The *First Radiation of the Fasciculiths*: Morphologic adaptations of the coccolithophores to oligotrophy

Marie-Pierre Aubry[1], Olga Rodriguez[2], David Bord[1], Linda Godfrey[3], Birger Schmitz[4], Robert W.O'B. Knox[5]

[1]Department of Earth and Planetary Sciences, Rutgers University, 610 Taylor Rd., Piscataway, NJ 08854-8066, USA

[2]PDVSA , E y P, Gerencia de Laboratorios y Nucleotecas, Puerto-La-Cruz, Venezuela

[3]Institut of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901-8521, USA

[4]Department of Earth and Ecosystem Sciences, Sölvegatan 12, 223 62 Lund, Sweden

[5]British Geological Survey, Keyworth NG12 5GG, UK

Key words: first radiation of fasciculiths, hyperthermal, Neo-Duwi Event, oligotrophy,

Abstract

The Qreiya section (Upper Egypt) contains a well-preserved record of the *first radiation of the fasciculiths*, an evolutionary event that affected the coccolithophores of the Order Discoasterales during the late Danian. At Qreiya it unfolds across the so-called Neo-Duwi Event. We describe the morphostructural changes that affected coccoliths and document a trend towards increased surface area of the coccoliths of the Order Discoasterales. Our isotopic data do not support earlier interpretation(s) that the Neo-Duwi Event may correspond to a Paleocene hyperthermal. We interpret the *first radiation of the fasciculiths* as an adaptive response to increased oceanic oligotrophy through the appearance of coccoliths adapted to food collection in nutrient-poor oceanic waters.

1. Introduction

Since the early 1980s there has been considerable interest devoted to mass extinction events. In contrast, little attention has been paid to diversification events, even though the dynamics of diversification may illuminate the dynamics of extinction. The latest Danian (~63-62 Ma; Westerhold et al., 2008) was a significant time in the Cenozoic diversification of the planktonic calcifiers (e.g., d'Hondt et al., 1994; Aubry, 1998; Coxall et al., 2006; Bown, 2005). This is when coccolithophores of the Order Discoasterales Hay 1977 emend Aubry (in press) began their Cenozoic diversification that led ~3.5 Myr later to the successive radiations of the families Helio-discoasteraceae and Eu-discoasteraceae (Aubry, 1998; Aubry and Bord, 2009). These two families, in turn, contributed almost half of the components of nannofossil

oozes at low- and mid-latitudes, both in terms of relative abundance and (to a lesser degree) species diversity, from the Late Paleocene to the late Pliocene.

The early Paleocene diversification of the Order Discoasterales has been documented in terms of species richness (Bown, 2005) and abundance patterns (Fuqua et al., 2008), but the fundamental morphological transformations that affected coccoliths at this time have not been described. The recovery of well preserved assemblages across the Danian/Selandian boundary (as defined by Schmitz et al., 2011) in the Qreiya section of Upper Egypt provides us with the first opportunity to discuss the significance of the "first radiation of the fasciculiths", the expression generally used following Romein (1979) to refer to a burst of diversification in the Order Discoasterales. We discuss this in the light of the Neo-Duwi Event (Speijer, 2003; Guasti et al., 2005) which is recorded in Egypt shortly after the radiation event.

2. The Qreiya Section

The outcrop at Gebel Qreiya (26° 21'N, 33° 01' E) is located at the southeastern end of Gebel Abu Had in the Egyptian Eastern Desert on the eastern side of the Wadi Qena (Fig. 1). Situated ~50 km ENE of the town of Qena, it is accessible by the road running essentially West to East from Qena to Safaga and then along a track in the desert. The almost 300 m high outcrop exposes, in stratigraphic succession, the Dakhla (Said, 1961), Tarawan (Awad and Ghobrial, 1965), Esna Shale (Said, 1960) and Thebes Limestone (Said, 1960) formations. The Maastrichtian to Ypresian stratigraphy was first described by Barron and Hume (1902) and revisited by Said (1962), Abd El Razi (1969, 1972), Faris et al. (1985) and Luger (1988) among others.

The base of the steep upper slope is formed by the upper part of the Dakhla Formation, consisting essentially of hemipelagic, homogeneous laminated shales of middle to outer neritic origin (Speijer, 2003). This monotonous succession is interrupted by a thin but distinctive organic-rich interval that occurs throughout Upper Egypt (Speijer and Schmitz, 1998; Speijer, 2003), albeit with varying thickness from a few centimeters to several decimeters. This distinct lithologic interval is associated with a sudden incursion of the shallow water benthic foraminifera *Neoponides duwi* into benthic foraminiferal assemblages typical of deep-water shelf environments. This abrupt event was referred to as the "Neo-Duwi Event" by Guasti et al. (2005), and as the "Late Danian Event [LDE]" by Sprong et al. (2011). We here refer to the phosphatic organic-rich interval that includes the Neo-Duwi Event as the Neo-Duwi beds. These correspond to the "el-Qreiya Bed" of Soliman and Obaidalla (2010).

At least three sections have been sampled at Gebel Qreyia around the Neo-Duwi beds in recent years, and studied for planktonic foraminifera (Qreiya 1, 3: Sprong et al., 2009; Qreiya 1: Soliman and Obaidalla, 2010), benthic foraminifera (Qreiya: Guasti et al., 2005; Qreyia 3: Sprong et al., 2011),