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Angolan fossil vertebrates and geotectonic influences inform Cretaceous and Cenozoic paleoenvironments of Africa

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Africa is unique among Gondwana continents in having a 12° northward drift and 45° rotation between the Early Cretaceous and the Late Paleogene (120-24 Ma) directly related to the opening and growth of the South Atlantic Ocean. The vertebrate fossil record of Angola elucidates the large-scale environmental consequences of the tectonic history of Africa, which straddles the arid descending limbs of both the northern and southern hemisphere Hadley cells. This paleogeographic legacy is apparent in Africa today. Clay mineralogy and stable isotope analyses of paleosols indicate arid conditions for the Early Cretaceous Congo Basin, suggesting a low productivity environment for the region including northeastern Angola, which preserves the tracks of dinosaurs, crocodylomorphs, and unexpectedly large mammals at a locality that falls on the Lucapa Fault Zone, which can be traced to the Mid-Atlantic Ridge. At a maximum of 117 Ma for the locality, the South Atlantic was on the order of 500 km wide and biogeographic affinity with South America was probably closer than at any subsequent interval. The Turonian through Maastrichtian record of Angola is dominated by mosasaurs, plesiosaurs, and sea turtles. Magnetostratigraphy and $\delta^{13}C$ stratigraphy at Bentiaba spans the interval from 95-71.5 Ma anchored by an 84.6±1.5 Ma $^{40}Ar/^{39}Ar$ date on the Ombo Basalt. It occurs along an unusually narrow portion of the continental shelf linked to northeastern Angola by the Lucapa Fault Zone. The Bench 19 fossil locality at Bentiaba (72 Ma, the best dated Late Cretaceous locality in Africa) formed in water temperatures of ~18.5°C at a time when the South Atlantic had a width half that of the modern South Atlantic (1375 km at 24°S latitude). Coastal Cretaceous localities in Angola were sequentially deposited in latitudes that today host the Benguela Large Marine Ecosystem and were subsequently transported northward. During the Cenozoic, in Cabinda, the section spans the Paleocene to the Oligocene-Miocene boundary, indicating the section formed over a span of time that encompassed a 10° latitudinal drift. Today, along the western African coast, that distance marks the difference between a desert-adapted *Welwitschia* grove at the northern limit of the Skeleton Coast Desert at Bentiaba and the

lowland tropical forest of Cabinda. We propose that latitudinal differences of similar magnitude may have been important during the Cretaceous as well. While our focus is on the Angolan record, the Cenozoic stratigraphy of the Sahara can plausibly be interpreted as reflecting drift-controlled paleoenvironmental change, suggesting that the gross anti-tropical patterns and historical distributions of environments have a common, specifically African, first-order cause related to northward drift of the continent. Continuing through the Paleogene, the evolution of African paleoenvironments during the Cenozoic drove the evolution of primates toward humans. Darwin considered that great apes probably originated in Africa but no large fossil apes were known in Africa during his time. With documentation of a large primate in the tropical Late Paleogene of Cabinda, Darwin has once again been proven correct.