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New Triassic finding in Andız Peninsula (İzmir, Western Turkey) and comparison of pre-Neogene sequences of Andız and Karaburun Peninsulas: Stratigraphic and tectonic implications

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Abstract: This study aims to review the geology of the Andız Peninsula and compare the pre-Neogene Andız succession with the middle part of the Karaburun Peninsula to discuss the nature of the Paleozoic-Mesozoic boundary in the Karaburun Peninsula. The pre-Neogene units of the Andız Peninsula are represented by the Paleozoic Dikendağı, Triassic Güvercinlik, and Jurassic Nohutalan Formations. In this study, the Triassic carbonate rocks in the Andız Peninsula are paleontologically defined for the first time. The Megalodont-bearing Güvercinlik Formation contains a late Norian-Rhaetian characteristic foraminiferal assemblage consisting of *Aulotortus* gr. *sinuosus, A. tenuis, A. friedli, A. impressus*, and *Triasina hantkeni*. The *Thaumatoporella*-bearing Nohutalan Formation conformably overlies the Güvercinlik Formation and yields a typical Liassic fossil assemblage of *Orbitopsella praecursor, Siphovalvulina gibralterensis, S. colomi, Meandrovoluta asiagoensis*, and *Palaeodasycladus mediterraneus*. In the Andız Peninsula, the Mesozoic Güvercinlik and Nohutalan Formations tectonically overlie the Paleozoic Dikendağı Formation along a displacement contact.

In the middle Karaburun Peninsula, the Triassic Gerence Formation lies directly on the Dikendağı Formation along a displacement contact. Lateral continuation of this displacement contact is discovered between the Triassic Gerence and Camiboğazı Formations at the top and Paleozoic Dikendağı Formation at the bottom. Further north, the same displacement contact extends into the Paleozoic sequence where the Carboniferous Alandere Formation tectonically overlies the Dikendağı Formation. These observations suggest that the succession in the Karaburun Peninsula ranging from Bashkirian to Cretaceous, is a tectonic slice or a package of slices over the Dikendağı Formation.

Keywords: Andız Peninsula, Karaburun Peninsula, Triassic-Jurassic transition, Paleozoic- Mesozoic boundary, displacement contact

1. Introduction

Andız and Karaburun Peninsulas are located in the western part of İzmir (western Turkey) and form the southwest continuation of the Bornova Flysch Zone (Okay and Tüysüz, 1999; Okay, 2008), which is bounded by Sakarya Continent of Pontide Belt in the north and metamorphic Cycladic units and Menderes Massif of Tauride-Anatolide Platform in the south (Figure 1). The Karaburun Peninsula with its thick succession, ranging from Paleozoic to Quaternary, and complex geology, besides its critical tectonic setting and geographic position, has been subjected to numerous local and regional studies (Kalafatçıoğlu, 1961; Brinkmann et al., 1967; Gümüş, 1971; Brinkmann et al., 1972; Erdoğan et al., 1990; Robertson and Pickett, 2000; İşintek and Altıner, 2001; İşintek, 2002; Rosselet and Stampfli, 2003; Okuyucu et al., 2005, Çakmakoğlu and Bilgin, 2006; Löven et al., 2017). The Andız Peninsula is situated on the eastern part of the Karaburun Peninsula and the western side of the Özbek Peninsula, extending northward into the İzmir Bay. Although they are so close to the Karaburun Peninsula, geological characteristics of the Özbek and Andız Peninsulas have relatively been ignored, and hence some critical geological data have been missed. Hydrogeological conditions of the area were documented by Tarcan (1989), and recently detailed geological aspects and its potential of being a geological heritage have been discussed by Çakmakoğlu and Bilgin (2006) and Sümer et al. (2020).

Even though the presence of Triassic units in the Özbek Peninsula has been mentioned by Çakmakoğlu and Bilgin (2006), the Triassic rocks exposing out in the Andız part of the Özbek Peninsula have never been mapped previously.

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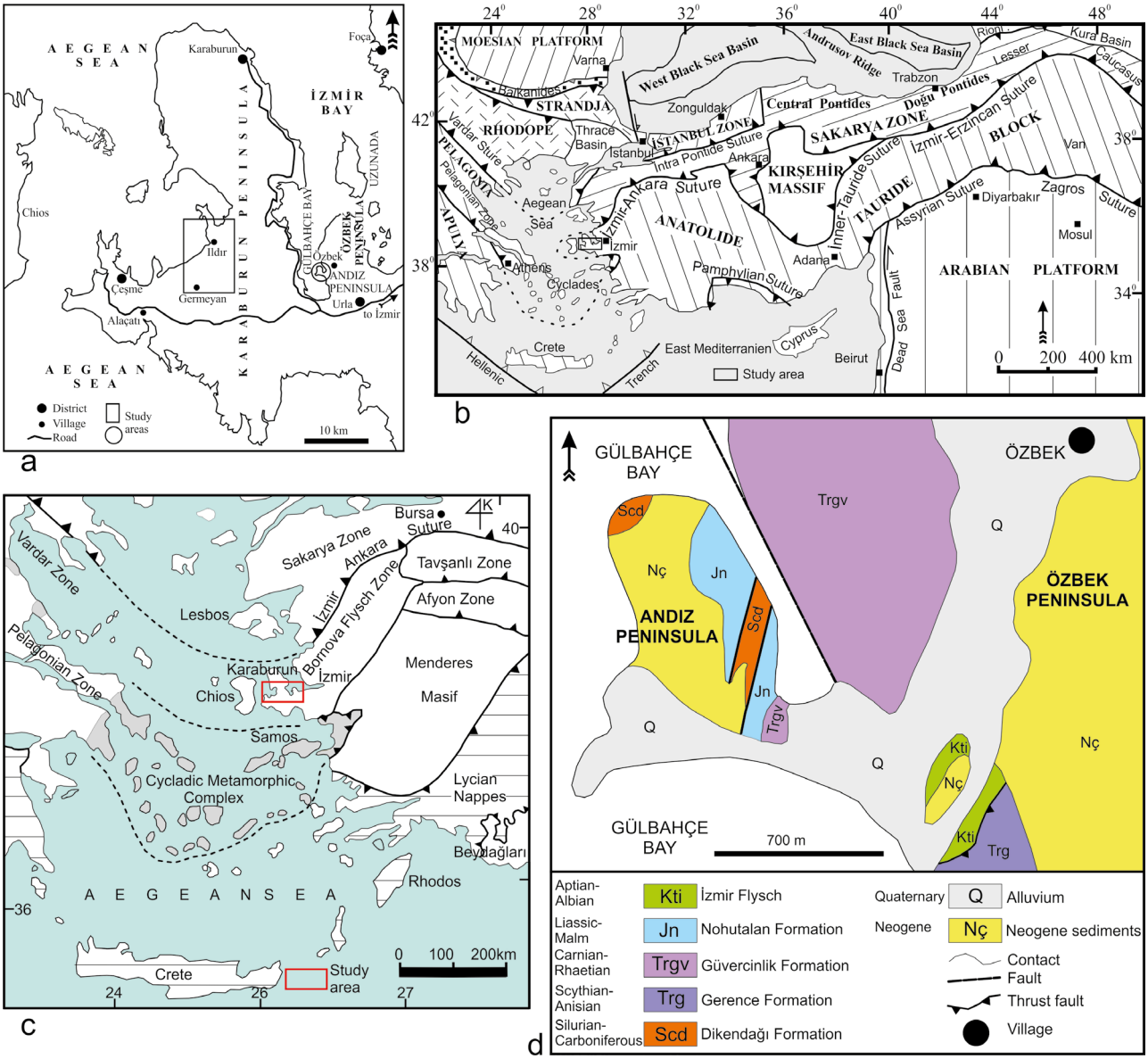


Figure 1. a) Location of the Karaburun, Özbek, and Andız Peninsulas b) Location of the study area and its place on the paleotectonic map of Turkey (Okay and Tüysüz, 1999; Okay, 2008), b) Location map of the Karaburun Peninsula, c) the location of the Karaburun and Andız Peninsulas on the detailed tectonic map of the Aegean Region (Okay, 2001), d) Geological map of the Andız Peninsula (Çakmakoğlu and Bilgin, 2006).

Besides, the Paleozoic Dikendağı Formation was mapped by Çakmakoğlu and Bilgin (2006) in the Andız Peninsula, without referring to its stratigraphic and tectonic setting.

The age and stratigraphic setting of the Dikendağı Formation (Çakmakoğlu and Bilgin, 2006) have been subjected to various studies and different views have been propounded (Erdoğan et al., 1990; Robertson and Pickett, 2000; İşintek and Altıner, 2001; İşintek, 2002; Rosselet and Stampfli, 2003; Çakmakoğlu and Bilgin, 2006). Erdoğan et al. (1990)) suggested that the formation is Triassic in age and laterally and vertically passes into the younger stratigraphic levels of the other Triassic units. Some other authors, on the other hand, suggested the Silurian-Carboniferous age for the Dikendağı Formation (Robertson and Pickett, 2000; Rosselet and Stampfli, 2003; Çakmakoğlu and Bilgin, 2006). Çakmakoğlu and Bilgin (2006) concluded that the Triassic Gerence Formation unconformably overlies the Dikendağı Formation, whereas Robertson and Pickett (2000) claimed that unconformity turned into a shear zone.

In this study, based on new geological mapping, a description of new foraminiferal taxa, and stratigraphic observations in the Andız Peninsula, some changes in the geology of pre-Neogene units of the Karaburun Peninsula are suggested.

2. Methods

In this study, Andız Peninsula (Figure 1) was mapped on a 1/25000 scale and sampled for petrographic and micropaleontological investigations. The study area is positioned on standard 1/25,000-scale topographic maps of Turkey, plate no: Urla L17 a3. A total of 28 samples were petrographically and paleontologically examined. Thin sections were prepared in Dokuz Eylül University, Engineering Faculty, Department of Geological Engineering, Thin Section and Gemology Laboratory. Carbonate rocks and sandstones were classified based on Folk (1959) and Dunham (1962). Microscopic determinations were made, and photomicrographs were taken in Olympos X50 and Olympos X20 microscopes. The foraminiferal nomenclature and descriptions, used here, are based on Ellis and Messina (1940) and supplements, Loeblich and Tappan (1988) and Boudagher-Fadel (2008).

3. Geological setting

In the Andız Peninsula, from bottom to top, the Silurian-Carboniferous Dikendağı, Norian-Rhaetian Güvercinlik, Liassic Nohutalan Formations, the Neogene sedimentary rocks and Quaternary Alluvium deposits are distinguished (Figure 2). In this study, pre-Neogene units are focused on detail without mentioning Neogene and Quaternary units.

3.1. Dikendağı Formation

The Dikendağı Formation was first defined in the Karaburun Peninsula by Çakmakoğlu and Bilgin (2006). The unit exposes in a small area in the eastern part of the Andız Peninsula, and in the northern part along narrow and steep slopes (Figure 2). Similar to the Karaburun Peninsula, in the study area, the unit is made up of green-pale green, thick, medium- or thin-bedded, in places, strongly sheared turbiditic lithic sandstones,

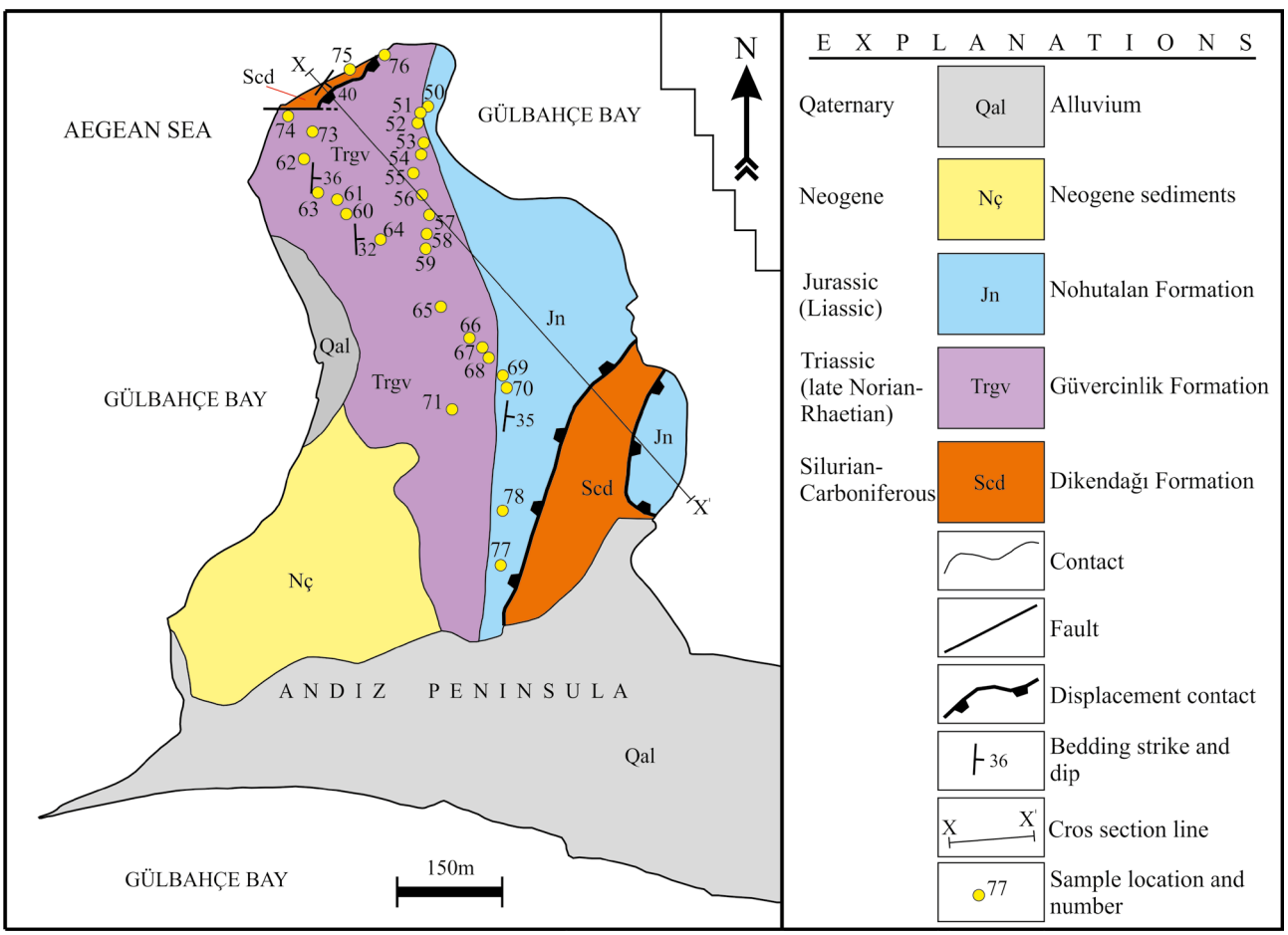


Figure 2. Revised geological map of the Andız Peninsula.

mudstones, and mud shales. Thin- to coarse-grained texture in sandstones is dominated by thin- to medium-size sands and black chert fragments are found in grain assemblage. The lower boundary is blanketed in the Andız Peninsula. Upward, the Norian-Rhaetian Güvercinlik and Liassic Nohutalan Formations cover the formation (Figures 3, 4). Along the contact, no depositional layer like regolith or basal conglomerate, is observed, indicating a stratigraphic unconformity. Instead, it is characterized by a horizontal cataclastic zone cutting the bedding planes of the underlying Dikendağı and overlying Güvercinlik and Nohutalan Formations that indicate a tectonic characteristic. However, there is no kinematic analysis carried out along this contact to clarify the nature and direction of tectonic transportation. Thus, it is avoided here to attribute this contact a particular name as normal fault or thrust fault but the "displacement contact" term is preferred.

3.2. Güvercinlik Formation

Although the Güvercinlik Formation (Gümüş, 1971; Brinkmann et al., 1972; Erdoğan et al., 1990; İşintek, 2002) was previously mapped in the Özbek Peninsula (Çakmakoğlu and Bilgin, 2006) it is first documented in this study that formation crops out in the Andız Peninsula as well (Figure 2). The Güvercinlik Formation with gray-pale gray, thick-bedded, or massif limestones exposes

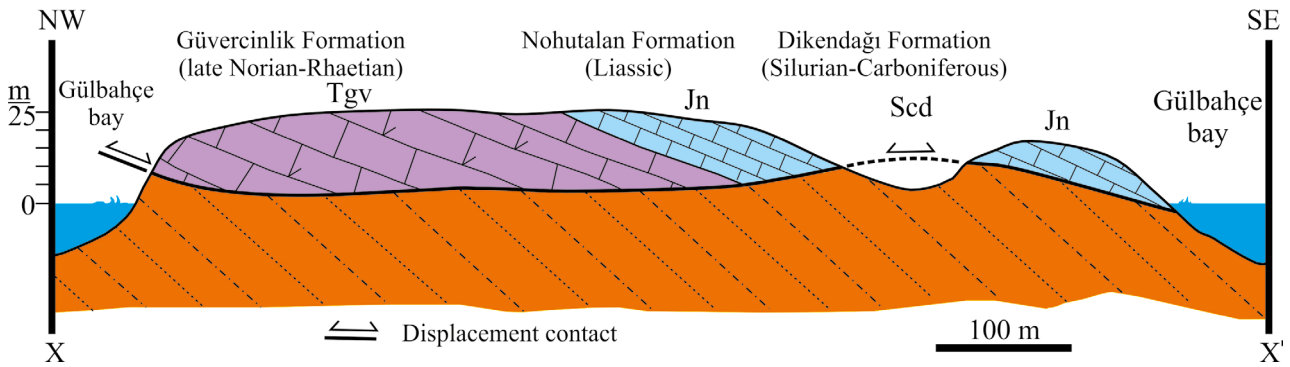


Figure 3. X-X' geological cross-section view of the Andız Peninsula (vertical scale is exaggerated).

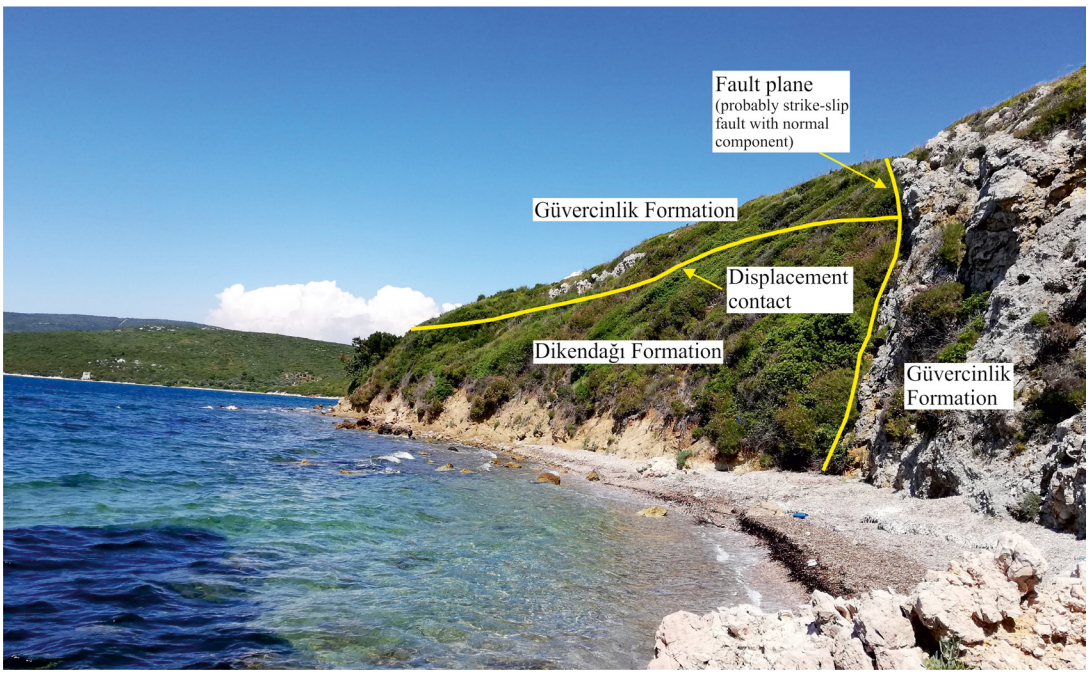


Figure 4. Field view of the boundary between the Dikendağı and Güvercinlik Formations on the northern coast of the Andız Peninsula.

in the north and middle parts of the peninsula. Wavy stromatolite laminates are commonly interlayer with limestone beds. Limestones and dolomitic limestones dominate the formation with, in places, dolomites. Thick-bedded and massif limestones include large *Megalodont* fossils representing subtidal conditions (Flügel 2004; Reolit et al., 2016). Dolomitic limestones with stromatolite laminae deposited in the intertidal zone and probably were dolomitized in the diagenetic phase. The Late Triassic Güvercinlik Formation tectonically overlies the Dikendağı Formation, at the base, along a displacement contact and passes upward conformably into the Liassic Nohutalan Formation. Limestones are dominated by bioclastic/intraclastic wackestones, bioclastic packstones, intraclastic grainstones, and carbonate mudstones. Bioclast association is dominated by bivalvia, gastropod, dasyclad algae, and benthic foraminifers. The Güvercinlik Formation, in the Andız Peninsula, is represented by a benthic foraminiferal association of *Endotriadella* sp., *Trochammina* sp., *Aulotortus* gr. *sinuosus, Aulotortus* cf. *communis, A. tenuis, A. friedli*, *A.* cf. *impressus*, *Aulotortus* sp., and *Triasina hantkeni* (Figure 5). The presence of *Triasina hantkeni* in this association indicates that Güvercinlik Formation is late Norian-Rhaetian in age.

3.3. Nohutalan Formation

The Nohutalan Formation crops out in a very narrow area in the northeastern part of the Andız Peninsula and is made up of gray-dark gray, medium to thick-bedded

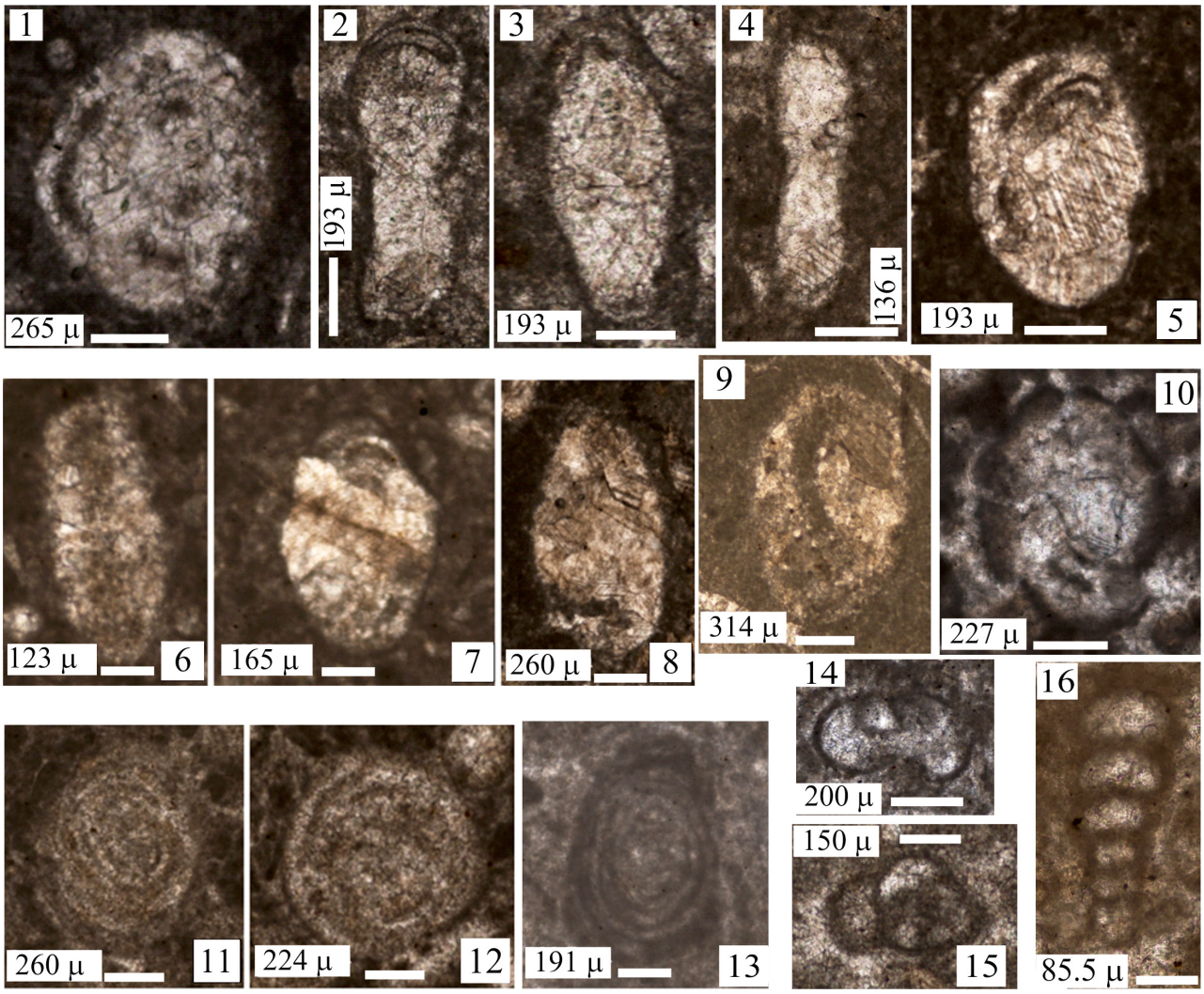


Figure 5. Foraminiferal content of the Güvercinlik Formation in the Andız Peninsula. 1: *Aulotortus friedli*, 2, 4, 6: *A. impressus*, 3: *A.* cf. *communis*, 5, 7, 9: *A.* gr. *sinuosus*, 8: *Aulotortus* sp., 10: *Triasina hantkeni*, 11-13: *Glomospira* sp., 14, 15: *Trochammina* sp., 16: *Endotriadella* sp.

competent limestones. Limestones are represented by *Thaumatoporella parvovesiculifera*-bearing carbonate mudstones, bioclastic/intraclastic wackestones, peloidal/bioclastic/intraclastic packstones and grainstones. Bioclast association is dominated by foraminifers and dasyclad algae with rare bivalvia and gastropods. *Thaumatoporella*-bearing boundstones with fenestral porosity are common in the formation. The Nohutalan Formation in the Andız Peninsula contains a fossil association of *Endotriadella* sp., *Lituosepta* sp., *Orbitopsella praecursor*, *Pseudocyclammina* sp., *Riyadella* sp., *Siphovalvulina gibralterensis, Siphovalvulina colomi, Duotaxis metula*, *Mesoendothyra* sp., *Meandrovoluta asiagoensis*, and *Palaeodasycladus mediterraneus* indicating Liassic age (Haig et al., 2007; Velic, 2007; Boudagher-Fadel, 2008) (Figure 6).

4. Discussion on the pre-Neogene sequences of the Andız Peninsula and the middle part of Karaburun Peninsula

In the previous studies, it was commonly suggested that the Triassic Gerence Formation overlies the Carboniferous Alandere Formation along a stratigraphic contact (Brinkmann et al., 1972; Erdoğan et al., 1990; İşintek and Altıner, 2001; Rosselet and Stampfli, 2003; Çakmakoğlu and Bilgin, 2006). However, there are some different suggestions on the nature of the contact between the Dikendağı Formation at the bottom and the Alandere and Gerence Formations at the top. In the NW Karaburun Peninsula, Gümüş (1971) and Erdoğan et al. (1990), based on the Triassic parts in the formation, claimed that the Dikendağı Formation (Karareis Formation of Erdoğan et.al., 1990) are Triassic in age and laterally and vertically passes into the Gerence Formation. However, it was not mentioned in those studies that to the south of Ildır village, around Narlıca, Domuzçukuru, and Germeyan-Laleköy localities where the Gerence Formation overlays the Dikendağı Formation (Figures 7, 8). Besides these localities, observations in the Andız Peninsula presented in this study, contradict the suggestion put forwarded by Gümüş (1971) and Erdoğan et al. (1990). Çakmakoğulu and Bilgin (2006) suggested an alternative definition for the upper boundary of the Dikendağı Formation. The authors mapped the Dikendağı Formation in the Domuzçukuru location and suggested that the Gerence Formation unconformably overlies the Dikendağı and Alandere Formations. Çakmakoğlu and Bilgin (2006) defined a muddy conglomerate layer at the base of the Gerence Formation (along the lower levels of the Boynuzcuk Member) and considered it a basal conglomerate layer evidencing that unconformity. However, the muddy conglomerate beds in the Domuzçukuru locality occur below the Gerence Formation in this locality and all over the Karaburun Peninsula they interlayer with the Dikendağı Formation. Moreover, they are not laterally continuous and mappable all along the contact, and their sedimentary characteristics indicate that they are debris flow deposits rather than basal conglomerates.

In this study, based on the observation in Alandere and Domuzçukuru locations and new data from the Andız Peninsula an alternative model is suggested for the contact between the Dikendağı Formation and the overlying Carboniferous-Jurassic succession. Although the Dikendağı Formation crops widely out around the Karaburun Peninsula, its contacts are rarely observed, which caused a wide range of geological interpretations on the stratigraphic and tectonic setting of the unit. The most open exposures of the unit exist around the Ildır village (Figure 7). In this area, different stratigraphic levels of the Carboniferous Alandere Formation and the middle Anisian Gerence Formation directly overlie the Dikendağı Formation along a sharp boundary. Contact cuts the geological elements of all three units. On the other hand, around Narlıca and Domuzçukuru localities to the south of Ildır, different levels of the Gerence Formation overlie the Dikendağı Formation (Figures 7–9), and southward around Laleköy locality near Germeyan village Dikendağı Formation exposes in a tectonic window opened on the contact between the Gerence and Camiboğazı Formations (Figures 7, 9). These contact relationships indicate that the different levels of the Carboniferous-Triassic Karaburun sequence tectonically overlie the Dikendağı Formation along a displacement contact as defined in Andız Peninsula. Kilometers far from the Ildır-Germeyan area, in the Andız Peninsula, much younger Güvercinlik and Nohutalan formations overlie the Dikendağı Formation along a similar tectonic contact that suggests the displacement contact. Between the Silurian-Carboniferous Dikendağı Formation and the overlying Carboniferous-Jurassic Karaburun succession is a laterally continuous tectonic surface all along the Karaburun Peninsula and the Karaburun succession is a tectonic slice or a package of slice lying on the Silurian-Carboniferous Dikendağı Formation.

6. Conclusions

In this study, the Andız Peninsula was mapped and based on the new field observations and foraminifera micropaleontology, geological relationships in the Silurian-Jurassic succession are redefined.

The latest Triassic (late Norian-Rhaetian) Güvercinlik Formation in the Andız Peninsula is first paleontologically defined here.

In the Andız Peninsula, the latest Triassic Güvercinlik and Liassic Nohutalan Formations tectonically overlie the Silurian-Carboniferous Dikendağı Formation along a displacement surface.

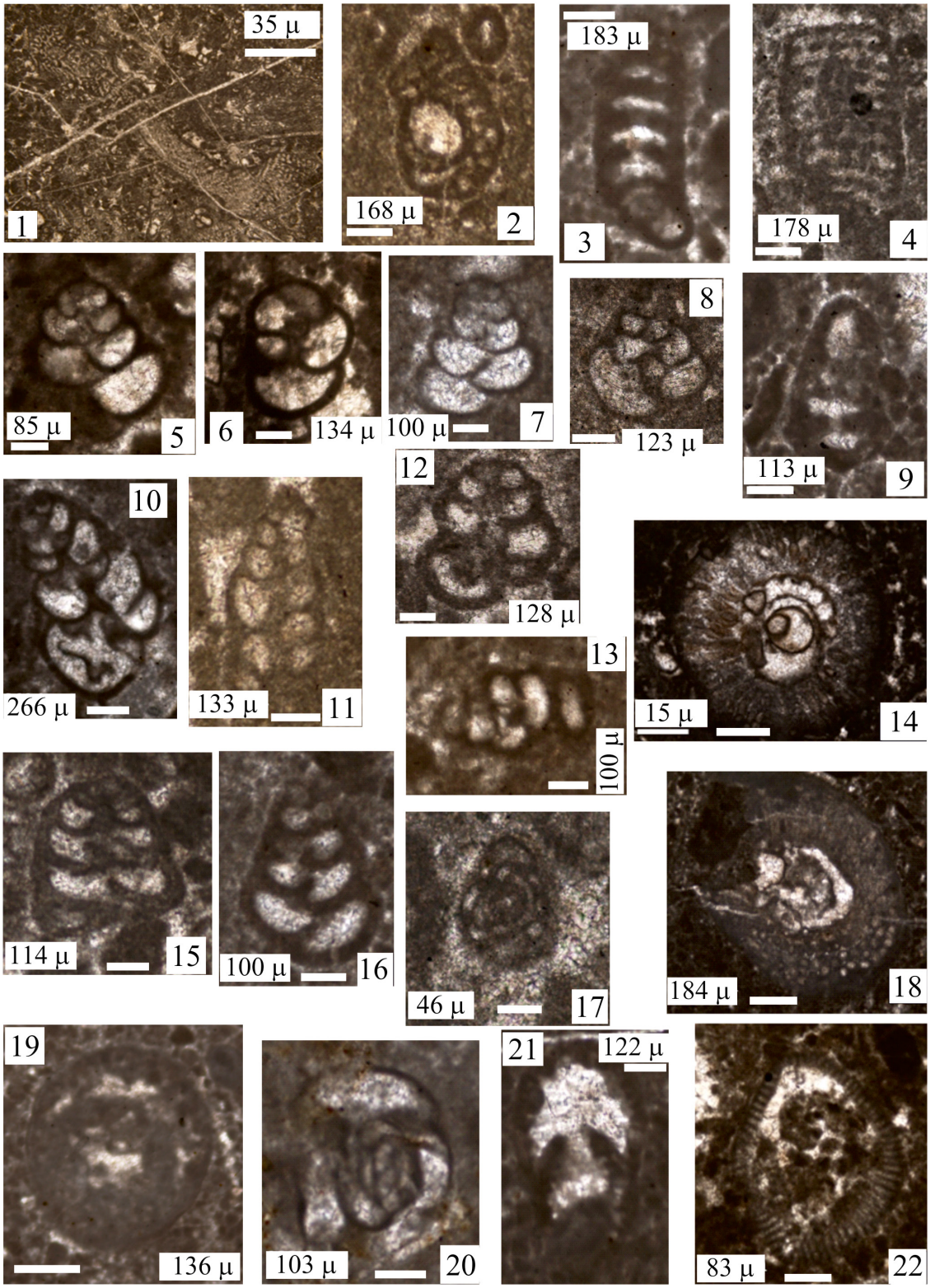


Figure 6. Foraminiferal and algal content of the Nohutalan Formation in the Andız Peninsula. 1, 2: *Orbitopsella praecursor*, 3, 9: *Paleomayncina termieri*, 4: *Lituosepta* sp., 5 8, 12: *Siphovalvulina gibralterensis*, 10, 11: *S. colomi*, 13, 17: *Meandrovoluta asiagoensis*, 14, 18: *Palaeodasycladus mediterraneous*, 15: *Duotaxis metula*, 16: *Riyadella* sp., 19: *Pseudocyclammina* sp., 20: *Mesoendothyra* sp., 21: *Reophax* sp., 22: *Thaumatoporella parvovesiculifera*.

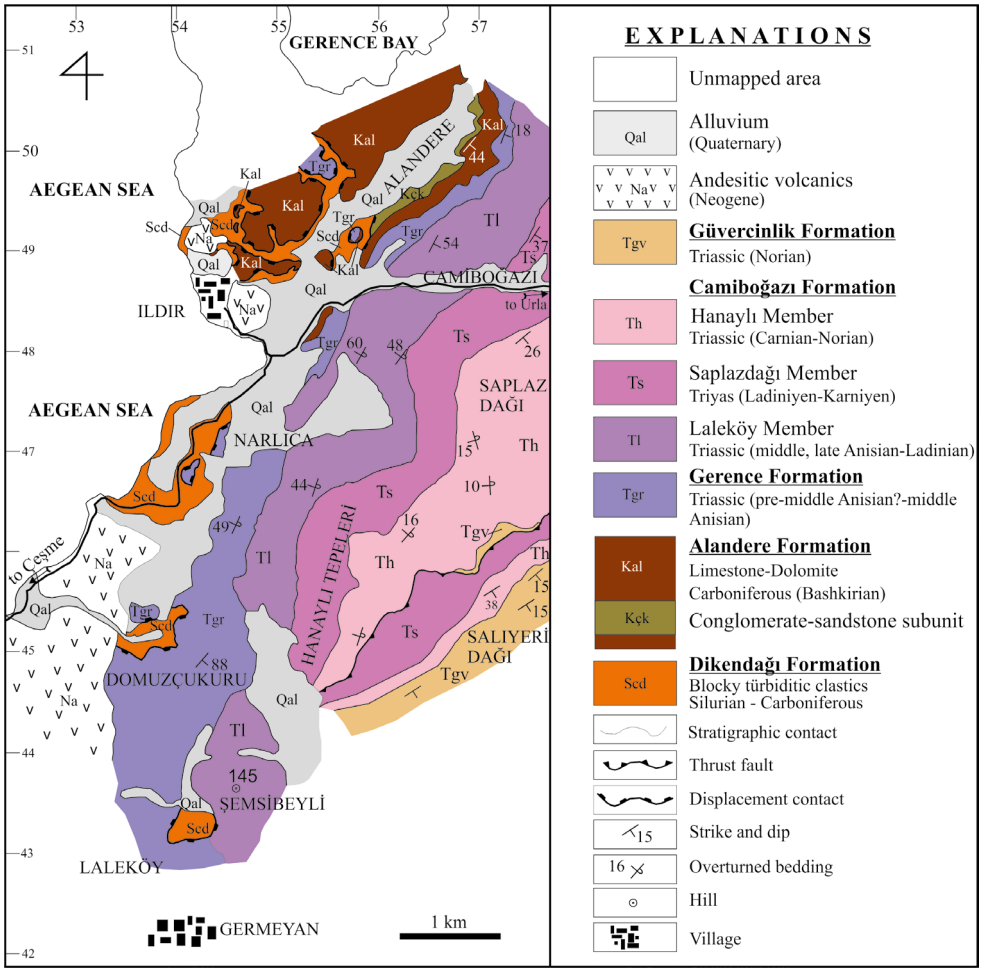


Figure 7. Geological map of Paleozoic and Triassic rocks in the middle part of Karaburun Peninsula (after Brinkmann et al., 1972; İşintek and Altıner, 2001; Çakmakoğlu and Bilgin, 2006, modified after İşintek, 2002). Coordinate lines indicate 1000 m Universal Transverse Mercator (UTM), Zone 37, ED 50 Datum.

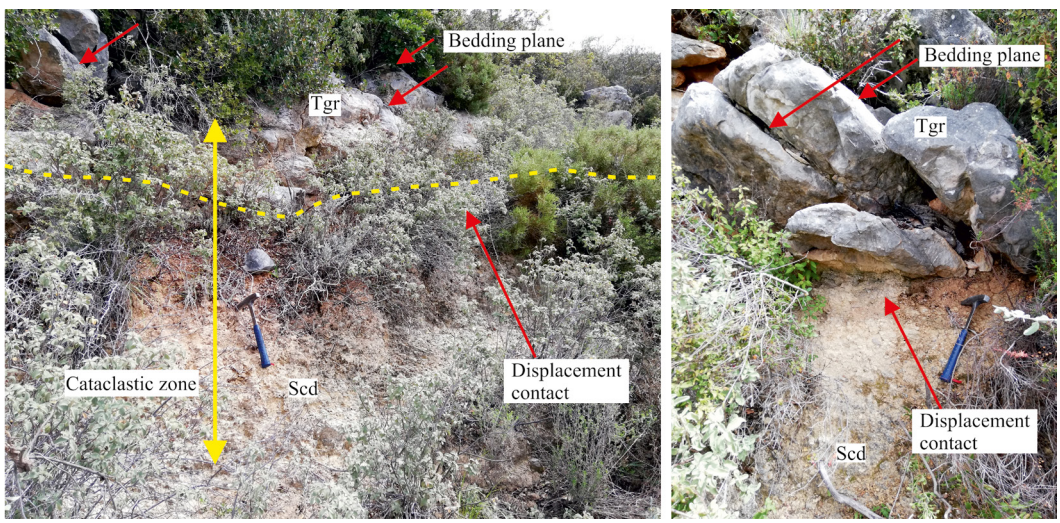


Figure 8. Field view of the displacement contact between the Dikendağı and Gerence Formations in the Domuzçukuru locality of the middle part of the Karaburun Peninsula (Scd: Dikendağı Formation, Tgr: Gerence Formation).

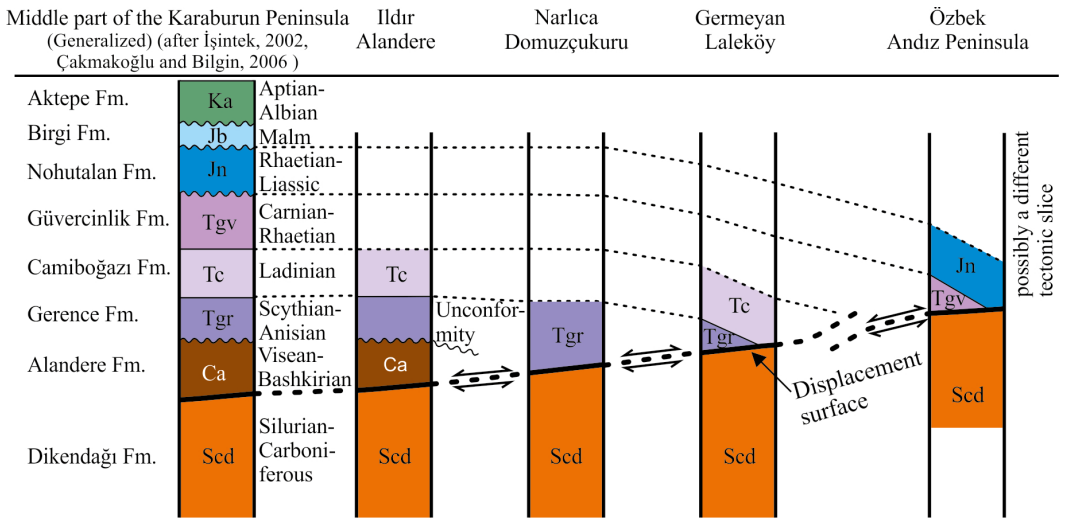


Figure 9. Correlation of the pre-Neogene sequences of the Andız and middle part of the Karaburun Peninsulas.

The displacement contact, in which the Carboniferous-Early Cretaceous Karaburun succession lays tectonically on the Dikendağı Formation, is a laterally continuous surface in the middle part of the Karaburun Peninsula. Thus, it might be suggested to be investigated from this point of view all around the Karaburun Peninsula.

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