

# Upper Cenozoic chronostratigraphy of the southwestern Amazon Basin

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## ABSTRACT

The lack of numerical age dates for upper Cenozoic strata of the Amazon Basin has prevented resolution of its geologic history and accurate dating of important paleofaunas. Here we present results of magnetostratigraphy and  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of two volcanic ash deposits from the Madre de Dios Formation of eastern Peru. The two ash ages,  $9.01 \pm 0.28$  Ma and  $3.12 \pm 0.02$  Ma, provide the first numerical age data necessary for accurate interpretation of late Tertiary sedimentation in Amazonia and establish approximate time constraints for the last major cycle of Cenozoic deposition within the southwestern Amazon Basin. The older ash age also provides a minimum age for numerous Amazonian paleofaunas, which allows a more definitive correlation of these paleofaunas with those in other regions of South America.

**Keywords:** Amazon Basin, argon-argon, chronostratigraphy, magnetostratigraphy, Miocene, Peru.

## INTRODUCTION

The Cenozoic geologic history of the Amazon Basin remains controversial; interpretations of the origin, number, and ages of formations present are quite varied. Several regional, pre-Cenozoic subbasins and structural arches add to the overall stratigraphic complexity of the basin, and the complete lack of numerical age dates for any Cenozoic sedimentary deposit within the basin has delayed resolution of its geologic history. We present here results from two  $^{40}\text{Ar}/^{39}\text{Ar}$  dates on volcanic ash deposits and magnetostratigraphy from eastern Peru that provide the first chronological anchors for interpreting the upper Tertiary Amazonian stratigraphy and late Tertiary paleofaunas of southwestern Amazonia. These results have broad application to understanding the geologic history of Amazonia if the Amazon Basin functioned as a single integrated sedimentary basin in the late Cenozoic, as has been proposed. In addition to facilitating the correlation of some Amazonian paleofaunas, the older ash age establishes the fact that at least one North American mammal was in South America more than 9 m.y. ago. This alters established interpretations regarding the timing of certain events associated with the Great American Faunal Interchange.

## UPPER CENOZOIC STRATIGRAPHY OF AMAZONIA

The Amazon Basin is an elevated sedimentary basin in the process of being dissected by

an entrenched river system. With possible limited exceptions (Neller et al., 1992; Dumont, 1993), all sediment carried into the basin is also carried out, although short-term residence as flood-plain deposits does occur (Mertes et al., 1996; Dunne et al., 1998). Some authors (Räsänen et al., 1987, 1990; Dumont, 1993) have suggested that regional subbasins were independently and differentially tectonically active in the late Cenozoic and as a consequence geologic formations cannot be correlated among these subbasins. These suggestions remain unsupported by direct geologic data, however, and we concur with the more traditional interpretation wherein two distinct Cenozoic stratigraphic intervals can be correlated throughout central and western Amazonia (Kummel, 1948; Schobbenhaus et al., 1984; Santos, 1974). The lower interval includes a Paleocene to upper Miocene sequence referred to as the Red Beds of the Contamana Group (Kummel, 1948) (Fig. 1). The formation at the top of this sequence in Peru is the upper Miocene Ipururo Formation (= Solimões Formation, in part, in Brazil [Schobbenhaus et al., 1984]). The Ucayali unconformity (Kummel, 1948) separates the older Tertiary deposits from the overlying sequence of younger deposits referred to in Peru as the Madre de Dios Formation (Oppenheim, 1946) (= Içá Formation in Brazil [Schobbenhaus et al., 1984]). The moderately to well consolidated, commonly faulted, and slightly dipping clay and mudstone horizons of the Ipururo Formation are readily distinguished from the unconsolidated, rarely faulted, horizontal sand, silt, and

clay beds of the Madre de Dios Formation in central and southern Amazonian Peru.

The Ucayali unconformity is an excellent stratigraphic marker because it is very obvious and widespread. Three of us (Campbell, Frailey, and Romero-Pittman) have observed this unconformity from the foothills of the Peruvian Andes to the Brazilian Shield, throughout eastern Peru, northern Bolivia, and western Brazil. On the basis of descriptions by others, we conclude that it has been identified in well cores on both sides of the Amazon River (Maia et al., 1977) and in eastern Colombia (Hoorn et al., 1995). The ubiquity of this unconformity and the observed uniformity in the overlying stratigraphic sequence of the Madre de Dios Formation are taken as evidence documenting a common late Cenozoic geologic history throughout central and western Amazonia.

Although complex intraformational facies variations among the heterogeneous beds of unconsolidated clays, silts, and sands of the Madre de Dios Formation are common, our field data led us to divide the Madre de Dios Formation into three informal units (Fig. 1). A basal clay-pebble or clay-ball conglomerate locally rich in fossil vertebrates is typical of the oldest horizon of the formation, unit A. This facies was dated to the upper Miocene (Huayquerian South American Land Mammal Age [SALMA], or 9–6 Ma) on the basis of its contained fossil vertebrates (Frailey, 1986). Others, however, thought these fossils could be older (Chasicuan SALMA, or 12–9 Ma) (de Broin et al., 1993; Webb, 1995). The top of the upper horizon, unit C, forms the Amazon planalto (Sombroek, 1966), or highest terra firma, of lowland Amazonia. Recognizable throughout the basin, although extensively eroded locally, the planalto represents the upper limit of deposition within the basin. The middle horizon, unit B, is set off from the other two by distinctive changes in lithology that we interpret as unconformities.

## MATERIALS AND METHODS

### $^{40}\text{Ar}/^{39}\text{Ar}$ Dating

Two localized deposits of lithologically distinctive volcanic ash from within the Madre

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