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Replicating the first known sea travel by humans: the Lower Pleistocene crossing of Lombok Strait

The first successful experimental crossing of the Wallace Line by means of a primitive raft without steering or sail is reported. Forming part of a long-term project of exploring the technology and use of the most archaic sea-going vessels, this experiment seeks to examine the minimum requirements of succeeding in crossing Lombok Strait, Indonesia. The first effective maritime colonization in human history is thought to have taken place there, leading to the subsequent hominid occupation of Flores about 850,000 years ago. The rationale and methodology of this replication experiment, which took place in January 2000, are discussed, and the implications of the principal findings are briefly considered. They are significant for the understanding of the technological, cultural and cognitive development of Pleistocene hominids.

Keywords: Hominid navigation, Early Pleistocene, Replication, Technology, Water craft, Indonesia

Introduction

Pleistocene seafaring has been demonstrated by several types of finds from about twenty islands that have never been connected to a mainland, or at least not during the Pleistocene, and from the continent of Australia (Bednarik 1997a). They consist of skeletal remains of approximately 200 humans, mostly from Australia, with seven from four islands (Santa Rosa, Okinawa, Crete and Sardinia); of human occupation evidence in the form of stone tools and other debris; and in some cases of rock art. The two main regions of Pleistocene maritime navigation evidence are the Mediterranean, where at least five deep-water islands were occupied during the Ice Age, and the general region of east Asia to Australia (Bednarik & Kuckenburg 1999). The only other island with known Pleistocene occupation is Santa Rosa, one of the Californian Channel Islands.

The earliest Mediterranean evidence, Clactonian stone tools found in Sardinia, is thought to be in the order of 300,000 years (300 ka) old (Martini 1992; Bini et al. 1993; Sondaar et al. 1995). By far the most extensive and the oldest proof of seafaring comes from Indonesia, however, where this technology was first developed in the order of a million years ago (Bednarik 1997b, 1999a). Evidence of hominid occupation of the late Lower Pleistocene and Middle Pleistocene is now available from Flores (Verhoeven 1968; Maringer and Verhoeven 1970; Koenigswald & Gosh 1973; Sondaar et al. 1994; Bednarik 1997c), Roti (Bednarik 1998) and Timor (Bednarik 1999a; Bednarik & Kuckenburg 1999). The early stone tools of Flores (Fig. 1) have been shown to be up to 840,000 years ago by a variety of dating methods, including fission-track dating (Morwood et al. 1998, 1999), palaeomagnetism (Sondaar et al. 1994), geology (Bednarik & Kuckenburg 1999), palaeontology and the presence of datable tektites (Koenigswald & Gosh 1973). Some of the strata containing these finds of stone tools and, in the case of Timor, charred animal remains (Bednarik 1999a) are overlain by substantial facies of solid Quaternary rock, of more than 150 m thickness in places.

The first journey to Australia, however, occurred significantly later, possibly 60-70 ka ago (Thorne et al. 1999). From Bali to Timor it had been possible to cross each sea barrier of Wallacea with the opposite shore clearly visible at the point of departure, especially because of the high volcanic vents on these islands, many of which rise to more than 2000 metres. The north of Australia, however, is comparatively flat, and especially the very wide continental shelf facing Timor, which was exposed during periods of low sea level, had no elevations of much more than 100 metres height. Consequently the shore became only visible after about nine-tenths of the distance from Timor had been crossed. This does not mean, however, that the Pleistocene inhabitants of Timor could not know the presence of a large landmass to their south. They would have been experienced mariners, attuned to recognizing indirect evidence of land. For instance smoke of large bushfires, which may rise several kilometres into the air, would have been visible occasionally, and in the tropics typical cumulus cloud formations often develop over islands, especially during afternoons. In addition, the directions of sea currents, prevailing wave direction and the seasonal or migratory movements of birds and sea creatures, such as tortoises, would have been observed by Pleistocene mariners. The crossing to Australia was therefore probably delayed for many hundreds of millennia because it demanded a highly developed symbolic tradition capable of placing sufficient trust in the conscious judgement of signs to accept the risks involved in sailing to an unseen destination.

Theoretical considerations

The first seafarers can therefore be assumed to have been enticed by visual contact with the target shore, and this seems to have been an essential precondition for attempting maritime colonization until well into the Late Pleistocene. All of the known crossings that occurred prior to the first landfall of Australia met this precondition. The actual distances to be journeyed in each case are not readily known, because (a) the time the crossings first occurred is not known precisely, (b) the exact sea levels at these times remain speculative, (d) the elasticity of the Earth's crust and the processes of isostatic compensation is a variable which it is almost impossible to account for, and (d) the high incidence of tectonic adjustments in the general region of Indonesia throughout the late Tertiary and the entire Quaternary with its attendant frequent vulcanism would resist any simplistic modelling. It is much safer to speculate about sea distances by determining which large land eutherians had managed to cross the sea barrier in question. By far the best maritime colonizers are elephants, followed by hippos, whereas deer, tapirs and pigs only manage considerably shorter sea distances (particularly under adverse maritime conditions), even though they and other genera take to the water readily. Small species are not relevant here, their ability to raft on floating vegetation is well known (Diamond 1977).

Various species of proboscideans crossed to numerous of the islands of Wallacea (Hooijer 1957; Verhoeven 1958, 1964; Glover 1969; Groves 1976) and the Philippines (Koenigswald 1949), where they experienced speciation and dwarfism in many separate

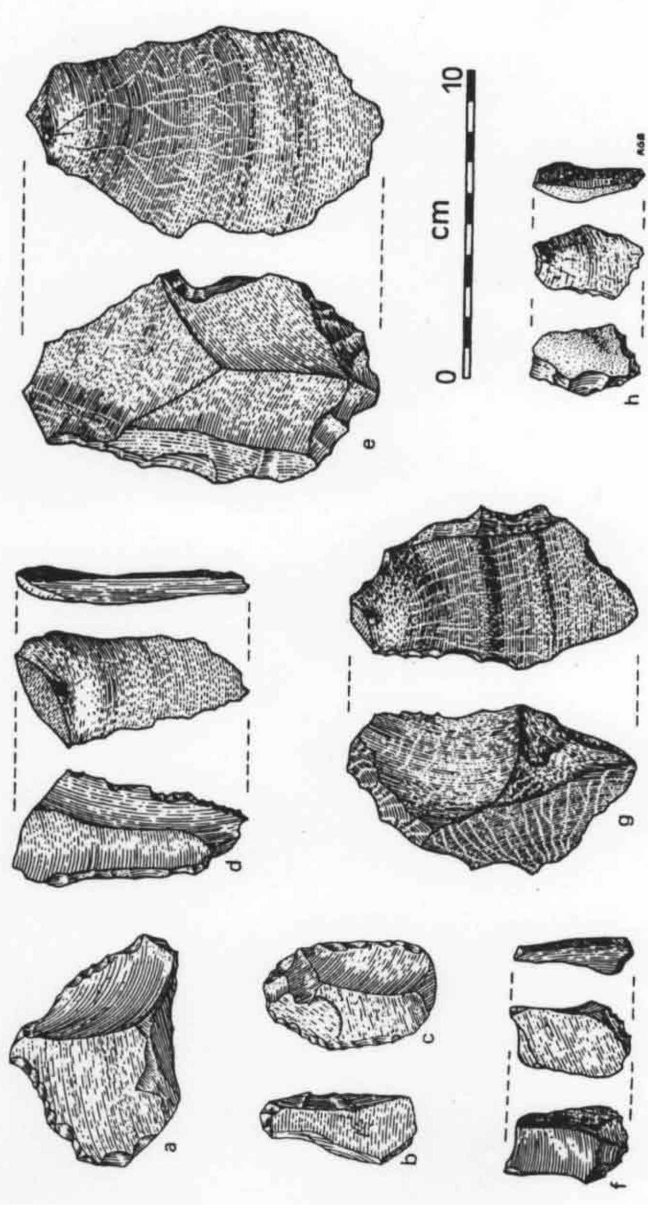

Figure 1. Stone tools of the final Early Pleistocene of the Soa Basin, central Flores, thought to be between 750,000 and 850,000 years old: Mata Menge (a-e, g) and Boa Leza (f, h).

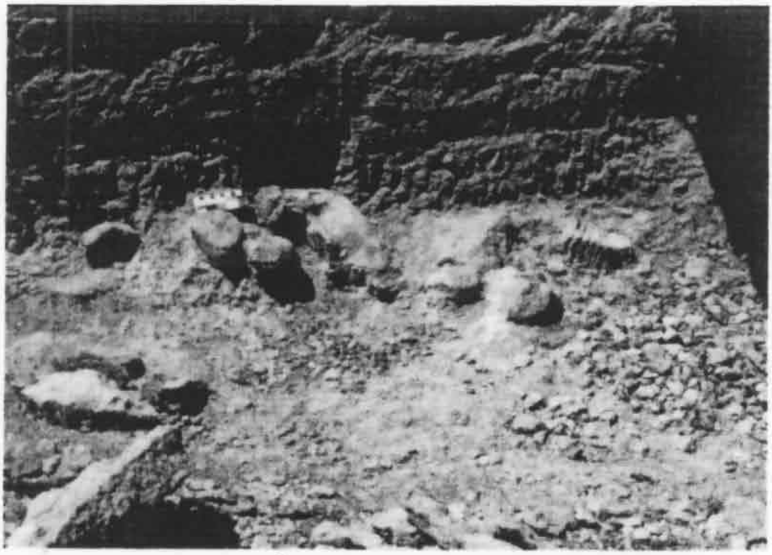

Figure 2. Excavation in solid sedimentary rock, Boa Leza, Flores, August 1998, showing Stegodont remains in situ. The chert tool in Fig. 1h was located to the right of the molar visible on the right.

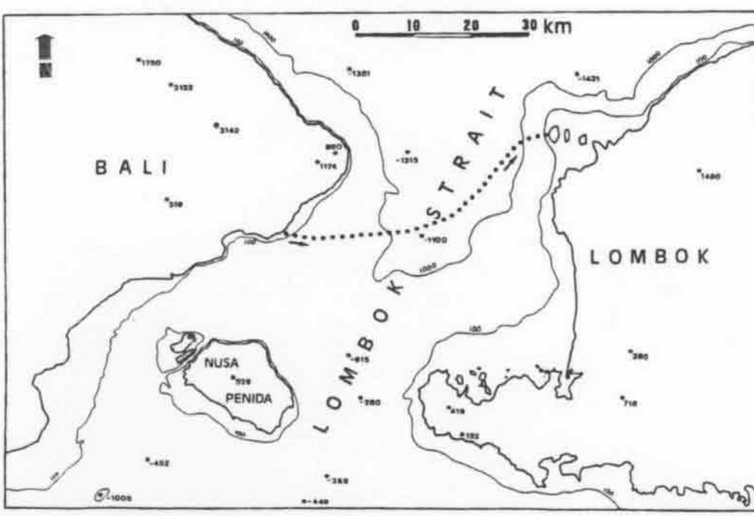

Figure 3. Map of Lombok Strait, Indonesia, indicating the course of the Nale Tasih 4 on 31 January 2000. The 100 m and 1000 isobaths are shown.

developments (Fig. 2). Elephants are superb long-distance swimmers, having been observed to swim for 48 hours in herd formation across African lakes (Bednarik & Kuckenburg 1999), and in one reported case swimming a distance of 48 km at sea and in another a speed of 2.7 km/h (Johnson 1980). There are frequent reports of elephants swimming to off-shore islands in India to feed. In swimming great distances, individuals may tow others to allow them to rest. Their buoyancy is helped by digestive gases in their intestines and their possession of trunks, while their habit of travelling as a herd would have facilitated the success of a founding population upon landfall.

All the other mammalian species mentioned, and many others capable of swimming in the sea, existed on the south-east Asian mainland during the Pleistocene, including on Java and Bali (Bednarik & Kuckenburg 1999), but none of them are known to have crossed Wallace's Line, the most important biogeographical barrier in the world. It is therefore unlikely that the distance between Bali and Lombok was ever less than 20 km, and it was quite probably at least 30 km at all times. Although the distance across Lombok Strait would be significantly shorter today by travelling via Nusa Penida (Fig. 3), especially at a sea level of up to about 150 metres below the present, both Bali and Lombok are being lifted due to their proximity to the subduction zone where the Asian and Australian plates have been colliding over the last several million years, a process that is still continuing. The highest point on Nusa Penida is only 529 m above the present sea level. Since the uplift over the past 800 ka almost certainly exceeded that much, we need to assume that the island, consisting entirely of recent coral limestone, probably did not exist at the time Lombok Strait was first traversed by hominids. This is supported by the complete absence of such animals as deer, tapir, hippo and pig on the islands of Nusa Tenggara (formerly the Lesser Sunda Islands).

In much the same fashion as we can use the absence or presence of certain species on deep-water islands to formulate tentative propositions about the former distances of sea to be crossed to reach them, we can also use the demonstrated capability of humans to cross sea barriers to estimate their technological capabilities at a given point in time. This premise rests primarily on one assumption: that a successful crossing occurred reasonably soon after the required cognitive or technological conditions had been acquired by the hominids in question. That this seems a reasonable line of argument is supported by the emerging pattern which suggests that the distances travelled increased gradually over time, as did the severity of other obstacles mastered. By about a million years BP we can assume that the use of navigation had emerged in the area of Java and Bali, probably to exploit off-shore fishing grounds. This led to the ability of crossing perhaps over 30 km of water with colonizing groups. By 840 ka BP at least three such sea barriers had been crossed and Flores had a no doubt large and well established population of *Homo erectus*. Perhaps around the same time or some time later, Acheulian mariners from north-western Africa managed to cross only between 10 and 14 km to Gibraltar, while the Indonesian sailors eventually conquered a distance of between 60 and 100 km, from Alor to Timor (Bednarik 1999a). Around 200 ka ago, the Acheulians of northern Africa are known to have crossed several kilometres on the huge inland lake then existing in western Libya (Werry & Kazenwadel 1999).

Much more development was required before humans were ready to cross to an unseen land, which involved an actual distance of around 200 km (the direct distance to the

Figure 4. Replicated Lower Palaeolithic stone tool and part of a wooden paddle made with it in January 2000.

Figure 5. The Nale Tasih 4 at the end of its journey, approaching the western coast of Lombok, Indonesia. The paddle in Fig. 4 is clearly visible.

continental shelf is not relevant, because crossing along the shortest route would have been impossible). This occurred much more recently, probably some time before 60 ka ago, at Australia. But by 30,000 ka BP, distances in excess of 100 km were crossed frequently, and often to quite small islands, even in both directions (Bednarik 1997a). By that time, seafaring would have still involved very high risks, but the settlement of around twenty islands that we know of (and no doubt others where we have yet to look) suggests that maritime navigation had reached the level of taking calculated risks. While it was now well developed in two world regions (Bednarik 1999b) and spreading to others, the most sophisticated tradition remained that of the region to the north of Australia, eventually extending further into the Pacific, and it probably remained the most developed maritime technology in the world until modern history.

On this basis I would like to distinguish four fundamental phases in the history of seafaring:

1. Coastal navigation, perhaps leading to increasingly audacious probing of off-shore waters (>850 ka).
2. Rare conscious decisions to cross to visible shores with a number of males and females providing adequate genetic diversity to succeed in establishing viable populations (850-60 ka).
3. Capability to sail towards an unseen but predicted large landmass with a colonizing party (60-35 ka).
4. The development of seafaring on the basis of detailed traditions of accumulated knowledge, from an increased incidence of 'blind' departures and controlled return journeys, developing to the habitual crossing of distances of hundreds of kilometres to exceedingly small targets (35 ka to historic times).

Next, we can rationalize about the level of maritime technology required for each of these steps. For phase 1, simple paddling and the use of currents would have sufficed, therefore we should expect small flotation equipment, increasing in size and constructional complexity gradually with time. Phase 2 required rafts of adequate carrying capacity to support the numbers of people needed, and of sufficient robustness to withstand the types of conditions found in places such as Lombok Strait, which are notoriously treacherous and difficult to cross. Nevertheless, there is no reason to assume that any significant steering ability was involved, crossings were more likely dependant upon favorable but unpredictable random currents, and the survival chances may have been very low. For phase 3, however, some rudimentary form of steering was essential in view of the strong prevailing currents found along continental shelves, which tend to force a vessel along the departure coast or out towards a major ocean. This may also help to explain the long time it took to pass from stage 2 to stage 3: steering would have almost certainly involved a greater reliance on wind-power, which means that there must have been an adequate sail area to render it effective. This does not necessarily have to be a proper sail, windsail area can be gained from any surface area offered to the wind: a bough or hut, some palm fronds, or indeed any object on the vessel reaching into the wind, including the bodies of the people standing on the raft. However, over such a long period of time of at least 800,000 years it seems likely that mariners would have not only felt the propelling effect of sail area, they would have also noticed eventually that a flat piece of material dragged behind the vessel could affect direction quite noticeably when the contraption was propelled by the wind. The utilization of this simple discovery might have led to the ability to navigate waters hitherto unsuitable, and to a progressive increase in maritime confidence.

This may have been one determinant that led to first landfall in Australia, but a second factor may have been more important. It concerns the semiotic competence of the people who first attempted this. It would appear that the decision to embark on this endeavour was based on the belief that there was a large landmass to the south-east of Timor — now the favored point of departure for the crossing to Australia. If this journey had been random or accidental, it would seem unlikely that there would have been a group of people, particularly one including a sufficient number of females, on the raft, and it would not have carried the supplies necessary for survival unless people were appropriately prepared. If signs of land had been observed by generation upon generation of off-shore fishermen, it needs to be asked to what degree such signs were perceived consciously and were communicated effectively enough to eventually convince the members of a group to face the immense risks of a one-way journey into profound uncertainty. In view of the great risks and the appallingly high probability of failure the great investment of labour, commitment and trust in the judgment of some individuals seems to imply a very high conscious reliance upon the individual interpretation of certain observations, such as smoke clouds on the horizon. Such a level of trust in mere signs implies a very high level of semiotic competence, i.e. the conscious estimation of the probability of the existence of a referent, suggested by the existence of an observed phenomenon, a referrer (such as smoke).

The First Mariners Project

It seems possible that the colonization of Australia became feasible because this advanced symboling competence and a correspondingly sophisticated communication system coincided with a growing ability to harness the energy of wind in an empirical fashion. Most certainly the first crossing of Lombok Strait, presumably the first sea crossing in human history, demanded considerably less sophistication, be it socially, cognitively or technologically. To establish the minimum level of technological sophistication required to succeed in this crossing, I decided in 1996 to conduct experiments with very primitive bamboo rafts in Lombok Strait, using only materials available to the Palaeolithic mariners.

These experiments were conducted over the following years as part of the First Mariners Project, a major series of replicative studies addressing the general question of Pleistocene navigation in a comprehensive fashion. First Mariners, a research program extending over at least six years, comprises archaeological field work in various world regions and replicative experimentation in Southeast Asia and the Mediterranean. At the time of writing this work has included the construction and testing of six sea-going rafts. Four of these were made from bamboo, and one each from cane and inflated animal skins. Two of these rafts were made entirely with chronologically relevant stone tool replicas, the remainder partly so. In all cases, each and every relevant work process was demonstrated and timed with stone tools, and the amount of experience so gained in material preparation, relevant material properties, and the recognition of microwear indices has been substantial. Moreover, as each raft is of different design and materials, and is built and sailed under very different conditions, the new knowledge already acquired in the technology and maritime mechanics of rafts is extensive. Some of the attempted sea crossings failed, others succeeded. Most importantly, the *Nale Tasih 2*, an 18 m bamboo raft of 2.8 tonnes succeeded in crossing from the southernmost tip of Timor to Australia in December 1998, taking 13 days to travel nearly 1000 km of open sea (Bednarik 1997a, 1999a; Bednarik et al. 1999). Part of this journey took place under sub-cyclonic conditions with 5 m waves, and what was learned about rafts under these extreme conditions is fundamental to our current knowledge of raft performance. The *Nale Tasih 2* was sailed deliberately under conditions of 'destructive testing', its rudder and upper yard were smashed, its palm-leaf sail torn to shreds, and all four forward guy ropes (made from rattan vines) snapped. Yet all repairs were carried out at sea with Middle Palaeolithic stone tool replicas by the crew of five men (the entire journey was made without a support vessel), and when the raft reached the Australian coast it was in much better ship-shape than when it had set out.

Combined with the material understanding gained from traditional artisans in Indonesia and Morocco this work led to the first attempt of crossing Lombok Strait with a small and very basic bamboo raft. The purpose of this part of the experiment series was not to demonstrate how the presumed first sea crossing was made, but to gain an understanding of the minimum technological requirements to succeed in traversing a rather capricious stretch of sea that is still feared by local fishermen. Lombok Strait is renowned for its localized strong currents, 'overfalls' (tidal, surf-like walls of water) and whirlpools, and while the target land, the west coast of Lombok, is clearly visible throughout the journey, reaching it without steering or wind power is a precarious endeavour.

The choice of bamboo as the preferred flotation agent has been determined not only by experience (it is a superior material for rafts), but also by the observation that seafaring seems to have begun in Southeast Asia, with its hundreds of bamboo species. This does not seem to be pure coincidence. Together with the occurrence of numerous other utilizable plant species (for fibres, vines, resins and food) in the region's vast forests, this wealth of a ready-made suitable and easily workable flotation material was quite probably crucial in facilitating the advent of maritime navigation in this region. Moreover, my experiments with alternative materials have conclusively shown the superiority of bamboo in raft construction, for a variety of reasons. Nevertheless, care must be taken in its use, in avoiding infestation by the ubiquitous bamboo beetle, and in protecting the bamboo from cracking in the full sun during the curing process of about five or six months. In understanding the cognitive and intellectual capabilities of the original raft builders it is important to appreciate that bamboo can be effectively worked with stone tools only in its green, freshly felled state, but it can be used for flotation only after careful drying for several months. In other words, the construction of a raft of sea-going dimensions, large enough to carry the minimum number of male and female passengers required to succeed in founding a new population, seems to presuppose the capacity of long-term planning, of focussed foresight, in addition to the presumed ability to communicate abstract intentions. While this is in principle fairly self-evident, it must be emphasized that the planning is not limited to the actual construction period, which from our experiments we know to be only a few weeks, but of necessity extends to the much earlier felling of the bamboo floaters. To a lesser extent the curing factor also applies to potential materials like wood, but if we favour the use of bamboo we must also accept the need for planning to have commenced up to six months before departure.

Crossing Lombok Strait

The First Mariners Project launched its initial attempt to cross from Bali to Lombok on a primitive raft in early 1999, soon after the successful journey of *Nale Tasih 2*. In March, an 11.4 m long bamboo raft was constructed by six local boat builders on a beach at Padangbai, using only natural binding materials (split *rattan*, a vine, and *gemuti*, a palm fibre). Oars were fashioned with stone tools from a local softwood (*bulalu*), and the thwart timbers from a hardwood species (*canari*). The vessel was equipped with a sunroof of woven palm leaves supported by a frame, and capable of being manipulated at sea so as to catch any available westerly breeze. Two days after the *Nale Tasih 3* was launched on 23 March, it was towed along the Balinese coast to Pula Giliselang, at the easternmost point of the island. From there we set out to reach the west coast of Lombok, a little over 35 km away, propelled by six oarsmen. The vessel made excellent progress east initially, peaking at 3.2 knots, but as it entered the deepwater channel, over 1300 m deep here, its northward drift in a strong current proved irresistible. Every effort was made to row against the current, but after about six hours it became evident that we would inevitably miss the northwestern corner of Lombok. The attempt was abandoned under appalling weather conditions, about 15 km from the nearest Lombok coast.

At our base in Padangbai some of the materials of *Nale Tasih 3* were salvaged for the next experiment. It was planned to construct a very similar vessel, a simple bamboo platform lacking any provision for steering or for a sail, thus reducing the design to the realistically simplest possible form. Six thwart timbers were to tie together horizontally arranged, tightly packed bamboo stalks, and the raft was to be propelled by twelve paddlers. Fully cured Balinese bamboo can carry a payload of 104-108% of its own weight before it becomes submerged, therefore the weight of the crew, 900-1000 kg, demanded a raft mass of just over a tonne. This translated into twenty-nine stalks of bamboo of up to 12 m length to keep the vessel just barely afloat, i.e. to secure the most favorable ratio of mass to buoyancy. Based on our previous experience, the maximal width of 309 cm at the helm demanded that the floaters be tightly packed, twenty in the upper layer. The finished vessel weighted about 1080 kg, was 12.0 m long and took about 70 man days to construct. This work was commenced on 16 January 2000 and included the production of paddles.

The preferred material for lashings was split *rattan* (*Calamus* sp.), although hand-made *gemuti* cordage was used for non-crucial fastenings. *Rattan* lashings were made by stripping the vines with stone flakes, and other stone tools were used throughout construction. Bamboo stalks, felled earlier with large hand-held stone choppers, were chopped through in 3-6 minutes by an experienced operator. The paddles, measuring from 126 to 154 cm (mean 144 cm), were fashioned from fairly green *akasia* (*Acacia* sp.) wood, using steep-angled thick planes and flake spokeshaves. It was found to take about three days to make one paddle out of a rough plank, and only two of the paddles were made entirely with stone implements, the remainder were roughly shaped with steel *parangs* and then given a stone tool finish. All stone artefacts used in the Bali experiments were replicas of typical Lower Palaeolithic lithics (of Southeast Asia and Flores) made from dark-grey to black sedimentary silica. The tools that have been subjected to the most extensive wear (i.e. that were used for several days in a specific work process) have undergone detailed micro-wear analysis. This applies not only to the tools used in woodworking, but also to those for felling of or chopping through green bamboo, cutting fibrous material or coconut palm leaves, and for stripping rattan, a skilled and particularly laborious process (for details on wooden implements of the Lower Palaeolithic, see Bednarik 1999c).

Very early on 31 January, the *Nale Tasih 4* was towed from Padangbai to the prominent tiny rock islet Pula Gilibiaha, near Bugbug, south of Amlapura. Twelve carefully chosen paddlers boarded the raft just off-shore and at 0625 hours commenced the marathon effort of paddling continuously all day. Initial progress was superb, with a consistent speed above 3 knots, peaking at 4.2 knots, and maintaining the planned eastern course well. However, once the depth excéeded 1000 m, the raft entered waters of choppy condition and waves of 1.5 m, with a distinct current. The current's strength increased and at times the vessel remained essentially stationary, despite enthusiastic efforts by the crew to overcome it. Shortly before noon, one of the Balinese paddlers collapsed unconsciously, and had to be transferred to the support ship and replaced. Much of the afternoon was spent progressing only minimally, and the northerly drift became impossible to counter, threatening failure of this attempt only about 7 km from Pula Trewangan, the nearest of the Gillies. However, shortly before the 1000 m isobath was reached, the southwestern wind turned to a westerly, and at the same time seas and current subsided, permitting a correction of the course and offering the chance to reach the now clearly visible coast. A final effort by the crew led to landfall on the western coast of Pula Trewangan at 1812 hours. The crew, several of whom had experienced episodes of severe fatigue but managed to overcome them, had paddled continuously and strenuously for almost twelve hours, covering a distance of just under 51 km. If we had rested even for minutes we would have probably failed to reach sheltered waters and drifted out to the Bali Sea. This crossing attempt did succeed — but only just.

Conclusions

These experiences lead me to suggest that crossing the Lombok Strait on an archaic raft was probably always a gamble, because it seems impossible to predict whether the currents would force a raft north or south, irrespective of the chosen point of departure. This would not appear to have been significantly different in the distant past. The success of a crossing attempt inevitably involved fortuitous conditions, and it is to be assumed that a number of Palaeolithic expeditions perished while trying to cross from Bali to Lombok. The fact that at least one group of *Homo erectus*, whose descendants eventually peopled first Flores and later Timor, did succeed tells us something about the determination and maritime competence of these people.

Despite predictions that it would not be possible to cross Lombok Strait on a primitive raft, and that perhaps Flores was colonized from Sulawesi instead, we have shown that with determination and some luck the crossing is perfectly possible on a very basic raft, consisting of nothing but a horizontal platform propelled by paddles shaped with stone tools. Naturally this does not prove that Wallacea was settled from Bali, but since Bali was the region's easternmost extension of the Asian mainland and since Flores was not visible from the south coast of Sulawesi I strongly favour Lombok Strait as the site of the first maritime crossing by a successful colonizing party. Moreover, there is no clear-cut evidence of a Lower or Middle Pleistocene human occupation of Sulawesi available (all available archaic stone tools are undated), while Java is well known to have been occupied by *Homo erectus*, perhaps since the beginning of the Pleistocene (Swisher et al. 1994). The time of this assumed first crossing of Lombok Strait remains unknown, but on the basis of the solid dating evidence from several sites of the Soa Basin of Flores as well as the geological stratification of the human occupation remains there (Bednarik & Kuckenburg 1999) it must have occurred during Lower Pleistocene times, more than 850,000 years ago.

The implications of this, and indeed of all Pleistocene seafaring evidence, are massive for Pleistocene archaeology and for palaeoanthropology. Most particularly, this evidence demands a virtual re-writing of our assumptions about the cognitive, technological, social and perhaps intellectual capabilities of hominids. The replicative studies currently in progress permit a unique appreciation of the maritime navigation exploits of *Homo erectus*, by demonstrating that such achievements were not just a matter of certain minimum technological capacities, but they must have involved long-term planning and they required social structures of some complexity, in addition to reflective communication capable of conveying abstract concepts. Clearly this model involves a cultural sophistication that is at odds with the capacities the until now dominant paradigm has conceded to these hominids. It is, however, in complete agreement with other evidence concerning the cognitive capabilities of Lower Palaeolithic humans, which includes the use of pigment materials, the collection of crystals and fossils, the production of beads and pendants, and of portable engravings and simple forms of rock art (Bednarik 1997d). If we add to this certain technological capabilities, such as the production of hunting spears, composite tools, shelters and the use of cordage, a radically new picture of the Lower Palaeolithic emerges, which is much more relevant to the earliest seafaring evidence than the traditional model. Indeed, by comparing the extraordinary achievement of these first mariners with those of present-day space travel, the parallels become immediately obvious. In both cases we are dealing with cutting-edge technology, which we do not necessarily find reflected in the general domestic evidence. Hence seafaring provides a much more reliable measure of the maximum technological and cognitive capabilities of humans at a given time than do the contents of refuse deposits, our usual sources of archaeological information.

However, there is another factor involved in what appears to have been a misinterpretation of the Pleistocene archaeological record. It is the implicit assumption that archaeological samples, of whatever kinds of variables, are valid random samples. They are almost never so, and according to taphonomic logic (Bednarik 1994) they are not just systematically distorted, the distortion increases linearly with age. For instance, taphonomy ensures that, due to the eustatic oscillations, no evidence of any coastal population can survive from the entire Pleistocene. Moreover, orthodox archaeology treats the '*taphonomic threshold*' as the earliest historical occurrence of the phenomenon the material finds are thought to represent. This is an error of logic, and as a consequence all archaeological pronouncements about human history in the Pleistocene, particularly the Early and Middle Pleistocene, need to be reviewed. Therefore evidence such as that of early maritime navigation, or, for instance, the early use of sophisticated wooden implements, does not indicate a 'running ahead of time', as some archaeologists have proposed (Vishnyatsky 1994), but such evidence is in fact from the *taphonomic lag time* of the evidence class in question. The spatial and chronological occurrence of finds from their lag period is almost irrelevant to the explanation of the phenomenon the evidence is thought to relate to, and their quantity is totally irrelevant in that context.

References

Bednarik R.G., 1994. *A taphonomy of palaeoart*. Antiquity, 68: 68-74.

Bednarik R.G., 1997a. *The origins of navigation and language*. The Artefact, 20: 16-56.

Bednarik R.G., 1997b. *The earliest evidence of ocean navigation*. International Journal of Nautical Archaeology, 26: 183-191.

Bednarik R.G., 1997c. *The initial peopling of Wallacea and Sahul*. Anthropos, 92: 355-367.

Bednarik R.G., 1997d. *The global evidence of early human symboling behaviour*. Human Evolution, 12(3): 147-168.

Bednarik R.G., 1998. *An experiment in Pleistocene seafaring*. International Journal of Nautical Archaeology, 27(2): 138-149.

Bednarik R.G., 1999a. *Maritime navigation in the Lower and Middle Palaeolithic*. Comptes Rendus de l'Académie des Sciences Paris, 328: 559-563.

Bednarik R.G., 1999b. *Pleistocene seafaring in the Mediterranean*. Anthropologie, 37(3): 275-282.

Bednarik R.G., 1999c. *Determining the maximum capability of Palaeolithic technologies*. Praehistoria Thuringica, 3: 80-97.

Bednarik R.G., Hobman B. & Rogers P., 1999. *Nale Tasih 2: journey of a Middle Palaeolithic raft*. International Journal of Nautical Archaeology, 28(1): 25-33.

Bednarik R.G. & Kuckenburg M., 1999. Nale Tasih: Eine Floßfahrt in die Steinzeit. Thorbecke, Stuttgart.

Bini C., Martini F., Pitzalis G. & Ulzega A., 1993. Sa Coa de Sa Multa e Sa Pedrosa Pantallinu: due 'Paleosuperfici' clactoniane in Sardegna. Atti della XXX Riunione Scientifica, 'Paleosuperfici del Pleistocene e del primo Olicene in Italia, Processi si Formazione e Interpretazione', Venosa ed Isernia, 26-29 ottobre 1991, pp.179-197. Istituto Italiano di Preistoria e Protostoria, Firenze.

Diamond J.M., 1977. Distributional strategies. In (J. Allen, J. Golson and R. Jones, eds.), Sunda and Sahul: prehistoric studies in South-East Asia, Melanesia and Australia, pp.295-316. Academic Press, London.

Glover I.C., 1969. *Radiocarbon dates from Portuguese Timor*. Archaeology and Physical Anthropology in Oceania, 4: 107-112.

Groves C.P., 1976. *The origin of the mammalian flora of Sulawesi (Celebes)*. Zeitschrift für Säugetierkunde, 41: 201-216.

Hooijer D.A., 1957. *A stegodon from Flores*. Treubia, 24: 119-129.

Johnson D. L., 1980. *Problems in the land vertebrate zoogeography of certain islands and the swimming powers of elephants*. Journal of Biogeography, 7: 383-398.

Koenigswald G.H.R. von, 1949. Vertebrate stratigraphy. In (R.W. van Bemmelen, ed.), The geology of Indonesia, pp.91-93. Government Printing Office, The Hague.

Koenigswald G.H.R. von & Gosh A.K., 1973. *Stone implements from the Trinil Beds of Sangiran, central Java*. Koninklijk Nederlands Akademie van Wetenschappen, Proc. Ser. B, 76(1): 1-34.

Maringer J. & Verhoeven T., 1970a. *Die Steinartefakte aus der Stegodon-Fossilschicht von Mengeruda auf Flores, Indonesien*. Anthropos, 65: 229-247.

Martini F., 1992. Early human settlements in Sardinia: the Palaeolithic industries. In (R.H. Tykot and T.K. Andrews, eds.), Sardinia in the Mediterranean: a footprint in the sea. Studies in Sardinian archaeology presented to Miriam S. Balmuth, pp.40-48. Monographs in Mediterranean Archaeology, Sheffield Academic Press, Sheffield.

Morwood M.J., O'Sullivan P.B., Aziz F. & Raza A., 1998. *Fission-track ages of stone tools and fossils on the east Indonesian island of Flores*. Nature, 392: 173-179.

Morwood M.J., Aziz F., Nasruddin, Hobbs D.R., O'Sullivan P. & Raza A., 1999. *Archaeological and palaeontological research in central Flores, east Indonesia: results of fieldwork, 1997-98*. Antiquity, 73: 273-286.

Sondaar P.Y., van den Bergh G.D., Mubroto B., Aziz F., de Vos J. & Batu U.L., 1994. *Middle Pleistocene faunal turnover and colonization of Flores (Indonesia) by Homo erectus*. Comptes Rendus de l'Académie des Sciences Paris, 319: 1255-1262.

Sondaar P.Y., Elburg R., Klein Hofmeijer G., Martini F., Sanges M., Spaan A. & de Visser H., 1995. *The human colonization of Sardinia: a Late-Pleistocene human fossil from Corbeddu Cave*. Comptes Rendus de l'Académie des Sciences Paris, 320: 145-50.

Swisher C.C., Curtis G.H., Jacob T., Getty A.G., Suprijo A. & Widiasmoro, 1994. *The age of the earliest hominids in Indonesia*. Science, 263: 1118-1121.

Thorne A., Grün R., Mortimer G., Spooner N.A., Simpson J.J., McCulloch M., Taylor L., Curnoe D., 1999. *Australia's oldest human remains: age of the Lake Mungo 3 skeleton*. Journal of Human Evolution, 36: 591-612.

Verhoeven T., 1958. *Pleistozäne Funde in Flores*. Anthropos, 53: 264-265.

Verhoeven T., 1964. *Stegodon-Fossilien auf der Insel Timor*. Anthropos, 59: 634.

Verhoeven T., 1968. Vorgeschichtliche Forschungen auf Flores, Timor und Sumba. In Anthropica: Gedenkschrift zum 100. Geburtstag von P.W. Schmidt, , pp.393-403. Studia Instituti Anthropos No. 21, St. Augustin.

Vishnyatsky L.B., 1994. *'Running ahead of time' in the development of Palaeolithic industries*. Antiquity, 68: 134-140

Werry E., & Kazenwadel B., 1999. *Garten Eden in der Sahara*. Bild der Wissenschaft 4/1999: 18-23.

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