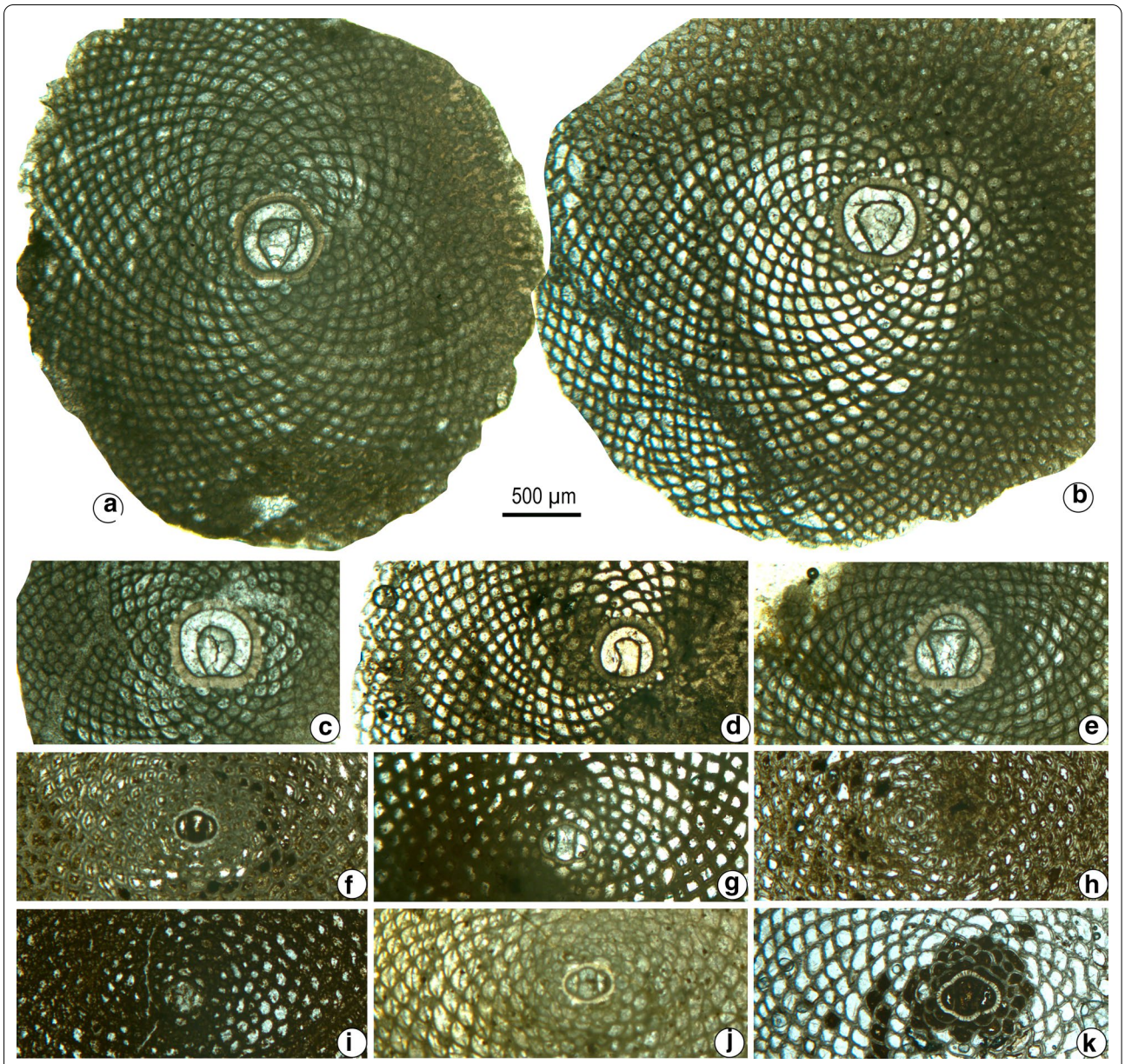

Fig. 14 Equatorial sections of *O.* ex. interc. *gruenbachensis–apiculatus* (**a**–**e**) and *O. pamiri* (**f**–**k**) from the Taraklı Formation in Epçeler A and Dereköy sections. **a** EPA18-4. **b** DE7-17. **c** EPA18-5. **d** DE7-4, **e** EPA19-2. **f** DE7-21. **g** EPA19-1. **h** EPA18-1. **i** EPA18-2. **j** EPA18-3. **k** EPA17-2

occur rarely. Based on 14 specimens from samples TC7 and 13, test diameter varies between 2.25 and 4.41 mm, with samples averages of 3.88 and 3.3 mm, respectively (Table 2). Test thickness varies between 0.97 and 2.12 mm, with sample averages of 1.72 and 1.77 mm. Test diameter to thickness ratio varies between 2.02 and 2.49 and 1.73 and 2.3 with a sample average of 2.27 and 1.89. A comparison of the test diameter versus thickness of these specimens and those of *O. medius* from the Campanian of Oman, and *O. pamiri* and *O.* ex. interc. *gruenbachensis–apiculatus* from the Taraklı Formation is shown in Fig. 11. The thickness of the equatorial layer (excluding the chamber wall) near its centre and periphery ranges between 140 and 190 µm and 130 and 165 220 µm and 220 and 285 µm and 215 and 290 µm, respectively, with sample averages of 160.0 and 146.6 µm and 252.5 and 249.1 µm (Table 2). Stolons connecting the equatorial chamberlets are about 30–40 µm in diameter in the late stage of ontogenetic development. The embryonic apparatus consist of small tri- to quadrilocular

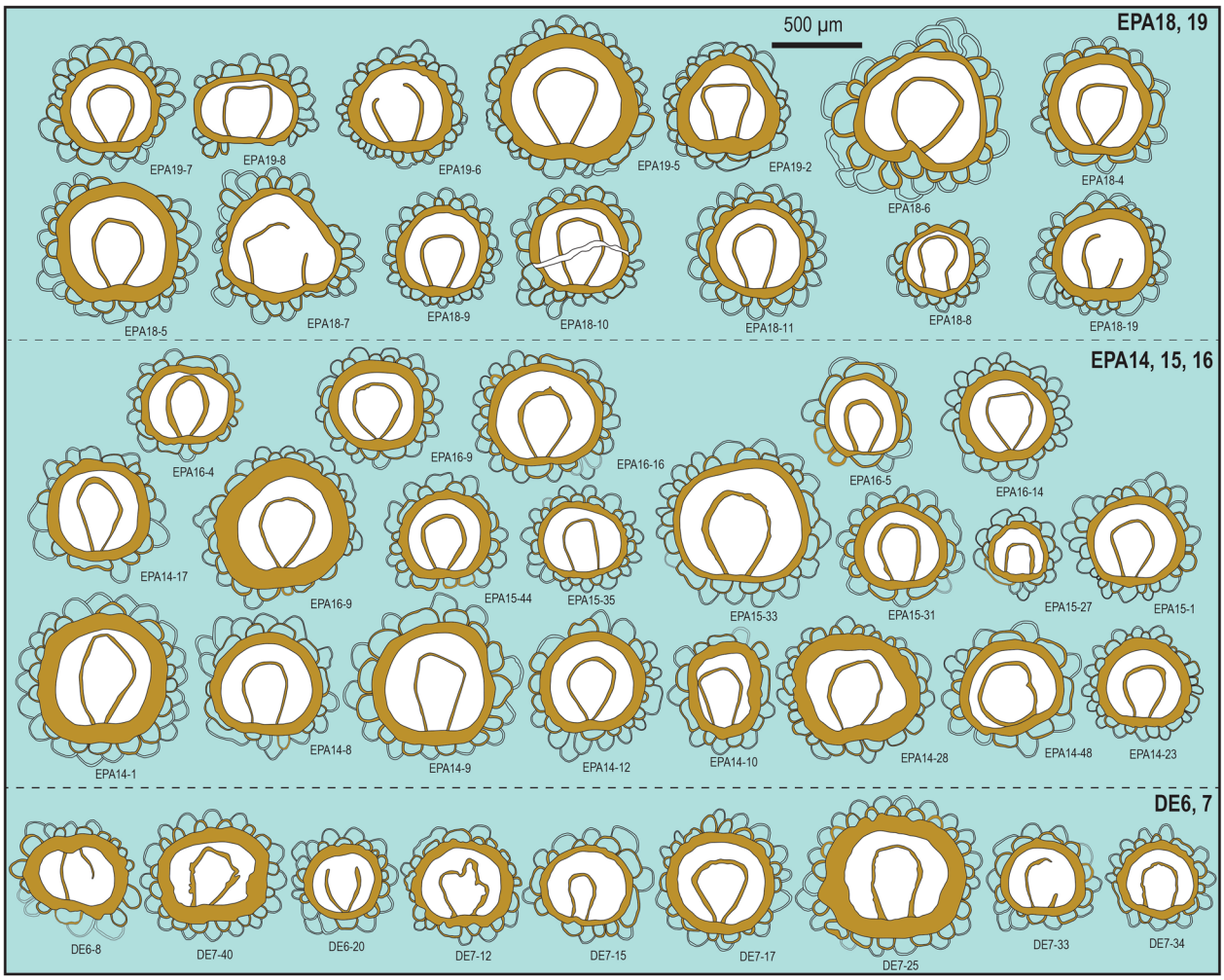

Fig. 15 Line drawings of the embryonic–nepionic stages of *O.* ex. interc. *gruenbachensis* Papp–*apiculatus* Schlumberger from the Taraklı Formation in Epçeler A and Dereköy sections

embryons, within the biometric limits of *O. medius*, surprisingly much smaller than those from the underlying Terbüzek Formation (Fig. 19; Table 1). The size of the embryonic apparatus based on 144 specimens in 6 samples (TC6, 7, 8, 9, 10 and 13) varies between 345.0 and 950 µm, with sample averages ranging between 461.7 and 554.4 µm. The average number of epi-embryonic chamberlets ranges between 4.4 and 5.41. This population is assigned to *O. 'medius'*, although, typologically, some specimens with larger embryons (e.g. TC8-47, TC6-33 in Fig. 19) are within the limits of *O. megaloformis*).

Orbitoides from the Beyobası Formation (Haymana Basin, Central Turkey)

Most of the specimens (34 out of 36) yielded bilocular and two yielded tri- to quadrilocular embryons (Fig. 8c, specimen DEG19-38). The size of the embryonic apparatus in bilocular specimens ranges between 665 and 1380 µm, with the sample average of 1023.4 µm (Figs. 8c and 16, Table 1). The mean E value varies between 11 and 20, with an average of 14.94. This population is assigned to *O. apiculatus*, although, in a typological sense, 2 specimens with small embryons may be assigned to *O. 'medius'*.

Orbitoides from the Qahlah and Simsima Formations (Oman)

Orbitoides from the upper Campanian Qahlah Formation (locality G) is represented lenticular, symmetrical biconvex, rarely asymmetrical tests (Figs. 11, 21). These specimens are within the biometric limits of *O. tissoti* and *O. medius* and are assigned to *O. medius* considering the presence of well-developed lateral chamberlets and the number of epi-embryonic chamberlets (Table 2). A

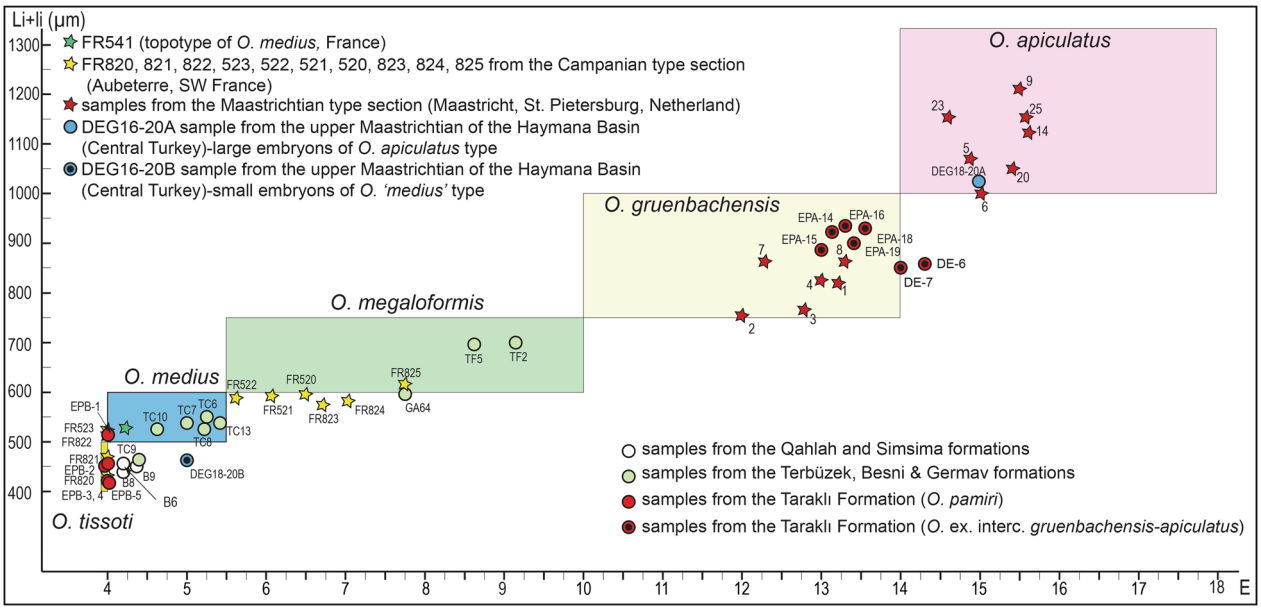

Fig. 16 Scatter diagram showing the relation between the average number of epi-embryonic chamberlets (E) and embryon size (Li + li) of the studied *Orbitoides* populations from Epçeler and Dereköy. Data from the Campanian and Maastrichtian type sections and the upper Maastrichtian Beyobası Formation (samples DEG 16-20) from the Haymana Basin are also shown. Species limits after van Hinte (1976). Data from the Campanian type section (samples FR 820, 821, 822, 523, 522, 521, 520, 823, 824 and 825 in ascending stratigraphic order) are from van Hinte (1966b) and those from the Maastrichtian type section (samples 1–9, 12, 14, 23, 25) are from Baumfalk and Willemsen (1986)

comparison of the test diameter versus thickness of this species with *O. 'medius'* from the Maastrichtian of Arabian plate and *O.* ex. interc. *gruenbachensis–apiculatus* from the Taraklı Formation is shown in Fig. 11. A comparison of the axial sections of *O. medius* and *O. pamiri*, which have a similar embryonic apparatus, is presented in Fig. 21. In sample BC6, the thickness of the equatorial layer near test centre and periphery ranges between 85 and 140 µm and 130 and 205 µm, with sample averages of 113.8 and 157.1 µm, respectively (Table 2). The stolons at the peripheral equatorial chamberlets are about 25–30 µm in diameter. The embryonic apparatus in all specimens is tri- to quadrilocular and shows a range of size between 260 and 690 µm, with sample averages ranging between 440 and 450 µm (Fig. 21; Table 1). The average number of epi-embryonic chamberlets ranges between 4.2 and 4.36.

The rare *Orbitoides* from the lower part of the Simsima Formation at Jabal Huwayyah (samples B28 and B32) yielded two types of embryons: a large, multilocular embryons and small ones with typical tri- to quadrilocular appearance in equatorial sections. In sample B28, the large multilocular embryon with Li + li value of 1710.0 µm is assigned to *O. gensacicus*, and two specimens possessing small, tri- to quadrilocular embryons with an average Li + li value of 477.5 µm are assigned to *O. 'medius'* (Fig. 22). These specimens have only 4 epi-embryonic chamberlets. In sample B32, two *Orbitoides* specimens are characterised by a large embryon with an average size of 1660 µm (Fig. 21). The number of epi-embryonic chambers could not be counted. These specimens are assigned to *O. gensacicus.* Two specimens characterised by trilocular embryons, with an average Li + li value of 527.5 µm are assigned to *O. 'medius'* (Fig. 22).

Discussion

The new data presented herein permit us to interpret the Maastrichtian *Orbitoides* from the Central Sakarya Basin and Arabian Platform in a broader Tethyan context for the first time and allow us a comparison with the records from Western Europe. In general, our data from various Maastrichtian localities in the Arabian Platform (Turkey and Oman) and Central Turkey show the predominance of '*O. medius*'-like specimens with small tri- to quadrilocular embryons and fewer epi-embryonic chamberlets, previously considered characteristic for the Campanian (Fig. 6). These specimens are characterised by two morphological types: biconvex tests (*O.* '*medius*'), and flat to biconcave tests (*O. pamiri*) and do not show any sign of reworking in terms of test features and composition of the associated foraminifera. *Orbitoides* are intact and well preserved without any sign of abrasion or decortication.

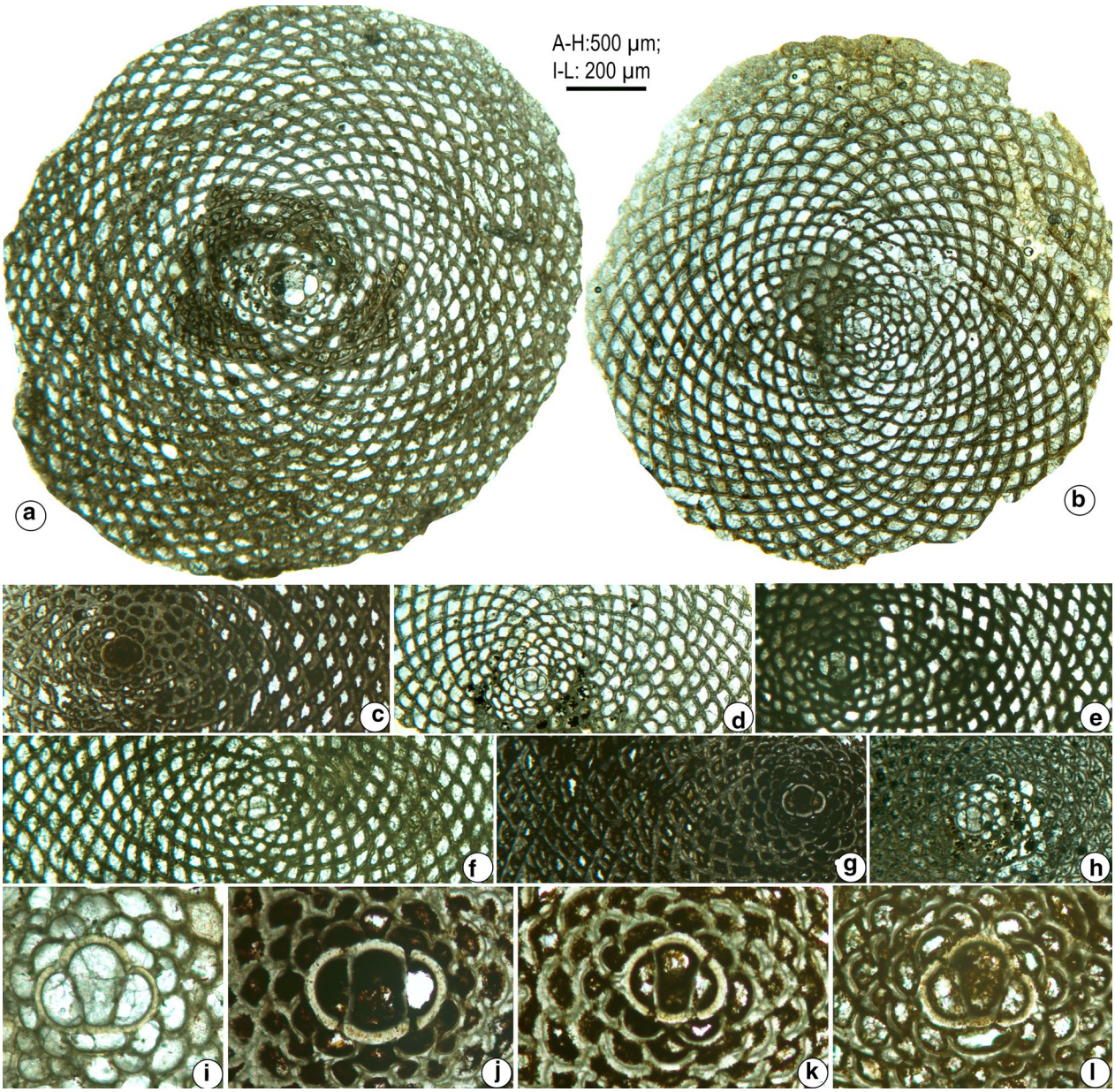

Fig. 17 Equatorial sections of *O. pamiri* from the Taraklı Formation in Epçeler B section. **a** EPB5-36. **b** EPB6-8. **c** EPB3-1. **d** EPB6-43, **e** EPB6-11. **f** EPB1-7. **g** EPB3-4. **h** EPB4-7. **i** EPB1-5. **j** EPB3-16. **k** EPB3-18. **l** EPB3-28. Note that specimens in **i** and **l** have 3 epi-embryonic chamberlets

No older foraminifera (e.g. Campanian foraminifera) were found in association with this species. In our material, *O. pamiri* is very abundant in the Taraklı Formation and all specimens are flat and/or biconcave in shape.

The Arabian Platform sequence in Southeastern Turkey yields *O. megaloformis–L. bisambergensis* assemblages in its lower part (Terbüzek Formation) and an *O. 'megaloformis' –L.* gr. *minor-socialis* assemblage in its upper part (Germav Formation) (Özcan, 1994; Fig. 17). The Maastrichtian *Orbitoides* present in this succession are characterised by biconvex tests with similar features to those recorded in some localities in Iran and Oman (Abdelghany, 2003; Payandeh et al. 2019). Considering the mean values of embryon size (Li + li) and number of epi-embryonic chamberlets (E), an evolutionary trend is not observed. Contrary to the principle of nepionic-embryonic acceleration, the most 'evolved' populations occur in the Terbüzek Formation and 'primitive' ones in the overlying beds of the Besni Formation which contains biconvex tests with predominantly *O. medius*-type

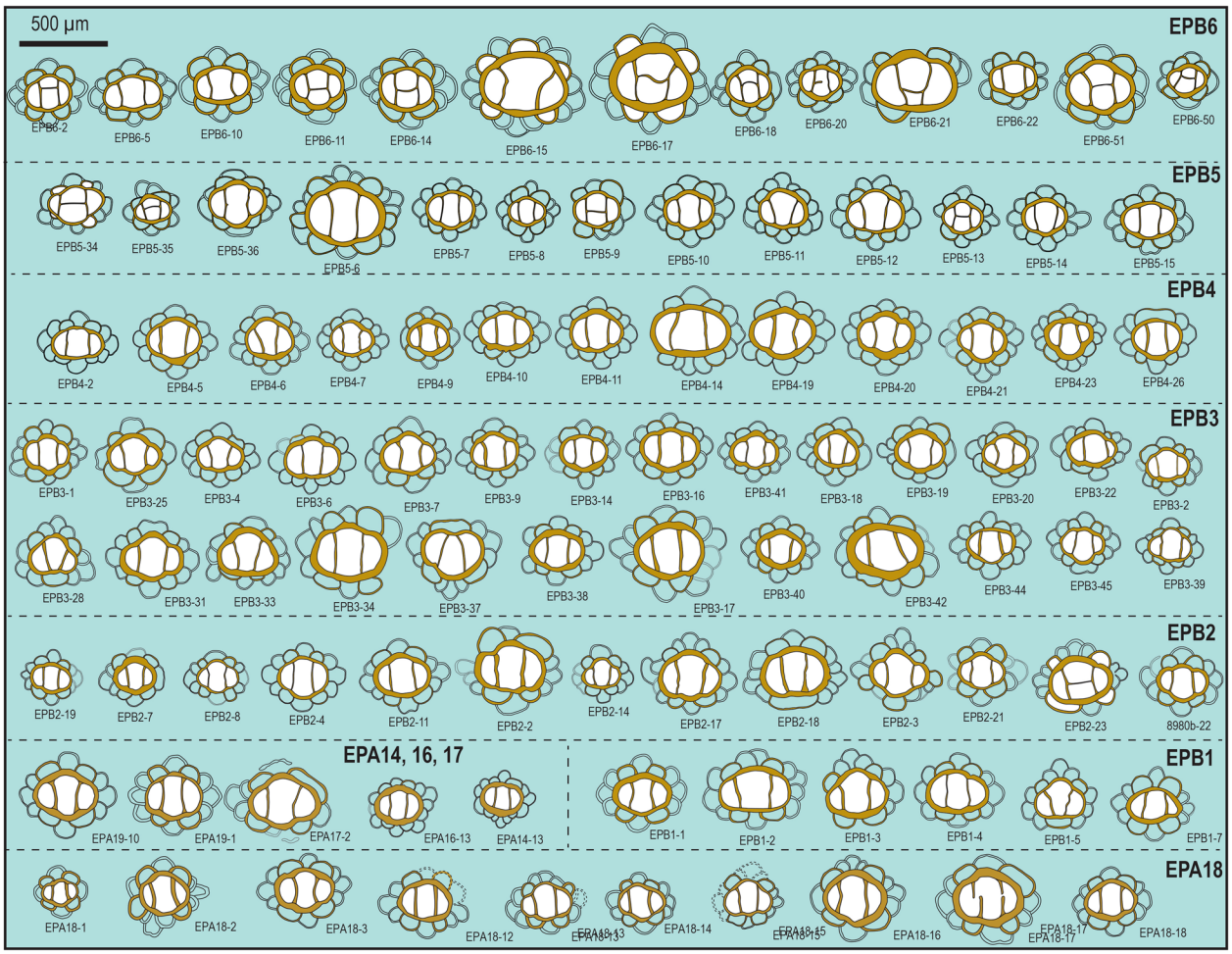

Fig. 18 Line drawings of the embryonic–nepionic stages of *O. pamiri* Meriç from the Taraklı Formation in Epçeler A, B and Dereköy sections

embryonic apparatus, associated with *S. calcitrapoides*, *O. anatoliensis*, *S.* cf. *orbitoidiformis*, and *C.* cf. *mamillatus*, *Loftusia* spp. (Özcan, 1993, 2007). The Germav Formation contains an *O. 'megaloformis'* assemblage with few specimens possessing *O. apiculatus*-type bilocular embryonic apparatus (Fig. 19).

In addition to the advanced specimens of the main *Orbitoides* lineage, which are here assigned to a transitional stage from *O. gruenbachensis* to *O. apiculatus*, the Maastrichtian Taraklı Formation yielded invariably flat to biconcave tests possessing very small embryonic apparatus (in the range of *O. tissoti* and *O. medius*) and a low number of epi-embryonic chambers (with predominantly 4 chamberlets), thus, very much resembling the Campanian species *O. tissoti* and *O. medius* in equatorial sections. These specimens, however, have well-developed lateral layers, making them distinct from *O. tissoti*, a very thick equatorial layer, almost twice as thick as that those of the biconvex specimens, and numerous large stolons connecting the equatorial chamberlets. Moreover, the number of lateral chamberlet cycles is much less than the biconvex *Orbitoides* specimens (compare the specimens in Figs. 12 and 13). In previous studies with well-documented morphometric data from Europe and Turkey, *Orbitoides* tests were invariably reported to be symmetric to asymmetrical in outline, with rare occurrences of plano-convex tests (Baumfalk & Willemsen, 1986; Caus et al. 1996; Eggink & Baumfalk, 1983; Meriç, 1965; Özcan, 1993). These variations were always interpreted as ecophenotypic, linked with prevailing environmental conditions (Eggink & Baumfalk, 1983; van Gorsel, 1978). The flat to biconcave specimens with small embryons from the Taraklı Formation strongly resemble to *O. apiculata pamiri* first described by Meriç (1974) from the upper Maastrichtian beds from SW Turkey. Meriç (1974) reported the associated foraminifera as *O. apiculatus*, *O. medius*, *L. minor*, *O. macroporus*, *S. calcitrapoides*, *L. anatolica* and *H. beotica*. A comparison of the axial sections