Dating Trinil: establishing an age framework for the *Homo erectus* site Trinil on Java

Hilgen, S.[1], Joordens, J.C.A.[1,3,8], Adhityatama, S.[2], Pop, E.[1], Berghuis, H.[1,3], Yurnaldi, D.[4], Vonhof, H.[5], Bos, R.[6], Reimann, T.[7], Kuiper, K.[8], Krijgsman, W.[6], Sutisna, I.[4], Alink, G.[3], Albers, P.[1], Prasetyo, B.[2]

[1]Naturalis Biodiversity Center (NL), [2]Pusat Penelitian Arkeologi Nasional, Jakarta (IND), [3]Leiden University (NL), [4]Geology Museum, Bandung (IND), [5]Max Planck Institute for Chemistry, Mainz (DE) [6]Utrecht University (NL), [7]Wageningen University and Research (WUR), [8]VU Amsterdam (NL)

Introduction

In the 1890's, Eugène Dubois found the first *Homo erectus* fossils (femurs, skullcap, molars) in a bone bed along the Solo river in Trinil, Java[1]. His interpretation of these fossils has been subject to debate ever since. Criticism focused on underestimation of the stratigraphic complexity of the site and on taxonomic attribution of the modern-looking Femur I to *Homo erectus*. Questions about the age, stratigraphic complexity and fossil assemblage of the site remain unsolved until this day[2].

Fig. 1. left) Remnants of bone bed Dubois Site in 2019. right) Location of Trinil on Java in Indonesia.

Aim

Dubois' focus was on the *Hauptknochenschicht* (HK), the main bone bed, which he stated yielded the hominin and other fossils. The fluviatile HK unconformably overlies Pleistocene lahar (fine volcanic breccia) deposits with estimated ages of ~2-1 Ma. The sequence is capped by more recent alluvial river sediments.

So far, the age of the hominin skullcap is estimated to be ~0.9-0.7 Ma based on comparative morphology. However, sediments inside doublet *Pseudodon* shells from the HK layer were dated to ~0.5 +/- 0.1 Ma, using combined Ar/Ar and OSL dating[3].

We aim to provide a solid geochronological framework of deposits at Trinil. This will allow us to place Trinil in the broader framework of hominin evolution, dispersal and colonization of Southeast Asia, and boost the scientific value of the historical fossil collections.

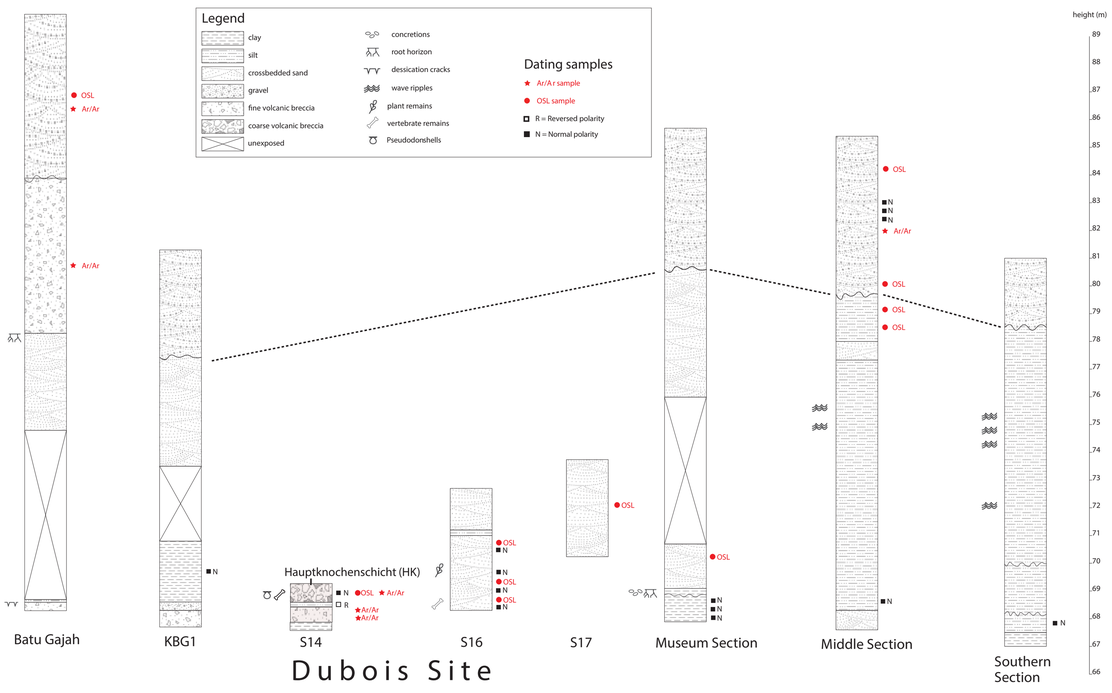

Fig. 2. Overview of stratigraphic sections along the Solo River (Fig. 3, photo below). The Batu Gajah section is stratigraphically below the fossil-bearing Dubois Site strata (S14 - S16), the Museum/Middle and Southern sections are situated above.

Fieldwork and test excavation

Small remaining outcrops of the fossil rich HK layer become available during low water levels of the Solo River. During fieldwork in 2018 we logged stratigraphic sections and took samples for dating (fig. 2, 3). We found that the HK is composed of coarse breccia (fluviatile volcanic-rich sediments) with intercalated silty lenses, grading laterally and upwards into cross-bedded sandstone. Test excavation showed that the HK contains abundant fossils including vertebrate bones and teeth, and *Pseudodon* shells, similar to those in the Dubois Collection.

Dating methods

Due to the complex depositional nature of the site, with reworking of (volcanic) sediments, we combine various dating methods:

1) $^{40}Ar/^{39}Ar$ dating is used to determine the ages of the youngest population of hornblende present in the sediments, providing a maximum age.

2) OSL dating is used to provide absolute ages up to ~0.4 Ma, and minimum ages beyond that range.

3) Innovative VSL dating may yield absolute ages older than ~0.4 Ma.

4) Magnetostratigraphy is applied to provide further constraints on the Ar/Ar and OSL/VSL ages.

5) U-series/ESR direct dating of fossil teeth may identify reworking.

Preliminary results and conclusions

We have been able to locate and sample the bone-bearing layers (HK) where Dubois collected hominin and other fossils. Our test excavation in HK yielded a typical "Trinil fauna". The fossil assemblage from HK appears to be a heterogeneous mix with respect to taphomomy and lithology: damaged and pitted fossils (like skullcap) derive from the coarse breccia, while complete and smooth fossils (like Femur I) derive from the cross-bedded sands. This may indicate a difference in age?

Preliminary Ar/Ar data confirm that the fine breccia unconformably underlying the HK is older than 1 Ma and younger than 2 Ma. OSL analysis of the HK coarse breccia shows that it is older than 0.4 Ma.

The polarity of the silt layer between fine breccia and HK coarse breccia is Reversed (and transitional) suggesting this layer is either > 0.79 Ma, or reflects a paleomagnetic event such as the Big Lost. The polarity of the HK and all layers above is Normal, indicating that these deposits are younger than 0.79 Ma.

The age of the HK coarse breccia (in S14) is constrained between 0.79 and 0.4 Ma, confirming previous dating based on sediments inside *Pseudodon* shells from the Dubois Collection in Naturalis. OSL analysis of bone-bearing cross-bedded sands of S16 is now ongoing. These ages will be crucial to determine possible heterogeneity in age of the HK.

References

[1]Dubois, E., 1894. Pithecanthropus Erectus, Eine Menschenähnliche Übergangsform aus Java. Landesdruckerei, 1894.

[2]Ruff, C.B., et al., 2015. Structure and composition of the Trinil femora: Functional and taxonomic implications. Journal of Human Evolution 80: 147–58.

[3]Joordens, J.C.A. et al., 2015. *Homo erectus* at Trinil on Java used shells for tool production and engraving. Nature 518: 228–31.