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Pedo-sedimentary dynamics of the Sangiran dome hominid bearing layers (Early to Middle Pleistocene, central Java, Indonesia): A palaeopedological approach for reconstructing 'Pithecanthropus' (Javanese *Homo erectus*) palaeoenvironment

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ABSTRACT

Fossil soils and pedosediments displayed in Quaternary fossil-bearing formations are an important proxy to describe the evolution of climates and environments. Through a study of the palaeosols in the Sangiran dome, a rich hominid-bearing site of central Java (Indonesia), we characterized their record of terrestrialization through regional volcano–tectonic activity and describe palaeoenvironments colonized by hominids.

The thick sedimentary formations of the Sangiran dome are known to reflect the geological evolution of Central Java from the beginning of the Quaternary until the Middle Pleistocene. *Homo erectus* fossils are found in the ca. 1.5 Ma Sangiran (or Pucangan) Formation up to the ca.0.8 Ma Bapang (or Kabuh) Formation.

This study combines field surveying, a micromorphological approach, and palynological data. The characterization of successive pedoclimatic contexts and toposequences helps in reconstruction of the local palaeogeography and climates (mainly influenced by south-eastern Asia monsoon cycles) that predominated during periods of palaeosol development.

The base of the Upper Sangiran member displays the earliest fully continental deposits, corresponding to the development of an open landscape with wide coastal marshes and mangroves, with a rain forest cover on the hinterland. Higher in the stratigraphic succession, environments reflect a contrasting seasonal climate with a long dry season alternating with periods of more humid palustrine conditions.

A further tectonic uplift of the hill ranges bordering the Solo depression (in which the Sangiran dome is located) resulted in topographic changes and increasing palaeogeographic heterogeneity, and therefore of soilscapes. From the Upper Sangiran member to the Bapang lower member, erosion of soil cover caused the accumulation of pedosediments in topographic depressions. These pedosedimentary deposits as well as volcanic ash accumulations were sudden and sometimes bury palaeoreliefs (catena, gilgai). Recurrent aridity proxies occur in the palaeosols found in the Bapang formation (which yielded the most numerous hominid fossils), reflecting a long dry season and an open vegetation landscape.

1. Introduction

On Java Island, the hominid-bearing sites of Mojokerto, Trinil, Sambungmacan and Sangiran offer fossiliferous sedimentary formations recounting some of the most important pages of human evolution history and of related dispersals during the Early and Middle Pleistocene. This is also the history of first Islanders, held on an archipelago reachable via landbridges during low sea levels

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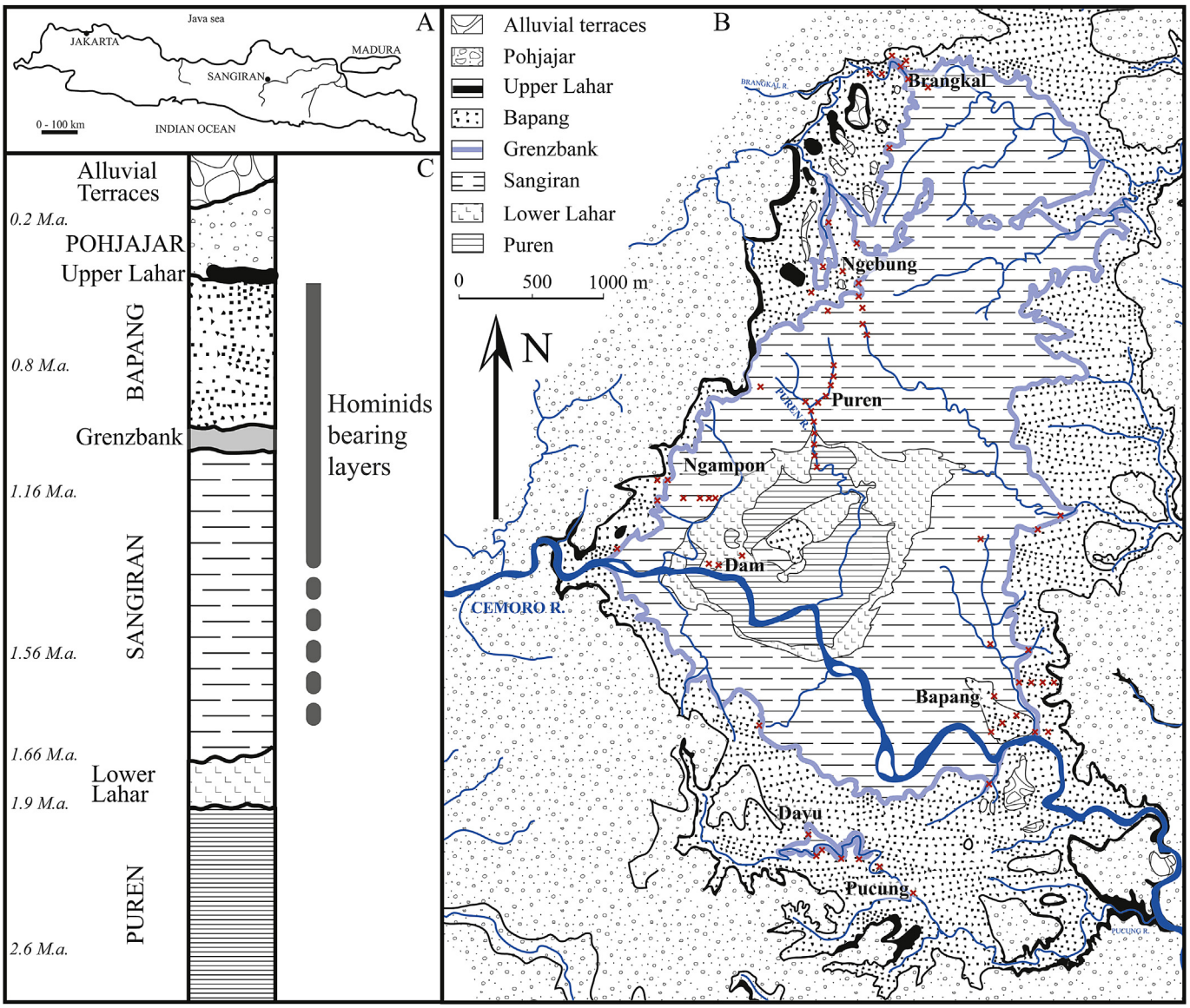

Fig. 1. A – Location of the Sangiran dome on Java Island. B – Geological map of Sangiran dome. The crosses indicate the main geological sections investigated. C – Stratigraphic log, modified from Watanabe and Kadar (1985); Sémah et al. (1992). This figure presents the major geological units (Puren, Sangiran, Grenzbank, Bapang, Pohjajar) used by Von Koenigswald (1940) and redefined by Watanabe and Kadar (1985) and the radiochronological dates (Suzuki and Wikarno, 1982; Sémah et al., 2000; Bettis III et al., 2004).

punctuating the last two million years (see for example, Sémah et al., 2010).

This area is of high interest for: i) its location, the "Indo-Pacific warm pool" at the Equator for which information on palaeoclimatic and palaeoenvironmental fluctuations during Pleistocene is scarce, ii) high aggradation rates from volcanic and sedimentary processes, burying successive coastal to continental landscapes through lower and middle Pleistocene times, iii) the presence in several sequences of human fossils and artifacts, and iv) the accessibility to surveying, thanks to upper Pleistocene neotectonic dome structures currently under erosion.

The thick volcano-sedimentary formations in the area of the Sangiran dome accumulated during the entire Quaternary period and represent a succession of environments, from coastal marine to various different terrestrial settings (Watanabe and Kadar, 1985). They contain more than 150 *Homo erectus* fossils in different stratigraphic positions, within sedimentary sequences with frequent intercalated palaeosols (Bettis III et al., 2009; Brasseur, 2009) whose pedogenetic pathways, diversity and environmental dynamics were still to be characterized. Using palaeosol characterization, the objectives are: i) to describe palaeosol diversity and spatial distribution, ii) to infer pedoclimates and pedo-sedimentary dynamics, and iii) to get a new insight of regional environmental and climatic changes coeval with hominid colonization of the Sangiran area.

2. Geological and archaeological frame of Sangiran dome

The Sangiran dome is located in the central part of Java volcanic island, 12–20 km north of Surakarta city, in the wide sedimentary basin of the Solo axial depression (Fig. 1). This depression is surrounded by the Merapi, Merbabu, and Lawu stratovolcanoes.

During the Upper Pleistocene, a regional tectonic stage triggered the development of several dome structures (Gesi, Bringinan, Onto, Klego, Gemolong and Sangiran) on the NW flanks of Lawu volcano. Their position around the base of this volcano, noticed by Van