LOWER PLEISTOCENE MARINE- CONTINENTAL TRANSITIONAL BEDS IN THE SOLO DEPRESSION AND THEIR RELATION TO THE ENVIRONMENT OF THE PUCANGAN HOMINIDS

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INTRODUCTION

The best known Plio-Pleistocene section within the Solo depression is that of the Sangiran dome, the famous paleoanthropological site. But the coastal and continental facies of the Sangiran series are subject to rapid horizontal changes (F. Sémah 1986). A stratigraphical section like that of Sangiran has only limited regional value. In order to understand the palaeoenvironmental changes within the Solo depression as a whole we have also to look at other neighbouring sites.

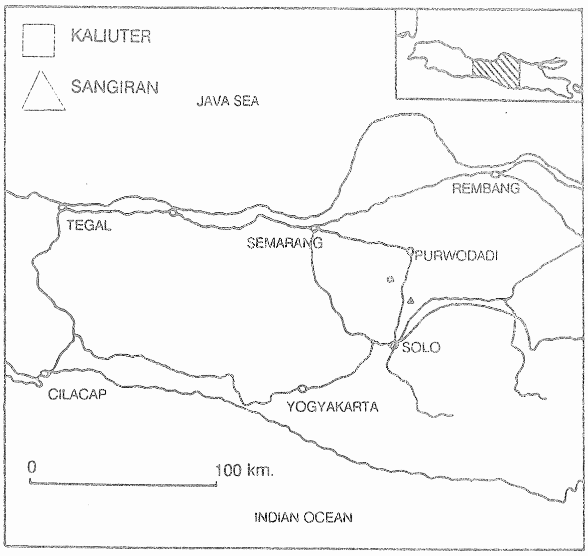

FIGURE 1: THE SITES OF KALIUTER AND SANGIRAN

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The stratigraphical section of Kaliuter (van Es 1931; Djubiantono 1986) is situated about 10 km north of Sangiran on the southern flank of the Kendeng Hills (Fig. 1). With respect to Sangiran it presents a complementary record of sedimentary environments in the northern part of the Solo depression during the last two million years.

STRATIGRAPHICAL FEATURES

The Kaliuter section (Fig. 2) comprises two main parts. Following our own field observations we shall describe these as the *folded series* and the *unfolded series*. The folded series shows a southward dip, with an angle between 30° in the lower part and 10° in the upper. It begins with the Mio-Pliocene *Globigerina* marls of the Lower Kalibeng formation. This is immediately followed by regressive facies:

Sandy and clayey limestones: in the lower part of the section we find sandy clays with many terrestrial materials like charcoal, leaves, seeds and amber, together with molluscs and fish bones. Overlying the Mio-Pliocene *Globigerina* marls, these facies point to a shallower environment and could mark the first regressive influence in the Solo depression.

Banked sandy marls: higher there are intercalations between soft, clayey layers and harder, limy banks. These show a high content of limy sand with a lot of sea urchin fossils. We can observe in this part of the section a thin layer of cinerite. The deposits seem to have originated in the probably already emerged oldest Kendeng limestones.

Mollusc-bearing sands: the uppermost part of this sequence locally consists of a layer of almost pure volcanic sand with many littoral molluscs. This means that the present volcanic arc was probably already active.

Blue clays: abruptly the facies changes to plastic blue clays. These thick layers become more and more sandy towards the top, with several intercalations of cinerite.

Deltaic conglomerate: above the blue clays is a deltaic conglomerate which contains a lot of fluviatile pebbles mixed together with littoral fossils like molluscs (*Ostrea, Pecten*), corals and *Balanus*. Vertebrate fossils first appear in this layer, most of them as small rolled river-laid fragments.

Marls and clays: the following layers comprise sandy marls with very high clay content. They pass upwards into a new sequence of pure blue clays, interrupted by beds containing fossil woods and coastal molluscs.

Balanus limestones and sands: the uppermost part of the folded series comprises coastal *Balanus* limestones and limy sandy conglomerates, sometimes with vertebrate fossils.

The unfolded series uncomformably covers this part of the section. They begin with a transitional sequence which comprises coastal dunes, tuffaceous and lignitic layers. The latter show erratic dips and synsedimentary smaller faults, pointing to a gentle folding phase. Then we find horizontal fluviatile sandstones, tuff layers and coarse volcanic

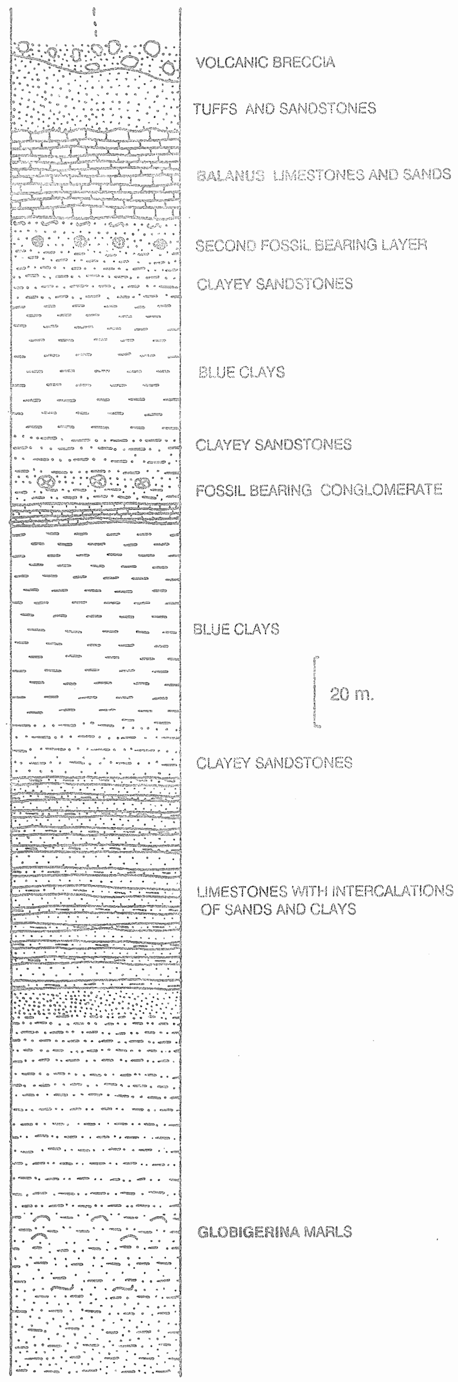

FIGURE 2: SYNTHETIC SECTION ALONG THE KALIUTER RIVER

breccias. Several rich paleontological sites have been recorded at the base of this horizontal series.

CHRONOLOGY

The bulk of this section had been already described in a schematic way by the Dutch geologist van Es in the early 1930s (van Es 1931). Impressed by the mainly marine character of the folded series and using his molluscan biostratigraphy he correlated it directly with what were later to be called the Upper Kalibeng layers, that is the lowermost part of the Sangiran section, dating back to the Upper Pliocene. Van Es attributed the unfolded series to the whole Pleistocene part of the Sangiran section (that is, the Pucangan and Kabuh units).

This interpretation is somewhat amazing, as it would imply an almost pure volcanic facies for the Pucangan-aged layers at Kaliuter. However, we know that the Pucangan layers have a swamp-like sedimentary aspect in the Sangiran and Onto domes in that part of the Solo zone which is situated west of the Lawu volcano. Our research in the area since 1984 contradicts several points of van Es' interpretation.

The first important discovery was that of land mammals in the deltaic conglomerate which occupies the middle of the folded series: remains of *Stegodon*, bovids, rhinoceros, cervids and suids, together with swamp and sea vertebrates like crocodiles, tortoises and fishes. These fossils leads to two alternative hypotheses. The first is that the Solo depression was already colonized by mammals during the Upper Kalibeng stage. The second is that the studied layers, while showing a typical Upper Kalibeng facies, in reality have nothing to do with the Sangiran Kalibeng layers.

Extensive stratigraphical survey and sampling along the Kaliuter river has been undertaken in order to know the precise age of the fossil-bearing layers. Paleomagnetic analysis gives the following results (Fig. 3):

1. The unfolded series is normal and definitely postdates the Brunhes-Matuyama boundary; there is no possibility that this series could cover the whole of the Pleistocene.

2. Two Potassium-Argon dating attempts were carried out by Y. Bandet in Toulouse on volcanic pebbles embedded in the breccias of the unfolded series. One gave a zero age and the other an age of 0.51±0.18 million years. We may thus infer that the deposition of the breccias was synchronous with the great activity phase of the larger volcanoes within the Solo zone. This activity was already paroxysmal during the Middle Pleistocene, as evidenced by the volcano-sedimentary facies of the Kabuh layers in Sangiran, and lasted until the Upper Pleistocene. The reworking of older sedimentary structures allowed Middle Pleistocene-aged pebbles to become mixed with more recent ones.

3. The top of the folded series, of normal polarity, seems to belong also to the Brunhes chron.

4. Going down the section, the reversed polarities which probably indicate the top of the Matuyama chron appear several tens of metres above the fossil-bearing deltaic conglomerate. Near this conglomerate the measurements point to a rather short normal event, while below it the magnetic polarity appears to be continuously reversed in the blue clays. Finally, the upper part of the banked marls/limestone has a normal polarity.

We have thus two hypotheses for the age of the fossiliferous conglomerate. It could belong to the Jaramillo event (0.97 to 0.9 m.y.), in which case the normal beds situated lower down would represent the Olduvai event. Or the conglomerate itself could date back to the Olduvai event (1.67-1.87 m.y.), in which case the lower normal beds would represent the Gauss chron. Both hypotheses are consistent with the occurrence of a long reversed period in the blue clays.

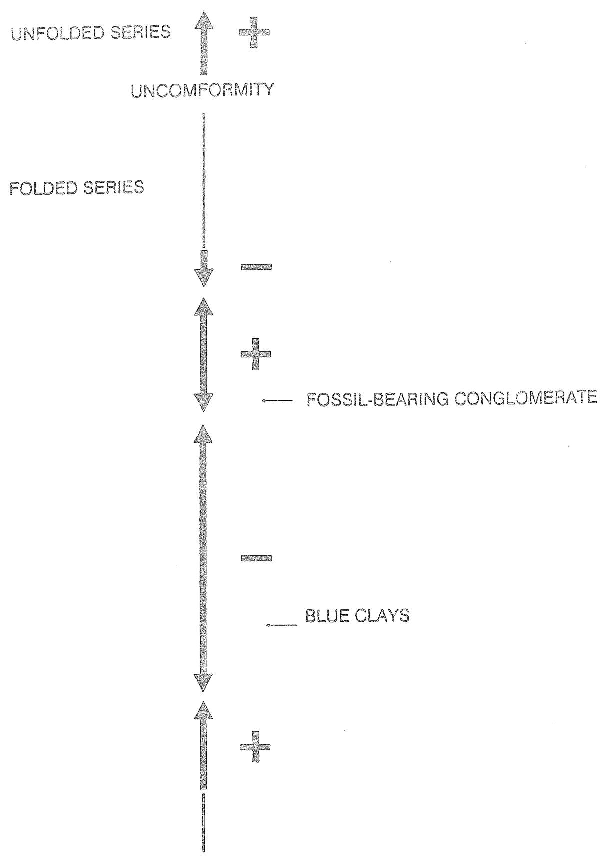

FIGURE 3: MAGNETIC POLARITY OF THE KALIUTER SERIES

The first Potassium-Argon dating attempts on several andesitic pebbles from the conglomerate gave a Miocene age (about 12 m.y.), except for one sample which gave 0.9 m.y., but with a very large error range. Absolute dating, while favouring the Jaramillo hypothesis, is therefore not yet fully conclusive.

Provisionally, we still choose a Jaramillo age for the fossil-bearing deltaic conglomeratic horizon. Such a choice is reinforced by two observations. Firstly, the thickness of the reversed layers above the conglomerate does not seem compatible with the long post-Olduvai reversed period. Secondly, the presence of thick volcanic sands deposited in a marine environment near the lower reversal, near the base of the blue clays, could point to the volcanic stage evidenced at the boundary between the Kalibeng and Pucangan units at Sangiran, where it is marked by volcanic breccias and lahars *c*.1.7 m.y. Indeed, this volcanic activity stage dammed up the lagoon and helped the establishment of regressive conditions.

In both cases, the results point to a non-Kalibeng age for the fossil-bearing conglomerate and for the shallow marine marls and clays found higher. The marine influence was thus stronger in the Kaliuter area when the Pucangan clays, of more continental type, were being deposited in Sangiran.

CONCLUSION

During the Lower Pleistocene a lagoon extended northwards along the foot of the Kendeng Hills and a large swamp formed in the Sangiran area. In the Sangiran Pucangan layers there are traces of several small marine ingressions in the form of estuarine diatomites and yellow clays with mangrove-like pollen (A.M. Sémah 1986). The blue clays of Kaliuter and the black Pucangan clays of Sangiran, deposited at the same time, seem to be two different sedimentary facies of the same original material, that is the soil which covered the emergent volcanic reliefs. The greater limestone content of the Kaliuter sediments probably originated from the closer Kendeng hills, especially the limestone pebbles of the conglomerate which give us a picture of the small hills of the Kendeng zone during the Lower Pleistocene. The cinerite layers of Kaliuter might be correlated with the tuffaceous banks which we find in the Sangiran Pucangan layers.

It seems that the folding phase we find near the transitional beds (approximately 0.7 m.y.) represents the last major uplift of the Kendeng hills at the end of the Lower Pleistocene. In Sangiran this resulted in the deposition of the so-called *Grenzbank* conglomerate. In Kaliuter we find coastal deposits like beach dunes whose structure has been disturbed by tectonics.

Such preliminary data confirm that the reconstruction of the natural environment in which *Pithecanthropus* lived has to be studied on a regional level, and not only from the sites in which the fossils were actually found. In fact, we know that most of the human and other land mammal fossils discovered in the Sangiran dome were transported there from sources in higher terrestrial regions like the proto-Kendeng hills. Any section showing a relation with fully emergent relief, like that of Kaliuter, is therefore of great interest for a better understanding of the older colonization of Central and Eastern Java.

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