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Mechanisms and age estimates of the endorheic to exorheic drainage evolution recorded by the Douro River

Mecanismos e estimativas de idade da evolução de drenagem endorreica para exorreica registada pelo Rio Douro

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Palavras-chave: Ibéria ocidental, drenagem transversa, transbordo de bacia, taxa de incisão, escadaria de terraços, datação por luminescência.

ABSTRACT

In western Iberia, mechanisms that can explain the transition from endorheic to exorheic continental-scale drainage reorganization are foreland basin overspill, headwards erosion and capture by an Atlantic river, or a combination of both. To explore these, we have investigated the Portuguese sector of the Douro River, the locus of drainage reorganization.

The Douro River is routed downstream through the weak sedimentary infill of the Douro Cenozoic Basin, after which the river cuts down through harder granitic and metamorphic rocks crossed by active fault zones, before reaching the Atlantic coast.

We investigated the drainage reorganization using an integrated approach that combined remote sensing, field survey and geochronology, applied to Pliocene–Quaternary fluvial sediments and landforms.

The complexity of the interpretation concerning the initiation and evolution of the Douro River was first presented by Lautensach (1933, 1987). Transverse drainage has been proposed to have developed from antecedance (erosional downcutting by an already existing river system) (Ferreira, 1978) or by drainage reorganization through headward erosion and capture (e.g., Feio, 1951; Ferreira, 1986; Martín Serrano, 1991; Antón et al., 2018; Struth et al., 2019). Overspill has not been explored hitherto as an explanation of Douro drainage evolution.

Most interpretations of the transition of the previously endorheic Cenozoic basins of central Iberia (e.g., Douro and Madrid Cenozoic basins) to Atlantic drainage systems have suggested that headward erosion by Atlantic fluvial systems captured the central Iberia drainage and eventually triggered drainage reversal (e.g., Gutierrez-Elorza and Pérez-González, 1993; and references therein). However, other studies of Iberian river systems have shown that similar drainage evolution may be instigated by a combination of aqueous overflow of the basin and by capture-related headward erosion (e.g., Ebro Basin; García-Castellanos et al., 2003). Also, the transition from endorheic to exorheic drainage in the Madrid Cenozoic Basin is considered to have occured by overspill into the Lower Tejo Cenozoic Basin, at ~ 3.7 Ma, as evidenced by a culminant sedimentary unit (Cunha, 1992); the later stage of fluvial incision associated with the River Tejo (Tagus) began as recently as ~ 2 Ma (Cunha et al., 2016; Silva et al., 2017).

The study area (Freixo de Espada à Cinta – Régua), comprising the upstream part of the Lower Douro catchment (Fig. 1), is crucial for understanding the regional transition from endorheic to exorheic drainage, due to its location between the previously endorheic Douro Cenozoic Basin and the Atlantic drainage of the Mondego Cenozoic Basin (Cunha, 2019).

The older drainage record is documented by a series of high and intermediate landform levels comprising: (1) a high level (1000–500 m a.s.l.) faulted regional fluvial erosion surface, the North Iberian Meseta planation surface and the Mountains and Plateaus of Northern Portugal, recording the endorheic drainage of the Douro Cenozoic Basin; (2) a first inset level at 650–600 m a.s.l., comprising a broad fluvial surface developed onto a large ENE–WSW depression, interpreted as recording the initiation of the continental scale reorganization; and (3) an inset fluvial surface at 550–400 m a.s.l., corresponding to the establishment of the exorheic ancestral Douro valley.

The younger drainage record comprises an entrenched fluvial strath terrace sequence of up to 9 levels (T9 = oldest, positioned at 246–242 m above the modern river base; T1 = youngest, positioned at +17–13 m. Levels T1 and T3 display localized fault offsets. The three lowest terrace levels (T3–T1) were dated using optically stimulated luminescence techniques with results ranging from >230–360 ka (T3), through 57 ka (T2) to 39–12 ka (T1).

Fluvial incision rates of the younger terraces were quantified and temporally extrapolated to model the ages of the intermediate to high elevation levels of the early drainage record. Integration of incision data informs on the probable timing of the drainage reorganization and the initial adjustment, ~ 3.7 to 1.8 Ma. This was followed by acceleration of incision, producing the entrenched river terrace sequence developed via spatial and temporal variations in rock strength, uplift and cyclic cool-climate variability as the river adjusted to the Atlantic base level.

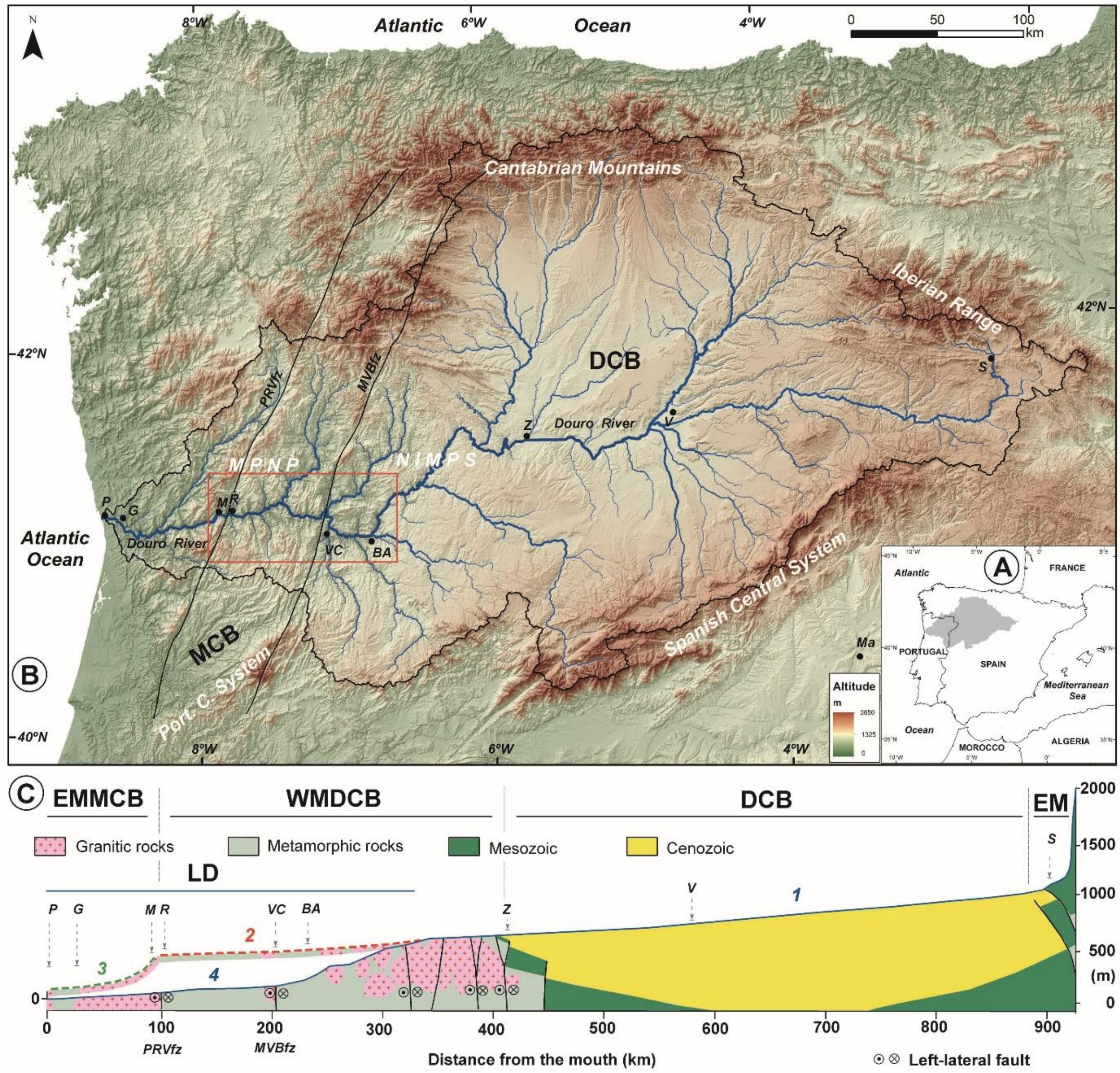

Fig. 1. The Douro catchment (drainage divide = black line) and its drainage network (blue lines) (B), inset showing location in Iberia (A) and longitudinal profile (C) with bedrock geology relationships. EM – eastern margin of the Douro Cenozoic Basin; DCB - Douro Cenozoic Basin; WMDCB - western margin of the Douro Cenozoic Basin; EMMCB - eastern margin of the Mondego Cenozoic Basin; MCB - Mondego Cenozoic Basin; MPNP - Mountains and Plateaus of Northern Portugal; NIMPS - North Iberian Meseta planation surface; MVBfz - Manteigas-Vilariça-Bragança fault zone; PRVfz - Penacova-Régua-Verín fault zone; LD - Lower Douro; 1 - long profile of the Douro River in the DCB; 2 - long profile of the ancestral Douro in the study area; 3 - long profile of an ancestral coastal Atlantic river; 4 - long profile of the modern Douro downstream of the DCB; P - Porto; G - Gondomar; M - Mesão Frio; R - Régua; VC - Vila Nova de Foz Côa; BA - Barca d'Alva; Z - Zamora; V - Valladolid; S - Soria; Ma - Madrid; Red rectangle on (B) - study area.

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