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The breakup of the L-chondrite parent body 466 Ma and its terrestrial effects – a search for a mid-Ordovician biodiversity event

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ABSTRACT

About a third of all meteorites that fall on Earth today, the stony L-chondrites, originate from a major breakup event in the asteroid belt 466 Ma, in the early Darriwilian. This is the largest asteroid breakup in the past three billion years documented by K-Ar gas-retention ages of recently fallen meteorites. There has been a debate whether the breakup had any effects on Earth's biota. Based mainly on brachiopod data from western Russia, some authors have argued for the existence of a major biodiversity 'event' at approximately the time of the L-chondrite breakup. An analysis of the distribution of three fossil groups (conodonts, ostracods and trilobites) across the late Dapingian and early Darriwilian in three sections in southern Sweden shows no evidence of any biodiversity event. The only biotic changes outside a normal trend are those related to a sea-level fall following the arrival of large amounts of dust from the asteroid breakup. We conclude that the Great Ordovician Biodiversification Event represents a sequence of changes over about 20 Myr, coinciding with an asteroid shower from the breakup of the L-chondrite parent body.

Introduction

During the early Darriwilian, 466 Ma, a 150-km-sized asteroid broke up in the asteroid belt, probably after having been hit by another large asteroid or a comet. This is the largest documented asteroid breakup over the past three billion years. The event still delivers the most common type of meteorites to Earth, the stony L-chondrites. The terrestrial effects of the breakup include a one-order-of-magnitude excess of impact craters of mid-to-late Ordovician age, indicative of an asteroid shower to Earth following the breakup (Terfelt and Schmitz 2021; Schmitz et al. 2022). This is the only resolvable asteroid shower in Earth's impact crater record (Fig. 1). In mid-Ordovician strata, in China, Russia and southern Sweden, a two- to three-order-of-magnitude increase has been recorded in the flux of micrometeorites and extra-terrestrial dust to Earth following the breakup (Schmitz et al. 2019). Abundant fossil meteorites recovered during quarrying of mid-Ordovician limestone at Kinnekulle in southern Sweden also attest to the event. In the Hällekis section at Kinnekulle, the onset of the flux increase coincides with the onset of an important sea-level fall, the Täljsten event, possibly related to a mid-Ordovician (short-lived?) ice age triggered by extraterrestrial dust that shaded Earth from some sunlight (Schmitz et al. 2019).

In sections in western Russia, the fossil brachiopod distribution has revealed a so-called biodiversity event in the early Darriwilian, approximately at the base of the *Lenodus variabilis* Conodont Zone (Rasmussen et al. 2007). Since the first dust from the breakup of the L-chondrite parent body, as also reconstructed in the Hällekis section, occurs close to the base of the *L. variabilis* Zone, it has been suggested that the asteroid breakup somehow indirectly triggered the biodiversity event (Schmitz et al. 2008). In order to shed more light on this, we have here compiled detailed biostratigraphic data for three fossil groups in late Dapingian to early Darriwilian sections in Sweden. We compare bed-by-bed the biodata with the registered sea-level changes and the first arrival of extraterrestrial dust from the L-chondrite breakup. Among the sites discussed, there is a depth transect from western Russia (shallowest) to Västergötland (intermediate) and to Scania (deepest), which may allow to discriminate the effects of sea-level changes on the biota.

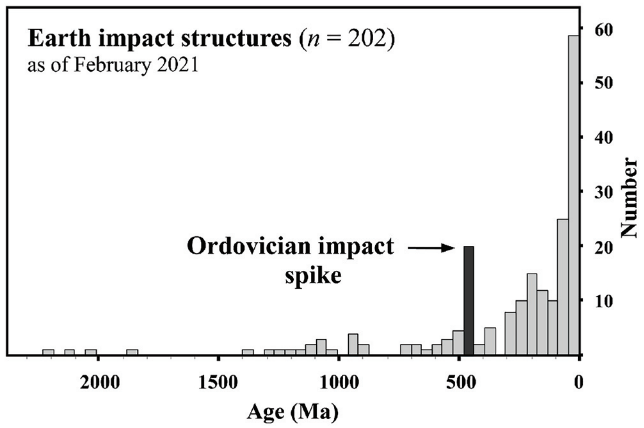

Fig. 1. Histogram that shows the age distribution of terrestrial impact structures. Note the distinct Ordovician spike at ca 470–450 Ma. The impact spike is indicative of an asteroid shower to Earth following the L-chondrite parent body breakup. Presented after Schmitz et al. (2022).

Materials and methods

We base our compilations on information from the literature referenced in the captions of the respective plot. The groups and sites considered are ostracods, conodonts and trilobites in the Hällekis section at Kinnekulle in Västergötland, and conodonts and trilobites in the Fågelsång and Killeröd sections, respectively, in Scania, southernmost Sweden. The timing of the breakup of the L-chondrite parent body has been determined using helium isotopes in bulk sediments, neon isotopes in fossil meteorites and the distribution of L-chondritic chromite in bulk limestone in the sections at Kinnekulle (Schmitz et al. 2019).

Results and discussion

Our compilations in Figs 2–4 show smooth and gradual biodiversity changes across the late Dapingian to the early Darriwilian for all three animal groups in all sections. The only 'event' is the appearance of some shallow-dwelling species in the Täljsten interval (Zhang 1998; Villumsen 2001; Tinn and Meidla 2001) in the Hällekis section, a feature not seen in the deeper setting at Killeröd and Fågelsång. There is no clear or obvious 'event-like' change in biodiversity in any bed over the stratigraphic interval considered.

It appears that the biodiversity event seen in brachiopod distribution in western Russia by Rasmussen et al. (2007) cannot be reproduced in other taxa such as conodonts,

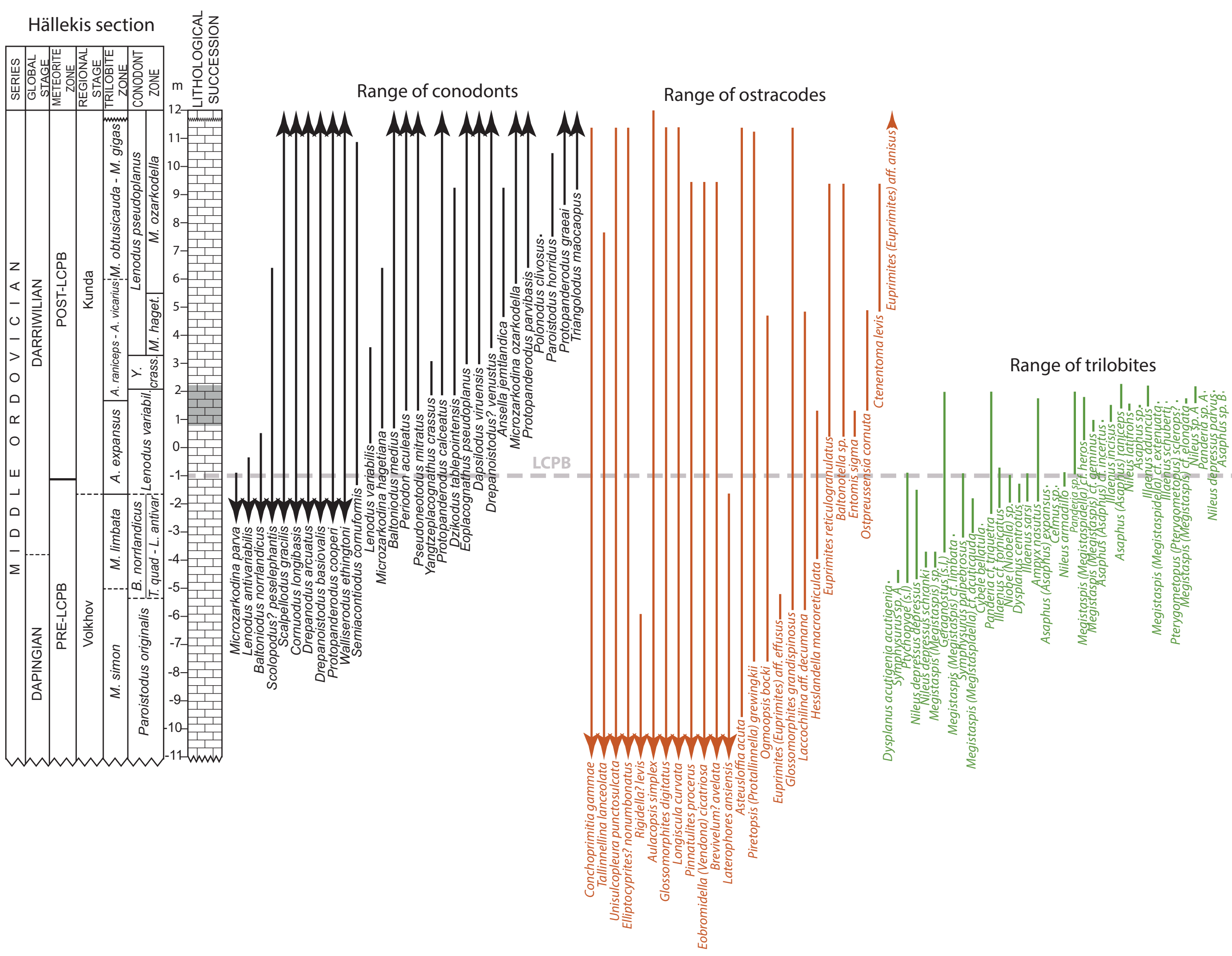

Fig. 2. Range and biodiversity data for conodonts, ostracods and trilobites in the Hällekis section, Västergötland, Sweden. The Täljsten interval is marked grey in the lithological log. The stratigraphic position of the L-chondrite breakup (LCPB) is marked with a dashed grey line. Data for conodonts are from Zhang (1998), for ostracods from Tinn and Meidla (2001) and for trilobites from Villumsen (2001). Biostratigraphy is after Lindskog et al. (2019).

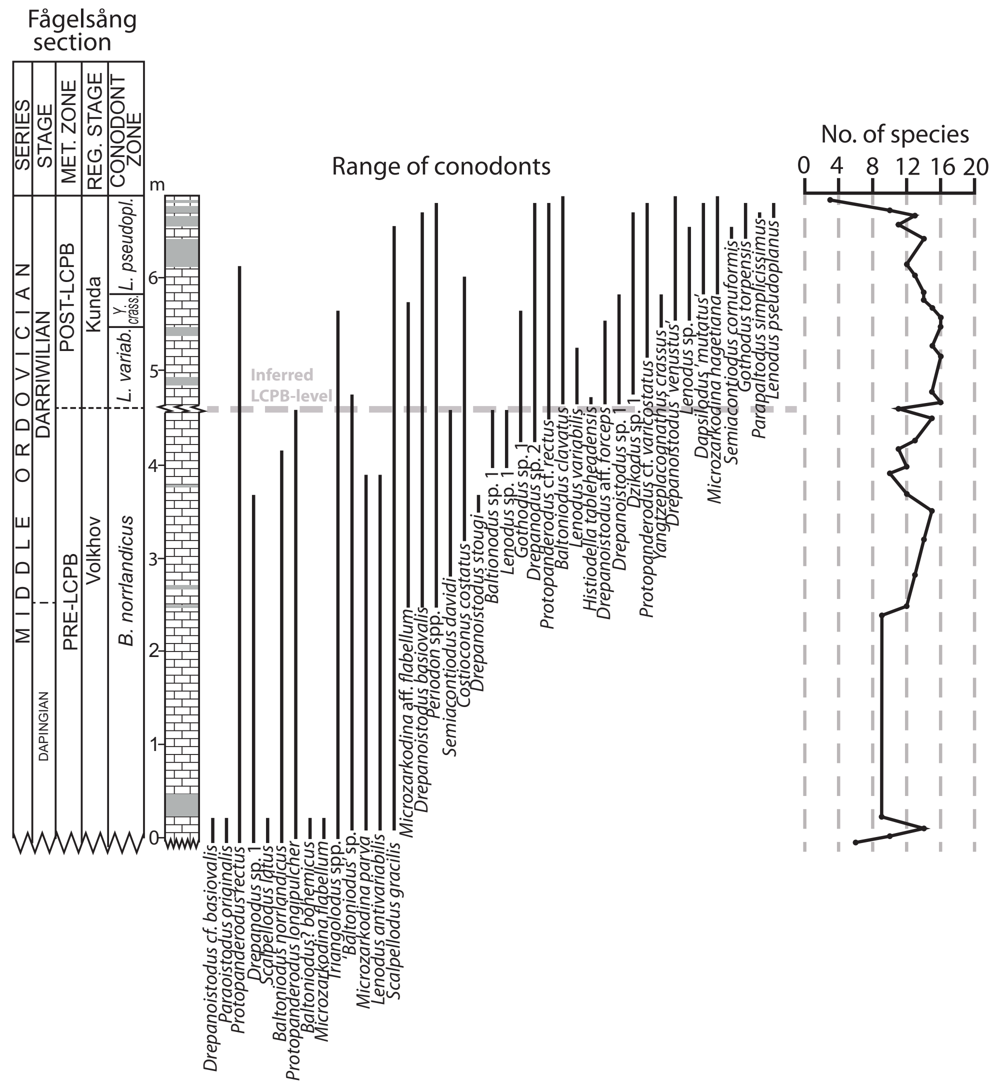

Fig. 3. Range and biodiversity data for conodonts in the Fågelsång section, Scania (Stouge and Nielsen 2003). Time of L-chondrite parent body breakup (LCPB) = dashed grey line.

ostracods and trilobites even at a regional scale. No detailed studies have yet been performed of the distribution of brachiopods in the sections in southern Sweden, but we plan such studies in the future. However, there are already reasons to believe that the changes in brachiopod faunas in western Russia may to a large extent reflect a facies shift rather than a true biodiversity event. It is obvious from the available compilations of western Russia brachiopod data that the claimed increase in biodiversity reflects the incoming of several shallow-water species related to a prominent sea-level fall. Our preliminary data suggest that this is the same sea-level fall as the Täljsten event in southern Sweden. A similar sea-level fall is also seen at the corresponding stratigraphic level in many sections worldwide. The onset of the lowstand in the Lynna section in western Russia may coincide with the first arrival of abundant dust from the L-chondrite breakup event. More detailed studies are ongoing to test this hypothesis. We stress that in order to resolve this and similar questions, it is important to adopt a bed-by-bed and section-by-section approach rather than to lump data together and apply various binning and correlation approaches with significant inherent uncertainties that allow great flexibility in arriving at different conclusions.

Although there is no apparent instantaneous biotic event recorded in connection with the breakup of the L-chondrite parent body, other than sea-level related changes, we note that on a more extended time scale the Great Ordovician Biodiversification Event appears to coincide with frequent impacts on Earth by up to kilometre-sized asteroids. This indicates that astronomical processes may somehow have accelerated the biodiversification process, as originally proposed by Schmitz et al. (2008).

Conclusions

Our data support the proposal by Servais et al. (2021) that the Great Ordovician Biodiversification Event is not a single event, but an extended sequence of biotic events spanning the period from the early Darriwilian to the Hirnantian. We argue that the early Darriwilian brachiopod event in western Russia may primarily reflect a sea-level fall rather than a biotic event of global, evolutionary significance. We note, similarly to Schmitz et al. (2008), that the 'extended' Great Ordovician Biodiversification Event coincides with the period when frequent asteroids from the L-chondrite parent-body breakup hit Earth.

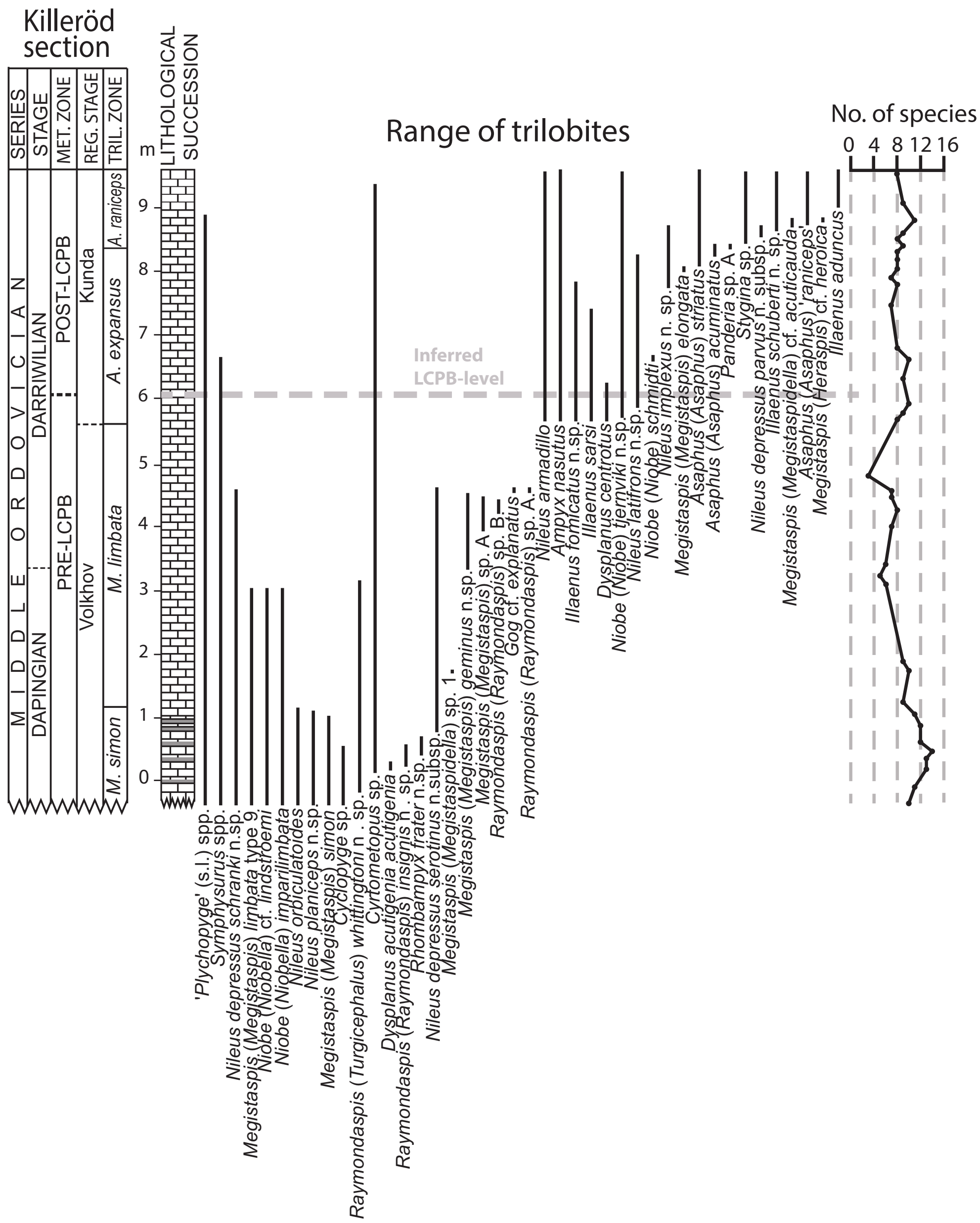

Fig. 4. Range and biodiversity data for trilobites in the Killeröd section, Scania (Nielsen 1995). Time of L-chondrite parent body breakup (LCPB) = dashed grey line.

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