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Evaluating macrobenthic response to the Cretaceous–Palaeogene event: A high-resolution ichnological approach at the Agost section (SE Spain)

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ABSTRACT

The Agost section (Betic Cordillera, Alicante Province, south-eastern Spain) is one of only a few places in the world where complete sedimentary successions across the Cretaceous–Palaeogene (K–Pg) boundary are available. Agost enables a high-resolution ichnological analysis illustrating the influence of environmental perturbations on burrowing organisms before, during and after the K–Pg boundary event. The uppermost Maastrichtian calcareous marlstones and marly limestones of the Raspay Formation (*Plummerita hantkeninoides* Biozone), beside the light-filled Maastrichtian trace fossils, contain dark-coloured early Danian trace fossils including *Chondrites targionii*, *Chondrites* ?*affinis*, *Chondrites* isp., *Pilichnus* isp., *Planolites* isp., ?*Teichichnus* isp., *Thalassinoides* isp., *Trichichnus linearis*, *Trichichnus* isp., and *Zoophycos* isp. The ichnotaxonomic composition of the late Maastrichtian and early Danian trace fossil association does not reveal major differences, indicating no significant influence on composition of their trace makers immediately after the K–Pg event. The main factors that most likely promoted survivorship of the trace makers were their feeding strategy (deposit feeders, microbe gardeners) and an increased delivery of organic matter to the seafloor due to the high mortality during the K–Pg boundary event. However, the differences in the size of trace fossils are noted: They are distinctly smaller in the dark boundary layer (*Guembelitria cretacea* Biozone) than in the underlying uppermost Maastrichtian calcareous marlstones. This is an example of the Lilliput Effect. The dwarfed ichnoassociation was produced during and shortly after sedimentation of the dark boundary layer pointing to a delayed reaction of the burrowing organisms to the K–Pg boundary event compared to other groups of organisms. The dwarfing might be caused by environmental stress resulting from lower food supply due to collapse of primary production in the later phases of the K–Pg boundary event.

1. Introduction

The Agost section (SE Spain) is one of the most important Cretaceous–Palaeogene (K–Pg) boundary interval sections worldwide, because of a very expanded and continuous sedimentary record across the boundary. This section has been profusely studied, including variable aspects, such as magnetostratigraphy (Groot et al., 1989), chronostratigraphy (MacLeod and Keller, 1991), mineralogy and geochemistry (e.g., Smit, 1990; Martínez-Ruiz et al., 1992, 1997, 1999; Martínez-Ruiz, 1994), micropalaeontology (e.g., Canudo et al., 1991; Molina et al., 1996, 1998, 2005; Pardo et al., 1996; Alegret et al., 2003; Arenillas et al., 2004). Recently, the study of trace fossils (Rodríguez-Tovar and Uchman, 2004a, 2004b) and the integration of ichnological with geochemical and isotopic analyses (Rodríguez-Tovar et al., 2004; Rodríguez-Tovar, 2005; Sosa-Montes de Oca et al., 2013, 2016) has revealed especially useful in the interpretation of the K–Pg boundary in the Agost section. Since the first ichnological studies of the K–Pg boundary in Denmark (Ekdale and Bromley, 1984), Alabama (Savrda, 1993), and NE Mexico (Ekdale and Stinnesbeck, 1998), and later studies at Agost, Caravaca, and Sopelana in Spain (Rodríguez-Tovar and Uchman, 2006, 2008; Rodríguez-Tovar et al., 2010, 2011), Bidart in France (Rodríguez-Tovar et al., 2010, 2011; Alegret et al., 2015), Gubbio in Italy (Monaco et al., 2015) and El Kef in Tunisia

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(Rodríguez-Tovar et al., 2016), new challenges have appeared, such as the selectivity of some palaeoenvironmental changes, the variable response of the biotic communities, or the timing of recovery after the K–Pg boundary event (see Labandeira et al., in press, for a recent review). Therefore, new high-resolution studies in the best-preserved sections worldwide must be conducted, focussing on the aspects that have been highlighted. The aim of this paper is a revised high-resolution ichnological analysis of the Agost section, in order to improve interpretation of some aspects of the K–Pg boundary event. For this purpose, the boundary interval has been examined centimetre by centimetre in order to record lithology and ichnological features, and to collect representative samples. As the result, the section has received a better characterization of trace fossils, with discoveries of new ichnotaxa, and a more precise determination of ichnological changes through the section, including detailed observations of the dark boundary layer.

2. Geological setting

The section crops out in a cut along the Agost-Castalla road (CV-827), about 1 km north of the town Agost in the Alicante Province, south-eastern Spain (N 38°27.147′, W 0°38.197′; Fig. 1). The Agost section belongs to the Prebetic, which corresponds to the outermost and northernmost part of the Betic Cordillera. The Prebetic is composed of Mesozoic and Cenozoic sedimentary rocks deposited in the southern continental margin of Iberia, which resulted from the breakup of Pangaea and divergence of Africa and Europe since the Triassic. The Agost section is located in the Internal Prebetic subdomain, which represents the relatively distal palaeogeographic part of the epicontinental shelf system developed on the South Iberian palaeomargin during the Mesozoic. The Agost section shows no hiatus, condensed interval, or erosional surface (MacLeod and Keller, 1991; Pardo et al., 1996; Arenillas et al., 2004; Molina et al., 2005).

The uppermost Maastrichtian deposits belong the uppermost part of the Raspay Formation (Chacón and Martín-Chivelet, 2005), which consists of medium and thick beds of grey calcareous marlstones and marlstones (Figs. 2; 3A) containing planktic and benthic foraminifera, ostracods and scarce fragments of echinoderms.

These beds are overlain by a 4–10 cm-thick layer of carbonate-poor, dark olive calcareous claystones (the dark boundary layer; $CaCO_3$ content 25%) with a 2 mm-thick rusty-red layer (the "rusty layer") at its base that marks the K–Pg boundary (Fig. 3A–C). The dark boundary layer is also called the "dark clay boundary layer", "boundary layer" or the "K–Pg boundary layer" in previous papers (e.g. Kędzierski et al., 2011; Rodríguez-Tovar et al., 2011; Alegret et al., 2015; Sosa-Montes de Oca et al., 2016). The rusty layer contains Kfs and Fe-oxide sphaerules and enrichment of iridium and other platinum-group elements and it is interpreted as a distal ejecta layer of the Chicxulub impact (e.g., Martínez-Ruiz et al., 1992, 1997, 1999; Martínez-Ruiz, 1994). The carbonate content increases up the dark boundary layer, which passes upward into cream-coloured calcareous marlstones ($CaCO_3$ content 70%) followed by rose marly limestones ($CaCO_3$ content 85%). The rose marly limestones constitute the top of the studied interval. The lowermost Danian deposits belong to the lowermost part of the Agost Formation (Chacón and Martín-Chivelet, 2005).

According to the benthic foraminiferal assemblages, the deposition of the sedimentary interval studied took place in middle bathyal depths (600–1000 m; Alegret et al., 2003; Molina et al., 2005). A detailed biostratigraphy of the Upper Cretaceous and the Lower Palaeogene transition in the section analysed is based on planktic foraminifera (Alegret et al., 2003; Arenillas et al., 2004; Molina et al., 2005). The *Plummerita hantkeninoides* Subzone (Pardo et al., 1996) corresponds to the uppermost 3.45 m-thick portion of the Maastrichtian deposits. Within the lower Danian, the *Guembelitria cretacea* Biozone (Canudo et al., 1991; Molina et al., 1996, 2004), correlated with the P0 Zone (Pardo et al., 1996), is differentiated from the first 14 cm of the lowest Danian, including the dark boundary layer and the overlying ~5 cm thick layer of light calcareous marlstones. This biozone was subdivided into the *Hedbergella holmdelensis* and the *Parvularugoglobigerina longiapertura* subzones by Arenillas et al. (2004). Above the *Guembelitria cretacea* Biozone, the *Parvularugoglobigerina eugubina* Biozone (Molina et al., 1996), which is equivalent to the P1a p.p. [P1a(1)] (Pardo et al., 1996) or to the *Parvularugoglobigerina longiapertura* p.p.

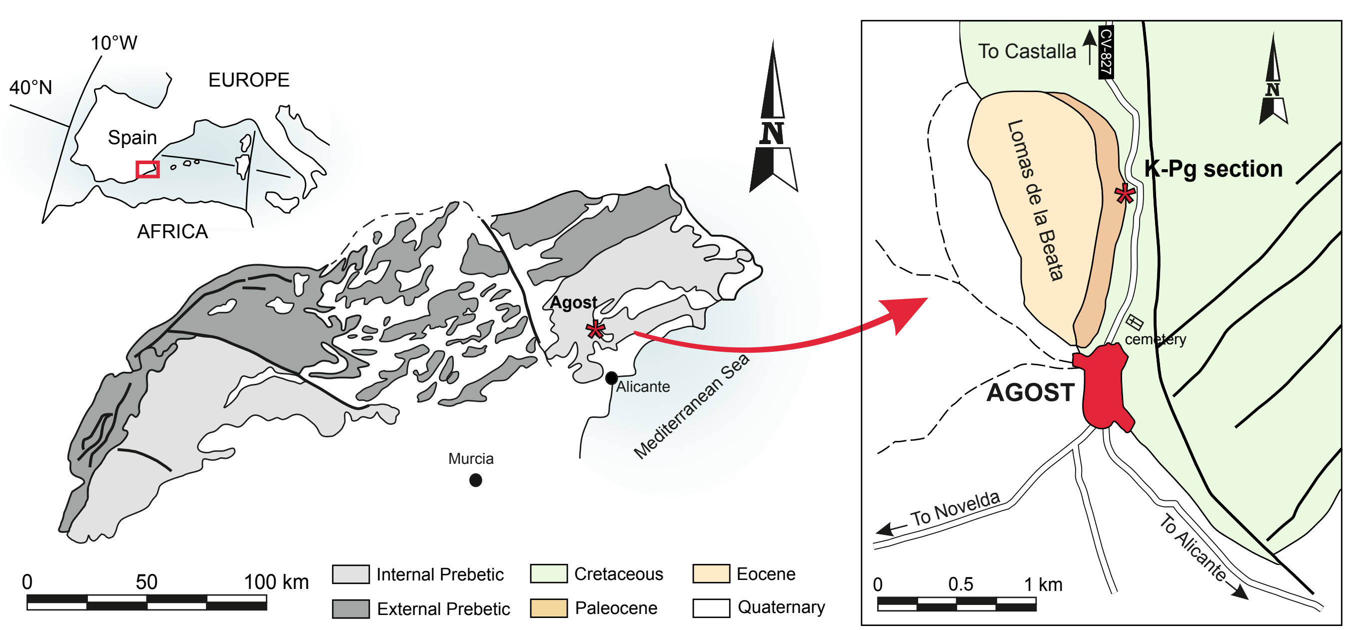

Fig. 1. Location of the K–Pg boundary section at Agost and main tectonic units of the south-eastern Spain.