A 3000 YEAR OLD DOG BURIAL
in Timor-Leste

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Abstract

The domestic dog (*Canis familiaris*) is considered to be the oldest domesticated animal in the world. It arrived in Island Southeast Asia and Australia-New Guinea relatively late in the Holocene, though the timing and means of its dispersal remain unclear. We report a dog burial from Timor-Leste dated to ~3000 cal. BP. Morphometric analysis demonstrates strong affinities between this individual and contemporary domestic dog groups, and particularly with the 'village dog' type, indicating it was indeed domesticated, rather than feral-wild. Isotope values which indicate a diet dominated by terrestrial plant foods rather than hunted foods suggest an association between the Timor dog and agriculturalists. Results suggest that the range expansion of *C. familiaris* in the Indo-Pacific is associated with the dispersal of farming groups in prehistory.

Introduction

Two points stand out in a review of the scanty record of early archaeological dog remains in the Indo-Pacific. First, the earliest dates for the dog in mainland Asia and Island Southeast Asia suggest that the animal spread mainly with the expansion of farming groups, although Oskarsson et al. (2011:1400) suggested that 'dogs may have been present in Island Southeast Asia before the arrival of the Neolithic'. Second, the oldest domesticated dog remains already display substantial inter- and intrasite morphological variation, in part from different environmental conditions, but probably more important were the particular relationships between dogs and different prehistoric human societies in the region. A closer association between dogs and people has been argued to be characteristic of the 'village dog' type (Medway 1977) in contrast to the more informal association between people and the 'large pariah' type, and a recent review of skeletal data suggests that the village dog evolved concurrently with the spread of Neolithic farming communities in tropical Asia and Africa (Gonzalez 2012). In this paper, we describe an early dog burial from Timor-Leste dating to ~3000 cal. BP, and report ancient DNA, isotopic and morphometric analyses. Results indicate a gracile dog aged three to four years of age that likely belonged to an agricultural community. The dog appears to have been well-cared for during its life, and was possibly used as a hunting aid/watch dog.

Background

Genetic evidence suggests the domestic dog (*Canis familiaris*) originated in Southeast Asia, south of the Yangtze River, less than 16,000 years ago, with numerous archaeological dog remains present in many parts of the world 10,000 years ago, including in north China (Jing 2008; Klütsch and Savolainen 2011; Pang et al. 2009). On archaeological evidence the arrival of the dog south of China appears to be relatively late, with the oldest dog remains dating to 4200–3500 BP in peninsular Southeast Asia, though an earlier introduction is possible from the presence of dog associated with the Tapenkeng culture in Taiwan 5000–4500 BP (Larson et al. 2012; Tsang 2005). In the Philippines and Batanes, dog is dated to ~2500 BP, although a single tooth in a layer from the Uattamdi site on Kayoa Island dating to 3500 BP suggests it may be older in the Moluccas (Bellwood 1998). In New Guinea the dog has an age of 2500–2350 BP (Bulmer 2001; McNiven et al. 2012); however, a recent study of the paternal ancestry of the dingo indicates it is exclusively derived from New Guinea dogs, suggesting that the dog was introduced to Australia-New Guinea 4000–3000 years ago and became wild-feral in Australia and feral-domesticated in New Guinea (Ardalan et al. 2012; Letnic et al. 2012).

The chronology of dog dispersal in Island Southeast Asia and the Pacific has been argued to be congruent with an early phase of Neolithic expansion (Bellwood 1998), but current archaeological data suggests the dog could have arrived on some Pacific islands later in the Neolithic (Addison and Matisoo-Smith 2010; Anderson 2009). In Island Southeast Asia the timing of the dispersal of dogs, as for other domesticates, has yet to be established by direct dating of dog remains (e.g. O'Connor et al. 2011). Nonetheless, it seems clear that the distribution of the domestic dog and feral/wild forms dramatically expanded as a result of Neolithic population movements in Island Southeast Asia and the west Pacific.

A detailed study of bones recovered from the Ban Chiang site in Thailand, dated to ~3200–3000 BP (Higham et al. 2011), and related excavations, identified two types of dog (Higham et al. 1980). One was a smaller type with an estimated body weight of 8.5 kg and the other was larger, with a carnassial length within the range of the Australian dingo (18.8–20.6 mm). The estimated body weight of the larger type was 12–20 kg, which suggests a dog similar in size to the dingo-type large pariah; this form is still present in parts of South Asia, Southeast Asia and the Middle East and is recognised by a medium body size, well-proportioned ribcage, relatively long back, long legs and a head with a 'pear-shaped' outline when viewed from above (Gonzalez 2012).

The morphology of the Ban Chiang specimens is similar to that of recent South Asia and Southeast Asia pariah populations, which Gonzalez (2012) divided into four types (dingo, sight hound, broad head dog and village dog). Measurements of dog remains from Neolithic levels in Niah Cave in Borneo indicate these animals had a body size smaller than the average village dog (Clutton-Brock 1959; Medway 1959). Further west, in east Java, Storm (2001) examined an incomplete skull from Hoekgrott Cave, which could represent either a large village dog, or a smaller dingo-type pariah; this specimen was tentatively dated to

2655±60 BP. In Timor, dog remains from Uai Bobo 1 (1400 BP) and Bui Ceri Uato (0–2500 BP) were described by Gollan (1982) as representing two types, one similar to the village dog, and the other larger and more dingo-like.

Matja Kuru 2 Excavation

In the east of Timor-Leste, adjacent to Lake Ira Laloro (~334 m asl), are two caves in uplifted limestone known as Matja Kuru 1 (MK1) and Matja Kura 2 (MK2). These are located approximately 9 km from the current coastline, with entrances facing south over the large freshwater lake (Figure 1). MK2 is one of several sites excavated locally which contain marine resources dating to the Pleistocene (Spriggs et al. 2003). A 1 x 1 m test pit yielded well-preserved faunal remains throughout the sequence, including abundant remains of giant rats, reptiles and freshwater turtles, from layers dating to ~36,000–30,000 cal. BP. Evidence for use of the coastal environment includes a broad range of marine shellfish, fish and turtle, which are most abundant in the earliest occupation phase. The earliest date obtained was ~36,000 cal. BP on marine shell from Spit 47, though bedrock was not reached during excavation and it is likely that older occupation deposits are present. Dates from higher in the sequence cluster into two periods: 13,000–9500 cal. BP and >3500 cal. BP. It thus appears that the deposit accumulated episodically, with an early occupation phase prior to 30,000 years ago, followed by a second occupation phase in the terminal Pleistocene-early Holocene, and a final phase in the mid- to late Holocene. MK2 currently has no evidence for human use between ~30,000 BP and 13,000 BP, the time coinciding with the Last Glacial Maximum (O'Connor and Aplin 2007; Veth et al. 2005).

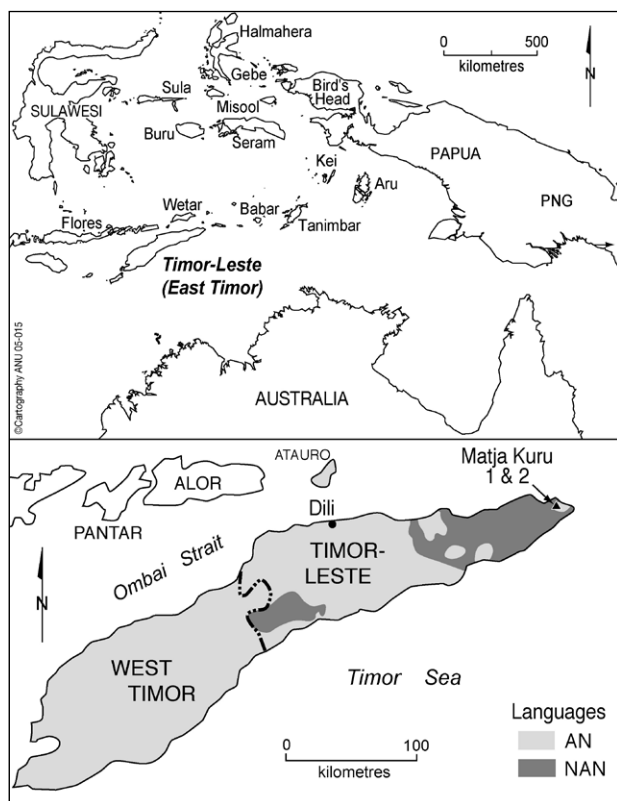During excavation a dog skeleton was found in Spits 26–25

Figure 1 Map of Timor-Leste (East Timor) showing the location of the Matja Kuru 2 (MK2) cave and other archaeological sites of relevance.

of MK2, with these remains appearing to have been interred in a pit dug from overlying levels. Pottery was present in small quantities in Spits 19–12, with most ceramics occurring in Spits 11–8. Two pot sherds in Spits 26–25 were found with the dog bone, indicating displacement of pottery from ceramic levels during digging of the burial pit.

AMS and Isotopic Results

Two samples from the dog bones were prepared at the Waikato Radiocarbon Laboratory, with AMS determinations run at the Rafter Radiocarbon Laboratory on graphite targets processed by the reduction of CO_2 with Zn in a reaction catalysed by iron powder at a temperature of ~575ºC. The first age determination was made on bone (L. humerus distal+midshaft) gelatin in 2003 and gave a conventional radiocarbon age (CRA) of 2967±58 BP (Wk-10051). However, the C:N ratio was 3.87 (carbon% 39.4, nitrogen% 11.87), indicating potentially poor sample quality. A new sample of ultrafiltered gelatin (L. femur prox+midshaft) was analysed in 2012 and produced a slightly younger CRA of 2867±26 BP (Wk-34931). The C:N ratio of 3.34 indicates good bone preservation (cf. Ambrose and Norr 1993:404; van Klinken 1999) and the sample produced an age of 2921–3075 cal. BP (Calib 6.1.0, two sigma, p=0.95).

[13]C and/or ^{15}N isotopic values from bone protein are regularly used as quantitative measures of different dietary protein sources for humans and animals (Allen and Craig 2009; Field et al. 2009; Richards et al. 2009; Valentin et al. 2010). Carbon isotopes are generally considered to have a linear relationship between marine and terrestrial food sources. Stable nitrogen isotopes indicate the trophic level of an organism and have been used to determine the amounts of animal versus plant protein (Schoeninger and DeNiro 1984).

On Nukuoro Atoll, Davidson (1992) dated two dog bones which had ^{13}C values of -15.4 and -12.5, suggesting a significant marine component in their diets. Two prehistoric dogs from New Zealand with values of ^{13}C values of -17.6 and -17.1 and ^{15}N values of 11.3 and 14.3 also consumed some marine foods (Leach et al. 2001:50). In contrast, Santa Rosa Island dogs of the late Holocene Chumash people, who relied exclusively on hunting and gathering wild foods (Rick et al. 2011), subsisted almost entirely on marine resources (^{13}C mean -1.5±0.8‰ and ^{15}N mean 17.9±0.5‰).

The Timor dog has a ^{13}C value of -19.47 and a ^{15}N value of 9.70 (Wk-34931), which suggests a terrestrial diet similar to that of Pacific pigs, but having less marine food compared to some dogs from the Cook Islands and Marquesas, which also appear to show a difference in the trophic level of marine foods consumed (Figure 2).

Ancient DNA Extraction

Several attempts were made to extract aDNA from the Timor dog remains. Both teeth (incisor, M[1]) and bone samples (rib fragment) were processed but, while in relatively good condition macroscopically, none were well-preserved with respect to aDNA. After multiple attempts using the bone and tooth samples we amplified a very small fragment of the mitochondrial d-loop, spanning approximately 84 base pairs from site 15536–15628 (based on complete mtDNA genome reported in Bjornerfeldt et al 2006). Over this very short region the Timor dog sequence
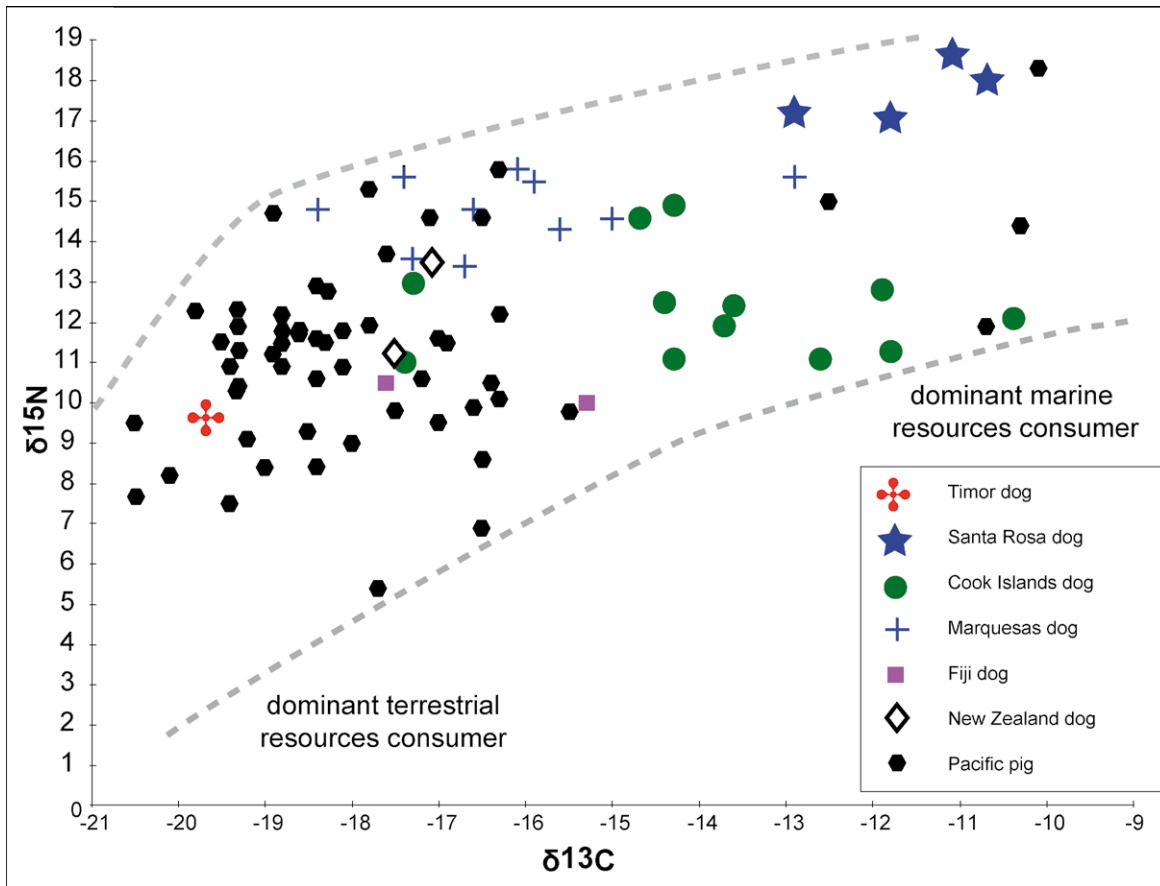
Figure 2 Comparison of Timor dog δ¹³C and/or δ¹⁵N isotopic values with those of prehistoric dogs in the Cook Islands (Craig 2009), Marquesas (West 2007), New Zealand (Leach et al. 2001) and Fiji (Jones and Quinn 2009; Valentin et al. 2006). Isotopic values from Santa Rosa dogs are from Rick et al. (2011). Pacific pig isotopic values are derived from Allen and Craig (2009), Beavan-Athfield et al. (2008), Field et al. (2009) and West (2007).

is identical to those of Asian and Asian-derived breeds. Further analyses will focus on the 100 base pairs following site 15628 to determine whether the Timor dog has the point mutations found in dingoes and New Guinea singing dogs (Savolainen et al. 2004).

Osteological Description

The dog burial comprised 125 bone fragments, representing 92 skeletal elements. The bone was well preserved with little sign of weathering, staining, trampling, burning or gnawing. There is a high incidence of incipient breakage lines that have not developed into cracks; these likely represent the combined effects of the weight of sedimentary overburden and natural decay. The most commonly observed taphonomic feature was recent bone fragmentation which probably occurred post-excavation during transport of the MK2 assemblage to Australia. No cut marks, indicating removal of meat or skinning, were observed on any bones, and the element representation is consistent with the deliberate burial of a complete dog.

Age and physical condition of the dog were evaluated using data related to epiphysial fusion, tooth eruption, pulp cavity size and limb bone thickness. The pulp cavity of the canine was assessed against previously published criteria (Kershaw et al. 2005; Knowlton and Whittemore 2001), and indicates an individual of three to four years of age. Tooth wear was, however, minimal, with dentition presenting well-defined cusps, perhaps reflecting a non-abrasive diet. The specimen was male, based on the presence of a complete os penis. Muscle attachments

on the limb bones and the occipital region were deep and well-developed. A degree of pathological development was detected on some lumbar vertebrae, with slight deformation of the spinous processes. Such anomalies can be caused by early extensive muscular growth or by repetitive pack carrying/pulling. The only other anomaly was a supernumerary nutrient foramen in the left tibia. Cause of death was not evident, and the overall condition of the skeleton suggests a well fed and healthy animal. In summary, the skeletal data indicates that the Timor dog was an adult male that lived for three to four years, in which time the animal did not experience severe nutritional shortages; there is no skeletal evidence for severe trauma or disease.

We have attempted to reconstruct the size and weight of the Timor dog using formulas developed by Anderson et al. (1985), Clark (1997), Hamblin (1984) and Wing (1978), which are based on measurements of length and diameter of limb bones, atlas and mandible. We also examined the degree of teeth crowding, which can help to identify wild from domesticated canids, following Davis and Valla (1978; but see Ovodov et al. 2011). Results suggest the Timor canine was a small to medium-sized dog with a body weight of 8–10 kg and a shoulder height of 39 cm (Table 1). In comparison with modern breeds, it is similar in height to a basenji, but the low body weight reflects a more gracile animal as suggested by the narrow diameter of limb bone mid-shafts. The value of the dental overlap index is 0.67, which indicates a slight degree of teeth crowding within the domesticated range.

Height Estimation, after Harcourt (1974)	Estimate
Tibia: (2.92xGL 131.37)+9.41/10	393.0 mm
Humerus: (3.43xGL 122.49)-26.54/10*	394.0 mm
Weight Estimation (kg)	
0.35√(femur circumference/1.5), after Anderson et al. (1985)	7.7 kg
Log body W= 2.1122 (log mandible H)+1.2722, after Hamblin (1984)	9.4 kg
Log body W= 2.2574 (log mandible H)+1.1164, after Wing (1978)	10.1 kg
Overlapping Index, after Davis and Valla (1978)	
Crown length of LM1/alveolar length from LPM4 to LM1	0.67

Table 1 Timor dog height and weight estimates. Key: GL = greatest length; W = weight; H = height; LPM4 = lower 1st premolar; LM1 = lower 1st molar; * = based on humerus GL= (atlas GL 29.32 x 4.57)-11.5, after Clark (1997).

Measurement	Number	Timor Dog (MK2)	New Britain Dog (NBD)	Australian Dingo	New Zealand Dog (Kuri)
Greatest length (radius)	1	119.7	121.6	178.1	114.5
Greatest breadth of the proximal end (radius)	2	14.6	13.1	17.6	16.1
Smallest breadth of diaphysis (radius)	3	9.3	9.4	14.5	11.5
Breadth of the glenoid cavity	4	13.4	12.5	19.0	13.8
Length of the glenoid cavity	5	20.0	19.2	26.0	22.7
Greatest length (ulna)	6	139.7	143.1	207.4	134.5
Smallest depth of the oleocranon	7	16.1	16.5	22.8	17.6
Depth across the processus anconaeus	8	18.1	17.9	25.8	21.9
Greatest diameter of the auditory bulla	9	18.8	20.4	25.8	18.6
UPM4 length	10	16.3	16.8	18.7	14.3
UPM4 breadth	11	6.3	6.2	7.3	8.3
UM1 length	12	11.2	10.4	12.2	9.0
UM1 breadth	13	15.1	14.1	15.3	11.7
Length of the upper molar row	14	16.6	16.9	18.7	16.5
Height of the mandible behind LM1	15	20.5	19.5	22.7	22.8
LM1 length	16	17.7	17.5	20.4	17.1
LM1 breadth	17	7.1	6.7	7.9	7.3
LM2 length	18	7.7	6.8	8.2	7.4
LM2 breadth	19	6.0	5.6	6.7	5.7
Length of the lower molar row	20	28.7	27.9	35.2	29.7
Smallest breadth of diaphysis (femur)	21	10.5	10.0	13.6	11.7
Greatest length (tibia)	22	131.3	132.4	190.4	128.3
Smallest breadth of the diaphysis (tibia)	23	8.5	9.8	13.4	11.3
Greatest breadth of the distal end (tibia)	24	17.4	16.7	23.4	18.3
Length of the acetabulum on the rim (pelvis)	25	16.2	16.9	20.9	18.6

Table 2 Measurements used in the log-based comparison shown in Figure 3. For a detailed description of these measurements see von den Driesch (1976). The total sample includes one specimen per group; all measurements are given in mm. Key: UPM4 = upper 4th premolar; UM1 = upper 1st molar; LM1 = lower 1st molar; LM2 = lower 2nd molar.

Morphometric Analysis

All measurements used in the comparative study of the Timor dog follow von den Driesch (1976), with the exception of the alveolar length from LP4 to LM1 which was initially described by Davis and Valla (1978). Measurements were collected by the lead author, except those of the prehistoric dog from New Zealand measured by Clark (1997). Measurements obtained are listed in Table 2. Owing to the scarcity of skeletal material from Indo-Pacific dogs we had to rely on a relatively low specimen number, particularly the comparison of the Timor dog with other village dogs. However, there is a large amount of published osteometric data available concerning the New Zealand dog (Clark 1997), the Australian dingo (especially cranial remains) and the Indian pariah dog. Admixture of the dingo material was assessed by a comparison of eight cranial measurements designed by Corbett (1995) to identify domestic dog-dingo hybrids and wild/feral domestic dogs from dingo remains.

The Australian dingo cranial sample consists of 28 individuals assessed as being dingo using Corbett's (1995) method. All specimens were recorded in public scientific centers and private collections. The sample includes individuals from different parts of the continent, with roughly equal numbers of males and females (as Gollan [1982] found that 68% of multivariate variation in dingo crania was due to sexual dimorphism).

The island New Guinea dog sample comprises two individuals collected in the 1960s from villages in West New Britain and now located in the Archaeozoology Laboratory in the Department of Archaeology and Natural History at ANU.

Prehistoric dogs from New Zealand (Clark 1997) were included, with the number of measurements varying from element to element. There were 117 measurements for the length of the molar row and 22 for the greatest diameter of the auditory bulla.

Measurements from 88 crania and 50 mandibles of Indian pariah dogs were collected at public organisations/institutions in India, the USA and the UK by the lead author.

Available data suggest the existence of four basic types of early dog in Southeast Asia and Melanesia: 1) the large pariah; 2) the tengger of eastern Java, which is possibly now extinct; 3) the village dog; and 4) a smaller dog similar in size to a lapdog (Gonzalez 2012). There also exist established wild/feral populations that have developed distinct morphological and behavioral adaptations in response to local conditions, as with the New Guinea highland dog (also known as the singing dog) and the Australian dingo. The status of the tengger remains unclear as it has been described as a bush dweller, but its morphology does not show any particular adaptation to life in the wild, and it has been described as being easily domesticated (Storm 2001). Among the four basic early dog types the most relevant to the Timor dog is the village dog type, commonly found in rural parts of Southeast Asia.

The village dog can be differentiated from other types by its restricted distribution, smaller overall size (in comparison to the large pariah), a statistical analysis of bone measurements and visual assessment of living animals by an experienced observer (Gonzalez 2012). Overall, the village dog type can be described as a small to medium-sized canid with features of both modern and primitive dogs. One of the key cranial markers is that the frontal region of the skull is often rather straight, which is a

sign of primitiveness, while the palate is usually broad (as in most domesticated dogs). The combination of skeletal traits often found in wild canids alongside those associated with domesticated dogs is a hallmark of the village dog type and is suggestive of incipient paedomorphism.

The log graph of 22 cranial, mandibular and postcranial measurements shown in Figure 3 demonstrates that the Timor and New Britain dogs are very similar to one another, but are different from more specialised forms like the larger-sized dingo and the shorter—but heavier—New Zealand dog. The dingo has a morphology well-adapted to hunting in open forest-scrubland, with long limbs, strong joints and a large auditory bulla. In contrast, the prehistoric New Zealand dog has shorter legs and a stocky body that appears to reflect use of the animal by prehistoric Maori for food (Clark 1997).

A discriminant function analysis of six mandibular variables (Figure 4) was undertaken to examine whether the Timor dog had a wild/feral morphology or was more like semi-domesticated/domesticated types of dog. The analysis of mandibular variables correctly grouped 88.9% of individuals to one of the three comparative populations (Indian pariah, Indian wolf, Australian dingo), with the first eigenvalue (2.260) responsible for 74.5% of group variance and the second eigenvalue (0.774) accounting for 25.5%. Wilk's lambda for both functions was highly significant ($p<0.000$). The mandibular measurements from the Timor dog and two New Britain dogs were entered as ungrouped cases and were grouped with the Indian pariah rather than the wild/feral canids. It should be noted that populations of pariah dogs in India present a wide degree of variability that includes animals with some skeletal dimensions similar to those of the village dog type. Cranial data from a dog collected by the lead author in Calicut (Kerala, India), and measurements of the Malay dog (Medway 1977), also suggest similarity between contemporary village dogs in South Asia-Southeast Asia and the Timor dog (Table 3).

Conclusion

The mid- to late Holocene-aged dog from Timor described herein has morphological characteristics similar to those of pariah and village dogs from South Asia, Southeast Asia and parts of the Pacific. The main geographic distribution of these types includes much of the tropics. The origins of the village dog may be explained as an adaptive response of the large pariah dog to a tropical environment (e.g. Windle and Humphreys 1890), and perhaps also to a closer association with sedentary human groups. The scant historical information on human-dog relations in this region suggests an animal often used as a hunting aid and watch dog that received shelter and food in exchange (Medway 1977; Erik Meijaard pers. comm.; Titcomb 1969). Some dogs in Timor-Leste today still receive preferential treatment for their hunting ability (Sue O'Connor pers. obs.). It is still unclear whether the initial dispersal of the dog in Island Southeast Asia was by hunter-foragers prior to the arrival of agriculturalists, as potentially indicated by genetic divergence estimates for the arrival of the dingo in Australia 4600–18,000 years ago (Oskarsson et al. 2011), or if range expansion was primarily due to a close association between dogs and farmers in the late Holocene. The diet, health and burial of the dog at the MK2 site suggest a domesticated
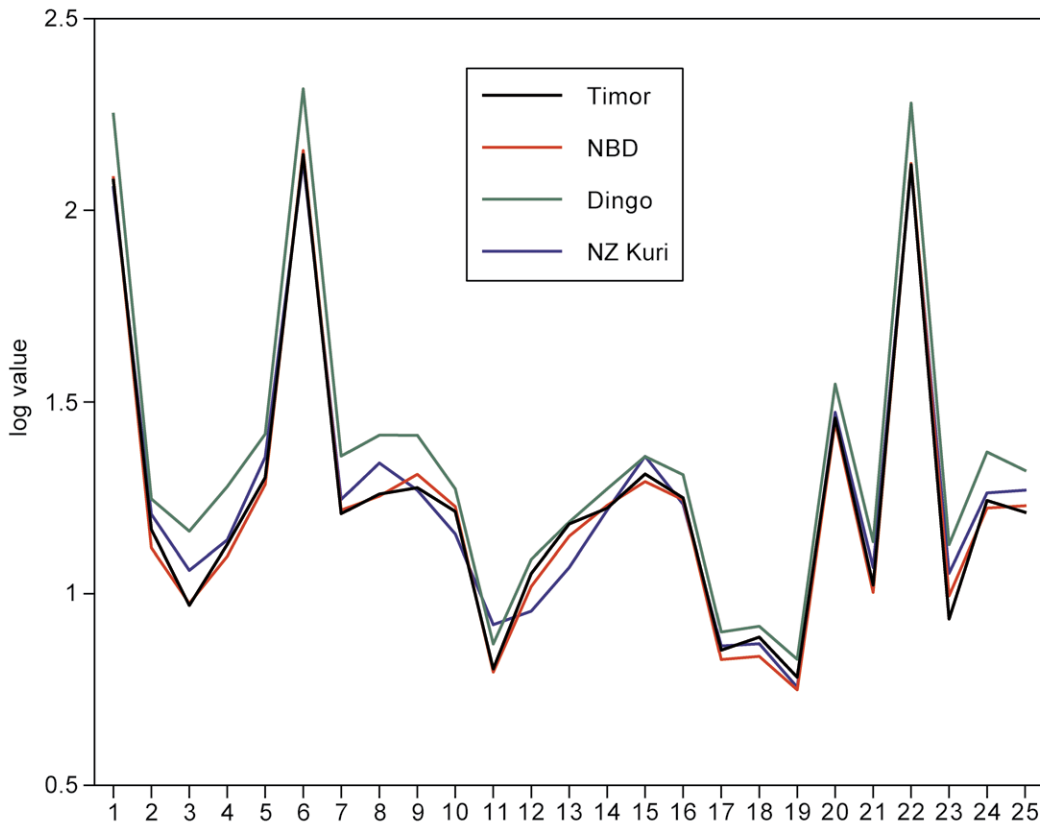
Figure 3 Log graph of 25 cranial, mandibular and postcranial variables from the Timor MK2 dog compared with individuals from New Britain (NBD), Australia (Dingo) and New Zealand (*Kuri*). See Table 2 for measurements and details of samples.
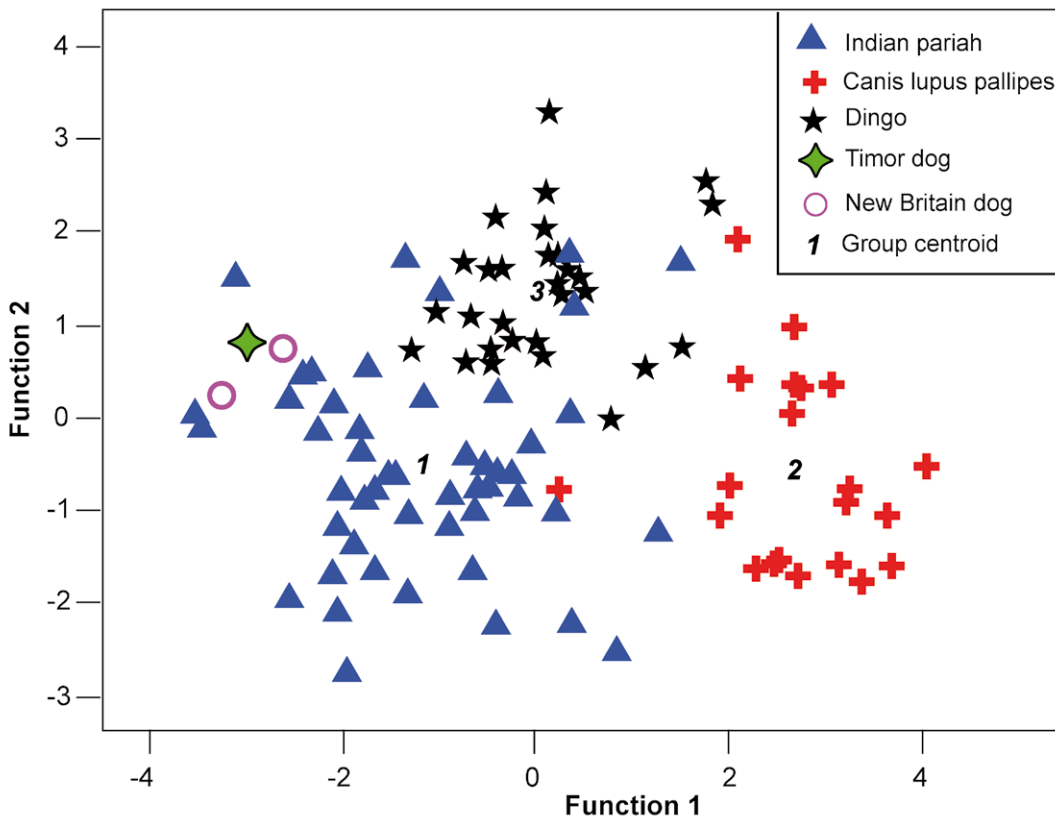

Figure 4 Canonical discriminant function analysis based on six mandibular variables from recent populations of Indian pariah dogs (*1*, n=50), Indian pale-footed wolves (*C. lupus pallipes*) (*2*, n=21), and Australian dingoes (*3*, n=28). Ungrouped specimens in the analysis were the Timor dog burial (MK2) and two recent specimens from New Britain, which were grouped with Indian pariah dogs. Mandibular variables used in the DFA were: height of the mandible behind the lower carnassial teeth; height of the mandible at front of the lower carnassial teeth; length of the lower molar row, measured along the alveoli; length of the lower carnassial alveolus; LP2-LP3 diastema; and alveolar length from LP4 to LM1. See von den Driesch (1976) for a detailed description of measurements.

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Measurement	Timor	Malaya	Calicut
UPM4 length	16.3	15.9	16.8
UM1–2 length	16.6	15.6	17.3
Mandibular height	20.5	19.4	20.8
LM1–3 (alv.) length	28.7	28.0	29.6
LM1 length	17.7	16.9	17.9
Auditory bulla length	18.8	20.0	21.6

Table 3 Cranial and mandibular measurements (in mm) of the Timor dog and two recent specimens of village dog from Malaya and Calicut (Kerala, India). All measurements are from von den Driesch (1976) except for UM1–2 (length of the upper molar row) (Gonzalez 2012), measured from the anterior edge of the cingulum of the 1st upper molar to the posterior edge of the cingulum of the 2nd upper molar). The Malaya specimen was initially cited as a live specimen by Medway (1977) as 'Manggis' from his private menagerie at Ikan Merah; the complete skull and long bones currently reside at the British Museum (BM 71753) and were measured by Gonzalez in March 2012. The Calicut specimen was collected by Deepak Mathew in nearby farmland and is currently curated in the Gonzalez collection (IN 238) Key: UPM4 = upper 4th premolar; UM1–2 = upper 1st and 2nd molars measured together; LM1–3 (alv.) = alveoli of lower 1st, 2nd and 3rd molars measured together; LM1 = lower 1st molar.

animal that was well-cared for during its life, and which probably had a hunting/watch dog function in a community that practiced agriculture, but also hunted wild/feral species such as cuscus and other fauna with the aid of dogs. Thus, the prehistoric spread of *C. familiaris* in Island Southeast Asia may attest to the ongoing importance of hunting-foraging in the subsistence of early farming groups, particularly in the new environments encountered during Neolithic dispersal (e.g. Higham 2002).

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