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Crossing the Timor Sea by Middle Palaeolithic Raft

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Abstract. – The implications of the initial Pleistocene crossing of the Timor Sea are considered, and it is shown why a detailed understanding of the seafaring technology of early periods is likely to provide the best available measure of the maximal technical capability of hominid populations. Such understanding, it is argued, can best be acquired through systematic applications of replicative archaeology to all aspects conceivably related to maritime achievements. Current evidence favours first landfall in Australia, almost certainly from Timor or Roti, to have been made by Middle Palaeolithic seafarers, perhaps about 60,000 years ago. Two replicative experiments to cross the Timor Sea with primitive bamboo rafts are described. One was abandoned, the other succeeded not only in crossing the sea barrier, but also in acquiring a great deal of new empirical data about the context of Pleistocene seafaring. *[Australia, Indonesia, Middle Palaeolithic, seafaring technology, hominids, replicative archaeology]*

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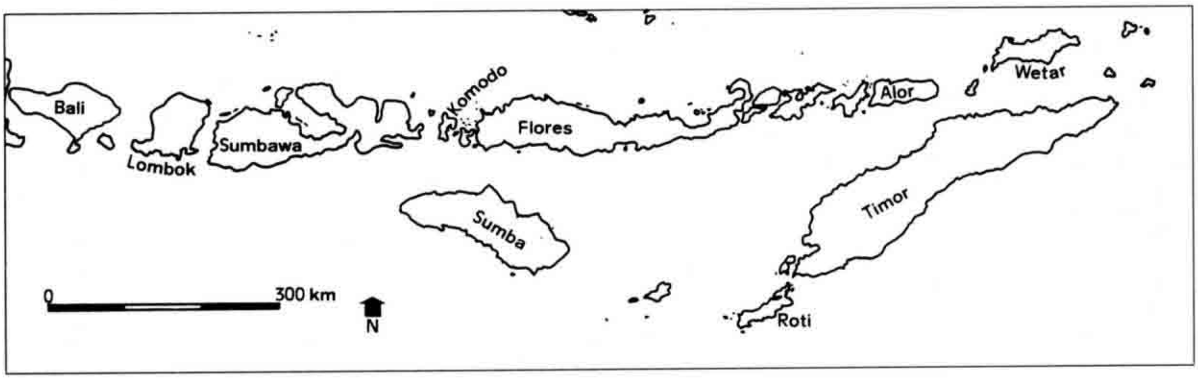
Introduction

Recently, in this journal, I have critically reviewed the topic of the initial hominid settlement of the Southeast Asian islands of Wallacea and of Australia (Bednarik 1997a). That paper illuminated some misunderstandings concerning this subject, which I found especially entrenched in the English language archaeological literature. My review has already led to a constructive reassessment of the hitherto dominant model of human evolution, and to better informed research work in the islands of Wallacea. Soon after I clarified certain misconceptions, particularly concerning the important work of Theodor Verhoeven (recorded in numerous articles in this journal), a major Australian-Indonesian project was initiated in Flores, the main area of Verhoeven's research. In combination with other work this is expected to ultimately lead to the complete refutation of the "African Eve" model (Bednarik and Kuckenburg 1999).

Important recent developments in clarifying the cultural, cognitive, and technological status of Wallacean hominids of the upper Early Pleistocene and the lower Middle Pleistocene are the first zircon-derived fission track dates from Mata Menge (Morwood et al. 1998), Boa Leza, Koba Tuwa, and Tangi Talo, on the Soa Plain in central Flores. Mata Menge and Boa Leza were initially examined by Verhoeven (1958), and later by Maringer and Verhoeven (1970). They confirm the great age of the human occupation evidence originally proposed by Koenigswald and Ghosh (1973) and later corroborated by Sondaar et al. (1994). More important still is the discovery, late in 1998, of evidence for the contemporaneity of Stegodontidae and hominids in the Middle Pleistocene of Timor, in a region near Atambua, in the northeastern part of West Timor (Bednarik 2000).

In my previous *Anthropos* article on this general subject I also mentioned briefly that an expedition was being prepared to attempt the replication, by essentially Middle Palaeolithic means, of the first crossing of the Timor Sea (Bednarik 1997a: 362). Since then, several progress reports of this



Map: The islands of Wallacea.

project have appeared, which show that, from the original proposal, two separate and competing expeditions developed, the "First Sailors" and the "Nale Tasih Expedition." Both wished to be the first to cross two sea barriers by replicating presumed conditions of Pleistocene navigation at the respective times in question. Some of these experiments are to explore the conditions under which Lombok Strait may have first been crossed, presumably some time before 850 ka (850,000 years) ago. Others are to recreate the circumstances under which Australia may initially have been settled via the Timor Sea, perhaps about 60 ka ago (Bednarik 1997b, 1997c, 1998, 1999, 2000). As the Chief Scientist of both expeditions I am responsible for the acquisition of all scientific data, and for ensuring that the conditions under which each experiment is conducted are as authentic as possible. In practical terms, this means that I must participate in each attempted sea crossing, in addition to collecting a great deal of highly relevant archaeological data on land. For instance, I work with the Australian-Indonesian excavation project in Flores, where I am responsible for sedimentary analytical studies and the detection of stone tool cutting marks on bone finds. Also, I conduct research in various parts of Timor, in Roti, and in the future hopefully in Sulawesi and Java (Map).

This work has shown that our knowledge about the Pleistocene history of Indonesia remains seriously impaired. Despite enthusiastic efforts by some individuals, usually non-archaeologists, there are great lacunae in the information available, and most studies of the region's Pleistocene archaeology and palaeoanthropology have been opportunistic (i.e., highly selective) and lack solid scientific data. There is a tendency to uncritically repeat secondhand data or superficial judgments in publications. For instance, the most frequently cited article about Pleistocene stone tools in Timor is merely about ten unprovenanced specimens in a museum collection. The rise of eastern Africa as the world's principal focus in matters of human evolution has resulted in a severe neglect of the hominid history of Asia generally, which at least in part is itself responsible for the massive research bias that fostered the fallacies connected with the African Eve model. However, first signs are now appearing that this trend is finally being reversed.

My long-term "First Mariners" project is expected to have several significant effects. Besides setting the record right concerning hominid cultural evolution, and refuting the hypothesis that "anatomically modern humans" evolved in isolation in a single region, the project has also implications for the initial settlement of Australia. More importantly, it provides unprecedented means of estimating technological capabilities at specific times in the distant past. Maritime technology is better suited than any other aspect of Pleistocene archaeology to determine the true level of sophistication of a population, and also provides a measure of cognitive, cultural, and perhaps even social circumstances of the accumulation of what is defined as archaeological evidence. The reasons for this are simple enough: pioneering sea journeys would have been fairly close to the limits of what was technically possible at a given time, so if we can establish the means by which they were accomplished, we also obtain a blueprint of maximal technological competence. The underlying idea is that maritime technology was always close to the cutting edge, and provides a secure measure of technological capability. After all, such journeys were probably matters of survival under extreme conditions. If we have a fair idea of *when* a particular crossing was first made, and the sea distance can be estimated, we could formulate a reasonably accurate scenario of its conditions, if only we had a large data bank of the design and performance of primitive rafts of the kind possibly in use in Pleistocene times. Such data did not exist until now, in fact the whole topic of Pleistocene maritime navigation has attracted no sustained interest at all.

Some archaeologists have long become concerned about basing our concepts of Lower and Middle Palaeolithic technologies entirely upon subjective stone tool typologies, suspecting that this minimalist approach may be misleading. This should be self-evident when we consider the highly economical lithic technologies of Tasmanians and Australians, which so sharply contrast with their complex spiritual, social, and cognitive sophistication. Moreover, the scenario provided by palaeoart studies of the Lower and Middle Palaeolithic has long negated the archaeological judgment of relative primitiveness and cultural sluggishness (Bednarik 1994a, 1996). Lower Palaeolithic sophistication can no more be determined from the period's refuse than modern capability to fly to the moon is indicated by the contents of a municipal garbage dump. Since maritime capability provides a reliable measure of maximal technical sophistication at a given time, it is ideally suited to clarifying the issue of the true cultural level of hominids. To explore it, we require a thorough understanding of how simple sea vessels perform. One of the purposes of the "First Mariners" project is to provide this.

Replicative Archaeology

With the term "replicative archaeology" we refer to research that seeks to explore archaeological issues through experiments of replication. A vast range of possibilities of this exists, and there is no sharp division between this field and the experimental study of taphonomic processes, or indeed the practical application of taphonomic logic (as defined in Bednarik 1994b). Such experiments may involve technical processes used in the past, such as in metallurgy or the production of ceramics, to determine how the products known from archaeology were arrived at. They are falsifiable, and therefore scientific, whereas traditional archaeology itself is not a scientific discipline. The scientific version of archaeology (i.e., its universal theory) is metamorphology, the most important application of which is taphonomic logic (Bednarik 1995a). Replicative archaeology is the practical application of scientific experimentation to questions of interpretation. Archaeology without it is a belief system, and generally unscientific, even where scientific (i.e., falsifiable) propositions are imported from other disciplines, such as nuclear physics, biochemistry, geomorphology, and so on.

This shows the great importance of replicative archaeology, provided it is used in a rigorous, repeatable, and systematic fashion. Broadly speaking, there are two forms of replication in archaeology, which I call *product-targeted* and *result-targeted*. The easier and more reliable procedure is the former, in which one endeavours to copy an archaeologically demonstrated physical result, generally an artefact. In order to arrive at precisely the same result, one identifies all its quantifiable variables, such as material type, form, surface striations, wear traces, damage, and so forth, and then determines experimentally how they can most readily be duplicated, using appropriate means. For instance, one might start with a Middle Palaeolithic bone harpoon and, having determined all its physical attributes (particularly at microscopic scale), acquire some freshly butchered bones of a similar species, and work them with stone replicate tools of the industry in question until one arrives at a product precisely matching the archaeological specimen (Fig. 1). One has then not only determined how the harpoon was probably made and how long it took to make it, one can go on to establish how it may have been used to acquire the microscopic wear traces or damage the original specimen exhibits. One is also likely to develop considerable expertise in discriminating between authentic artefacts of this type and modern fakes of them, because one would become familiar not only with production processes, but also with the surface traces, from both manufacture and wear, the genuine article is likely to present. In this sense the amount to be learnt from such work vastly exceeds the validity or veracity of what mere speculative examination of the same specimen might induce us to believe.

Result-targeted replication, on the other hand, is less straightforward and may involve considerably greater efforts. Here, the artefacts or strategies involved are unknown, as no physical trace of the relevant artefacts has survived. Essentially, one begins with a result archaeology has determined, such as, for example, the first appearance of humans in Australia, perhaps about 60 ka ago. We have testable propositions about the locations of shores at that time, we may even reasonably speculate about the prevailing current and wind directions. But in the absence of any hard physical

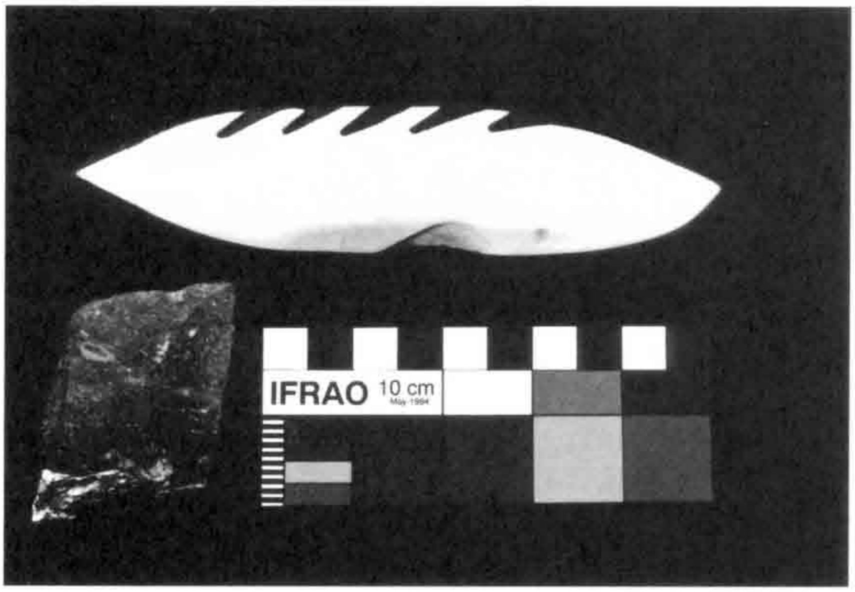


Fig. 1: An example of product-targeted replication: replicate of Middle Palaeolithic bone harpoon made as part of the First Mariners Project, with stone implement used in its manufacture.

evidence of how the necessary sea crossings were accomplished, traditional archaeology can go no further. In result-targeted replication we begin by deconstructing the demonstrated phenomenon (that humans did cross to Australia, as demonstrated by the remains of about 200 Pleistocene hominids, by tools, and rock art) to identify those crucial variables archaeology cannot account for. They then need to be examined empirically to enable their quantification, and this is done by systematic replication work. The greater the number of variables or determinants one can account for in this fashion, the greater the confidence in the eventual outcome of this procedure.

Once each crucial variable can be adequately quantified, a framework of probability is derived from them, which permits the testing of propositions. While this will always involve uncertainties, these can be greatly minimized by rigour, and the procedure can remain scientific at all stages. Each step is accessible to falsification, as one can always attempt a more parsimonious explanation of the data available, or by providing new data. The principal shortcoming of this approach is, that the most "sensible," economic, or logical course of action in our scenario was not necessarily the one actually taken by the original actors, such as the first colonizers of Australia. However, in matters to do with human survival, as would be the case in pioneering sea journeys, this potential error factor is itself severely limited by the limits of choice and survivability. Moreover, we are not entirely without information about the level of technology available to the humans concerned, even though the pronouncements of archaeology in this matter need to be augmented by taphonomic logic.

The "First Mariners" project involves both product-targeted and result-targeted replication studies. Among the former are the production of stone implements and bone harpoons, and the study of wear and use traces. Result-targeted replication work includes the most archaic methods of making fire and using it on a vessel, making and using fish spears, the felling and treatment of bamboo, woodworking with stone tool replicas, the storing and transport of water and food rations, experimentation with various types of utensils, the use of stone tools in constructing and repairing rafts, in gutting fish and food preparation, the making of experimental raft models, and the sailing of various full-scale models under a range of conditions. The project has many other aspects, especially land-based archaeological, sedimentological, palaeontological, and geological research in Wallacea. Begun in 1996, it will not be completed before the end of 2001, and is expected to result in hundreds of publications, especially about replicative archaeology, and in documentary films. It is indeed the largest project of replicative archaeology ever attempted, and its work to date has already involved the collaboration of about 650 people. While its principal geographical focus is on Indonesia, it will also examine the question of Pleistocene seafaring elsewhere, especially in the Mediterranean, where seafaring also has a long history, beginning with the Middle Pleistocene (Bednarik 1999; Bednarik and Kuckenburg 1999).

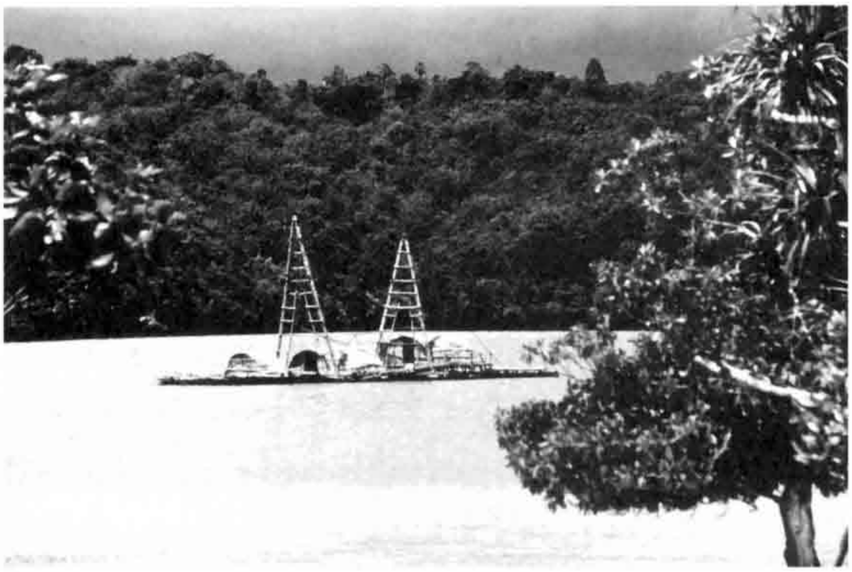


Fig. 2: The Nale Tasih 1 anchored in Oeseli Lagoon, southern Roti, Indonesia.

One of the project's principal aspects is the construction of seagoing rafts and their sailing, which is addressed below in a preliminary form. While this does include attempts to cross several sea barriers, it must be emphasized that such crossings are not a main feature of the project, and there is no intention to "attempt true reconstructions" of such initial crossings. Rather, the main purpose of the overall project is to create a framework of empirical knowledge within which hypotheses about the topic can be tested, for the simple purpose of determining maximum technological capacities of hominids at given points in time. In short, the knowledge to be generated by the project is to be applied to correcting major misconceptions about levels of technology available to Pleistocene people. In this sense, the rather large project is revisionary in intent and very focused, but naturally its findings will have many other implications. Among them, hopefully, will be a resurgence in replication work of the type pioneered by Semenov (1964).

The Nale Tasih 1 Experiment

The 23-m-long pontoon-type bamboo raft "Nale Tasih 1" was built between August 1997 and February 1998 at the remote fishing village Oeseli, near the southern tip of Roti (Fig. 2). Its five parallel pontoons were of roughly circular section, each consisting of about 110 stalks of bamboo. A variety of bamboo species and local variants was used, and these stalks were lashed together by essentially three types of binding material: *gemuti*, the hairy bark of the *enang* palm; *pipa lontar*, dried strips from the inside spine of the *lontar* palm leaf (*Borassus sundicus*), and the skin of the rattan vine (*Calamus* sp.). The bamboo was gathered over eight months, some seasoned after soaking in the lagoon to kill bamboo beetle infestation, but most was cured under cover to avoid splitting, tied together in bundles of four to prevent bending of individual stalks. To acquire its maximal buoyancy, bamboo needs to cure for 4–6 months, depending on its variety, size, and drying conditions. The bamboo for Nale Tasih 1 was gathered at random and included all of Roti's native species, although the smaller types, not dissimilar to *Bambusa arnhemica* found in northern Australia, were favoured, to make the stalks easier to lash. The pontoons were spaced and held together by thirteen cross members of multiple, lashed together large-diameter bamboo lengths (Fig 3). The cross members supported a deck of split bamboo, much of it raised well above the waterline. The deck supported three weatherproof huts woven of *lontar* palm leaves, supported by a frame of thin bamboo, and two A-frame masts of strong and reinforced bamboo. The sails were woven from *lontar* palm fibre, in fact the leaves and leaf spines of both the *lontar* and *gewang* palms found extensive use in raft construction and in baskets, mats, sun hats, and cooking buckets (*haik*). The superstructures of the Nale Tasih 1 included two V-frames for steering oars. Only these, the oars and the mast joints were made of wood, naturally bent branch forks from local trees. All construction work was either by the use of Middle Palaeolithic stone tool replicas, or by handmade steel *parangs*. In the latter case, replicative experimentation with stone implements demonstrated that the work could be done with them alone, and how long it would take. This work established that the 11 tonnes (dry weight) of bamboo in the pontoons could easily be felled, cleaned, and assembled at the site in one or two weeks by eight adults, provided the bamboo stands occurred within a few hundred metres of the launching site (Bednarik 1997c).

Food provisions carried on the raft included pork and goat meat cooked and preserved in *lontar* sugar syrup and a local tree foliage vegetable preserved in palm vinegar. These were all stored in sections of bamboo, capped with woven palm leaf covers dipped in beeswax. More of the palm syrup was contained in gourds, while 600 litres of drinking water was carried in three large mangrove trunks, hollowed out by termites and blocked off at the ends with wood, and sealed with paper bark and beeswax. Coconut shells served as eating and drinking cups. Live shellfish were carried alongside the raft in baskets but they died during the voyage. Only food provisions we presumed might have sustained the original voyagers to Australia were aboard, and they included

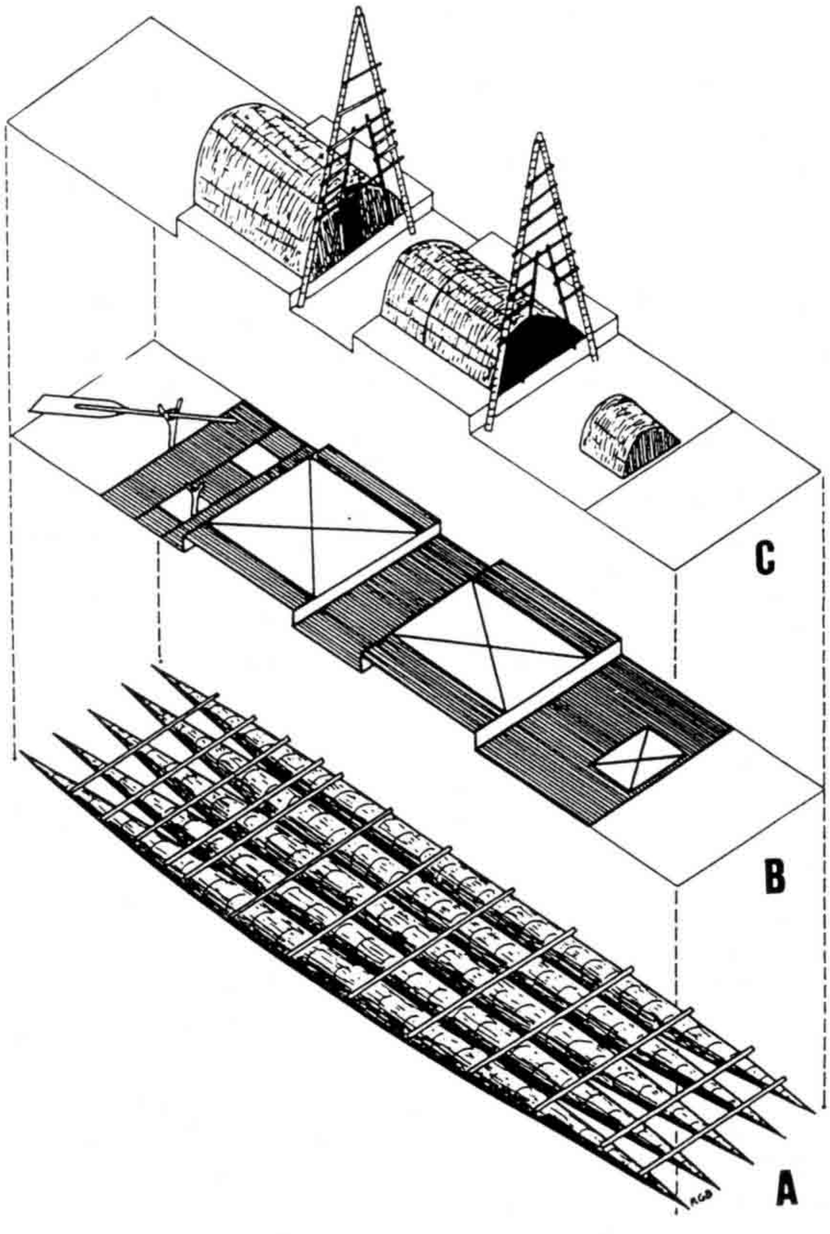


Fig. 3: Exploded view of the Nale Tasih 1 bamboo raft, showing pontoons (A), decks (B), and superstructures (C).

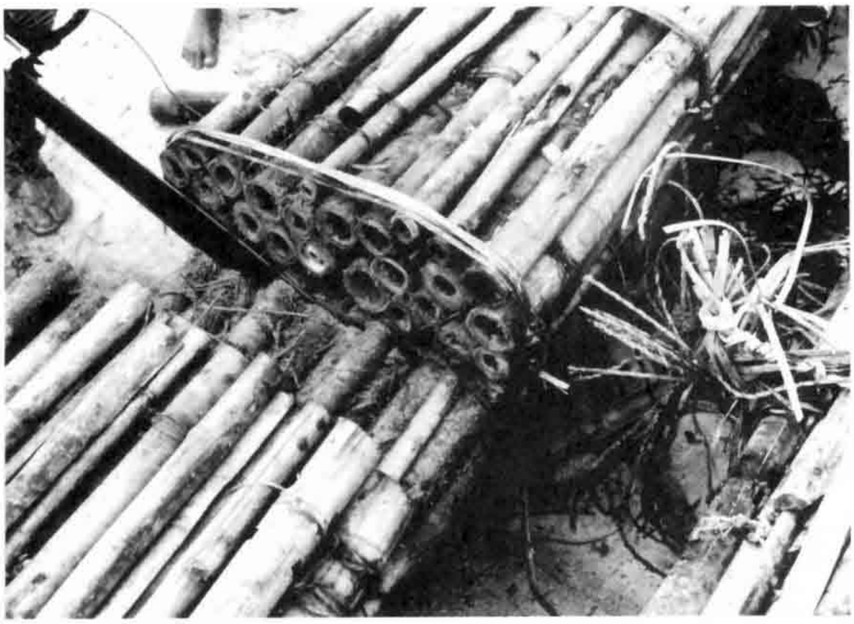


Fig. 4: Destructive material testing of the Nale Tasih 1: a pontoon is sectioned by chain saw for sampling.

the local staple, wild foxtail millet (*pottok*), *kusambi* fruit, a large supply of ripe and green drinking coconuts, dried fish and sun-dried octopus, and squid boiled in palm vinegar. The millet gruel and the preserved meat were successfully cooked in the *haik* palm baskets over a firebox. The fire was lit each time it was required by drilling soft wood with hard wood, using dry coconut husks as tinder.

However, it was expected that the principal sustenance would be provided by marine food acquired at sea. For this purpose, the raft was equipped with eleven bone harpoons, replications of Middle Stone Age and Middle Palaeolithic bone harpoons. There were 170 stone tools on board, all of Middle Palaeolithic types, most made from dark-grey, microcrystalline sedimentary silica, a few from brown jasperite. The majority were multipurpose cutting and chopping tools, and the most worn specimens are destined for microwear study. Finally, the vessel's anchor consisted of a naturally perforated block of Tertiary limestone.

After the launch of Nale Tasih 1 on 14 February 1998, when 400 enthusiastic Rotinese hauled the raft into the lagoon (not without causing severe damage to lashings), the superstructures were completed, and supplies and equipment were loaded. On 6 March, the raft was towed through the entrance to Oeseli Lagoon to commence sea trials, with a crew of eleven, including three females. One of the objectives was to determine whether the vessel was capable of reaching Australia, some 800 km away.

The displacement of the raft was found to be significantly greater than anticipated, and after 24 hours at sea, the deck was under about 15 cm of water. Sails and rigging performed exceptionally well, but could not compensate for the excessive weight of the largely submerged vessel. The raft showed excellent flexibility as its overall construction allowed it to flex with every wave rolling under it. However, the El Niño effect, as feared, had so affected the prevailing northwest monsoon, the resulting current and wind direction made it impossible for the raft to make headway to the east. Even with a maximum speed of 1.7 knots achieved in moderate to brisk conditions it was unrealistic to expect the raft to reach Australia in any reasonable period of time. After completion of sea trials and tests, it was towed back to Oeseli and beached on 9 March, in order to conduct extensive examination and destructive testing of selected components.

Over the following week, the raft was completely stripped down to its basic components. A 30-cm section was removed by chain saw from one of its pontoons, to determine the performance of various bamboo species and the effects of water penetration (Fig. 4). It was found that 93% of all air chambers had contained water, mostly as a result of infestation by bamboo borers, and to a lesser degree through cracking, which was observed even in the thick-walled species. Some of the cordage types used, particularly *pipa lontar*, were found to have a dramatically reduced tensile strength as a result of having been soaked in seawater, while others had performed very well. It is clear that the raft had been overloaded and would have sunk further, had it travelled on. While the thorough examination of the raft showed clearly that it was unlikely the Nale Tasih 1 would have reached Australia, it also provided a great deal of valuable data for the design of "Nale Tasih 2," and some of the expensive components of the first raft were salvaged for reuse.

The Nale Tasih 2 Experiment

In contrast to the Nale Tasih 1, whose design was based on the recommendations of leading marine designers, the second raft was based on the experience of indigenous and traditional boat builders of Indonesia, and the intuition of its captain, Bob Hobman, and myself. It differed radically in design from the first raft, being much simpler. The separa-

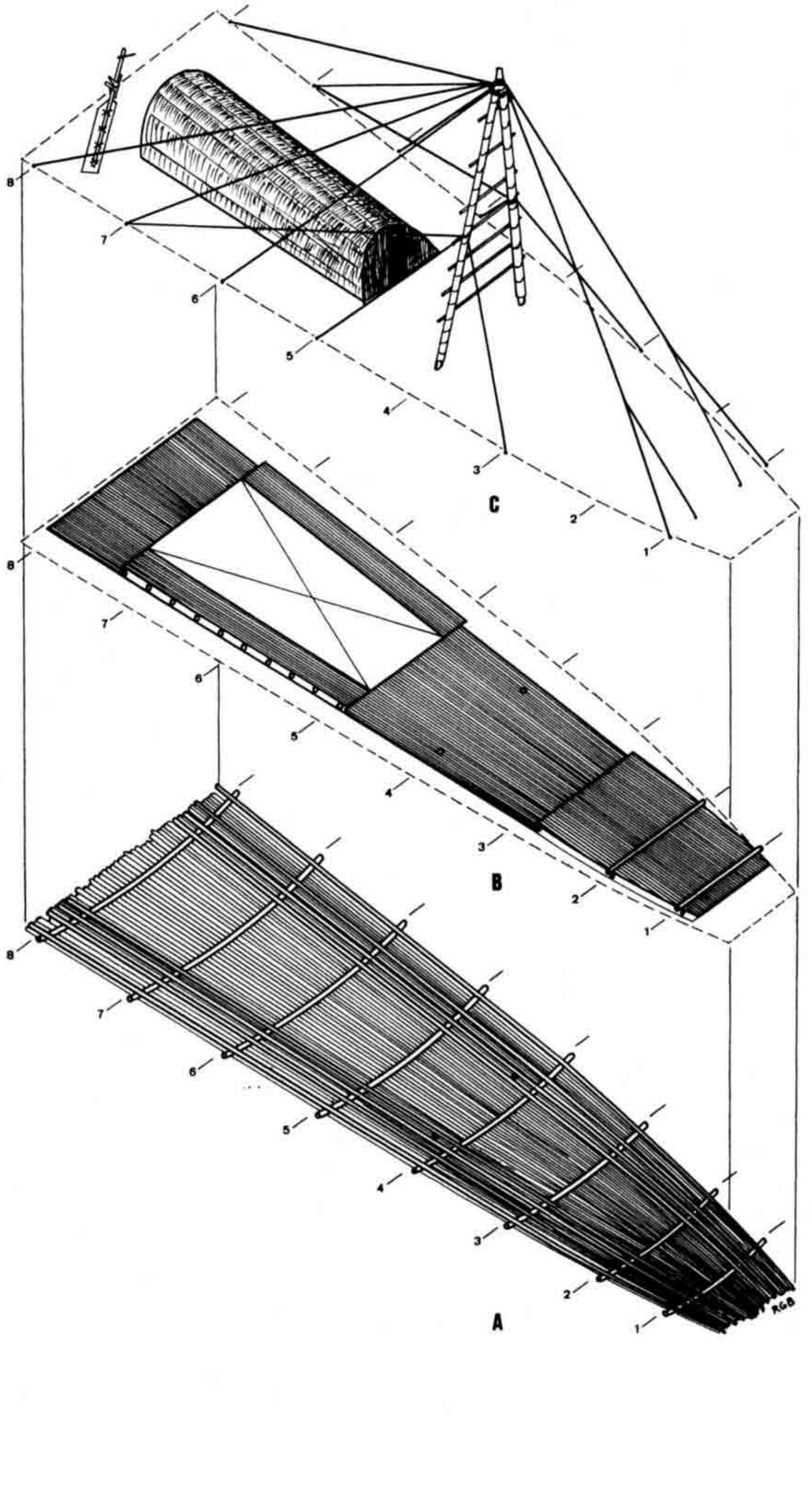


Fig. 5: Exploded view of the Nale Tasih 2, showing raft structure (A), deck (B), and superstructures (C).

tion of structural from buoyancy components was eliminated, and the two problems of raising the deck sufficiently above the water and of meeting the impact of waves arriving from the sides were solved by simply curving the sides of the raft upwards (Fig. 5). Apart from this one factor, the Nale Tasih 2 was as basic in design as a bamboo raft can possibly be: 87 bamboo stalks arranged flat in three layers were held in place by eight cross timbers made from naturally curved trunks.

Although only a few metres shorter than Nale Tasih 1, at 18 m, the second raft weighed only 2.8 tonnes plus equipment and supplies, compared to the 15 tonnes of the first vessel. Construction of the Nale Tasih 2 began in August 1998 near Kupang, West Timor, involving the work of eight boatbuilders for three months. The primitive raft was launched in mid-November, and left Kupang harbour with a crew of five on 17 December. They were captain Bob Hobman from Bali, scientist Robert G. Bednarik from Melbourne, cameraman Peter Rogers from Queensland, traditional boatbuilder Emmanuel Filipus Littik from Roti, and boatbuilder and fisher Jacobus Zakawerus from North-Sulawesi. The raft had been constructed entirely from materials available to Middle Palaeolithic people of Indonesia, but in contrast to Nale Tasih 1, all critical rope bindings consisted of full rattan vines. In particular, most mast guy ropes were rattan, and the individually lashed bamboo lengths were collectively tied to the thwart timbers by rattan forest vines.

On board were two mangrove logs, hollowed out by termites and sealed off with wood, beeswax, bark and tree resin, and containing 350 litres of drinking water. The one A-frame mast bore a 24-square metre sail woven from palm leaf. A single steering oar on the stern was effective at reasonable velocity, augmented by six steering boards. The latter were not found to improve steering ability greatly. The Nale Tasih 2 was well equipped with spare parts, including two sails, a steering oar, vines, ropes, and other cordage, and to effect repairs at sea it carried 65 stone artefacts, replicas of Middle Palaeolithic types made from black sedimentary silica stone. A stone mortar and pestle was used in food preparation. A wooden anchor, weighted down with a limestone block, was on board, also a quantity of firewood and coconut husks, used as fuel and tinder. Finally, the raft carried an old sampan (dugout) of 4.77 m length strapped across the stern, for the purpose of permitting the cameraman to film the vessel from some distance during the journey.

Food provisions included 30 coconuts, several bundles of bananas, a basket of mangoes, some melons and cassava, salted meat, a basket of *pottok*, about seven litres of palm sugar, some salt, and a few limes, carrots, and cucumbers. However, these were supplementary supplies, it was intended to derive most food from the sea. For this purpose the raft was equipped with several harpoons and fish spears. It also carried a firebox of wood, filled with sand and three heating stones of limestone. Utensils were made from coconut shells, and buckets from folded *lontar* palm leaves. Food was cooked in such containers.

Fish up to 1.5 m length were harpooned or speared on the journey, including dorado, yellow fin tuna and angelfish. They were immediately gutted and filleted with stone knives (which were found to be at least as effective as steel knives) and roasted on the fire. Sharks followed the raft persistently but their hard skin proved a good defence against the harpoon. A sea turtle tried to board the Nale Tasih 2 but was not killed for food. Two poisonous sea snakes were encountered, and various marine birds were sighted daily, as well as butterflies.

The Nale Tasih 2 travelled without an escort boat, it had no radio, and the crew's only contact with the outside world was via a satellite telephone, reporting its position twice a day to a contact in Darwin. With the exception of this item, and equipment for navigation, recording, and scientific purposes, all equipment would have been available to sailors 60 ka ago. The experimental raft reached the continental shelf of Australia, which formed the continent's shore during most of the Late Pleistocene, at noon on the 6th day, thus having completed its primary objective. To gain more knowledge in the handling of the craft, the crew continued on towards Darwin. On the 11th day, the seas became rough and the raft was sailed under extreme conditions for the next two days. The steering oar broke, a yard broke in two, and at one stage, all forward guy ropes of the mast snapped in unison, which created a dangerous situation. However, all repairs were effected successfully in heavy seas (Fig. 6). On the 13th day, waves of 4–5 m forced the raft towards Melville Island, north of Darwin, the coast of which is heavily populated by saltwater crocodiles. The Australian coast guard insisted that, as a precaution, the crew be taken from board three hours before the raft was to reach the shore. The crew of the Nale Tasih 2 transferred to the oil tender "Pacific Spear" under dramatic circumstances on the evening of 29 December 1998. Three days later, the raft

Fig. 6: The Nale Tasih 2 crossing the Timor Sea, 26 December 1998, under rough conditions. The sail has been destroyed by the wind, and the spare sail is being hoisted.

was recovered in calmer seas from where it was beached on the south coast of Melville Island, and towed to Darwin. It had survived without structural damage and was in fact in better condition than when it left Timor, having been improved at sea. After fumigation by Australian quarantine it was released for public exhibition.

Discussion

These expeditions have provided adequate scientific information to begin estimating the essential minimum conditions to colonize Australia 60 ka ago. The "First Mariners" project will continue for three more years at least. Next, the very first sea crossing in history, when *Homo erectus* reached Lombok from Bali more than 850 ka ago (Bednarik 1995b, 1997a, 1997b, 1998, 1999; Bednarik and Kuckenburg 1999; Morwood et al. 1998), was examined by means of result-targeted replication work in March 1999. My discovery of evidence of hominid occupation in Timor (Bednarik in prep.) renders it also necessary to determine how *H. erectus* managed to cross from Flores or Alor to Timor.

Obviously it would be premature to offer any conclusions at this early stage of the project, nor is this the purpose of the present paper. A massive amount of replication work has been conducted. Two full-scale vessels have been sailed and models were tested, and it has become clear that the Nale Tasih 2 performed outstandingly well at sea. It was found to behave like a raft at speeds under 1.5–2 knots, i.e., it drifted with wind and current, but at speeds exceeding 2 knots it sailed rather like a boat, and was perfectly steerable. Its most economical velocity over the ground, however, was at the relatively low speed of between 2 and 3 knots. Above that, any increase in wind velocity prompted only a modest increase in travel speed, and even a strong gale of over 30 knots only resulted in a maximum speed of 4.5 knots at most. The swell of several metres under such conditions merely buffeted the raft, demanding flexibility in excess of the vessel's natural elasticity. This strained bindings and rigging, without a corresponding gain in speed. The main function of the steering boards was their ability to provide the raft with a "pseudo-keel" at reasonable speed, and I regard it as very doubtful that such means were employed 60 ka ago.

An important aspect of the Nale Tasih 2 expedition was the opportunity to sail the raft under very rough conditions, which meant that we were able to determine its weakest aspects, correct them, and test the improvements. Additional forward guy ropes were installed behind the sail, and cross timber No. 2 was reinforced above deck. It was due to the personal risks the crew accepted with this "destructive testing approach" that the most important information on this journey was secured. It concerned aspects of fundamental design, limits of material strengths, and limits of human endurance. Most importantly, it was discovered through this approach that, in any seagoing bamboo raft constructed with full-length stalks (as almost certainly would have been used in Pleistocene vessels), the greatest tensile stress is in the forward section, and thus in the forward guy ropes. In the design of a very simple raft such as the Nale Tasih 2 it is therefore essential to reinforce the forward thwart timbers, particularly those serving as guy rope anchors, by releasing the tension created by longitudinal flexing. It seems possible to overcome the structural problem by omitting the forward section altogether, replacing it with some projecting poles to serve as guy rope anchors. This possibility may be investigated in a further experiment.

It is now possible to state categorically that, on the basis of current knowledge, the vessel used in first landfall in Australia did have a windsail area sufficient to provide steering capability. Whether this was an actual "sail" of some type remains to be clarified. The sea crossing was not possible without at least rudimentary steering. Moreover, it was totally impossible without a number of indirect factors. To begin with, it would have involved several months of concerted efforts by a social group, directed towards one totally abstract goal: reaching land that remained invisible for about nine tenths of the journey. Consequently language of sufficient complexity to convey abstract concepts, to motivate construction crews, to convince others to participate, and to organise the work was clearly essential. Moreover, any hominids capable of seafaring also possessed the ability of forward planning. They did not have a "fifteen minute culture" (Gamble 1993: 138), nor did they "forget the beginning of a sentence before it had been finished" (Gamble 1993: 171).

The construction of a vessel was only one aspect of these Palaeolithic efforts, literally hundreds of specific technologies and forms of knowledge had to be harnessed, in procuring, transporting, processing, curating, storing, preserving and working of materials, in understanding their properties and technical limitations. All of this specialist knowledge had to be passed on culturally, and much the same can be stipulated for almost a million years. In these circumstances the until now dominant model of hominid evolution, based on the "African Eve" hypothesis, must now be regarded as soundly refuted: it is totally incompatible with what we are learning in Indonesia – and as yet this learning experience remains profoundly incomplete.

The most important data collected on the Nale Tasih 2 expedition were only made possible by the courage of the crew, and their willingness to risk life and limb in the process. For this, I thank Bob, Peter, Ifé and Om Mberu from the bottom of my heart. I regard them as heroes of science. My special gratitude to Peter Rogers, for his heroic act, and to Bob Hobman, whose sheer persistence and dedication made this work possible. Finally, I thank Silvia Schliekelmann, without whom the Nale Tasih expeditions would not have been, and Richard Creswick, who stood by us when he was needed most.

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