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Unraveling Java's Middle Pleistocene: the palaeoanthropological Sogen site (Indonesia) as a sedimentological and environmental archive

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Since Eugène Dubois' discovery of the first *Homo erectus* fossils at Trinil, Central and East Java have been recognized as a 'hominin hotspot' in Southeast Asia. The Early Pleistocene record, documenting the earliest known *Homo erectus* presence in the region, is well-studied, particularly in the fossil-rich Sangiran Dome, which offers laterally traceable exposures

that are analyzed through chronological and palaeoenvironmental methods.

In contrast, the Middle Pleistocene is less understood, relying largely on fragmented exposures along the northern margin of the Madiun Basin. Here, the riverine nature of the Early and Middle Pleistocene deposits that are eroded and exposed by the modern Solo River resulted in discontinuous and short stratigraphies, as e.g. at the famous Trinil site. The fragmented and complex nature of the Middle Pleistocene record complicates efforts to assess the impact of the period's high-amplitude global glacial-interglacial cycles on the local environment and their effects on local fauna. This includes *Homo erectus*, which persisted in the region until ~120 ka.

A new Pleistocene locality along the Solo River, Sogen, marks a significant step forward. Here, the Solo river exposes Early to Middle Pleistocene deposits over a distance of at least 1.3 km, comprising approximately 57 meters of inclined strata. The lower 20 meters are predominantly lahars, dated to the Early Pleistocene through correlation and palaeomagnetic data. The overlying 20 meters represent a low-energy flood-plain deltaic environment with fining-upward sequences capped by paleosols with carbonate concretions and vertic properties, indicating seasonally dry conditions. Fossils, though sparse overall, are concentrated at the paleosol interfaces and overlying carbonate-rich layers. These include Bovidae, Cervidae, Suidae, Proboscidea, Crocodylidae, Gavialidae, and aquatic fauna such as catfish, freshwater gastropods, and bivalves. A hominin parietal, possibly from *Homo erectus*, was found in secondary position and likely derives from one of these fossiliferous intervals. Stone artifacts from this period on Java are rare, but were found too. The upper 17 meters suggest a shift to wetter conditions, with conglomerates and lake deposits tentatively correlated with OIS 11 or 9. These inclined deposits are capped horizontally by Late Pleistocene terrace deposits.

The sedimentary cycles observed in the middle, fossiliferous part of the section raise questions about their origin. Are they autogenic, resulting from lateral shifts in fluvial systems and/or tectonic activity within the basin? Or are they allogenic, driven by glacial-interglacial eustatic sea-level cycles? If allogenic, what is the relationship between specific lithologies (and pedogenesis) and glacial-interglacial periods? Finally, what caused the apparent transition from relatively dry to wetter conditions in the upper section?

To address these questions, we present chronological, stable isotope, and palaeoenvironmental data, and consider the implications for the fossil and archaeological evidence contained in this record. We also examine the limitations of basin-margin context for interpreting hominin behavior and environmental conditions, including the effects of discontinuous sedimentation on fossil and artifact preservation and representation, as well as the lithology-dependent preservation of palaeoenvironmental proxies. Finally, we consider future directions for research, specifically regarding the scientific potential of deeper facies of the Madiun Basin.

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