The reversal of valve overlap in *Cyprideis* (Ostracoda, Crustacea) as a mechanism for sympatric speciation in the Pebas System (Miocene) of Western Amazonia

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1. Introduction

During the Miocene, a huge (~1 million km^2), long-lived (~10 Myr) aquatic environment, the so-called Pebas System [1] (Fig. 1A) existed in Western Amazonia, which is known for its highly diverse and endemic aquatic fauna (crocodylian, mollusks and ostracods) [2, 3, 4, 5, 6].

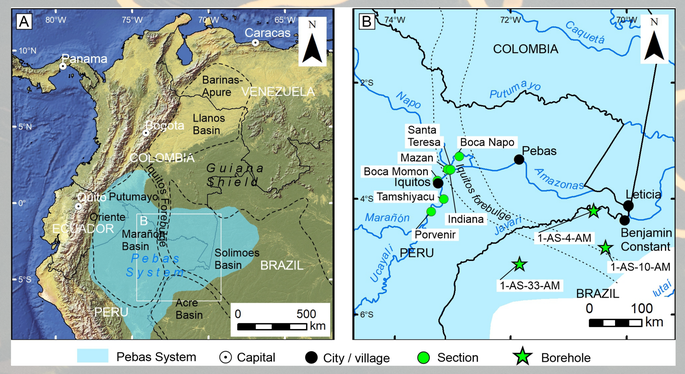

Figure 1. Location of the studied area. **A.** Overview of Northern South America. **B.** Location of the material in this study.

Among ostracods, the genus *Cyprideis* is the most relevant, both in terms of abundance and number of endemic taxa, generating a flock of species in the Pebas System [5, 7]. Although the understanding of certain aspects of this flock, such as taxonomy, has improved in recent years, the mechanisms responsible for this speciation remain elusive. In this study, we focus on a peculiar feature of the *Cyprideis* species flock, as about one-third of its species have an 'inverse' hinge and reverse valve overlap compared to what is typical for the genus.

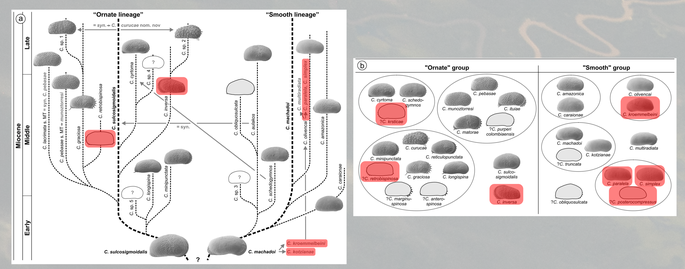

Figure 2. A. Phylogeny of the *Cyprideis* species flock of wester Amazonia; **B**. Taxonomical affinities of the flock species; after [5]. Highlighted species are considered 'reverse'.

2. The reversion phenomenon in Ostracoda

The asymmetrical-shelled genus *Cyprideis* has a 'normal' hinge, where the positive terminal elements (teeth) are placed on the right valves. The normal overlapping occurs when the left valve (Lv) covers most of free margin of right valve (Rv) (Figure 3).

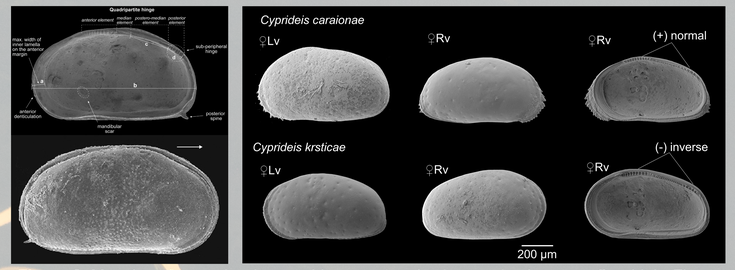

Figure 3. Meaning of normal vs inverse hingement and valve overlap in genus *Cyprideis*. Figures on the left, from [11, 12] correspond to *C. torosa* (type species); on the right to the Pebasian 'normal' species *C. caraionae* and 'reverse' *C. krsticae* from core 1AS-33-AM.

3. Chronostratigraphy

The outcrops and boreholes were dated with their mollusk and/or palynological available data for each location, then using the mollusks and palynological zonation for the western Amazonia Basins [8, 9, 10]. The analyzed material roughly spans over the Early to Middle Miocene (~18-12 Ma).

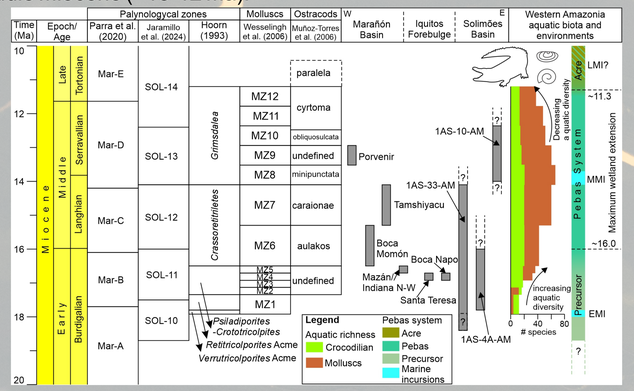

Figure 4. Regional chronostratigraphic chart of the Miocene of western Amazonia, showing main biozonations, temporal range for sections and boreholes studied and regional biotic and ecological events.

4. Results and discussion

Several outcrops (Marañón Basin, Peru) and boreholes (Solimões Basin, Brazil) yielded abundant and well-preserved material of some little known species (*Cyprideis caraionae* Purper & Pinto, 1985, *Cyprideis krsticae* Purper & Pinto, 1985 and *Cyprideis retrobispinosa* Purper & Pinto, 1983) with complete 'populations' (males, females and juvenile stages) within the samples, allowing us to understand the variation of these species over a broad temporal span (~18-12 Ma) (Figure 5).

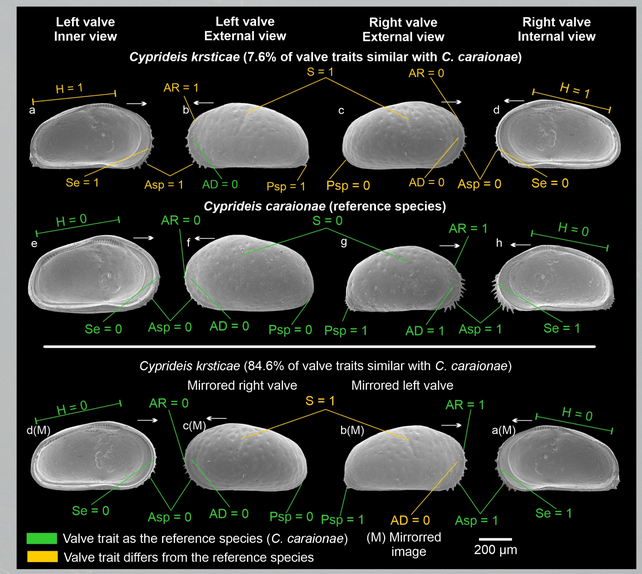

Figure 5. Morphological comparison between the 'normal' species *C. caraionae* and the 'reverse' *C. krsticae*. Note the increasing of the similarity in the valve traits of both species when the valves images of *C. krsticae* are mirrored. All specimens come from the same sample in Boca Napo section.

5. Conclusions

- Morphological affinity of 'normal' with mirrored (!) reverse species in the Pebas system demonstrates that the reversal is an effective mechanism for reproductive isolation (then for sympatric speciation) of the species.
- The reversal of the carapace in *Cyprideis* (and by extension in Ostracoda) is a very rare phenomenom, but is relatively common in the Pebas System (~1/3 of the species)
- The biological or ecological factors behind the concentration of reversal species are not clear. We are working to try to unravel it.

Acknowledgements

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Abbreviations: Fig. 3: ♀ = female; Lv = left valve; Rv = right valve; **Fig. 4:** EMI: Early Miocene incursion; MMI: Middle Miocene incursion; LMI; Late Miocene incursion; **Fig. 5:** AD: Anterior depression (0 = absent; 1 = present); AR: Anterior rim (0 = absent to very thin; 1 = conspicuous; dorsally inwarded); Asp: Anterior spines (0 = reduced compared to the opposite valve; 1 = larger compared to the opposite valve); H: Hingement (0 = normal hingement; 1 = inverse hingement); Psp: Posteroventral spines (0 = absent; 1 = present); S: sulcus (0 = absent; 1 = present); Se: Selvage (0 = thick, in relatively distal position; 1 = thin, sharp, in relatively proximal position)