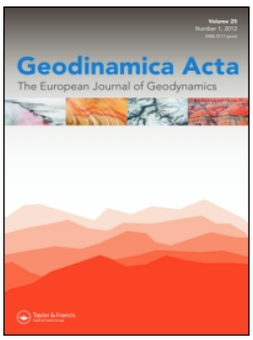

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Comments on "Deformation of the Lower Cambrian Sequence in the Sandıklı Region (Afyon), central Turkey" by T. Güngör

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1. Introduction

Güngör [1] has recently presented his data and interpretations on the geology and deformational history of a series of slightly metamorphic rocks in the Sandıklı region (Afyon), Western Anatolia. We have been working since 1995 on the geological, petrological, and deformational features of the same rock-units in the same area [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14] and will comment on several issues including very critical field observations, geological mapping and petrographic/microtectonic features. The comments of ours are more than local disagreements in the fieldwork. They are of crucial importance, as they directly concern the regional geological interpretations regarding the presence of a Cadomian (or Pan-African *sensu* Şengör *et al*. [15]) tectonothermal event in the Taurides. This event is a critical feature of the Peri-Gondwanan terranes but does not occur in Baltica and Siberia and hence important for the correlation of the Late Neoproterozoic terranes.

2. Comments on the Stratigraphy

The Tauride Belt in southern Turkey represents a Gondwana-derived continental microplate with a pronounced alpine deformational history. It includes telescoped tectonostratigraphic units [16], once forming different parts of a platform (Tauride-Anatolide Platform). More and less complete Late Neoproterozoic - Early Palaeozoic rocks within Tauride units are best exposed in the Geyikdağ unit of Özgül [16]. A chard with several cross-sections in previous studies [3, 7, 8, 14, 17, 18, 19, 20] of this interval is given in Fig. 1 to correlate with the stratigraphic section presented by Güngör [1].

Güngör [1] described the interval under question simply as "Lower Cambrian rocks" composed of the Kocayayla Group including the Celiloğlu and Göğebakan formations, Kestel Çayı Volcanics and Taşoluk formation in ascending order. The stratigraphic succession presented by Güngör [1] is inconsistent with the two-fold division of ours [3, 4, 5, 6, 7, 8, 9, 11, 12, 13] including a Neoproterozoic basement (Sandıklı Basement Complex) and its Early Palaeozoic cover (Fig. 1, 2). The basement comprises a thick and low-grade metamorphic series of clastic rocks with rare bands and lenses of lydites, black shales and stramatolitic limestones (Güvercinoluk Formation) and felsic igneous rocks of Kestel Çayı Porphyroid Suite (Kestel Çayı Volcanics), mainly rhyolites and quartz-porphyries.

The key-unit in the Sandıklı Basement Complex, the Kestel Çayı Volcanics [3, 5, 12] was evaluated by Güngör [1] as Lower Cambrian (Tommotian or younger) in age, based on its assumed stratigraphic position above the trace fossil bearing levels of the Göğebakan Formation [21]. Moreover, in contradiction to previous work [3, 4, 5, 8, 12], Güngör [1] stated that these felsic rocks are mainly composed of

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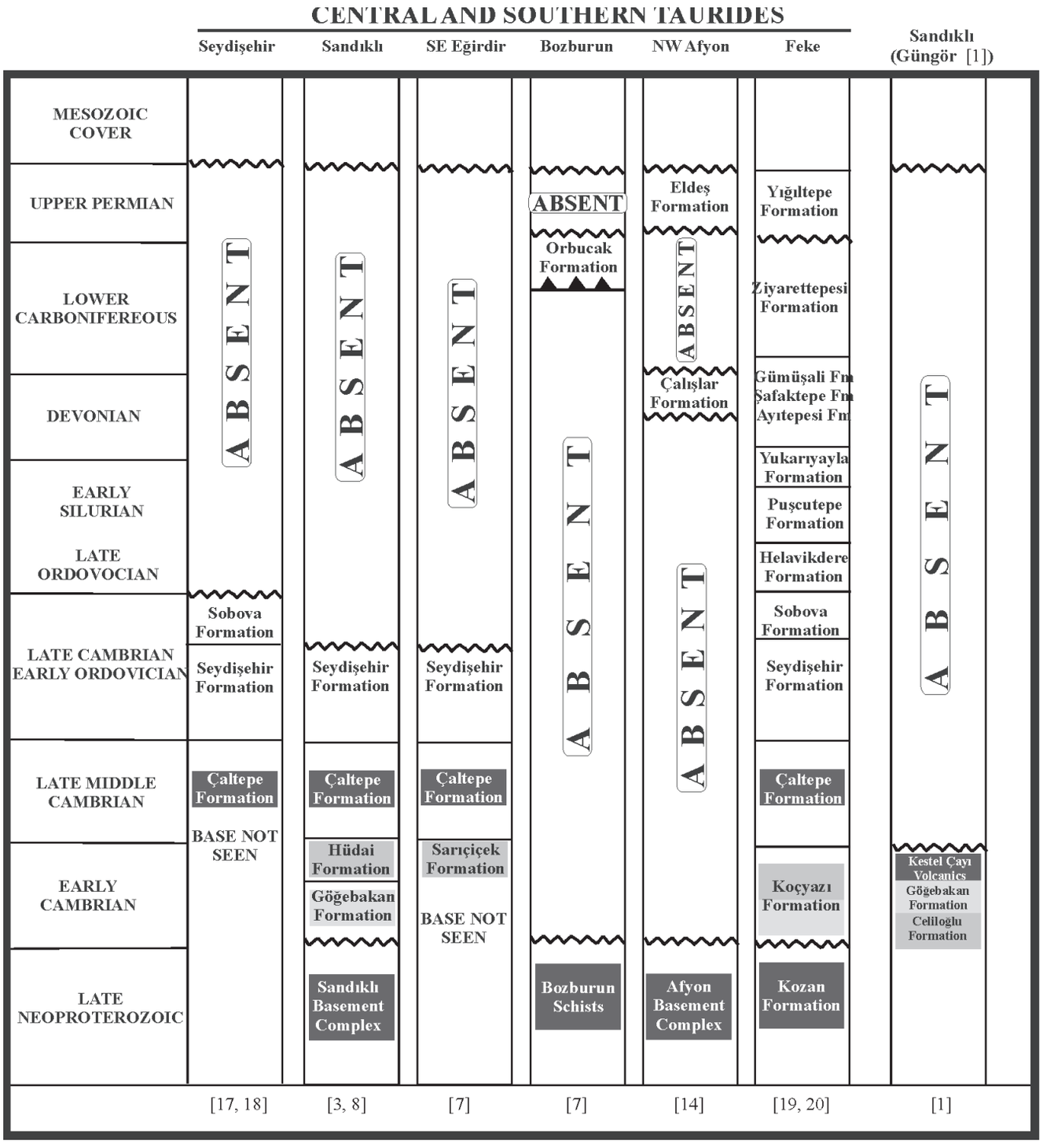


Fig. 1: Generalized correlation charts of Geyikdağ unit in Central and Southern Taurides with the stratigraphy of Güngör [1]. Shaded areas indicate the similar lithologies in Central and Southern Taurides.

rhyolitic extrusives, hyaloclastic to volcanoclastic rocks and no intrusive relations were observed with the country rocks in the investigated area.

However, our studies revealed that none of these statements are supported by evidences. First of all, in contrast to the suggestion of Güngör [1], Kestel Çayı Volcanics not only comprise rhyolites but also quartz-porphyries and microgranites. This is obvious from photomicrographs of the microlithons on Figure 9c and d in Güngör [1].

Regarding the age, the single zircon $^{207}Pb/^{206}Pb$ evaporation ages [22] of the Kestel Çayı Volcanics indicate Late Neoproterozoic ages (543±7 Ma in metaquartz porphyry rocks at the SW of Değirmendere village and 541.3±10.9 Ma in metarhyolites near Merdiven Hill (Fig. 2), GPS location:

247150/4248700, supporting the initial findings of Kröner and Şengör [22]. On the other hand, field evidence clearly indicates that the quartz-porphyries of the Kestel Çayı Volcanics intrude the metaclastic of the Güvercinoluk Formation (Fig. 3). The intrusive contact of metaquartz porphyry rocks within the Güvercinoluk Formation are clearly observed in the SW Sandıklı, mainly in Kocayayla, at Akoluk, Güvercinoluk, NE of Karabel Tepe and at the Alacakilise plateau in Taşoluk area (Fig. 2, 3). On the other hand, it is important to note that no intrusive contacts of the Kestel Çayı type felsic rocks can be observed within the Göğebakan Formation.

The next point of disagreement is the stratigraphic position of the Early Cambrian Göğebakan Formation. Gürsu [4], Gürsu and Göncüoğlu [3, 11, 12], Gürsu *et al*. [5, 6, 7, 8] clearly demonstrated that this formation disconformably overlies the Sandıklı Basement Complex. It commences on the metarhyolites of the basement with basal conglomerates. The pebbles of the conglomerate are mainly represented by metamorphosed and deformed rhyolites and quartz-porphyries but also include clasts of lydites, slates and metasandstones derived from the low-grade metamorphic Sandıklı Basement Complex. It is very important to note that the rhyolites are deformed and metamorphoses prior to their incorporation as pebbles in the basal conglomerates (Fig. 4c). The contact relations and the succession to the W of Orta Tepe, also shown in the N of Güngör's [1] map on Figure 3, is the key area to study the disconformity between the basement (Kestel Çayı Volcanics) and cover (Göğebakan Formation), the deformed basal conglomerates and the overturned succession (Fig. 4a, b). In microphotograph in Fig. 4c, deformed porphyroid pebble (DPP) with straight fabric (S1) is clearly discordant with external schistosity (S2) in metaconglomerate of Göğebakan Formation.

Upwards follow a succession of variegated sandstones and mudstones with sporadic basic lava-flows. This field observation is a conclusive evidence for the relative age of the basement-cover relations in SW Sandıklı area [3, 4, 8, 9, 12, 13] and shows that both the deposition of the Güvercinoluk sediments, the intrusion of the Kestel Cayı Porphyroid Suite (Kestel Çayı Volcanics) and their dynamic metamorphism all predate deposition of the Göğebakan Formation.

Güngör[1], following Erdoğan *et al*. [21], however, suggests that this formation underlies or is transitional to the Kestel Çayı Volcanics and ignores the importance of the basal conglomerates. In fact, Güngör [1] notices the presence of these conglomerates within Göğebakan or between Kestel Çayı and Taşoluk units. On pages 355 and 357, respectively, it is also confirmed that they include pebbles of the underlying Güvercinoluk Formation (green metaclastics, black chert, gray limestones in Sandıklı area) or of the Kestel Çayı Volcanics (deformed quartz and rhyolite). However, these conglomerates are repetitively considered as channel-fills. For us, it is not clear, how a conglomerate with deformed rhyolite pebbles is formed as channel-fill just above a metarhyolite unit without a period of deformation, erosion and renewed deposition in between.

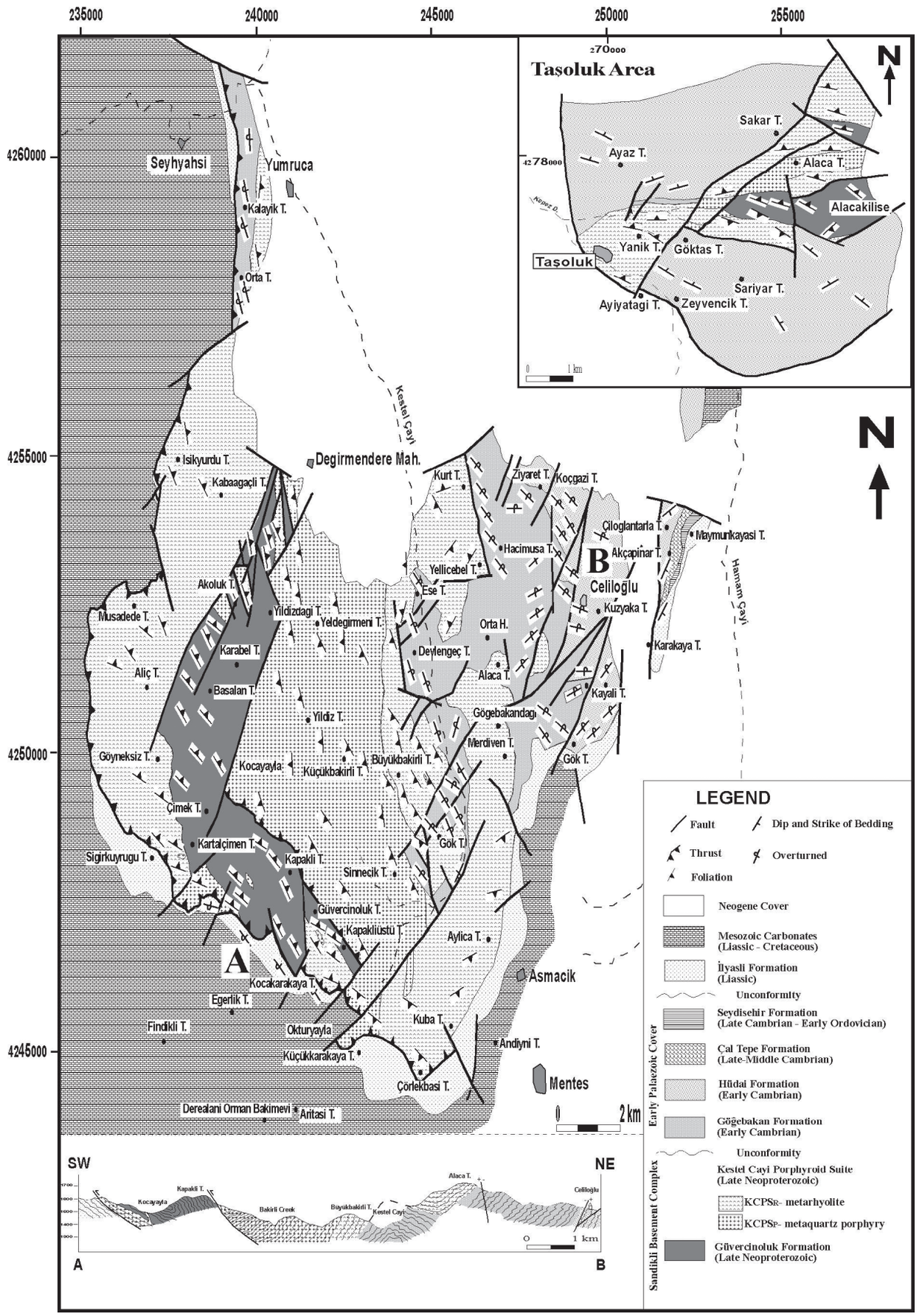
This misinterpretation of the stratigraphic position is due to the fact that in several outcrops the succession is overturned. This is very clearly observed in Orta Tepe (Fig. 4a, b. GPS location: 239575/4258700), where the well-foliated metarhyolites structurally overlie along an overturned contact the basal conglomerates and clastics of the Göğebakan Formation with metarhyolite pebbles. Besides, Güngör [1] very probably failed to differentiate the very typical metaclastics of the Güvercinoluk Formation with green and rarely black slates, stromatolithic limestones and lydites from the dominantly fluvial-shallow marine clastics of the Göğebakan Formation that unconformably cover these metasediments and the felsic igneous rocks intruding them. Upwards, the mudstones of the Göğebakan Formation are followed by quartz-siltstones (Celiloglu Formation in Güngör [1]) with Tommotian ichno-fossils Erdoğan *et al*. [21]. The fossiliferuos layers in the fossil location obviously dip beneath the Göğebakan and Kestel Çayı Volcanics (see the x-x¹ cross-section in Fig. 3 in Güngör [1]) but the fossil casts of the skolithos tubes as well as the cross-lamination clearly indicate that the succession is overturned (Fig. 5).

It is also obvious that the Tommotian Celiloglu Formation can not be older then the Late Neoproterozoic Kestel Çayı Volcanics and hence can not underlie them with a normal stratigraphic contact as mentioned by Güngör [1].

3. Comments on Metamorphism and Deformation

By using paragenesis of whole rock and clay-fractions, illite crystallinity, illite and chlorite polytypes and illite/muscovite b_0 cell dimensions in clay fractions Bozkaya *et al*. [9] investigated metamorphism of the Sandıklı Basement Complex and its cover. Güngör [1] cites this study, but does not take into account the data and interpretations therein for deciphering the differences in deformation and metamorphism within the basement and the cover.

According to Bozkaya *et al*. [9, 13] illite crystallinity studies reveal that both the basement and cover units were metamorphosed at high anchizonal to epizonal conditions (~300 ºC). Textural data together with detailed evaluation of the P-T-b_0 grid, however, indicate that this thermal event has multiple phases. The first tectonothermal event, which only affected the Sandıklı Basement Complex (Güvercinoluk Formation and the porphyroids) was realized at pressures of ~4.2 kb on the basis of b_0 and resulted in deformation and development of blastomylonites. In the P-T-b_0 grid of Guidotti and Sassi [23] the b_0 curves of the basement rocks is found in the sub-greenschist facies P-T space. Assuming a temperature of ~300 °C and average b_0 value of 9.043 Å, a burial depth of ~15 km is calculated. This thermal event is accompanied by deformation, as supported by the presence of dynamo-metamorphosed pebbles within the basal conglomerates (see Fig. 4c) of the Early Palaeozoic cover series. These deformed conglomerates were also noticed by Güngör [1, page 357]. The second thermal event, pre-Jurassic in age, with a lower average b_0 data around 9.026 Å for the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LEGEND
Fault
Dip and Strike of Bedding
Thrust
Overturned
Foliation
Neogene Cover
Mesozoic Carbonates
(Liassic - Cretaceous)
İlyasli Formation
(Liassic)
Unconformity
Seydisehir Formation
(Late Cambrian - Early Ordovician)
Çal Tepe Formation
(Late-Middle Cambrian)
Hüdai Formation
(Early Cambrian)
Göğebakan Formation
(Early Cambrian)
Unconformity
Kestel Cayi Porphyroid Suite
(Late Neoproterozoic)
KCPSR- metarhyolite
KCPSP- metaquartz porphyry
Güvercinoluk Formation
(Late Neoproterozoic)
Early Palaeozoic Cover
Sandikli Basement Complex

Fig. 2: Geological map of the Sandıklı and Taşoluk areas in Central Taurides [4]

formation, occurred at lower pressures ~3.2 kb and produced a weakly developed cleavage in the siliciclastic rocks of the Early Palaeozoic cover. The corresponding pressure conditions indicate a burial depth of ~10 km. The mineralogical/textural data across the basement-cover boundary therefore indicate the removal of an entire metamorphic zone and thus a metamorphic hiatus. The KI ($\Delta°2\theta$) value of the Mesozoic units (İlyaslı Formation in Güngör [1]), unconformably overlying the basement, ranges between 0.31 and 0.48, indicative for late diagenetic stage. This data also indicate that the Alpine deformation in this tectono-stratigraphic unit was not accompanied by a thermal event.

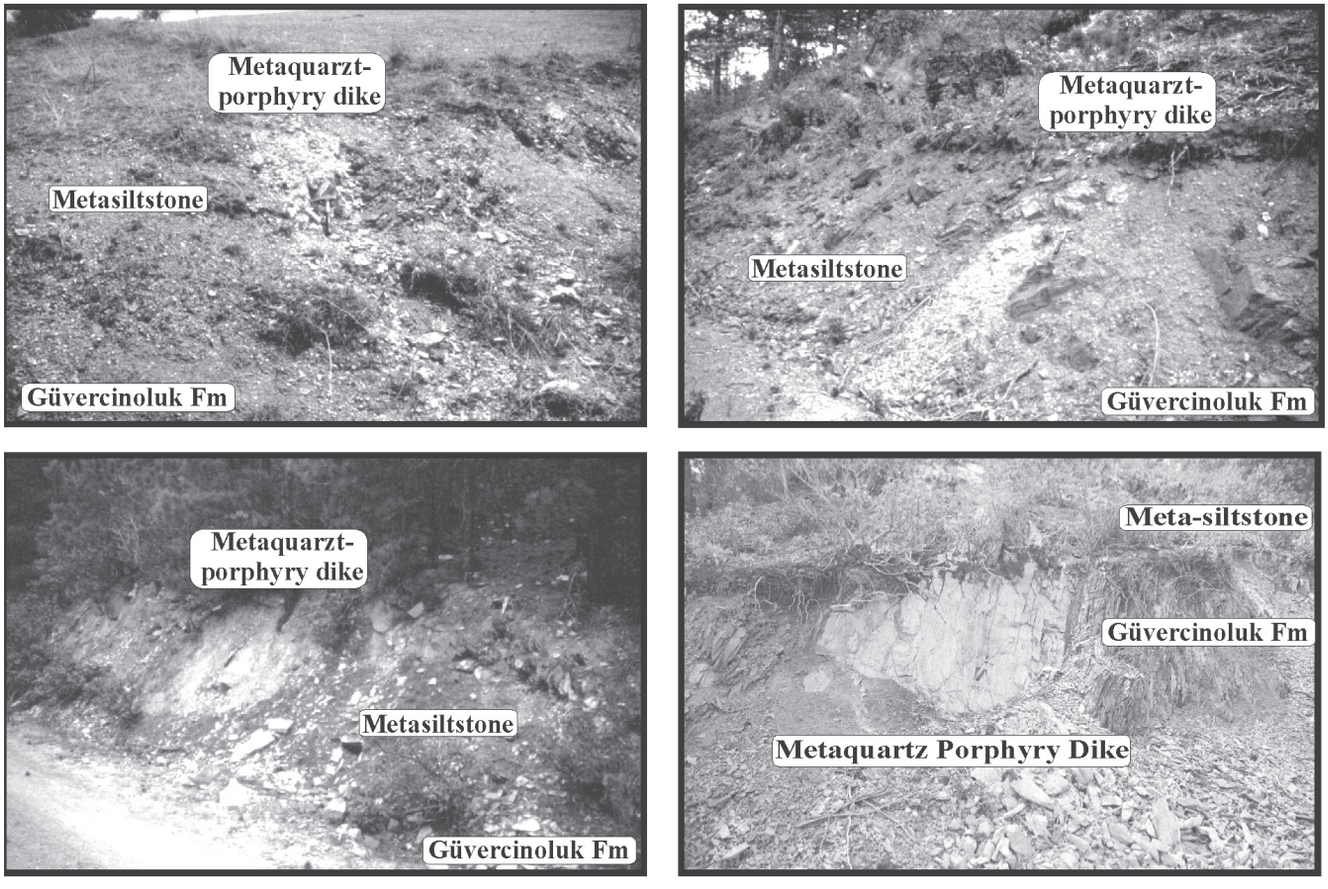
Together with the mineralogical data the analyses of the microfabrics in the core and cover rocks also indicate for more then one deformational event. This is a very critical issue, as Güngör [1] refused this polyphase deformation and has used a selective approach in the presentation of the photomicrographs, used as evidences for the single phase deformation in the basement.

Within the metapelitic rocks of the basement (Güvercinoluk Formation) discrete crenulation cleavage is well-developed (S1) and is overprinted by an S2 crenulation cleavage nearly 75° to S1 and is accentuated by the parallel alignment of fine-grained sericite and chlorite flakes (Fig. 6a) and the separation into phyllosilicate-rich domains and quartz-rich domains is clearly seen. S_3 has overprinted and folded S2 crenulation fabric diagonally trending at low angles about 15° (Fig. 6 a). Similarly, three distinct deformational phases represented by variably penetrative foliation planes are observed in Kestel Çayı Volcanics (Fig. 6b).

The fine grained clastic rocks of the cover (Göğebakan Formation and Celiloğlu Formation), on the other hand, only include two sets of planar fabrics. The initial foliation S1 is a well-developed discrete crenulation-type cleavage. It corresponds to the S2 of the metapelites of the basement. The overprinting deformation resulted in formation of S2 fabric along which fine-grained sericite is formed (Fig. 6c, d).

The last deformation is ascribed to the Alpine compressional events by Gürsu *et al.* [8] and Bozkaya *et al.* [9, 13]. On the regional scale, this deformation is exemplified by thrusts and reverse faults. On micro-scale this event is characterised by a non-penetrative cleavage or brittle deformation within the clastic rocks and crenulations in the shales close to the faults. The most striking Alpine feature is the thrust fault between the Kestel Çayı Volcanics and the Jurassic cover to the NW of Menteş (Fig. 2). Along this contact the basement rocks are thrust towards SW onto the overturned Jurassic

Fig. 3: The intrusive relations of metaquartz porphyry rocks of Kestel Çayı Volcanics (Kestel Çayı Porphyroid Suite) with metasedimentary rocks of Sandıklı Basement Complex (Güvercinoluk Formation), where is named as Göğebakan Formation by Güngör [1]).



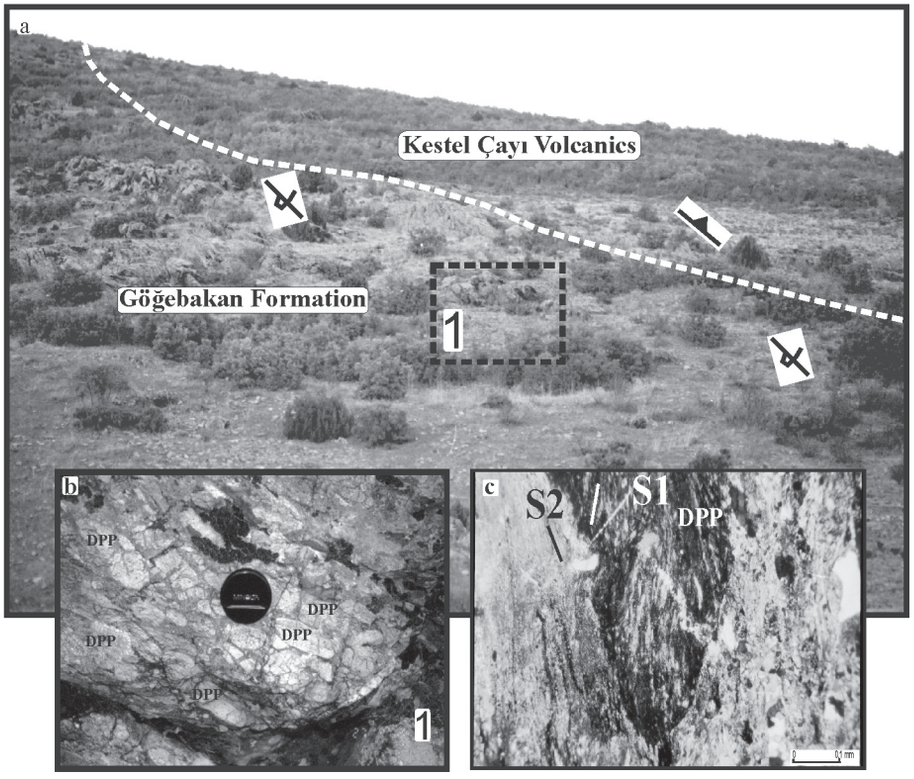
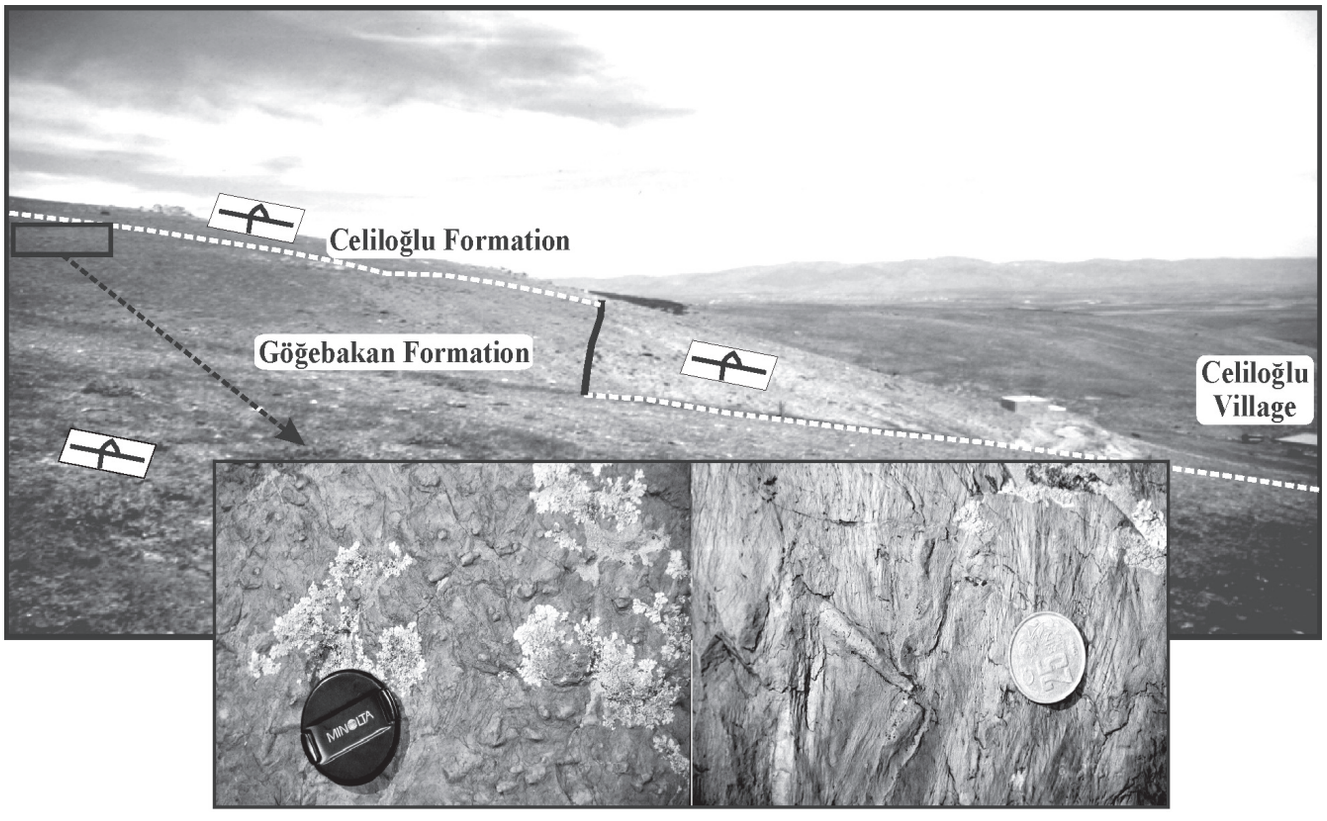


Fig. 4: a) The overturned contact between Göğebakan Formation and Kestel Çayı Porphyroid Suite at north of Orta Tepe, **b)** Basal conglomerates with angular deformed porphyroid pebbles (DPP) in the lowermost part of the Göğebakan Formation, **c)** Microphotograph of angular/sub-angular deformed porphyroid pebble surrounded by a serizitic matrix within the basal conglomerates of Göğebakan Formation. Note that straight fabric (S1) within the deformed porphyroid pebble (DPP) is clearly discordant with external schistosity and is overprinted by an S2 cleavage nearly 45° to S1.

Fig. 5: The overturned contact between Göğebakan and Celiloğlu Formations at Celiloğlu village. The positive relief of the fossil casts of the skolithos tubes on the bedding plane clearly indicates that the succession is overturned.



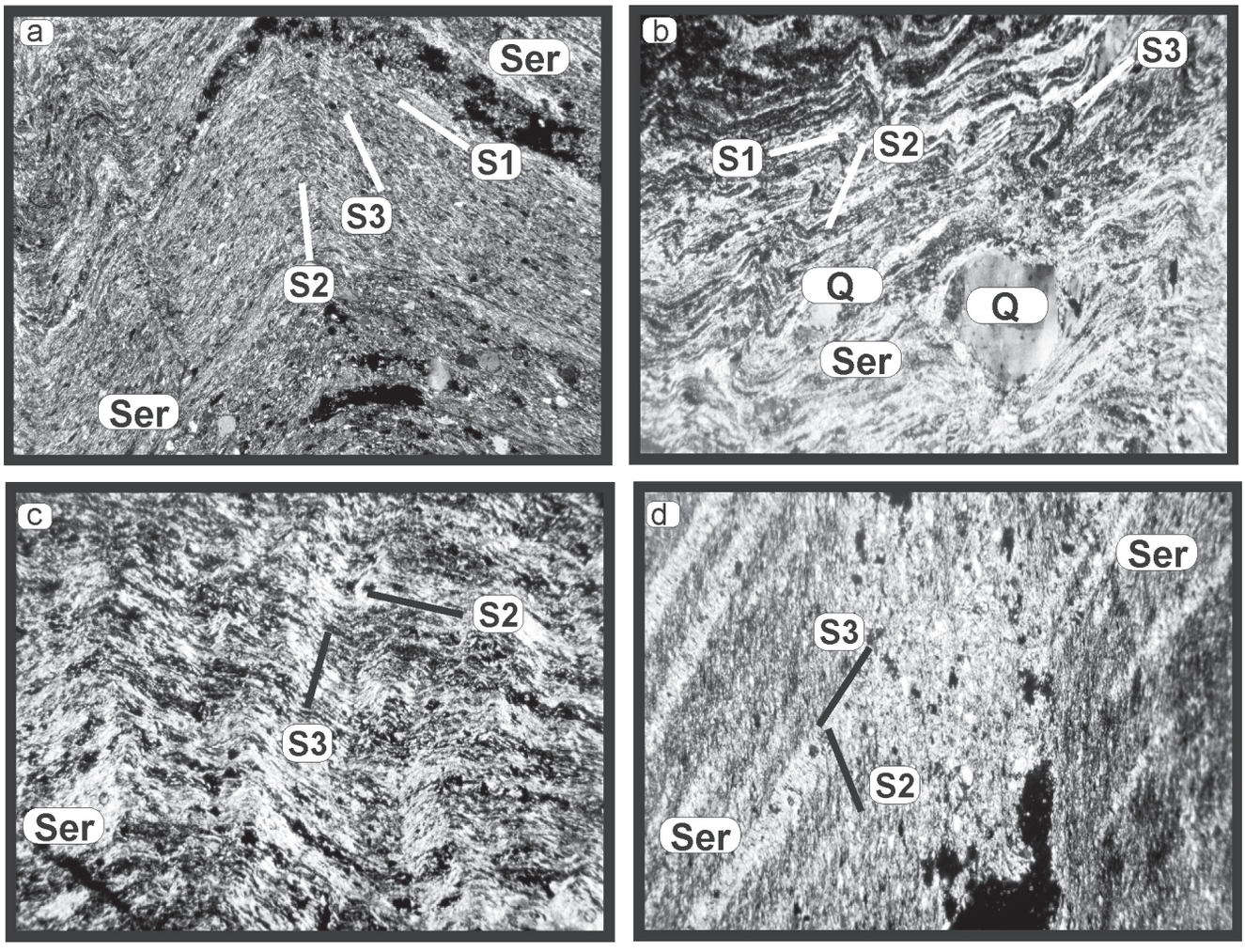


Fig. 6: Polyphase deformation of the core and cover units in the Sandıklı area. **a)** well-developed discrete crenulation cleavage in the metasiltstones of Güvercinoluk Formation indicating three distinct deformational phases, **b)** three distinct deformational phases in the metarhyolites of Kestel Çayı Volcanics (S1-S2-S3), **c) d)** two deformational phases in the slates/metamudstones of Göğebakan Formation and in metasiltstones of Celiloğlu Formation (S_2-S_3). Q-quartz, Ser-serizite.

cover (Fig. 7a, b, c). Captivatingly, the thrust/reverse fault character of this contact is known in the previous studies [24, 25] but rejected by Güngör [1] on page 351 but later confirmed on page 356.

4. Conclusions

The field, structural and mineralogical data obtained Sandıklı areas of the Central Taurides, the Sandıklı Basement Complex is intruded by post-collisional felsic rocks, affected by regional dynamo-thermal metamorphism, uplifted and eroded at the end of Neoproterozoic, prior to the deposition of the Early Cambrian red clastic rocks of Göğebakan formation [3, 8, 12]. These data coincides with the Cadomian metamorphism in several peri-Gondwanan terranes [26, 27, 28, 29, 30, 31, 32].

Güngör's [1] refusal of this Cadomian/Late Pan-African event in his conclusions is based on considerable problems in the field observations and interpretations that directly have an effect on the geological evolution of the Late Neoproterozoic basement and Early Palaeozoic cover units in the Sandıklı area.

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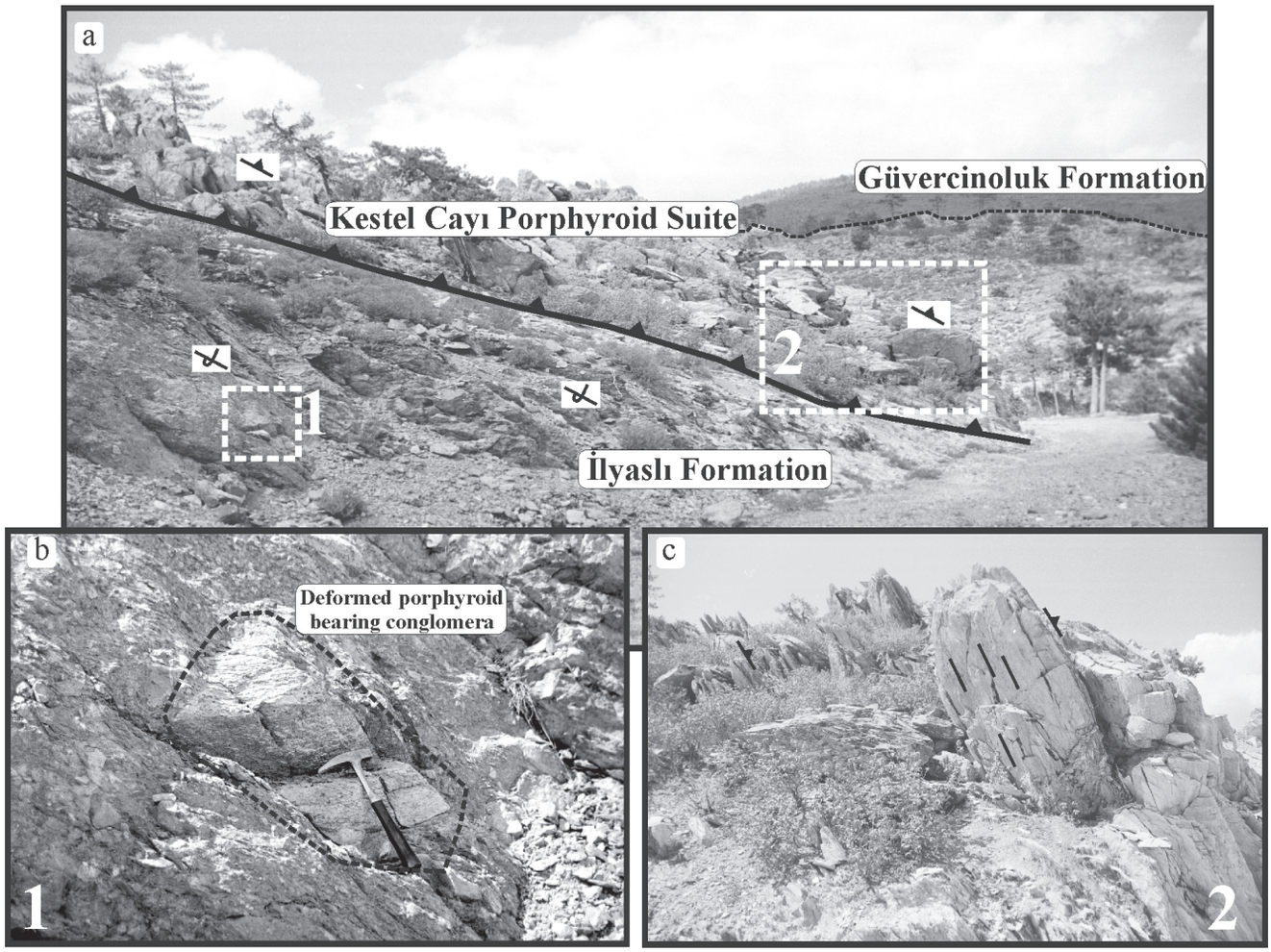

Fig. 7: a) Tectonic contact of the Liasssic İlyaslı Formation and Kestel Cayı Porphyroid Suite (Kestel Çayı Volcanics) and Güvercinoluk Formation of Sandıklı Basement Complex, **b)** Deformed porphyroid pebbles bearing Liassic İlyaslı Formation, c: arrows indicate slickensides in Kestel Çayı Porphyroid Suite.

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