# Nature, timing and controls of Mediterranean Quaternary river development: the Rio Bergantes, Ebro basin, northeast Spain

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**DECLARATION**

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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## Abstract

Geomorphological, sedimentological and geochronological analyses have been undertaken to decipher the effects of Quaternary environmental change on the development of the Rio Bergantes, Ebro basin, northeast Spain. Field mapping and profiling utilising large-scale aerial photography and airborne LiDAR data has identified a sequence of six river terraces. Age control, provided by luminescence dating methods, has revealed two major phases of valley floor aggradation at ~ 183 - 130 ka (Terrace BT1, elevated ~ 25 m above the modern river channel) and ~ 111-26.8 ka (BT2, ~ 18-20 m), punctuated by ~ 20 m of incision in the intervening period. Following these two phases of large-scale aggradation, the Bergantes river system adjusted to a more sediment limited regime and responded to environmental changes through a series of smaller cut and fill cycles. This resulted in four lower elevation terraces (BT3-BT6) inset within the older (BT1 and BT2) valley fills. These lower terraces have been temporally constrained at ~ 24.5-14.2 ka (BT3); 10.6-9.8 ka (BT4); 8.3-6.2 ka (BT5) and ~ 3 ka (BT5). Field sedimentological and stratigraphic analysis of the alluvial fills, combined with sediment storage and export calculations, indicates the large influence of tributary and hillslope derived sediment supply during the aggradation of BT1 and, to a lesser extent BT2. This contrasts with the predominantly trunk river derived deposits which make up the fill of BT3-BT6, when the hillslopes and tributaries in the study area appear to be relatively de-coupled with the trunk river. A lack of lithological variation in the Bergantes catchment, combined with large amounts of carbonate, has restricted the possibility of deciphering any spatial or temporal changes in sediment source areas. However, a new and innovative methodology has been designed and implemented which calculates automatic sedimentary section-scale grain size measurements from Terrestrial Laser Scan (TLS) data. This methodology can now be applied to other ancient fluvial sedimentary successions.

Data presented in this thesis suggest that the Bergantes river system has responded to, and has preserved, a record of environmental changes operating both in sync with, and at higher frequency than Milankovitch-driven glacial-interglacial cycles. Major valley floor aggradation phases (or those associated with relatively large amounts of fluvial sediment e.g. BT1 and BT2) correlate with Pleistocene glacial conditions in MIS 6 and MIS 5, when the climate on the Iberian Peninsula was cool and dry. Intervening phases of major valley incision appear to coincide with warmer and moister climates in Pleistocene interglacials. The younger terraces (BT3-BT6) are characterised by much smaller amounts of fluvial sediment. Dating control suggests that their development correlates with stadial (aggradation) and interstadial (incision) events during the Late Pleistocene and Holocene. Many phases of aggradation appear to coincide with the North Atlantic Heinrich Events, which are also recorded in marine cores off the west coast of the Iberian Peninsula, and also to other securely dated phases of aggradation elsewhere in the Mediterranean basin.

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## List of Acronyms

| | |
|---|---|
| ka | Kiloannum; unit of time equal to 1000 years |
| OSL | Optically Stimulated Luminescence |
| $^{14}C$ | Radiocarbon |
| IRSL | Infrared Stimulated Luminescence |
| SAR | Single Aliquot Regeneration (Protocol) |
| MIS | Marine Isotope Stage |
| OIS | Oxygen Isotope Stage |
| D-O | Dansgaard-Oeschger (Cycle) |
| GI | Greenland Interstadial |
| HE | Heinrich Event |
| LGM | Last Glacial Maximum |
| SIRM | Soft Isothermal Remenance Measurements |
| HIRM | Hard Isothermal Remenance Measurements |
| GIS | Geographical Information System |
| LiDAR | Light Detection and Ranging |
| TLS | Terrestrial Laser Scan(ning) |
| RMSE | Root mean square error |