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The controversy space on Quaternary megafaunal extinctions

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ABSTRACT

In this work, we analyze the origin and development of the debate on megafaunal extinctions using the Controversy Space Model (CSM). The CSM is composed of a common ground of theoretical agreements and a dialectical dynamic of disputes regarding the causes of extinction, called refocalization, identifying phases of conceptual blockage and unblockage. The hypotheses are clustered in three major groups, according to causes of extinction: anthropic, biotic, and environmental. We argue that the evolution of the controversy space follows a succession of questions relevant to each period, the answers to which need to be settled to allow the debate to move forward. We postulate that nowadays this controversy space is suffering a period of conceptual blockage. This may be because authors are assembled around two major paradigms: environmental versus anthropic causes. Each of these two theoretical positions looks at a portion of reality that may be partially true, but incomplete in terms of a global theory of extinction. We propose that this conceptual blockage could be solved by developing a mathematical model in which each hypothesis plays a role in a mechanistic way. The relative importance of each hypothesis may vary depending on its respective context. It follows from this that it should not matter which cause is favored: the emphasis should be given to all causes acting together in a predictable manner.

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1. Introduction

We are all looking for the hidden serial killer.

Resembling the fascination for crime stories, speculations about the causes of terrestrial mammal extinctions in the Quaternary have been at the center of one of the most exciting and unresolved debates in contemporary biology. For over the last two centuries, hundreds of papers have been written on this topic, proposing a range of explanations. There is plenty of literature supporting or attacking these proposed hypotheses, and to this day there is no agreement forthcoming (Koch and Barnosky, 2006; Haynes, 2009). In this paper we introduce a different paradigm that can provide a vantage point from which to encompass the various positions in

this debate. This is the model of *controversy spaces* (Nudler, 2011), a heuristic tool for the reconstruction of the process of conceptual change in the history of the scientific debates.

A controversy space has a range of features. Above all, it proposes a unit of epistemic analysis located above the competing theories within the debate, and ranging across various controversies that may seem otherwise unconnected or incommensurable. The controversy space model (CSM) assumes that all controversies take place against a background of shared theoretical agreements: what Nudler (2011) calls the common ground. The Quaternary megafaunal extinctions debate, as we propose in this paper, is a controversy space whose origin and development over time is amenable to analysis from the perspective of the CSM.

The CSM emerged originally from the study of conflicts and adheres to a dialectical conception of knowledge. Controversies, disputes and disagreements are the engines of scientific and philosophical progress. Unlike conflicts, controversies take place on an underlying common ground shared by all the parties in dispute. On

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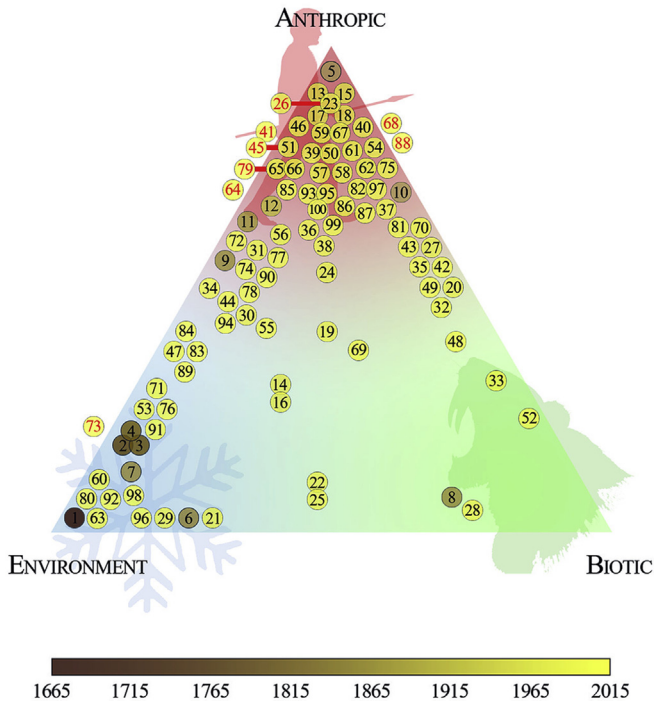


Fig. 1. To construct our CSM and illustrate the philosophical changes in the search for the causes of Quaternary extinctions, we performed an exhaustive search in the related scientific literature. We first selected papers related to the controversy space, and in a second cut, those related with debates regarding the causes of megafaunal extinctions. Finally, we selected about 100 papers as representatives of the foci of the controversy space (see supplementary information 1 for references). After this, we discussed the relative position of each selected work into this figure; the position of each paper is qualitative (and, for visualization purposes, avoids overlapping), reflecting a consensus among the authors. Circles outside the main area of the triangle represent papers that stand in opposition to one side of the debate (or to a specific paper, in the cases where they are connected by a red line), without providing support to alternative extinction explanations.

Controversy spaces are dynamic structures. The foci of discussion may change over time, a process called refocalization. This refocalization can occur for several reasons: a new actor may appear with a new hypothesis, a focus may become part of the common ground (as a result of agreements reached during the discussions), or an assumption or agreement that belonged to the common ground may rise to the surface and become itself the focus of controversy. Refocalization implies the creation of new concepts or the redefinition of the already available ones (Nudler, 2011). Also, new discoveries may create a new conceptual framework in which some concepts can be readapted. Rational dialectical engagement is the main driver of the dynamic of a controversy space. However, no scientific theory is context-free and there are other, non-rational aspects that shape the controversy spaces, which need to be considered in this study.

While we recognize the influence of non-rational elements in the evolution of ideas, we believe that science makes its path in history overcoming obstacles that impede the progress of thought. Given these difficulties, the dialectical evolution of the controversy space has stages of conceptual stagnation or conceptual blockage, and stages of conceptual unblockage in which the controversy space recovers its initial momentum. The aim of this paper is to analyze the historical pattern of conceptual change in the debate on the causes of Quaternary extinctions using the model of controversy spaces.

2. Origin and evolution of the controversy space on megafaunal extinctions

We argue that the evolution of the controversy space follows a succession of questions relevant to each period, the answers to which need to be settled to allow the debate to move forward. Answering these questions implies several things: application of new technologies, creation of new concepts, formation of the common ground and reformulation of new questions; all of which are at the origin of the process of refocalization.

For example, we identified a starting point, perhaps too old, but unequivocally at the beginning of the series of questions that lead us to modernity and our specific topic. The series begins with the dispute over the origin of the fossil material, and from there develops in a cascade of other questions. Following a chronological scheme in dealing with such questions (see Fig. 1), we analyze the difficulties of the framework, the evolution of common ground composition, the refocalization, the conceptual blockages and conceptual unblockages that occurred in the evolution of ideas from 1665 to 2015 (Tables 1 and 2 for summary).

the surface, controversies consist of a set of disagreements that provide the foci of discussion. Almost no philosophical or scientific controversy is isolated but intersects with other disciplinary disputes that, in turn, may have other foci or objects of disagreement, but which share the same common ground. In other words, a controversy space is a structured set of controversies woven around shared problems (Nudler, 2011).

Table 1
Major episodes of the controversy space.

Date	Raise of major questions	Entrances into the common ground	Foci of dispute	Relevant actors	Conceptual blockage	Unblockage/refocalization
1565	The nature of fossil material	Resemblances with living organisms (drawings of Gessner)	Organic versus inorganic origin	Gessner, Colonna	In situ creation of fossils or "celestial" origin	none
1665–1700	Origin of the controversy space regarding causes of the existence of fossils. Matter, form and placement of fossil materials Age of fossils	Resemblances with living organisms Organic origin of stony fossils	Origin of fossil matter, biological versus mineral composition, explanations regarding the placement of fossils and the resemblances of the forms Fossils as remains of recent organisms versus the conception of the old antiquity of fossils	Gessner, Hooke, Stensen Hooke vs Wallis, also Kircher	No link between fossils and organic origin, creationist hypotheses have more convincing explanatory power Lack of understanding of the process of fossilization. Limited perception of time frame	Evidences of organic origin of fossils in the works of Hooke and Stensen. Links to the extinction of once-living organisms Fossil antiquity proposed by Hooke, but neglected in his time

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