asia almost 1 million years before migrating northwards, i.e. to what is now the People's Republic of China with a similar late Early Pleistocene basal age for the earliest hominids as Java where the Gongwangling (Lantian) hominid locality in central China at c. 1 million years ago (see Wei 1995; and see An et al. 1990 for their age estimate of 1.15 million years ago) and the Donggutuo and Xiaochangliang (Nihewan Basin) cultural sites in northern China at c. 1 million years ago (Pope & Keates 1994) have afforded the earliest evidence. Swisher et al. (1994: 1121) also contend that the lack of Acheulean technology in 'Asia' can be explained by hominid migration to the Far East predating the emergence of the African Acheulean at 1.4 million years ago based on the new dates for Mojokerto and Sangiran. A provisional age for handaxes recovered from sites at West Turkana, however, now dates the basal Acheulean in Africa to 1.7/1.6 million years ago (F. Brown in Roche & Kibunjia 1994). Meaningful interpretations of Far Eastern hominid technology must incorporate the palaeoenvironmental and palaeoecological evidence (e.g. Pope 1988a; contra Swisher et al. 1994). The greater time depth of Javanese hominids proposed by Swisher et al. (1994) would suggest a very slow increase in hominid endocranial capacity.

A note on the taxonomy and age of the '*Meganthropus*' hominid specimens. The S27 (Jacob 1980; Sartono 1982) and S31 (e.g. Sartono 1982) fossils supposedly represent this 'taxon', but until more information becomes available on the anatomy of these hominid specimens it is not possible to make an independent interpretation of their taxonomic and phylogenetic status. Using multivariate and cladistic analyses, Kramer & Konigsberg (1994) conclude that Sangiran 6 is within the range of variation of *H.erectus*, but anthropologists have yet to agree as to what '*Meganthropus*' represents (Pope 1988b). The size and robusticity of Sangiran 5 (cf. Sangiran 5 and 9 in Franzen 1985; Fig. 2) and Sangiran 6 (? and S8) may be attributable to insularism of *H.erectus* due to long periods of geographic isolation of Pleistocene Java (Pope 1985, 1988a, 1996; see below). Correlation of the results of fluorine studies with fission-track stratigraphy (Suzuki et al. 1985) by Matsu'ura (1982) suggests that Sangiran 6 derives from the Grenzbank dated to c. 1.0-1.1 million years ago and Sangiran 5 from the upper Pucangan Formation or the Grenzbank at c. 1.0-1.3 million years ago. Other *H.erectus* sampled by Matsu'ura (1982) date to between 0.800 and 1.1 million years ago. Island faunas because of their isolation have a tendency to either gigantism or dwarfism. If endemism is the cause of the '*Meganthropus*' hominid morphology this does not seem to be indicated by the stratigraphic age of Sangiran 5 and 6 compared to the ages of Javanese hominids lacking this morphology: one would expect '*Meganthropus*' to be later because of the time that would have to be allowed for anatomical change. Taking into consideration the predominance of less robust fossil hominid mandibles from Java, it may be hypothesized that '*Meganthropus*' was part of an early *H.erectus* population which became isolated. Although estimating rates of morphological change must be tenuous bearing in mind that this would require, a) a more refined chronology than available at present, and b) a larger sample of '*Meganthropus*' fossils, including other cranial and also post-cranial bones, cases of isolated mammalian populations could serve as a rough index for such estimates (for example, the evolution of normal-sized mammoths into dwarf mammoths on an Arctic island over approximately 5000 years, see Vartanyan et al. 1993).

2.2 *The identification of early hominid culture in Java*

Most or all of the evidence for early hominid occupation in island Southeast Asia is palaeontological and occurs in Java (e.g. Bartstra 1985; Hutterer 1985; Bellwood 1985: 53; Pope 1988a; see also Section 3). None or very few of the early archaeological localities in Java contain artefacts which can be tied in with the stratigraphy, and Pleistocene hominid fossils have never been found associated with artefacts (Van Heekeren 1972: 32; Hutterer 1985; Bellwood 1985: 53; Pope 1988a; Bartstra & Basoeki 1989). There is disagreement as to whether or not evidence of early hominid behaviour has been identified. Two stone artefacts in fresh condition from Sambungmachan in Central Java derive from a normal polarity sand and gravel bed of Brunhes Normal Epoch or Jaramillo age (Jacob et al. 1978). F. Sémah (in A.-M. Sémah 1983-1984) attributes the archaeological layer to the Brunhes, and Bartstra (1985) to the later Late Pleistocene or to the Holocene. More recent work by Sémah et al. (1992) has uncovered a living floor in the Kabuh Formation (Middle Pleistocene) at Ngebung, Sangiran. The excavations at Ngebung identified several layers of fluvial origin containing lithic artefacts (Simanjuntak & Sémah 1996). The twenty lithic artefacts were recovered from a total thickness of approximately 3.50 m (Simanjuntak & Sémah 1996; Fig. 2). These specimens are patinated and most show abrasion suggesting fluvial though limited movement (Simanjuntak & Sémah 1996). In their small size and relatively simple technology these artefacts seem to resemble those found by Bartstra (1985) in Late Pleistocene sediments of Ngebung (and see Sémah et al. 1992). The small number of artefacts recovered by Sémah et al. (1992) and Simanjuntak & Sémah (1996) and scarcity of debitage indicates stream/river sorting. The configuration of the artefactual layers (Simanjuntak & Sémah 1996; Fig. 2) cannot substantiate the claim that a 'living floor' has been discovered. Furthermore, Sartono and Bartstra (pers. comm.) are not convinced that this 'living floor' belongs to the Kabuh sequence. In their opinion the excavations cut through a part of an old Brangkal terrace (the Brangkal is a small river in the area), which would seriously undermine the claim of a Middle Pleistocene age. The stratigraphy near Ngebung is very confusing, as all sorts of fluviatile material is present, ranging from the (basal) Middle Pleistocene to well into the Holocene.

The fact that so very few artefacts have been found in Java supposedly manufactured by early hominids and their fluvial origin at Sambungmachan and in the Kabuh Formation of Ngebung indicates a non-primary context and redeposition.

3 FLORES

In the course of two excavations at the Mata Menge locality in west central Flores (see Fig. 1), Sondaar et al. (1994) and Van den Bergh et al. (1996a) recovered artefacts and fossils from a deposit which belongs to the Ola Bula Formation. These excavations are an extension of excavations at Mata Menge carried out by Verhoeven and Maringer in the sixtees (see Maringer & Verhoeven 1970; Van den Bergh et al. 1996a). The Mata Menge locality is situated on the left bank of a former riverbed.

During the first excavation at Mata Menge Sondaar et al. (1994: 1257) recovered four stone artefacts and three fossils (of *Stegodon trigonocephalus florensis*) in situ from a '...well-sorted, fine grained sandstones and sandy siltstone...' layer which is the upper part of a 1.5 m thick '...fining-up tuffaceous sandstone layer...'. The artefacts are described as two flakes and two '...rounded basaltic pebbles with one or more sharp breaks.' including a pebble with a bulb of percussion, all manufactured in basalt (Sondaar et al. 1994; see also Van den Bergh et al. 1996a: 32). The 1.5 m thick layer also yielded freshwater molluscs, plant materials and localized large rodent fragments, and Sondaar et al. (1994: 1258) suggest a freshwater origin of this layer based on the molluscs and 'locally faint laminations'.

Subsequent excavation of the same 1.5 m thick layer found lithic artefacts and fossils (*Stegodon trigonocephalus florensis*) in a well-consolidated layer of fluvial sandstone (Van den Bergh et al. 1996a). These artefacts comprise more than 15 flakes and one core, made on basalt with the exception of a chert flake. Some artefacts (eight flakes, one pebble tool) originate from the silts (Van den Bergh et al. 1996a). It is unclear whether these silts are the silty sand directly above the sand layer or the silt above the silty sand layer, or both (Van den Bergh et al. 1996a; Fig. 3). The total number of artefacts recovered during the second excavation from the fossiliferous layer(s) is +25, although only 19 of these are shown in the excavation plot (cf. Van den Bergh et al. 1996a: 32-33; and Fig. 4; and see Sondaar et al. 1994: 1261). The sandstone layer above the 1.5 m deep 'main archaeological layer' yielded a further two artefacts (Van den Bergh et al. 1996a). The illustration of only one artefact has been published so far (Van den Bergh et al. 1996a; Fig. 5).

The artefacts were found distributed over a vertical distance of 1.05 m (between 0.93 and 1.98 m below a zero reference, Van den Bergh et al. 1996a; Fig. 4). The stratigraphic context of the archaeological specimens is interpreted as in situ (Van den Bergh et al. 1996a). On the basis of the abraded condition of the sandstone layer artefacts in contrast to the unabraded specimens from the silt, Van den Bergh et al. (1996a) argue that the former specimens were deposited by water. Bioturbation was noted at the border(s) of the silt and sand (Van den Bergh et al. 1996a; Fig. 3).

The age of the Mata Menge artefacts is inferred from a palaeomagnetically dated section near Mata Menge where intermediate to '...a 3 m thick palaeosoil overprinted on...' pumice tuffs and '...the top of the silty clay layer...' occurring directly below the archaeological layer a reverse to normal polarity transition is indicated (Van den Bergh et al. 1996a: 35). Reversed polarity was noted in the central part of the palaeosoil (Van den Bergh et al. 1996a). The transition is assumed to identify the Matuyama-Brunhes boundary at 0.730 million years ago (0.780 million years ago, see Valet & Meynadier 1993), and on this basis and '...the depositional hiatus indicated by the palaeosoil...' suggests an early Middle Pleistocene antiquity for the archaeological layer (Van den Bergh et al. 1996a: 27, 35; Sondaar et al. 1994). This hiatus is estimated as not more '...than a few hundred thousands of years.' (Van den Bergh et al. 1996a: 35; and see Sondaar et al. 1994: 1260) which presumably (assuming an early Middle Pleistocene age) would date the artefacts at somewhere between 0.780 and 0.562 million years ago.

Assignment of the artefact layer to the Matuyama-Brunhes boundary rather than to an earlier transition is based on faunal correlation of the Mata Menge stegodont with the Javanese *Stegodon trigonocephalus* from the Kendeng Brubus fauna which has been dated to approximately 0.700-0.850 million years ago (Sondaar et al. 1994: 1260; Van den Bergh et al. 1996a, b). However, there is no consensus that the Kendeng Brubus fauna represents an homogeneous collection and its recognition as such seems doubtful because it conflicts with the known litho-stratigraphy; it is also important to consider the uncertain provenance of the Kendeng Brubus fauna (Hooijer 1983; Bartstra 1983b; Pope 1988a). There is in addition the question if a biostratigraphic correlation between the Flores fauna and the Kendeng Brubus fauna from Java has any validity.

The small number of artefacts from Mata Menge, including the presence of only one core and their dispersed vertical distribution could indicate that the artefacts are not contemporaneous and not in an undisturbed stratigraphic context. This seems to be supported by the worn condition of the artefacts found in the sand layer which is thought to represent evidence of water transport and also by evidence of bioturbation, although more information is needed on the extent of bioturbation (see Van den Bergh et al. 1996a; see above). These data, and the discovery of two artefacts above the fossiliferous layer may suggest that some or all artefacts were introduced from younger levels. Further investigation is needed to ascertain if the palaeosoil is representative of a depositional break (see above), and, if so, the time estimate of the sedimentary rate calculated at a few hundred thousand years needs to be tightened up.

The presumed early Middle Pleistocene context of the Mata Menge artefacts and their attribution to *H.erectus* is interpreted to mean that in consequence *H.erectus* '...was apparently able to cross small water barriers...' to reach the island of Flores (Van den Bergh et al. 1996a: 35). Van Heekeren (1972: 71-72, 78) also believed that early humans and proboscideans were able to disperse to islands east of Wallace's Line with an estimated late Middle Pleistocene antiquity attributed to the Flores artefacts of Maringer & Verhoeven (1970). The means by which *H.erectus* supposedly reached early Middle Pleistocene Flores is a critical issue which needs to be discussed. Sondaar et al. (1994) and Van den Bergh (1996a) offer no suggestions as to how *H.erectus* reached Flores. Furthermore, what would have been the incentive to colonize Flores, and by inference, other islands between Flores and Java if we assume that the Flores *H.erectus* derived from Java (see Sondaar et al. 1994), the only island in Southeast Asia with evidence of this hominid species? Should one assume that colonization was deliberate or accidental (see also Van den Bergh et al. 1996b)? Considering low population numbers of early hominids, one may exclude population pressure and possibly also environmental pressure to have been the cause of apparent sea travel. In view of this the risk of a sea voyage may have been too great. It is not the purpose of this paper to provide a hypothesis for the motive *H.erectus* might have had to cross water barriers, merely to point out that this is an issue which should be addressed.

Flores does not constitute part of the Sunda shelf, and therefore could not have been reached by hominids from the mainland or Sundaland via dry land (Ollier 1985; Van den Bergh et al. 1996b; Fig. 4). The earliest evidence for hominid occupation of other islands and of Sahul that would have been impossible without the aid of watercraft is about 30,000 years ago based on radiometric dates (Glover 1981) or c. 50,000 years ago (Keates & Bartstra 1994) for Sulawesi. In Australia thermoluminescence dating appears to document the first evidence of hominids at 50,000 years ago (Roberts et al. 1990). Even the latest claim of a c. 116,000 or 176,000 year old antiquity for the Jinmium cultural locality in Australia (Fullagar et al. 1996; and see Bahn 1996) is well below the age claimed for the colonization of Flores.

Hypothetical hominid migration scenarios would be a route either from Java to Flores or from the Southeast Asian mainland to Flores. Two possibilities can be envisaged of how *H.erectus* reached Flores: either by swimming or by watercraft. Assuming that the source of hominid colonists was Java, the following route, Java – Bali – Lombok – Sumbawa – Komodo – Rinca – Flores would have provided the shortest sea distance that needed to be covered based on the present geography (see Fig. 1). The combined sea distance between Java and Flores is well over 100 km. This distance would be reduced to about 20 or 30 km at a maximum sea-level drop of 150 m. Colonization of Flores using rafts or boats would imply a highly sophisticated technology for the time in question. If either of these scenarios (i.e. swimming or watercraft) with a Middle Pleistocene age for hominid occupation of an island were to be verified, it would force us to rethink the pace of human behavioural evolution, and put into serious doubt our ability to identify instances of what in effect would be called modern human behaviour. There is, however, a lack of evidence of modern human behaviour expressed in the material culture of the Middle Pleistocene (an exception may be represented by the Berekhat Ram female figurine approximately dated to the Middle Pleistocene, see Bahn 1996).

The possibility of early *H.erectus* having colonized Flores can also be examined from another angle, that is that of faunal species richness. The very small landmass of Flores has seven indigenous species and six endemic species (Groves 1985: Table 1). Thus it seems that very few animal species ever reached the island, which could be interpreted as further reducing the possibility of *H.erectus* ever having colonized Flores, especially in view of the relative rareness of early hominids.

4 CONCLUSION

In matters of dating archaeological specimens, it is of the utmost importance to ensure the stratigraphic integrity of each specimen. By itself, a dating technique cannot resolve the long standing controversy surrounding the provenance of Javanese fossil hominids, nor can it clarify the problematic complexity of the depositionary history of East and Central Java. In their radiometric assessment of the Mojokerto and Sangiran hominids, Swisher et al. (1994) and Swisher (1994) have failed to appreciate these issues. As those who are familiar with the problems of Javanese geology, geomorphology and biostratigraphy can testify, there is no substitute for an intricate knowledge of the field situation. Without recognition of the facts which are closely associated with chronometric evaluations in Java, the new dates lack scientific credibility, and introduce confusion. In contrast, the c. 1 million year old entry date of African derived hominids (*H.erectus*) to island Southeast Asia was established within a multidisciplinary framework. It remains a viable basis for interpretations of hominid chronology in this region.

The evidence for early hominid culture in Java is still ambiguous. This is largely because of a sedimentary situation (e.g. high-energy fluvial deposits) which is often detrimental to the primary context preservation of archaeological localities. However, long-term, assiduous surveys and excavations and geomorphological analyses have the potential of advancing our knowledge and understanding of early hominid behaviour in Java.

The processes involved in the formation of the archaeological deposit in which the Mata Menge artefacts were found and an early Middle Pleistocene attribution to the locality call for further investigation in view of the fluvial nature and thickness of the archaeological horizon, the dispersed spatial range of the artefacts and their small frequency which together would seem to argue against a primary context. Invariably connected with the subject of the stratigraphic setting of Mata Menge is the evaluation of the palaeomagnetic stratigraphy and the inference of early *H.erectus* sea migration. If the artefacts were redeposited, what is their relationship to the palaeomagnetic sequence? Occupation by *H.erectus* of other regions lying to the north and east of Java, that is Sulawesi, Irian Jaya, Papua New Guinea, the eastern Moluccas, the Sunda Islands and Australia, has so far not been discovered (and see Birdsell 1977: 152). This negative and consistent evidence strongly suggests that early hominids either would not or could not cross open water.

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Short history of the archaeological exploration of the Maros caves in South Sulawesi

1 INTRODUCTION

Successful archaeological research in some caves on the Bird's Head, Irian Jaya – conducted two decades ago by Solheim cum suis and more recently by Jelsma and Pasveer (see this volume) – proves that this area was accessible to prehistoric man. According to a first ^{14}C date from Kria cave, man was apparently present in the interior of the Bird's Head eight thousand years ago.

As far as human migration towards the Bird's Head is concerned, the so-called western approaches deserve attention. The island of Sulawesi (formerly Celebes) plays a prominent role in this, either as a starting point, or as a staging post en route. In South Sulawesi is a well-known and archaeologically well-researched cave region: the karst near Maros, to which the prehistoric 'culture' of the Toalean is linked. This paper will briefly explore the history of archaeological research in the Maros caves, and throw light on some theoretical attitudes which were once held and some which are still cherished with regard to the rich prehistoric material from these sites. In a way, this text may be considered to be an introduction to the next paper in this volume, written by Pasqua and Bulbeck.

2 THE EARLIEST INVESTIGATIONS

On 2 September 1856, the ship carrying Alfred Russel Wallace arrived at the roadstead of Makassar. Although Wallace's first impressions were not very thrilling (he saw a flat monotonous coast with a hazy mist hiding the interior), he did like the small port itself, nowadays the bustling metropolis of Ujung Pandang. In the end, however, Wallace considered the place too expensive for a prolonged stay and, in fact, there was nothing to busy himself with in this harbour town. For he was what was then called a naturalist, and he wanted to start collections of beetles and butterflies and birds. Thus he headed off eastwards into the flat but wooded coastal interior, and had a wonderful time there for several weeks.

Wallace became a famous man. During the years that he roamed the islands of Southeast Asia he developed a theory of evolution of flora and fauna that was virtually identical to Darwin's. Wallace's ideas were very nearly publicly known before Darwin's, but in the end he did not begrudge the latter the honour and even dedicated the account of his travels in the East (including the descriptions of his journeys in Sulawesi) to him. The story of Wallace's travels, published in two volumes, still makes exciting reading[1]. In addition, Wallace's name has been immortalized in the so-called Wallace's Line, a zoogeographic barrier running right through the Indonesian archipelago. To the left of the Line, which runs between Bali and Lombok and then between Kalimantan and Sulawesi, there was supposedly an Asiatic animal world, to the right an Australian. Wallace suggested this Line on the basis of his journeys and biological observations[2].

In July 1857 Wallace arrived again in Makassar. This time he was able to penetrate further into the interior, past the coastal plain, into the limestone mountains of Maros (see Fig. 1). The lack of roads at the time meant that his journey lasted a long time. First there was an all-night boat journey from Makassar north to the mouth of the Maros river, and then an upriver journey until three in the afternoon to the village of Maros itself. From there on it was all trekking on foot, with many bearers, along narrow paths. The country appeared flat at first with dried out, stubbly rice fields; then craggy limestone rocks came into view, covered with virtually impenetrable vegetation. This of course was ideal hunting ground for Wallace and he stayed there until the beginning of November when the monsoon rains began. Wallace is one of the first to report on the caves in the Maros district. He described them as 'gloomy caverns'. In particular it was a journey to the waterfalls of Bantimurung, where exotic butterflies were to be found, which drew Wallace's attention to the many holes and caves in the limestone. He did not explore them thoroughly, however.

Bantimurung is still a well-known and pleasant place. The present-day traveller could cover the distance from Ujung Pandang to Maros in a car in just about an hour. Like Wallace he will notice the remarkable morphology of the landscape: between Ujung Pandang and Maros the land is almost flat. If one looks behind the small houses that continuously line the roadside, rice fields and other arable land stretch as far as the hori-

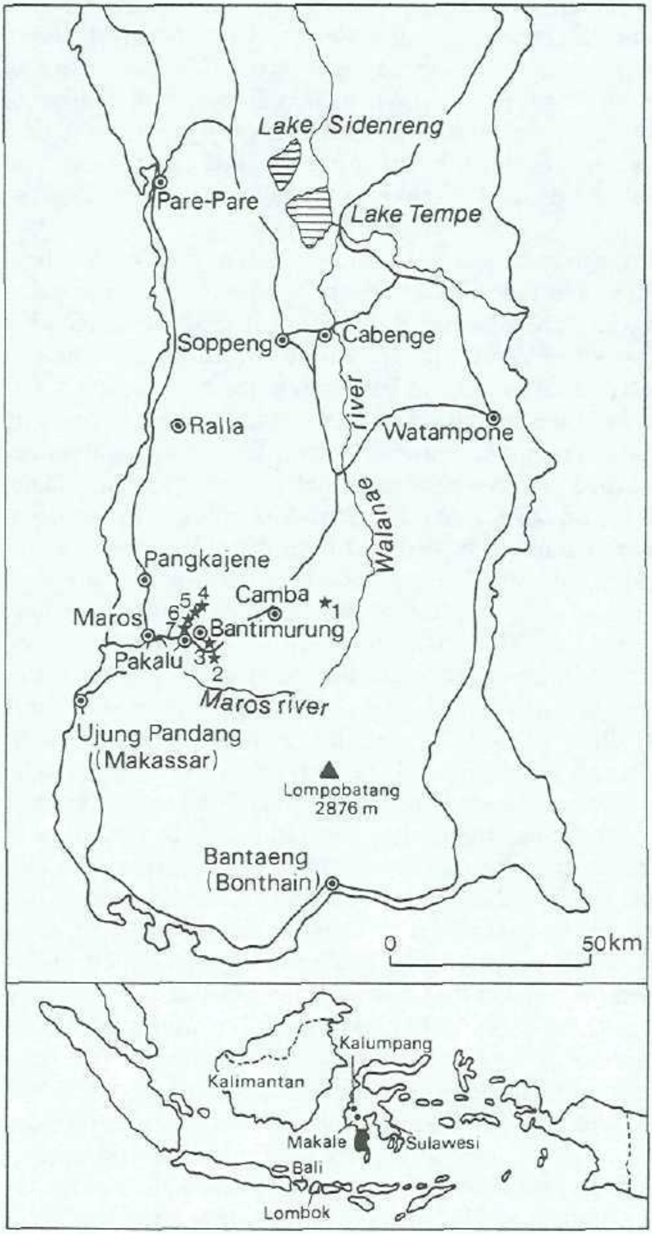

Figure 1. Maps of island Southeast Asia and South Sulawesi, with geographical names mentioned in the text. The numbers refer to caves: 1. Lamoncong, 2. Karassa, 3. Saripa, 4. Pattae, 5. Ulu, 6. Burung 1, and 7. Burung 2.

zon. The woods which Wallace described so lyrically during his first visit to South Sulawesi are now gone. A short way past Maros the limestone mountains loom up like a greeny-grey wall. The rocks rise like towers from the flat land (see Pl. 4). When one stands directly in front of them, some turn out to be over a hundred metres high. In geological terms this remarkable erosion of the limestone is called a tower-karst. On aerial photographs the region looks like a plateau segmented by deep fissures.

With a bit of imagination and an eye for the geology, it is possible to see the many caves and holes, rock shelters or abris, and over-hanging ridges or ledges which are to be found at the foot of these limestone towers as once being a surf zone, with sea caves, eroded by wave action. The plain between Maros and Ujung Pandang (to the east: the karst border plain; to the west: the coastal plain) must then have been covered by the sea at one time, with waves crashing against the steeply rising limestone rocks: a savage world with a perpetual mist of spray and foam, where a landfall would have been difficult and hazardous, if not impossible. This picture can indeed be deduced from the older geological literature about South Sulawesi. The area between Maros and Ujung Pandang was once regarded as an old seabed, risen as a result of tectonic (epeirogenetic) processes. The underwater shelf off the present coast on which the coral reefs of the Spermonde archipelago are built is seen as the continuation of the now dry coastal plain[3]. The modern geological ideas are slightly different, however, certainly as far as the formation of the caves and abris are concerned. It is perfectly possible for these to be the result of the erosive action of small local rivers which have washed around and through the limestone rocks for millennia[4]. In fact, there is no proof whatsoever that the caves were formed by marine abrasion: there is no typical polish (gloss) or smoothness in the cave interiors (although this may have been removed by later corrosion), and there is no marine sediment either (no patches of marine conglomerate left undisturbed in protected places). On the other hand: the sea did of course play a role in the formation of the limestone itself. The Maros limestone originated in a sea during the Eocene, Oligocene and Miocene (the transition period Palaeogene-Neogene, or Lower to Upper Tertiary), between 50 and 10 million years ago. However, there was also land then already, and not too far away, as is demonstrated by the finds of certain species of fossilized fish in layered limestone (so-called 'Plattenkalk') which indicate lagoon-like situations[5]. This land bore volcanoes, because material of volcanic origin is quite common at Maros and farther inland. One finds eruptive, intrusive and effusive rock, sometimes older, sometimes contemporaneous, sometimes younger than the limestone. The now-extinct volcano Lompobatang, the highest mountain in South Sulawesi and previously known as the Peak of Bonthain (see Fig. 1), is a relict of those turbulent days.

The Lompobatang was once climbed by Paul and Fritz Sarasin. They were Swiss and cousins, and became famous as a result of their expeditions into the interior of Sulawesi in the years 1893 to 1896, and 1902 to 1903. The Sarasins were the first to more thoroughly investigate the alluring caves in the limestone regions of southern Sulawesi.

In 1902 they arrived at the kampong, or small village, of Lamoncong, about 40 km to the east of Maros, where they found caves in which people were living. In accordance with the evolutionary ideas of the time, the Sarasins regarded these cave dwellers as the last of the original inhabitants of Sulawesi. They called the shy tribesmen Toala, after the local designation for forest people[6]. When they began to dig in the caves, the Sarasins found stone tools of flakes and blades, and in their opinion these implements must have been made by the ancestors of the Toala. The tools were described by the Sarasins as the prehistoric Toalean culture. They also thought that the Toala were related to the Wedda of Sri Lanka, and that both tribes were the survivors of a race of primitive representatives of *Homo sapiens*, that once inhabited South and Southeast Asia in an unbroken line from Sri Lanka into Melanesia. The theory swiftly faded from scientific esteem, however. The living Toala of Lamoncong turned out to be the descendants of exiles from the nearby kingdom of Bone, who had come to the caves in historical times.

It was the legendary Van Stein Callenfels who played a role in the dismantling of the Wedda theory (see Pl. 1). Stein, the patriarch of Indonesian archaeology, travelled to the caves of Lamoncong in 1933 to see the Toala for himself. The journey to Lamoncong is a typical Stein story, preserved in a letter which Van Stein Callenfels sent to a female admirer in Holland[7]. His fame had gone before him, and when after arriving at the desa, or village, of Palatae the journey to Lamoncong had to continue along footpaths, a huge sort of palanquin stood ready, specially constructed for the tuan of whom the villagers had been told that he was 2.5 m tall and weighed 200 kg, and drank a barrel of beer every morning all by himself. Thus, swaying above a chattering throng of nearly eighty bearers, Stein was carried over a mountain ridge, along a path that in his own words went vertically upwards and on the other side vertically downwards. In Lamoncong he immediately began a preliminary anthropometric study of the Toala. In his letter to Holland, Van Stein Callenfels mentioned in passing that there could be no question of a relationship with the Wedda[8].

Even if the cave dwellers of Lamoncong were not the last of the original inhabitants of Sulawesi, the Toalean implements in the sediments of the cave floors were certainly old, of that Van Stein Callenfels was just as convinced as the Sarasins. In November and December 1933 he investigated at least three Toala caves near Lamoncong. He found tools and debitage of stone and bone in them. In the deeper layers, however, beneath what he and the Sarasins called deposits with a Toalean culture, he came across different tool types. To this older assemblage he gave the name Proto-Toalean, or, in Dutch: Oer-Toaliaan. Although Van Stein Callenfels expounded his ideas about the Lamoncong discoveries in later lectures[9], the precise differences between Toalean and Proto-Toalean remain unclear. This is something one has to resign oneself to, studying the great Stein's written legacy: his purely scientific notes take up less space than his anecdotes about his journeys.

3 THE HEYDAY OF THE DISCOVERIES

In the thirties, research into the Toalean in the caves to the east of Maros was enthusiastically undertaken by Van Heekeren. He was in fact a tobacco planter in East Java, but had made a name for himself with archaeological excavations in his spare time. Van Heekeren was eager to work in South Sulawesi because he was looking for parallels for the cultural remains and sequences found in the caves of Java. Thus, in 1936 he excavated in the Leang Karassa or Ghost Cave, on the way from Maros to Lamoncong (via Camba), in which it was said that the Sarasins had once spent the night (see Fig. 1). In this excavation, Van Heekeren tried to trace the dichotomy in the cave stratigraphy as described by Van Stein Callenfels. The results were unclear at first, but by a slow process of careful description and illustration an insight was achieved[10].

This typological approach led to ideas about the prehistoric occupation of the caves near Maros which were generally accepted. In nearly every cave deposit artifacts of bone, horn, shell and stone could be found. It looked as if prehistoric man had always made use of anything around him which appeared to be suitable. The stone tools were usually made of silicified limestone, also referred to as chalcedony in the literature. Sometimes jasper, quartz, obsidian, and even andesite were used. Pebbles and cobbles of all these materials were at hand and can still be found in the small rivers to the east of Maros.

In the top layer of many a cave sequence pottery was found, including Chinese porcelain. In the thirties, however, these sherds were not systematically collected, because in the view of the prehistorians they were 'recent', dating from historical times when the caves or abris were used as temporary residences or as places to house animals.

Excavating below this pottery layer, one came across sediments which were called Neolithic, and the name Upper Toalean, Late Toalean, or

Plate 1. The illustrious P.V. Van Stein Callenfels, the patriarch of Indonesian prehistory. He lived from 4 September 1883 to 27 April 1938.

Plate 2. Archaeologists in the field in 1937. From left to right: F.D. McCarthy, P.V. Van Stein Callenfels, unknown mantri, and W.J.A. Willems. It is not certain where this picture was taken. It may be somewhere south of Watampone where the four of them were excavating that year.

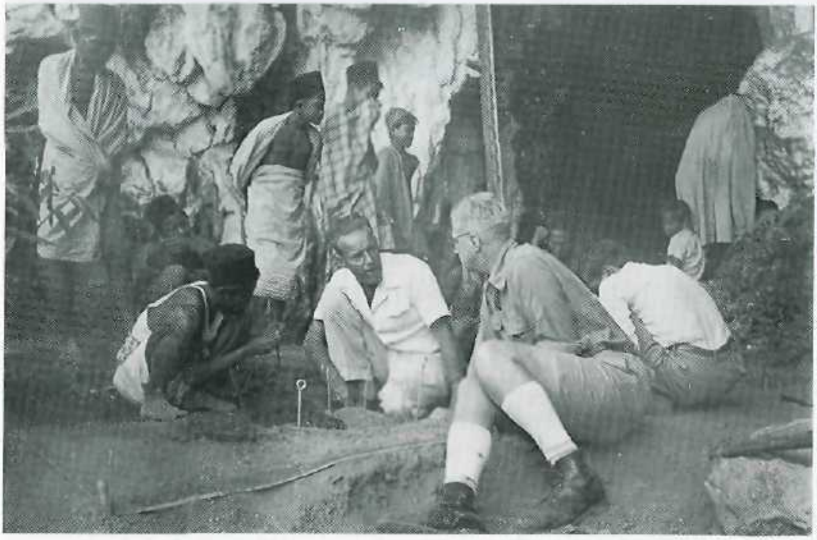

Plate 3. February 1950. H.R. Van Heekeren (left) excavating in the Leang Pattae. On his right sits A.J. Bernet Kempers, at that time head of the Archaeological Service. Clearly visible is the small cave at the back of the abri, where the hand stencils and drawing of a pig were later found.

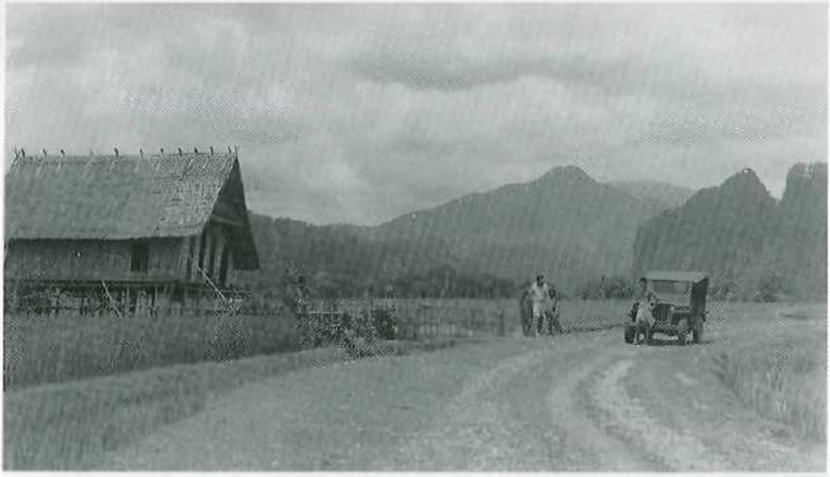

Plate 4. February 1950. the unpaved road from the village of Pakalu to the Leang Pattae. The jeep, a war relic, was temporarily lent to Van Heekeren by the local government. In the background to the right are the towering karst mountains; in the middle is the promontory of the intrusive Peak of Maros or Gunung Maros or Saraung. The peak itself (height 271 m) is hidden in the clouds.

Plate 5. August 1996. Standing on the same spot as the picture above. The area has become more crowded: houses have been built, electricity and telephone have appeared and the road has been asphalted. The Peak of Maros is still hidden in the clouds.

Plate 6. Artifacts from the Maros caves: to the left and right the winged and denticulated Maros points; in the middle a so-called Muduk point, made of bone. This particular point, with a length of 3 cm, comes from the Leang Jarie, about halfway between the village of Pakalu and the Leang Karassa.

Plate 7. The hand stencils in the Maros caves: often painted high on the ceiling or in remote corners, and therefore difficult to photograph.

Toalean I was bestowed upon them. Characteristic of these sediments, in addition to many shell artifacts of various aspect, were supposed to be the stone Maros points and the bone Muduk points (see Pl. 6). Maros points are small, flexed or winged implements, with a concave or hollow base, and serrated or denticulated or barbed sides. They probably functioned as arrowheads. Muduk points are usually pointed at both ends, the so-called bone bi-points; but there are also single or uni-points (in some cases merely broken bi-points). The Muduk point might have functioned in fishing or hunting gear as a barb.

Excavating deeper still, one came across the so-called Mesolithic layers, for which the term Middle Toalean came into being, or Toalean II. The most characteristic items from these sediments were thought to be blades with different forms and (geometrical) microliths.

Finally, directly above the rock floor of the cave lay what was presumed to be the real Palaeolithic part, called Lower Toalean, or Early Toalean, or Proto-Toalean, or Toalean III. This sediment contained larger flakes, often (what was indicated as) 'archaic-looking', and rather patinated or weathered, and usually unifacially worked or trimmed, such as the triangular Pirri points and the so-called tanged points. Pirri points were understood as 'incipient' Maros points, that is, as non-denticulated 'forerunners' of the Maros points.

In the thirties, the material from the caves in southwestern France was often used for comparison, and Van Heekeren therefore wrote about a 'laat-moustier-onontwikkeld aurignacien' (Late Mousterian, 'not yet developed' Aurignacian) to describe the Lower Toalean from the Leang Karassa[11]. With this terminology he indicated the level of technology of the tool manufacture. But furthermore, it was an indication of age: Van Heekeren was convinced that the Lower Toalean dated to the Upper Pleistocene, that is, was more than 10,000 years old.

With hindsight, the stratigraphy described above can be dismissed as superficial and simplistic. It was taken for granted that technological and typological development had to follow a unilinear evolutionary scheme, and this was looked for in every cave or abri. If, for example, there was no Upper Toalean or Lower Toalean, then the cave was old or young respectively. The assumed evolution was the guiding principle, and if Maros points were found in the same stratum as, for example, core scrapers, then they were immediately separated and the cave sediments were said to be disturbed or jumbled together. On the other hand: the excavators of the thirties succeeded for the first time in getting to grips with an enigmatic ('esoteric' as Van Heekeren put it in 1972) cave culture of prehistoric hunter-gatherers in southern Sulawesi, and also to seek parallels with surrounding areas. Terms such as Muduk points and Pirri points have clearly been 'borrowed' from implement assemblages in Australia.

The Maros point appears to be confined to southern Sulawesi: it does not occur elsewhere[12].

Towards the end of the thirties there was a lot of archaeological activity in the caves and abris of South Sulawesi. Van Stein Callenfels was back there in 1937, and excavated at the south coast near Bonthain. In the same year Van Heekeren investigated another cave in the Maros area, the Leang Saripa, a few hundred metres to the west of the Leang Karassa (see Fig. 1). Then there was McCarthy, an Australian archaeologist; and Willems, who had learned his trade in Groningen, the Netherlands, under the legendary Van Giffen. Both McCarthy and Willems had a thorough command of the techniques needed for excavating in caves (see Pl. 2). They went to work at different places; Willems, for example, was in May 1939 near Makale, because he wanted to know whether a genuine Toalean could also be found to the north of Lake Tempe (see Fig. 1). He was not able to prove this, however. The Toalean seemed to be restricted to the caves and abris in the southern part of South Sulawesi. The region to the east of Maros was considered to be particularly rich in prehistoric material[13].

4 OF ANIMALS AND ART

During the years of the Japanese occupation, archaeological research in the Maros caves came to a standstill. Van Stein Callenfels had died unexpectedly in 1938, McCarthy was back in Australia, and Willems had left the Dutch East Indies. Van Heekeren had vanished into a Japanese prisoner-of-war camp. In 1946, though, he was back in Sulawesi, this time in the official role of 'Prehistorian' working for the Archaeological Service[14]. He enthusiastically took up cave research once again[15], but soon his attention shifted from the tools of the Toala to the implements of an even older race which he had found near the little town of Cabenge, alongside the Walanae river, together with the remains of fossil vertebrates (see Fig. 1)[16]. The exploration of the caves near Maros was temporarily left in the hands of what could be called very competent amateurs, such as, for example, Franssen and Heyning[17]. Attempts were also made to come to a more precise dating of the cave sediments, mainly using faunal remains. For in addition to artifacts, many animal bones were found in the Toalean caves, undoubtedly the remains of once hunted prey. Some of the seemingly archaic tools from the lowest levels of the cave sequence were estimated by the archaeologists as being more than 10,000 years old, but it would of course be interesting to know whether the analysis of the fossil fauna gave a similar indication.

In 1950 a publication appeared by Hooijer, a vertebrate palaeontologist at the (then) Natural History Museum in Leiden, Holland, and a prolific author of scientific papers[18]. Hooijer had investigated a lot of faunal remains from, among others, the Lamoncong caves, where Van Stein Callenfels excavated in 1933[19], and from the caves where Stein, Willems and McCarthy excavated in 1937; also, he investigated post-war material sent to him by Franssen and by Van Heekeren[20]. According to Hooijer, all the animal species met with in the caves or abris are still extant somewhere on Sulawesi. Not a single type turns out to be extinct[21]. Therefore, Hooijer came to the conclusion that the fossil fauna from the caves of southern Sulawesi could not be too old. Also, the state of preservation of the bone material ('subfossil') led him to assume a lower limit for the Toalean of about 10,000 years (where the Pleistocene ends and the Holocene begins)[22].

In 1950 Van Heekeren's attention was again drawn to the caves of Maros. For political reasons, and the outbreak of a guerilla war, it had now become too dangerous in South Sulawesi to venture far from the capital Makassar (Ujung Pandang). Van Heekeren might have wanted to return to his favourite prehistoric sites such as Cabenge or Watampone or Kalumpang, but this was just not possible[23]. Therefore, he organized an excavation season in the Leang Pattae in the Maros region, not far from the Leang Karassa and the Leang Saripa which he had investigated before the war. Leang Pattae, actually a large abri with a small cave at the back, lies in a picturesque valley to the north of the desa Pakalu where, if one reads his travel descriptions carefully, Wallace, too, must have had his temporary home somewhere (see Fig. 1, and Plates 3-5). The excavations began in February 1950, and resulted in what appeared to Van Heekeren as a well-known stratigraphy with pottery in the top sediment, Maros points below, and larger stone flakes at the bottom. It was not possible, however, for the stratigraphy and the dating to be checked in the light of Hooijer's and Heyning's ideas, because at the beginning of April the team had to flee back to Makassar. Violent fights between rival groups, whether or not politically motivated, broke out everywhere. South Sulawesi entered a long period of unrest and it would be the year 1969 before archaeological explorations in the interior were again possible. In fact, typical Dutch involvement in the archaeology of the Maros caves ended in 1950.

On Sunday 26 February, one of the members of the excavation team in the Leang Pattae, Mrs Palm, discovered seven so-called hand stencils on the roof of the small cave at the back of the abri. These had been made by placing a hand against the rock wall and then splashing red colour over it. In the first exuberant notes on the discovery – at that time the most westerly rock paintings in the Indonesian archipelago – it was stated that they were apparently all female handprints, and usually the left hand for that matter, an observation which led to digressions on ritual meanings. A more mundane explanation is quite possible, of course: practical women would not let their right hands be covered with sticky paint. The same holds true for the fact that the thumbs are often missing in the hand stencils. Instead of horror stories about mutilations, it should be remembered that thumbs can easily and inadvertently be turned away (see Pl. 7).

A day later, on 27 February, Van Heekeren himself found a drawing of a leaping pig (or a charging boar, as he often called it), in a remote corner of the cave, again drawn in red. Close to the head, but on the body itself, a hook-shaped symbol had been painted, which Van Heekeren regarded as an arrowhead or spearhead, an interpretation which led to enthusiastic stories of hunting magic. Small triangles on the head and just behind it were described by Van Heekeren as tufts of hair. This led to a discussion about what type of pig it could be. The heavy body and the slender legs point in the direction of a babirusa, the famous 'pig-deer' of Sulawesi, but this animal is hairless – at least, the present-day babirusa is hairless[24].

Van Heekeren corresponded at length about these matters with Hooijer in the autumn of 1950, but the latter was not able to come to a conclusion either. He had problems with Van Heekeren's interpretation of the tufts of hair and regarded the foremost (solidly deep red painted) triangles as two horns bent forwards. The so-called arrowhead he considered to be the heart. In turn, this was difficult for Van Heekeren to accept. Finally it was decided that it was an ordinary wild pig (*Sus celebensis*, the Sulawesi wild boar)[25].

This mild dispute between two good friends about what exactly the drawing depicted was nevertheless important for the dating of it. For as said, in those days faunal remains played a major role in the dating of the Toalean, to which 'culture' all the drawings or paintings were attributed. Van Heekeren, in the euphoria of the discovery and not quite agreeing with Hooijer's opinions on the age of the cave faunas, initially considered the hand stencils and the pig as belonging to the Lower Toalean, and thus spoke of an (Epi-) Palaeolithic cave wall art, and even saw close connections with Australia and New Guinea (Irian Jaya), where hand stencils for example are widespread (for instance in the area of the Berau Bay, the former MacCluer Gulf). In the early fifties it was still assumed that the tool assemblage of the Maros caves also hinted at easterly connections, but this opinion did, in fact, reveal nothing about the age of hand stencils and drawing. The latter are positioned high up on the cave walls, far away from the implementiferous sediments on the floor. The distribution of red ochre (hematite) in the deposits provided no clues either.

To date, it appears that the cave drawings in the Maros district proper are not too numerous. Apart from the Leang Pattae, they have been discovered in a few neighbouring caves, but they do not seem to constitute a dominant factor in the occupation history of the caves and abris. Röder, who published on rock paintings in Australia and New Guinea, estimated the age of the Maros 'art' at a thousand years at the most, and more likely at three to four hundred years old[26]. It is now generally accepted that in the Far East there are no rock paintings or drawings which date to the Palaeolithic or Old Stone Age, that is, which are older than 10,000 years[27].

The Maros rock paintings are difficult to find. They are not easy to recognize against the weathered and corroded limestone rock walls. The tropical climate has affected the colour. This might say something about their age: it could be yet another indication that the drawings are not old. Truly ancient pictures would have vanished completely. It is possible, though, that in concealed places farther into the limestone area there are more (fading) hand stencils and depictions of animals to be found. A thorough exploration of the mountains of Maros, might still result in a few surprises.

5 SUMMARY OF LATER RESEARCH

By the end of the sixties the interior of South Sulawesi was considered to be safe enough again to allow archaeological fieldwork. The similarities observed and dwelt upon by earlier researchers between certain types of tools from the Toalean caves and those from more eastern parts of the Indonesian archipelago and from Australia, were reason enough for Australian prehistorians to explore again the region near Maros in a joint expedition with the Indonesian Archaeological Service. This expedition was headed by Mulvaney and Soejono; among others, the Leang Burung or Bird Cave and the Ulu Leang or Principal Cave were excavated (see Fig. 1)[28]. The work was continued in subsequent years by the English archaeologist Glover, which has resulted in a substantial increase in our knowledge about the prehistoric occupation of the caves[29]. An important result of Mulvaney's and Soejono's, and later Glover's research was that they could not trace the familiar tripartite division of the Toalean, which had been propagated since the thirties. They therefore consider that 'wishful thinking' must have played a large role in the field analyses of the earlier researchers, as well as a strong tendency to arrive at broadly applicable conclusions. Mulvaney and Soejono also question certain artifact types. The tanged points from the so-called Lower Toalean are in their opinion 'fortuitously shaped primary flakes'.

One of the marked results of Glover's excavations was a series of ^{14}C dates. The samples consisted of the shells of freshwater gastropods; the analysis provided data for the cave sediments between roughly thirty thousand and twenty thousand years old. This came as a complete surprise, because after Hooijer's dictum, everyone had acquiesced in the notion of a mainly Post-Pleistocene Toalean 'culture', that is, a cave occupation that began less than 10,000 years ago[30]. The initial reactions to the new dates were therefore rejective and disbelieving: the samples were probably not reliable. The ^{14}C determinations were done with shells from sediments through which water from the Tertiary limestone had seeped for millennia. That could never be right. Glover's results were and are thus often treated with reserve, but in the light of the most recent dates for prehistoric cave sediments in the eastern Moluccas, New Guinea and Australia[31], Glover's ^{14}C data could be quite acceptable. However, not all of the caves in the Maros district turn out to have such an ancient occupation as Leang Burung 2.

Much research has also been carried out in the Maros caves by members of the Archaeological Service of Indonesia. This has resulted in more facts concerning the prehistoric occupation. Unfortunately these are not always accessible as they lie hidden in unpublished reports and accounts. A worthwhile project for some future archaeologist may well be an excavation in the archives of Ujung Pandang and Jakarta, rather than in the field.

6 EPILOGUE

It appears to me that the time has come to refine or redefine the term Toalean, which has for so long haunted the literature on the prehistory of Southeast Asia. The problem, though, is probably that still too few cave sequences have been reliably documented to allow such an endeavour. There are two ways of proceeding. Firstly, the term Toalean could continue to be used for the 'classic', Post-Pleistocene cave assemblages of South Sulawesi (in which the hand stencils and the drawings perhaps belong to the youngest phase), and one should introduce a different name for the (scarce?) truly Pleistocene occupational traces[32]. A second way could be followed if it is considered that the boundary between Pleistocene and Holocene (Post-Pleistocene), as far as the archaeology of South Sulawesi is concerned, is too artificial. The term Toalean might then refer to all of the prehistoric occupational remnants in the caves of southern Sulawesi. The next step would be to have subdivisions; and then it would be virtually impossible to avoid allocating the oldest artifacts from, for example, Leang Burung 2 to (a phase of) the Lower, Early, or Proto-Toalean.

I am slightly in favour of this latter approach. I am aware that Mulvaney and Soejono, on the basis of their experiences, do not approve of the typological Toalean sequence as established by e.g. Van Stein Callenfels and Van Heekeren. In fact, they do not like the word Toalean at all[33]. Glover, in his reports on Leang Burung 2, does not use the term Toalean either. But I think that the term Toalean is so firmly entrenched in the literature and has for so long been connected with the cave assemblages of Maros, that it is better to define the term more precisely rather than discard it or invent another one, or even worse: endow every prehistoric cave assemblage with its own unique features, without attempting to fit the finds into a framework of grander industrial or cultural conception, no matter how fragmentary the observational data are. Perhaps one should start to think along the lines of Pasqua and Bulbeck (see the next paper in this volume), who consider the Toalean to be more of a 'tradition' than a 'culture'.

Future purposeful research on the Toalean will have to include the results of reconnaissance and investigation of numerous non-cave sites with stone artifacts that have been discovered in southern Sulawesi in recent years. Glover[34] has already pointed out similarities between certain artifacts from Leang Burung 2 and artifacts collected on the terraces of the Walanae river (see Fig. 1). In fact, non-cave sites or open sites where Maros points have occasionally been found have not only been reported from various places within the Walanae valley[35], but also, for example, from a hilly region about 80 km north of Maros (Padang Lampe, near Ralla) on the western side of the mountain range which borders the Walanae depression[36]. It is thus most probable that the erstwhile cave dwellers at the western fringe of the Maros Karst moved around a lot, and that the various sites have to be studied in the light of seasonal or occupational duties.

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Figure 1 was drawn by Mr J.H. Zwier of the Department of Archaeology in Groningen. Plates 5 and 7 were taken by Drs H.A. van Bemmel in August 1996; Plate 6 was photographed at the museum of the Balai Arkeologi in Ujung Pandang; all the other Plates come from the author's archive.

NOTES AND REFERENCES

1. A.R. Wallace 1869. *The Malay Archipelago: the land of the orang-utan, and the bird of paradise. A narrative of travel, with studies of man and nature.* 2 vols. London: MacMillan and Co.
2. Wallace first noted these ideas in an article in 1860: On the zoological geography of the Malay Archipelago. *Journ. Linn. Soc.* London, 4: 172-184. His ideas remained rather vague, however; it was in fact T.H. Huxley who in 1868 constructed Wallace's Line: On the classification and distribution of the Alectoromorphae and Heteromorphae. *Proc. Zool. Soc.* London 1868: 294-319. Since then many other zoogeographical barriers have been drawn through the archipelago (see G.G. Simpson 1977). Too many Lines; the limits of the Oriental and Australian zoogeographic regions. *Proc. Am. Phil. Soc.*, 121(2): 107-120. At the beginning of this century a transitional region, to which Sulawesi belongs, with a mixed Asian/Australian fauna was already considered. It is now often called Wallacea.
3. For example: J.H.F. Umbgrove 1930. De koraalriffen van de Spermonde Archipel. *Leidsche Geol. Meded.* 3: 227-247; later incorporated into: J.H.F. Umbgrove 1949. *Structural history of the East Indies.* Cambridge: University Press. Chapter 1. Close examination shows that the flat plain between Ujung Pandang and Maros still has patches of broken ground. This is usually the result of local outcrops of the so-called Kuri stone, called Napara in the local language, a calcareous tuff deposit of littoral facies presumably of a Lower Pleistocene age. Often the villages on the plain turn out to have been built on these Kuri stone 'islands' (just as the Ujung Pandang airfield is (Hasanuddin or Mandai)).
4. This may appear strange. A karst region, after all, is characterized by an absence of surface drainage. This, however, is only true in the so-called 'deep' karst. At the edges of a limestone region, such as to the east of Maros, in the 'shallow' karst, there are many small rivers. That this local drainage might be responsible for the cave formation in the Maros region was already suggested by J.H. Druif in: C.J.H. Franssen, 1949 (see Note 17). For a discussion of the Maros limestone morphology in a general sense, see, for example, M.A. Sunartadirdja & H. Lehmann 1960. Der tropische Karst von Maros und Nord-Bone in SW-Celebes (Sulawesi). *Zeitschrift für Geomorphologie*, Suppl. Band 2. Also: R.C. McDonald 1976. Limestone morphology in South Sulawesi, Indonesia. *Zeitschrift für Geomorphologie*, Suppl. Band 26.
5. For example in the river valley near Patanuang Asue, a few hundred meters to the east of the Leang Karassa (see Fig. 1): H.A. Brouwer 1924. Geologische beschrijving der omgeving van de tertiaire fossielrijke lagen nabij Patanoeang Asoe E in Zuid-Celebes. *Jaarb. v.h. Mijnwezen* 1923: 153-165. The presence of land in the Tertiary is also indicated by recent discoveries to the north of Maros near Ralla (in the region of Padang Lampe) of fossil marine vertebrates with a near-shore habitat. The remains of turtles have been found there, and fragments of robust ribs from a Tertiary ancestor of the present-day dugongs (sea cows; Order Sirenia). The fossils are found in an area with outcropping sandstones and claystones (mudstones) with coal seams. Geological information on this area is already available in: C.W.A.P. 't Hoen & K.G.J. Ziegler 1915 (1917). Verslag over de resultaten van geologisch-mijnbouwkundige verkenningen en opsporin-

gen in Zuidwest-Celebes. *Jaarb. v.h. Mijnw. in Ned. Oost-Indië* 44(Verh. II): 302-305 ('Het kolenterrein van Podo'). See also Note 36.

6. P. Sarasin & F. Sarasin 1903. Ueber die Toála von Süd-Celebes. *Globus* 83: 277-281.
7. Partially reprinted in 1945 in: *Cultureel Indië* 7: 186-196. See also: B.D. Swanenburg 1951. *Iwan de Verschrikkelijke. Leven en werken van Dr P.V. van Stein Callenfels.* Maastricht: Leiter Nypels. From page 230 on.
8. Stein's data were further processed by W.A. Mijsberg 1941. De anthropologische betekenis van de Toala's in Zuid-Celebes (op grond van metingen, verricht door wijlen Dr P.V. Van Stein Callenfels). *Geneesk. Tijdschr. v. Ned. Indië* 81: 1279-1309. Mijsberg, too, could demonstrate no relationship with the Wedda. D.A. Hooijer 1950 (see Note 18), came to the same conclusion.
9. P.V. Van Stein Callenfels 1938. Het Proto-Toaliaan. Verslag van een lezing gehouden op 30 november 1937 voor het Nederlandsch Indisch Bureau voor Anthropologie te Batavia. Verslag opgesteld door Dr A.N.J. Thomassen à Thuessink van der Hoop. *Tijdschr. v. Ind. Taal-, Land- en Volkenkunde* 78: 579-584.
10. In this analysis Van Heekeren used splendid French nomenclature, such as: 'Lame courte avec bout formant grattoir museau, reserré en arrière par coche de fracture' and 'Eclat avec coche formant un bec terminal'. See H.R. van Heekeren 1937. Aanteekeningen over een ingraving in de 'Liang Karrassa' nabij Maros, Zuid-Celebes. *Trop. Nederland* 10: 281-285. Depending on the Indonesian or Buginese or Makassarese spelling, names are spelt differently. For Leang one finds Liang or even Loang; the meaning is 'cave'. For Karassa one finds Karrassa, Karasa, Kerassak, or Karassa' (the apostrophe standing for a so-called glottal stop).
11. H.R. Van Heekeren 1937, in the same article as in Note 10, page 283.
12. Maros points are also absent from the cave assemblages of Toé and Kria on the Bird's Head (see the papers by Jelsma and Pasveer, this volume). Muduk points or bone (bi)points are found in both caves, however. See also J.M. Pasveer & G.J. Bartstra 1996. Naalden in de hooiberg. Verslag van een opgraving in Kria, de Vogelkop, Irian Jaya, Indonesië. *Paleo-Aktueel* 7: 30-33.Van Heekeren mentions the 'esoteric' character of the Toalean in his revised edition of the Stone Age of Indonesia from 1972, on page 124 (see Note 30).
13. See also F.D. McCarthy 1940. Comparison of the prehistory of Australia with that of Indo-China, the Malay Peninsula, and the Netherlands East Indies. *Proc. Third Congr. of Prehistorians of the Far East*: 30-50.
14. For an account of Van Heekeren's wanderings during the years of war and directly after, see his book: *De onderste steen boven*, which appeared in 1969, Assen: Van Gorcum en Comp. The Archaeological Service was the well-known 'Oudheidkundige Dienst', with its main office in Batavia (Jakarta).
15. H.R. Van Heekeren 1949. Rapport over de ontgraving van de Bola Batoe, nabij Badjo (Bone, Zuid-Celebes). *Oudheidk. Verslag 1941-1947*. Oudheidk. Dienst in Indonesië: 89-108. In this report Van Heekeren uses the term Palaeo-Toalean, which he considered to be older than the Proto-Toalean. In later writings, however, the difference between Palaeo- and Proto-Toalean becomes blurred, and both names are used for the same assemblage.
16. H.R. Van Heekeren 1949. Voorlopige mededeling over palaeolithische vondsten in Zuid-Celebes. *Oudheidk. Verslag 1941-1947*. Oudheidk. Dienst in Indonesië: 109-110. This was one of the first scientific reports on the Cabenge 'culture'. For

a detailed account see G.J. Bartstra 1997. A Fifty Years Commemoration: fossil vertebrates and stone tools in the Walanae Valley, South Sulawesi, Indonesia. *Quartär* 47/48. Further G.J. Bartstra, D.A. Hooijer, B. Kallupa & M. Anwar Akib 1994. Notes on fossil vertebrates and stone tools from Sulawesi, Indonesia, and the stratigraphy of the northern Walanae depression. *Palaeohistoria* 33/34: 1-18; and S.G. Keates & G.J. Bartstra 1994. Island migration of early modern Homo sapiens in Southeast Asia: the artifacts from the Walanae depression, Sulawesi, Indonesia. *Palaeohistoria* 33/34: 19-30.

17. For example: C.J.H. Franssen 1949. Bijdrage tot de kennis van het Toaliaan op Zuid-Celebes. *Tijdschr. v. Ind. Taal-, Land- en Volkenkunde* 83: 331-339. Franssen excavated in the Leang Lampoa (see Fig. 1, and Pl. 2). N. Heyning explored the Leang Pattae and the Leang Burung in October 1949, and published in 1951: Praehistorische vindplaatsen bij Maros in Zuid-Celebes. *Tijdschr. v.h. Kon. Ned. Aardr. Genootschap* 68: 21-30.
18. D.A. Hooijer 1950. Man and other mammals from Toalian sites in South-Western Celebes. *Verhand. Kon.Ned.Ak.v.Wet.* 46(2): 1-158. This is not just a publication, but in fact a very thorough and detailed manuscript, which truly serves as a reference work. See also A.T. Clason 1989 (1987). Late Pleistocene/Holocene hunter/gatherers of Sulawesi. *Palaeohistoria* 29: 67-76.
19. As has been said, the Sarasins were the first to excavate in the Lamoncong caves; in addition to tools, they also found animal remains. These were described in F. Sarasin 1905. Die Tierreste der Toála-Höhlen, included in P. Sarasin & F. Sarasin 1905. Materialien zur Naturgeschichte der Insel Celebes, Vol. 5(1): 29-62. Wiesbaden: Kreidel's Verlag.
20. Franssen supplied bone material from the Leang Lampoa (see Note 17); Van Heekeren brought samples from the Bola Batoe (see Note 15). The vertebrate material from the Leang Karassa and Leang Saripa, which Van Heekeren had collected in the thirties, appears to have been lost during the war. G.H.R. von Koenigswald, another well-known vertebrate palaeontologist who worked on the fossil faunae of Southeast Asia, had been able to draw some preliminary conclusions from it, however (mentioned in Hooijer 1950; see Note 18).
21. Extant somewhere on Sulawesi, but not in the southern part anymore. This holds true, for example, for the remarkable babirusa (the 'pig-deer': *Babyrousa babyrussa*): present in a (sub)fossil state in the caves, but nowadays only found 'in the flesh' in Central and East Sulawesi. Also the anoa, the graceful pygmy buffalo (in the older literature sometimes referred to as sapi hutan and wild cow), the bones of which often lie embedded in the cave sediments of southern Sulawesi, now only occurs much farther to the north in inaccessible and forested mountain regions. It is thus noteworthy that the Sarasins at the beginning of this century report having seen anoas on the slopes of the Lompobatang (South Sulawesi). According to Hooijer (see Note 18), these were presumably the small *Anoa quarlesi*; one of the two anoa species still extant in Sulawesi. The other species is *Anoa depressicornis*. The anoa bones which the Sarasins excavated from the caves of Lamoncong might all be of *Anoa quarlesi*, although the relative size of the bones points to the larger *Anoa depressicornis*. Hooijer, however, came to the conclusion that most of the present-day descendants of the cave faunas have become smaller. Thus, *Anoa quarlesi* used to be the size that *Anoa depressicornis* is now.

22. Heyning (see Note 17) in fact supported this from a physical-geographical standpoint by stating that the caves in the Maros region were probably all created in the post-glacial era (= Post-Pleistocene).
23. Cabenge (see Note 16); Watampone (see Note 15): (the Bola Batu is situated near Watampone); Kalumpang: H.R. Van Heekeren 1950. Rapport over de ontgraving te Kamasi, Kalumpang (West Centraal-Celebes). *Oudheidk. Verslag 1949*, Oudheidk. Dienst in Indonesië: 26-48.
24. See Note 21. The cave drawings of the Leang Pattae have been pictured in various publications. See for example Van Heekeren's *The Stone Age of Indonesia*. See Note 30.
25. The Leang Pattae and neighbouring caves and rock shelters are now protected in a so-called prehistoric park, the 'Taman Prasejarah Leang-Leang', which attracts many visitors. The first detailed report by Van Heekeren about his activities at this site is entitled: Rock paintings and other prehistoric discoveries near Maros (South West Celebes). *Laporan Tahunan 1950*. Dinas Purbakala Republik Indonesia: 22-36. His correspondence with Hooijer about the rock art and its association with the Toalean has luckily been preserved, and is worthwhile reading for anyone interested in the history of archaeological research in southern Sulawesi.
26. J. Röder & A. Hahn 1959. *Felsbilder und Vorgeschichte des MacCluer-Golfes West-Neuguinea*. Darmstadt: Wittich. On page 85. It should be noted that although the paintings in the caves near Maros may not be numerous, they are more common in the caves to the north, near Pankajene (see Fig. 1): H. Kadir 1985. Tinjuan tentang lukisan dinding gua di daerah Sulawesi Selatan. *Pertemuan Ilmiah Arkeologi Ke-III, 1983*. Pusat Penelitian Arkeologi Nasional, Jakarta: 176-181. Perhaps it should be emphasized here that the present paper deals with the caves east of Maros only. But there are more archaeologically significant cave areas in southern Sulawesi. Apart from the cave sites near Lamoncong and in Bonthain, both mentioned in this text and notes, there is thus Pangkajene (for example N.A. Subagus 1986. Alat-alat batu dari Pangkep, Sulawesi Selatan. *Pertemuan Ilmiah Arkeologi Ke-IV*. Pusat Penelitian Arkeologi Nasional, Jakarta: 246-270; and also Yusmaini Eriawati & M. Fadhlan S. Intan 1995. Gua-gua di Maros dan Pangkep, Sulawesi Selatan. *Laporan Penelitian Arkeologi Bidang Arkeometri*. Pusat Penelitian Arkeologi Nasional, Jakarta. This latter report has a good bibliography of Indonesian papers on the areas concerned), and furthermore some isolated limestone complexes to the east of the Walanae valley (for example Bulu Mampu).
27. Stated again recently by S.G. Keates 1994. Archaeological evidence of hominid behaviour in Pleistocene China and Southeast Asia. *Courier Forsch. Inst. Senckenberg* (Frankfurt am Main) 171: 141-150. See also W. Marschall 1995. Die frühen Kunsttraditionen und ihr Nachwirken. In *Versunkene Königreiche Indonesiens*. Exhibition Catalogue Hildesheim Museum: 188-192. Marschall even doubts whether paintings from the so-called Mesolithic (Epi-Palaeolithic) exist in Indonesia. He dates the rock paintings from Southeast Sulawesi (Muna) to the Metal Age, mainly on the basis of what they depict.
28. D.J. Mulvaney & R.P. Soejono 1971. Archaeology in Sulawesi, Indonesia. *Antiquity* 45, 177: 26-33. Because the names Leang Burung and Ulu Leang are used for several caves, the excavations of 1969 are now referred to in the literature by the names Leang Burung 1 and Ulu Leang 1. The Australian-Indonesian team also excavated on the south coast of Sulawesi, in Bonthain.

29. I.C. Glover 1976. Ulu Leang cave, Maros: a preliminary sequence of post-Pleistocene cultural development in South Sulawesi. *Archipel* 11: 113-154; and I.C. Glover 1981. Leang Burung 2: an Upper Palaeolithic rock shelter in South Sulawesi, Indonesia. *Modern Quat. Research in Southeast Asia* 6: 1-38. Van Heekeren had found a few hand stencils in this latter cave in 1950.
30. In Van Heekeren's *The Stone Age of Indonesia (= Verhandelingen van het Kon.Inst. voor Taal-, Land- en Volkenkunde*, 21) from 1957, but also in the second edition (= *Verhandelingen*, 61) from 1972, the Toalean is classified in a so-called Mesolithic or Sub-Neolithic stage. Notions on an (Epi-)Palaeolithic rock art or tool assemblage have then vanished.
31. For example, P. Veth et al.; J. Lilley; J.M. Pasveer; and P. Bellwood et al, all in this volume. See also M.A. Smith & N.D. Sharp 1993. Pleistocene sites in Australia, New Guinea and Island Melanesia: geographic and temporal structure of the archaeological record. In M.A. Smith, M. Spriggs & b. Frankhauser (eds), *Sahul in review*, etc.: 37-59. Canberra: Australian national University. A critical evaluation of some early dates may also be found in R. Shutler 1991. Colonization, expansion, and successful adaptation in Southeast Asia, New Guinea and Australia 40,000-10,000 BP. *Asian Profile* 19(2): 151-157; and in S. Bowdler 1992. The earliest Australian stone tools and implications for Southeast Asia. *IPPA Bulletin* (Indo-Pacific Prehistory Association), 12: 10-22.
32. As in P. Bellwood 1985. *Prehistory of the Indo-Malaysian archipelago*. Sydney: Academic Press; and to a certain extent also in the next paper in this volume, by Pasqua & Bulbeck.
33. See Note 28.
34. See Note 29.
35. For example G.-J. Bartstra 1978. Note on new data concerning the fossil vertebrates and stone tools in the Walanae valley in South Sulawesi (Celebes). *Modern Quat. Research in southeast Asia* 4: 71-72. It is stated that 'at high spots alongside the river are to be found in distinct concentrations very small flakes and cores, neither rounded nor patinated, and associated with arrow-heads (denticulated and with hollow base)'.
36. Reported upon in, for example B. Kallupa 1992. The 4-days Ralla trip. A survey report for the Biologisch-Archaeologisch Instituut (BAI), Groningen, Holland. Unpubl. report from the Suaka Peninggalan Sejarah dan Purbakala, Sulselra (Archaeological Service, Ujung Pandang); and A.M. Ramli 1993. Laporan pendahuluan survai situs prasejarah Panincong dan Padang Lampe di desa Lompo Ri Aja, Dec. Tanete Riaja, Kab. Barru, Sulsel. Unpubl. report from the Suaka Peninggalan Sejarah, etc.; and: M. Fadhlan S.I and H. Sukendar, 1994. Keadaan geologi dan peninggalan arkeologi situs Ralla, Kab. Baru, Sulawesi selatan. Unpubl. report from the Suaka Peninggalan Sejarah, etc. From this same area come fossil remains of marine vertebrates (see Note 5).

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A technological interpretation of the Toalean, South Sulawesi

1 INTRODUCTION

This article is a slightly revised summary of Pasqua's (1995) Honours research on Toalean lithics carried out at the University of Western Australia under Bulbeck's supervision. In broad terms, the research re-interprets the Toalean from a technological perspective rather than the traditional typological approach. In particular, comparative statistical analysis of the debitage categories in the studied assemblages correlates with the available typological and chronological information to suggest systematic variation within the Toalean. The possible explanations for this apparent variation are discussed at the end of the paper.

The Toalean is apparently confined to the southwest peninsula of Sulawesi (see Fig. 1) where it spanned the Middle to Late Holocene. Early investigations by the Sarasin cousins (1905), Van Stein Callenfels (1938) and Van Heekeren (e.g. 1939) recognized a Toalean 'culture' through a number of sparsely documented excavations in rockshelters. Van Heekeren (1972: 113-115) proposed a three-stage chronology with a Lower Toalean, made up of large crude flakes and frequently tanged tools, a Middle Toalean characterized by projectile points with rounded bases and abundant geometric microliths, and an Upper Toalean when hollow-based points, bone points and pottery appeared (for details see preceding paper in this volume: Bartstra on Maros).

Radiometric dates first became available from the excavations directed by Mulvaney and Soejono (1970) and Ian Glover (1976, 1978). Glover's sequence at Ulu Leang 1 showed the broad chronological transition that would be expected from Van Heekeren's scheme, and dated the first microliths to between 7000 and 6000 BP, whilst the hollow-based (or Maros) points appeared by 5500 BP and were most popular at 4000-3500 BP (Presland 1980: 36-39). However, in Mulvaney and Soe-

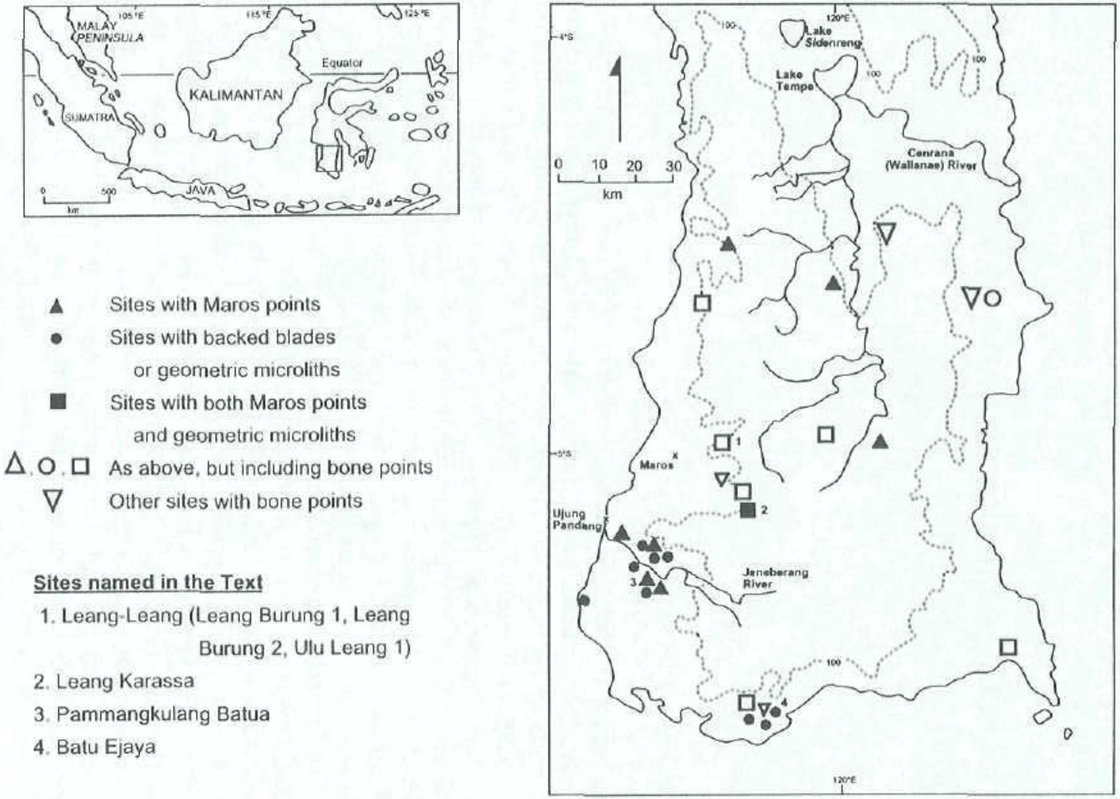

Figure 1. Distribution of sites with Toalean tool types (after Bulbeck & Pasqua, in prep.).

jono's sequence at Leang Burung 1, Maros points tend to be older than the microliths, suggesting to Chapman (1986: 81) that no single typological sequence applied universally (but see below).

As well as attempting to produce a radiometrically dated culture history of the Toalean, these studies also initiated a technological approach. Presland (1980) looked at flake dimensions and choice of stone material to compare Leang Burung 2, which has an Upper Pleistocene sequence (Glover 1981), and Ulu Leang 1. From the lack of significant differences, he inferred that the technology of flaking remained unchanged despite the Middle Holocene appearance of microliths. Chapman (1981) considered such technological variables as the prevalence of bipolar flaking, the dimensions of cores and complete flakes, and the size grades of broken debitage. However, both Presland and Chapman were descriptive rather than analytical in their technological comparisons and remained essentially committed to a typological analysis. In contrast, the present study focuses on the debitage from three assemblages, in order to reconstruct the reduction sequences represented and to identify the manufacturing technology employed at each site.

2 MATERIALS

The studied lithics come from two excavated rockshelters and one open-air site (see Fig. 1). The two rockshelters, Leang Karassa and Leang Burung 1, were excavated in 1969 by the 'Australian-Indonesian Archaeological Expedition to South Sulawesi' (Mulvaney & Soejono 1970). The third assemblage, from Pammangkulang Batua, was collected in 1987 by Bulbeck during his 'South Sulawesi Prehistoric and Historical Archaeology Project' (Bulbeck 1992). A summary of the unpublished details discussed in Pasqua (1995) is necessary as background to these assemblages.

2.1 *Leang Karassa*

Leang Karassa is located within a karst valley adjacent to the Taddaiang River approximately 20 km from Maros town. The site was originally excavated by Van Heekeren in 1936. He found a high frequency of bladelets, scrapers, knives, and points with serrated edges, but few bone tools and no Maros points. The dominance of his Lower to Middle Toalean markers suggested it was one of the oldest Toalean sites, although still of Holocene age as indicated by the modern faunal associations (Van Heekeren 1972: 111; cf. Glover 1978: 69).

In 1969 Campbell Macknight excavated 2 m^2 to a maximum depth of approximately 80 cm, to the point where bedrock or cemented deposits were encountered (see Fig. 2). As at Leang Burung 1, the deposits were sieved through a 6 mm mesh, which implies that the smallest debitage pieces would not have been retained. Chapman (1981, Appendix), after cursorily examining the lithics, concluded that they broadly matched those described by Van Heekeren. Strangely, however, sherdage occurred throughout Macknight's excavation, whereas Van Heekeren had reported that pottery was restricted to the uppermost layers. Chapman accordingly inferred that either the squares excavated by Macknight had suffered substantial disturbance, moving sherds throughout the profile, or the age Van Heekeren attributed to Leang Karassa is too old. Our new data indicate that there has been disturbance, but only in the form of one redeposited layer, and that the rest of the deposits excavated by Macknight are Late Holocene.

The four stratigraphic layers are, top to bottom, a brown sediment, a black greasy layer, a brown clayey sediment which constitutes most of the deposits in square A at the south, and a shelly deposit at the base (see Fig. 2). A charcoal sample from 10 cm below the surface in square A returned a date of 370 ± 50 BP (Wk-3824), which calibrates to

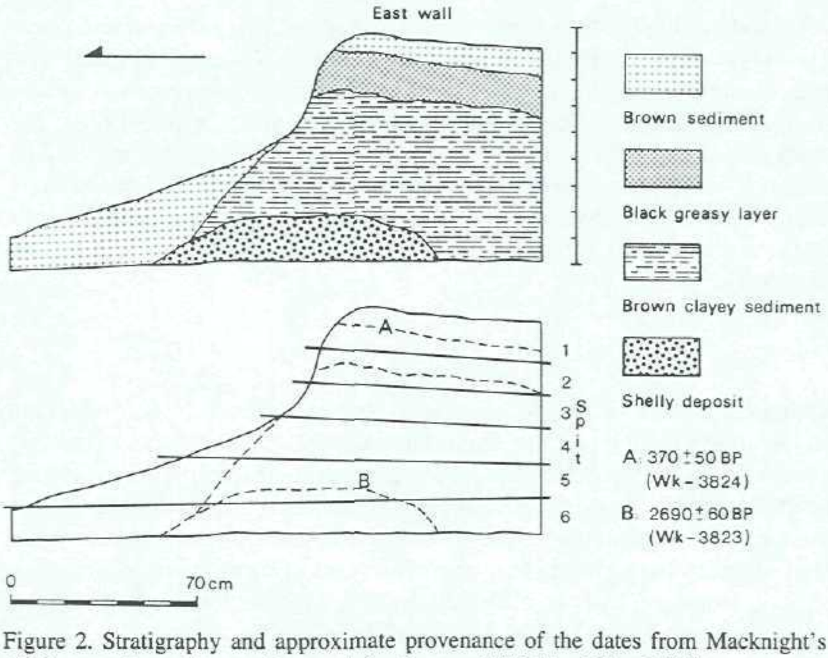

Figure 2. Stratigraphy and approximate provenance of the dates from Macknight's 1969 excavation of Leang Karassa (after Pasqua 1995: Figs 5.2 and 5.3).

1438-1651 AD at two sigma (cf. Stuiver & Reimer 1993). Thus the deposition of the extant black greasy layer ceased at some point between the 15th and the 17th century. The second charcoal sample, collected from 65 cm below the surface in square A, is dated to 2690 ± 60 BP (Wk-3823), i.e. a calibrated age of 2740-2880 BP at two sigma. It dates the approximate age at which the clayey sediment began building up. Square A thus appears to have an intact stratigraphy with two late Holocene dates in correct order. However, along the face which slopes steeply into square B, most of these deposits have subsided or otherwise been removed (see Fig. 2).

In square A Macknight excavated six spits, each 15 cm deep, which slant across the layers, so any attempt to relate the recovered artifacts to stratigraphy will be inexact (see Fig. 2). For instance the basal spit has the lowest ratio of sherds to lithics (1:3) which could be either because the shelly layer is aceramic or because sherds are comparatively rare at the base of the clayey sediment too. Similarly, the geometric microlith Pasqua identified among the lithics in spit 6 could, without further information, have come from either an aceramic (preceramic) or an early ceramic context. In spits 5 to 2, sherds consistently outnumber lithics, reaching a ratio of 3:1 in spit 4. Immediately above, among the spit 3 lithics, Pasqua identified a second geometric microlith. From the available sections it must have been excavated in either the upper levels of the clayey sediment or the greasy layer, and so dates somewhere between 2700 and 500 BP, and has an unquestionable association with pottery. One would guess that it was deposited closer to 2700 than to 500 yrs ago.

The top spit in square A shows a peculiar reversal: the sherdage count again falls behind the lithics (a ratio of 1:2), and indeed this spit has the highest lithics count within the excavated deposits. Even more strangely, the lithics include a Maros point with the classical serrated edge and a hollowed base or, more precisely, the basal two thirds of it (Pasqua 1995: Fig. 5.4). The re-emphasis on lithics, and the inclusion of a type whose popularity peaked over 3500 yrs ago, are totally out of keeping with the recent date for this spit. Accordingly, we infer that the uppermost brown layer consists of sediments and artefacts redeposited from elsewhere in the rockshelter. This redeposition event, which can be no more than 500 yrs old, can probably be identified with known instances of recent disturbance, either during the construction of the paved highway which runs along the front of the rockshelter, or at around 1957 when organic-rich sediments were removed from the site to be used as fertiliser. Having lost their original depositional context, all the materials in spit 1 are essentially undated.

It might seem unlikely that Van Heekeren would have excavated Maros points or microliths at Leang Karassa and then failed to have observed them. However, Van der Hoop's (1941) catalogue notes one denticulated and winged arrowhead from Leang Karassa (Acc. No. 3411) and even a geometric knife (Acc. No. 3424), so apparently Van Heekeren had indeed excavated a Maros point and possibly a geometric microlith too. On the other hand, where his brief notes (1972: 110-111) mention shell-rich layers with sherdage only at the top, these layers would appear to correspond to the shelly deposit at the base of Macknight's excavations. In support of the idea that most of the deposits consist (or anyway consisted) of an aceramic shell midden, Bulbeck (1995) observed only lithics, and no sherds, attached to the cemented deposits along the rear wall of the site. Accordingly, any general difference between Van Heekeren's and Macknight's assemblages would be understandable in terms of the greater age of the former assemblage.

This issue however does not affect the quite straightforward interpretation of Macknight's square A. Spits 2 to 6 contain an in situ lithics assemblage which is mostly or entirely ceramic in its associations and dates between approximately 3000 and 500 BP. Spit 1 in square A, and both spits in square B, are dominated by disturbed, redeposited materials which could be of any age. Accordingly, the technological analysis focuses on the in situ layers as an assemblage representing the ceramic or 'Neolithic' Toalean.

2.2 *Leang Burung 1, Trench B*

Leang Burung 1 is a large rockshelter, with a steeply sloping floor, within the Leang-Leang limestone karst where they abut the Maros coastal plain. The excavated areas comprise Trench A within the shelter, Trench B outside the entrance, and Trench C which connects them. The stratigraphic integrity of the site has always been under a cloud as the excavating team noted numerous sand-filled depressions piercing the surface, and as preliminary study recovered several cases of matching but widely separated sherds of decorated pottery (Chapman 1981). More recently Bulbeck (1992) has extracted human bone from Trench A. These not only exhibit numerous cases of fragmentation and widespread dispersion of originally whole items, as previously found with the pottery, but also suggest that prehistoric burials may have been one cause of the disturbance.

The outlook for Trench B, however, is more promising. A mere eight earthenware sherds were excavated, indicating that the deposits are preceramic in their virtual entirety. Sorting through the faunal remains, Bulbeck found 15 fragments of semi-fossilized human bone which cover the whole skeleton without overlapping on any portion of it. Hence they appear to represent a primary burial whose extent of post-depositional disturbance is charted by the five separate provenances of the fragments (labelled B in Fig. 3). The radiocarbon date obtained on this bone, 4610 ± 220 BP (ANU-6175), calibrates to 5855-4650 BP at two sigma. It falls between the original charcoal dates of 4880 ± 480 BP, i.e. 6670-4360 BP (ANU-1264), and 3420 ± 400 BP (ANU-390), i.e. 4830-2750 BP (see Fig. 3). The promise of a relatively tight chronology prompted Pasqua to select the Trench B lithics for study.

Closer inspection of the stratigraphy, however, reveals the problem that the younger charcoal date (A in Fig. 3) appears to be provenanced beneath most or all of the dated bone fragments. If this charcoal date is to be accepted, then the simplest scenario would interpret it as dating the event which disturbed the burial. In this scenario, at a time when the area of Trench B was covered with brown sand, human or natural disturbance deposited the 4830-2750 year old charcoal at A, and brought some of the burial to the surface. These upwardly displaced bone fragments became incorporated within the grey unit which was subsequently deposited. In

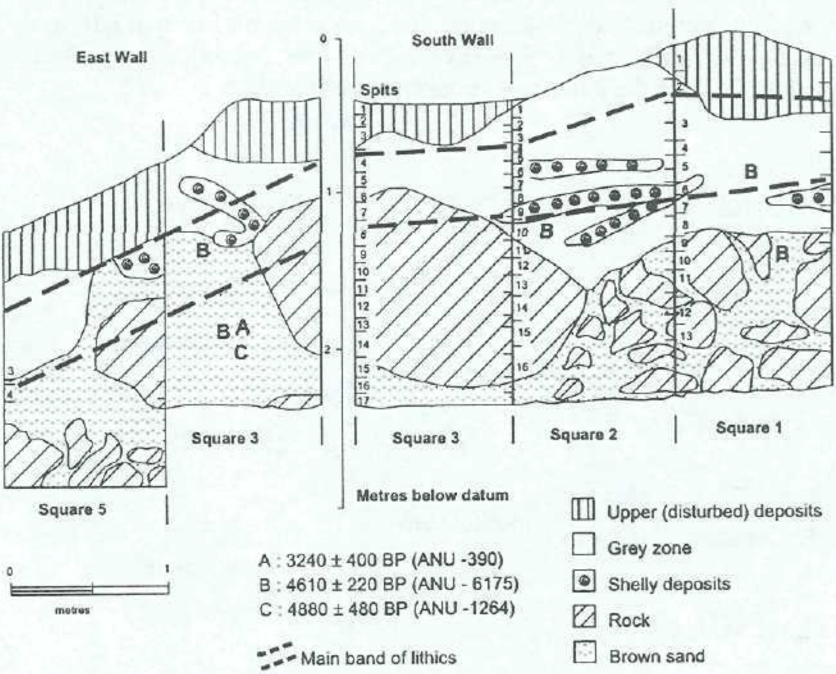

Figure 3. Stratigraphy and approximate provenance of the dates from the excavation of Leang Burung 1 Trench B (after Pasqua 1995: Figs 4.3 and 4.4).

support of this scenario, we can refer to Trench A which has both the grey zone and the underlying brown sand found in Trench B (see Fig. 4). The only charcoal date from Trench A, apparently located at the base of the grey zone directly above the brown sand (Chapman 1981: 20A), clocks in at 2820 ± 210 BP (ANU-391), i.e. 3460-2360 BP when calibrated at two sigma. If we let this determination also apply to the base of the grey zone in Trench B, the changeover from brown to grey sands would be dated to around 3500 BP.

Chapman (1981) noted that the main concentration of lithics in Trench B at Leang Burung 1 occurred in the shelly deposits which, as shown in Figure 3, were intercalated with the basal levels of the grey sands. From the available information, it is impossible to be sure that the main band of lithics also dipped into the top of the brown sand. However, the dated samples in Trench B all underlie this main band, suggesting a maximum age of 4000 BP for its accumulation. The lack of ceramics suggests a minimum age of 3000 BP (cf. Leang Karassa) or, more likely, 3500 BP (Bulbeck 1992: 13, 1995: 5-6). Finally, note that the lithics from this trench include 24 Maros points but only ten microliths (Chapman 1986). Hence at Leang Burung 1, as at Ulu Leang 1 (Presland 1980), 4000-3500 BP appears to have been the peak period of popularity of Maros points. Trench A, whose Toalean assemblage essentially post-dates 3000 BP, shows a relative increase of microliths over Maros points, because the latter type dropped out after that date.

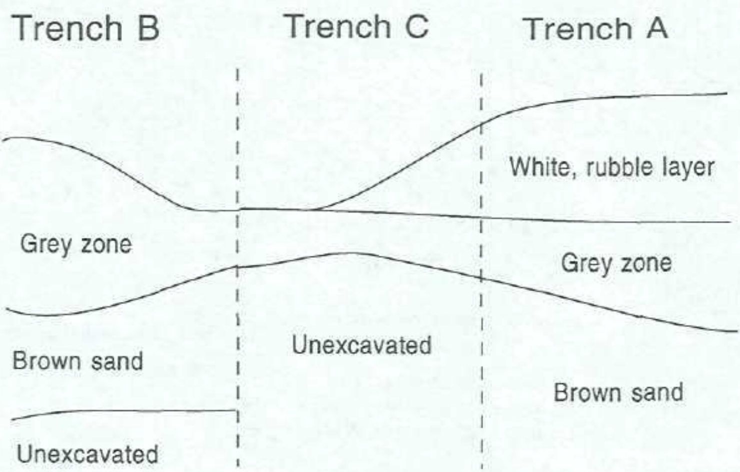

Figure 4. Schematization of the relation between the grey zone and the brown sand in trenches A and B at Leang Burung 1 (after Pasqua 1995: Fig. 4.2).

In summary, the assemblage which Pasqua studied from Leang Burung 1 consists of an essentially preceramic Toalean industry which includes more Maros points than microliths. The composition of the assemblage and the available radiocarbon dates suggest a main dating of approximately 4000-3500 BP, although this estimate could possibly be too young.

2.3 *Pammangkulang Batua*

Pammangkulang Batua is located on the west bank of the Jeneberang River where it enters the coastal plain before running towards the modern capital city of Ujung Pandang (see Fig. 1). Not only is it an open site, it also lies well away from the Maros sites, approximately 50 km south of Leang Karassa. Bulbeck's team surveyed a 300 m long footpath and its associated fields, where they recorded 422 lithics, 57 earthenware sherds, and 39 fragments of Chinese and European ceramics dating between the 18th and 20th centuries. The site also retains quarrying scars from the 17th century when conglomerate blocks were hewn at Pammangkulang Batua for use in the Somba Opu fortress near Ujung Pandang. The earthenware sherds probably relate to the 17th century and later use of the site, but unfortunately they were not collected for laboratory examination. The only hint of the age of the lithics is the frequency of Maros points, seven complete or fragmented specimens, without a single backed blade or geometric microlith in the collection. As argued for Trench B at Leang Burung 1, this may suggest a most likely age of around 4000-3500 BP. However, specialized site use is another feasible explanation for the large proportion of points, in which case the assemblage could date to any time during the period when Maros points were manufactured (c. 5500-3000 BP).

Given the evidence of quarrying at the site, as well as traffic of humans and water buffalos along the footpath, and tillage of the adjacent fields, it is very likely that the Toalean lithics would have been subject to treadage, scuffage and other post-depositional disturbance. Much of the site is also seasonally inundated, which would appear to account for the soft, hydrated, even 'soapy' consistency of much of the stone. The likelihood of post-depositional edge damage and artefact breakage needs to be remembered when the Pammangkulang Batua assemblage is compared with the lithics from the Maros sites.

3 METHODOLOGY

Having discussed the main lithic types at the three sites, to order them in a culture-historical perspective, we can move to the technological analysis. This was undertaken with a slightly elaborated version of Sullivan and Rozen's (1985, 1989) hierarchical key where debitage categories are identified on the basis of the presence or absence of specific attributes. The first attribute, positive percussion features, separates cores (which lack this feature) from other artifacts. The latter are classified into debitage and retouched pieces. Debitage is then classified into debris (no single interior surface discernible), flake fragments (which have a single interior surface, but lack a point of applied force), broken flakes (having both a single interior surface and a point of applied force, but with their margins incomplete), and complete flakes. Broken flakes were further divided into longitudially and transversely broken flakes, depending on which margin is lacking (O'Connor 1990). Among the flakes, blades were recognized by their length, parallel lateral margins, and longitudial arrises on the dorsal surface. Bending flakes, attributed to pressure rather than percussion flaking, were identified by the absence of a bulb of percussion and their typically diffuse platform (Cotterell & Kamminga 1990: 142). Finally, bipolar flaking was recognized on cores from the presence of crushing or grinding of the raw material at opposing ends, and on flakes from crushing of the striking platform and/or crushing at the distal end.

To interpret the proportions of debitage categories and realize which further observations are required, we require a theoretical model of the reduction sequence that was followed in knapping a stone nodule through the stages of core preparation and manufacture of useful flakes. The most appropriate model would seem to be the reduction sequence proposed by Flenniken and White (1985) for Australian flaked-stone assemblages, with which the Toalean is often compared (e.g. Van Heekeren 1972: 124; Glover & Presland 1985: 194; Chapman 1986). This model identifies seven stages:

– Stage 1. The conscious selection of raw materials which will be most suited to tool manufacture, and the procurement of such resources;

– Stage 2. Preliminary treatment of a stone nodule to produce a workable core;

– Stage 3. The further refinement and treatment of these cores and the manufacture of blades and linear flakes;

– Stage 4. Continuation of blade manufacture and the manufacture of medium-sized flakes (points may be made at this stage by retouching the flake blanks);

– Stage 5. The manufacture of smaller artifacts, either in the form of implements (especially microliths) or micro-debitage;

– Stage 6. Exhaustion of the core with the production of debris;

– Stage 7. Discard of debitage into the archaeological record.

A concentration on Stage 2 in the reduction sequence should be correlated with large flakes and cores, the frequent presence of cortex on cores and debitage, and a low proportion of prepared as opposed to opportunistic striking platforms. As the reduction sequence proceeds through Stages 3 and 4, cores and flakes should reduce in size, flakes should elongate and blades should appear, a higher proportion of artifacts lacking cortex should be apparent, and preparation of striking platforms should be more evident. Retouched points, including miscellaneous points which lack a hollowed base, may also be among the artifacts associated with Stage 4 reduction. Stages 5 and 6 should be associated with even smaller flakes and debitage pieces, the absence of cortex and a higher occurrence of bipolar working.

The following definitions were employed to gauge these tendencies. Cores were subdivided into those with a single platform, multi-platform cores, and broken cores. Single-plane cores, also called broken pebbles, were not observed in any assemblage. Core length is the maximum length of the stone nodule parallel to the direction of the longest flake scar; core breadth is the maximum measurement perpendicular to core length across the same face; and core thickness is the maximum measurement perpendicular to this face. Flake length is the distance from the point of percussion to the termination; flake breadth is the maximum distance perpendicular to flake length across the ventral surface; and flake thickness is the distance, from ventral to dorsal surface, at the intersection of flake length and breadth. Preparation of the striking platform was associated with the flat and faceted types, the latter containing at least two flake scars, while platforms with a crushed or a cortex-covered surface were considered unprepared. Further evidence of platform preparation was recognized from overhang removal in the form of tiny flake scars on the dorsal surface touching the striking platform. The terminations of the complete flakes were divided into feathers, hinges, steps and snap (cf. Cotterell & Kamminga 1987). The representation of cortex on an artifact was estimated visually as >50%, 25-50%, under 25%, and none.

Further observations were taken to monitor factors which may have affected the reduction sequences. Stone material was classified as cryptocrystalline, medium-grained siliceous, coarse-grained siliceous, volcanic, and limestone (found only at Leang Burung 1). Cortex was classified as geological (thick and unsmoothed), secondary (thin and unsmoothed), and riverine (smoothed through water rolling). On specimens where more than one cortex type was observed the cortex was classified by the major type present. Evidence of heat treatment of the stone, to improve its knapping qualities, was noted in terms of potlid fractures, negative potlid scars, crazing of the surface, and colour alterations.

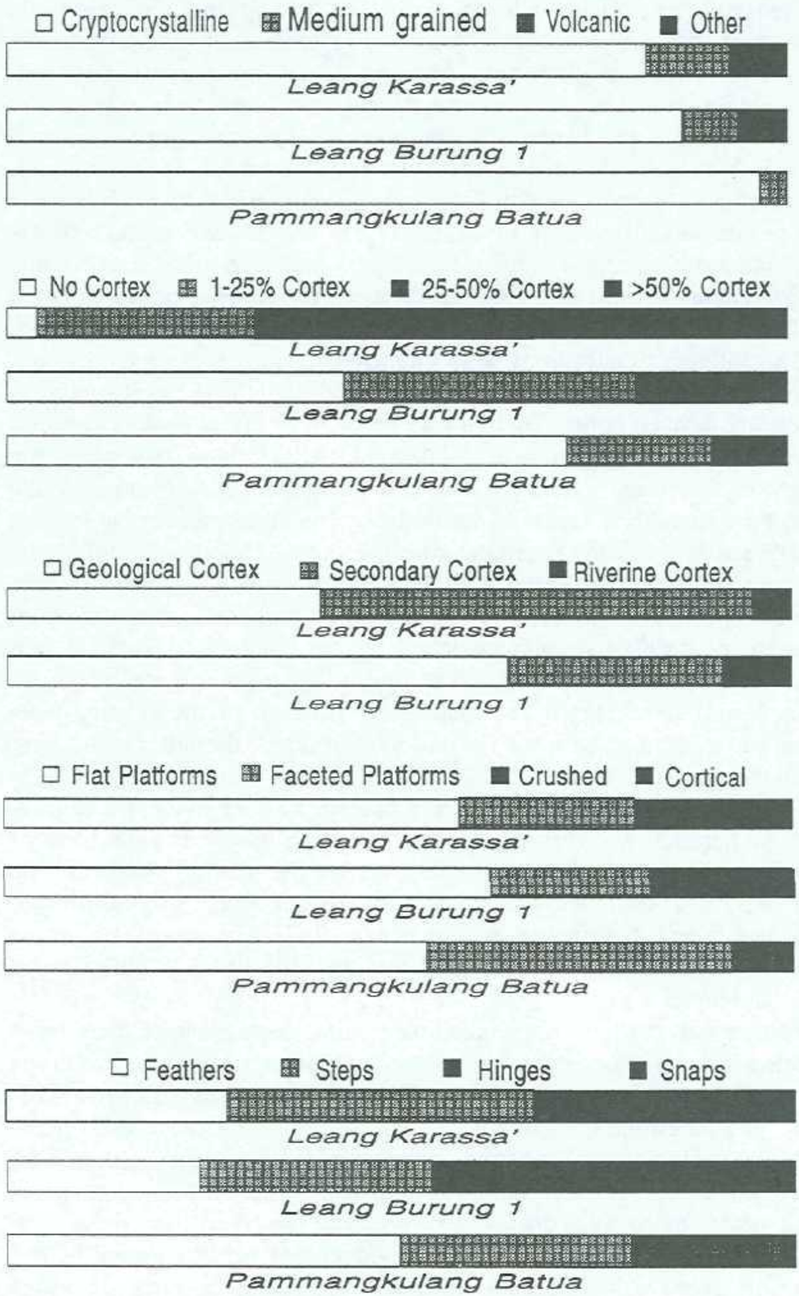

Figure 5. Raw material, cortex characters and major technological attributes of the three compared Toalean assemblages.

4 RESULTS

Basic statistical data on core and flake dimensions expressed to a single decimal place are given in Table 1, along with a summary of the statistically significant differences identified by two-tailed t-tests (calculated from the data as expressed to two decimal places). Comparative analysis of the three assemblages found that quality of raw material, percentage of cortex coverage, striking platform types and flake termination types are the main non-metrical features that distinguish between the three compared Toalean assemblages. The proportions of these features, as well as cortex class (for Leang Karassa and Leang Burung 1 Trench B), are depicted in Figure 5, to which the reader is referred as she/he reads the following presentation of the study's results.

4.1 *Leang Karassa*

81% of the 667 studied Leang Karassa lithics were of cryptocrystalline stone, with small proportions of medium-grained (11%) and volcanic stone (7%). Cortex was ubiquitous, covering more than 50% of 33% of the artifacts, 25-50% in 36% of cases, under 25% in 27% of cases, and absent from only the remaining 4%. This prevalence equally character-

Table 1. Means, standard deviations and t-test results from the three Toalean sites.

	Number	Length	Breadth	Thickness
Single-platform cores				
Leang Karassa	16	32.7 ± 11.6^{1}	$29.9 \pm 10.0^{2,3}$	11.0 ± 3.5^{4}
Leang Burung	151	30.7 ± 9.3^{2}	20.5 ± 7.7^{1}	9.1 ± 4.6
Pammangkulang Batua	15	23.3 ± 7.3	15.7 ± 6.8	10.9 ± 3.5
Multi-platform cores				
Leang Karassa	40	$31.8 \pm 13.2^{5,6}$	$29.5 \pm 9.2^{1,2}$	15.0 ± 6.9^{1}
Leang Burung 1	175	26.4 ± 8.1	20.9 ± 6.1^{2}	10.7 ± 4.9
Pammangkulang Batua	17	24.5 ± 7.2	16.8 ± 3.7	12.3 ± 4.6
Complete flakes				
Leang Karassa	111	$26.5 \pm 11.3^{1,2}$	$22.0 \pm 8.4^{1,2}$	5.5 ± 3.2^{4}
Leang Burung 1	789	22.0 ± 9.5^{2}	19.0 ± 7.4^{2}	4.9 ± 2.7^{7}
Pammangkulang Batua	85	18.5 ± 6.1	15.9 ± 5.1	5.7 ± 3.0

[1]Larger than Pammangkulang Batua at $p(H_0) < 0.02$. [2]Larger than Pammangkulang Batua at $p(H_0) < 0.001$. [3]Larger than Leang Burung 1 at $p(H_0) < 0.001$. [4]Larger than Leang Burung 1 at $p(H_0) < 0.05$. [5]Larger than Leang Burung 1 at $p(H_0) < 0.02$. [6]Larger than Pammangkulang Batua at $p(H_0) < 0.01$. [7]Smaller than Pammangkulang Batua at $p(H_0) < 0.02$.

izes the cores and core fragments, debitage categories, the two geometric microliths, and the ten miscellaneous points, indicating that veins of cortex typically permeated right through the nodules worked at Leang Karassa. Its interdigitation with cortex-free zones allowed the knappers to select suitable surfaces to strike, with the result that 58% of platforms are flat, 22% are faceted, 12% are crushed, and only 8% are cortical.

When present, cortex was almost always secondary (56%) or geological (40%). Only complete cores show a higher frequency of geological (82 cases) over secondary cortex (56 cases), suggesting that nodules with geological cortex were more readily available but that the knappers preferred to focus on portions of the nodules with secondary cortex. All nodules of siliceous stone had presumably been found among the lumps of chalcedony embedded in the limestone along the Taddaiang River bed where Leang Karassa looks over it (Van Heekeren 1972: 111). The difference between geological and secondary cortex presumably reflects localized variation in the extent of exposure to the elements.

Apparently, the knappers at Leang Karassa accepted using the local stone despite the drawback that they could rarely produce cores free of flaws. Step fractures are common among the flakes, characterizing 38% of terminations, which can be attributed to the density of significant flaws (cf. Cotterell & Kamminga 1987: 700). Feather terminations (28.5%) and hinges (30%) are also common. 43% of platforms show evidence of overhang removal; this high proportion may reflect the care with which the knappers had to select and then prepare the limited areas suitable for striking. Pressure flaking or percussion with a soft hammer was very occasionally undertaken, as suggested by the two bending flakes (compared with 216 typical flakes). Evidence of bipolar traits on 5% of the complete flakes, yet on none of the cores, suggests that bipolar flaking was occasionally carried out, but at fairly early stages in the reduction sequence before the cores neared the end of their use life. A casual attempt to improve the flaking quality of the stone is suggested by evidence of heat treatment on 7% of the cores and core fragments, although strangely this evidence was proportionately far more common on medium-grained and volcanic cores than on cores of cryptocrystalline stone.

Several observations indicate that the assemblage reflects a focus on Stages 3 and 4 of Flenniken and White's reduction sequence, i.e. a lower intensity of core reduction than at the other two sites. T-tests show that the single-platform cores, multi-platform cores, and complete flakes are significantly longer, broader and thicker than their counterparts at Leang Burung and Pammangkulang Batua in 14 of the 18 available comparisons (see Table 1). Only 30% of the Leang Karassa cores are broken, compared to over 50% at the two other sites. The ratio of blades to flakes (including broken flakes), 1:55, is higher than in the other assemblages. Points also reach their highest proportion of the total lithics count at Leang Karassa (2.6%), even if none of them are Maros points. Van Heekeren (1972: 111) also drew attention to the high frequency of primary bladelets and points in the Leang Karassa assemblage which he excavated. The two geometric microliths may suggest occasional core reduction to Flenniken and White's Stage 5.

In summary, both the deeply flawed nature of the cryptocrystalline stone used at Leang Karassa and its ready availability seem to have encouraged the site occupants to focus on the intermediate stages of Flenniken and White's reduction sequence.

4.2 *Leang Burung 1, Trench B*

A high proportion of the lithics at Leang Burung are cryptocrystalline, 86%, well in excess of the 7% which are medium-grained, and the approximately 3% contributions each of volcanic stone and limestone. Cortex coverage occurs fairly commonly in low amounts, with 18% of artifacts having 25-50% coverage, 33% under 25% coverage, and 43% exhibiting no cortex at all. Geological cortex (66%) dominates over secondary cortex (25%) and riverine cortex (8.5%). Thus the major source of flaking stone would appear to have been nodules of cryptocrystalline rock located among the Leang-Leang karsts, even if river pebbles of medium-grained and volcanic stone were often brought to the site to function as hammers, anvils and hearth stones (cf. Chapman 1986: 77).

The low proportion of lithics with over 50% cortex coverage, 6%, suggests that the preliminary treatment of the stone nodules, involving the removal of the exterior cortex with decortification flakes, occurred away from the site. Heat treatment of the stone also apparently occurred elsewhere, as negative potlid scars were occasionally observed on the cores, but no potlid fractures were found among the debitage. However, only 3% of cores and core fragments exhibited any signs of heat treatment, so it would not seem to have been a common practice. The treated cores were percussed at Leang Burung, with very occasional pressure flaking or percussion with a soft hammer (three bending flakes compared to 1189 other flakes). The high quality of the stone may have obviated the need for much platform preparation, as only 19% of the flakes show overhang removal. The proportions of platform types are very similar to those at Leang Karassa (61% flat, 20% faceted, 10% crushed and 10% cortical).

Core reduction seems to have been carried further at Leang Burung than at Leang Karassa, with a focus on Stages 4 and 5. The cores and flakes are significantly smaller on every measurement, except the lengths of single-platform cores which are equal across the sites. Far more of the cores are broken. Small size of the cores may also be associated with the need to knap along flattish surfaces which, according to Cotterell and Kamminga (1987: 701), would explain the high proportion of Leang Burung flake terminations which are hinges (44%). (The other common terminations are steps, 29%, and feathers, 25%.) The blade to flake ratio is very low at 1:149, while the proportion of points to all stone artifacts is also slightly lower at Leang Burung (1.9%). However, bipolar working seems to have been as rare at Leang Burung (2% of cores, 0.5% of flakes) as at Leang Karassa, so the cores were not reduced to the point of total exhaustion. Indeed there is little evidence that the cores with bipolar working are smaller than the other cores, suggesting that bipolar flaking was used as an occasional optional strategy at various steps along the reduction sequence.

The technological differences between the two rockshelters boil down to less cortex, smaller cores and flakes, more broken cores, and a greater emphasis on Stage 5 at Leang Burung. These differences probably reflect an overall better quality of stone (including a higher proportion of cryptocrystalline stone), more curation of the stone, and the absence of preliminary core preparation at the site.

4.3 *Pammangkulang Batua*

The surface collection from Pammangkulang Batua merits an interpretation similar to that provided for Leang Burung, and any attempt at a more precise interpretation may be premature for two reasons. First, as a surface assemblage it has been exposed to different site-formation processes, and as a surface collection its composition depends on the skill of the survey team to pick out the lithics from the background earth and grass. Second, most of the assemblage was studied and drawn by Bulbeck in Ujung Pandang in 1987, so Pasqua had only a small 'control sample', 90 of the total assemblage of 422 lithics, to observe directly in terms of her modified Sullivan and Rozen scheme. The main value of our observations on Pammangkulang Batua may thus lie in demonstrating that our understanding of the Toalean, as developed on assemblages in rockshelters, can also be applied to open sites.

There is little doubt that cryptocrystalline stone dominates the assemblage, accounting for an estimated 96% of pieces, while the remainder consists of medium-grained stone. The cryptocrystalline stone includes a bewildering variety of red, brown, pink, grey, white, and banded varieties. Fully 11.9% of the cores and core fragments show evidence of heat treatment, but because only negative potlid scars (and no potlid flakes) were identified, any heat treatment occurred elsewhere rather than at Pammangkulang Batua itself.

Cortex was rarer than at either rockshelter assemblage, being detected on only 76, or 29%, of complete, broken or fragmented flakes. As at Leang Burung 1, the most frequent category of cortex coverage is under 25% (17%), followed by 25-50% (8%), while decortification pieces with over 50% cortex are rare (4%). The cortex classes which Pasqua observed were either geological (79% of cases) or secondary (21% of cases), and Bulbeck positively identified only a few cases of riverine cortex in the sample he observed in South Sulawesi (almost all other cases being unspecified). As regards platform morphology 54% are flat, 39% are faceted, 6.5% are crushed, and 1% is cortical. This negligible number of cortical platforms supports the inference that preliminary core preparation did not take place at Pammangkulang Batua. In short, Pammangkulang Batua appears to have been either a home base or a special-purpose site to which the occupants carried their prepared cores (and other curated stone) collected predominantly from a wide sweep of outcrops in the adjacent hills and monadnocks.

There are two aspects of technological observations where Pasqua's data from the control sample produced a different perspective from Bulbeck's observations made in South Sulawesi. Pasqua recorded more step than feather terminations on complete flakes whereas Bulbeck recorded more feathers than steps (with hinges and especially snap terminations rare in both samples). The combined observations (50% feather terminations, 29% steps, 19% hinges, and 2% snaps) make sense in terms of the other attributes of Pammangkulang Batua discussed below, but need confirmation from re-observation of the collection retained in South Sulawesi. A more serious discrepancy relates to the frequency of bipolar working, as Pasqua found no evidence of this on her control sample, whereas Bulbeck's notes mention bipolar traits on 40% of cores and core fragments, and classify 9% of flakes as bipolar. Probably, Bulbeck confused post-depositional damage (see below) with bipolar working, which was actually as rare at Pammangkulang Batua as at the rockshelter sites.

Several lines of evidence indicate that treadage, scuffage and other disturbances have substantially influenced the Pammangkulang Batua assemblage. First, it has a low proportion of complete flakes as a total of flakes and flake fragments, 33% compared to 40-50% at the rockshelter sites, and a high ratio (in this case equalled at Leang Burung) of core fragments to complete cores. Second, while core and flake lengths and breadths are smaller than at either rockshelter site, significantly smaller than at Leang Burung on five of the six comparisons (see Table 1), core and flake thicknesses always exceed those at Leang Burung. Longer, broader cores and flakes are more likely to be broken through postdepositonal disturbance, and hence may be under-represented among the complete examples at Pammangkulang Batua. whilst thicker items may be over-represented as they are more likely to have remained intact. Third, 38% of the observed striking platforms exhibit signs of overhang removal, i.e. a higher proportion than at Leang Burung. This may reflect a technological strategy involving more fidgety work, related to the smaller size of the Pammangkulang Batua cores and flakes, just as the high incidence of feather terminations may reflect the knapping of thickish flakes from very high-quality stone. However, post-depositional damage could also account for these observations, as it could have produced flake scars behind the striking platform which mimic platform preparation, and had the effect of selectively culling flakes weakened by their preparation on flawed stone (associated more frequently with step and hinge terminations) from the sample of complete flakes.

If we allow for the likely post-depositional effects at Pammangkulang Batua, the available observations suggest a focus on Stages 4 and 5 of the reduction sequence. This conclusion is supported by the absence of geometric microliths, the low ratio of blades to flakes (1:133), and the moderate ratio of points compared to all lithics (2.4%). Finally, the absence of bending flakes at Pammangkulang Batua agrees with the interpretation, suggested by the rockshelter assemblages, that the Toalean involving controlled knapping with a hard hammer to produce flakes, often as blanks for points, with only the most sporadic production of blades.

5 DISCUSSION

Discussion of the technological analysis boils down to a comparison between the rockshelter assembages at Leang Karassa and Leang Burung 1, as both occur in the similar context of the limestone karsts of South Sulawesi, in deposits which were built up through similar site-formation processes. The Pammangkulang Batua assemblage, by contrast, was apparently exposed to very different post-depositional processes, in a context lacking any evidence of ecofacts, and where usewear analysis would be hard to distinguish from the mimicking effects of trampling (cf. Shea & Klenck 1993). Further, as the available profile of technological characteristics suggests a basic similarity with the Leang Burung 1 assemblage, and as the assemblages could well be of the same age, any discussion of Pammangkulang Batua can be subsumed under a discussion of Leang Burung 1.

The Leang Burung assemblage differs from the Leang Karassa lithics by exhibiting less cores, smaller cores and flakes, more broken cores, more hinge terminations, and an emphasis on Stages 4 and 5 of Flenniken and White's reduction sequence (compared to Stages 3 and 4 at Leang Karassa). These differences can be accounted for in terms of raw-material quality and curation methods. The local stone utilized by the knappers at Leang Karassa appears to have contained frequent flaws and deeply inlaid cortex which decreased core productivity and increased the difficulty in manufacturing suitable flakes. The knappers at Leang Burung 1, however, apparently imported raw materials which contained less flaws and were therefore easier to work.

These technological differences do not seem to explain the typological contrasts which distinguish the aceramic assemblages from the ceramic assemblage at Leang Karassa. For instance points constitute 2-3% of total lithics in all cases, but round- and straight-based varieties appear to have persisted into the Late Toalean after the hollow-based Maros points dropped out. Geometric microliths also apparently persisted, even though the weak expression of Stage 5 at Leang Karassa would have provided a sound explanation for their absence. Additional evidence of a decline in the knapping of standardized tools in South Sulawesi's late prehistory comes from Batu Ejaya 1, which is currently dated to around 1000 BP. The excavated assemblage retains the 'magic' 2% frequency of points as a proportion of all lithics, but geometric microliths are reportedly absent (Chapman 1986: 82). Possibly, then, the Leang Karassa late Toalean occupants were prepared to tolerate the poorer quality of stone available near the site as part of a temporal decline in the production of formal tools. Excavation and technological analysis of a preceramic assemblage from Leang Karassa could test whether this aspect of the assemblage excavated by Macknight reflects a temporal Toalean trend or rather the site's immediate access to flakeable stone of inferior quality.

Any wider attempt to systematize our understanding of the Toalean would need to investigate the economic activities undertaken at the sites. Faunal assemblages were recovered during the 1969 excavations at Leang Burung 1 and Leang Karassa, as well as at Batu Ejaya, but these had not been documented or analyzed by the time this paper was written. Chapman (1981, 1986) identified and described the flakes with phytolith gloss from Leang Burung 1 and Batu Ejaya, but not from Leang Karassa. In addition to this data shortfall, there is some disagreement over the interpretation of glossed flakes, as Sinha and Glover (1983/1984) argued that gloss morphology can be used as a guide to the sort of plants that were processed, whereas Chapman (1986: 81) objected that gloss characteristics may only reflect the sort of activity that was performed. Microscopic identification of the phytoliths themselves should reveal what sort of plant had been processed, but this avenue of investigation has not been started on any Toalean assemblage. Equally important in future investigations, and yet untried, would be the study of residues (besides phytolith gloss) on Toalean tools.

6 CONCLUSION

On the basis of the definitions of the terms 'tradition' and 'industry' given by Bahn (1992), the Toalean is best regarded as a tradition. The required 'long-term continuity in either individual technologies or attributes' (Bahn 1992: 513) is at least partly satisfied by Pasqua's successful application of Flenniken and White's core-reduction sequence to explain the technological differences between the c. 4000 and c. 2500 year old assemblages at Leang Burung 1 and Leang Karassa. The knappers appear to have followed the same core-reduction strategy despite the typological differences comparing Leang Burung 1 (and Pammangkulang Batua) with Leang Karassa.

These typological differences are precisely why the Toalean cannot be considered an industry, as it does not measure up to 'a frequently repeated assemblage of restricted content' (Bahn 1992: 227). Indeed, as Figure 1 suggests, Maros points do not appear to have been found northeast of the upper Walanae drainage, whilst bone points are absent from some Late Holocene assemblages such as those excavated in 1969 at Leang Karassa and Batu Ejaya. The question therefore arises whether older South Sulawesi assemblages, such as the Upper Pleistocene lithics from Leang Burung 2, and younger assemblages such as the Batu Ejaya lithics, should be included in the Toalean. These assemblages would certainly be excluded if Flenniken and White's reduction sequence were found to be inapplicable; however, their model is quite general and may well apply to numerous traditions. Unless 'Toalean' is simply to become a synonym for 'South Sulawesi flaked artifacts', it is probably wisest to restrict usage of the term to assemblages including a 'Mesolithic' component, especially points with serrated edges, backed blades, geometric microliths and bone points. At the same time, location within South Sulawesi (or a nearby Indonesian region) should be considered a necessary attribute of a Toalean assemblage, so as to distinguish the Toalean from similar traditions in Australia, South Asia and elsewhere.

In sum, the Toalean can best be considered a tradition based on a chronologically variable expression of a limited range of formal 'Mesolithic' tools, of which points are a consistent constituent, mediated through application of a general flaking technology similar to that proposed for Australia. This conclusion is, however, only the starting point for an attempt to explain variability within the Toalean through economic and technological factors, as well as the typological indicators.

We still do not have answers to such basic questions as whether the introduction of ceramics and horticulture to South Sulawesi were associated with each other, whether ironworking displaced stone knapping (cf. Chapman 1986: 84), or whether rockshelter sequences (as opposed to open sites) might bias the archaeological record towards the apparition of cultural continuity reaching across what were really junctures of major economic and cultural change.

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35,000 years of prehistory in the northern Moluccas[1]

1 INTRODUCTION

The northern Moluccan islands, comprising Halmahera, Morotai, Bacan, Obi and the various small satellite islands of the region, occupy an obviously strategic geographical location between the major islands of Sulawesi, the southern Philippines and New Guinea. Given current understanding of the archaeological and linguistic prehistories of Indonesia and Oceania, it can be suggested that the northern Moluccas could have played important roles in the following periods of prehistory:

1. During the period of initial human migration through eastern Indonesia towards Australia and New Guinea. Currently, it is not clear whether the first Australians reached Australia by crossing from Timor and Nusa Tenggara, or whether they reached New Guinea first via the close-set islands which run from eastern Sulawesi and Sula, via Obi, to Halmahera, Gebe and west New Guinea. We may never know the exact route, indeed there could have been crossings of both, and the chronology of this dispersal is also under debate. Radiocarbon dating in Australia suggests earliest dates of c. 40,000 BP, whereas luminescence dating suggests dates greatly in excess of this, perhaps as much as 60,000 years.

2. During the period of Austronesian (AN) population dispersal into the Pacific, dated in the case of western Oceania by archaeological and linguistic means to c. 3300 BP. Linguistic evidence suggests that the AN languages of southern Halmahera relate, more closely than any other AN languages in Indonesia, to the Oceanic AN languages of Melanesia, Micronesia and Polynesia. If this is so, then the Halmahera region could have been the immediate homeland for the languages of the Oceanic subgroup and their speakers. The archaeology of this dispersal in western Melanesia is related directly to the Lapita cultural complex, which apparently commenced c. 3300 BP in the Bismarck Archipelago.

3. During the period of international trade in spices. Beginning c. 2000 BP the Moluccas acquired international importance in the early spice trade with India, China and the Mediterranean. The finding of quantities of Indian pottery at Sembiran in Bali, in deposits dating between 150 BC and AD 200 (Ardika & Bellwood 1991; Ardika et al. 1997), has brought this phase of early Indian contact into archaeological reality. So far, no Indian material has yet been reported from the Moluccas.

The purpose of this paper is therefore to focus on the archaeological findings from recent fieldwork which cover the period from the Late Pleistocene (c. 35,000 BP) through to about 1500 BP. Issues discussed will relate to:

– Initial Pleistocene colonisation,

– Subsequent inter-island contact and marsupial translocation,

– Incipient agriculture, Austronesian colonisation and related pottery sequences,

– Interaction prior to about 1500 years ago between the speakers of languages in the unrelated Austronesian and Papuan language families.

2 THE SETTING

The islands of the northern Moluccas occupy an important geographical position between Sulawesi, the Philippines and New Guinea (see Fig. 1). Any discussion of the human colonisation of the Pacific must take some account of the prehistory of this region. Halmahera is an island which has clearly never been land-bridged to any other major land mass; any would-be human colonists would always have had to cross sea to reach this island, with the easiest route of island intervisibility being the eastern route from western New Guinea via Gebe, closely followed by the western route from Sula via Obi.

The island of Halmahera comprises two separate western and eastern geological provinces (Hall et al. 1988; Hall 1996), both of oceanic volcanic arc origin, which have fused together to make up the present spider-like shape. Down the western side of Halmahera is a chain of active volcanoes which extends from the northern arm of the Halmahera mainland down through Ternate and Tidore to as far south as Makian (Hall et al. 1988: Fig. 6). Halmahera, unlike islands such as Sulawesi, Seram and Timor, is not known to contain any rafted segments of Australian crust; there are no indications that Halmahera has ever been linked to any other land mass in geological time, and it also seems unlikely that Morotai has ever been directly joined by dry land to Halmahera.

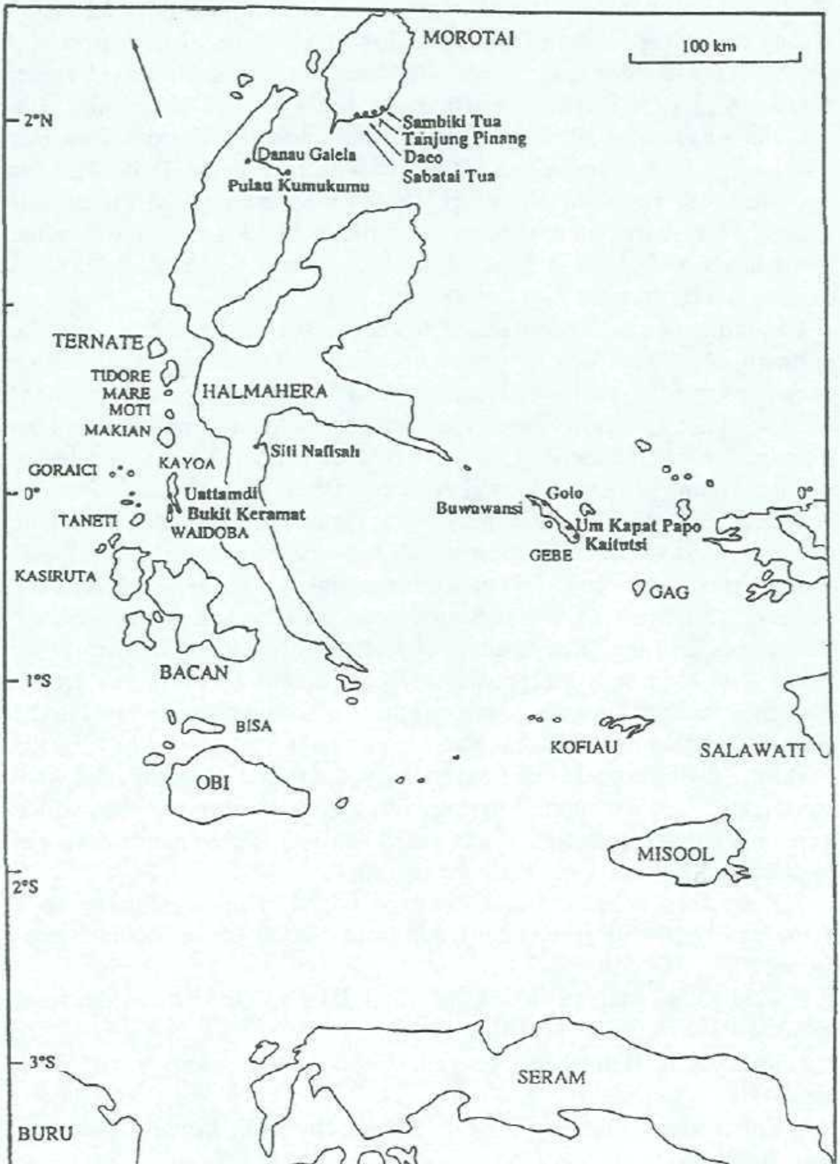

Figure 1. The northern Moluccas in their regional setting, showing major archaeological sites.

Halmahera has an equatorial environment and climate today, although during the last glaciation the area of lowland equatorial rainforest was considerably reduced under cooler and drier climatic conditions (Van der Kaars 1991). Low Pleistocene sea levels would perhaps have joined Bacan and Kasiruta to Halmahera. They would also have turned Kau Bay into a large freshwater or brackish lake (Van Bemmelen 1949: 48; Van der Kaars 1991). So far, however, the only securely-dated Pleistocene evidence for human occupation in the northern Moluccas comes from the two islands of Gebe and Morotai, both presumably surrounded by sea even at glacial maxima.

Excluding obviously introduced mammals such as pigs and deer, the northern Moluccas have a rather impoverished 'native' fauna which comprises mainly species of Muridae (rats) and bats. Halmahera also has a sugar glider (*Petaurus breviceps*), suggested to be a possible human introduction by Flannery (1995: 112). Most islands have a species of cuscus; *Phalanger ornatus* on Halmahera, Bacan and Morotai, *Phalanger alexandrae* on Gebe (Flannery 1995; Flannery & Boeadi 1995). One of the greatest surprises of the research reported here is that recently extirpated species of ground-dwelling marsupials also once existed in the northern Moluccas; a *Dorcopsis* species of wallaby and a bandicoot on Halmahera, and the same species of wallaby on Gebe (Flannery et al. 1995). These animals are presumably of ultimate New Guinea origin. How they reached Halmahera is a question of considerable interest, to be discussed further below.

During the four phases of field research a number of major sites were investigated by excavation, together with a number of minor sites which were only surface-collected or test-pitted. Only the seven major sites will be discussed in this paper. They are as follows:

1. Kabupaten Maluku Utara, Morotai Island, *Tanjung Pinang rock shelter*; c. 37,500 BP (prehuman), and from 10,000 BP for human occupation.

2. Kabupaten Maluku Utara, Morotai Island, *Daeo cave 2*; from 15,500 BP.

3. Kabupaten Halmahera Tengah, Gebe Island, *Golo cave*; from 33,000 BP.

4. Kabupaten Halmahera Tengah, Gebe Island, *Um Kapat Papo cave*; from 7000 BP.

5. Kabupaten Halmahera Tengah, Halmahera Island, Kecamatan Weda, *Siti Nafisah cave*; from 5500 BP.

6. Kabupaten Maluku Utara, Kayoa Island, *Uattamdi rock shelter*; from 3300 BP.

7. Kabupaten Halmahera Tengah, Gebe Island, *Buwawansi open site*; from 9000 BP.

Radiocarbon dates received so far for the above sites are listed in Table 1. In the following text each site is described, in the above order.

2.1 *The Southern Morotai Sites: Tanjung Pinang and Daeo Cave 2*

Several cave/shelter and open sites have been investigated along the coastline of southern Morotai. Here the focus will be on the two important limestone cave/shelter sites of Tanjung Pinang and Daeo 2, both of which raise important questions about early human colonisation and associated biogeography.

2.1.1 *Tanjung Pinang*

The rock shelter of Tanjung Pinang is situated in a raised coral massif which lies about 140 m inland from the sea. Today, the earth floor of the shelter lies about 9 m above high tide level. A total of 7 adjacent square meters has been excavated in the mid-front of the shelter, which has a habitable area of about 30 m^2. The deposits extend downwards for 2.4 m and contain two visible layers; the upper (Layer 1) containing cultural materials and the lower (Layer 2) grading down into a mass of coral rubble and being apparently prehuman throughout (see Fig. 2). The colour separation between the two layers is sharp and seems to reflect the coming of humans into the site at the base of Layer 1, with the consequent release of microscopic darkening agents such as comminuted charcoal and burnt shell into a continually-accumulating deposit.

Tanjung Pinang Layer 1 contains quite rich detail concerning human activity for over 10,000 years and this is presented in distributional terms in Table 2. Layer 1 is 80-90 cm deep and it is clear from Table 2 that all cultural materials in the site are contained within it. In the top 30 cm we discovered at least six secondary burials comprising mainly skulls with a few other postcranial bones. These skulls were placed in shallow pits and clustered together in the centre of the shelter, at the northern end of the excavated area. They probably belong to a single human population and were apparently buried during a restricted period of time. One of the skulls has been ^{14}C dated to about 2000 BP (see sample ANU 8439 in Table 1) and has been characterized as having a Melanesian-like morphology (David Bulbeck, pers. comm.). The other skulls are still under analysis. It is apparent that the pottery found down to 30 cm depth also occurs in close (albeit quite heavily disturbed) association with these bones. The pottery belongs to an incised style widespread during the Indonesian Metal Age, dated to as recently as 700 BP (ANU 7784) at the nearby open site of Sambiki Tua (Bellwood et al. 1993: 23-7) (see Fig. 3). Its overall date range at Tanjung Pinang could thus be between c. 2000 and 500 BP. Also from this late phase, or perhaps from the top of

Table 1. Radiocarbon dates for the northern Moluccas (further dates are still in process).

Lab. No.*	Site and layer or depth (cm)	Lab. date BP (uncal, Libby half-life)	Calibrated date BP, 1 sigma range (CALIB Version 3.0)	Material	Cultural context
7772	Uattamdi A 20-25	900 ± 100	928-695	Charcoal	Jar burial, Chinese coins
7773	Uattamdi B 0-5	1190 ± 70	1175-988	Charcoal	Jar burial, glass beads
9322	Uattamdi B 5-10	2330 ± 70	1879-1715	Marine shell	Jar burial, glass beads
7774	Uattamdi B 15-20	390 ± 190	550-0	Charcoal	Disturbed context
7775	Uattamdi C 10-15	2610 ± 170	2860-2378	Charcoal	Red-slipped pottery, shell beads and shell tools
9323	Uattamdi D 0-15	3260 ± 70	2973-2798	Marine shell	As 7775
9320	Uattamdi D 10-15	650 ± 180	725-512	Charcoal	Disturbed context
7776	Uattamdi D 15-20	3440 ± 110	3342-2971	Marine shell	As 7775
9321	Uattamdi E	3530 ± 70	3364-3176	Marine shell	Prehuman beach
7785	Siti Nafisah A 5-10	2540 ± 70	2139-1951	Estuarine shell	Incised pottery
7786	Siti Nafisah B 0-5	3410 ± 70	3215-2983	Estuarine shell	Preceramic midden, extinct marsupials
7787	Siti Nafisah C 10-15	4690 ± 120	4871-4571	Estuarine shell	As 7786
7788	Siti Nafisah D 5-10	4890 ± 70	5253-4873	Estuarine shell	As 7786
7789	Siti Nafisah D 15-20	5120 ± 100	5572-5296	Estuarine shell	As 7786
7790	Siti Nafisah ceramic midden	1870 ± 80	1356-1278	Estuarine shell	Incised and red-slipped pottery
8439	Tanjung Pinang (1) 5-10	2090 ± 180	2322-1835	Human bone	Secondary burials, incised pottery
7778	T. Pinang (1) 5-10	3390 ± 70	3209-2959	Marine shell	Preceramic?
7779	T. Pinang (1) 25-30	4090 ± 70	4078-3840	Marine shell	Preceramic
7780	T. Pinang (1) 30-35	4720 ± 70	4867-4659	Marine shell	As 7779
7781	T. Pinang (1) 50-55	5390 ± 70	5737-5599	Marine shell	As 7779
7782	T. Pinang (1) 65-70	8860 ± 110	9485-9260	Marine shell	As 7779
7783	T. Pinang (2) 0-10	37510 + 650/–600	–	Marine shell	Prehuman

Table 1. Continued.

Lab. No.*	Site and layer or depth (cm)	Lab. date BP (un-cal, Libby half-life)	Calibrated date BP, 1 sigma range (CALIB Version 3.0)	Material	Cultural context
9455	T. Pinang (2) 120-140	37510 ± 1860	–	Marine shell	Prehuman (1.3 m below 7783)
7784	Sambiki Tua 20 cm	720 ± 180	786-540	Charcoal	Pottery manufacture
9450	Daeo 2 60-65	13930 ± 140	15798-15305	Marine shell	Preceramic
9451	Daeo 2 55-60	1420 ± 150	1416-1178	Charcoal	(Disturbed context)
9452	Daeo 2 20-25	5530 ± 70	6405-6283	Charcoal	Preceramic
9316	Um Kapat Papo Layer 2: 15-20 cm	2030 ± 60	1532-1396	Marine shell	Incised pottery
9317	UKP Layer 3: 5-15 cm	4830 ± 70	5041-4861	Marine shell	Preceramic
9318	UKP Layer 3: 55-65 cm	6670 ± 60	7198-7017	Marine shell	Preceramic
9319	Buwawansi 2: 10-15 cm	1930 ± 70	1410-1299	Marine shell	Red-slipped and incised pottery
4630	Buwawansi 5A: 35 cm	1940 ± 60	1410-1309	Marine shell	As 9319
9454	Buwawansi 6: *15-20* cm	*2230* ± *70*	*1805-1575*	*Marine shell*	As *9319*
9770	Buwawansi 5: 25-30 cm	3160 ± 60	2856-2757	Marine shell	As 9319
9453	Buwawansi 3B: 130-135cm	4010 ± 80	3962-3706	Marine shell	Preceramic
4628	Buwawansi 1: B 35-45 cm	8550 ± 70	9182-8955	Marine shell	*Tridacna* adze
9448	Golo M5 45-55	3230 ± 180	3680-3255	Charcoal	Preceramic
9449	Golo M4 50-55	7400 ± 110	7893-7629	Marine shell	Preceramic, marsupials
9769	Golo M5 135-140	10540 ± 70	11925-11121	Marine shell	Preceramic, shell adzes
9512	Golo M5 145-150	11480 ± 70	13028-12862	Marine shell	Preceramic, shell adzes
9768	Golo M5 195-200	9260 ± 80	9911-9653	Marine shell	Preceramic (disturbed?)
4629	Golo M6 210-215	32210 ± 320	–	Marine shell	Preceramic
9447	Golo M5 230-235	31030 ± 400	–	Marine shell	Preceramic

*Numbers are ANU, *italic* numbers are Waikato. For marine shell dates a deduction of 450 years has been made before calibration, using the bidecadel tree ring dataset to 9440 cal BC in CALIB3 (following advice from John Head, Radiocarbon Lab., ANU). Older dates are calibrated using coral data to 20,000 cal BC.

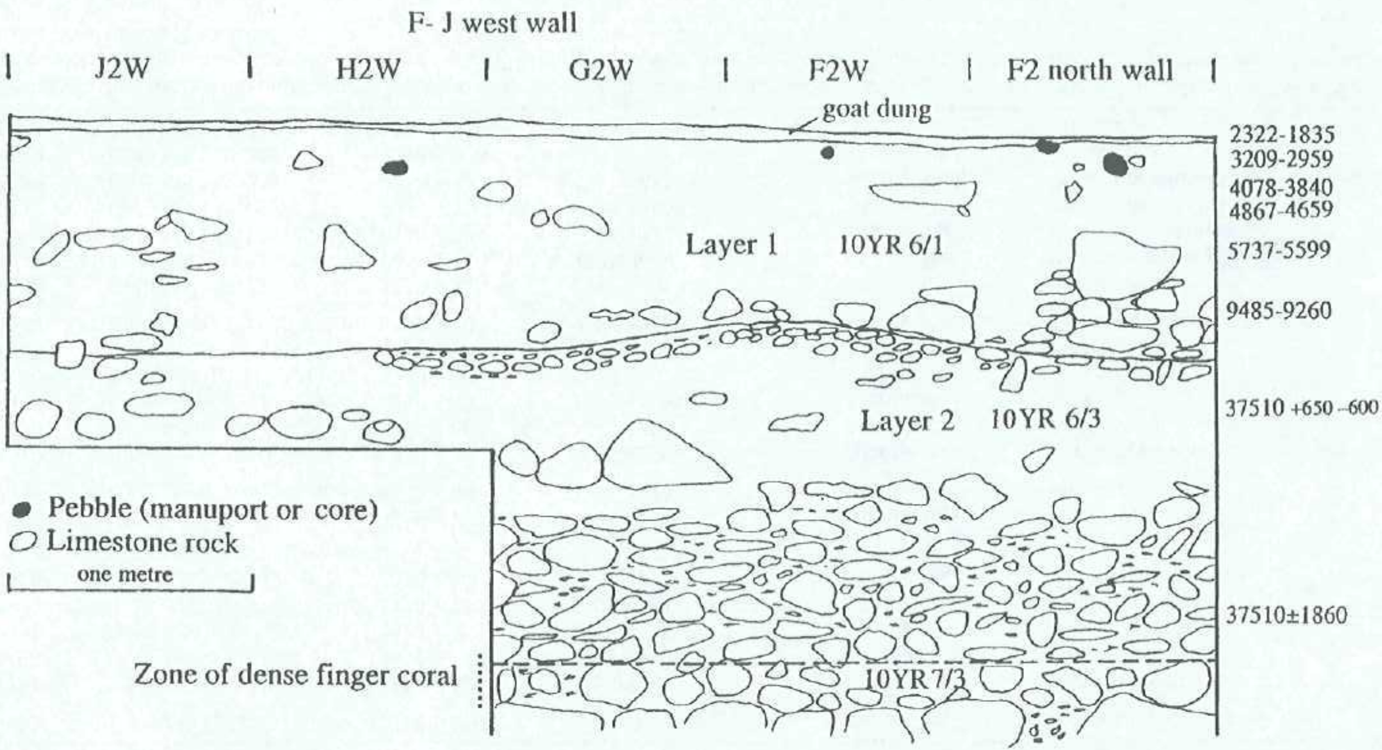

Figure 2. Section of Tanjung Pinang cave deposits. Calibrated radiocarbon dates in years BP are given on the right hand side.

Table 2. Distribution of natural and cultural materials in Tanjung Pinang, by 10 cm level.

Tanjung Pinang, depth cm	Total shell weight in gms (squares FG2)	Landsnails by number (squares FG2)	Animal bone, all squares, gm	Flaked beach pebbles, all squares, no./gm	Canarium anvils, all squares, no./gm	Human bone, all squares, gm	Sherd numbers, all squares	^{14}C date BP (calibrated)
0-10	3400	36	57	8/3775	3/1000	578	735	3209-1835
10-20	6925	76	0	3/635	4/1425	1265	345	
20-30	10300	76	14	4/1820	6/2400	623	36	4078-3840
30-40	5550	74	69	5/1250	4/1560			4867-4659
40-50	2300	39	14	3/435	1/450			
50-60	1850	21	4	2/415				5737-5599
60-70	1200	16	10	2/935				
70-80	825	43	3	2/80				9485-9260
80-90	500	18	1	1/15				
90-100	200	3						37510
100-110	600	11						
110-120	200	7						
120-130	175	7						
130-140	135	13						
140-150	20	6						
150-160	25	13						
160-170	90	38						
170-180	140	74						
180-190	80	26						
190-200	115	23						
200-210	120	11						
210-220	90	22						
220-230	115	24						37510
230-240	60	15						

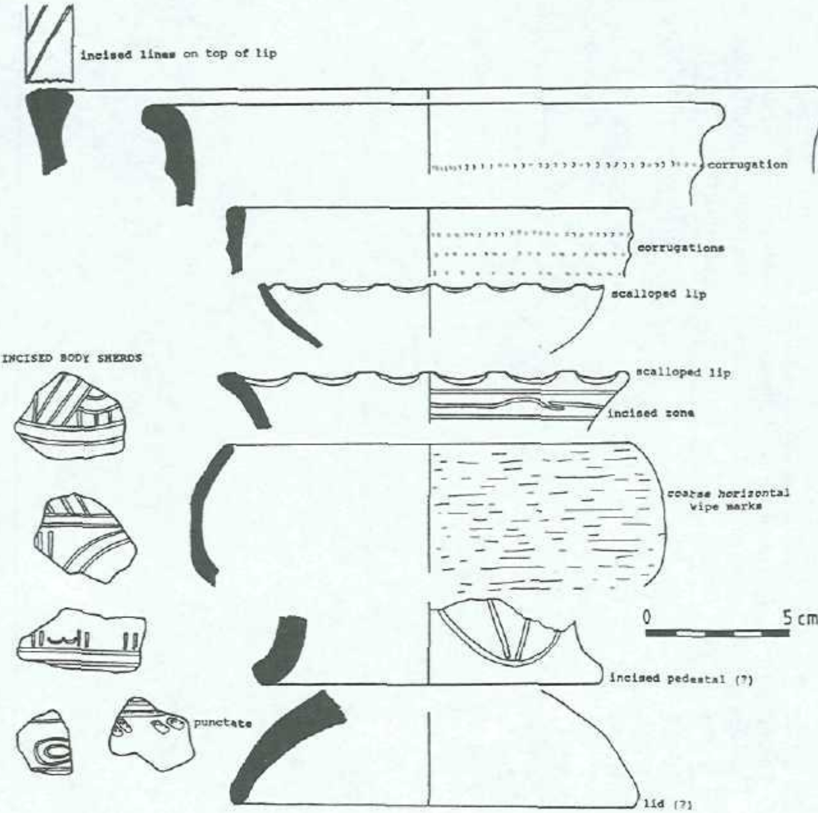

Figure 3. Pottery from Tanjung Pinang.

the preceramic assemblage, comes a single piece of obsidian from an unknown source.

The burials were dug into the top of a preceramic occupation layer which is dated by an orderly C14 sequence to between 3000 and perhaps 10,000 BP (Table 1: Samples ANU 7778-7782). Marine shells of a number of locally-occurring coral reef and lagoon species are common and there is a very minor presence of animal bone down to the base of Layer 1. The stone tool industry from this layer comprises pitted pebble anvils of a type stated by local informants to have been used ethnographically for crushing *Canarium* nuts (see Fig. 4a), large numbers of unworked pebbles collected from the nearby beach, and a flaked stone industry of large pebble cores and unretouched flakes. All the flaked stone appears to be local, apart from a piece of red chert from a depth of 60-65 cm. Small amounts of red ochre also occur.

The cultural sequence from Tanjung Pinang Layer 1 offers no matters of controversy, but the situation changes with Layer 2. In 1991 we were not able to dig deeply into Layer 2 but the dating of ^{14}C sample ANU 7783 to 37,510 BP, from just below the base of Layer 1 with its date of c. 9000 BP (ANU 7782), led us to wonder whether the site contained traces of much older Pleistocene settlement. In 1994 a larger trench was opened and excavated to solid limestone rubble at a depth of 240 cm. As Table 2 indicates, small quantities of both marine shells and landsnails were found to the base of Layer 2, even amongst the very dense limestone and coral finger rubble in the base of the trench. Yet clear signs of human activity, including the tiny fragments of charcoal and burnt shell which occur in Layer 1, were totally absent. While some shells were broken, this need not necessarily imply human breakage. The marine shells in Layer 2, like those in Layer 1, are all of types which still exist in the local reef and lagoon environment.

The interpretation of Layer 2 in Tanjung Pinang could present problems, but we believe that the marine shells have worked out of fissures in the raised coral limestone massif into which the shelter is cut, as a result of natural erosion (the massif limestone is very crumbly and fissured in appearance). Layer 2 is thus not interpreted as a cultural deposit at all.

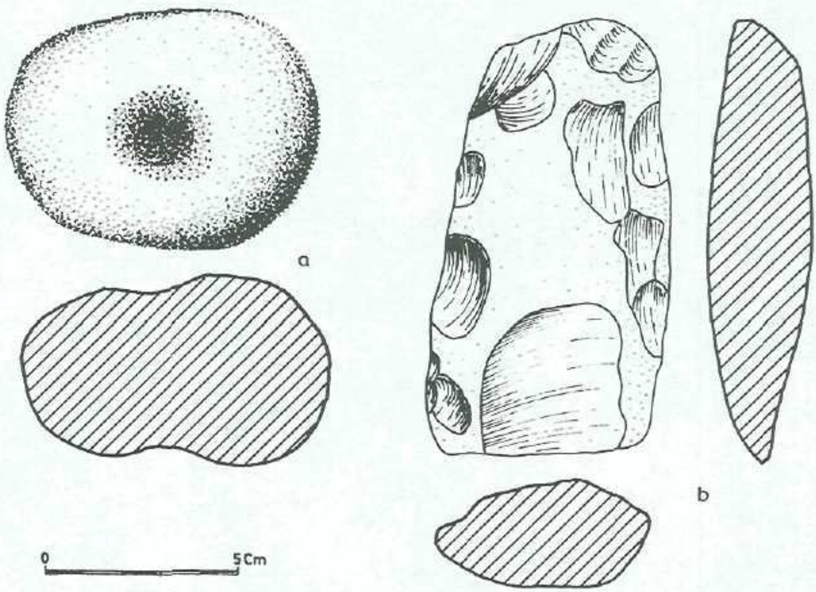

Figure 4. a) A stone anvil from Tanjung Pinang, c. 5000 to 3000 BP. b) Polished stone adze from Uattamdi, c. 3300 BP.

Table 3. Distribution of cultural materials by depth in Daeo Cave 2.

Daeo Cave 2: cm below surface	Animal bone gms*	Manuports and cooking stones, gms*	Total shell wt. in gms*	Land-snails, total no.*	(Potentially) artefactual stone, gms	Pottery (no. of sherds)	Bone points	Human bone, gms	^{14}C Date BP (calibrated)
0-10	0	100	715	90	18	21		300	
10-20	62	1300	2300	126	90	15		356	
20-30	159	2200	6375	101	91 + 1 × 400 gm *Canarium* anvil	1		343	6405-6283
30-40	204	3000	3100	205	135	1	1 bipoint	230	
40-50	95	1650	1900	59	490	1	1 (?)		
50-60**	42	1325	1500	68	570				(1416-1178)
60-70	20	215	1000	40	370				15798-15305
70-80	16	70	560	148	15				
80-90	6	20	170	31					
90-100	0	20	85	24					
100-110	1		95	21					
110-120	2		30	17					
120-130			25	10					
130-140			5	4					

*Below 90 cm only one third of the excavation area was continued into Layer 2. Actual statistics could therefore be multiplied by 3 from levels below 90 cm to make the data comparable, although this has not been done in this table since the interface between layers 1 and 2 was not totally flat and such action could introduce unwanted distortion of the data. **Fragments of charred *Canarium* nut shell identifiable to this depth.

Both the coral limestone massif and the shells are ostensibly dated to c. 37,500 years ago according to the two marine shell ^{14}C dates ANU 7783 and 9455, both about 1.5 m apart vertically. If these dates are correct, they imply quite a rapid rate of uplift for southern Morotai, given that eustatic sea level at 37,000 years ago was more than 70 m below present level (Chappell 1994: Fig. 2) and the top of the limestone massif is now about 12 m above high tide level.

On the other hand, the dates could be from samples of much greater absolute (rather than ^{14}C) age as a result of undetectable contamination with small amounts of younger radiocarbon. In such a case, the period when the uplifted coral reef was formed could have been long before 37,000 years ago, perhaps even as far back as the last interglacial c. 125,000 years ago when the sea was close to its present eustatic level. Australasian archaeology is currently beset by problems over the interpretation of ^{14}C ages close to the limits of the method, and such problems are clearly going to spread into Indonesia once dates of the order of 30,000 to 40,000 BP become available in large numbers. For Tanjung Pinang the issue might only be resolved by uranium series dating of the coral massif itself.

All of this would be a major issue for further archaeological and geomorphological research if Layer 2 were full of artefacts. Alas, it is not. Yet, given the good coastal location of the shelter and the density of Holocene occupation within Layer 1, we might conclude that traces of human occupation should occur in Layer 2 if humans were on the island in the time span represented by it. The clear fact that there are no traces of occupation in Layer 2 suggests strongly that it is prehuman. Since sedimentological evidence (to be described elsewhere) suggests that there was no hiatus in deposition in the Tanjung Pinang sedimentary sequence between Layers 1 and 2, we must conclude that human occupation in this site truly began c. 10,000 BP and not before. Additional insight into Morotai prehistory is provided by the excavation data from the cave of Daeo 2.

2.1.2 *Daeo cave 2*

Daeo village lies on the coastal alluvial plain about 4 km west of Tanjung Pinang. Behind it lies a coral cliff, presumably of the same geological age as the cliff which contains the shelter at Tanjung Pinang. In this cliff are three caves, of which two were excavated in 1994, although only cave number 2 gave sufficient information to warrant discussion here. The earth floor of Daeo cave 2 is about 8 m above high tide level and has a habitable area of about 14 m^2, of which 4 m^2 were excavated in the mouth of the cave. The disposition of finds is given in Table 3, reflecting a situation very like that at Tanjung Pinang.

Pottery of Tanjung Pinang type and human bone are again restricted to the top of the deposit, presumably, as at Tanjung Pinang, dating to within the past 2000 years. The main cultural deposit, which is clearly preceramic from very close to the surface, extends down to a depth of about 70-80 cm and sits, after a transition zone with a few shells and animal bones, on a culturally sterile basal deposit situated over limestone bedrock. Marine shells from a depth of 60-65 cm have been dated to c. 15,500 BP (ANU 9450; Table 1). From above this, at a depth of 20-25 cm, comes a charcoal date of 6405-6283 BP (ANU 9452), which seems to be in good stratigraphic relationship with the lower date. The much younger date of 1416-1178 BP (ANU 9451) from 55-60 cm is from scattered fine charcoal which has possibly washed down through the section. Given the overall depth of the cultural stratigraphy (down to 80 cm for the stone tools), one can perhaps guess a basal date for site occupation slightly in excess of 16,000 years.

Daeo 2 was quite productive of ochre, stone flakes and manuports, the stone flakes being from beach pebbles and virtually identical in technology to the examples from Tanjung Pinang. Animal bones were especially common in the protected alkaline deposits furthest into the cave. Bone preservation was very poor near the drip line, a phenomenon noted in all excavated caves and shelters (especially Tanjung Pinang, which was very poor in bone) and probably reflecting fluctuating dampness. The Daeo 2 animal bones, analyzed by Peter White, comprise *Phalanger ornatus* (cuscus), two or more species of rat, including one very large species, and many fish bones which are interestingly concentrated in the upper layers of the site, clearly in the Holocene period following the postglacial rise of sea level. However, the faunal absences are especially significant because there are no ground-dwelling marsupials. Neither the extinct wallaby nor the extinct bandicoot documented by this research project on Halmahera (the wallaby also on Gebe) are present in any Morotai sites at all. Explanations for the lack of these ground-dwelling marsupials on Morotai are rather hard to imagine, given that the island is so close to Halmahera and easily visible from it. Morotai is also a large and rugged island so we would expect their survival there until similarly late periods (to as recently as 2000 years ago on Halmahera, see below) had they once occurred on the island. This problem will be discussed in more detail below, but it would appear that humans have never attempted to transport these animals to the island.

Morotai, therefore, offers some puzzling archaeological questions. Although the island is visible from and close to Halmahera, the preceramic inhabitants appear to have remained fairly isolated until the appearance of pottery (c. 2000 years ago on Morotai), since there are no clear indications of any trade in or transport of life ground-dwelling marsupials, tool stones or other materials. However, it is possible (but at present unprovable) that the cuscus was introduced by humans in the Late Pleistocene, and such translocation of live animals is suggested to have been of major importance after about 20,000 years ago in contemporary sites in the western Melanesian fringes of New Guinea (see below). Fish bones do occur in Holocene layers in Daeo 2, but apart from these there are no real signs of any major maritime adaptation in preceramic times. Colonization seems to have been followed by a period of long relative isolation.

2.2 *Gebe Island: Um Kapat Papo and Golo caves*

Research took place in 1994 and 1995-1996 on the stepping-stone island of Gebe (see Fig. 1), currently the site of nickel mining by PT Aneka Tambang, an Indonesian mining company which assisted us greatly in the field. Gebe lies between Halmahera and the islands off the western tip of Irian Jaya, and both of these regions can be seen from it. Four important sites have been excavated on this island; the caves of Golo and Um Kapat Papo and the open site of Buwawansi, all described below; and the cave of Wetef, about 1 km northwest of Golo, excavated by Geoffrey Irwin and Daud Tanudirjo in January 1996. The results from Wetef will be presented in a later publication.

2.2.1 *Um Kapat Papo (Table 4)*

The first site on Gebe to be excavated was the coastal cave of Um Kapat Papo (UKP), the floor of which lies about 13 m above high tide level in a cliff cut into the raised coral of the southeastern coast of the island, near Umera. 11 m^2 were excavated in UKP but cultural stratigraphy was quite shallow, at only 70 cm or less with no sterile layer beneath. Cultural deposits rested directly on bedrock. The upper zone to c. 30 cm contained incised pottery related to that from the site of Buwawansi (below), and more distantly, Siti Nafisah cave on Halmahera (below) and the Morotai sites. In UKP this pottery is dated to c. 1500 BP (ANU 9316; Table 1).

The lower preceramic deposit in UKP yielded marine shellfish, stone flakes, *Canarium* anvils and manuports, together with animal bones mainly of *Dorcopsis* wallaby (but not the bandicoot) and cuscus (*Phalanger alexandrae*), with rare fish, rat, bat and reptile. Stone tools are rare in UKP and the majority belong to the upper ceramic phase. The preceramic deposit also contains a very large earth oven in the middle of the cave which contained more than 26 kg of volcanic cooking stones, but the stratigraphy did not indicate conclusively whether it truly belonged to the preceramic phase or whether it was cut from the ceramic layer above.

^{14}C dates indicate that the preceramic layer dates back to a com-

Table 4. Distribution of cultural materials by depth in Um Kapat Papo.

Um Kapat Papo, depth (cm)	Shell, gms (squares K8, K9, L8 and L9 only)	Pottery, no. sherds (all squares)*	Manuports and cooking stones, no./gms (all sq.)	Flakes stone (no.) (all squares)	Animal bones gms (all squares)	^{14}C date BP (calibrated)
Layer 2 (10-15 cm thick)	230	204	8/1425	8	60	1532-1396 (Layer 2, 15 cm)
Layer 3, 0-10	355	67	8/1030**	3	38	
10-20	300	7	8/1200**	–	93	5041-4861 (Layer 3, 5-15 cm)
20-30	630	3	–	–	134	
30-40	565	1	4/900	–	73	
40-50	325	–		–	50	
50-60	100	–	2/800	1	36	7198-7017 (Layer 3, 55-65 cm)
60-70	135	–	–	–	12	

*Table does not include 46 sherds found in surface Layer 1. **One complete earth oven in Layer 3, 10-20 cm, has 268 stones weighing 26,050 grammes (not included in the table).

mencement about 7000 BP (ANU 9318), before which time the cave seemingly had a floor of bare rock, unless deposit has somehow been removed, which seems very unlikely given the configuration of the site. This lack of older occupation may relate to the need to scale a 3 m high vertical coral cliff in order to enter the cave (we used a ladder!), thus making occupation a little inconvenient. Indeed, prior to 7000 years ago it is probably that the scree slope which now leads up to the cave from the modern beach did not exist, so that the cave might have been very high and out of reach up a high vertical sea cliff. Compared to the other caves and shelters sites excavated, the density of archaeological materials in Um Kapat Papo was quite low throughout.

2.2.2 *Golo cave*

Golo is a large cave on the northern coast of Gebe situated 60 m inland from the beach in a coral cliff, above a coastal strip of coral rubble and soil. Its earthen floor lies about 8 m above high tide level and its deposits are about 250 cm deep. During excavation periods in 1994 and 1995-1996 two areas were excavated in the cave, the main one occupying a total of 4.8 m^2. This larger trench produced the deepest sequence and the most significant information.

Two layers and a burial feature are visible within the trench section (see Fig. 5). The layers are not clearly differentiated and there is no rea-

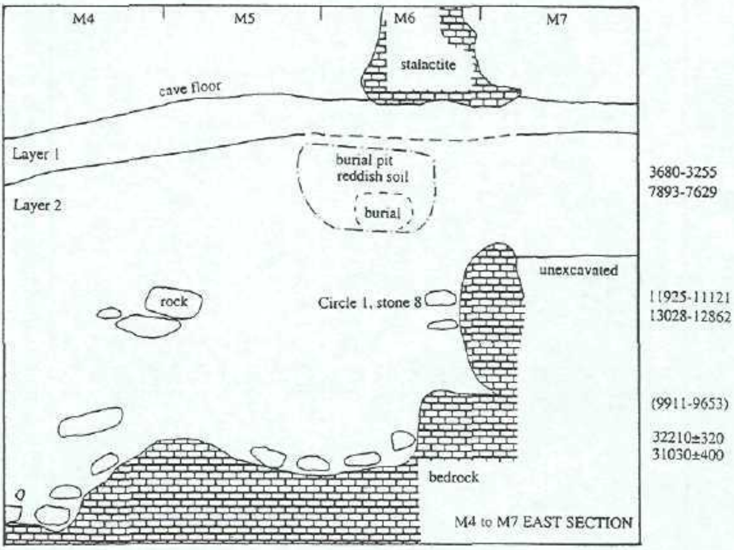

Figure 5. Section of Golo cave deposits, squares M4 to M7 east wall. Calibrated radiocarbon dates in years BP are given on the right hand side.

Table 5. Distribution of cultural materials by depth in Golo cave.

Golo cave, depth in cms	Animal bone, gms (sqs M4 and M5)	Shell, gms (sq. M5)	Shell adzes (all sqs)	Bone points no. (all sqs)**	Facetted ochre tablets, no. (all sqs)	Non-facetted ochre pieces, no. (all sqs)	Volcanic cookstones no./gms (sq LM6)	Coral cookstones no./gms (sq LM6)	Sherds no. (all sqs)	Canarium anvils (all sqs)	Flaked stone, no./gms (sqs LMN4-7)	^{14}C date BP (calibrated)
0-10	8	600	2 *Cassis*	1	0	0	0	?	6		0	
10-20	66	890	2 *Cassis*	3	0	1	4/700	?	6		1/175	
20-30	299	2150	3 *Cassis*	4	0	0	1/50	?	12		3/17	
30-40	1100	3050	3 *Cassis*	39	6	0	7/350	?	3	1 (640 gm)	3/30	
40-50	840	3800		34	7	2	33/1010	?			13/114	3680-3255
50-60	370	2085	2 *Cassis*	33	14	0	24/1000	?			18/317	7893-7629
60-70	125	1875	2 *Cassis*	5	12	2	28/1125	?	1		29/443	
70-80	23	1275		2	5	2	17/1350	?			16/215	
80-90	0	1050			3	2	29/1650	34/2250			13/448	
90-100	6.5	1350	1 indet.		0	4	18/1000	3/150			3/68	
100-110	3.5	775	1 *Hippopus*		2	1	29/2250	17/1200			4/200	
110-120	4	800			1	6	10/575	20/1650			6/37	
120-130	10*	575	1 *Tridacna*			3	3/100	4/200			6/129	
130-140	0	550	1 *Tridacna*			4	5/210	14/1120			4/157	11925-11121
140-150	7*	825	1 *Hippopus*			1	1/400	3/120			7/197	13028-12862
150-160	0	775				0	3/1000	1/50			0	
160/170	0	600			1	1	5/95	3/100			1/3	
170-180	0	950				0	1/165	28/2250			0	
180-190	0	550				0	0	66/4700			1/55	
190-200	0	350				0	0	48/4300		1 (175 gm)	2/56	(9911-9653)
200-210	0	325				2	0	46/5700			10/160	
210-220	0	690				0	2/220	67/2550			4/125	32210 ± 320
220-230	0	1050				0	1/10	4/100			7/255	31030 ± 400
230-240	0	375				0	1/410				3/31	

*Single bones of large unidentified mammals (human?). **These are provisional identifications – not all are proven artefacts.

son to assume any change in depositional conditions within the cave during the time span of its human occupation. If the vertical distribution of cultural materials is considered (Table 5), there appear to be four main phases of human activity represented. These are as follows:

1. Layer 1. The upper layer contains a very small number of potsherds, rather low densities of occupation materials such as shell and animal bone (the wallaby characteristic of the layer beneath seems to have been locally extirpated by this time), and no less than 14 shell adzes made from *Cassis* lips. Table 5 indicates that some *Cassis* adzes are found down to 70 cm, thus within Layer 2, but most of these were probably cached in holes close to the large stalagmite which stands next to square N6 and so probably belong to Layer 1. This upper cultural layer postdates 3500 BP (ANU 9448).

2. The upper part of Layer 2 down to 70 cm below surface contains a very high density of shell (all marine, apart from a few non-food land snails), animal bones (mainly wallaby and cuscus, but with a total absence of bandicoots and only very rare fish, reptile and bird), and an increase in the numbers of volcanic cooking stones and flaked stone. Bone points are common in this layer, many perhaps made from wallaby incisors. Pottery does not occur. This layer is associated with a date of c. 7500 BP (ANU 9449), and further dating precision will be obtained from Wetef, where a similar bone-rich layer is dated between c. 8000 and <5000 BP (Geoff Irwin, pers. comm.).

2a. The burial pit in Layer 2 represents one of the most remarkable discoveries in Golo. A fully extended adult skeleton (still under analysis) was laid on its back in a shallow grave dug in the cave floor. The grave, which was only visible very faintly in section and cut from an uncertain surface (probably near the top of Layer 2), was backfilled with soil mixed with copious quantities of red ochre. The fill contained a very high density of faceted pieces of ochre which had probably been scraped on the spot and then discarded into the soil. The skeleton was not associated with any grave goods, but is of considerable significance since it is apparently preceramic (a ^{14}C date on the bone is awaited).

3. The middle part of Layer 2, between 70 and 150 cm beneath the cave surface is in many ways the most interesting zone in the site. Human occupation was rather less dense than above (Table 5) and this zone contains virtually no animal bone. It does contain low but continuous densities of well-preserved marine shell, volcanic and coral cooking stones, and flaked stone. It has yielded the remarkable series of shell adzes made from giant *Tridacna* or *Hippopus* shells, quite different from the *Cassis* adzes within and buried from Layer 1 and separated from these by a very significant stratigraphic gap. These adzes presumably date between 13,000 and perhaps 8000 BP and are a very significant find.

In the same general level as the adzes, at about 130 cm from the surface, occurred two very definite arrangements of coral blocks, the largest being semi-circular, 90 cm in diameter, and the second much smaller one being fully circular and 30 cm across. The smaller circle contained a volcanic pebble at its centre, and three volcanic pebbles were found under the stones of the larger semi-circle. These pebbles must have been brought to Golo from the southern part of Gebe. The semi-circle also faced into the cave towards a massive boulder. These circles are too small to have had habitation functions and the pebble associations suggest some sort of ritual activity, the exact nature of which may never be known. To my knowledge such structures are unrecorded from Pleistocene layers elsewhere in Southeast Asia.

4. In the lower part of Layer 2, between 150 and 240 cm below the cave surface, immediately over bedrock, there is a basal increase in the density of human occupation as represented by shellfish (many burnt), flaked stone and coral cooking stones (Table 5). Volcanic cooking stones, which had to be brought into Golo from the southern part of the island, faded to virtual insignificance in this zone. This lower zone has two dates of c. 32,000 BP (ANU 9447 and Waikato 4629). An aberrant date from just above ANU 9447, of only c. 9500-10,000 BP (ANU 9768), appears to be on shells which have moved down the profile (crab holes could be responsible).

The flaked stone tools from Golo are made on a wide range of volcanic/metamorphic and chert-like rocks. The northern end of Gebe is apparently all coral so the rocks could not have been derived from entirely local sources, but the southern part of Gebe has varied geology and it is possible that the sources were located here. The shell adzes made from *Tridacna* are similar to a series excavated from Pamwak Shelter in the Admiralty Islands (off the north coast of Papua New Guinea: see Fredericksen et al. 1993), here also dated terminal Pleistocene and early Holocene. Another example, from the site of Buwawansi, is dated to c. 9000 BP and is discussed below. Daud Tanudirjo has recently collected another specimen of this type from the site of Manaf in the Sula Islands.

The animal bones from Golo, which form a prolific layer focused within the upper part of Layer 2, are currently being analyzed by Tim Flannery and Peter White. They contain the extinct species of *Dorcopsis* wallaby found in Siti Nafisah and the cuscus (*Phalanger alexandrae*, Flannery & Boeadi 1995), but they lack the Halmahera extinct bandicoot.

2.3 *Siti Nafisah cave, southern Halmahera*

The cave of Siti Nafisah, excavated in 1991 and partially reported in Bellwood et al. 1993, is located in a limestone hillside south of the town of Weda, on the southern arm of Halmahera. It is entirely a Holocene site and has produced no flaked stone tools at all. The main trench of 4.25 × 1 m excavated in the cave produced a preceramic shell midden deposit dated between 5500 and 3000 years ago (see Table 6 and Fig. 6, Layers B to E). Layer A at the surface of the site produced incised and red-slipped pottery dated to c. 2000-1500 BP, perhaps related to the incised pottery of similar age from Tanjung Pinang (above), together with fragments of ground stone adzes. The preceramic deposit contained absolutely no flaked stone at all, despite the presence of a few pebble manuports and many small bone points, some pointed on both ends. This total absence of flaked stone is obviously unusual in the archaeology and contact-period ethnography of non-metal-using humans; generally, flaked stone is rare in all the investigated north Moluccan sites but this is the only case of total absence.

However, this preceramic shell midden at Siti Nafisah was the first deposit to yield one of the major finds of the Moluccan research project, the bones of two now-extinct species of marsupial wallaby and bandicoot (identified by Tim Flannery, see Flannery et al. 1995). The wallaby belongs to the genus *Dorcopsis* and is currently being described by Flannery. The bandicoot is not yet identified as to genus but may be related to new Guinea bandicoots of the genus *Echymipera*. Bones of wallaby appear throughout the deposit to as recently as the ceramic phase at c. 1870 BP, whereas the bandicoot only occurs in the preceramic layers, apparently surviving only to c. 3000 BP. Siti Nafisah also produced bones of the extant tree-dwelling cuscus (*Phalanger* sp.), as did all other excavated caves in the northern Moluccas.

As at Daeo 2, the cultural deposits at Siti Nafisah lie over a basal sterile clay deposit over bedrock. However, because this site is about 70 m above high tide level and about half a kilometer inland, the absence of human activity before 5500 years ago may be of little significance. Halmahera has so much archaeological terra incognita that conclusions must be guarded at present. Surely Pleistocene occupation will one day be found here (see the unprovenance 'hand-axe'' from Halmahera illustrated in the frontispiece to *Modern Quaternary Research in Southeast Asia* 8, 1983-1984, presumably someone on the Halmahera mainland made stone tools, but where and when?).

2.4 *Kayoa island: Uattamdi rock shelter*

The Uattamdi rock shelter is cut into a cliff of raised coral about 60 m

Table 6. Distribution of cultural materials by depth in Gua *Siti Nafisah.*

Siti Nafisah: Layer/ spit codes and depths from surface*	Stone manuports, no./gm (F8 only)	Ochre (presence only, squares F5-F8	Total shell weights, gm (*F8 only*)	Animal bone weights, gm (*F8 only*)	Bone points, no. (squares F5-F8)	Pottery, sherd no. (squares F5-F8)	^{14}C date BP (calibrated)
A1 (0-4)	–		2200	10		103	2139-1951
A2 (4-7)	–		1450	10		31	
B1 (7-13)	1/150		2000	50	3	9	3215-2983
B2 (13-20)	1/200		1100	20		8	
C1 (20-25)	3/250		1700	75	5	5	
C2 (25-30)	–	*	900	17	2	1	
C3 (30-35)	5/550		2250	85	4	1	4871-4571
D1 (35-40)	2/200	*	775	52	1		
D2 (40-50)	3/400**		3150	42	1		5253-4873
D3 (50-60)	22/1900**	*	6750	50	1		
D4 (60-70)	7/650**	*	3075	24			5572-5296
E1 (70-80)	2/250		400	30	2		
E2 (80-90)	–	*	250	35			

*Depths in cm; spits are not of equal thickness. **Volcanic cooking stones.

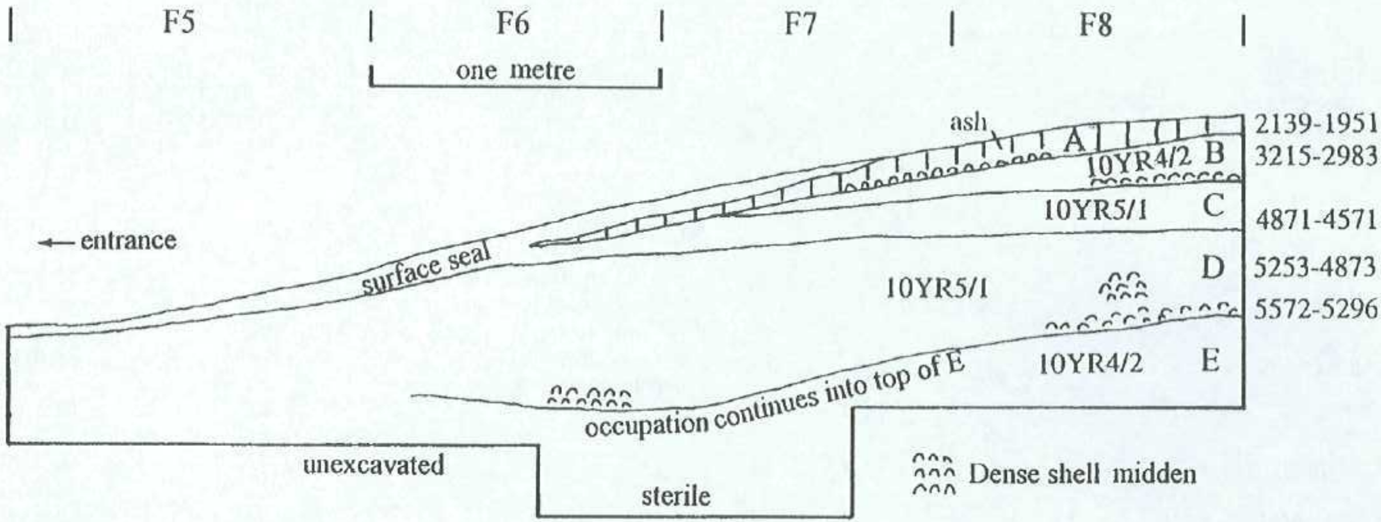

Figure 6. Section of the Gua Siti Nafisah excavations. Calibrated radiocarbon dates in years BP are given down the right hand side.

Table 7. Distribution of cultural materials by depth in Gua Uattamdi.

UI layer and spit (cm)	Stone adzes and adze chips	Other stone (mainly flakes)	Bone points	Shell bracelets	Shell tools	Shell beads	Glass beads	Copper/ bronze	Iron	Burial jar sherds	Human bone	^{14}C date BP (calibrated)
A 0-5							2					
A 5-10							1		1	3		
A 10-15							2			8	*	
A 15-20							9	Chinese coin	1	5	*	
A 20-25							7	Chinese coin	1	5	*	928-695
B 0-5			1			2	8			9	*	1175-988
B 5-10						1	17	1		13	*	1879-1715
B 10-15							17			8	*	
B 15-20							21	1	1	3	*	(550-0)
C 0-5	1 adze, 1 chip	1	1				15					
C 5-10		2	1		Pearlshell scraper, cut shell		13					
C 10-15	1 chip	2			Cut shell	2	3					2860-2378
C 15-20		6	2		Fishhook core (?), 2 cowry tops	2	3					
C 20-25		3		1	Cut shell, cowry top	5						
C 25-30	1 chip	4			Pearlshell scraper	3						
C 30-35	2 chips	2		3								
D 0-5	1 adze	3			Cowry top							2973-2798
D 5-10	1 adze, 1 chip	1				2						
D 10-15	1 adze, 1 chip			2	2 cowry tops							(725-512)
D 15-20	1 chip	1	1		Shell adze							3342-2971
E prehuman												3364-3176

behind the modern beach on the western coast of Kayoa Island. A total of 16 m^2 was excavated in the site in 1991 and 1994. The archaeological deposits, about 1m deep (see Table 7 for vertical distributions of cultural materials), lie on a layer of clean beach sand (Layer E), which lies at virtually the same level as the present beach, indicating that sea level along this coastline has not changed since occupation began. The 60 m wide coastal plain has been built up by sedimentation since this time (possibly as a result of agricultural clearance).

This site has no preceramic deposits at all. The first inhabitants created a very large hearth area in the basal part of Layer D. This was buried by a thick deposit of coral pieces in Layer C, which might have been derived from roof fall (the shelter has a very fissured roof), but no break in occupation seems to have occurred. The two lower layers (C and D) in Uattamdi yielded red-slipped but otherwise mostly plain pottery (a few rare incised pieces also occurred), shell ornaments (beads and armbands), a *Tridacna* shell adze, a few small bone points, stone flakes (including chips from polished adzes), a partly polished stone adze with a lenticular cross-section (see Fig. 4b) and a small polished stone chisel with a circular cross-section. The assemblage is related closely to contemporary red-slipped pottery assemblages in sites such as Leang Tuwo Mane's (Talaud Is), Bukit Tengkorak and Madai cave (Early Atas phase) in eastern Sabah (Bellwood 1988, 1989, 1996). In Uattamdi shelter this layer is dated to between 3300 and 2500 BP. These lower levels were also coinfirmed to contain bones of pig, dog and cuscus (*Phalanger ornatus* – the same species as that of Halmahera and Morotai) from the base of the site (c. 3300 BP).

Above this layer of red-slipped pottery at Uattamdi are Layers A and B, which have yielded the remnants of secondary jar burials with incised pottery, glass beads, iron and bronze fragments, dated to within the past 1800 years. Two undated Chinese coins were also found in this layer. Two massive burial jars can be in part be reconstructed (with possibly two more) and large reef shells seem to have been used, together with the above artefacts, as grave goods. Unfortunately, these jar burials were heavily disturbed. The materials of this upper jar burial phase relate to contemporary sites across eastern Indonesia and in the Philippines, such as Leang Buidane (Talaud), Madai cave (Mature Atas Phase) in eastern Sabah, and sites of the Tabon and Kalanay pottery complexes in the Philippines.

2.5 *Gebe Island: Buwawansi open site*

The site of Buwawansi consists of two major sherd concentrations on a sandy coastal terrace, with rock shelters in uplifted blocks of coral on the

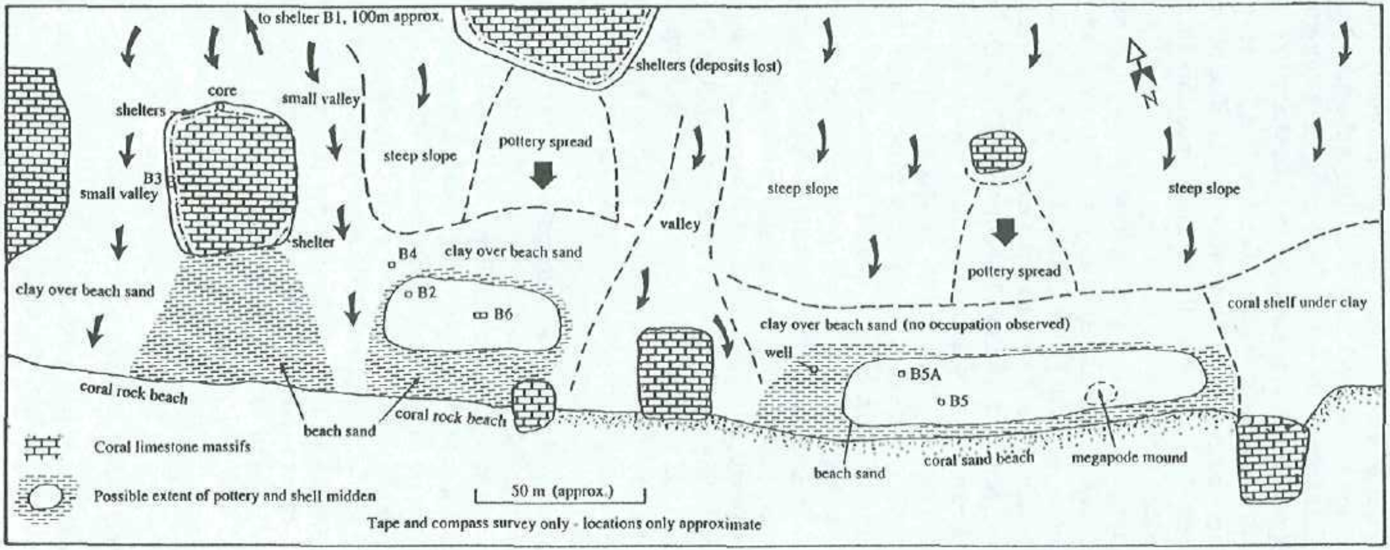

Figure 7. Map of excavated locations at Buwawansi, Gebe.

terrace and inland of it (see Fig. 7). The terrace is about 400 m long by 50 m wide. In 1994 and 1996, excavations and test pits were made in 6 locations, including two of the shelters (denoted B1 and B3), and four open site areas on the terrace (B2, B4, B5 and B6). Detailed analysis of the Buwawansi finds has not yet been undertaken, but available ^{14}C dates are listed in Table 1. Buwawansi is the largest open site found to date in the northern Moluccas.

Rockshelter B1, which lies under a large block of raised coral inland from the main coastal complex, was excavated in January 1996. A trench of 6 × 1 m was excavated from front to rear of the shelter, but cultural deposits were fairly thin. The deposits contained pottery almost throughout, of a red-slipped and incised type which bears some resemblance to some of the incised pottery from Siti Nafisah and Tanjung Pinang. At the base of B1 was also found a large *Tridacna* shell adze similar to the examples from the terminal Pleistocene layers in Golo cave (see above), here dated by Waikato 4628 to c. 9182-8955 BP (Table 1). Apart from this discovery the B1 shelter produced no coherent preceramic layers. Preceramic occupation dating from only about 3962-3706 BP (ANU 9453) was documented in the shelter of B3, down on the coastal flat, but only in the form of discarded shells. However, this date is important because it provides a secure terminus post quem for the local appearance of pottery.

The Buwawansi open site test pits were all dug into the shallow sandy occupation layer (up to 30 cm deep) which occupies the slightly higher areas along the coastal terrace, away from areas of periodic inundation by water flowing off from the inland hills. Beneath the occupation layer this terrace consists of clean beach sand and is clearly a remnant of a time when the local sea level was relatively higher than at present, perhaps during the mid-Holocene when the sea would have reached the base of the hill slopes. With the retreat of the sea the coastal terrace became available for human occupation.

The 2 × 1 m test pit at B6 produced evidence for a shallow scoop hearth and a possible posthole, but otherwise no clear traces of structures were found anywhere, perhaps because of the disturbance caused by agricultural activities in the past (the terrace is today used as a coconut plantation). Test pits B5, B5A and B6 yielded large amounts of red incised pottery (some definitely red-slipped, but much eroded), associated with three ^{14}C dates on marine shell ranging from 2856 to 1299 BP. This is rather a wide range, but the pottery is very homogeneous stylistically and it seems unlikely the site was occupied continuously for almost 2000 years. The Buwawansi pottery appears to be different from the red-slipped but otherwise undecorated pottery from Uattamdi and seems to be younger, possibly c. 2000 to 1500 BP on parallels in other sites.

3 DISCUSSION: THE PRECERAMIC, c. 33,000 TO 3500 BP

Recent research in Australia and western Melanesia has indicated the remarkable ability of humans to cross sea gaps, often out of sight of land (clearly so in the case of the Timor route to Australia) by at least 40,000 years ago, possibly before. In Australia, dating depends very much upon how one interprets the various forms of radiometric dating currently being applied to the problem (e.g. Allen 1994). Apart from Australia, the past decade has indicated that humans also moved into the Bismarck and Solomon Islands east of New Guinea at about the same time (Allen et al. 1989; Allen 1993; Allen & Gosden 1991; Irwin 1992; Pavlides & Gosden 1994). The Melanesian region has also yielded evidence that humans were transporting small amounts of New Britain obsidian and certain animal species such as wallabies and cuscuses between islands at various times after about 20,000 years ago (Flannery & White 1991). The distances involved were never large – there is no evidence for any passage at this time of the wider sea gaps east of the Solomons. Elsewhere (Bellwood 1994), it has been suggested that the human dispersal indicated could have been achieved with a raft-based water technology no more developed than that recorded in the Gulf of Carpentaria in northern Australia about 100 years ago (see Clark 1991 and Irwin 1992 for further discussion of this question).

The results of the Moluccan research do not seem to contradict this last view. The preceramic inhabitants of Gebe probably acquired their tool stone locally – there is no sign of any inter-island trade in raw materials, although it has to be stated that this is only negative evidence in the absence of detailed petrological research. Obsidian is not definitely present in the preceramic (there is only one small piece from an unidentified source from an upper layer in Tanjung Pinang) and there appears to be no source of this stone in the northern Moluccas. The bulk of the animal bones in Golo come from land animals, and fish bones are quite rare. The same can be said for Siti Nafisah, where flaked stone tools, quite incredibly, are completely absent over a period of more than 2000 years. Although shellfish and a few fishbones do occur in these sites it is clear that there was no major maritime focus to the economy. Fishbones seem to be more common in the Morotai sites, especially in the Holocene layers in Daeo 2, but since there were no land mammals larger than cuscus on the island this may hardly be surprising. Likewise, the stone tools in the Morotai sites seem all, with only minor exceptions, to have been made on locally-occurring volcanic cobbles. All of this suggests that these people were quite capable of crossing sea on rare occasions, but did not do it habitually for purposes of regular trade or contact with other societies. Presumably, each island yielded sufficient resources for its human populations to be locally self-sufficient, with only local exchange being required for tool stone and perhaps ochre.

On the other hand, there are definite indications, as in western Melanesia, of an increase in the tempo of cultural activity after about 15,000 years ago. The large shell adzes and circular strone structures appear in Golo soon after this date, and the first evidence appears at about this time for the occupation of Morotai. Gosden (1993) has noted evidence for a similar intensification of human activity after 20,000 years ago in western Melanesia. As he states:

'Instead of moving peoples to resources, resources were moved to people' (Gosden 1993: 133).

This statement is made in reference to the evidence for movements of obsidian and live marsupials claimed to occur after 20,000 years ago in Melanesia. In the Moluccas likewise, the marsupial evidence raises particularly interesting questions. The Golo and Um Kapat Papo dates suggest that the wallaby only appeared on Gebe at about 8000 BP and that it had been extirpated there by 1500 BP, if not earlier. In Siti Nafisah the wallaby, cuscus and bandicoot are all present from c. 5500 to 3000 BP, after which the bandicoot disappeared first, followed by the wallaby during the ceramic phase by about 1500 BP (the cuscus has not been extirpated anywhere because of its tree-dwelling and nocturnal habits). On Morotai the cuscus might be present from 15,000 years ago (there are certainly a few bones present at this date in Daeo cave 2), and this is the earliest evidence so far for any marsupial presence in the northern Moluccas. It should be noted here that Tim Flannery and Boeadi are currently of the opinion that the Gebe cuscus is an endemic species (Flannery & Boeadi 1995), as may be that on Halmahera and Morotai, but further research on these questions is proceeding. The wallaby is now believed to be from Misool by Tim Flannery (pers.comm.), and translocation in the early Holocene is strongly implied by the current evidence.

Concerning the extinction of the wallaby and bandicoot there perhaps need be no surprise, given the frequent occurrence on Pacific islands of extinctions of vulnerable faunas very soon after settlement by agriculturalists, most marked perhaps for the moas of New Zealand (Anderson 1989). In all cases we are presumably looking at the results of activities by agricultural populations with introduced dogs and pigs (many rapidly becoming feral), rather than the preceramic hunter-gatherer populations.

Were the preceramic economies of the northern Moluccas entirely non-agricultural? Spriggs (1993) has recently pointed out there is no evidence for truly agricultural activities in lowland Melanesia before Lapita times, despite the presence of older indigenous agricultural activity in the New Guinea Highlands. The same applies to the northern Moluccas. But it must also be remembered that *Canarium* nut anvils (assuming this has always been their function) are quite common in the later preceramic record in the sites discussed (from possibly 5000 BP in Tanjung Pinang, and there is a single example from the lower part of Layer 2 in Golo – c. 30,000 BP?), and sago starch is still a major economic resource for many Halmahera populations, Austronesian and Non-Austronesian alike. A preceramic economy which laid heavy emphasis on the exploitation of tree foods – sago starch, nuts and fruits – could have sustained locally quite dense populations without any actual field agriculture of tubers. The fact that all the caves investigated have quite a heavy density of Holocene occupation suggests that preceramic populations were well-distributed and perhaps quite large. Maybe this is why the ceramic evidence suggests that early Austronesian populations restricted themselves to a number of islands off the west coast of southern Halmahera (Kayoa and its neighbours) for a period of perhaps one millennium before Austronesian settlement spread to the Halmahera mainland itself (see below).

To date, therefore, the northern Moluccas have yielded one of the longest dated preceramic archaeological occupation sequences for the Wallacean region between the Sunda and Sahul shelves, paralleled only by the rock shelters of Leang Burung 2 in southern Sulawesi and Leang Sarru in the Talaud Islands with their c. 30,000 BP chert industries (Glover 1981; Tanudirjo pers.comm.). Of course, there are now strong hints that tool-making hominids might have moved down the Nusa Tenggara chain to as far as Flores (and Timor?) during the Middle Pleistocene (Van den Bergh et al. 1996), and putatively Late Pleistocene industries are reported from the Walanae Depression in Sulawesi (Keates & Bartstra 1991-1992). But only further research is going to give these sites dependable absolute chronologies.

4 THE CERAMIC PERIOD, AUSTRONESIANS, AND QUESTIONS OF AUSTRONESIAN-PAPUAN INTERACTION

I wish now to move to the question of the regional relationships of the northern Moluccan cultures during the ceramic period, after 3500 BP, and to look at the evidence, both linguistic and archaeological, for Austronesian-Papuan (AN-PN) interaction since that time.

4.1 *The Ceramic Phase in the Northern Moluccas*

Red-slipped (but otherwise undecorated) pottery with associated stone adzes, shell beads and bracelets, fish bones, pig and dog bones (the last two being domesticated and introduced species) appeared in the Uattamdi sites on Kayoa Island at about 3300 BP. As indicated elsewhere (Bellwood et al. 1993), this assemblage relates to contemporary red-slipped pottery assemblages from eastern Indonesia and the Philippines, and also perhaps in a cousinly way to the Lapita cultural complex in western Melanesia. It can be regarded as an archaeological record of Austronesian colonization, not least because of the close fit between the archaeological record and the vocabulary reconstructed for early stages of Austronesian language history (Blust 1976, 1984-1985; Bellwood 1991, 1997). The interesting point is that this type of assemblage has only been found in Kayoa so far, and is quite absent from the archaeological sample recovered from the other northern Moluccan sites examined. Whether AN plant food production practices were any more complex than those of the preceramic populations already resident is not known, but AN linguistic reconstructions suggest that they might have been, with field agriculture of a wide range of tubers, fruits and possibly even cereals (foxtail millet, but perhaps not rice in this region).

On Morotai, the Halmahera 'mainland' and Gebe, the first appearance of pottery seems to occur only c. 2500-2000 BP in the form of incised, footed, carinated and sometimes red-slipped vessels. This pottery is of a style very widespread in the Indonesian Metal Age, as excavated by Ardika in Bali (Ardika 1991) and by Bellwood in various sites in eastern Indonesia and Sabah (Bellwood 1989; 1988; Bellwood & Koon 1989 (Madai, Baturong and Bukit Tengkorak late phase); Bellwood 1976; 1980 (Leang Buidane, Talaud)). It also matches Solheim's Kalanay (Metal Age) pottery style from the Philippines (Solheim 1964). This is a very widespread horizon in the Halmahera region and seems to terminate the local preceramic in many of these islands; there may be a strong element of agricultural dispersal as well as trade factors involved in its spread. It also replaces the red-slipped ceramic horizon on Kayoa and is there associated with glass beads and fragments of bronze and iron, together with jar burials of a very widespread eastern Indonesian and Philippine Metal Age type. It seems hardly coincidental that the northern Moluccas also entered the Spice Trade about 2000 years ago, according to Classical and Indian records (a date which might be modified by recent claims of Middle Bronze Age cloves from Terqa in Syria, in the event that they should be verified; see Buccellati & Bucellati 1983). This entry was perhaps initiated by western Indonesian traders linked to southern Indian buyers from ports such as Arikamedu in Tamil Nadu (Ardika & Bellwood 1991).

If the above observations are broken down into essentials, then two ceramic phases in northern Moluccan late prehistory and protohistory seem fairly clear. The first is the phase of the Philippine- and eastern Indonesia-related early red-slipped pottery of the second and first millennia BC represented at Uattamdi, and the second is the phase of the widespread 'Indonesian Metal Age' style pottery dating everywhere in the northern Moluccas from about 2500-2000 years ago and onwards. Can we see such patterns reflected in the linguistic records?

4.2 *West Papuan and Austronesian language subgroups in the Northern Moluccas*[2]

The languages of the Halmahera region belong to two genetically unrelated families – West Papuan in the north (one of several Papuan language families in the New Guinea region), and Austronesian (a language family of ultimate mainland Asian origin) in the south (see Fig. 8, page 266-267). The only linguist to offer an overall classification and discussion of the West Papuan languages has been Voorhoeve (1988). His research has been based on lexicostatistics rather than full use of the comparative method to plot shared innovations, but the results still offer a picture of considerable interest.

The Papuan languages of northern Halmahera are classified into a North Halmahera Stock by Voorhoeve, this stock belonging to the West Papuan Phylum, which evidently has its greatest level of diversity in the Bird's Head region of West New Guinea. It is possible, but presently unprovable, that the West Papuan languages of Halmahera were taken to the island by migrants from New Guinea. How long ago might this have occurred? Since glottochronology in this region is unlikely to be a reliable technique owing to gross differences in rates of language change (Blust 1993: 245), all one can offer is an estimate of several millennia based on a minimum shared cognate percentage between all pairs of languages in the North Halmahera Stock of only 21% (a figure perhaps inflated by hidden borrowing: Voorhoeve 1988: 182). It is quite possible that the West Papuan languages of Halmahera were first introduced there well back in the preceramic period, indeed perhaps as long as 30,000 years ago, although there is no visible patterning in the phylum which could possibly support or refute such an enormous antiquity. However, the fact that the local roots of Papuan phyla in New Guinea clearly predate the arrival of Austronesian languages in that region makes it very likely that the same situation holds for the northern Moluccas.

The remarkable point about the North Halmahera Stock languages is that the largest subfamily contains languages which are very closely related. This largest subfamily is termed the Halmahera Subfamily (Wurm & Hattori 1983, Map 45: Voorhoeve calls it the North Halmahera Family) and it covers the whole of northern Halmahera, Morotai, Ternate and Tidore, with the exception of part of the island of Makian. Within it all languages share over 65% of basic vocabulary (100-word list). The second subfamly contains only the West Makian isolated language which shares between 21 and 28% of cognates with the languages in the Halmahera Subfamily. This suggests a situation in which the West Makian language has remained in place for several millennia, but earlier Papuan languages in northern Halmahera have been completely replaced by a recent language radiation or levelling. This radiation presumably took place some time within the past 2000 years given the very shallow level of linguistic diversity. It could have been stimulated in part by a dispersal of agriculturalists into remote forested terrain previously inhabited by foragers, a dispersal perhaps in turn stimulated by the demands of the spice trade. The very wide occurrence across Indonesia after 2000 years ago of characteristic incised pottery of Indonesian Metal Age style also surely reflects increased communication and population movement from this time onwards.

Another very interesting observation made by Voorhoeve (1988: 194) is that the North Halmahera Stock languages of Ternate, Tidore, West Makian and Sahu, all located in the mid-western geographical portion of the Halmahera group, have adopted many elements of Austronesian grammar. Some of this borrowing is also claimed by Voorhoeve to be quite ancient, although no exact date is suggested. The locations of these four languages, perhaps not coincidentally, are all quite close to the island of Kayoa with its so-far unique assemblage of early Austronesian affinity dating from 3300 BP and onwards in the Uattamdi shelter. Was the initial enclave of Austronesian speakers at about 3300 BP localized to a relatively small area focused on the chain of small islands from Bacan up to Ternate?

There is no simple answer to this question from an Austronesian linguistic viewpoint at present since quite a lot of basic research still needs to be done. According to Blust (1978, 1993), the Austronesian languages of the Halmahera region, which presumably at some time replaced preexisting Papuan languages, belong to the South Halmahera subgroup of the higher-order South Halmahera-West New Guinea (SHWNG) subgroup of the Austronesian family. The SHWNG subgroup is defined by about 13 linguistic innovations (Blust 1978, 1983-1984, 1993), sufficient perhaps to suggest several centuries of linguistic unity prior to expansion and diversificiation. Whether this phase of unity occurred in the Moluccas or Irian Jaya is at present unclear. The South Halmahera subgroup contains, according to Blust, two lesser-order subgroups; one (Southern) comprising the languages of eastern Makian, Kayoa and the southern mainland of Halmahera (Giman); the other (Central-Eastern) comprising the languages of eastern Halmahera (including Weda). The archaeological enclave of early Austronesian-related settlement located on Kayoa lies within the area of the Southern subgroup, which one might thus ex-

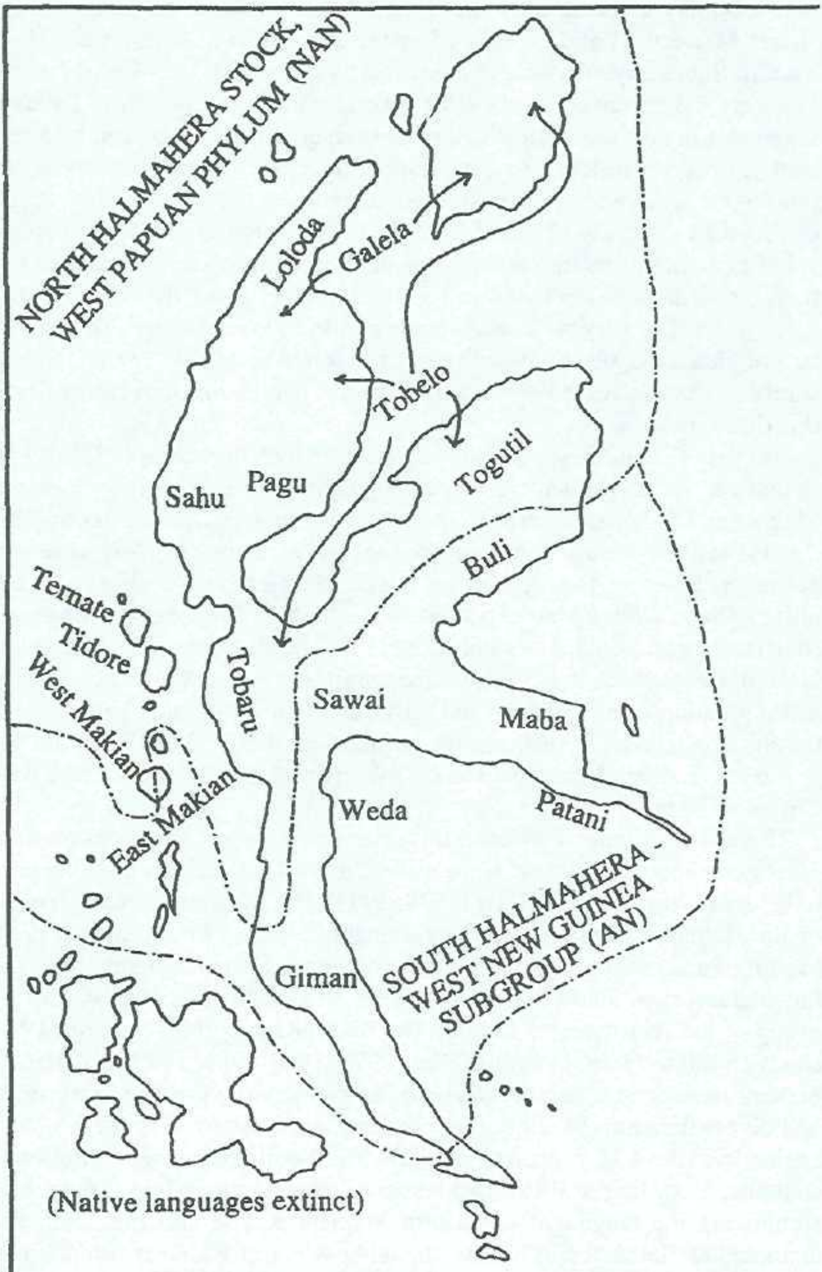

Figure 8. Map of the major Papuan and Austronesian languages of the northern Moluccas. (After Wurm & Hattori 1981-1983, map 45).

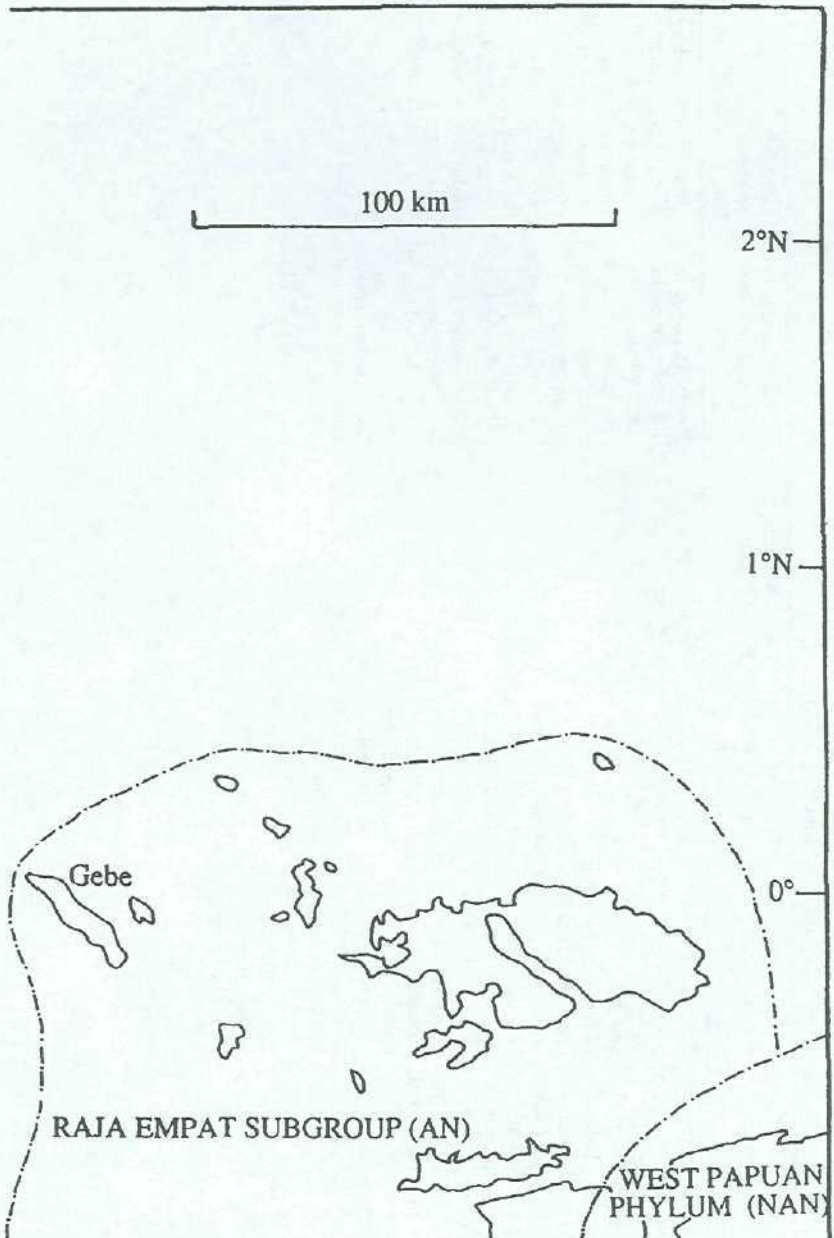
100 km
2°N
1°N
0°
Gebe
RAJA EMPAT SUBGROUP (AN)
WEST PAPUAN
PHYLUM (NAN)

Table 8. Cultural changes through time in the northern Moluccas, 35,000 to 1000 BP.

Date BP	Morotai Island (several sites)	Gebe Island (several sites)	Gua Siti Nafisah, Weda, Halmahera	Gua Uattamdi, Kayoa Island	Economic and general cultural observations	Possible linguistic correlations
35,000 to 3500 BP	Preceramic occupation from 15,000 BP; volcanic pebble tool and flake industry, bone points, ochre, *Canarium* anvils. Fishing only significant in Holocene. Mammals include giant rat and cuscus, but no wallaby or bandicoot.	Preceramic occupation from at least 32,500 BP; core and flake industry of fine-grained crystalline rocks, ochre. After 13,000 BP: shell adzes and circular stone arrangements. After 8000 BP; ochre-covered extended burial, bone points, *Canarium* anvils, economic focus on marsupials (translocated?) rather than fish. Wallaby and cuscus present, bandicoot absent.	Preceramic occupation from 5500 BP; bone points, ochre, virtually no flaked stone, *Canarium* anvils, balance of marsupial and fish exploitation. Marsupials include wallaby, bandicoot and cuscus. *Rattus morotaiensis* present.	No preceramic occupation	Observations for the Holocene: no good data for Pleistocene; *Canarium* and sago exploitation (the latter presumed only), ground-dwelling marsupials hunted on Halmahera and Gebe (not present on Morotai), fishing on Morotai and Halmahera but virtually absent on Gebe. No evidence for trade in lithic materials as yet. Cultural pattern suggests considerable local isolation	Initial settlement by Non-Austronesian speakers, followed by linguistic diversification. Source of first population unknown, but presumably from Sulawesi via Sula or from New Guinea via Gebe.

Table 8. Continued.

3500 to 2000 BP	Continuation of above pattern	Continuation of above pattern	Continuation of above pattern	3500 to 2000 BP; red-slipped pottery, bone points, stone flakes, polished adzes, shell beads and bracelets, introduction of pig and dog, focus on fishing (no marsupials except cuscus present on Kayoa). This assemblage is paralleled closely from 3500 BP onwards in Philippines, Sulawesi, Sabah and in Lapita sites in Melanesia.	Continuation of above with regional isolation on Morotai, Halmahera and Gebe. Introduction of domestic animals by Austronesian populations into Kayoa. Systematic field agriculture assumed but unproven for Kayoa, given PAN and PMP reconstructions for agricultural crops and technology. Uattamdi assemblage paralleled very widely in eastern Indonesia and Philippines	Austronesian settlement in Kayoa and adjacent areas, leading to beginnings of close PN-AN liguistic interaction. PN languages still dominate Halmahera itself.
2000 to 1000 BP	Secondary human burials in cave floors with incised pottery, shell ornaments, iron	Incised pottery, *Canarium* anvils	Incised pottery, shell ornaments, polished stone adzes, introduction of pig and dog	Incised pottery, jar burials, bronze and iron, monochrome glass beads, Chinese coins (the latter dated c. 1000 BP)	International spice trade via Java and Bali to India and Western ports, Chinese interest from late 1st millennium AD. Pan-Indonesian ceramic pattern spread after 2200 BP with glass and metal	Expansion of NE Halmahera Stock of PN languages, perhaps as a population dispersal? Possible spread of AN languages through eastern Halmahera, and from western New Guinea into Gebe (Gebe belongs to Raja Empat subgroup of SHWNG)

pect from archaeological data to present more internal diversity, hence greater time depth, than the Central-Eastern subgroup. Unfortunately, the only available lexicostatistical percentages for the Halmahera region are those given by Grimes and Grimes (n.d.), but these do not extend to any regions of related languages in Irian Jaya so it is not possible to state which of the Halmahera Austronesian subgroups represents the earliest area of Austronesian settlement. The languages in the two subgroups share as few as 33% of cognates on a 195-word list, but all this tells us is that Austronesian linguistic differentiation within the Halmahera islands has been continuing for several millennia.

Despite these problems of proceeding further with Austronesian linguistic prehistory in the northern Moluccas, there still remains the important lexicostatistical observation of Grimes and Grimes (n.d.) that the languages of the eastern arm of Halmahera (Maba, Buli, Patani) are very closely related. They probably represent a relatively recent spread within the past 2000 years, as suggested already for the North Halmahera Subfamily of the Papuan languages further north. Like these, the eastern Halmahera Austronesian languages might have spread through a combination of causes, including population movement, trade, and perhaps even some degree of forcible population replacement in recent centuries (Andaya 1993).

Some conclusions about linguistic-archaeological correlations for the norther Moluccas are presented in Table 8 (page 268-269). It is perhaps worth adding that the only available genetic analysis for this region (described in Bhatia et al. 1995) has examined the Ternate and Galela populations, who speak Papuan languages in the Halmahera Subfamily. Given the linguistic affinities of these languages with the West Papuan Phylum spoken in New Guinea it might be expected that these populations would group with New Guineans in terms of their genotype. In fact they do not. They group instead with the Indonesian populations to the west, whom they also resemble most closely phenotypically (e.g. Ishige 1980: 4-5). Clearly, this is a situation where languages have been maintained throughout a long period of fairly intense intermarriage between Austronesian groups of Southeast Asian origin and Papuan groups of western Pacific origin, intermarriage which has shifted the biology of the Papuan speakers closer to an Asian form. Much of this intermarriage can be expected to have occurred during the past 500 years of very intense trade, tribute collection and political interference mediated through the sultanates of Ternate and Tidore. Even though the native languages of these two sultanates were Papuan, their cultural heritage was very much derived from western Indonesian sources, a point recently stressed by the social anthropologist Jos Platenkamp (1990). It is worth adding that some degree of Austronesian-Papuan intermarriage can in theory also have occurred much earlier, from 3500 years ago.

5 CONCLUSION

Because this is a data paper most of the conclusions have already been presented. Basically, the northern Moluccas have an archaeolaogical and linguistic prehistory which covers more than 32,000 years. As such, the region has one of the most detailed prehistoric sequences for this period of any region of Indonesia. Further research to improve our understanding of this sequence will continue.

The essential conclusions of this research so far are presented in Table 8, with respect to changes in both the linguistic and the archaeological landscapes of the northern Moluccas. In my opinion, one of the most important questions for future research will be the date of initial human settlement. Did it occur, as in Australia, beyond the range of radiocarbon dating? The only way to test this will be to apply different dating techniques in the region, particularly luminescence dating of quartz-bearing materials from ancient sediments.

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Analytical expertise has been provided by: Dr Tim Flannery, Mammals, Australian Museum, Sydney (identification of marsupials and ro-

dents); Dr Peter White, Archaeology, University of Sydney (analysis of animal bones); Dr David Bulbeck, Anthropology, University of Western Australia (analysis of human bones); John Head, Radiocarbon Laboratory, ANU (radiocarbon dating); and Mahirta, MA student in Archaeology at ANU (archaeological ceramics and a study of the ethnographic pottery industry of Mare Island, near Tidore, see Mahirta 1996).

NOTES

[1]A slightly modified version of this paper under the title 'The Northern Moluccas as a Crossroads between Indonesia and the Pacific' was presented at the International Conference on Linguistic and Cultural Relations in East Indonesia, New Guinea and Australia, held at Gadjah Mada University, Yogyakarta, 24-26 June 1996.

[2]Language grouping terminology differs somewhat between the Papuan and Austronesian languages, reflecting to some extent the respective usage of lexicostatistical versus shared innovation methodology for analysis. The term 'family' for Austronesian corresponds roughly to the term 'phylum' for Papuan.

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