3. Excavations at Tangi Talo, central Flores, Indonesia.

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Abstract

This paper describes the 1999 excavations at Tangi Talo, the oldest fossil site located in the Soa Basin, Central Flores. It occurs in the basal tuffaceous interval of the Ola Bula Formation, and contains the fossilised remains of pygmy *Stegodon sondaari*, giant tortoise and Komodo dragon. These deposits accumulated shortly after a massive volcanic eruption about 900,000 BP. No *in situ* stone artefacts were found in the excavations, and on present evidence the site predates the arrival of hominins in the basin.

3.1. Introduction

Tangi Talo, meaning 'Difficult Ladder Step', occurs in a saddle cut through a plateau and on the associated erosional terrace (Figs. 3.1 and 3.2). The Coordinates of the location are: 008.69806° S, 121.13611° E. It lies 416 meters above sea level (asl) near the base of the Ola Bula Formation – the site is stratigraphically 108 metres below the base of the Gero Limestone and just 8 metres above the Ola Bula/Ola Kile boundary. Tangi Talo takes its name from the steep slope that provides track access to the main plateau above and the (now abandoned) fortified village of Ola Bula. The adjacent slopes of the Ola Bula Formation are steep; while just below there are the precipitous breccia slopes of the Ola Kile Formation, which here forms a gorge along the Ae Bha River 85 metres below. The Ola Bula fossils site, first investigated by Verhoeven in 1956, also lies on the main plateau about 500 metres to the northwest.

Tangi Talo is the oldest fossil site yet discovered in the Soa Basin. It is the only Flores site that yielded fossils of the pygmy *Stegodon sondaari* and giant tortoise. In addition, fossils of Komodo dragon (*Varanus komodoensis*) were excavated at the site in 1992 (van den Bergh, 1999). The fossils are eroding from a 75 cm thick (maximum) tuffaceous silt layer that can be traced for at least 160 metres along the saddle. Two smaller exposures, at the same stratigraphic level on the south and west slopes of the hillock on the south side of the saddle, indicate that this fossil deposit is very extensive.

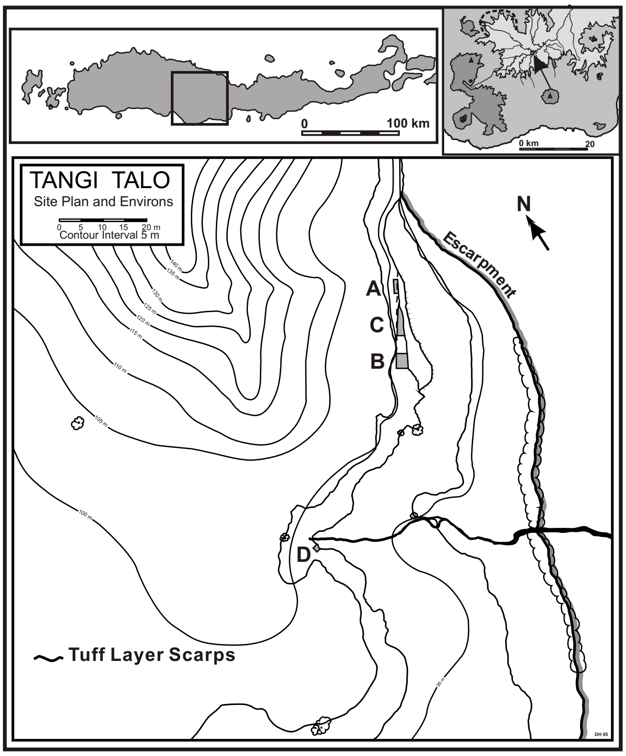

Fig. 3.1. Map of fossil vertebrate locality Tangi Talo and the environs, showing the locations of excavations A-D.

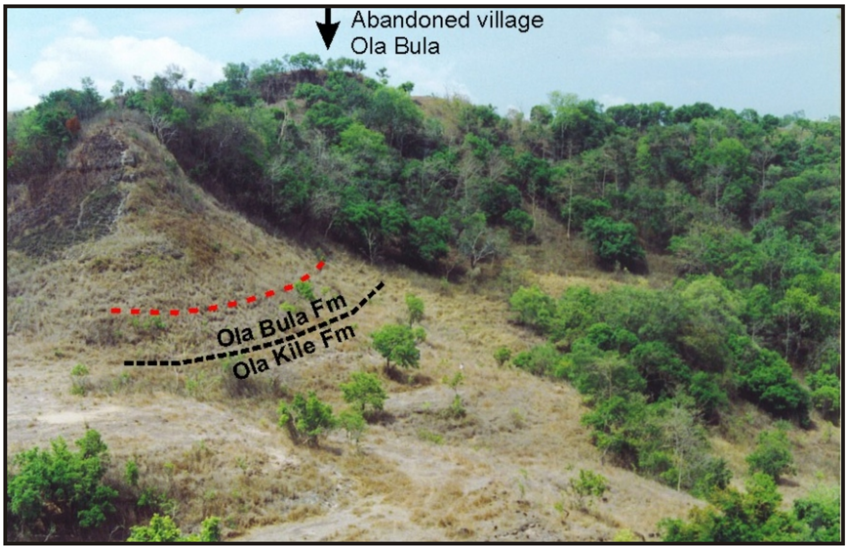

Fig. 3.2. View of Tangi Talo towards the northwest, showing the boundary between the Ola Kile Fm and Ola Bula Fm (black dashed line) and the position of the fossil-bearing horizon (red dashed line). The location of the abandoned village of Ola Bula is indicated with an arrow, whereas the fossil locality with the same name and excavated by Verhoeven is located on top of the same plateau ca 500 m to the northwest (not shown in this picture).

Just north and east of the fossil deposit at the base of the slope from the main plateau, differential erosion has formed an erosional terrace flat at the top of the resistant volcanic breccias of the Ola Kile Fm (Figures 3.1 and 3.2). Fossils, stone artefacts and pottery fragments occur on the surface of this terrace flat. These are of very mixed ages with some items being derived from Ola Bula Village slope wash, while some surface stone artefacts in the area seem to document use of materials from the alluvial deposits for stone artefact manufacture. Examples include proto-handaxes, picks and massive basalt flakes made on volcanics, silcrete and chert.

In 1992, Sondaar *et al.* (1994) excavated a narrow 10 metre length of the fossil layer at the northern end of the site and a smaller area to the south. The remains of pygmy *Stegodon*, Komodo dragon and giant tortoise were found, but no *in situ* artefacts. A sequence of samples was also taken for palaeo-magnetic dating, indicating that the fossil deposit accumulated about 900,000 years ago. These results were confirmed by fission track dating of a block of tuff collected in 1996, which yielded an age of 900,000 $\pm$ 70,000 BP (Morwood *et al.*, 1998).

We worked at Tangi Talo from 27th July to 13th August 1999. Our aims included:

a) Record the stratigraphy and other information on the context of deposition.

b) Ascertain whether stone artefacts occur in the deposits associated with fossils.

c) Collect geological samples for dating, grain size analysis and palynological assessment.

d) Recover a representative sample of fossils.

3.2. Excavation procedure

The 10 metre scarp of the previous excavation was cleared, straightened and cleaned to enable the stratigraphy to be recorded and interpreted. This scarp revealed a series of largely horizontal stratigraphic layers, which appeared to have escaped any major post-depositional deformation or disturbance (Fig. 3.3).

A baseline was established running at 40° N and parallel with the scarp of the Sondaar *et al.* (1994) excavation. Within the main site area three locations (Areas A, B and C) were selected for excavation as a means of examining spatial differences in deposition (Fig. 3.1). A fourth area (D) was later excavated approximately 50 metres south-west of the main site area in order to recover the remains of a pygmy *Stegodon* evident in a low erosional scarp, and to verify the relationship between the tuffaceous silt layer and the concentrated fossil deposit which had been recognised in the main excavation.

In all excavation areas the surface soil and non-fossil-bearing upper rock layers were simply removed in bulk. Rock layers with the potential to contain fossils were then excavated more carefully in 15 - 20 cm thick units using picks, geological hammers and small chisels as appropriate. Sieving proved impractical, so blocks of stone were broken up and closely examined before being discarded. In each area, fossil beds were photographed and drawn in plan prior to recovery. The fossils were stabilised with PVA as necessary to ensure their adequate preservation before being removed for more detailed laboratory examination and classification at GRDC in Bandung.

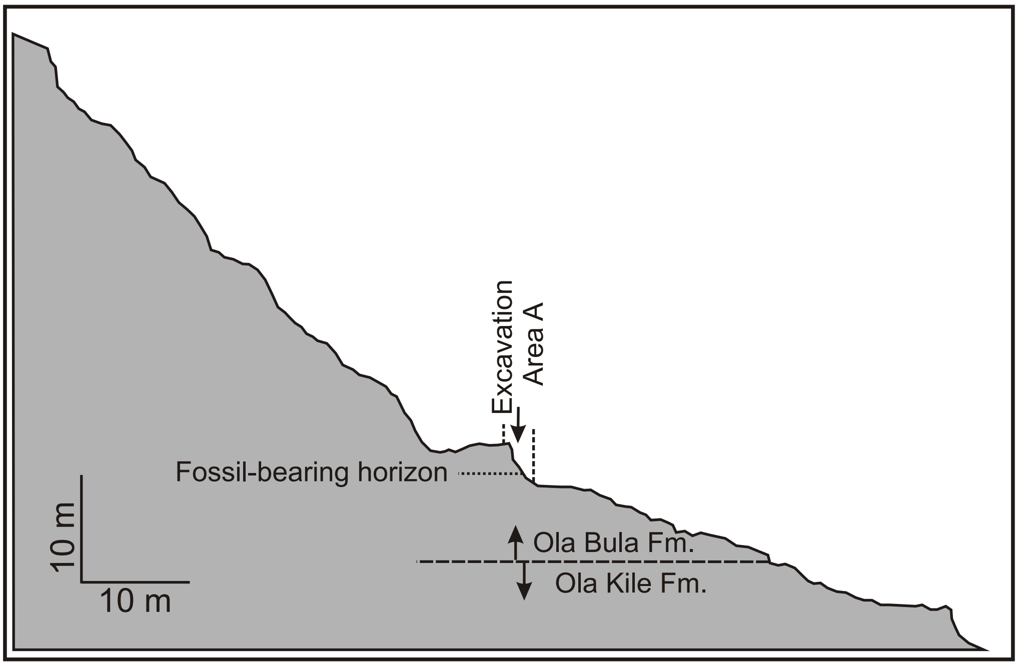

Fig. 3.3. Cross-section through the excavation in Area A.

3.2.1. Excavation Area A

This lies toward the northern end of the Sondaar *et al.* (1994) excavation area. Here a 3.7 metre long and 1.2 metre wide area was undercut into the scarp to reveal the fossil bed (Fig. 3.1).

3.2.2. Excavation Area B

This lies along the same low outcropping escarpment 13 metres south of Area A. The locality had not been subject to previous archaeological investigation. It was 3.6 metres long, 2.2 metres wide and dug to a depth of 1.5 metres below the overlying soil surface to access the fossil bed. Following photography, mapping and recovery of the fossils, a further 35 cm of basal deposit was removed to determine its depositional context and fossil-bearing potential.

3.2.3. Excavation Area C

In order to clarify the stratigraphic and palaeontological relationship between Area A and B, Area C was excavated approximately mid-way. It was 6 metres long and up to 2 metres wide and was dug to a depth sufficient for revealing the fossil bed and its underlying deposit.

3.2.4. Excavation Area D

Area D comprises a 1 metre by 1 metre square that was excavated into a low eroded tuff outcrop orientated at 120˚ N some 50 metres west of Area B. This excavation was conducted to recover the remains of a *Stegodon sondaari* pelvis, which was found eroding from the scarp. The excavation ceased at a depth of 110 cm below the surface soil.

3.3. Stratigraphic results

3.3.1. General stratigraphy

Five main stratigraphic layers were recognized in the excavations. These layers are orientated horizontally and are clearly chronologically sequential (Figure 3.4):

Layer I- A surface layer of friable dark brown topsoil, sterile of cultural or fossil evidence.

Layer II- A thin ($\leq$ 3 cm) discontinuous horizon of fine-grained cream-coloured sandstone, sterile of cultural or fossil evidence.

Layer III- An 80 - 90 cm thick layer of light brown tuffaceous sandstone with pumice clasts, containing occasional fossilised fragments of pygmy *Stegodon sondaari* bone and fossil plant roots throughout. Layer III caps all fossil-bearing deposits in the Tangi Talo vicinity. Erosional flow structures (flutecasts) at the base of the layer indicate that the sediment source area was higher ground to the west.

Layer IV- A 15 - 25 cm thick layer of white, tuffaceous silty clay, containing occasional fossils throughout, but these are concentrated at the Layer IV/Layer V interface. Layer IV extends across the entire Tangi Talo site area and probably reflects a massive flow of new material into the area as a result of volcanic activity.

(Layer IVb)- A layer of light-brown/green, tuffaceous silty clay, indicative of standing water. It only contains pumice fragments, indicative of mixing, at the edge of the pool in Area B.

Layer V- A layer of unsorted clast-supported pumice, which is 50 cm thick at the northern end of the site. The bases of many of the fossils were embedded in the surface of Layer V, which lacks internal structure and is probably the result of a single volcanic event. Reddening of the layer, especially at the northern end of the exposure, indicates a palaeo-soil. Layer V also formed the bank and at least part of the base of the pool evidenced in Areas B and C (Fig. 3.4).

(Layer Vb)- A light-brown, tuffaceous silty clay with pumice clasts. It features multiple thin layers indicative of standing water.

3.3.2. Area A

A total of 41 fossils or fragments of pygmy *Stegodon* and giant tortoise, as well as several pieces of andesite, were recovered from Area A. The condition and disposition of the remains indicates post-

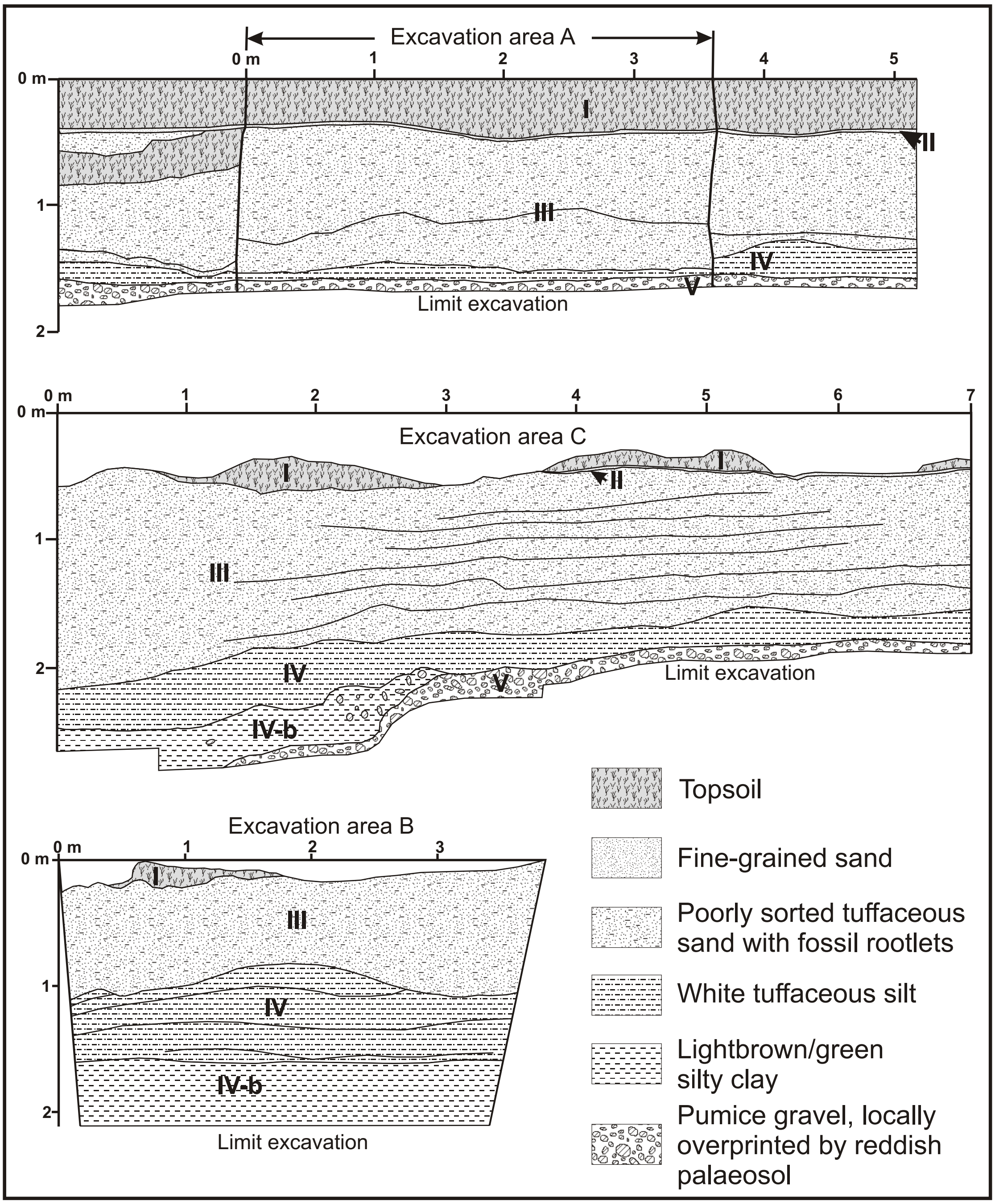

Fig. 3.4. Stratigraphic profiles of the northwest baulks of the Tangi Talo excavations (from northeast to southwest) A, C and B. Roman numbers refer to the units referred to in the text. Fossils are concentrated at the boundary between Units V and IV in Areas A and C, and at the boundary of Layers IV and IV-b in Areas C and B.

depositional attrition and disturbance, although the tortoise remains tended to occur in clusters often representative of a single animal (Fig. 3.5). As noted previously, the main fossil concentration at Tangi Talo lies at the interface between the pumice layer and its overlying tuffaceous silty clay (van den Bergh 1999). Given the high fragmentation and post-depositional damage of most specimens, the faunal material appears not to have been covered directly by white tuffaceous silt after death. The presence of Komodo dragon teeth, including examples actually within a tortoise carapace, indicates scavenging of fleshed bones at the site prior to being covered by silt (van den Bergh 1999). The pumice gravel (Layer V) shows irregular reddish mottling in Area A, indicating subaerial exposure and soil formation prior to deposition of lacustrine Layer IV.

3.3.3. Area C

Moving south along the scarp, Layers III and IV dip and generally increase in thickness. Again, fossils were concentrated on the Layer IV/V interface. The basal pumice (Layer V) extends along the entire Area C. However, at the southern end of the excavation the water-deposited Layer IV-b separates Layers IV and V. This begins at a point where the top surface of Layer V suddenly dips down (Figures 3.4 and 3.5), suggesting that Layer IV-b was formed in a pool. Bones were also concentrated on the Layer IV/IV-b interface but mostly in close proximity to the 'bank'. A total of 33 fossils, mostly scattered fragments of pygmy *S. sondaari*, were recovered from Area C. The condition and distribution of the fragments indicates a relatively high degree of post-depositional attrition and disturbance. The spatial density of bone decreased markedly where Layer IV-b (i.e. pool sediment) begins.

3.3.4. Area B

This area is interpreted as a deeper section of the pool. Layers III and IV continue south from Area A and C through Area B, and IV-b is at least 50 cm thick, possibly much more. The excavation did not go deep enough to encounter Layer V, which presumably formed the base of the pool.

Although the density of bone in Area B was much less than in Areas A and C, some fossils occurred at the Layer IV/IV-b interface. Some isolated fragments also extended into the overlying Layer III. The thin sandstone layer (Layer II) is absent, but the most significant stratigraphic difference occurs in the covering of pumice Layer V with a fine-grained, light brown tuffaceous silty clay with pumice clasts (designated Layer IV-b). It was further evident from the profile in Area B that the top of layer IV has been eroded prior to deposition of layer III (Fig. 3.4).

Unlike Layer V that was clearly deposited on dry land, Layer IV-b contains multiple thin sediment laminae indicative of deposition out of suspension in a standing body of water. A change from 'dry land' (Area A) to lacustrine conditions (Area B) is further suggested by an increase in the thickness of Layer IV (from 20 to 75 cm) and a basal dipping of the Layer IV sediments.

Eight fossils and fragments of pygmy *S. sondaari* and one piece of andesite were recovered from Area B, all toward the base of Layer IV. These include two opposing rami of a *S. sondaari* mandible, which though disarticulated, were found in close association to each other.

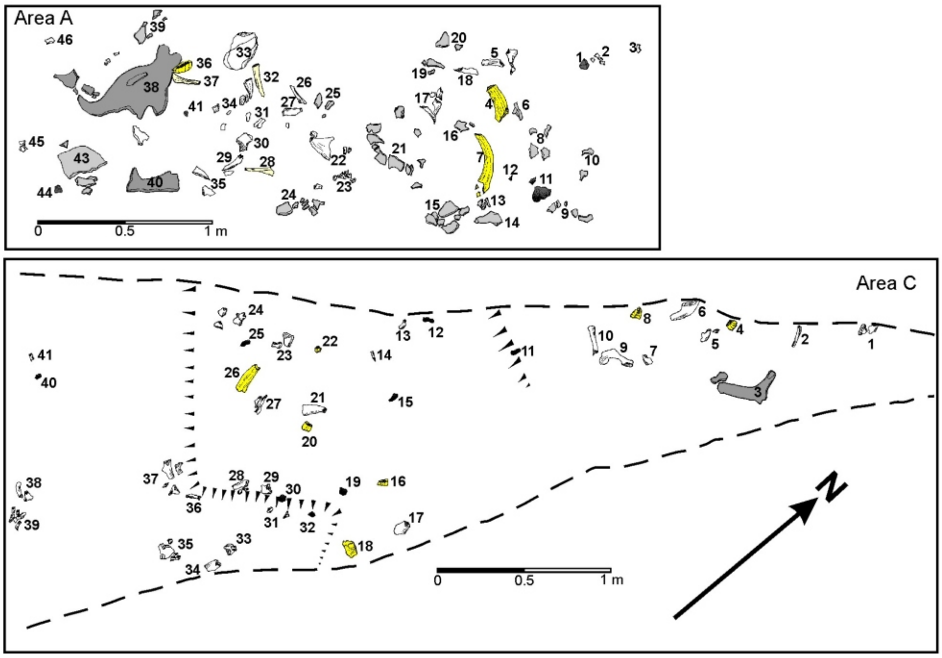

Fig. 3.5. Plan of the fossil finds at the boundary between Units IV/IV-b and V in excavation areas A and C. Shown in black are: rock fragments; white: bone fragments; yellow: Stegodon tusk and molar fragments; pale yellow: Stegodon bone fragments; light grey: tortoise carapace fragments; dark grey: tortoise bone fragments. Area A, no. 38 is a tortoise pelvis; Nrs 28, 32 and 37 are dorsal vertebra spines of Stegodon. Area C, no. 3 is a tortoise scapula. Blacks dents indicate the areas where the surface of Layer V suddenly dips down (edge of pool).

3.3.5. Area D

Two fossils, both from a pelvis of a single individual of *S. sondaari*, were recovered from Area D at the head of a small gully. The stratigraphy comprised 15 cm of dark brown topsoil, (Layer 1) over 30 cm of hard brown tuffaceous sandstone (Layer III) which capped 25 cm of white tuffaceous silty clay (Layer IV). The bones lay at the base of this layer on light brown-green silt (Layer IV-b). Two metres to the north on the other side of the gully, some bone fragments occurred on the boundary between Layers IV and IV-b, but the latter contains pumice fragments, suggesting that the bones were deposited in water but close to the bank.

3.3.6. Other areas

We cleaned and recorded the stratigraphies at two other locations where fossil bones were evident. In both cases the bones were found to have been deposited on a light brown/green silty clay (Layer IV-b), indicative of standing water, rather than dry land, but the presence of pumice fragments in the silt suggests that the area was adjacent to the water's edge. In the area 15.3 metres south along our baseline from Area B, van den Bergh (1999) found a concentration of fossils similar to those encountered in Areas A and C, and not present in Area B. The stratigraphic evidence suggests that the pool was about 25 metres across (north-south) in this section of the site.

3.4. Environmental interpretation of the Tangi Talo site

About 900,000 years ago, volcanic eruptions produced widespread pumice gravel layers of which the earliest, at the base of the Ola Bula Fm, has ignimbritic features. However, only one of these layers occurs at Tangi Talo (Layer V), presumably because the area constituted a "basement high" during initial infill of the Soa Basin, leading to a condensed stratigraphy (O'Sullivan *et al.*, 2001).

At Tangi Talo, the pumice gravel was exposed subaerially for a substantial period of time causing reddish soil formation and local erosion. Later, a pool formed and fine-grained tuffaceous silt was deposited in the lower areas, filling in the depressions of the existing relief (Layer IV-b). The remains of pygmy *Stegodon* and giant tortoise accumulated around the margins of the pool, and some were also washed in. Evidence of scavenging by Komodo dragon indicates that the remains included fleshed carcasses (van den Bergh, 1999). In fact, the paucity of *Stegodon* post-cranial elements on the 'dry land' area of the Tangi Talo flat can be attributed to such scavenging, while trampling also may have caused considerable damage to the bones scattered on the surface.

There seems to have been areas of standing water along the full length of the Tangi Talo flat, which extended for at least 160 metres (north-south). Whether there was a single pool, or a series, is not known. The flat was formed on a substratum of the pumice tephra, which had been exposed long enough for some soil development to occur. Flow structures visible within the overlying sandstone (Layer III) indicate that higher ground lay immediately to the west of the site.

The *Stegodon*, tortoise and Komodo dragon bones accumulated during a period when a layer of fresh white tuff (Layer IV) was deposited in the pool. At this stage the water level in the pool seems to have risen, causing deposition out of suspension on the higher ground surrounding the pool, rapidly covering the bones scattered on the surface. The apparently short-term concentration of bone on a specific land/lacustrine surface (transition Layers IV/IV-B and V) is suggestive of mass death, rather than gradual accumulation. This is also suggested by the *Stegodon* death assemblage (see below), which shows that non-selective death affected individuals from all ages.

The majority of bone at the site occurs in discrete clusters at the base of Layer IV, which presumably represents a renewed period of volcanic activity that may have been responsible for the mass death of animals at the site. However, mass death does not seem to have been instantaneously, as considerable bone attrition by trampling (*Stegodon*) and scavenging by Komodo dragons occurred. The animals may have died slowly as a result of breathing in and consuming fine-grained volcanic ash particles.

The fossil-bearing Layer IV at Tangi Talo was subsequently covered by a series of tuffaceous sandstones, siltstones and tuffs. The boundary between Layers IV and III is clearly erosive, suggesting that water levels in the pool lowered allowing erosion of Layer IV. The few poorly preserved bone fragments present in Layer III may have been reworked from erosion of Layer IV more to the west.

The fact that the Ola Bula fossil site, dated to around 850,000 years BP (O'Sullivan *et al.,* 2001; Table 1), occurs 50 metres higher in the local stratigraphic sequence indicates that this build-up of fluviatile and volcanic deposits occurred rapidly with an average deposition rate of 1 mm per year.

On present evidence there are no indications for hominin activity in the Tangi Talo deposits. Pieces of conchoidally fractured andesite do occur with the fossils, but all resemble naturally shaped pieces of andesite currently eroding from breccias of the Ola Kile Formation. As these pieces of stone occur in the same level as the main fossil bed, the stones and bones may have undergone some water transport prior to burial by the white tuffs of Layer IV.

3.5. Palaeontology

Among the fossil material excavated at Tangi Talo in 1999, there are 2 complete isolated *Stegodon sondaari* molars from excavation Area C and a lower dentition still embedded in a mandible from Area B. In addition there are a number of molar and tusk fragments from Area A. Excavated postcranials of pygmy *Stegodon* include an almost complete left pelvis from Area D; a left scapula fragment, left fibula diaphysis and thoracic vertebra body from Area C; and a lumbar vertebra body and three dorsal spines of thoracic vertebrae from Area A. The tortoise remains are presently being studied by Erick Setiabudi. Tortoise carapace fragments were found mostly in Area A. No additional fossils of *Varanus komodoensis* were recovered in 1999. Below we describe the *Stegodon sondaari* remains. The additional molar material was briefly described in an earlier paper (van den Bergh *et al*., 2001).

For a more detailed terminology and a description of the parameters used to measure *Stegodon* dental elements the reader is referred to Van den Bergh (1999). Abbreviations used here when referring to measurable parameters are as follows: L = total length of molar at intermediate crown height; W = maximum width of molar; H = maximum height of unworn molar ridges; LF = lamellar frequency, defined as the number of ridges occurring in anteroposterior direction along 10 cm of the crown base. Calculated as the average of the 2 lamellar frequencies from both the buccal and lingual side of a molar; ET = enamel thickness; P = plate formula, which is the number of ridges developed in a complete molar. Incompletely developed anterior and posterior ridges are designated with “x” in front and/or behind the number indicating the amount of fully developed ridges, e.g. “x6x”. A “-“ in front or behind the ridge number indicates that 1 or more ridges are missing in incompletely preserved molars, e.g. “–5x”. Measurements followed by “e” are estimated values; molar measurements followed by “(c)” indicate that some buccally or lingually deposited cementum is included in the measurement.

3.5.1. Stegodon sondaari dentition and mandible

Specimen GSI no TT4257 is a completely preserved sinistral M3 in the initial stage of wear. The specimen has x8x ridges, which is 1 to 2 ridges more than in the M2 of *S. sondaari*. The crownward convexity, the posterior tapering and the relatively large number of 8 ridges indicate that an upper M3 is concerned. The M3 has a length of 103.7 mm measured along the crown base, or 107.5 when measured at intermediate height. The maximum width (W) is 42.9 mm at ridge 3. This falls within the W range of the M2 (van den Bergh *et al*., 2001). The L/W ratio amounts to 2.51, which is higher than in the M2 due to the larger length. Ridge 3 has been worn to such an extent that an almost complete wear figure has developed. Of the succeeding ridge 4 only the tips of the tubercles have been abraded, whereas ridge 5 is unworn. Ridge 5 has a height (H) of 78 mm and a W of 42.1 mm, giving a hypsodonty index of 78. Enamel thickness (ET) varies between 3.3 and 4.0 mm. A stepwise wear or "stufenbildung" of the enamel is developed at the occlusal surface, which is one of the diagnostic characteristics for *Stegodon*. Plesiomorphic characters are the low number of ridges compared to other *Stegodon* species from the Indonesian region, and the relatively thick, only weakly folded enamel. Ridge 1 has a marked median cleft extending towards the base of the crown, which is lacking in more advanced *Stegodon*ts.

Another complete molar (Coll. GSI no. TT-4256) represents an unworn isolated dextral upper M1. It has x6x ridges, a total length (L) of 88.5 mm and a maximum width (W) of 40 mm at ridge 4. Ridge 1 shows a deep median cleft laterally offsetting the buccal and lingual half of this ridge. Ridge 2 is aberrant in being incompletely developed at the lingual side. The average lamellar frequency (LF) amounts to 8.3. The L lies 3.5 mm above the recorded length of the upper M1 and 3.5 mm below the recorded minimum L of the upper M2. However, the relatively thin enamel thickness (ET) of 2.2 mm and the W of 40 mm, slightly below the range observed in the M2 but within the range of the M1, suggest that the molar is a M1.

The mandible (Coll. GSI no TT-4255; Fig. 3.6) has both the left and right dentition preserved. At both sides a small completely worn remnant of the dP4's in front is still unshed, followed by the half worn M1's. Of the left side the ascending ramus is preserved with an anterior fragment of the M2 under formation still in the alveole. The superior portions of both ascending rami, including the condyles, are broken. The left dp4 has a preserved width of 26.5 mm. The succeeding m1 has five of the eight ridges worn (P = x8x). It has a L of 90 mm and a W of 36.6 mm at ridge 4. The LF is 9.9. The ET is rather thin, between 1.8 and 2.3 mm. The enamel shows a stepwise wear pattern at the occlusal surface and is weakly folded, with 0-2 folds per cm with amplitude of less than 1.3 mm. Because the molar is still in the mandible the maximum height of unworn ridges could not be measured. On the unworn ridges there are 6 conules present. The L of this specimen is 12 mm

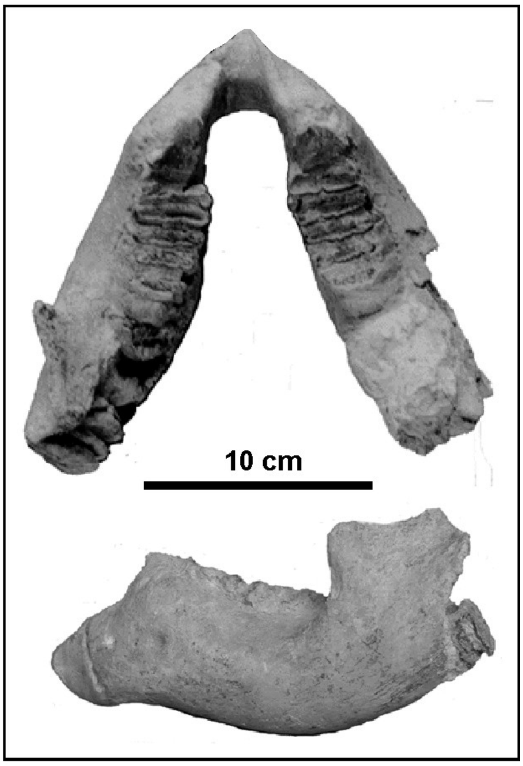

Fig. 3.6. Juvenile Stegodon sondaari mandible (GSI Reference TT-4255) from excavation Area B at Tangi Talo. Top: occlusal view; bottom: left lateral view.

shorter than the lower limit of complete M2's recorded previously (van den Bergh, 1999). This is the first complete lower M1 recorded for *Stegodon sondaari*.

In the same left ramus there are only 4 ridges still present of the M2 under formation in the alveole. These are still incomplete and unfused at their base. The W of the third ridge is 33+ mm, but this would be larger if the enamel formation had been completed. The dental wear stage of the current mandible can be given as dP4/M1-C, (= Age Group 1, juvenile) according to the method described in van den Bergh (1999). The individual was slightly younger than that of the holotype mandible that belonged to a subadult (Age Group 2). This fits with the slightly smaller dimension of mandible TT-4255 (Table 3-1). TT-4255 has a more protruding symphysis as the extremely brevirostrine type specimen, and actually resembles the typical situation usually developed in *Stegodon*. There are 2 mental foramini at each side. The coronoid process is angular, lacking the strong tuberosities for muscle attachment seen in the holotype mandible. Besides mandible TT-4255, there are 2 sinistral ramus fragments lacking dentition in the 1999 collection (TT-4282 and TT-4277). Only a few measurements could be taken, indicating that adult individuals are concerned (Table 3-1).

3.5.2. Tusks

Among the fossil specimens excavated at Tangi Talo in 1999 are some very nicely preserved tusk fragments of adult *S. sondaari* individuals. The largest one is a distal tusk portion (GSI No. TT-4268) that was excavated in Area A. Another proximal portion of presumably the same left tusk

Table 3.1. Measurements of Stegodon sondaari mandibles

Measurement	TT4255	TT3837 (holotype)	TT4282	TT4277
M1	>194	245e	-	-
M2	>108	225e	-	-
M3	>82	>94 (99e)	-	-
M4	95	140e	-	-
M5	59	68	>75	74
M6	52	52e	-	-
M7	67	68	-	-
M11	>212	206	-	-
M15	166e	150e	-	-
M16	190e	204	-	-
M17	51	-	-	-
M18	59	65e	-	-
M19	34	43	-	-
M20	23	26	31	29.8
M21	35	41	-	-
M22	37	54	-	-
M23	32	38	-	-
M24	74.5 (average)	103	-	-
M25	32.5 (average)	40	-	-
M25/M18	0.55	0.62e	-	-

Table 3.2. Measurements of Stegodon sondaari vertebrae

Specimen Measurement	TT-4278 Thor. (V or VI)	TT-4283 Thor. XIII-XV?	TT-4289 Lumbare	TT-4274 Thoracale	TT-4273 Thoracale
V1	39.3	41.5	44	-	-
V2	52	47	52	-	-
V3	56	48	45.5	-	-
V4	53	-	53	-	-
V5	51	49e	44	-	-
V6	30	45e	37	-	-
V7	-	-	30	-	-
V8	> 121	-	98	-	-
V9	-	-	>37	-	-
V10	-	-	-	>129	>141

(TT-4269) was found in close proximity (No's. 7 and 4 in Fig. 3.5), but the two pieces do not fit together. The distal portion is strongly curved (Fig. 3.7). It measures 408 mm along the convex medial surface (345 mm when measured straight from tip to the most proximally preserved medial end. Proximally nothing of a pulp cavity is present, indicating that still a proximal portion of the tusk is missing. As is usual in *Stegodon,* the tusk is slightly dorsoventrally compressed, the most proximally preserved transverse diameter measuring 63 mm, versus 56 mm in dorsoventral direction. The ventromedial surface of the distal end is strongly worn, to such an extent that the tusk tapers much more rapidly at the distal end than the proximal portion. The worn surface shows macroscopically visible transverse striae. On the proximal portion of the tusks, in particular on the ventrolateral surface, longitudinal ribbons of ca. 1 cm wide are developed. At the most proximally preserved end a second wear surface is developed as a longitudinally concave polished surface on the medial side.

The proximal tusk fragment excavated in the same Area A includes the pulpa cavity. The specimen (TT-4269) is 17 cm long and has a proximal transverse diameter of 70 mm versus 59 mm dorsoventrally. The pulpa cavity has a transverse and dorsoventral diameter of 61 mm and 50 mm, respectively. The distal part of this fragment is heavily fractured, and there is no fit with specimen TT-4268. However, both fragments have the same strong curvature, dark grey colour, presence of well developed longitudinal ribbons and approximate diameter suggesting that they are part of the same tusk (Fig. 3.7).

A slightly smaller but similarly strongly curved distal tusk portion, also of the left side, is specimen TT-4267 (Fig. 3.7), which was excavated in Area B. It measures 332 mm along the convex medial surface (305 mm measured straight between the same points). Nothing of a pulpa cavity is preserved. The most proximal transverse diameter measures 55.6 mm, versus 48.5 mm in dorsoventral direction. Like specimen TT-4268 the ventromedial side of the distal end is strongly worn, resulting in an oval-shaped flattened wear surface. Specimen TT-4270 is an intermediate tusk portion. It is about 14 cm long, strongly curved, and has a transverse diameter of 52.9 mm versus 50 mm dorsoventrally.

Fig. 3.7. Three Stegodon sondaari tusk fragments excavated at Tangi Talo in 1999.

Specimen TT-4266 is the polished tip of a dextral tusk, originating from Area B. The fragment is only 65 mm long, and has a most proximally preserved transverse diameter of 21.3 mm, versus 19 mm dorsoventrally. It has similar proportions as a juvenile tusk described earlier (TT-3819; van den Bergh 1999). Wear at the distal tip has not yet proceeded to such an extent as in the adult tusks described above.

The *Stegodon sondaari* tusks so far discovered are characterized by a strong curvature, unlike tusks of *Stegodon trigonocephalus*. In addition to the plesiomorphic molar plateformula, with relative low numbers of ridges, and the small overall size, the strong curvature of the tusks appears to be a diagnostic criterion for this pygmy *Stegodon* from Flores. The tusks appear to have been extensively used as shown by heavy abrasion on the ventro-medial surfaces, presumably for digging (waterholes, edible roots?). This ventro-medial wear of the distal tusks is also developed in *Stegodon florensis* tusks.

3.5.3. Vertebrae

Specimen TT-4278 is a thoracic vertebra with the dorsal spine broken. The epiphyses of the articulation facets have been fully fused. On both sides of the cranial and caudal articulation facets of the corpus there are relatively large articulation facets for the costae. This, and the fact that the processi transversal are heavily built, suggest that a thoracale V or VI is concerned. Measurements of this and other vertebrae are given in Table 3-2.

TT-4283 is a corpus of a thoracic vertebra from the posterior region of the vertebra column, as indicated by the small processus transversals (partly preserved on the dextral side) and the small articulation facets for the costae, one caudally and one cranially on each side. Also here the epiphyses have been fully fused.

TT-4289 is a lumbar vertebra with only the tip of the processus spinosus broken. There are no articulation facets for the costa. The ventral part of the processus spinosus has two inclined facets for articulation with the succeeding vertebra.

TT-4274 is a long portion of a processus spinosus of a thoracic vertebra from the anterior region of the vertebra column. The sinistral side of the arcus is also preserved, showing that the foramen magnum was wide and relatively large. The dorsal tip of the spine is broken. The length of the spine as far as preserved is 129 mm.

Another spine of a thoracic vertebra is specimen TT-4273. Also here the dorsal tip is broken and the length as far as preserved is 141 mm.

3.5.4. Other postcranials

There is one scapula fragment amongst the material collected in 1999. It is a proximal glenoid joint of the left side (TT-4291), with a proximal part of the spine preserved. There is some superficial damage on the ventral and dorsal side of the collum scapulae. The maximum proximal transverse diameter (S1) measures 44.3 mm; the maximum proximal anteroposterior diameter (S2) is larger than 66+ mm, estimated to have been around 70e mm. The anteroposterior diameter of the glenoid (S3) is approximately 56 mm. The minimum anteroposterior diameter of the collum scapulae (S4) is at least 46 mm as far as preserved. The minimum transverse diameter of the collum scapulae (S5) measures 31 mm. These size measurements are all below the values of pygmy proboscideans from South Sulawesi, and like the other postcranial and dental elements indicate that the size of *S. sondaari* was well below that of *S. sompoensis*, and much smaller than *S. trigonocephalus* from Java and *S. florensis*, known from younger localities in the Soa Basin.

A very well preserved left pelvis from excavation Area D is TT-4289, which is almost complete. Pelvis fragments were not recorded from the earlier collections from Tangi Talo. TT-4289 includes the complete acetabulum, the pubis, the ischium and a major portion of the ilium, of which the outer margins have been eroded to some extend. The anteroposterior diameter of the joint cavity of the acetabulum (measurement P1) measures 56 mm, dorsoventrally (P2) it measures 54 mm. The maximum dorsoventral diameter of the acetabulum between its outer margins (P3) measures 77 mm. The minimum transverse diameter of the shaft of the ilium (P4) measures 59 mm, whereas the maximum transverse diameter of its wing measures 254 mm as far as preserved, though there is some superficial damage at the tuber coxae and at the symphysis with the sacrum. The shaft of the ilium is relatively elongated and narrow, which is characteristic for *Stegodon* when compared with the relatively short and wide shaft occurring in *Mammuthus* and *Elephas* (Hooijer, 1957). The minimum transverse diameter of the ischium (P5) measures 30 mm. The minimum anteroposterior diameter of the pubis (P6) is 24 mm. The longitudinal length of the pubic symphysis measures around 129 mm. Because there is only one pelvis of *S. sondaari* available for study so far, it is not possible to determine the gender of the present specimen. Again, the size measurements of this adult specimen indicate a very small size when compared with the adult *S. trigonocephalus* pelvis from

Java. In the latter measurement P2 varies between 125 and 150 mm, and measurement P4 between 120 and 190 mm, which is more than 2 times larger than in the current specimen. In a *Stegodon florensis* acetabulum from Mata Menge (MM05-28) measurements P2 and P4 amount to 118 mm and 137 mm, respectively.

Specimen TT-4271, excavated in Area C, represents the twisted diaphysis of a fibula which varies in width from 26.1 mm to17.3 mm. It widens at both ends, but there is no suture with any of the epiphyses preserved. There is a longitudinal groove bordered by crests on both sides on one half of the specimen, and an elongated surface with tuberosities for muscle attachment present on the other half.

In addition, the bone assemblage includes costa fragments attributable to S. *sondaari* and small indeterminable bone fragments.

3.5.5. Age structure of the Stegodon sondaari fossil assemblage.

In a previous study, van den Bergh (1999) noted that the mortality age profile of the Tangi Talo *S. sondaari* remains matched the age profile of living elephant populations. He therefore attributed the fossil assemblage at the site to non-selective, catastrophic death, affecting individuals of all ages in a relatively short period of time. More specifically, the fact that the remains were covered by volcanic tuff suggested that the animals were victims of a volcanic eruption. However, a minimum sample size of 30 individuals is necessary for reliable age profile analysis (Lyman, 1987), and the interpretation was based on an estimated 12 individuals,

Inclusion of the additional dental material collected in 1999 has increased the number of *Stegodon* represented in the Tango Talo fossil assemblage to a minimum of 20 individuals, and their age mortality profile (Fig. 3.8) confirms the earlier hypothesis that the bone assemblage was the result of a catastrophic mass death event that affected an entire population, including prime-adults. In

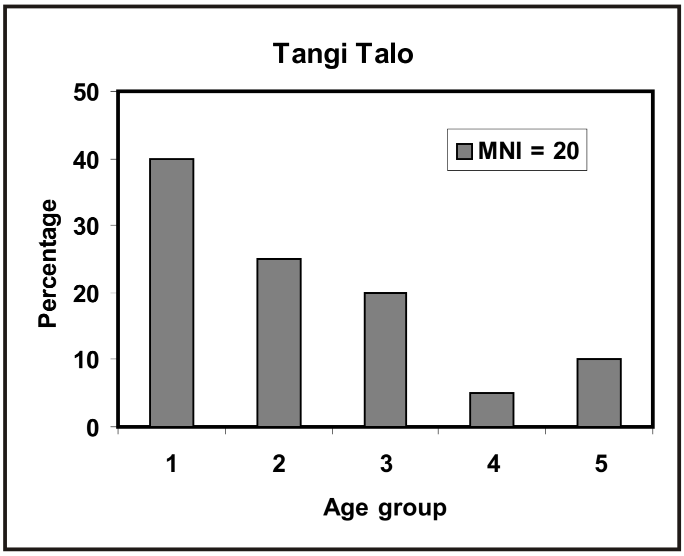

Fig. 3.8. Age profile of the Stegodon sondaari death assemblage from Tangi Talo, based on an MNI of 20 individuals.

combination with the nature of the deposits, the evidence shows that a volcanic eruption was the most likely cause of this mass death - by inhalation of ash particles or more slowly by intake of ash-contaminated food and water. However, the lack of articulated skeletons or parts of skeletons, and the considerable damage to most bones that accumulated on the higher banks of the pool, strongly suggests that postmortem agents disturbed the bones prior to burial.

The mortality profile of the Tangi Talo *Stegodon* is similar to the mortality profile of deer killed in the 1980 eruption of Mount St. Helens (Lyman, 1989). Interestingly, in this latter case there was evidence that partly buried deer carcasses were disturbed by scavenging carnivores in the summer and autumn after the eruption. In the case of Tangi Talo, *Stegodon* carcasses seem to have attracted scavenging Komodo dragons. This would explain the disarticulation and removal of skeletal parts from the original death assemblage, and, the fact that the interior of a Geochelone plastron-carapace contained several Komodo dragon teeth. The presence of stones in the bone layer also suggests that some water transport may have occurred, removing bone material from the assemblage.

3.6. Conclusions

At 900,000 years old, Tangi Talo is the oldest fossil locality in the Soa Basin and the only one that has yielded the remains of the dwarf *Stegodon sondaari* and giant tortoise. The bones of these animals, as well as Komodo dragon, accumulated near the margins of one or more pools. The animals that gathered around the pool were probably killed by a volcanic eruption; specifically by inhalation of volcanic particles and intake of these particles with contaminated water or food, which caused slow, non-selective death affecting individuals of all ages. Weathering, trampling of bones by other animals and scavenging of carcasses by Komodo dragons may explain the postmortem damage and scattering of the bones.

Following a rise in water level, the pool(s) and surrounding higher areas were covered by an up to 60 cm thick layer of volcanic tuff, which levelled the relief and rapidly covered the scattered faunal remains.

Because no *Stegodon sondaari* or giant tortoise remains were recovered in any of the younger sites in the Soa Basin, the volcanic eruption that caused the mass-death of animals at Tangi Talo might also have caused the extinction of these endemic species. There is no evidence of hominin activity at the site.

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