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AN INTRODUCTION TO THE PALEOZOIC OF ANATOLIA WITH A NW GONDWANAN PERSPECTIVE

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HISTORICAL BACKGROUND

The earliest attempts to recognize the Paleozoic rocks in Turkey in a more or less systematic approach and correlate them with those in Europe dates back to the second half of the 19. Century, where a number of natural scientists reported in their classical work also the stratigraphy and fossil findings in different Paleozoic successions in Turkey (e.g. Tchihatcheff, 1864; de Verneuil, 1869). The interest of the international geological community grew with the building of the Anatolian and later the Bagdat railways and the “discovery” of the Kirkuk (Musul) oil fields in northern Iraq during the end of the 19. and early 20. Century, where a number of studies on the Paleozoic of Turkey were published (e.g. Frech, 1916; Penck, 1919). The establishment of the Mineral Research and Exploration Institute of Turkey (MTA) followed by the Turkish Petroleum Corporation (TPAO) resulted in systematic mapping of Paleozoic in Turkey, pioneered by a small number of geologists (e.g. Tolun and Ternek, 1952; Dean 1961 to 2006, Ketin, 1966, Kaya, 1973). The litho- and biostratigraphic information obtained between 1950 and 1990 was discussed during a field-meeting of IGCP 256 (Paleozoic of NW Gondwana) in 1995, organized again by the Turkish Association of Petroleum Geologists (TPJD) and published in a special issue of the Association (Göncüoğlu & Derman, 1996).

Following the Iraq War in 2003, the interest of the petroleum companies on the geology of the Northern Mesopotamia made another peak. A number of new research and exploration projects were started also in southern Turkey and a number of detailed studies with new data and models were put forward. To discuss them and record the state-of –art knowledge, TPJD organized this second field-meeting to one of the best preserved Paleozoic sections in the Eastern Mediterranean

THE TECTONIC FRAMEWORK

Turkey with Thrace in the European continent and Anatolia on the Asiatic one is located in the central part of the Alpine Orogenic Belt between the Balkans and the western Asia. It was formed by the closure of at least three oceanic stands of the Neotethys between the continents Laurasia in the N and Gondwana in the south. These oceanic strands were separating smaller continental microplates rifted off from Gondwana. During the closure of the Neotethys during the Late Mesozoic-Early Tertiary by the counter-clockwise rotation of Africa, the oceanic as well as continental units (terranes) accreted to form a complex mosaic, what makes up Turkey now. For the alpine period (for a brief review see Göncüoğlu, 2010) the geological evolution as well as the boundaries of these terranes, as shown in Figure 1, are more or less well-established (Figure 1). From N to S these alpine units are: the Istranca Terrane with a complex pre-alpine history including a Variscan arc, not yet fully understood; the Istanbul-Zonguldak Composite Terrane including a Cadomian basement and a Variscan passive margin; the Intra-Pontide Suture Belt with remnants of Triassic-Cretaceous northernmost Neotethys; the Sakarya Composite Terrane with Variscan and Cimmerian compounds; the Izmir-Ankara-Erzincan Suture Belt with the remnants of the middle branch of Neotethys; the Tauride-Anatolide Terrane with a Cadomian/Pan-African basement and a well-developed Paleozoic platform sequence underlying its Mesozoic platform cover; the Amanos-Elazığ-Van-Zagros Suture Belt with remnants of the southern branch of Neotethys and the SE Anatolian Autochthon with well-developed Paleozoic-Mesozoic platform sequences on the N continuation of the Arabian Continent.

Considering the presence of at least three pre-alpine orogenic events in the alpine terranes of Turkey, it is obvious that the configuration of the continental and oceanic micro-plates in relation to the Cimmerian, Variscan and Cadomian/Pan-African Wilson cycles is a multi-disciplinary puzzle-work as well as a challenge for the earth scientists.

In this introduction we will briefly concentrate on the geological record of the Paleozoic in different alpine terranes in Turkey and evaluate its evolution within the NW Gondwanan perspective.

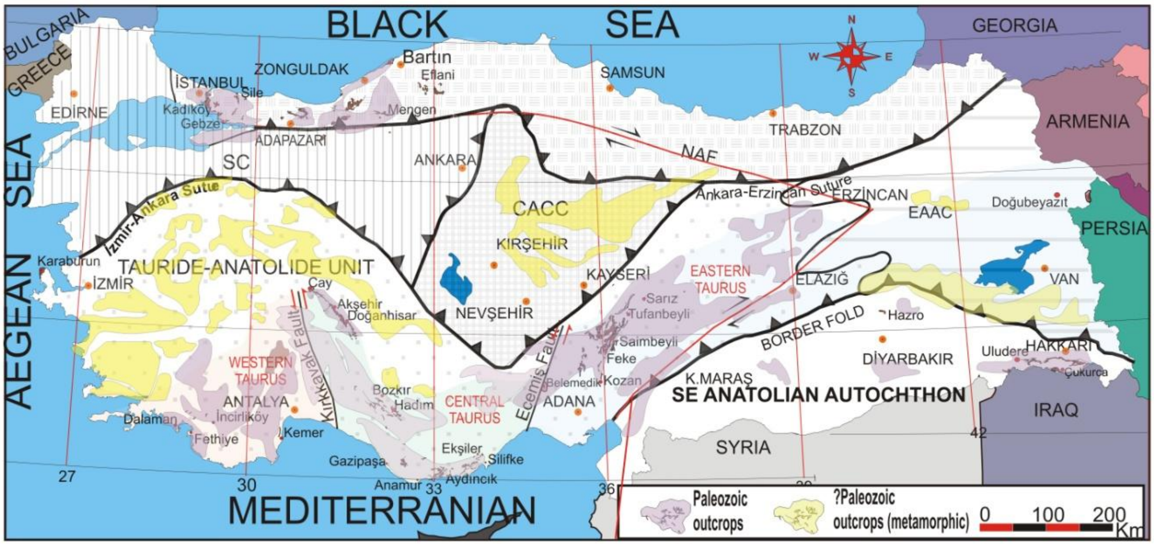

Figure 1: Distribution of the Paleozoic rocks in the alpine tectonostratigraphic units (terranes) of Turkey.

DISTRIBUTION OF PALEOZOIC ROCKS IN THE ALPINE TERRANES IN TURKEY

The Istranca Terrane, which is considered as a "suspect terrane", comprises a number of nappes with arc-type granitoids that yielded Early Permian ages (Okay et al, 2001) that intrude a metasedimentary succession of probably Late Paleozoic age.

The Paleozoic of **Istanbul and Zonguldak terranes** is one of the relatively well-studied successions in Turkey and had been revised recently by Özgül (2012 and the references there in). The generalized columnar section of the Istanbul Terrane (Figure 2) shows an almost complete cycle that starts with Ordovician rift-related continental clastics above a Cadomian basement. The Late Ordovician transgression is followed by the deposition of open shelf carbonates and clastics during Silurian – Middle Devonian interval. By progressive deepening of the Paleozoic basin during the Late Devonian and Early Carboniferous, slope to basin conditions with deposition of nodular limestones and radiolarian cherts were realized.

From the Early Carboniferous onwards deposition of flysch-type clastics with sporadic limestone bands indicates the onset of Variscan tectonics that culminated with the intrusion of Permian granites and folding of the Paleozoic rocks.

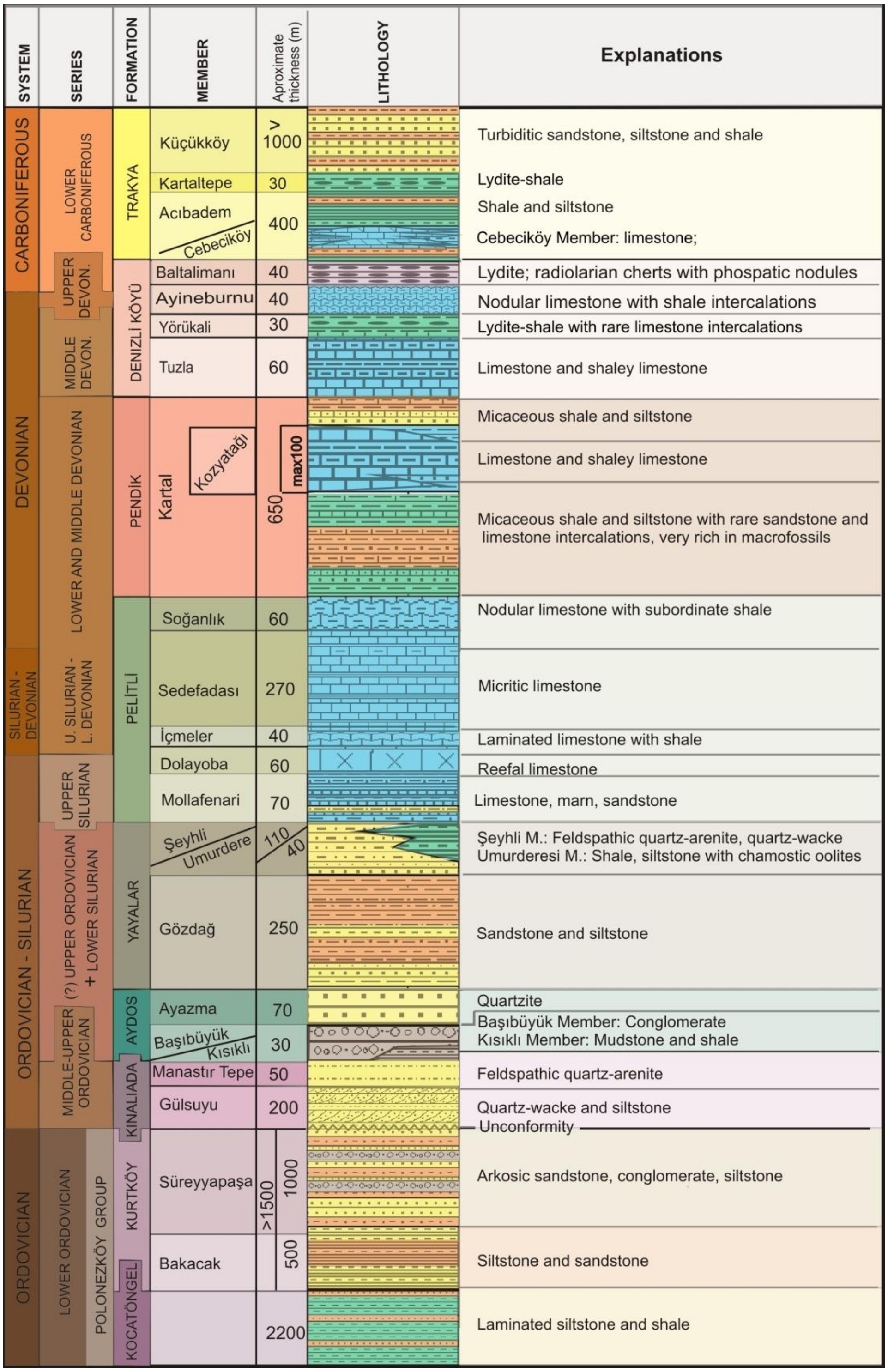

Figure 2: Paleozoic stratigraphy of the Istanbul Terrane (Özgül, 2012).

To the E, a regional scale thrust seperates the Paleozoic of the Zonguldak Terrane from Istanbul. In this unit, Lower Ordovician clastics transgress onto a Cadomian basement with arc-type granitoids. The Middle Ordovician-Middle Silurian interval is mainly represented by black shales with rare limestone intervals. In contrast to the continuous Silurian-Devonian deposits in the Istanbul Terrane, the Wenlock graptolitic shales in Zonguldak are affected by a low-grade metamorphic event and unconformably overlain by Middle Devonian shelf-type carbonates (Bozkaya et al, 2012). The carbonate deposition lasted until the Late Mississippian. Unlike the Istanbul Terrane, the Early Pennsylvanian in Zonguldak is represented by coal bearing fluvial sediments. Recently, late Middle Permian fluvial and lagoonal deposits were discovered in the Zonguldak Terrane. By this, Zonguldak unit correlates with the Moesian Terrane (Yanev et al, 2006) rather then to the Avalonian-Central European terranes.

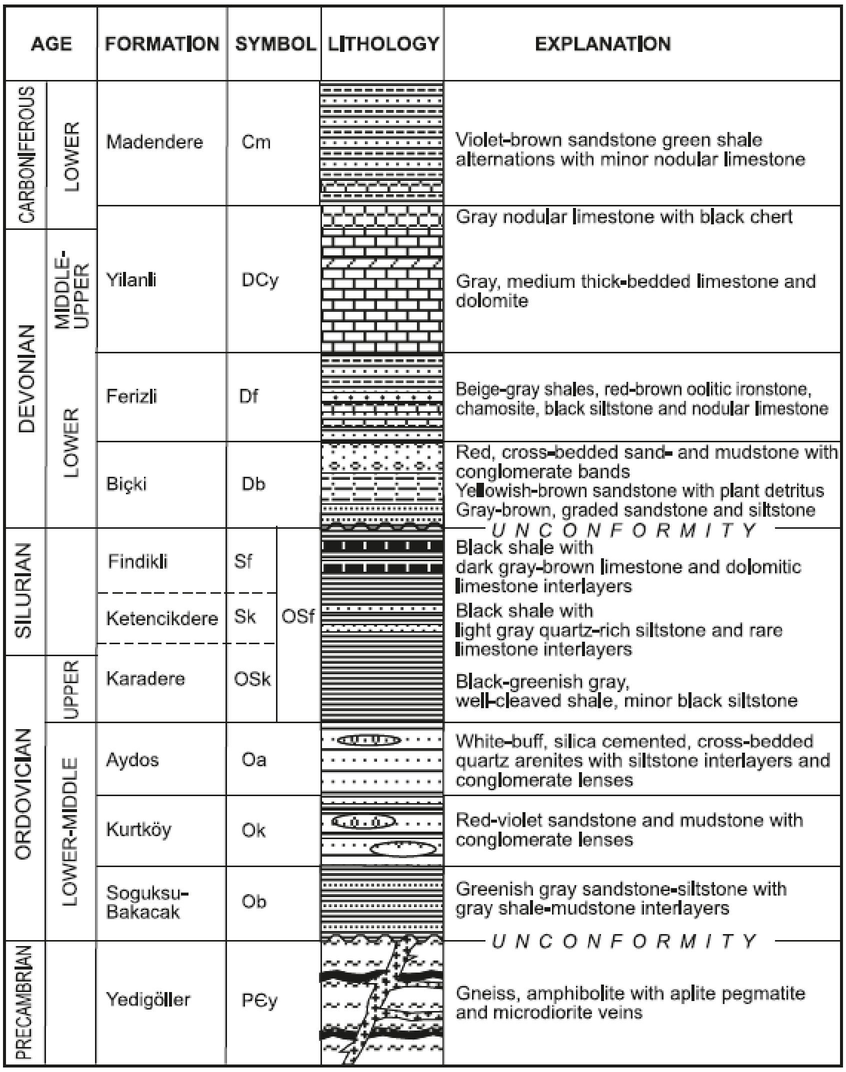

Figure 3: Generalized columnar section of the Paleozoic rocks in the Zonguldak Terrane (Göncüoğlu et al., 2004a, Bozkaya et al., 2012).

In the **Sakarya Composite Terrane**, Paleozoic rocks are represented by Devonian (Aysal et al., 2012) and Carboniferous (Okay et al., 2006; Ustaömer et al, 2012) granitoids intruding a Variscan metamorphic basement. This basement is unconformably overlain by Middle Permian carbonates (Okuyucu and Göncüoğlu, 2010). Moreover, Devonian, Carboniferous and Permian sedimentary rocks of unknown origin were found as allochthonous blocks within the Cimmerian mélange complexes.

The main body of the Paleozoic rocks occurs within the **Tauride-Anatolide Terrane** located on the northern continuation of Arabia-NW Africa before its Late Permian rifting and drifting towards north by the opening of the southern branch of Neotethys or the Avanos-Elazığ-Van-Zagros Ocean (Göncüoğlu et al., 1997a). By this, the Paleozoic successions in the Tauride-Anatolide and the N-Arabian-SE Anatolian units display similarities and facial continuities as they were formed on the same N-facing platform. The Paleozoic rocks in the **Anatolites**, representing the N edge of the Tauride-Anatolide Platform were metamorphosed and intensively imbricated during the closure of the middle branch of alpine Neotethys (Izmir-Ankara-Erzincan Ocean) during the end of Mesozoic and Early Tertiary. By this, the Paleozoic outcrops in the Anatolides (Figure 1) are variably metamorphosed and rarely represent continuous successions. Lower Paleozoic sedimentary rocks are not proven by reliable data. Sporadic data from the Konya and Karaburun (Izmir) area (Göncüoğlu et al, 2011), however, suggests a deep marine deposition towards N of the Paleozoic carbonate platform that lasted until the Carboniferous (Figures 4 and 5). In the Anatolides, Middle Permian is disconformable on different Paleozoic successions indicating the re-establishment of the carbonate platform after a Variscan-time event at the N Tauride-Anatolide margin (Figures 4 and 5).

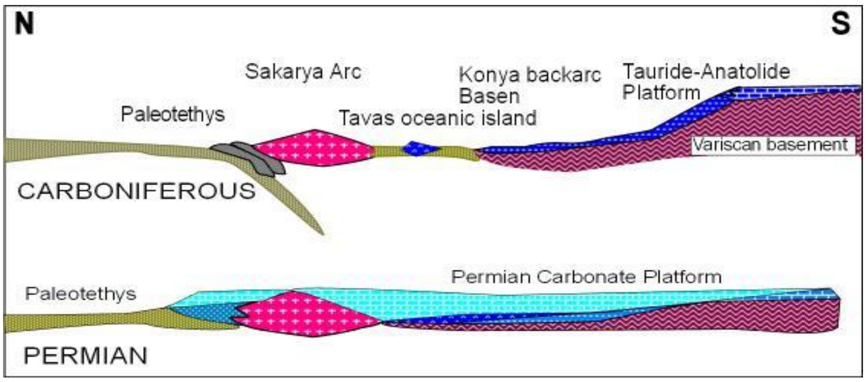

Figure 4: Carboniferous-Permian evolutionary model of the N edge (Anatolides) of the Tauride-Anatolide Platform (Göncüoğlu et al., 2007b).

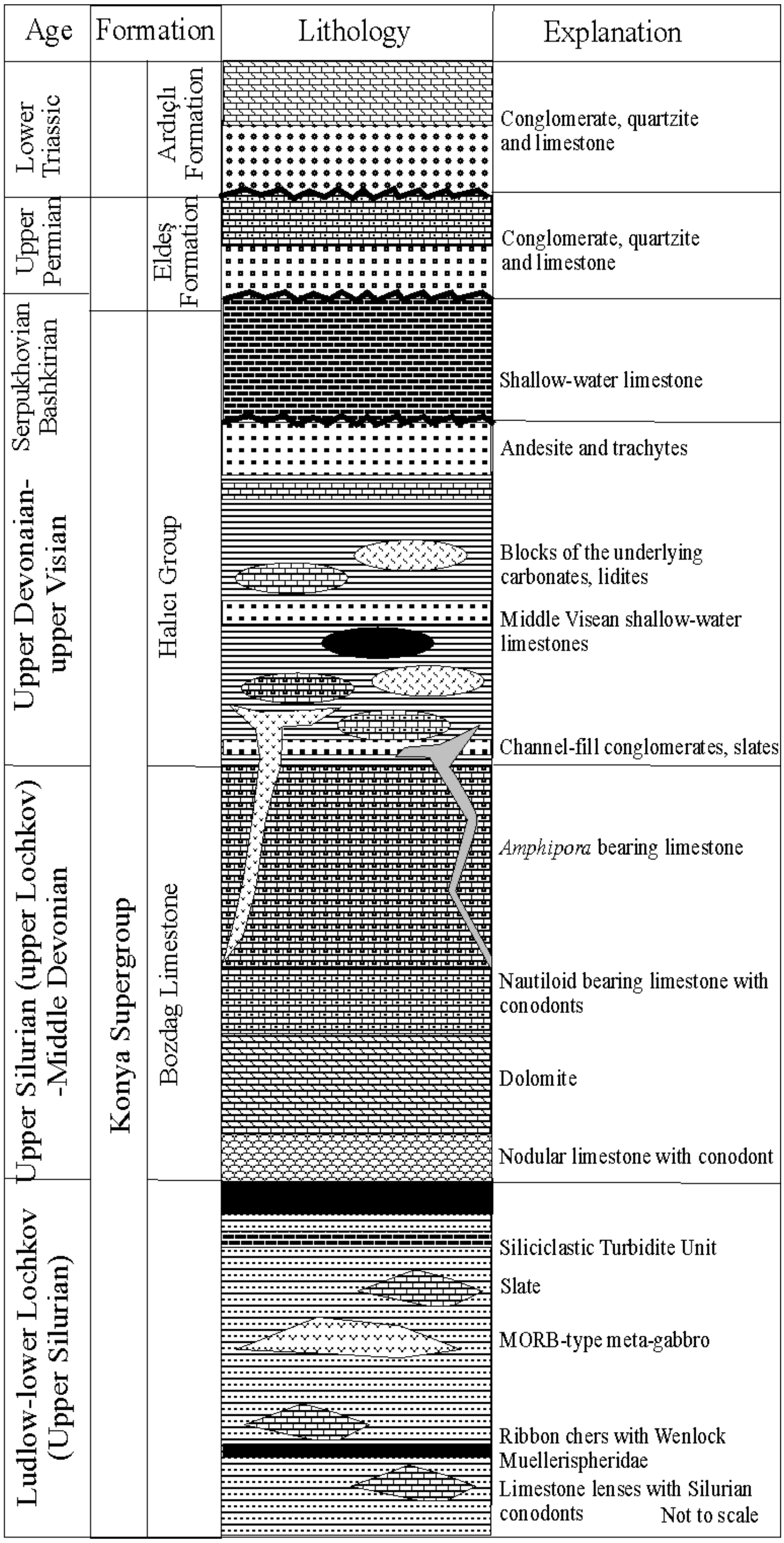

Figure 5: Low-grade metamorphic Paleozoic succession of the Anatolides in the Konya area (Göncüoğlu, 2011)

The Taurides, where the main bulk of the non-metamorphic Paleozoic rocks are found, comprises a pile of nappes, or tectono-stratigraphic units (Özgül, 1976, 1984). A comprehensive tectonic classification of these nappes was proposed by Özgül (1976, 1984) regarding their palaeogeographic origins. Özgül (1984) suggested the presence of a central "autochthonous" belt (Geyikdağı Unit), overthrust by northerly (Bozkır, Bolkar, and Aladağ units) and southerly (Alanya and Antalya units) derived tectono-stratigraphic units (Figure 6). From these, the Bozkır and Aladağ units do not comprise Lower Paleozoic successions (Figure 7). All along the belt, the Geyikdağ Unit provides more or less continuous Paleozoic successions.

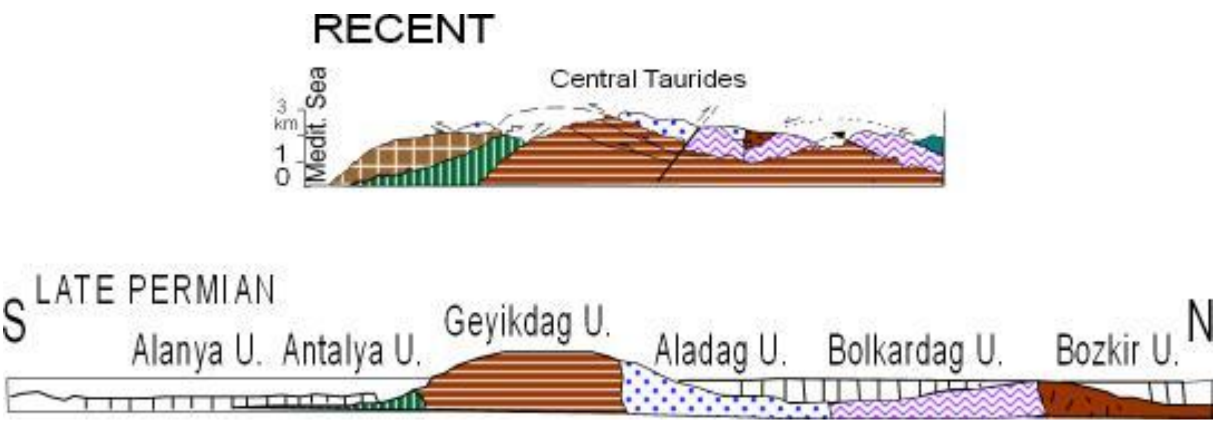

Figure 6: Palinspastic restoration of the Tauride tectonostratigraphic units (Özgül, 1984)

The most prominent and uninterrupted Paleozoic successions, however, are observed in the Geyikdağı Unit in the Eastern Taurides, to where the field-excursion of this meeting will be realized.

The details of these units will be the topic of the following chapters.

The **SE Anatolian Autochthon** (Figure 1) on the northern edge of the Arabian Plate is another area, where metamorphic as well as non-metamorphic Paleozoic units crop out. The metamorphic Paleozoic rocks (Bitlis-Pötürge Massifs, Figure 1) are of allochthonous character and were affected by the alpine closure of the Southern branch of Neotethys that was opened between Tauride-Anatolide Platform and the Arabian Plate during the Permian. They were imbricated together with Neotethyan oceanic units and were thrust initially during the Early Tertiary on top of each other, and then onto the Arabian Platform in successive pulses at the end of Eocene and during the Miocene. The Main Thrust Zone (Figure 1) between the Metamorphic Allochthons and the Arabian Autochthon is still an area of compression.

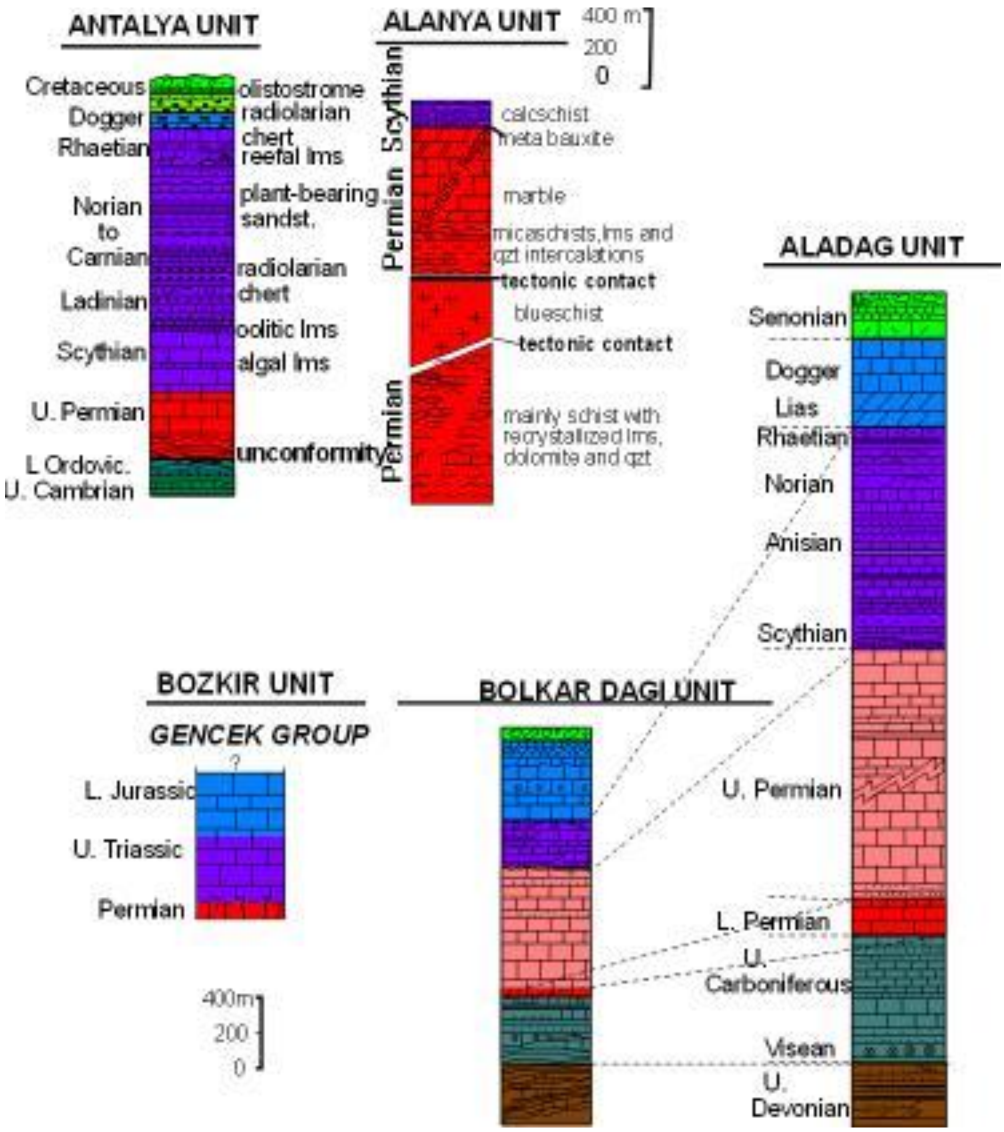

Figure 7: Stratigraphy of the Tauride Units (after Özgül, 1984).

Also supported by subsurface data from about 70 wells, the Paleozoic of the SE Anatolian Autochthon is subdivided (Yılmaz and Duran, 1997) in the following lithostratigraphic units (Figure 8):

Cambrian; Derik Group (Sadan, Koruk and Sosink formations),

Ordovician; Habur Group (Seydişehir and Bedinan formations),

Silurian-Middle Devonian; Diyarbakir Group (Dadaş, Hazro and Kayayolu formations),

Late Devonian-Early Carboniferous; Zap Group (Yığınlı, Köprülü and Belek formations),
Upper Permian; Tanin Group (Kaş and Gomaniibrik formations).

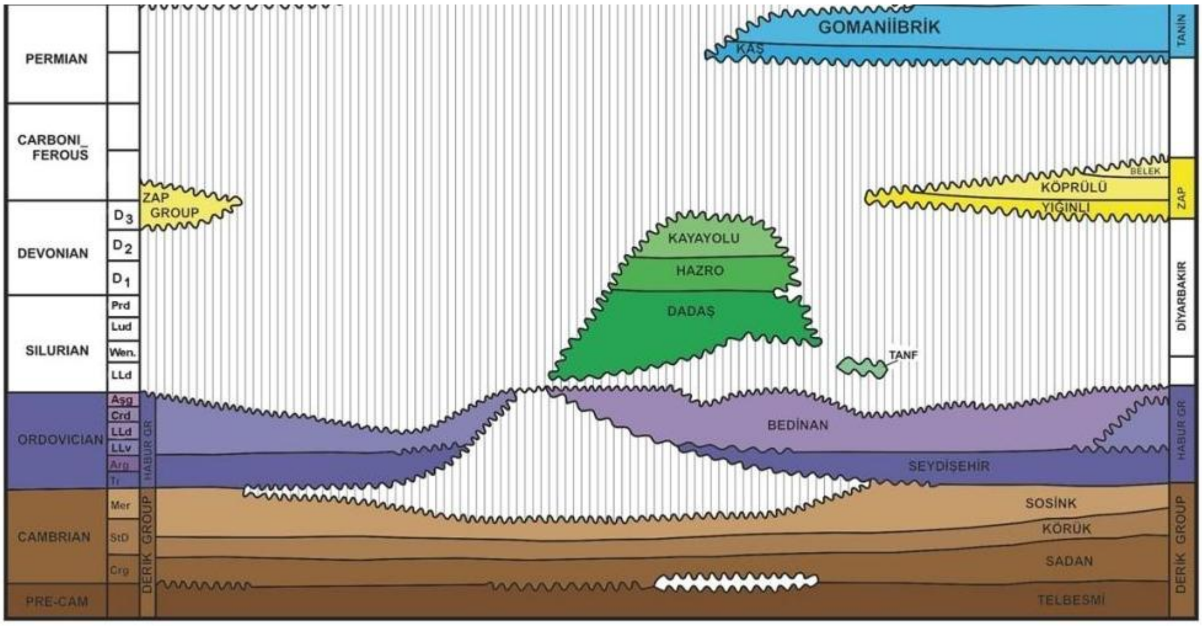

Figure 8: Stratigraphic chart of the Paleozoic of the SE Anatolian Autochthon (after Bozdoğan and Ertuğ, 1997)

Correlations between the Tauride and SE Anatolian Paleozoic units are reported in Göncüoğlu and Kozlu (2002) evaluated in detail in the following related chapters.

THE NW GONDWANAN FRAMEWORK

Geological records from SE Anatolia and further E in the Zagros Belt and Oman suggests that pieces of the Arabian-Gondwanan margin, including the Tauride-Anatolide platform were rifted off the main body, by the opening of the southern branch of Neotethys (e.g. Şengör and Yılmaz, 1981; Göncüoğlu et al, 1997; Stampfli, 2000, Kozlu and Göncüoğlu, 2001). Based on this and the lithological correlations, oversimplified evolutionary models (Figure 9) were proposed for the Turkish terranes within the N Gondwanan framework (Göncüoğlu, 1995).

In the last years, supported by more detailed work on paleobiogeography, paleomagnetism, zircon provinciality etc has resulted in better constrained but still speculative models (Ruban et al., 2007; van Raumer et al., 2002; Bozkurt et al, 2008; Torsvik and Cocks, 2011; Nance et al, 2012).

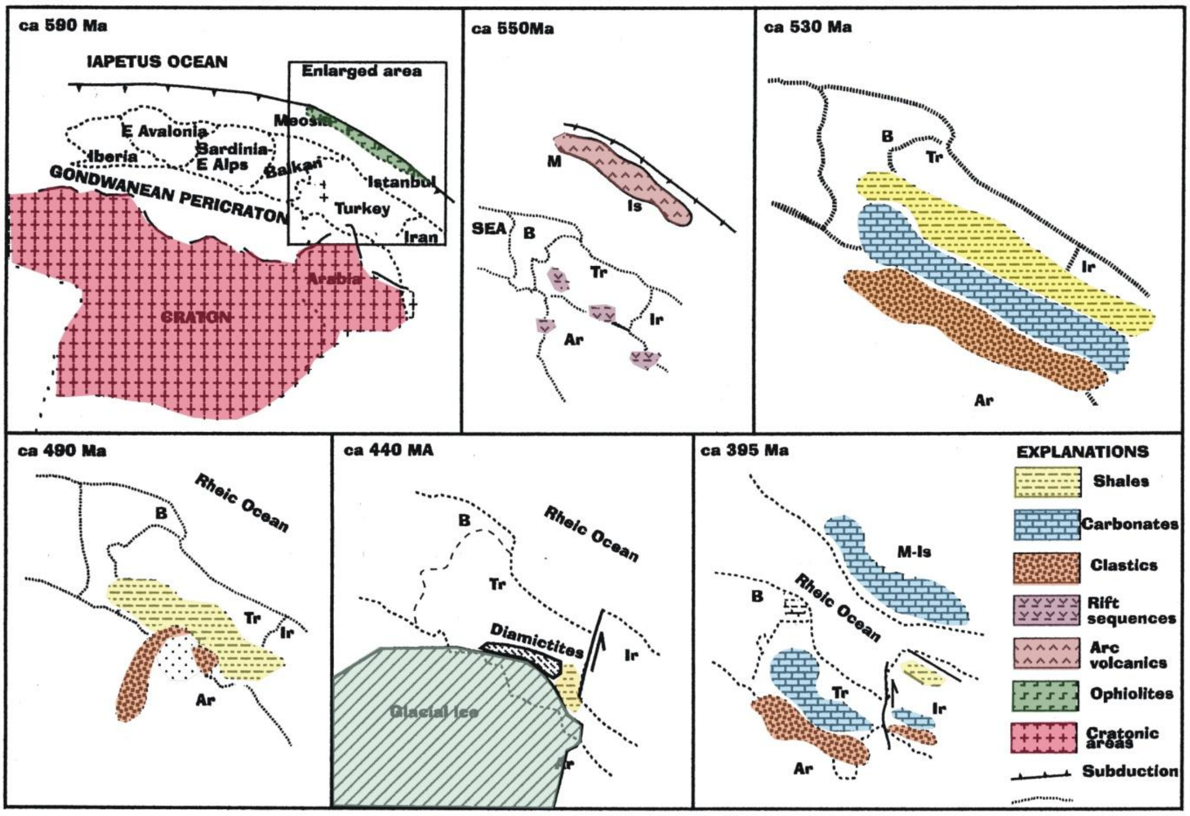

Figure 9: An earlier attempt to model the evolution of the Turkish terranes in NW Gondwana (Göncüoglu, 1995, 1997).

Briefly, these models suggest the following:

During the Late Neoproterozoic, the northern margin of central Gondwana (in the sense of Torsvik and Cocks, 2012; see Figure 10 below) was the site of the Cadomian Orogeny. The products of this event are found as arc-type magmatic rocks and back-arc-type volcanism in the southern Turkey (e.g. Gürsu and Göncüoğlu, 2005) and attributed variably to the Pan-African (e.g. Oberhaensli et al, 2010) or Cadomian (e.g. Göncüoğlu et al, 2011) magmatism.

The Taurides and the SE Anatolian areas (Figure 10) in NE central Gondwana, remained from Cambrian to Late Permian in the platform margin position. They may have been affected by extensional or transtensional events related to the opening of the Rheic Ocean that separated the Avalonian terranes from NW Central Gondwana during the Early Ordovician.

Figure 10: The position of the “central Gondwana” terranes at about 480 Ma (Torsvik and Cooks, 2011).

The rifting of the Armorican (or Cadomian by Nance et al, 2012) terranes from the central part of central Gondwana during the Early Devonian has also been affecting the NE Central Gondwana. Both in the Taurides and SE Anatolian autochthon local unconformities in respective periods may be related to these events as discussed in Göncüoğlu et al. (2004a). These events are very probably also responsible for the separation of the Istanbul and Zonguldak terranes of NW Anatolia, which drifted during Devonian (Figure 11) towards N and collided with the Laurussian continent by the closure of the Rheic Ocean (Yanev et al, 2006).

The Late Carboniferous closure of the Rheic Ocean and the amalgamation of several terranes to form Pangea has obviously not directly affected the NE central Gondwana and hence the southern Turkish area. However, in the northern edge of the Taurides, in the Anatolides, a narrow back-arc basin developed during the Carboniferous was closed by creating mélanges (Figure 4; Konya Mélange, Göncüoğlu et al, 2007; Robertson and Ustaömer, 2009).

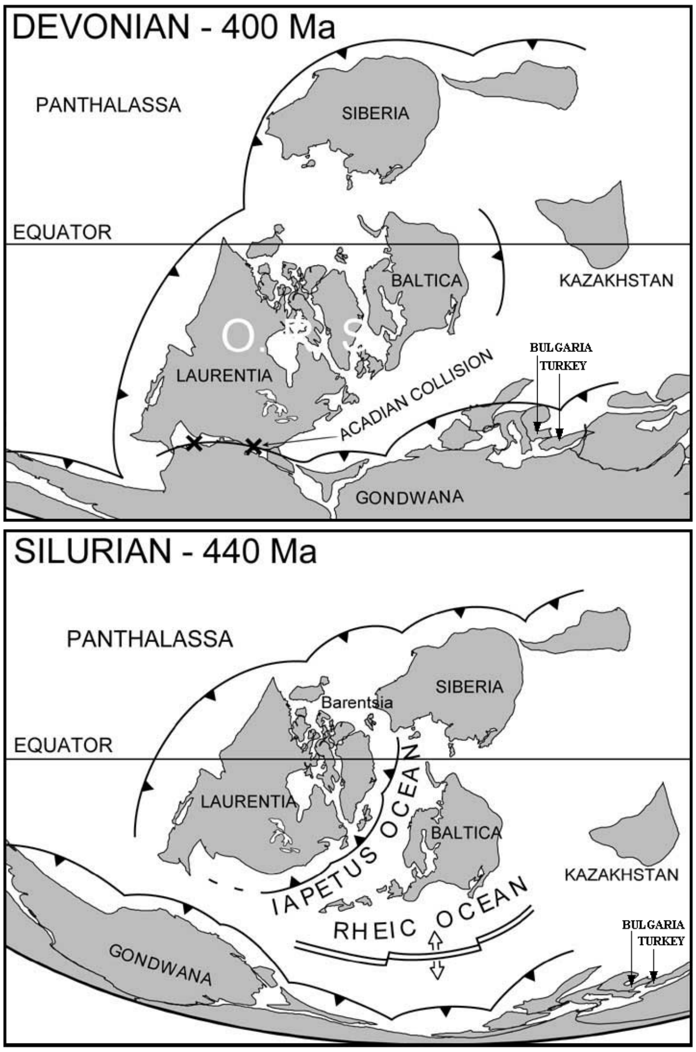

Figure 11: Paleogeographic position of the NW Anatolian and Balkan terranes with respect to the Taurides (Yanev et al., 2007).

In the Tauride-Anatolide platform and in SE Anatolia, the affects of this Variscan-time event is recorded by regional unconformities (Figures 5, 7 and 8). In most cases, Middle Permian is transgressive upon variably eroded Paleozoic successions (e.g. Altıner et al, 2000; Altıner and Özgül, 2001). This event is evidently not related to the

Variscan orogeny on the northern margin of Paleotethys generated by the closure of the Rheic Ocean but to the collision of an oceanic plateau and the closure of a marginal back-arc basin with the Anatolide margin.

Late Permian in Turkey is characterized by the deposition of oceanic sediments in the prevailing (Paleotethys) and new oceans (Neotethys). Paleontological record from the Paleotethys in NW Turkey (radiolarian data, e.g. Göncüoğlu et al., 2004b) evidences oceanic basin conditions during the Changxingian. In Oman, on the E continuation of the Bitlis-Zagros Belt, similar findings were reported (e.g. Şengör, 1990). On the continental microplates, such as the Tauride-Anatolide Unit or Sakarya Composite Terrane, on the other hand, platform-type carbonates were deposited.

To conclude, the Paleozoic Turkish terranes in the N (Istanbul-Zonguldak) and in the S (Tauride-Anatolide and SE Anatolia) although derived from N Gondwana, went through completely different evolutionary paths. Our available data is still very fragmentary to be able to reconstruct this complex geological history.

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