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The influence of extraterrestrial material on the late Eocene marine Os isotope record

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Abstract

A reconstruction of seawater $^{187}Os/^{188}Os$ ratios during the late Eocene (~36–34 Ma), based upon bulk sediment analyses from the sub-Antarctic Southern Atlantic Ocean (Ocean Drilling Program (ODP) Site 1090), Eastern Equatorial Pacific Ocean (ODP Sites 1218 and 1219) and the uplifted (land-based) Tethyan section (Massignano, Italy), confirms that the previously reported abrupt shift to lower $^{187}Os/^{188}Os$ is a unique global feature of the marine Os isotope record that occurs in magnetochron C16n.1n. This feature is interpreted to represent the change in seawater $^{187}Os/^{188}Os$ caused by the Popigai impact event. Higher in the Massignano section, two other iridium anomalies previously proposed to represent additional impact events do not show a comparable excursion to low $^{187}Os/^{188}Os$, suggesting that these horizons do not record multiple large impacts. Comparison of records from three different ocean basins indicates that seawater $^{187}Os/^{188}Os$ begins to decline in advance of the Popigai impact event. At Massignano this decline coincides with a previously reported episode of elevated ^{3}He flux, suggesting that increased influx of interplanetary dust particles (IDPs) contributed to the pre-impact shift in $^{187}Os/^{188}Os$ and not to the longer-term latest Eocene $^{187}Os/^{188}Os$ decline that occurred ~1 million year after the Popigai impact event. Published by Elsevier Ltd.

1. INTRODUCTION

Toward the end of the Eocene Epoch, multiple impact events occurred (Koeberl, 2009) contemporaneously with an episode of increased accretion of IDP's (Farley, 2009). The cause of this episode of increased extraterrestrial (ET) influx is controversial.

It is argued to result from either collisions in the asteroid belt of a L-type ordinary chondrite based on platinum group element (PGE) concentration in Popigai impact melts (Tagle and Claeys, 2005), or from a comet shower based on ^{3}He flux in the Massignano section (Farley et al., 1998). More recently, Kyte et al. (2011) use chromium isotopes in late Eocene ejecta to show that the ejecta contained extraterrestrial Cr indistinguishable from ordinary chondrites. Although this result is consistent with the conclusion of Tagle and Claeys (2005), Kyte et al. (2011) note that the Popigai PGE data (Tagle and Claeys, 2005) are also consistent with a H-type ordinary chondrite impactor. Therefore, Kyte et al. (2011) have speculated that the Brangäne asteroid family could be the source of the Popigai projectile. The suggestion is consistent with available data because the Brangäne asteroid family displays an infrared spectrum consistent with ordinary chondrites. These workers note that this includes the H-type chondrites, a meteorite group with cosmic-ray exposure age that clusters around 33–36 Ma, similar to the Popigai impact event.

In a previous study Paquay et al. (2008a) used the impact-induced excursion in the late Eocene portion of the marine $^{187}Os/^{188}Os$ ratio record to calculate the amount of meteoritic Os that dissolved in seawater following the Popigai impact, and estimate the size of the projectile. Here,

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we report a new high-resolution late Eocene Os isotope record from the land-based Massignano section (Odin and Montanari, 1988; Premoli Silva and Jenkins, 1993) and expanded Os isotope records from three previously studied deep-ocean drilling sites. These records, together with complementary Os and Ir concentration data, are used to, (1) critically evaluate claims that two separate Ir anomalies in the Massignano section represent additional late Eocene impact horizons (Montanari et al., 1993; Bodiselitsch et al., 2004), (2) provide an updated discussion of impact-induced Os isotope excursions and projectile size estimation and (3) examine the relationship between the late Eocene episode of increased IDP flux (Farley et al., 1998) and the marine Os isotope record. These results have important implications for understanding the ways in which ET matter delivered to the Earth system influence the marine Os isotope record.

2. SAMPLE MATERIAL

The sites studied in this contribution include the Massignano section (Coccioni et al., 1988: 43°32′13″N; 13°35′36″E), ODP Site 1218 from the Equatorial Pacific (8°53.378′N, 135°22.00′W; 4826 m water depth: Lyle et al., 2002), the Southern Atlantic Ocean ODP Site 1090 (42°54.8′S, 8°54.0′E; 3700 m water depth: Gersonde et al., 1999) and a second Equatorial Pacific Site ODP 1219 (7°48.019N, 142°00.940′W; 5063 m water depth) (Fig. 1). Massignano, ODP Site 1218 and Site 1090 were selected for further investigation because all three sites can be correlated to one another based on magnetostratigraphy, and previous works (Ravizza and Peucker-Ehrenbrink, 2003; Dalai et al., 2006; Paquay et al., 2008a) have established that these sediments effectively record secular change in the $^{187}Os/^{188}Os$ of seawater. The additional data reported here allow detailed comparison of late Eocene Os records from different oceanic basins.

2.1. The Massignano section

Previously reported late Eocene Os isotope data from the Massignano section compare favorably with the Os records from multiple deep sea sediment records of similar age (Ravizza and Peucker-Ehrenbrink, 2003), but this original low-resolution dataset does not allow identification of any late Eocene impact. Here, we report a high resolution Os isotope record (110 new analyses) in the Scaglia Variegata Formation from 0.5 msl to about 6.4 msl, (meters stratigraphic level, where greater height corresponds to younger sediments). Additional samples between 10 and 11 msl were analyzed to further investigate earlier reports of Ir enrichment at this level (Bodiselitsch et al., 2004). These new data combined with previously published data (Ravizza and Peucker-Ehrenbrink, 2003) fall within the magnetochrons C16n.2n-C13r (Jovane et al., 2007), planktonic foraminiferal Zones P15–P16 or E14–E15 (Coccioni et al., 1988, 2009) and calcareous nannoplankton Zones NP18–NP19/20 (Coccioni et al., 1988; Monechi et al., 2000). The sediments that comprise the Massignano section were deposited at an estimated paleodepth of 1000–1500 m (Coccioni and Galeotti, 2003). They consist of marly limestone, with $CaCO_3$ content varying from 50 to 80 wt% (average 76 wt%, Jovane et al., 2009). Sediment color alternates from greenish to reddish, likely due to changes in redox conditions on the sea floor. Biotite-rich layers of volcanic origin at 2.04, 5.25, 5.8, 6.5, 7.25, 7.75, 12.1 and 12.7 msl (Jovane

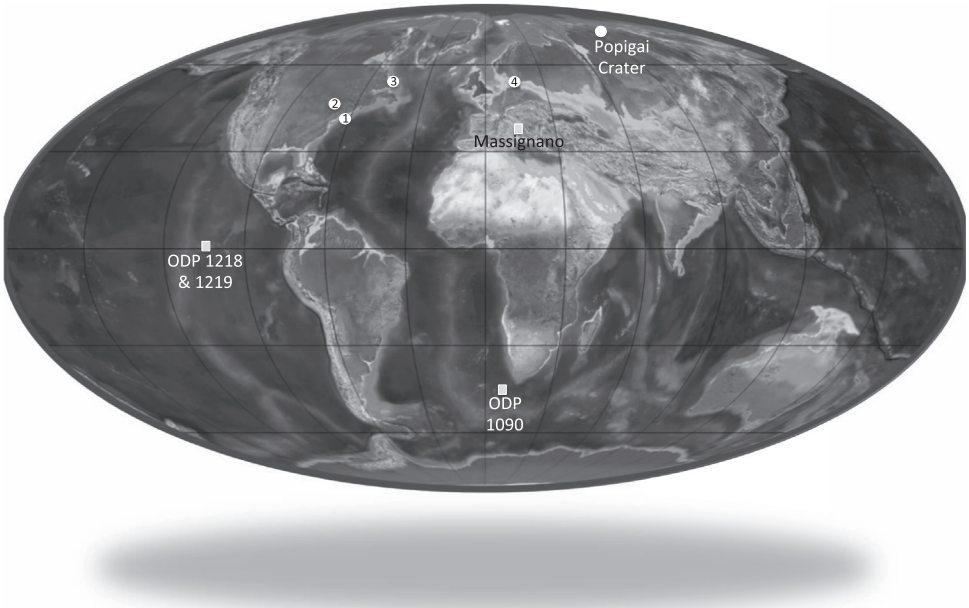

Fig. 1. Approximate locations of the studied ODP cores/uplifted section (squares) and impact craters (circles) of late Eocene age in a paleogeographical reconstruction of 35 Ma. The Popigai crater is the likely source of the global ejecta horizon within C16n.1n. Other known craters with ages that may overlap with the time interval studied here are indicated by numbers: Chesapeake Bay (1) Wanapitei (2) Mistastin (3) and Logoisk (4). The base image is taken from (http://jan.ucc.nau.edu/~rcb7/globaltext2.html).