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# Reassessing the age of Karpathos ophiolite (Dodecanese, Greece): consequences for Aegean correlations and Neotethys evolution

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1 *Title page*

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3 *Title:* Reassessing the age of Karpathos ophiolite (Dodecanese, Greece): consequences for  
4 Aegean correlations and Neotethys evolution.

5

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15

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19

20 *Abstract*

21 While the Neogene history of the Eastern Mediterranean region is now fairly well understood,  
22 our knowledge of older regional paleogeographies is less accurate, especially the positions of  
23 blocks and nappes constituting the Aegean Islands prior to the Cenozoic. Our study focuses  
24 on the ophiolite exposed on the island of Karpathos (Dodecanese), which is located in the  
25 Aegean fore-arc at a pivotal position between the ‘western’ and ‘eastern’ ophiolites of the  
26 Mediterranean region and where conflicting Late Jurassic and Late Cretaceous ages have led  
27 to diverging tectonic and paleogeographic interpretations. To test these ages, we targeted the  
28 radiolarian cherts that depositionally overlie the ophiolite and extracted diagnostic radiolarian  
29 assemblages of Aptian (~125–113 Ma), early-middle Albian (~113–105 Ma), and Turonian  
30 (~93.9–89.8 Ma) ages. These results suggest that previous Late Cretaceous K-Ar isotopic  
31 ages (from  $95.3 \pm 4.2$  Ma to  $81.2 \pm 1.6$  Ma) may have been reset by Late Cretaceous  
32 metamorphism or affected by argon loss. Overall, the new Early Cretaceous ages show that  
33 the Karpathos ophiolite should not be correlated with the Pindos Nappes of Greece or the  
34 ophiolites of Cyprus or Syria but rather with the Lycian Nappes of Turkey and their root  
35 located in the Izmir–Ankara–Erzincan Suture Zone. Therefore, the Karpathos ophiolite  
36 represents a remnant of the Northern Neotethys, not the Pindos Ocean or the proto-Eastern  
37 Mediterranean Basin.

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40 *Keywords:* ophiolite, radiolarite, Radiolaria, Cretaceous, Karpathos, Aegean fore-arc,  
41 Neotethys.

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## 43 **1. Introduction**

44

45 Present-day convergent margins are often characterized by the occurrence of ophiolites along  
46 the upper plate(s) in a large variety of settings related to terrane accretion processes (see Dilek  
47 & Furnes, 2014, and references therein). This study focuses on the island of Karpathos  
48 (Dodecanese, Greece), which belongs to the Aegean fore-arc (Figure 1) and is located at the  
49 junction between two important ophiolite domains of the Mediterranean region: the western  
50 region (Dinarides, Hellenides) and the eastern region (Taurides, Cyprus, Syria) (Robertson,  
51 2002). Although the Neogene history of the Eastern Mediterranean region is fairly well  
52 understood following a very large number of studies and the application of powerful tools  
53 such as high-resolution seismic tomography (Royden & Faccenna, 2018, and references  
54 therein), our knowledge of older regional paleogeographies is less accurate. In the Aegean  
55 Sea, the origin of scattered blocks and nappes constituting the Cyclades, Crete and the  
56 Dodecanese is not well understood. In particular, there are some difficulties in establishing  
57 precise geological correlations between these islands and the surrounding continental margins  
58 (Roche *et al.* 2018).

59 Due to its “pivotal” position between the ophiolite regions of Greece and Turkey, Karpathos  
60 has attracted significant geological attention for more than a century (see Appendix  
61 “Pioneering studies on Karpathos”, online Supplementary Material at  
62 <http://journals.cambridge.org/geo>), but diverging interpretations about the age of the ophiolite  
63 have led to conflicting views: while K-Ar geochronology documented Late Cretaceous  
64 isotopic ages (Koepke, Kreuzer & Seidel, 1985; Hatzipanagiotou, 1991; Koepke, Seidel &  
65 Kreuzer, 2002), the sedimentary rocks overlying the ophiolite were considered to be early  
66 Early Cretaceous based on calpionellids, suggesting that the ophiolite could be as old as Late  
67 Jurassic (Davidson-Monett, 1974; Aubouin, Bonneau & Davidson, 1976). These two distinct  
68 ages led to very different paleogeographic scenarios: the Karpathos ophiolite has been

69 interpreted as a remnant of the Pindos Ocean (Aubouin, Bonneau & Davidson, 1976), the  
70 Northern Neotethys (Robertson, 2002), or the Southern Neotethys due to age and petrological  
71 affinities with Late Cretaceous ophiolites of Turkey, Syria and Oman (Koepke, Seidel &  
72 Kreuzer, 2002).

73 Since no modern radiolarian study has ever been undertaken on the island, we have revisited  
74 Karpathos and reassessed the potential of its supra-ophiolitic sedimentary strata, with three  
75 major objectives: 1) to solve this chronological conundrum by focusing on radiolarian cherts,  
76 2) to improve the correlations between Karpathos and the surrounding Mediterranean  
77 ophiolites (Greece, Crete, Rhodes, Turkey), and 3) to develop a better understanding of  
78 Neotethys paleogeography and tectonics in the Aegean region.

79

## 80 **2. Geological setting**

81

### 82 **2.a. The Xindothio Unit**

83 The Karpathos ophiolite forms relatively small exposures (Figure 2a–c) of mainly  
84 serpentinized peridotite with minor occurrences of gabbro and dolerite dykes ('dismembered'  
85 type after Coleman, 1977). Early geological studies provided some preliminary descriptions  
86 of the magmatic rocks and associated sedimentary strata (de Stefani, Forsyth Major & Barbey,  
87 1895; Martelli, 1916; Christodoulou 1960; Aubouin & Dercourt, 1970; online Supplementary  
88 Material at <http://journals.cambridge.org/geo>). Later, geological mapping demonstrated that  
89 these rocks lie within tectonic slices at the top of the nappe pile exposed in the central part of  
90 the island and belong to a tectono-stratigraphic succession described as the 'Xindothio Unit'  
91 (Davidson-Monett, 1974; Aubouin, Bonneau & Davidson, 1976; Hatzipanagiotou, 1987). The  
92 Xindothio Unit overlies the Kalilimni Unit, a Jurassic to Eocene parautochthonous carbonate  
93 platform (Figure 2a), and comprises eight subunits from base to top (Figure 3a): ammonite-  
94 bearing marl, belemnites-bearing sandstone, platy limestone with filaments (*Halobia*), grey

95 platy limestone, mafic and ultramafic rocks (serpentinite, gabbro, dolerite), red radiolarite and  
96 pink microcrystalline limestone, platy green limestone, fine-grained limestone and siliceous  
97 beds. The base of the Xindothio Unit has been dated as early Late Triassic (Carnian) with  
98 ammonites (*Tropites subbullatus*; Aubouin, Bonneau & Davidson, 1976), while the top is  
99 Campanian–Maastrichtian based on planktonic foraminifera (*Globotruncana stuarti*, *G.*  
100 *stuartiformis*, and *G. contusa*; Aubouin, Bonneau & Davidson, 1976).

101 Mafic and ultramafic rocks are commonly found in tectonic contact with the underlying units,  
102 whereas the radiolarites depositionally overlie the ophiolite at many locations in the Lastos  
103 and Menetes areas (Davidson-Monett, 1974; Aubouin, Bonneau & Davidson, 1976;  
104 Hatzipanagiotou, 1987, 1988) (Figures 2a–c, 3a). The depositional nature of this contact is  
105 supported by good lateral continuity of the radiolarites which show no significant  
106 deformation. The rarity of basalts and the direct contact between the magmatic rocks and the  
107 radiolarites suggest that the Karpathos ophiolite formed by relatively slow spreading. Near the  
108 contact, red chert beds are 5-15 cm thick, whereas these beds are less abundant upsection and  
109 crop out as thin continuous layers or chert nodules. Overall, the radiolarite-pink limestone  
110 subunit is approximately 40 m thick (Figures 3a, 4).

111

## 112 **2.b. Previous ages of the ophiolite and overlying strata**

113 Vinassa de Regny (1901) provided the first study of Karpathos radiolarians, which he  
114 observed within ‘phtanites’ (black cherts) and ‘argillaceous jaspers’ (red-maroon cherts)  
115 collected in the Lastos area (Figure 2a, b). This pioneering work led to the description of fifty-  
116 eight radiolarian morphotypes (online Supplementary Material at  
117 <http://journals.cambridge.org/geo>), although most of the identified genera are now classified  
118 as *nomen dubium* (O’Dogherty *et al.* 2009). In the light of current radiolarian taxonomy, some  
119 of the forms illustrated by Vinassa de Regny (1901) resemble the modern genera  
120 *Archaeospongoprunum*, *Hiscocapsa*, *Paronaella*, *Pseudoeucyrtis*, *Pseudodictyomitra*, and

121 *Triactoma*, but their occurrence is difficult to confirm given the discrepancies between 1900s  
122 drawings and present-day taxonomy based on three-dimensional scanning electron  
123 microscope (SEM) observations. Vinassa de Regny (1901) suggested that the faunal  
124 assemblage was possibly Late Cretaceous, although this age determination was tentative due  
125 to the absence of radiolarian biozonation at the time. Later, an age determination was obtained  
126 on the radiolarite-pink limestone subunit with one calpionellid assemblage (Davidson-Monett,  
127 1974; Aubouin, Bonneau & Davidson, 1976) and was assigned to the middle–late Berriasian  
128 (145–139.8 Ma; Cohen *et al.* 2013, updated 2018). Consequently, these authors suggested  
129 that the ophiolite could be as old as Late Jurassic.

130

131 The K-Ar isotopic ages obtained later on the magmatic rocks (hornblende grains extracted  
132 from intrusive dolerites) are much younger than the overlying sedimentary strata (Table 1;  
133 Koepke, Kreuzer & Seidel, 1985; Hatzipanagiotou, 1991; Koepke, Seidel & Kreuzer, 2002).  
134 In Lastos, two ages range between 84.7 and 79.6 Ma, encompassing the middle  
135 Santonian–middle Campanian interval (Cohen *et al.* 2013, updated 2018). In Menetes, the  
136 isotopic ages range between 99.5 and 88.4 Ma, corresponding to the middle  
137 Cenomanian–middle Coniacian interval.

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139

### 140 **3. Studied sections and methods**

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142 Our study focused on identifying the contact between mafic/ultramafic rocks and the  
143 overlying radiolarian cherts in order to select a few localities for sampling. This contact is  
144 exposed in the high valley of Lastos on the eastern flank of Mount Kalilimni (Figures 2b, 5)  
145 and near the village of Menetes on the southern flank of Mount Homali (Figure 2c). To  
146 maximize the quality of the faunas, we selected a variety of radiolarian samples in accordance

147 with specific field techniques previously applied to suture zones and fore-arc belts (Cordey &  
148 Krauss, 1990; Cordey & Cornée, 2009). Radiolarians were then extracted by repetitive  
149 leaching of samples with low-concentration hydrofluoric acid (HF) and then hand-picked and  
150 mounted on aluminium stubs for SEM observation and taxonomical identifications (Tabletop  
151 SEM Phenom ProX, University of Lyon).

152

153 In Lastos, our samples were collected from two sections:

154 1/ section 'North Lastos road' (Figure 2b; Table 2). This section is composed of an outcrop of  
155 serpentinites depositionally overlain by radiolarian cherts and pink limestones. KAL01 was  
156 collected from a red radiolarite bed situated 30 cm above the serpentinite body (Figure 3b).

157 Similar stratigraphic contacts between serpentinites and radiolarites are visible at several  
158 locations along the North Lastos road (Figures 2b, 5b, c).

159 2/ section 'Hill 730 m' (Figure 2b, Table 2). This section was previously described by  
160 Davidson-Monett (1974) and Aubouin, Bonneau & Davidson (1976) under the name 'section  
161 of hill 738 m' (Figures 3b, 4) and renamed to follow the revised topography available on the  
162 Karpathos-Kasos map sheet (Psimenos *et al.* 2017). Sample KAL02 is from a bed of red  
163 radiolarian chert at the base of the radiolarite-pink limestone subunit located just above the  
164 contact with gabbros and serpentinites (Figures 3b, 5a, 5e). Sample KAL03 is from a red  
165 nodular radiolarian chert bed and was collected at the top of the radiolarite-pink limestone  
166 subunit (Figures 3b, 5d).

167

168 Near Menetes, our sample locality KAM01 (Figure 2c, Table 2) is from a bed of radiolarite  
169 interbedded with pink limestones, 150 m to the south of a well-exposed serpentinite outcrop at  
170 the foot of Mount Homali (Figure 3b).

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172 **4. Results**



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The preservation of radiolarians extracted from our chert samples varies from moderate to good at both the Lastos and Menetes locations. All of the radiolarian taxa and assemblages identified in the samples are listed in Table 3. Morphotypes with biochronological significance are illustrated in Figure 6.

KAL01 comprises sixteen identified taxa (Table 3). Among them, an assemblage composed of *Archaeodictyomitra gracilis*, *Crucella euganea*, *Crucella messinae*, *Hiscocapsa asseni*, *Hiscocapsa grutterinki* and *Pseudodictyomitra lodogaensis* corresponds to the unitary associations zones (UAZ) 4–9 of O’Dogherty (1994) of early-late Aptian age. Other Early Cretaceous species include *Cenodiscaella sphaeroconus*, *Homoeoparonaella* sp. cf. *speciosa*, *Mesosaturnalis* sp., *Paronaella* sp., *Pseudocrucella* sp. aff. *kubischa*, *Pseudoeucyrtis*(?) *fuscus*, *Stichomitra communis*, *Ultranapora* sp. cf. *durhami* and *Xitus* sp. aff. *spicularius*. Among them, *Stichomitra communis* is known from the Aptian–Turonian interval (UAZ 42–46; Goričan, 1994). We interpret the morphotype illustrated in Figure 6 (n° 14) as *Dictyomitra montisserei*, which we consider to have a slightly longer age range than previously proposed (UAZ 10–20 of Albian–Turonian age; O’Dogherty, 1994).

KAL02 is composed of eight radiolarian taxa (Table 3). The co-occurrence of *Crucella messinae*, *Cyclastrum satoi*, *Dactyliosphaera leptota*, *Hexapyramis* sp. cf. *precedis*, *Mesosaturnalis levis* and *Xitus spicularius* points to UAZ 11–12 of early–middle Albian age (O’Dogherty, 1994). Some other taxa have longer age ranges, such as *Alievium* sp. (Bajocian–Maastrichtian, O’Dogherty *et al.* 2009) and *Obeliscoites* sp. cf. *perspicuus* (UAZ 1–19, Barremian–Cenomanian; O’Dogherty, 1994).

198 KAL03 comprises ten radiolarian taxa (Table 3). *Alievum* sp. cf. *superbum*, *Crucella*  
199 *cachensis*, and *Dictyomitra napaensis* are known as Turonian (Pessagno, 1976). Other taxa  
200 have been found to co-occur in Turonian biozones, such as *Stichomitra communis* (UAZ  
201 42–48 of late Aptian–Turonian; Goričan, 1994), *Dictyomitra montisserei* (UAZ 10–20,  
202 Albian–Turonian; O’Dogherty, 1994), *Pseudodictyomitra pseudomacrocephala* (UAZ 10–21,  
203 Albian–Turonian; O’Dogherty, 1994), and *Afens* sp. (Turonian–Campanian; O’Dogherty *et*  
204 *al.* 2009).

205

206 KAM01 contains seven radiolarian taxa, including species reported from the biozonation of  
207 O’Dogherty (1994), such as *Distylocapsa micropora* (UAZ 10–18) and *Thanarla brouweri*  
208 (UAZ 1–12), corresponding to a middle Albian age. Other taxa are *Archaeospongoprunum*  
209 *renaensis* (Albian; Pessagno, 1977), *Cenodiscaella tuberculatum* (early Cenomanian–?early  
210 Turonian; Pessagno, 1977), *Staurosphaeretta* sp. (late Aptian–early Turonian; O’Dogherty *et*  
211 *al.* 2009), *Pseudodictyomitra lodogaensis* (UAZ 42–46, late Aptian–late Albian; Goričan,  
212 1994), and *Triactoma* sp. (early Pliensbachian–late Turonian; O’Dogherty *et al.* 2009).

213

214 In summary, the radiolarian ages established for the radiolarite-pink limestone subunit of the  
215 Xindothio Unit are from base to top: early–late Aptian (KAL01; ~125–113 Ma; Cohen *et al.*  
216 2013, updated 2018), early–middle Albian (KAL02; ~113–105 Ma), middle Albian (KAM01;  
217 ~110–105 Ma), and Turonian (KAL03; ~93.9–89.8 Ma) (Figure 3a, b).

218

## 219 **5. Discussion**

220

### 221 **5.a. Comparison with previous microfossil ages**

222 The three Aptian and Albian radiolarian ages (~125–105 Ma) obtained at the base of the  
223 radiolarite-pink limestone subunit at Lastos (KAL01, KAL02) and Menetes (KAM01) are  
224 significantly younger than the Berriasian age (145–139.8 Ma) previously reported from the  
225 same sequence (Davidson-Monett, 1974; Aubouin, Bonneau & Davidson, 1976). A similar  
226 issue applied on Rhodes, where Danelian *et al.* (2001) established that Berriasian  
227 calpionellids from the Profitis Ilias succession had been misidentified. This situation could  
228 also be the case in Karpathos. Another hypothesis is that these calpionellids have been  
229 reworked. In any case, based on results obtained in three sections in two separate areas  
230 (Lastos and Menetes; Figure 3a, b), our data show that the radiolarites of the Xindothio Unit  
231 are not Berriasian but rather Aptian–Albian.

232

233 Our younger radiolarian assemblage is Turonian (~93.9–89.8 Ma) and was obtained at the top  
234 of the radiolarite-pink limestone subunit (KAL03). Foraminifera of similar age were reported  
235 from the base of the platy limestone subunit (Davidson-Monett, 1974; Aubouin, Bonneau &  
236 Davidson, 1976).

237

### 238 **5.b. Comparison with K-Ar isotopic ages**

239 K-Ar isotopic ages of Koepke, Seidel, & Kreuzer (2002) are shown in Table 1. At Menetes,  
240 the age difference with the radiolarian data is minor, as the oldest isotopic age of  $95.3 \pm 4.2$   
241 Ma fits into the early Cenomanian (Cohen *et al.* 2013, updated 2018). At Lastos, the age  
242 difference is greater: while radiolarians near the contact are Aptian, the oldest isotopic age is  
243 middle Santonian (84.7 Ma, Table 1). To explain such a discrepancy, four hypotheses are  
244 considered below:

245 1/ Aptian–Albian radiolarians were reworked and redeposited in younger Late Cretaceous  
246 sediments. This process seems unlikely since the radiolarian assemblages do not show any  
247 unusual mixing of incompatible taxa (Table 3). These assemblages also document a coherent

248 succession of upward-younging ages (Aptian > early–middle Albian > middle Albian >  
249 Turonian; Figure 3a). In addition, the Turonian ages obtained independently with planktonic  
250 foraminifera (Aubouin, Bonneau & Davidson, 1976) and radiolarians (this study) near the  
251 contact between radiolarite-pink limestone and platy limestone subunits are both older than  
252 the K-Ar isotopic ages of Koepke, Seidel, & Kreuzer (2002).

253 2/ The contact between mafic/ultramafic rocks and radiolarites is tectonic. However, this  
254 hypothesis is not consistent with our field observations or those of Davidson-Monett (1974),  
255 Aubouin, Bonneau & Davidson (1976) and Hatzipanagiotou (1988). The Xindothio Unit is  
256 not an accretionary-type “broken formation” where subunits are chaotically juxtaposed.  
257 Instead, it shows good reproducibility of the stratigraphic contact between the magmatic rocks  
258 and the overlying radiolarian cherts, not only at Lastos but also at Menetes (Figure 2b, c). In  
259 addition, there is good lateral continuity of the contact as shown by the parallel bedding of the  
260 radiolarite-pink limestone subunit along strike (Figure 5b, c). One could argue that the  
261 Karpathos ophiolite is dismembered and that mafic and ultramafic rocks may not be of the  
262 same age as the overlying strata, but in a dismembered or *mélange*-type configuration, the  
263 radiolarian-bearing sedimentary matrix should be closely synchronous or younger than any  
264 such olistoliths, not older (Cordey, 1998).

265 3/ The Karpathos ophiolite has a longer age range than previously envisaged, i.e., spanning  
266 the Early–Late Cretaceous, more precisely the Aptian–Santonian (from ~125–113 Ma to 84.7  
267 Ma), representing the interval between the radiolarites overlying the ophiolite and the oldest  
268 isotopic age in Lastos. In this case, the Xindothio radiolarites should be diachronous.  
269 Considering the consistent Early Cretaceous ages from Lastos and Menetes areas (this study),  
270 as well as the relatively small volumes of mafic and ultramafic rocks exposed on the island  
271 (Figure 2a-c), we do not favour this hypothesis.

272 4/ Isotopic ages from Lastos have undergone some metamorphic overprint or are affected by  
273 argon loss. This is, to us, the most likely cause of the chronological discrepancy, as both

274 phenomena can cause calculated K-Ar ages to be younger than the true ages of the dated  
275 material (McDougall & Harrison, 1999). Similarly, it has been established that some of the  
276 youngest Cretan ophiolites underwent such overprinting during the Late Cretaceous (95 Ma;  
277 Koepke, Seidel & Kreuzer, 2002). Other authors have also shown that some Cretan isotopic  
278 ages record the age of obduction rather than oceanic crust formation (Liati, Gebauer &  
279 Fanning, 2004; Stampfli, Champod & Vandelli, 2010). In Turkey, Ar-Ar isotopic ages of the  
280 metamorphic soles of the Lycian peridotites are mainly 92–90 Ma (Dilek *et al.* 1999), an age  
281 range that is similar to the K-Ar isotopic ages on Karpathos. More recently, U-Pb ages on  
282 zircons from the metamorphic sole of the Marmaris ophiolite (Lycian Nappes) have shown  
283 that their tectonic emplacement occurred between 100.4 Ma and 93.5 Ma (Cenomanian),  
284 suggesting an Early Cretaceous age for the ophiolite and the associated sedimentary rocks  
285 (Güngör *et al.* 2018). Unfortunately, previous geochronological studies carried out on  
286 Karpathos (Koepke, Kreuzer & Seidel, 1985; Hatzipanagiotou, 1991; Koepke, Seidel &  
287 Kreuzer, 2002) did not document the precise locations for the K-Ar samples or indicate  
288 whether the magmatic rocks were overlain by sedimentary strata, preventing comparative  
289 sampling of sections.

290

291 We do not know to what extent the discrepancy between biochronological and  
292 geochronological data observed on Karpathos is a localized problem or a larger issue  
293 concerning Mesozoic ophiolites. Some isotopic ages established on these ophiolites using K-  
294 Ar methods in the 1980s and 1990s probably need to be tested with more up-to-date methods  
295 such as Ar-Ar and/or U-Pb, as carried out by and Liati, Gebauer & Fanning (2004) and Smith  
296 (2006), who obtained zircon ages on hornblendites and gabbros from Cretan ophiolites, and  
297 Parlak *et al.* (2013) who used hornblendes and zircons from ophiolites of the Tauride belt.

298

299

## 300 **6. Eastern Mediterranean correlations and implications for Neotethys evolution**

301

302 Tectonic reconstructions of the Eastern Mediterranean region imply the southward migration  
303 of the Aegean fore-arc relative to Eurasia since Eocene times, a result of the rollback of  
304 subducting African lithosphere (Zachariasse, Van Hinsbergen & Fortuin, 2008; Jolivet *et al.*  
305 2013). Prior to the Paleogene, the paleogeographic evolution of the region has been described  
306 by many authors at the scale of the Tethyan Realm (Robertson, 2002; Barrier & Vrielynck,  
307 2008; Menant *et al.* 2016; Barrier *et al.* 2018), but these descriptions lack precision for the  
308 islands of the Aegean Sea. Several hypotheses have been proposed for the Karpathos  
309 ophiolite: initially, it was correlated with the ophiolites of Crete, both of which were  
310 considered the easternmost remnants of the Pindos Nappes of continental Greece and the  
311 Peloponnese (Figures 1, 7; Aubouin, Bonneau & Davidson, 1976; van Hinsbergen *et al.* 2005;  
312 Papanikolaou, 2013; Ersoy *et al.* 2014; Pantopoulos & Zelilidis, 2014). Other authors have  
313 interpreted the Karpathos and Rhodes ophiolites as southwestward extensions of the Lycian  
314 Nappes exposed in southwestern Turkey (Figure 1; Robertson, 2002; Koepke, Seidel &  
315 Kreuzer, 2002; van Hinsbergen *et al.* 2010). The ophiolites of Karpathos and Rhodes have  
316 also been associated with the Late Cretaceous ophiolites of Cyprus, Syria, and Oman  
317 (Koepke, Seidel & Kreuzer, 2002), hence as potential remnants of a basin located to the south  
318 of Turkey, in a precursor position of the present-day Eastern Mediterranean Basin. In  
319 summary, these conflicting interpretations consider the Karpathos ophiolite as an element of  
320 the western Northern Neotethys (Pindos Zone), the central Northern Neotethys  
321 (Izmir–Ankara–Erzincan suture and Lycian Nappes), or the Southern Neotethys  
322 (Cyprus–Syria) (Figure 7).

323

324 A geological review of ophiolites exposed in the Aegean fore-arc (Figure 8a) shows that the  
325 ophiolite of Karpathos is younger than those of Crete, where K-Ar isotopic ages range from

326 160 to 140 Ma (Middle–Late Jurassic) (Koepke, Seidel & Kreuzer, 2002; Liati, Gebauer &  
327 Fanning, 2004). Notably, the youngest Cretan radiolarites are Late Jurassic in age (Stampfli,  
328 Champod & Vandelli, 2010), similar to the Pindos radiolarites of continental Greece (De  
329 Wever & Cordey, 1986). Another significant difference is that, on Karpathos, a shallow  
330 marine Upper Eocene conglomerate overlies the dismembered ophiolite together with the  
331 Mesozoic limestones (Kalilimni Unit) (Figures 2b, 5f), showing that these units were already  
332 tectonically assembled while flysch deposition was still continuing in the Pindos Basin farther  
333 west.

334

335 Our results indicate that the closest chronological and petrological similarities with the  
336 ophiolite of Karpathos are found in southwestern Turkey, more specifically within the Lycian  
337 Nappes (de Graciansky, 1967; Collins & Robertson, 1997, 2003; Dilek *et al.* 1999; Robertson,  
338 2002). In the Lycian Mélange, Danelian *et al.* (2006) documented Jurassic and Early  
339 Cretaceous radiolarian cherts. In the Marmaris ophiolite, the youngest sediments associated  
340 with the ophiolite are pre-Cenomanian (Güngör *et al.* 2018).

341

342 Many authors have established a link between the Lycian Nappes and the  
343 Izmir–Ankara–Erzincan Suture Zone situated to the north of the Menderes metamorphic  
344 complex (Figure 8a) (Robertson & Pickett, 2000; Okay *et al.* 2001; Collins & Robertson,  
345 2003; Robertson *et al.* 2004). The Izmir–Ankara–Erzincan Suture Zone is itself considered a  
346 remnant of the Northern Neotethyan Ocean (Danelian *et al.* 2006) and records a long history  
347 of radiolarite accumulation. In the Central Sakarya Zone, the Dağköplü Mélange includes  
348 several slices of mid-ocean ridge metabasalts (MORB-type) that alternate with radiolarites  
349 dated to the Middle–Late Jurassic (Bathonian–Tithonian), Early Cretaceous  
350 (Hauterivian–Aptian) and early Late Cretaceous (Cenomanian) (Göncüoğlu *et al.* 2000,  
351 2001). Farther east in the Ankara Mélange, blocks of radiolarite associated with gabbro and

352 pink micritic limestone are dated as Late Triassic, Early Jurassic, Late Jurassic and Early  
353 Cretaceous, including Aptian and Albian strata such as on Karpathos (Bragin & Tekin, 1996).  
354 As in the Dağküllü Mélange, the youngest radiolarites of the Ankara Mélange are  
355 Cenomanian (Bragin & Tekin, 1996). Previous authors noted great similarities in both  
356 petrography and trace elements between Karpathos and Rhodes mafic and ultramafic rocks  
357 and those of western Turkey, emphasizing the depleted nature of the peridotites and the  
358 geochemistry of dykes that are typical of supra-subduction zone ophiolites (Koepke, Seidel &  
359 Kreuzer, 2002).

360

361 Farther south in the Antalya Complex, MOR-type (mid-ocean ridge) volcanic rocks are  
362 overlain by Late Jurassic–Early Cretaceous radiolarian cherts (Robertson & Woodcock, 1982;  
363 Yilmaz, 1984; Robertson, 2002), partly coeval with Karpathos radiolarites. However, the  
364 Antalya Complex records a distinct geological history and tectonic setting of an oceanic  
365 domain located to the south of the Tauride carbonate platform (Figure 7; Barrier & Vrielynck,  
366 2008; Robertson, Parlak & Ustaömer, 2012; Barrier *et al.* 2018).

367

368 The ophiolites of Karpathos and Rhodes have also been correlated with the Late Cretaceous  
369 ophiolites of Cyprus, Syria, and Oman (Koepke, Seidel & Kreuzer, 2002) and hence  
370 interpreted as potential remnants of the Southern Neotethys (Figure 7). However, this  
371 hypothesis is not supported by the tectonic interpretations that imply that the emplacement of  
372 the Karpathos and Rhodes ophiolites proceeded southward during the closure of a basin  
373 located to the north of Turkey (van Hinsbergen *et al.* 2010; Schettino & Turco, 2011).

374

375 In summary, the comparison of these various interpretations suggests that the Karpathos  
376 ophiolite originated in the central Northern Neotethys (Figure 7; Dilek *et al.* 1999; Robertson,  
377 2002; Barrier & Vrielynck, 2008; Menant *et al.* 2016; Barrier *et al.* 2018) and is linked to the



378 Lycian Nappes and their root, the Izmir–Ankara–Erzincan Suture Zone. A slight difference  
379 lies in the age of the youngest radiolarites between these units: while Karpathos radiolarites  
380 are Aptian–Albian (125–100.5 Ma; Cohen *et al.* 2013, updated 2018), the youngest  
381 radiolarites of the Lycian Nappes and the Izmir–Ankara–Erzincan Suture Zone are  
382 consistently Cenomanian (100.5–93.9 Ma). In addition, the age range represented by the  
383 ophiolite is much shorter on Karpathos (late Early Cretaceous). This suggests that the  
384 Karpathos ophiolite may be a remnant of a short-lived segment of the Northern Neotethys that  
385 was originally located in the westernmost part of the Izmir–Ankara–Erzincan Suture Zone  
386 (Figures 7, 8). The convergence and closure of the Northern Neotethys during the Paleogene  
387 then led to the thrusting of ophiolite-bearing tectonic slices over the Karpathos  
388 parautochthonous carbonate platform, similar to the Lycian Nappes over Rhodes (Figure 8b).  
389 Eventually, the southward movement of the Aegean arc during the Neogene distorted the  
390 original Paleogene configuration, separating Karpathos farther from the ancient  
391 Izmir–Ankara–Erzincan root zone.

392

393

## 394 **7. Conclusions**

395

396 Our study documents the occurrence of Early Cretaceous radiolarians in sedimentary rocks  
397 overlying mafic and ultramafic rocks on the island of Karpathos, with the following  
398 implications:

399 - The older radiolarian assemblage provides a minimum Aptian age (~125–113 Ma) for the  
400 ophiolite, while the younger assemblage indicates that the top of the radiolarite-pink  
401 limestone subunit is Turonian (~93.9–89.8 Ma). The Aptian and Albian radiolarian ages raise  
402 questions regarding the accuracy of a Berriasian age obtained previously from a single  
403 calpionellid assemblage in the same subunit.

404 - The oldest radiolarian ages (late Early Cretaceous) are significantly older than those  
405 proposed for the ophiolite using K-Ar geochronology (Late Cretaceous, from  $95.3 \pm 4.2$  Ma to  
406  $81.2 \pm 1.6$  Ma), suggesting that these isotopic ages may have been reset by Late Cretaceous  
407 metamorphism, or were affected by argon loss.

408 - The Karpathos ophiolite should not be associated with the Pindos Nappes or the ophiolites  
409 of Cyprus or Syria but rather with the Lycian Nappes and their root located in the  
410 Izmir–Ankara–Erzincan Suture Zone, possibly representing the westernmost part of this  
411 structure. Consequently, the ophiolite of Karpathos is likely to be a remnant of the Northern  
412 Neotethys, not of the Pindos Ocean or the proto-Eastern Mediterranean Basin.

413 - From an analytical viewpoint, our study suggests that previous K-Ar isotopic ages obtained  
414 from the ophiolites of the Mediterranean region should be revised with more recent and  
415 accurate methods (Ar-Ar, U-Pb), particularly for geological units that have been affected by  
416 syn- or post-emplacement metamorphism and deformation.

417

418

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429

430 **Declaration of Interest**

431 None

432

433 **Supplementary Material**

434 Appendix “Pioneering studies on Karpathos” available online at

435 <http://journals.cambridge.org/geo>

436

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### Figure captions

**Figure 1** (Colour online). Structural map of the southern Aegean region with location of the island of Karpathos (black frame) and the distribution of ophiolites in southern Greece and western Turkey. Compiled from Bornovas & Rontogianni-Tsiabaou (1983), Jolivet *et al.* (2004, 2013), van Hinsbergen *et al.* (2005, 2010), Stampfli, Champod & Vandelli (2010), Ersoy *et al.* (2014), and Gürer *et al.* (2018). The ‘eastern’ and ‘western’ ophiolite regions refer to the classification by Robertson (2002). IAE: Izmir–Ankara–Erzincan Suture Zone.

**Figure 2.** (a) Geological and structural map of Karpathos (modified after Aubouin, Bonneau & Davidson, 1976). (b) Geological map of the Lastos area and location of the radiolarian localities KAL01 (section ‘North Lastos road’), KAL02 and KAL03 (section ‘Hill 730 m’ outlined by a white band). Topography from the Karpathos-Kasos map sheet 1:30 000 (Psimenos *et al.* 2017). Geology based on Christodoulou (1968), Davidson-Monett (1974), Aubouin, Bonneau & Davidson (1976), and personal field observations. (c) Geological map of the Menetes area and location of the radiolarian locality KAM01. Topography from the Karpathos-Kasos map sheet 1:30 000 (Psimenos *et al.* 2017). Geology from the Karpathos map sheet (Christodoulou, 1968).

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720

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722 ‘Hill 730 m’ and position of samples KAL02 and KAL03 close to the contact with  
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725 but underwent Cenozoic extension and normal faulting visible in the southwestern part of the  
726 section.

727

728 **Figure 5.** Field views of the studied Karpathos units and localities (see Fig. 2b for locations  
729 of photographs). (a) Overview of section ‘Hill 730 m’ in Lastos (Figs. 2b, 3b, 4) and subunits  
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731 limestone exposures of Kalilimni Unit; Mount Kalilimni (1215 m) is the highest point on the  
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736 the contact between serpentinite and radiolarite (dashed line) along the north Lastos road near  
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738 middle part of section 'Hill 730 m' (total thickness 1 m). (e) Close-up of thick radiolarite beds  
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744 **Figure 6.** Scanning electron microphotographs (SEM) of radiolarian taxa from Lastos (KAL)  
745 and Menetes (KAM). For each sample: age and radiolarian assemblage. For each picture:  
746 radiolarian taxon, scale length.

747 - Sample KAL03 (Turonian); 1. *Pseudodictyomitra pseudomacrocephala* (SQUINABOL)  
748 (210 µm); 2. *Dictyomitra napaensis* PESSAGNO (200 µm); 3. *Dictyomitra montisserei*  
749 (SQUINABOL) (220 µm); 4. *Stichomitra communis* (SQUINABOL) (190 µm); 5. *Afens* sp.  
750 (200 µm); 6. *Crucella cachensis* PESSAGNO (180 µm); 7. *Patellula verteroensis*  
751 (PESSAGNO) (160 µm).

752 - Sample KAL01 (Aptian); 8. *Cenodiscaella sphaeroconus* (RÜST) (200 µm); 9.  
753 *Homoeoparonaella* sp. cf. *speciosa* (PARONA) (320 µm); 10. *Crucella messinae*  
754 PESSAGNO (240 µm); 11. *Crucella euganea* SQUINABOL (240 µm); 12. *Ultranapora* sp.  
755 cf. *durhami* PESSAGNO (140 µm); 13. *Pseudodictyomitra lodogaensis* PESSAGNO (180  
756 µm); 14. *Dictyomitra montisserei* (SQUINABOL) (180 µm); 15. *Xitus* sp. aff. *spicularius*  
757 (ALIEV) (210 µm); 16. *Archaeodictyomitra gracilis* (SQUINABOL) (200 µm); 17.  
758 *Archaeodictyomitra gracilis* (SQUINABOL) (180 µm); 18. *Hiscocapsa asseni* (TAN) (120  
759 µm); 19. *Hiscocapsa grutterinki* (TAN) (150 µm).

760 - Sample KAL02 (early–middle Albian); 20. *Obeliscoites* sp. cf. *perspicuus* (SQUINABOL)  
761 (180 µm); 21. *Xitus spicularius* (ALIEV) (190 µm); 22. *Dactyliosphaera lepta* FOREMAN  
762 (200 µm); 23. *Dactyliosphaera* sp. cf. *lepta* FOREMAN (200 µm); 24. *Mesosaturnalis* sp.

763 (190  $\mu\text{m}$ ); 25. *Hexapyramis* sp. cf. *precedis* JUD (190  $\mu\text{m}$ ); 26. *Cyclastrum satoi*  
764 (TUMANDA) (180  $\mu\text{m}$ ).  
765 - Sample KAM01 (middle Albian); 27. *Cenodiscaella tuberculatum* (DUMITRICA) (160  
766  $\mu\text{m}$ ); 28. *Staurosphaeretta* sp. (130  $\mu\text{m}$ ); 29. *Thanarla brouweri* (TAN) (120  $\mu\text{m}$ ); 30.  
767 *Archaeospondoprumum renaensis* PESSAGNO (180  $\mu\text{m}$ ); 31. *Distylocapsa micropora*  
768 (SQUINABOL) (180  $\mu\text{m}$ ).

769

770 **Figure 7.** Schematic paleogeographic map of western Neotethyan basins in the Cretaceous.  
771 Compiled from Barrier & Vrielynck (2008), Robertson, Parlak & Ustaömer (2012), Menant *et*  
772 *al.* (2016), Barrier *et al.* (2018), Maffione & van Hinsbergen (2018). Star: hypothetical  
773 position of Karpathos ophiolite prior to obduction. Note that the ophiolites and the tectonic  
774 nappes depicted in the diagram have been emplaced diachronously: they just indicate the  
775 initial locations and relationships to the surrounding oceanic basins.

776

777 **Figure 8.** (a) Map of the Aegean region prior to the complete southward migration of the  
778 Aegean fore-arc during the Neogene (modified after Garfunkel, 2004). The map shows the  
779 position of the ophiolites and the extensions of the Pindos and Lycian nappes, which have  
780 been proposed as potential sources for the ophiolite-bearing units of Crete, Karpathos, and  
781 Rhodes. A-B: cross-section shown in (b). Isotopic ages, Crete: Koepke, Seidel & Kreuzer  
782 (2002); Liati, Gebauer & Fanning (2004). Karpathos and Rhodes: Koepke, Seidel & Kreuzer  
783 (2002). Southwestern Turkey: Dilek *et al.* (1999); Güngör *et al.* (2018) (see references for age  
784 ranges, error margins and local distribution). Age of radiolarites, Crete: Stampfli, Champod &  
785 Vandelli (2010); Turkey: Danelian *et al.* (2006); Karpathos: this study. IAE:  
786 Izmir–Ankara–Erzincan Suture Zone. (b) Cross-section A-B (Fig. 8a) from the Eastern  
787 Mediterranean Basin to the Izmir–Ankara–Erzincan Suture Zone (modified after van



788 Hinsbergen *et al.* 2010), illustrating the southward thrusting of the Lycian Nappes and related  
789 ophiolites over Rhodes and Karpathos.  
790

791 Table 1. K-Ar isotopic ages in the Lastos and Menetes areas (Koepke, Seidel & Kreuzer,  
 792 2002) and correlation with geological stages (Cohen *et al.* 2013, updated 2018).

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	K-Ar age (Ma)	Error (Ma)	Lower limit	Upper limit
Lastos	83.1	± 1.6	84.7	81.5
			middle Santonian	early Campanian
	81.2	± 1.6	82.8	79.6
			early Campanian	middle Campanian
Menetes	91.9	± 3.5	95.4	88.4
			late Cenomanian	early Coniacian
	95.3	± 4.2	99.5	91.1
			early Cenomanian	middle Turonian
	88.8	± 5	93.8	83.8
			basal Turonian	late Santonian

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Table 2. Geographic coordinates of radiolarian samples from Karpathos.

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Lastos	KAL01	N 35° 34' 51.90"	E 27° 08' 35.96"
	KAL02	N 35° 34' 16.08"	E 27° 08' 26.14"
	KAL03	N 35° 34' 20.66"	E 27° 08' 30.57"
Menetes	KAM01	N 35° 29' 28.59"	E 27° 09' 3.84"

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Table 3. Radiolarian taxa and assemblages from Karpathos.

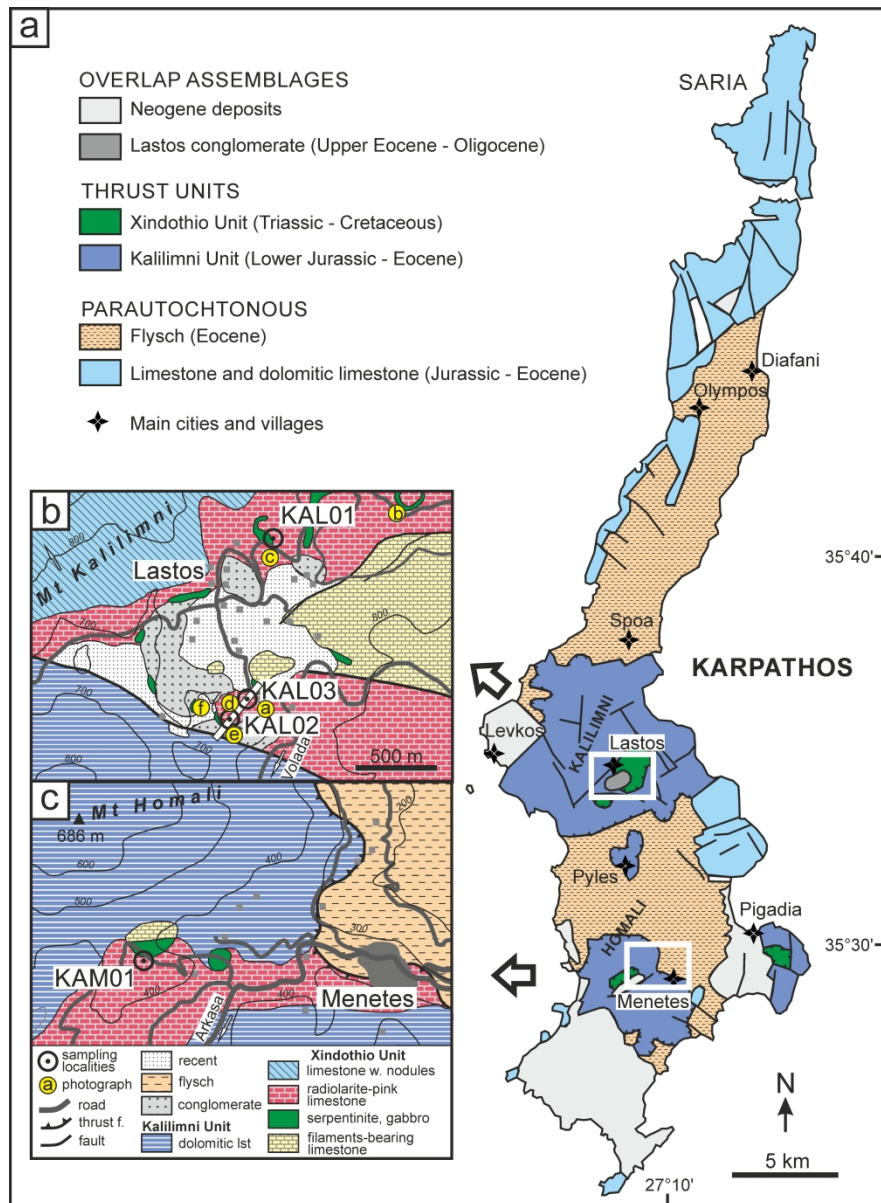
Taxa	KAL01	KAL02	KAL03	KAM01
<i>Afens</i> sp.			x	
<i>Alievium</i> sp.		x		
<i>Alievium</i> sp. cf. <i>superbum</i> (SQUINABOL)			x	
<i>Archaeodictyomitra gracilis</i> (SQUINABOL)	x			
<i>Archaeospongoprimum renaensis</i> PESSAGNO				x
<i>Archaeospongoprimum</i> sp.			x	
<i>Cenodiscaella sphaeroconus</i> (RÜST)	x			
<i>Cenodiscaella tuberculatum</i> (DUMITRICA)				x
<i>Crucella cachensis</i> PESSAGNO			x	
<i>Crucella euganea</i> SQUINABOL	x			
<i>Crucella messinae</i> PESSAGNO	x	x		
<i>Cyclastrum satoi</i> (TUMANDA)		x		
<i>Dactyliosphaera leptota</i> FOREMAN		x		
<i>Dictyomitra montisserei</i> (SQUINABOL)	x		x	
<i>Dictyomitra napaensis</i> PESSAGNO			x	
<i>Distylocapsa micropora</i> SQUINABOL				x
<i>Falsocromyodrymus</i> sp.			x	
<i>Hexapyramis</i> sp. cf. <i>precedis</i> JUD		x		
<i>Hiscocapsa asseni</i> (TAN)	x			
<i>Hiscocapsa grutterinki</i> (TAN)	x			
<i>Homoeoparonaella</i> sp. cf. <i>speciosa</i> (PARONA)	x			
<i>Mesosaturnalis levis</i> (DONOFRIO & MOSTLER)		x		
<i>Mesosaturnalis</i> sp.	x			
<i>Obeliscoites</i> sp. cf. <i>perspicuus</i> (SQUINABOL)		x		
<i>Paronaella</i> sp.	x			
<i>Patellula verteroensis</i> (PESSAGNO)			x	
<i>Pseudocrucella</i> sp. aff. <i>kubischa</i> EMPSON-MORIN	x			
<i>Pseudodictyomitra lodogaensis</i> PESSAGNO	x			x
<i>Pseudodictyomitra pseudomacrocephala</i> (SQUINABOL)			x	
<i>Pseudoeucyrtis</i> (?) <i>fuscus</i> JUD	x			
<i>Staurosphaeretta</i> sp.				x
<i>Stichomitra communis</i> (SQUINABOL)	x		x	
<i>Thanarla brouweri</i> (TAN)				x
<i>Triactoma</i> sp.				x
<i>Ultranapora</i> sp. cf. <i>durhami</i> PESSAGNO	x			
<i>Xitus</i> sp. aff. <i>spicularius</i> (ALIEV)	x			
<i>Xitus spicularius</i> (ALIEV)		x		

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167x114mm (600 x 600 DPI)



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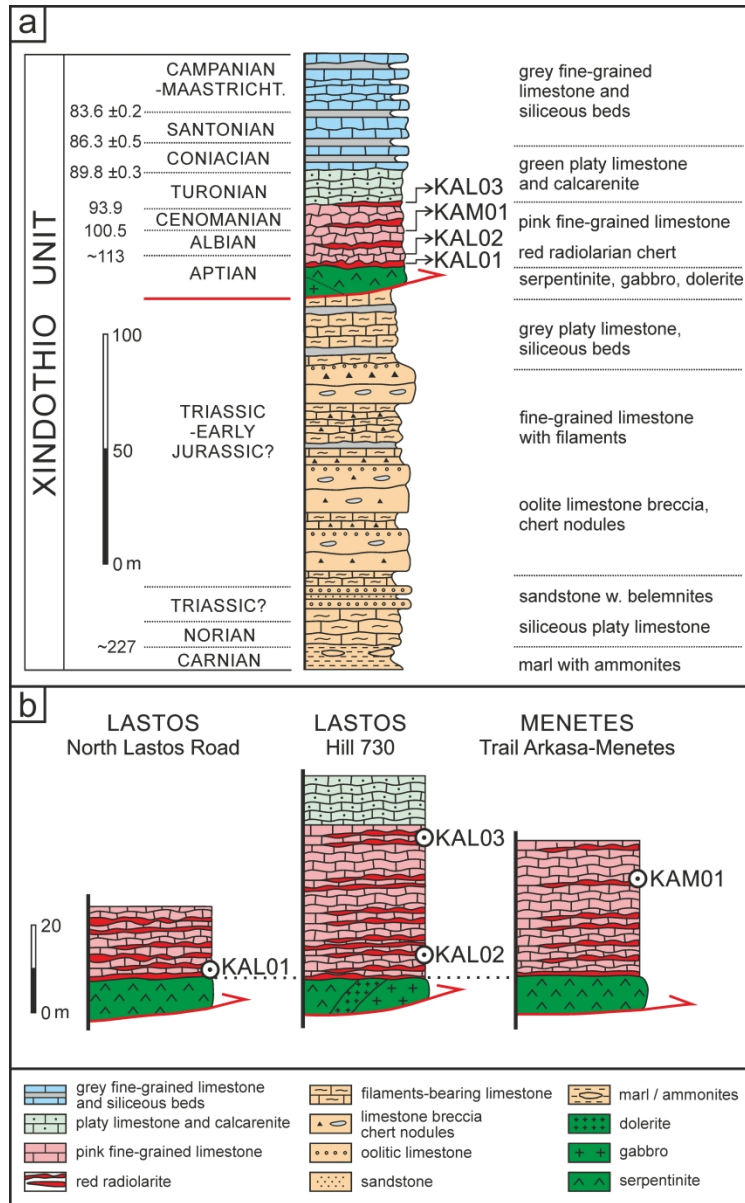


Figure 3. (Colour online) (a) Synthetic lithostratigraphic column of the Xindothio Unit succession (modified after Aubouin, Bonneau & Davidson, 1976). Basal radiolarites overlying mafic/ultramafic rocks are presently dated as Aptian (this study) instead of Berriasian (Aubouin, Bonneau & Davidson, 1976). Isotopic ages are from Cohen *et al.* (2013, updated 2018). Dotted lines (left): probable positions of stage boundaries based on biochronological data; red line: thrust fault at the base of mafic/ultramafic rocks; dotted lines (right): boundaries between subunits. (b) Sections in the Lastos and Menetes areas and stratigraphic positions of the radiolarian samples.

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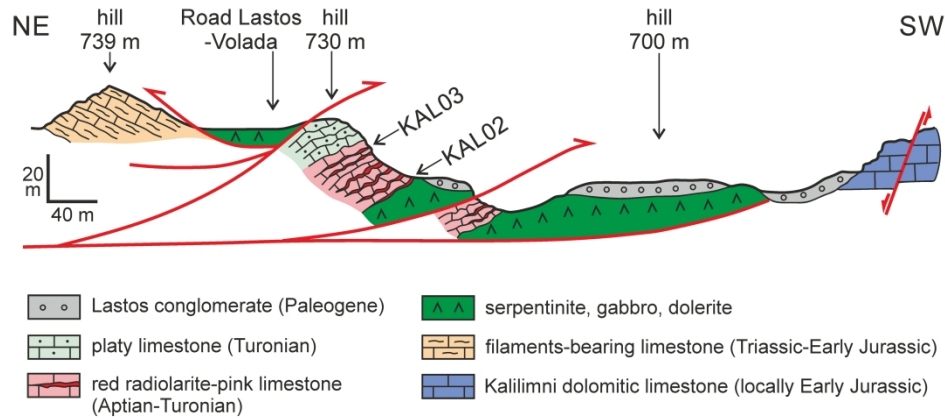


Figure 4. (Colour online) Schematic cross-section of the south Lastos area including section 'Hill 730 m' and position of samples KAL02 and KAL03 close to the contact with mafic/ultramafic rocks (modified after Aubouin, Bonneau & Davidson, 1976). Note that the Xindothio Unit is structurally situated above the dolomitic limestones of the Kalilimni Unit but underwent Cenozoic extension and normal faulting visible in the southwestern part of the section.

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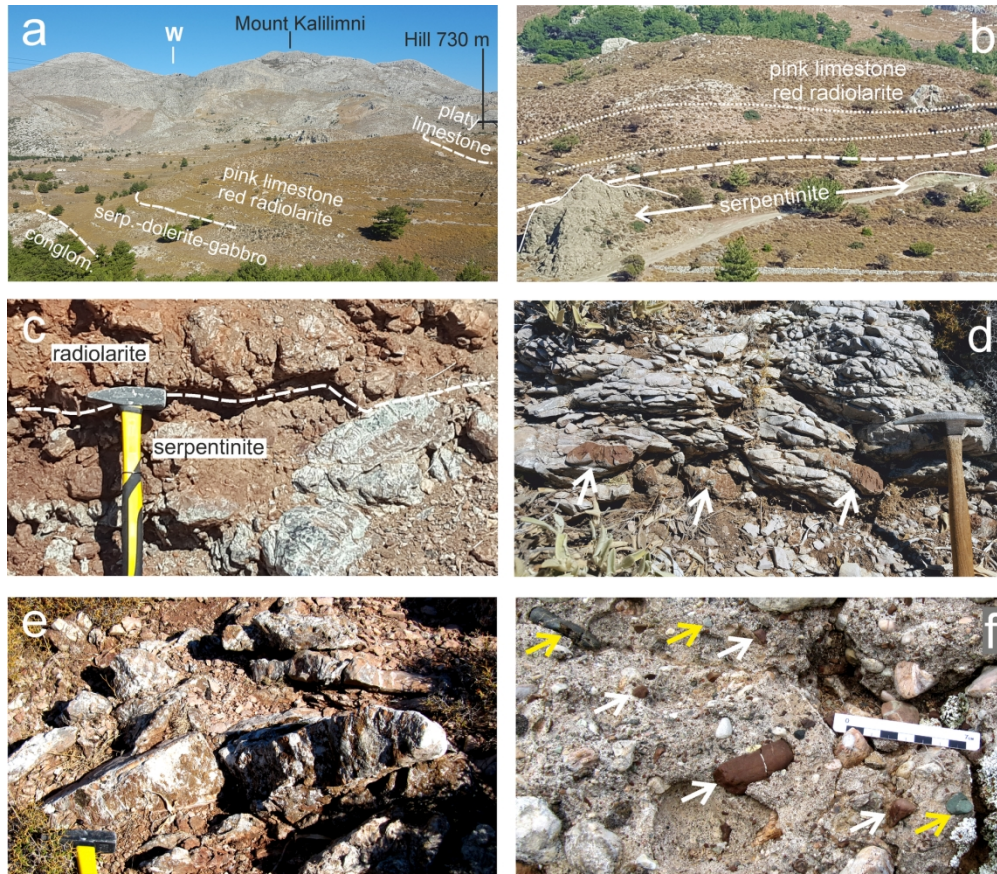


Figure 5. Field views of the studied Karpathos units and localities (see Fig. 2b for locations of photographs). (a) Overview of section 'Hill 730 m' in Lastos (Figs. 2b, 3b, 4) and subunits within the Xindothio Unit (Fig. 3); in the distance towards the west: parautochthonous limestone exposures of Kalilimni Unit; Mount Kalilimni (1215 m) is the highest point on the island. (b) Exposure of serpentinite (white arrows) overlain by the red radiolarite-pink limestone subunit along the north Lastos road (Fig. 2b). White dashed line: contact between ultramafic and sedimentary rocks. White dotted lines: bedding of radiolarite and pink limestone, parallel to the contact between ultramafic and sedimentary rocks. (c) Close-up of the contact between serpentinite and radiolarite (dashed line) along the north Lastos road near locality KAL01 (Fig. 2b). (d) Pink limestone and chert nodules (white arrows) exposed in the middle part of section 'Hill 730 m' (total thickness 1 m). (e) Close-up of thick radiolarite beds at the base of section 'Hill 730 m' (Lastos, Figs. 2b, 3, 4). (f) Exposure of the Lastos conglomerate (Eocene) displaying a variety of pebbles of radiolarite (white arrows), serpentinite (yellow arrows) and limestones from the underlying Kalilimni and Xindothio units.

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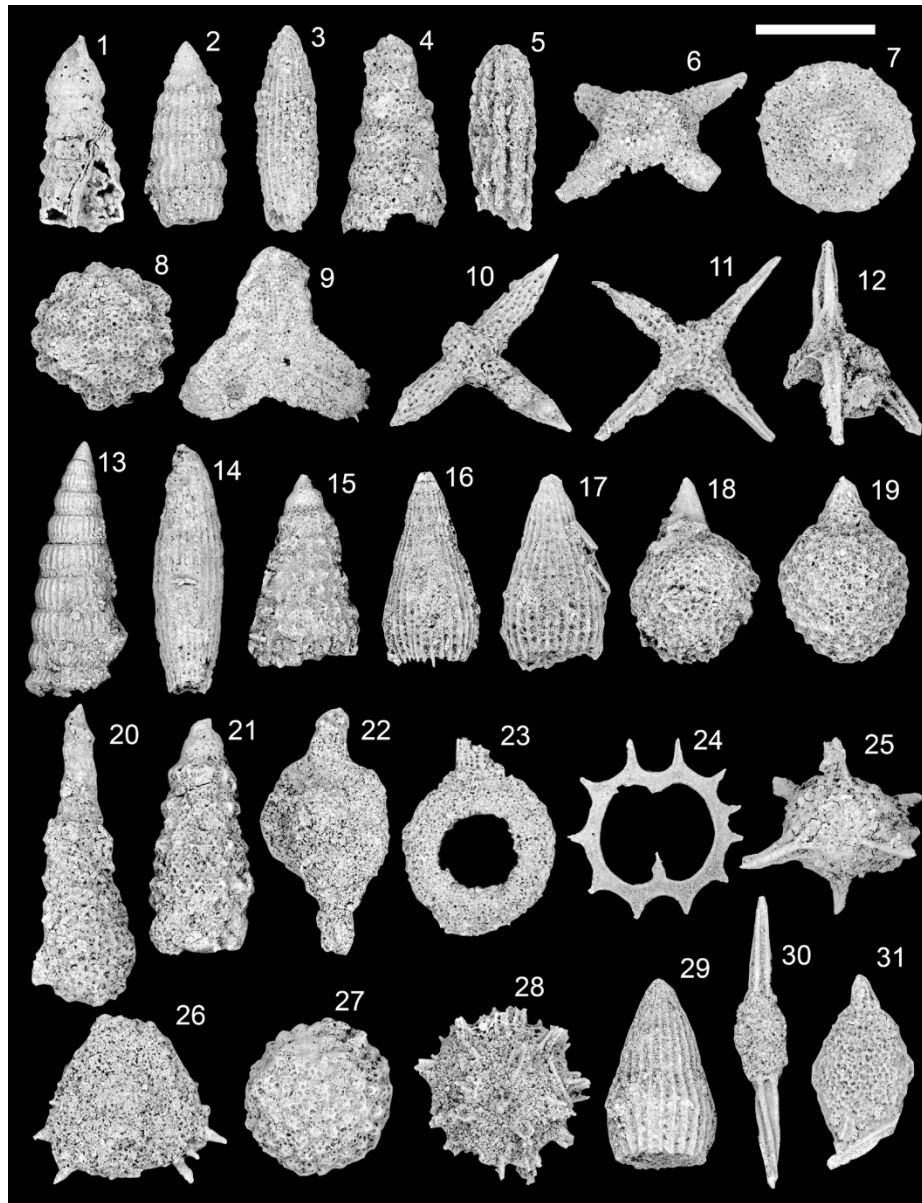


Figure 6. Scanning electron microphotographs (SEM) of radiolarian taxa from Lastos (KAL) and Menetes (KAM). For each sample: age and radiolarian assemblage. For each picture: radiolarian taxon, scale length.

Sample KAL03 (Turonian): 1. *Pseudodictyomitra pseudomacrocephala* (SQUINABOL) (210  $\mu\text{m}$ ); 2. *Dictyomitra napaensis* PESSAGNO (200  $\mu\text{m}$ ); 3. *Dictyomitra montisserei* (SQUINABOL) (220  $\mu\text{m}$ ); 4. *Stichomitra communis* (SQUINABOL) (190  $\mu\text{m}$ ); 5. *Afens* sp. (200  $\mu\text{m}$ ); 6. *Crucella cachensis* PESSAGNO (180  $\mu\text{m}$ ); 7. *Patellula verteroensis* (PESSAGNO) (160  $\mu\text{m}$ ). Sample KAL01 (Aptian): 8. *Cenodiscaella sphaeroconus* (RÜST) (200  $\mu\text{m}$ ); 9. *Homoeoparonaella* sp. cf. *speciosa* (PARONA) (320  $\mu\text{m}$ ); 10. *Crucella messinae* PESSAGNO (240  $\mu\text{m}$ ); 11. *Crucella euganea* SQUINABOL (240  $\mu\text{m}$ ); 12. *Ultranapora* sp. cf. *durhami* PESSAGNO (140  $\mu\text{m}$ ); 13. *Pseudodictyomitra lodogaensis* PESSAGNO (180  $\mu\text{m}$ ); 14. *Dictyomitra montisserei* (SQUINABOL) (180  $\mu\text{m}$ ); 15. *Xitus* sp. aff. *spicularius* (ALIEV) (210  $\mu\text{m}$ ); 16. *Archaeodictyomitra gracilis* (SQUINABOL) (200  $\mu\text{m}$ ); 17. *Archaeodictyomitra gracilis* (SQUINABOL) (180  $\mu\text{m}$ ); 18. *Hiscocapsa asseni* (TAN) (120  $\mu\text{m}$ ); 19. *Hiscocapsa grutterinki* (TAN) (150  $\mu\text{m}$ ). Sample KAL02 (early–middle Albian): 20. *Obeliscoites* sp. cf. *perspicuus* (SQUINABOL) (180  $\mu\text{m}$ ); 21. *Xitus spicularius* (ALIEV) (190  $\mu\text{m}$ ); 22. *Dactyliosphaera lepta* FOREMAN (200  $\mu\text{m}$ ); 23. *Dactyliosphaera* sp. cf. *lepta* FOREMAN (200  $\mu\text{m}$ ); 24.



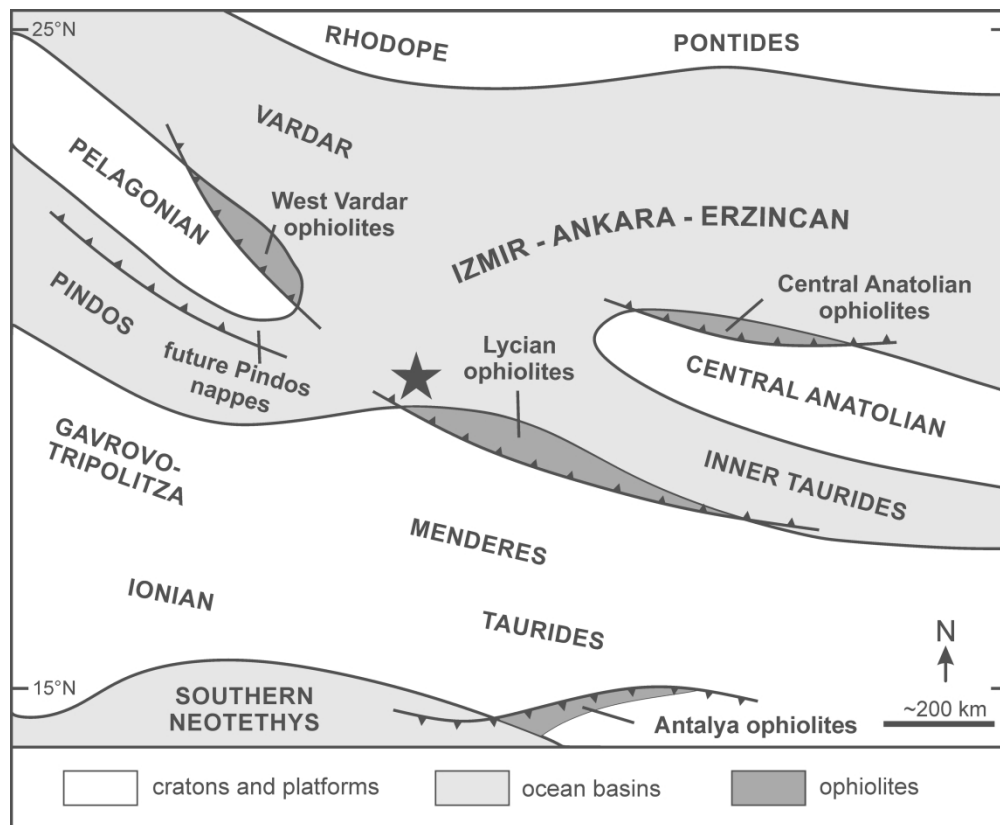


Figure 7. Schematic paleogeographic map of western Neotethyan basins in the Cretaceous. Compiled from Barrier & Vrielynck (2008), Robertson, Parlak & Ustaömer (2012), Menant *et al.* (2016), Barrier *et al.* (2018), Maffione & van Hinsbergen (2018). Star: hypothetical position of Karpathos ophiolite prior to obduction. Note that the ophiolites and the tectonic nappes depicted in the diagram have been emplaced diachronously: they just indicate the initial locations and relationships to the surrounding oceanic basins.

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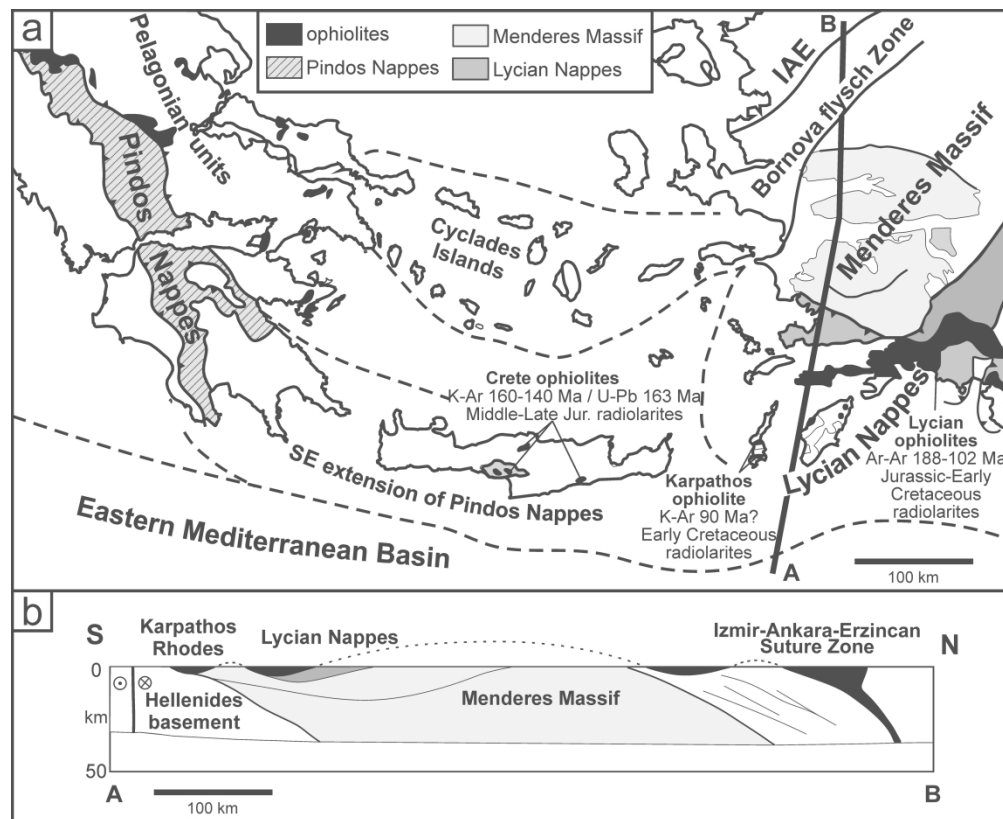


Figure 8. (a) Map of the Aegean region prior to the complete southward migration of the Aegean fore-arc during the Neogene (modified after Garfunkel, 2004). The map shows the position of the ophiolites and the extensions of the Pindos and Lycian nappes, which have been proposed as potential sources for the ophiolite-bearing units of Crete, Karpathos, and Rhodes. A-B: cross-section shown in (b). Isotopic ages, Crete: Koepke, Seidel & Kreuzer (2002); Liati, Gebauer & Fanning (2004). Karpathos and Rhodes: Koepke, Seidel & Kreuzer (2002). Southwestern Turkey: Dilek *et al.* (1999); Güngör *et al.* (2018) (see references for age ranges, error margins and local distribution). Age of radiolarites, Crete: Stampfli, Champod & Vandelli (2010); Turkey: Danelian *et al.* (2006); Karpathos: this study. IAE: Izmir–Ankara–Erzincan Suture Zone. (b) Cross-section A-B (Fig. 8a) from the Eastern Mediterranean Basin to the Izmir–Ankara–Erzincan Suture Zone (modified after van Hinsbergen *et al.* 2010), illustrating the southward thrusting of the Lycian Nappes and related ophiolites over Rhodes and Karpathos.

167x136mm (600 x 600 DPI)