

A new, richly fossiliferous member comprised of tidal deposits in the Upper Cretaceous Maevarano Formation, northwestern Madagascar



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ABSTRACT

A new member of the Upper Cretaceous (Maastrichtian) Maevarano Formation is proposed to accommodate a distinctive succession of strata exposed along the shores of Lac Kinkony in northwestern Madagascar. The new Lac Kinkony Member overlies fully terrestrial sandstones of the Anembalemba Member of the Maevarano Formation, and is capped by marine dolostones of the Berivotra Formation. In the stratotype section, the base of the Lac Kinkony Member consists of siltstone interbeds that host networks of *Ophiomorpha*. Siltstone facies pass up-section to distinctive white sandstones packed with dolomitic mud matrix that exhibit rhythmic clay drapes, flaser and wavy bedding, and oppositely-oriented ripples developed on the toes of larger foresets. Thin flat interbeds of microgranular dolostone and claystone comprise the uppermost facies of the Lac Kinkony Member, and a laterally traceable ravinement bed mantled by cobbles of rounded dolostone marks the contact with the superjacent Berivotra Formation. Deposits of the Lac Kinkony Member are interpreted to represent siliciclastic and carbonate tidal flats dissected by tidally-influenced rivers. Vertebrate fossils are abundantly preserved in these coastal deposits, and are locally concentrated in microfossil bonebeds that have the potential to yield thousands of small identifiable specimens. In addition to many taxa already known from the Maevarano Formation, the Lac Kinkony Member has yielded a wealth of phylloodontid albuloid fish skull elements, the distal humerus of a new frog taxon, five vertebrae representing two new snakes, a tooth of a possible dromaeosaurid, and a complete skull of a new mammal. The discovery of several new vertebrate taxa from this new member reflects the fact that it samples a previously unsampled near-shore, peritidal paleoenvironment in the Late Cretaceous of Madagascar.

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1. Introduction

The Maevarano Formation is a spectacularly fossiliferous sedimentary deposit of Late Cretaceous (Maastrichtian) age that crops out in the Mahajanga Basin of northwestern Madagascar (Fig. 1). Ongoing studies of the formation's copious and exquisitely preserved vertebrate fossils have revealed key insights into the

evolutionary history of Madagascar's biota (e.g., Krause et al., 2006), and advanced our understanding of the paleobiogeography of Madagascar as an island continent (e.g., Samonds et al., 2012) and of Gondwana as a whole (e.g., Ali and Krause, 2011). Besairie (1938, 1972) originally identified the "série de Maevarano" during his wide-ranging reconnaissance of the geology of Madagascar, noting in particular the unit's terrestrial affinities and abundant vertebrate fossils. He did not, however, describe any surface localities in detail, and thus the precise nature of Besairie's "série de Maevarano" and its relations to surrounding sedimentary units remained rather obscure for decades. Rogers et al. (2000) subsequently described a stratotype for the Maevarano Formation in the central Mahajanga Basin based on outcrops in the vicinity of the village of Berivotra, which lies ~35 km southeast of the port city of Mahajanga.

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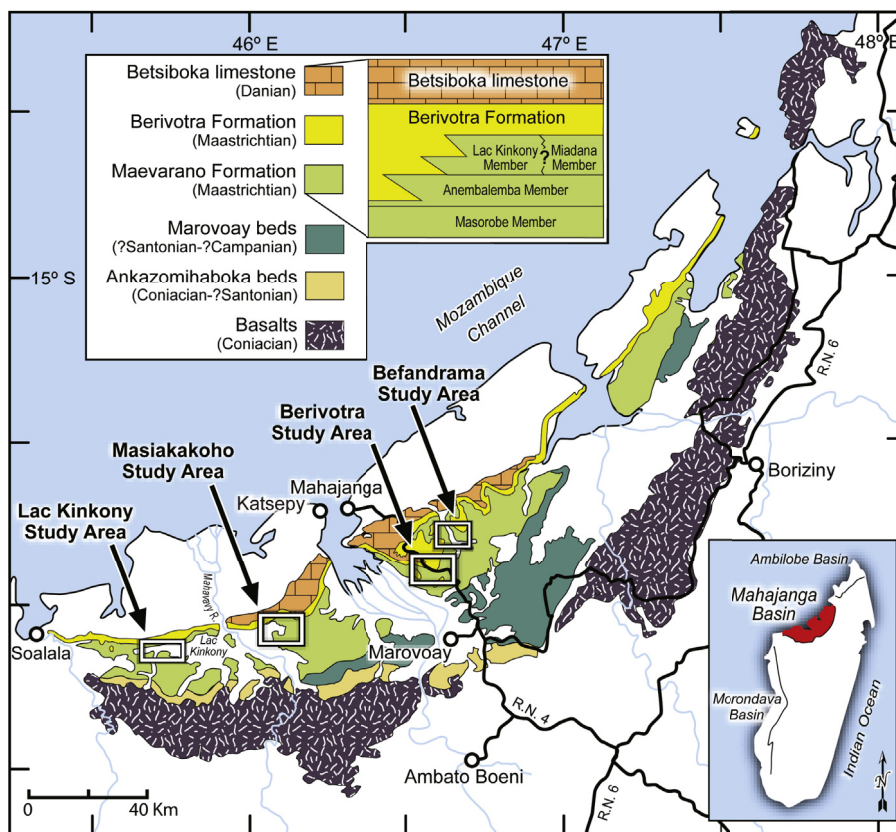


Fig. 1. Outcrop map of Upper Cretaceous and Paleogene strata in the Mahajanga Basin of northwestern Madagascar, with location of Lac Kinkony, Masiakakoho, Berivotra, and Befandrama study areas. Top inset illustrates stratigraphic relations among the four members of the Maevarano Formation and marine facies of the Berivotra Formation.

Updated descriptions of the Maevarano Formation's sedimentology and lithostratigraphy, coupled with refined reconstructions of the unit's depositional environments and regional stratigraphic relations (Rogers et al., 2000; Rogers, 2005), have led to a better overall understanding of the formation in the context of Madagascar's Cretaceous rock record, and facilitated paleontological and taphonomical research in the Mahajanga Basin.

In this report we focus on recently explored exposures of the Maevarano Formation in the vicinity of a large body of water (~22 km long in E–W axis) known as Lac Kinkony, the western edge of which is located approximately 100 km to the west-southwest of the Berivotra Study Area. We have previously designated this region as the Lac Kinkony Study Area (e.g., Gaffney et al., 2009, fig. 1). Our investigation centers on outcrops that rim the northwestern margin of Lac Kinkony, near the village of Analalava (Antongomena on more recent maps). Exposures to the west of the lake along the main route (a dirt track) to Soalala from Katsepy were also studied to gain a better appreciation of the regional stratigraphy and paleontology (Fig. 2).

Some of the rocks exposed in the Lac Kinkony Study Area can be relegated to existing members of the Maevarano Formation. For example, mottled red beds of the Masorobe Member are present in the outcrop belt at Lac Kinkony, as are fossil-rich deposits of the superjacent Anembalemba Member. Marine claystones and marlstones of the overlying Berivotra Formation also crop out along the escarpment that flanks the northwestern shore of Lac Kinkony. There are also strata in the Lac Kinkony Study Area that are decidedly distinct lithologically from known deposits of the Maevarano Formation further to the east. These strata, which are intercalated between the Anembalemba Member and the Berivotra Formation, are herein described and formalized as the Lac Kinkony

Member, a new member of the Maevarano Formation. Rocks of the Lac Kinkony Member represent a heretofore unrecognized near-shore facies tract of the Maevarano Formation, and have yielded a wealth of vertebrate fossils, including very well preserved and articulated material, that significantly augment and, in part, complement existing collections.

2. Geologic setting

2.1. Stratigraphy of the Maevarano Formation

Four sedimentary units of Late Cretaceous age have traditionally been distinguished above widespread flood basalts within the Mahajanga Basin (Perrier de la Bâthie, 1919, 1921; Besairie, 1938, 1972; Boast and Nairn, 1982; Storey et al., 1995, 1997; Torsvik et al., 1998, 2001). Besairie (1972) described these four units as distinct lithostratigraphic entities or "series," but provided little detail in relation to sedimentological composition, contacts, or regional trends in thickness or facies distribution. He referred to the basal unit as the "série d'Ankazomihaboka," and described it as consisting of tan and brown cross-bedded sandstones and claystones of terrestrial origin. More recent work in the Ankazomihaboka beds (e.g., Curry, 1997; Gottfried et al., 2004) confirms previous interpretations of a terrestrial depositional setting, and further indicates that this unit includes coarse-grained, mineralogically immature sheet sandstone bodies that represent deposits of large fluvial systems with, at least locally, northeast trending paleocurrents. These fluvial deposits, which preserve isolated vertebrate fossils and abundant fossil wood, are intercalated with finer-grained paleosols and clay pebble conglomerates that also yield vertebrate and plant fossils (Perrier de la Bâthie, 1921; Priem, 1924; Piveteau, 1926; Curry, 1997; Gottfried

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