From the Solo to the Madura Strait: Quaternary geology, vertebrate palaeontology and hominin chronology of eastern Java and submerged Sundaland

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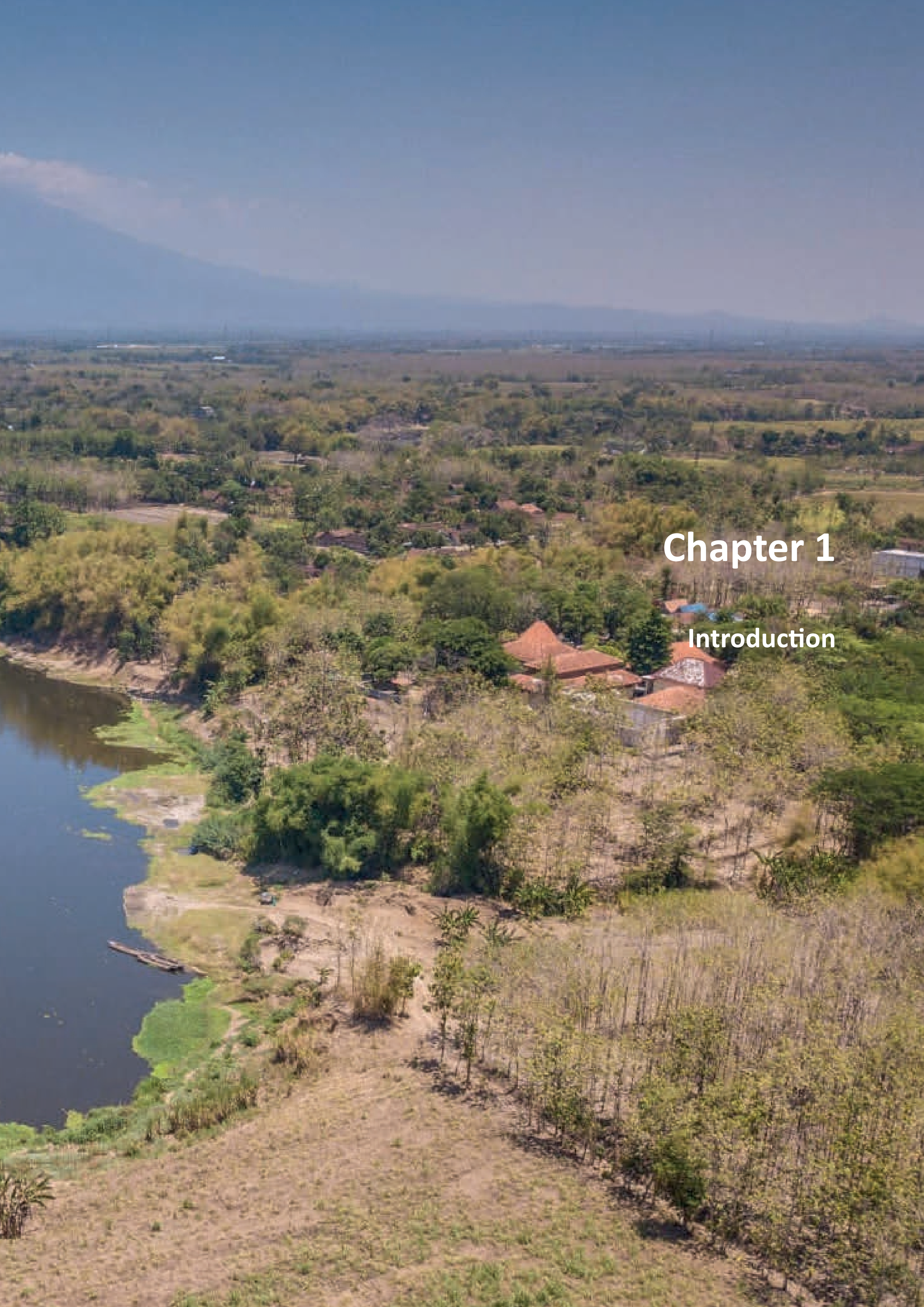
Drone view of the Solo at Trinil. The shallow zone is the historic excavation site of Dubois. The blue plastic cover is where a small part of the bone-bearing beds have remained. The museum is on the opposite bank (red roofs). The volcano Lawu lies in the distance. Picture by Eduard Pop.

Chapter 1

Introduction



CHAPTER 1

Introduction

1. Discovery of the Madura Strait site and research questions

Between 2010 and 2016, I worked as a geotechnical consultant for the Port of Surabaya (Indonesia), on the deepening and expansion of the harbour. The work involved the development of land reclamations along the coast. One of these reclamations was the BMS-site, a 100-ha artificial island in the Madura Strait, along the coast of Gresik **(Fig. 1A-B)**, which was planned to become a new cargo handling area. For its construction, we used sand that was extracted from the nearby seabed. In June 2015, the sand suppletion was completed. The island was left for dewatering and compaction, and was completely desolated. As I walked over the site, I noticed that the surface was strewn with bone fragments, beautifully mineralized and obviously old. I called local museums, but I could not find someone to investigate the material. Within a couple of months, further construction work would start. I decided to collect the bones, before they would be lost forever. It took me several lonely weeks to search its surface, collecting more than 6,000 fossils.

Fig. 1. A: The BMS island in the Madura Strait shortly after reclamation, June 2015. View to the east, toward Madura. **B:** Surface of the BMS-island during the dewatering stage. **C:** Ordering specimens in the Geological Museum Bandung.

The boxes with fossils had been piling up in my Surabaya office. In 2016, I sent everything to Iwan Kurniawan, vertebrate palaeontologist at the Geological Museum in Bandung. Together, we cleaned and numbered the material and did some provisional taxonomical ordering **(Fig. 1C)**. For a full analysis of the assemblage, we needed funding and a team of skilled zoologists, which would be hard to arrange. However, I liked the fossils and appreciated my time in the museum, so why wouldn't I do it myself? I only needed osteological training and supervision. Back home, I called Thijs van Kolfschoten, professor zooarchaeology at Leiden University, and yes, he was willing to receive me in his lab. Surrounded by mounted skeletons, I showed him pictures of my fossils. A bit to my surprise he said, 'Alright, let's do it!'.

So I became a PhD-student of Professor Van Kolfschoten. He introduced me to Professor José Joordens, an expert on hominin evolution. She was preparing a study of the Dubois excavation site in Trinil, eastern Java, and proposed to integrate my Madura Strait study into her larger project. Together, we formulated six research questions:

1. What is the species composition of the Madura Strait assemblage?

2. What is the taphonomic background of the assemblage?

3. What can we say of the vertebrate community structure and the former landscape?

4. Is there evidence of hominin presence?

5. What is the geological setting and age of fossiliferous deposits?

6. How does the Madura Strait site relate to the famous find sites of Java, in terms of stratigraphy, age and biostratigraphy?

The first four research questions are reasonably straightforward and may largely be based on a thorough analysis of the assemblage. Research question five is more difficult to answer due to the subsea setting of the setting of the site. However, as an engineer at the port of Surabaya, I had access to a wealth of unpublished geotechnical data, including dredging reports, sonar surveys and logs of deep drillings, which appeared to be of great help for reconstructing the geological build-up of the site. However, after reading through more than 100 years of palaeontological and geological publications of eastern Java, I realized that research question number six would be the most challenging.

2. The stratigraphy and biostratigraphy of eastern Java

The excavations of Dubois

Eastern Java is renowned for its rich Pleistocene vertebrate localities. The fossils had sparked the imagination of the Javanese for centuries. Large, petrified bones were regarded as the remains of giants from a mythical past, with bone beds as the remains of their battlefields. In the 1850's, the *Natuurkundige Vereeniging van Nederlandsch-Indië* gained interest in this matter. On their initiative, Junghuhn and Raden Saléh surveyed several fossil-rich sites. Both wrote short notes on their work (Saléh, 1867; Junghuhn, 1857). Later, Martin (1886) elaborated on their findings in more detail. He noted that the fossil species are similar to those from the Siwalik Hills of India, described by Falconer and Cautley (1846).

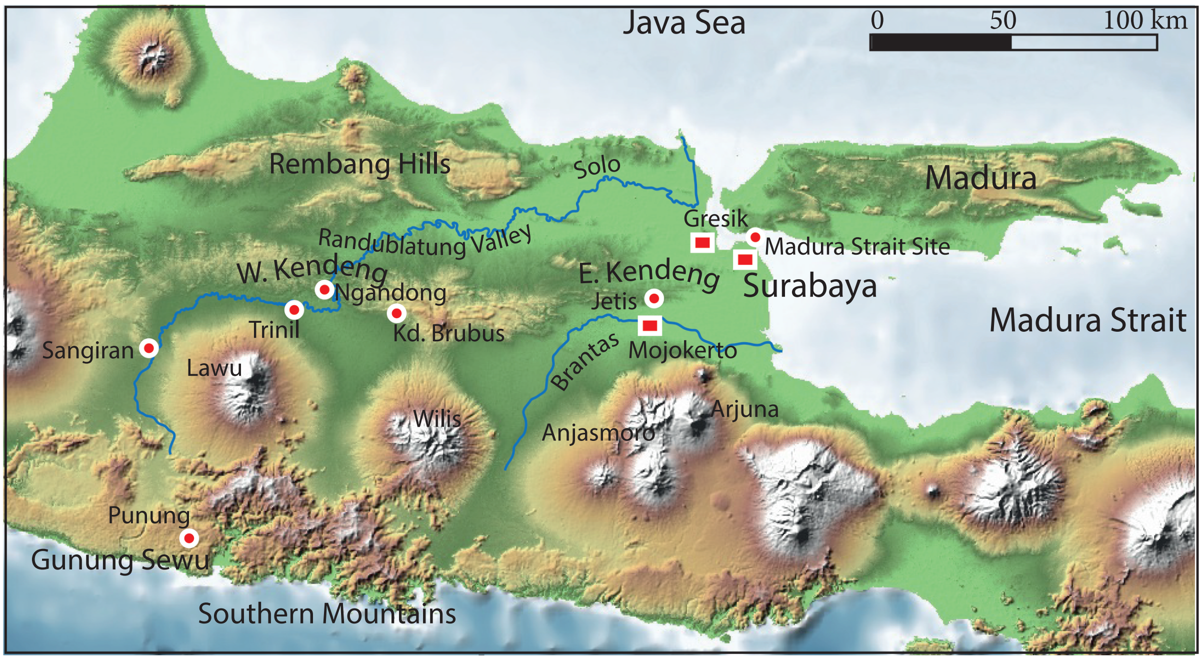


Fig. 2: Eastern Java, with the Madura Strait subsea site and on-land sites mentioned in the text. The Kali Glagah Section lies in Central-Java, outside the range of this map. The site has not been included in this study. Its significance for this study lies in the projection of its fossil fauna to the Sangiran site, as proposed by Leinders et al. (1985).

In the 1890s, Eugène Dubois came to Java on his quest for fossil evidence of a transitional form between apes and humans. He made large excavations in outcrops of fluvial sandstones, exposed in the gentle southern footslopes of the Kendeng Hills **(Fig. 2)**, collecting many thousands of vertebrate bones. His most productive site was Trinil, along the banks of the Solo River. Here, he found the hominin fossils that brought him fame (Dubois, 1894a). Originally described as *Pithecanthropus erectus*, the Trinil skullcap is nowadays regarded as the type specimen of *Homo erectus* (Pop et al., 2024; Mayr, 1950). Dubois referred to the fossil-bearing fluvial sandstones in this region as the Kendeng Schichten. He regarded the vertebrate fossils from these strata as one homogenous fauna, the Kendeng Fauna or the Trinil Fauna, with an estimated Late Pliocene or Early Pleistocene age (Dubois, 1907, 1895).

The vertebrate faunal stages of Von Koenigswald

Three decades later, relevant new vertebrate sites were discovered in the eastern part of the Kendeng Hills near Djetis and Mojokerto (Cosijn, 1932, 1931), in the Glagah Valley near Bumiayu (Van der Maarel, 1932) and in a terrace of the Solo near Ngandong (Ter Haar, 1934; Oppenoorth, 1932). The latter site yielded a spectacular discovery of 12 partial hominin crania and two hominin tibiae. Von Koenigswald (1935, 1934) analysed the fossil assemblages from these sites and found relevant differences in species composition, which he regarded as a reflection of the changing local vertebrate community over time. He defined several faunal stages for eastern Java **(Table 1)**, which he provisionally dated by faunal comparisons with dated fossil assemblages from the Asian mainland.

The stratigraphy of Duyfjes

Around this same period, the geologist Duyfjes was assigned to map the Kendeng Hills and its surroundings. He chose the ~1,500 m thick depositional record exposed in the eastern part of the hill range as his standard section, subdividing this section into four stratigraphic units **(Fig. 3)**. The base of the series consists of calcareous and diatomaceous mudstones, which he referred to as the Lower and Upper Kalibeng Formations, with an assumed Pliocene age. These are overlain by several hundred meters of marine clays, which Duyfjes named the Pucangan Formation, with an assumed Early Pleistocene age. The clays are overlain by deltaic sandstones and finally by fluvial sandstones and conglomerates, by Duyfjes regarded as a deltaic sequence. In the fluvial top of this sequence, Duyfjes resorted to Von Koenigswald's vertebrate biostratigraphy. He noted that the lower part of these fluvial strata yields vertebrate fossils of the Jetis Fauna, whereas the upper part contains the Trinil Fauna. This justified the incorporation of the basal fluvial strata into the Early Pleistocene Pucangan Formation. For the overlying fluvial strata he proposed a new unit: the Kabuh Formation, which he assumed to be of Middle Pleistocene age.

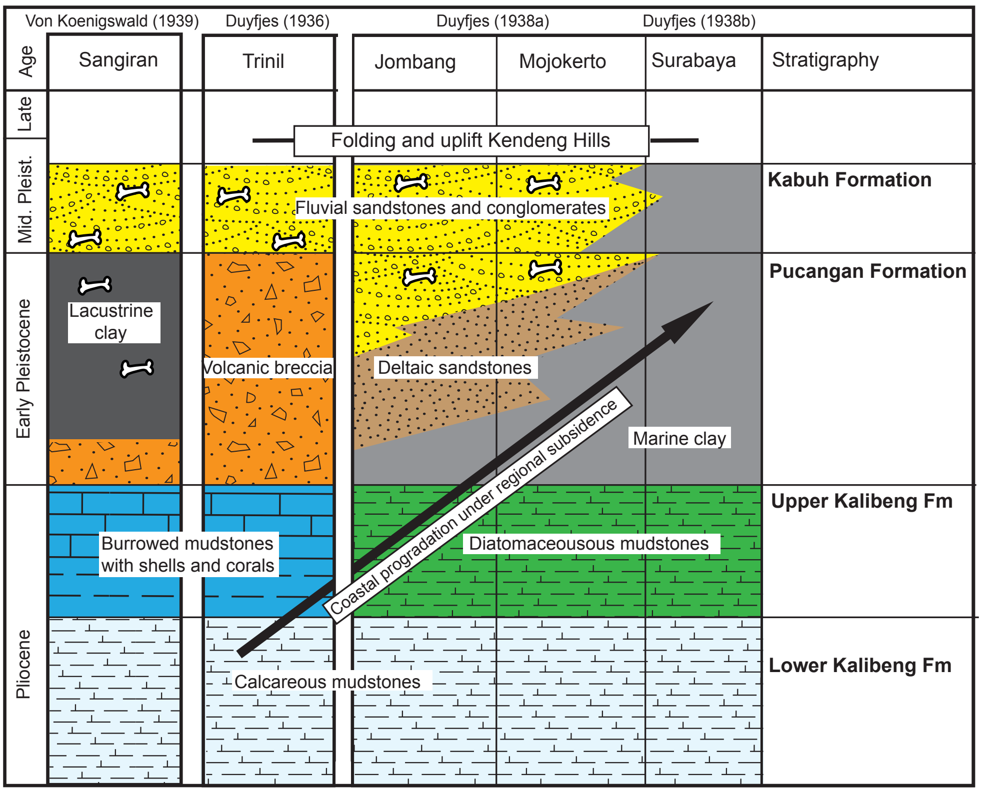


Fig. 3: Published and commonly accepted Pliocene and Pleistocene stratigraphy of eastern Java, for the Kendeng Hills and surroundings, based on Duyfjes (1936,1938a,b). For Sangiran, Duyfjes' units are also referred to under local names, as proposed by Itihara et al. (1985): Upper Kalibeng Fm = Puren Fm; Pucangan Fm = Sangiran Fm; Kabuh Fm = Bapang Fm.

As was normal in those days, Duyfjes' units have a chronostratigraphic significance. For his interpretations, he assumed that eastern Java, north of the volcanic arc, had been a subsiding basin throughout the Pliocene and the Early to Middle Pleistocene, and that this area had been subject to uninterrupted deposition in this period. He thus regarded his standard section as an uninterrupted regressive record, reflecting deltaic progradation driven by volcanic supply (Duyfjes, 1938a). He further assumed that the folding and uplift of the Kendeng Hills postdate this prolonged period of continuous deposition. This model allowed him to correlate his units over the hill range. If lithologies changed, he based his correlations on thickness measurements (he speaks of 'parallelization'), combining strata of different facies in the same unit, assuming that the strata have the same age and that the changing facies represent lateral changes of the depositional landscape.

Moving westwards, the Kendeng Hills consist almost entirely of folded calcareous mudstones, which Duyfjes referred to in his stratigraphic framework as the Lower Kalibeng Formation. Younger strata appear along the southern foothills, and consist of mollusc-bearing mudstones, volcanic breccias and fluvial sandstones. Duyfjes (1936) correlated these one by one with his eastern-Kendeng units **(Fig. 3)**. For the fluvial sandstones at the top of this series, he had an important palaeontological justification for this correlation: these sandstones yielded Dubois' Trinil Fauna and thus, by default, form the Middle Pleistocene Kabuh Formation. Von Koenigswald (1939) extended Duyfjes' correlations further westward to Sangiran. At this site, he described fluvial sandstones with a Trinil Fauna underlain by black clays with dispersed vertebrate fossils, which, according to his observations, belong to the Jetis Fauna. Within Duyfjes' chronostratigraphic framework, this implies that the clays are part of the Early Pleistocene Pucangan Formation.

The revised faunal stages of de Vos et al. and Sondaar

In the 1980s, De Vos et al. (1982) and Sondaar (1984) reviewed the faunal units of Von Koenigswald, through a re-inventory of museum collections and excavation reports. The authors concluded that Von Koenigswald's units had been based on mixed finds with a poorly documented provenance. They proposed a new vertebrate biostratigraphy based on fossil material with a well-described provenance **(Table 1)**. The Satir and Ci Saat Faunas form a subdivision of the previous Kali Glagah Fauna, distinguishing between fossil species from the base and the top of this Glagah River excavation site. The Trinil HK Fauna refers only to the fossil species of the *Haupt Knochenschicht* of Trinil, which forms the base of Dubois' excavation site. The authors introduced the Kedung Brubus Fauna as a new unit, containing the fossil species that Dubois excavated at this site, ca. 35 km east of Trinil. According to the authors, it records the arrival of new species and therefore must be younger than the Trinil HK Fauna. Remarkably, the authors recognized this Kedung Brubus Fauna also in the basal fluvial strata of the eastern Kendeng, around Mojokerto and Jetis. This implies an inverted age relationship compared to Von Koenigswald's previous interpretations, in which the fossils from Jetis were considered to be older than those from Trinil.

Von Koenigswald 1	Age range	Sondaar 1984	Age range
Sampoeng	Holocene	Wajak	>37.4 – 28.5 ka[1]
		Punung	128 – 118 ka[2]
Ngandong	Late Pleistocene	Ngandong	140 – 90 ka[3]
Trinil	Middle Pleistocene	Kedung Brubus	< 900 ka[4]
Djetis	Early Pleistocene	Trinil HK	~900 ka[4]
Kali Glagah	Late Pliocene	Ci Saat	1.3 - 0.9 Ma[4]
		Satir	< 1.9 Ma[4]

Table 1: Vertebrate biostratigraphy of eastern Java. Age ranges from: 1: Storm et al. (2013). 2: Westaway et al. (2007). 3: Rizal et al (2019). 4: Matsu'ura et al. (2022). All age ranges are based on dating studies of type localities, except Matsu'ura et al. (2022), which is based on dating studies of the Sangiran depositional record.

The Punung and Wajak Faunas are new units in the biostratigraphic framework of Sondaar (1984). They are based on fossil assemblages collected from caves in the Southern Mountains. The material from Punung was excavated by Von Koenigswald in the 1930s, who had regarded the fossils as a representant of the Trinil Fauna. Badoux (1959) and De Vos (1983) recognized the fossils as a younger assemblage. The Wajak Fauna is a cave fauna excavated by Dubois in the 1890s and described by Van den Brink (Van den Brink, 1982).

Leinders et al. (1985) projected most of the new faunal units onto the depositional record of Sangiran, referring to find lists from the excavations by Aimi and Aziz (1985). According to these authors, the lower part of the black clays contains the Satir Fauna, whereas the top contains the Ci Saat Fauna. Subsequently, the authors noted that the basal conglomerate of the overlying fluvial strata (the *Grenzbank*) contains the Trinil HK Fauna, whereas the overlying fluvial sandstones contain the fossil species of the Kedung Brubus Fauna. Referring to the available numerical ages of the Sangiran depositional record, Leinders et al. (1985) were able to provide age ranges for the faunal units. Van den Bergh et al. (2001) updated the species lists and the age ranges. **Table 1** offers a new update of these age ranges, based on recent dating studies.

Contradictions

The new faunal units have become widely accepted. Meanwhile, Duyfjes' Pucangan and Kabuh Formations, which are based on the older biostratigraphy of Von Koenigswald, have remained in use, obviously leading to contradicting ages.

This is not the only contradiction between the local biostratigraphy and the stratigraphy. Duyfjes' stratigraphy is based on continuous deposition, whereas De Vos et al. (1982), Sondaar (1984) and Van den Bergh et al. (2001) relate the faunal stages to alternating island conditions and mainland connections. In this model, island conditions are linked to highstands, causing isolation of species and endemism. These alternate with lowstand-related stages of mainland connection, allowing new species to migrate to Java. Today, these climate-related sea-level cycles are referred to in terms of Marine Isotope Stages (MIS). As a geologist, I would argue that it should be possible to trace this cyclicity in the depositional record. In fact, recognizing depositional cyclicity is likely easier than detecting subtle changes in the vertebrate fossil record.

This highlights a fundamental flaw in Duyfjes' stratigraphy: the model of continuous deposition is a grave oversimplification. Throughout the Pleistocene, eastern Java must have been subject to tectonism, climate change, intermittent eruptions, developing drainage systems and sea-level fluctuations. It is essential that we regard the Pleistocene deposits of Java as a record of this dynamic landscape. Instead of 'uninterrupted and laterally continuous', the depositional record is probably incomplete and laterally variable.

The Madura Strait coastline of Surabaya and the submerged shelf

In this respect, it is interesting to zoom in on the Surabaya coastline, with the new vertebrate locality below the seabed of the Madura Strait. Duyfjes (1938b) also correlated his units with the depositional record of this area. Deep drilling data had shown him that the local subsoil is made up of marine clays, overlying at, a depth of ~200 m, a substrate of calcareous mudstones. He concluded that the area has remained outside the maximum range of Pleistocene deltaic progradation. Holding on to his stratigraphic model, he assigned the lower half of the clays to the Pucangan Formation and the upper half to the Kabuh Formation, with a projected, invisible unit boundary, assumed to represent the Early to Middle Pleistocene boundary **(Fig. 3)**. This peculiar stratigraphic procedure is exemplary of Duyfjes' chronostratigraphic approach.

Interestingly, seismic surveys of the deeper Madura Strait and the Java Sea reveal a sub-seabed depositional record of stacked marine sequences separated by unconformities. This features a distinct signal of alternating highstands and lowstands. But where are the traces of these Pleistocene sea-level changes in the coastal record of Surabaya?

The subsiding Sunda Shelf

I had just started thinking about these issues when some relevant new publications came out. Husson et al. (2020) and Sarr et al. (2019) showed that the Pleistocene Sunda Shelf had not been a tectonically stable surface, as had commonly been assumed, but instead, has been subject to subsidence throughout most of the (Middle) Pleistocene. The authors presented a new landscape model, in which Sundaland was widely exposed during the Early Pleistocene. Middle Pleistocene subsidence gradually brought its surface within the range of sea-level fluctuations, resulting in progressive inundation of the lower reaches of the shelf during highstands **(Fig 4A-B)**. Only from MIS11 onward, this caused short periods of significant shelf-drowning, possibly leaving only the mountainous cores of Borneo, Sumatra and Java exposed. This is indeed what we see on the seismic profiles of the deeper parts of the shelf: a basal unconformity representing prolonged Early Pleistocene exposure, overlain by four or five marine cycles. Their preservation and stacking, with the basal unconformity today lying at a depth of ~ 200 m below sea level, can only be explained by shelf subsidence.

This new tectonic model of the Sunda Shelf places the Pleistocene geology and biogeography of Java in a completely new perspective. Rather than being an island with intermittent land connections, Java must have been part of continental Sundaland. Only from the second half of the Middle Pleistocene onward, there may have been several short island stages.

3. Geological investigations (2017 - 2021)

Research question 6 (*How does the Madura Strait site relate to the famous find sites of Java, in terms of stratigraphy, age and biostratigraphy?*) had been based on the idea that there is a well-defined and coherent stratigraphic and biostratigraphic framework for eastern Java. Unfortunately, this is not the case. The stratigraphy and biostratigraphy contradict each other, and neither system aligns with the offshore geology nor with the regional Sundaland landscape models.

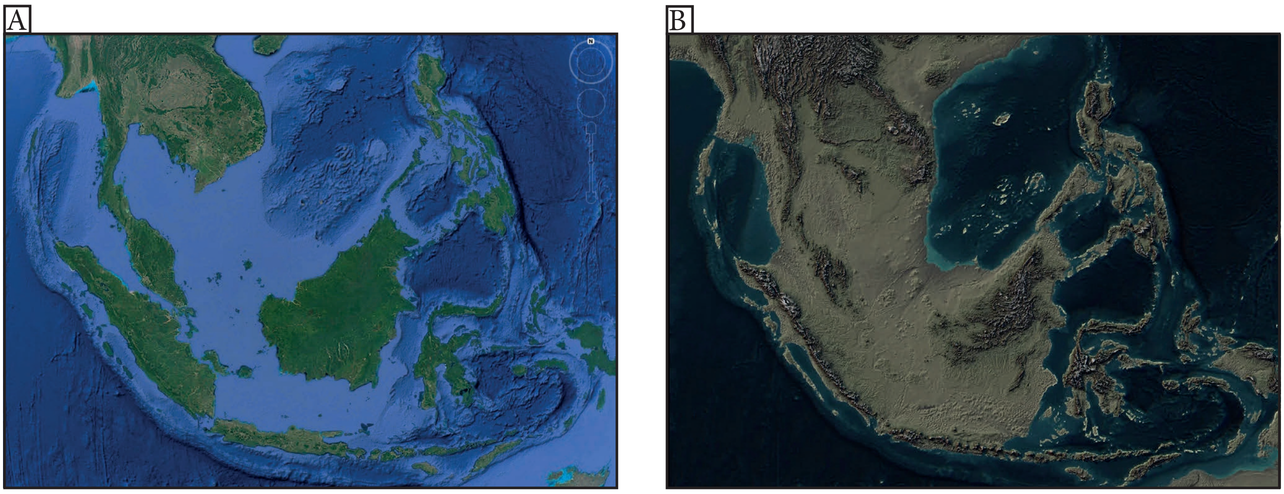


Fig. 4. A: The drowned Sunda Shelf, current situation, with the island of Java centrally in the south. Stages of large-scale shelf-drowning during highstands probably go back to MIS11. Map data: Google Earth. **B:** The exposed Sunda Shelf or Sundaland. The shelf was probably widely exposed during the Early Pleistocene and the beginning of the Middle Pleistocene. From MIS11 onward, this exposed state probably alternated with flooding stages. Map data: Vivid maps, coastlines of the ice age.

The problem is most urgent for the stratigraphy. We might very well say that Duyfjes' model of continuous deposition hinders our understanding of a more complex and possibly cyclic depositional record. Therefore, if I wanted to understand the position of the Madura Strait site and its fossil fauna within the larger (bio)stratigraphic framework of Java, I also had to work on the framework.

This would be a huge task, clearly beyond the scope of my studies as I had envisioned. On the other hand, the Madura Strait site offered an excellent starting point for such a broader stratigraphic study. The site, located along the Java coastline, has an intermediate position between the island and the shelf sea. If I could establish a stratigraphic connection between the onshore stratigraphy of Java and the offshore seismic stratigraphy of the deeper Madura Strait, this would not only explain the stratigraphic position of the new fossil locality, but this could also be used as a basis for a revised Pleistocene landscape model and possibly a revised stratigraphic framework for eastern Java.

'Why don't you come along?' Professor José Joordens and her counterpart Shinatria Adhityatama (ARKENAS, Jakarta) were preparing their fieldwork in Trinil, with a team of archaeologists and palaeontologists. Indeed, I had come to realize that I would not make progress with the Madura Strait site without investigating the onshore geology of Java. This was the beginning of what would become a huge detour in my studies. Between 2017 and 2019, I spent long months surveying the wider surroundings of Trinil, Jombang and Mojokerto. I followed the traces of the Brantas and the Solo rivers. I moved to Madura and mapped its southern coastline. During these months, I met Professor Tom Veldkamp, who came to visit the Trinil study team. Tom is an extraordinary geologist with a keen eye for fluvial responses to changing landscapes. His feedback has been of great help and an important motivation to continue with my geological reinterpretations.

4. Analyses of the Madura Strait assemblage (2022-2024)

The geological investigations and the subsequent publication of the results had put my work on the Madura Strait assemblage on hold. Moreover, the collection, stored at the Geological Museum in Bandung, had become inaccessible due to COVID travel restrictions.

By the end of 2022, I resumed my work on the fossils. It had taken some time, but by this point, I had a much better understanding of their age and geological context. Finally, I could truly analyse the Madura Strait assemblage and work on the first five research questions.

THESIS OUTLINE

The thesis comprises ten chapters: an introduction, eight published papers, and a synthesis. These are followed by summaries in both Dutch and English, acknowledgements, the author's CV and a list of references.

Chapters 2 to 6 of this thesis address the geology of eastern Java, chapters 7 to 9 concentrate on the Madura Strait assemblage. All of these chapters are stand-alone papers, which have been peer-reviewed and published in scientific journals. For all papers, I have been the main investigator with respect to research design, field investigation, fossil collecting, museum and laboratory analyses, manuscript writing and visualization, with of course important advice and support from the involved co-authors. Relevant exceptions are the OSL-datings, which were carried out by Tony Reimann and Alice Versendaal, and the foraminiferal determinations, which were carried out by Simon Troelstra.

The Supplementary Information of the papers has not been included in this thesis. For these documents, please refer to the (open-access) on-line publications.

Chapter 2: ***Plio-Pleistocene foraminiferal biostratigraphy of the eastern Kendeng Zone (Java, Indonesia): the Marmoyo and Sumberingin Sections***

Published in: Palaeogeography, Palaeoclimatology, Palaeoecology (2019)

The base of the eastern Kendeng exposures consists of calcareous and diatomaceous mudstones, which grade into marine clays. It represents a gradual transition from open marine conditions to coastal conditions, which is a crucial stage in the early development of eastern Java. In this chapter, we draw up a detailed foraminiferal biostratigraphy of this marine series, with an interpretation of its significance in terms of ages, depositional depths, regional landscapes, and the continuity of the depositional record.

This study was conducted in close cooperation with Simon Troelstra (Vrije Universiteit, Amsterdam), a leading expert on planktonic and benthic foraminifera.

Chapter 3: ***Hominin homelands of East Java: Revised stratigraphy and landscape reconstructions for Plio-Pleistocene Trinil***

Published in: Quaternary Science Reviews (2021)

The banks of the Solo around Trinil reveal a ~3 Ma record of coastal and terrestrial deposition. Numerous researchers have described this depositional record. In this chapter, we briefly summarise earlier depositional and stratigraphic models. We proceed with a thorough re-interpretation of the local strata, against a background of volcanism, tectonism, the development of the Solo drainage system, sea-level fluctuations and climate change. This results in a revised stratigraphic framework, representative of Trinil and its direct surroundings.

This chapter does not address the detailed build-up and numerical ages of the site excavated by Dubois, which were published in subsequent publications (Hilgen et al., 2023; Pop et al., 2023). In the synthesis of the thesis, I will go deeper into the spectacular results of these publications and their consequences for the interpretation of the Trinil fossil record.

Chapter 4: ***The eastern Kendeng Hills (Java, Indonesia) and the hominin-bearing beds of Mojokerto, a re-interpretation***

Published in: Quaternary Science Reviews (2022)

The top of the eastern Kendeng exposures consists of deltaic and fluvial strata. Duyfjes selected his reference sections for the Pucangan and Kabuh Formations in this area. Today, large sand quarries offer an unprecedented insight into this complex series.

We present a detailed description and a re-interpretation of the record against a background of volcanic supply, tectonism, ancient climates, the development of the Brantas drainage system, and sea-level fluctuations. Duyfjes' stratigraphy is revised and re-interpreted as a local framework, representative of the Jombang and Mojokerto exposures only.

The fluvial strata at the top of the eastern Kendeng exposures exhibit a cyclic build-up that can be correlated with the Middle Pleistocene sea-level sequences of the offshore Madura Strait.

Chapter 5: *Response to the comment* by Huffman and Zaim

Published in Quaternary Science Reviews (2023)

Our re-interpretation of the eastern Kendeng stratigraphy has important consequences for the age, landscape context and stratigraphic position of the *Homo erectus* child skull from Perning (Mojokerto). Our analysis was criticised by Huffman and Zaim, in a comment published in Quaternary Science Reviews in 2023. We gratefully accepted the offer by the journal to write a response.

Chapter 6: A late Middle Pleistocene lowstand valley of the Solo River on the Madura Strait seabed, geology and age of the first hominin locality of submerged Sundaland

Published in: Quaternary Environments and Humans (2025)

This chapter presents a detailed description of the coastal subsoil around Surabaya, down to a depth of ~100 m. We place the local coastal development in a larger landscape framework, by correlations with the coastal record of the nearby eastern Kendeng Hills, the upstream terraces of the Solo, and the off-shore geology of the deeper Madura Strait.

Chapter 7: First vertebrate faunal record from submerged Sundaland: the late Middle Pleistocene, hominin-bearing fauna of the Madura Strait

Published in: Quaternary Environments and Humans (2025)

Among the Madura Strait fossils, we identified 36 vertebrate species, divided into four taxonomical Classes and eleven Orders. This chapter provides an extensive and richly illustrated description of the assemblage, including measurements and specimen counts. The assemblage is interpreted in terms of vertebrate communities. A comparison is made with relevant fossil assemblages from Java, and the significance of the assemblage within the regional biogeography of Sundaland is discussed.

Chapter 8: The taphonomy of the Madura Strait fossil assemblage, a record of selective hunting and marrow processing by late Middle Pleistocene Sundaland hominins

Published in: Quaternary Environments and Humans (2025)

A systematic study of the taphonomy of the Madura Strait assemblage provides new insights into several relevant research questions, such as: What is the accumulation history of the fossils? Are OSL-ages of the sediment representative of the ages of the fossils? Can we translate the assemblage to living populations and ecosystems? And, are there signs of hominin foraging behavior?

Chapter 9: The late Middle Pleistocene *Homo erectus* of the Madura Strait, first hominin fossils from submerged Sundaland

Published in: Quaternary Environments and Humans (2025)

The Madura Strait assemblage contains two hominin cranial fragments: a frontal fragment and a parietal fragment. In this chapter, we provide a metric and morphological description of the two cranial fragments and compare them with Pleistocene hominin remains from Java, Flores and mainland Asia.

Chapter 10: The Pleistocene stratigraphy, biozonation and hominin chronology of eastern Java, a synthesis

The thesis concludes with a discussion and revision of the Pleistocene stratigraphy, biozonation and hominin chronology of eastern Java, against a larger ‘Sundaland’ landscape context.