Upper Cretaceous radiolarians reworked in the Eocene London Clay Formation, SE England

Tom Fer1, Taniel Danelian1* & Haydon W. Bailey2

1 Université de Lille – Sciences et Technologies, CNRS, UMR 8198 Evo-Eco-Paleo, F 59655 Villeneuve d’Ascq, France
2 Network Stratigraphic Consulting Ltd, Harvest House, Cranborne Road, Potters Bar, Hertfordshire EN63JF, UK

*Correspondence: taniel.danelian@univ-lille1.fr

Abstract: Radiolarians were recently discovered in the lower Eocene London Clay Formation of the London Basin from samples in a drainage borehole in the River Thames. They come from a c. 10 m thick sequence of silty shales in the lower part of the formation. The radiolarians are, in general, rather poorly preserved, with the exception of six samples that yielded moderately well-preserved radiolaria that allowed the identification of eighteen taxa. All radiolarial samples are of Late Cretaceous age and they are therefore reworked into the lower part of the Eocene London Clay Formation. The best preserved sample yielded an assemblage of twelve morphospecies, including Diaconthecapora ovoidea, Theocapsomma amphora and Theocapsomma sp. aff. T. amphora sensu Popova-Goll et al. 2005, suggesting an original Santonian–Campanian age, and more likely only the Campanian. However, the stratigraphic origin of these radiolaria from the Upper Cretaceous sequence of the London Basin is uncertain.

Keywords: London Clay Formation; Eocene; Upper Cretaceous; radiolaria; London Basin

Received 23 December 2014; accepted 25 November 2015

Over the last 20 years a large number of taxonomic and biostratigraphic studies have been devoted to Cretaceous radiolaria from Europe, but the majority of them concern Tethyan basins in Spain and Italy (Judd 1994; O’Dogherty 1994), Montenegro (Gorican 1994), Greece (Danelian et al. 2002; Danelian 2008), Poland (Bak 1995, 1996; Bak & Sawlowicz 2000) and the Czech Carpathians (Smreckova 2011). Cretaceous radiolaria from the NW European and Boreal realm are much less well known; the few data available come from the Danish Trough, where radiolaria have been described from Coniacian to Santonian sequences (Packer & Hart 2005). In the UK, rare radiolaria were reported at the end of the nineteenth century (Rüst 1888; Hill & Jukes-Browne 1895; Holmes 1900) from the Upper Cretaceous, mainly Turonian, chalk (Melbourn Rock) of the London Basin (Fig. 1), but there is no modern taxonomic study.

Recently, we discovered moderately well-preserved radiolaria in London Basin sediments from a borehole drilled by Thames Water Utilities Ltd in the River Thames in London. They come from the London Clay Formation (Fig. 2), which is Ypresian (early Eocene) in age and rather rich in microfossils where they are preserved. In terms of siliceous microfossils, only diatoms have been identified before from this formation in an unpublished report by C. King. This is, therefore, the first report of radiolaria from the London Clay. They appear to be Late Cretaceous in age and, thus, reworked in the lower Eocene London Clay Formation. Following a taxonomic account of the radiolaria identified, the material is compared with coeval assemblages known worldwide (i.e. Denmark and the Russian platform: Vishnevskaya & De Wever 1998; Popova-Goll et al. 2005).

Geological and stratigraphic settings

The London Basin of SE England is a 250 km long sedimentary basin, the sequences of which also crop out in the northern Dieppe and Hampshire Basin (Fig. 1). It is a large synclinal fold, formed during the Alpine orogeny (Oligocene to mid Miocene). The major part of the basin is filled with Upper Cretaceous chalk sequences (Mortimore 2011). Only the uppermost part of the Upper Cretaceous is relevant to this study, but the full Upper Cretaceous and Palaeogene sequence is shown in Figure 2. The Upper Cretaceous Chalk Group is 150–250 m thick; it is less expanded than the chalk of the Dieppe and Hampshire Basin, where its thickness exceeds 400 m (Royse 2010). Figure 2 displays all the nine mapping formations recognized for the onshore Chalk of England (Hopson 2005). The two lowermost Chalk formations, of Cenomanian age, contain numerous marly intervals. More particularly, the West Melbury Marly Chalk is characterized by couplets of soft, marly levels and limestone beds. The overlying Zig Zag Chalk, although it contains rhythmical alternations of marls, marly chalk and chalk, is mostly characterized by firm beds of chalk. The well-known Plenus Marls, which accumulated during the late Cenomanian critical interval of the Oceanic Anoxic Event 2, are situated at the base of the Holywell Chalk Formation, the general lithology of which is characterized by hard nodular chalk with abundant shell debris. The Melbourn Rock Member, in which Hill & Jukes-Browne (1895) observed radiolaria in thin sections of nodules, overlies conformably the Plenus Marls and is characterized by the absence of bioclasts. The New Pit Chalk Formation is made essentially of firm chalk beds that include numerous marly intercalations and sporadic flint in the deeper sequences. The Lewes Chalk Formation is characterized by massive beds of hard nodular chalk and hardgrounds and includes some regular seams of nodular flint (chert). The overlying Seaford Chalk Formation is made of ‘white chalk with conspicuous semi-continuous nodular and tabular flint seams’ (Hopson 2005, p. 25). The Newhaven Chalk Formation is characterized by rather soft and white chalk beds intercalated by frequent marl seams and flint bands. The Culver Chalk Formation is of rather similar lithology with the underlying Newhaven Chalk but there is relatively little marl. Finally, the Portsdown Chalk Formation displays marl seams intercalated in the white chalk, which is at some levels rich in inoceramid debris, but its flint bands are much less developed than in the Culver Chalk.
The Thanet Sand Formation is the oldest deposit of the Paleocene sequence in the basin. This unit is followed by a succession of three formations: Woolwich, Reading and Upnor formations, which are part of the Lambeth Group (Ellison et al. 2004). The Eocene Harwich Formation overlies the Lambeth Group; it is mainly composed of sand, clayey sand and pebbles. This thin formation is overlain by the Ypresian London Clay Formation which is composed of brownish clay and silty clay 90–130 m thick (Ellison et al. 2004). This formation is the thickest part of the Palaeogene; together with the Harwich Formation, it comprises the Thames Group. It is in the London Clay Formation that radiolarians were found during this study.

Stratigraphy of the studied well

The borehole SR 5019 (90 m deep) was drilled by Thames Water Utilities Ltd as a test borehole for the Thames Tideway project, in the Barnes neighbourhood of Richmond, west London. This well penetrates the London Clay Formation, the Harwich Formation, the Lambeth Group and the Thanet Sand Formation (Fig. 3). The London Clay Formation extends from 6 to 48.42 m below the surface and may be divided from the top down as follows:

1. Unit B (18.5 m thick) – homogeneous grey-brown to brown clay, rich in glauconite, grey claystones, rare nodules of pyrite and rare layers of fine sand, with a 1 m thick bed of grey silty clay at the base. Foraminifera and some sponge spicules were found in the lower part of the unit.

2. Unit A3ii (9.45 m thick) – grey-brown clay with glauconite and silt and very fine sand partings. This unit is rich in foraminifera and calcareous nanofossils.

3. Unit A3i (2 m thick) – similar lithology to unit B. Homogeneous brownish clay with thin beds of grey claystones associated with calcite veins. Few microfossils occur in this unit. The boundary between units A3ii and A3i is not well defined.

4. Unit A2 (12.42 m thick) – silty clay beds with small pockets of silt interbedded with greyish-brown sandy silty clay with greenish silt and burrows filled with white silt. A2 is rich in foraminifera and it is in this unit that radiolarians were found. The base of this unit is marked by a very high concentration of bivalve debris.

Below A2 is a 0.5 m thick interval of sands and clays, rich in glauconite, with shell debris and pockets of brown sand; this unit is the Harwich Formation.

Material and methods

Six sediment samples were washed with a 63 µm mesh sieve. Microfossils were picked with a thin brush, under a stereo-binocular microscope, and then placed on slides. Several groups of microfossils were found, including foraminifera, molluscs and radiolarians. The specimens were photographed with a scanning electron microscope.

Taxonomy

For the taxonomic concepts used at family level we have followed De Wever et al. (2001) and at genus level O’Dogherty et al. (2009). A small selection of references is given under each synonymy to clarify the accepted morphological variability at species level.
Order *Nassellaria* Ehrenberg, 1875

Family *Amphipyndacidae* Riedel, 1967


*Amphipyndax stocki* (Campbell & Clark, 1944)

(Fig. 4: 6, 21)

1944 *Stichocapsa (?) stocki* Campbell & Clark: 44; l. 18, figs 31–33.

1982 *Amphipyndax stocki* (Campbell & Clark); Taketani: 52; pl. 10, figs 13, 14.

2005 *Amphipyndax stocki* (Campbell & Clark); Popova-Goll et al.: 10; pl. 5, fig. 6.

2007 *Stichomitra stocki* (Campbell & Clark); Musavu-Moussavou et al.: 273; pl. 4 figs 9–10 (only).

**Material.** 2 specimens.

Family *Archaeodictyomitridae* Pessagno, 1976

Genus *Archaeodictyomitra* Pessagno, 1976

*Archaeodictyomitra* sp. cf. *A. simplex* Pessagno, 1977

(Fig. 4: 20, 22)

cf. 1977 *Archaeodictyomitra simplex* Pessagno: 43, pl. 6, figs. 1, 24; pl. 12, fig. 12.

**Remarks.** Two incomplete or poorly preserved specimens that display 11–13 continuous costae visible in a lateral view, running throughout an elongate, conical test, which is only gently affected by slight constrictions.

*Archaeodictyomitra* sp. cf. *A. squinaboli* Pessagno, 1976

(Fig. 4: 23, 26)

cf. 1976 *Archaeodictyomitra squinaboli* Pessagno: 50; pl. 5, figs 2–8.

**Material.** 2 specimens.

**Remarks.** From their general test outline which is affected by gentle segmental constrictions, the number of their postabdominal
segments and number of costae, the illustrated specimens resemble *A. squinaboli*.

**Genus Dictyomitra Zittel, 1876, emend. Pessagno, 1976**

*Dictyomitra napaensis* Pessagno, 1976

(Fig. 4: 18–19)

?1976 *Dictyomitra napaensis* Pessagno: 53; pl. 4, fig. 16; pl. 5, figs 1, 9.

**Material.** 2 specimens.

**Remarks.** In spite of their poor preservation, the specimens resemble *D. napaensis* by the lobate subcylindrical outline of their test, displaying 12 to fifteen costae visible in lateral view.

**Family Cannobotryidae Haeckel, 1881**

**Genus Rhopalosyringium Campbell & Clark, 1944**

*Rhopalosyringium* (?) sp. (Fig. 4: 7, 15)

**Material.** 10 specimens.

**Remarks.** Although all observed specimens display a small hemispherical cephalis, no horn was observed, probably because the proximal part is always rather poorly preserved. The large subspherical thorax is perforated by circular pores surrounded by polygonal (mostly hexagonal) pore frames.

**Family Carpocaniidae Haeckel, 1881**
The caption to Figure 4 can be found on p.138.
Genus *Diacanthocapsa* Squinabol, 1903, emend. Dumitrica, 1970

*Diacanthocapsa ovoidea* Dumitrica, 1970

(Fig. 4: 9a–b, 13)

1970 *Diacanthocapsa ovoidea* Dumitrica: 63; pl. V, figs 25a–b; pl. VI, figs 26–29a, b.

1997 *Diacanthocapsa ovoidea* Dumitrica; Hashimoto & Ishida: pl. 3, fig. 1.


**Material.** 2 specimens.

**Occurrence and age.** Lower Campanian of Valea Mare, Romania (Dumitrica 1970), upper Campanian of Shikoku island, Japan (Hashimoto & Ishida 1997).

**Remarks.** The laterally open aperture situated at the end of the oval abdomen appears to be slightly broken in our material. Our specimens are smaller (total height 117 and 138 µm) than those described by Dumitrica (1970; total height 170–200 µm).

*Diacanthocapsa* sp. A

(Fig. 4: 14)

**Material.** 1 specimen.

**Remarks.** Egg-shaped general outline, with a clear constriction delimiting the thorax from the abdomen. Continuous rows of pores are equally widespread.

Genus *Theocapsomma* Haeckel, 1887 emend. Foreman, 1968

*Theocapsomma amphora* Campbell & Clark, 1944

(Fig. 4: 5, 10, 27)

1944 *Theocapsa* (*Theocapsomma*) amphora Campbell & Clark: 35; pl. 7, figs 30–31.

1997 *Theocapsomma amphora* Campbell & Clark; Hollis: pl. 15, figs 1–2.

2005 *Theocapsomma amphora* Campbell & Clark; Popova-Goll et al.: 26; pl. 1, fig. 3; pl. 7, fig. 11.

**Material.** 3 specimens.

**Occurrence and age.** Campanian–Paleocene, California, Atlantic and SW Pacific (Hollis 1997; Popova-Goll et al. 2005), Santonian–Upper Campanian, Russia (Popova-Goll et al. 2005).

*Theocapsomma* sp. aff. *T. amphora* Campbell & Clark, 1944 *sensu* Popova-Goll et al., 2005

(Fig. 4: 11–12)

2005 *Theocapsomma* sp. aff. *T. amphora* Campbell & Clark; Popova-Goll et al.: 26; pl. 1, fig. 2; pl. 3, fig. 17.

**Material.** 2 specimens.

**Occurrence and age.** Santonian–Lower Campanian of Russian platform (Popova-Goll et al. 2005).

**Remarks.** As mentioned by Popova-Goll et al. (2005), this species is distinguished from *T. amphora* by its third segment being smaller and less swollen, which results in a rather cylindrical outline.

Family *Eucyrtidiidae* Ehrenberg, 1847

Genus *Stichomitrida* Cayeux, 1897

*Stichomitrida* sp. cf. *S. manifesta* Foreman, 1978

(Fig. 4: 24)

(cf. 1903 *Stichomitrida communis* Squinabol: 141; pl. 8, fig. 40.

(cf. 1978 *Stichomitrida manifesta* Foreman: 748; pl. 5, fig. 4.

(cf. 1981 *Novodiacanthocapsa manifesta* (Foreman); Empson-Morin: 270; pl. 9, figs 2A–4D.

(cf. 1982 *Stichomitrida manifesta* Foreman; Taketani: 55; pl. 3, fig. 8a–b; pl. 11, figs 7–8.

(cf. 2001 *Stichomitrida ex. gr. manifesta* Foreman; Vishnevskaya: pl. 7, fig. 9.

**Material.** 2 specimens.

**Remarks.** Doubts about identification are due to poor/incomplete preservation.

*Stichomitrida* sp. A

(Fig. 4: 25)

**Remarks.** One single specimen perforated with small pores throughout the test. Proximal part incomplete. Segmental constrictions very subtle.

Family *Sethocapsidae* Haeckel, 1881

Genus *Sethocapsa* Haeckel, 1881

?*Sethocapsa orca* Foreman, 1975

(Fig. 4: 17)

(cf. 1975 *Sethocapsa (?) orca* Foreman: 617; pl. 2J, figs 1–2, pl. 6, fig. 12.

(cf. 2011 *Sethocapsa orca* Foreman; Kurilov & Vishnevskaya: pl. 3, fig. 2.

**Material.** 1 specimen.

**Remarks.** Proximal part poorly preserved. Abdomen subspherical, perforated all over with circular pores.

Family *Williriedellidae* Dumitrica, 1970

**Table 1. Radiolarian occurrence in the studied samples from borehole SR 5019**

<table>
<thead>
<tr>
<th>Species</th>
<th>Samples (m below surface)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphipyndax stocki</td>
<td>x</td>
</tr>
<tr>
<td>Archaeodictyomitra cf. A. simplex</td>
<td>x</td>
</tr>
<tr>
<td>Archaeodictyomitra cf. A. squinaboli</td>
<td>x</td>
</tr>
<tr>
<td>?Crucella crux</td>
<td>x</td>
</tr>
<tr>
<td>Cryptamphorella sp. cf. C. sphaerica</td>
<td>x</td>
</tr>
<tr>
<td>Diacanthocapsa ovoidea</td>
<td>x</td>
</tr>
<tr>
<td>Diacanthocapsa sp. A</td>
<td>x</td>
</tr>
<tr>
<td>?Dictyomitra napaeaensis</td>
<td>x</td>
</tr>
<tr>
<td>?Oribiculiforma multa</td>
<td>x</td>
</tr>
<tr>
<td>Praeconocaryomma (?) sp. cf. P. californiaensis</td>
<td>x</td>
</tr>
<tr>
<td>Praeystosphaera (?) sp.</td>
<td>x</td>
</tr>
<tr>
<td>Rhopalosyringium (?) sp.</td>
<td>x</td>
</tr>
<tr>
<td>?Sethocpasa orca</td>
<td>x</td>
</tr>
<tr>
<td>Stichomitra sp. cf. S. manifesta</td>
<td>x</td>
</tr>
<tr>
<td>Stichomitra sp. A</td>
<td>x</td>
</tr>
<tr>
<td>Theocapsomma amplhora</td>
<td>x</td>
</tr>
<tr>
<td>Theocapsomma sp. aff. T. amphora</td>
<td>x</td>
</tr>
<tr>
<td>Total number of specimens</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>202</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
</tbody>
</table>

---

**Genus Cryptamphorella Dumitrica, 1970**

*Cryptamphorella* sp. cf. *C. sphaerica* (White, 1928)

(Fig. 4: 1, 7, 8, 16)

*cf.* 1928 *Baculogypsina (?) sphaerica*; White: 306; pl. 41, figs 12–13.

*cf.* 1970 *Cryptamphorella sphaerica* (White); Dumitrica: 82; pl. XII, figs 73a–b, 74a–c, 75a–b, 76, 77; pl. XX, figs 133a–b, c–f.

*cf.* 2004 *Cryptamphorella sphaerica* (White); Bragina: S383; pl. 12, fig. 7; pl. 31, fig. 3; pl. 32, fig. 4.

*cf.* 2005 *Cryptamphorella sphaerica* (White) Dumitrica; Popova-Goll et al.: 11–12; pl. 1, fig. 6; pl. 6, fig. 1.

Material. 1 specimen.

Remarks. The illustrated specimen closely resembles *C. sphaerica* and its dimensions are similar to those given by Dumitrica (1970). Doubts regarding its identification lie with the preservation of its proximal part that does not allow observation of longitudinal ridges developed on its cephalis, and because we did not observe a sutural pore. All the studied samples contain spherical forms at different stages of preservation (e.g. *Fig. 4*: 8, 16) which may also belong to this species.

Order *Spumellaria* Ehrenberg, 1875 emend. De Wever et al., 2001

Family *Hagiastridae* Riedel, 1971

Genus *Crucella* Pessagno, 1971

*cf.* 1928 *Baculogypsina (?) sphaerica*; White: 306; pl. 41, figs 12–13.

*cf.* 1970 *Crucella crux* (Lipman, 1952)

(Fig. 4: 28)

*cf.* 1952 *Histiastrum crux* Lipman: 34; pl. 2, fig. 4.

*cf.* 2005 *Histiastrum crux* Lipman; Popova-Goll et al.: 14; pl. 7, fig. 5.

Family *Oribiculiformidae*, Pessagno, 1973

Genus *Oribiculiforma* Pessagno, 1973

**Genus *Oribiculiforma multa* Kozlova in Kozlova & Gorbovetz 1966**

(Fig. 4: 3)

*cf.* 1966 *Spondogisus (?) multus* Kozlova; Kozlova & Gorbovetz: 87–88; pl. 4, fig. 10.

*cf.* 1998 *Oribiculiforma multa* Kozlova; Vishnevskaya & De Wever: 247–248; pl. 1 figs 2, 3, 6, 9; pl. 2, fig. 13.

*cf.* 2005 *Oribiculiforma multa* Kozlova; Packer & Hart: 152; fig. 7A.

Material. 2 specimens.

Remarks. In spite of their poor preservation, the specimens retrieved are composed of a cylindrical test made of two disks.

Family *Praeconocaryommae* Pessagno, 1976

Genus *Praeconocaryomma* Pessagno, 1976

*Praeconocaryomma (?) sp. cf. *P. californiaensis* (Fig. 4: 2)


*cf.* 2005 *Praeconocaryommae multa* Kozlova; Popova-Goll et al.: 20, pl. 3, figs 5–6; pl. 6, fig. 10.

Material. 1 specimen.

Remarks. Internal mould, displaying mammae arranged after a hexagonal pattern.

Family *Stylosphaeridae* Haeckel, 1881

Genus *Praestylosphaera* Empson-Morin, 1981

*Praestylosphaera (?) sp.*

(Fig. 4: 4)


*cf.* 2005 *Praestylosphaerae multa* Kozlova; Popova-Goll et al.: 20, pl. 3, figs 5–6; pl. 6, fig. 10.

Material. 1 specimen.

Remarks. Based on the observed subspherical lattice shell, made of polygonal (mostly hexagonal) pore frames surrounding circular
pores, this specimen is tentatively assigned to the genus *Praeconocaryomma*. The two polar spines appear to be broken.

### Radiolarian distribution and preservation

In spite of the overall poor preservation of the radiolarians, nearly half of the specimens retrieved in our material could be identified (Table 1). Spumellaria appear to be more abundant than Nassellaria in all samples.

Sample 38.00 mbs (metres below surface) yielded a very poorly preserved fauna, in which several *Orbiculiforma*-like specimens, two multicyrtid Nassellarians and one possible *Rhopalosyringium* were recognized. Although the number of radiolarians in sample 42.00 mbs is the lowest found and their state of preservation rather poor, two were identifiable with previously described species. Some taxa identified in this study were found only in this sample, thus contributing to improving understanding of the overall diversity preserved in the studied sequence. This is especially true for *Cryptamphorella* sp. cf. *C. sphe rica* (Fig. 4: 1), but also for the internal mould tentatively assigned to *Praeconocaryomma californi aesis* (Fig. 4: 2).

The radiolarian preservation is much better in sample 43.00 mbs in which *Theocapsomma amphora* and *Amphiphynax stocki* (Fig. 4: 5, 6) were identified. The presence of specimens resembling *Orbiculiforma multa* and *Praeconocaryomma* is also of significance (Fig. 4: 3, 4), as these morphotypes were found only in sample 43.00.

Although the number of identifiable radiolarians is low in sample 45.00 mbs, a well-preserved specimen of *Diacanthocapsa ovoidia* was found in it (Fig. 4: 9a, b).

Sample 48.00 mbs is the most interesting of the six samples, because of both the large number of specimens and their better preservation. Out of a total of *c*. 200 specimens, one-third was sufficiently well preserved to be identified. In addition to several archaeodictyonid morphotypes, an interesting diversity of carpocanid morphospecies was also found in which a distinctive morphotype was identified, *Theocapsomma* sp. aff. *T. amphora sensu* *Popova-Goll et al. 2005* (Fig. 4: 11–12), known previously only from the Santonian to early Campanian interval of the southern Russian platform.

Finally, radiolarians are again much less well preserved in sample 48.42 mbs; however, some morphotypes were found only in this sample (i.e. *?Crucella crux*, *Stichomitra* sp. A).

### Discussion

We discuss here the chronostratigraphic significance of the identified radiolarian taxa and their possible origin from the Cretaceous sequences of the London Basin.

*Amphiphynax stocki* is a world-wide species known from most of the Upper Cretaceous–Paleocene interval (*Popova-Goll et al. 2005*). As discussed earlier, *Diacanthocapsa ovoidia* is known from lower Campanian levels of Romania and upper Campanian strata of Japan. *Dumitrica* (1970) reports its presence in a poorly time-constrained interval covering the Turonian to Maastrichtian in Italy. *Theocapsomma amphora* is known from the Santonian to Paleocene (see above), while *Theocapsomma* sp. aff. *T. amphora* is known only from the Santonian to lower Campanian of the Russian Platform (*Popova-Goll et al. 2005*).

For some other species, although they were not identified with confidence, it is interesting to review their currently known age range as they might provide some additional evidence for the age of the original radiolarian-bearing strata. Thus, *Cryptamphorella sphe rica* is known mainly from the Coniacian–Santonian of Japan (*Okamoto et al. 1994*), the Santonian–lower Campanian of SW Russia (*Popova-Goll et al. 2005*) and the lower Campanian of the Caribbean region (*Pessagno 1963*) and of Romania (*Dumitrica 1970*). *Orbiculiforma multa* is known from the Coniacian–Santonian of Denmark (*Packer & Hart 2005*) and of Russia (*Vishnevskaya & De Weyer 1998*).

In summary, based on the presence of *Diacanthocapsa ovoidia*, *Theocapsomma amphora* and *Theocapsomma* sp. aff. *T. amphora sensu* *Popova-Goll et al. 2005*, the only possible common source interval of the identified radiolaria appears to be the Santonian–Campanian, and more likely only the Campanian. The specimens found in the London Clay Formation are therefore definitely reworked from older formations of the London Basin.

The sedimentary sequences of the London Basin dated as Coniacian–early Campanian are the Lewes Chalk, Seaford Chalk and Newhaven Chalk formations (see Fig. 2). The Lewes Chalk Formation, of late Turonian to early Coniacian age, is composed of massive chalk with some seams of flint nodules. Based on the age of this formation, it does not seem likely to be the formation of origin for the discovered radiolaria. The Seaford Chalk Formation, of late Coniacian–early Santonian age, is composed of limestones with numerous layers of flint. One possibility is that radiolarians come from this formation. It is worth noting that the early Santonian corresponds to a transgressive interval, which would have favoured the abundance of planktonic organisms, such as radiolarians; however, none has been recorded from the extensive studies of chalks of this age in this region. The Newhaven Chalk Formation is Santonian to early Campanian in age and is characterized by white chalk that includes numerous flint layers. Therefore, such a lower Campanian level could possibly be the source of the radiolaria found reworked in the Eocene London Clay Formation. It should also be stressed that *Packer & Hart (2005)* mention the presence of a silicified level at the base of the lower Campanian chalk of the Trunch borehole (north Norfolk, UK) in which they observed siliceous moulds of foraminifera. Previous reports on radiolarian occurrences from the Chalk Group in England date from the end of the nineteenth century; most were based on thin-section observations with only some radiolarian drawings amongst them. *Rüst (1888)* described a new radiolarian species (*Dictyomitra anglica*) from flints of the Upper Chalk; however, the single illustrated specimen of this multicyrtid Nassellarian is inadequately documented and should be considered as nomen dubium. *Hill & Jukes-Browne (1895*, p. 601) reported that they have searched for radiolarians in ‘almost all the various divisions of the Chalk, from many different localities’, but they have found them, calcitized, only in nodules of the Melbourn Rock. As mentioned earlier, this member is part of the Holywell Chalk Formation and spans the Cenomanian/Turonian transition. The observed calcitized radiolarians were found only in nodular beds of the Melbourn Rock, which represent, according to the authors (*Hill & Jukes-Browne 1895*, p. 602), semi-consolidated chalk-ooze that ‘rolled into lumps on the sea-bottom under the influence of currents’. It is worth noting that they observed radiolarians in nodules from a large area covering Cambridgeshire, Bedfordshire, Oxfordshire, Lincolnshire, Yorkshire and Dover. Some of the illustrated specimens may belong to the Late Cretaceous genus *Patellula*; however, their drawings (based on thin-section observations) are not sufficient for more detailed identification. *Holmes (1900)* published on radiolarians coming from flints of the Upper Chalk at Coulson (southern part of the Greater London area, Surrey). The radiolarians he described come from two loose flint samples found on the pile of stones left from the railway cuttings following the newly opened railway line in the area. Although ‘the exact horizon from which they were derived is difficult to determine’, based on the presence of echinoids and brachiopods in the same pile of rock-cuttings, the author concludes that it is very likely that the radiolarian-bearing samples come from the flint horizons present in the Sternotaxis plenus Zone (upper Turonian) of the Lewes Chalk Formation


O’Dogherty, L. 1994. Biochronology and Paleontology of Mid-Cretaceous Radiolarians from Northern Apennines (Italy) and Betic Cordillera (Spain). Mémoires de Géologie (Lausanne), 21.


