DISTRIBUTION OF LOWER PALEOZOIC ROCKS IN THE ALPINE TERRANES OF TURKEY: PALEOGEOGRAPHIC CONSTRAINTS

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ABSTRACT

With well-studied Lower Paleozoic successions in the alpine terranes in Turkey are described in the İstanbul Terrane, Tauride-Anatolide Composite Terrane and the SE Anatolian Autochton. The İstanbul Terrane characterizing the southern active margin of the Laurasian Megaplate during the alpine period is composed of a pre-Lower Paleozoic basement mainly consisting of ophiolites and granitoids. The anchi-metamorphic Lower Paleozoic cover is represented by a sequence of ?Cambrian to Lower Carboniferous sediments. The Tauride-Anatolide Composite Terrane represents a Gondwanean continental microplate between the Vardar-İzmir-Ankara and Pindos-Bitlis-Zagros Sutures during the alpine period. The Anatolide subunit of this terrane is made up of allochthonous assemblages, which contain medium-high grade metamorphic Lower Paleozoic units. The Tauride subunit is characterized by a double verging nappe-pile consisting of low-grade and non-metamorphic platformal sequences. Relatively well studied Infra-Cambrian and Lower Paleozoic successions are located as continuous successions within the nappes. The SE Anatolian Autochton with the Bitlis subunit represents the northern margin of the Arabian Plate to the South of the Pindos-Bitlis-Zagros Suture. It includes well-developed Lower Paleozoic sequences that correlate best to the NW Gondwanean successions of the same age. The palinspastic reconstruction of Lower Paleozoic events in the Anatolian portion of NW Gondwana reveals that the Tauride and SE Anatolian-Arabian terranes had a common geological history that differs from a northern zone represented by Balkan and İstanbul terranes.

INTRODUCTION

During most of its geological past the Anatolian area was located between two megacontinents: Gondwana to the south and Laurasia to the north. It is generally accepted that numerous continental fragments belonging to one of these megacontinents were rifted away from the main body and amalgamated to the next, so that the Anatolian realm is made of several oceanic and continental "terranes" with different geological features. The last main orogenic event, the alpine orogeny, related to the closure of diverse Neo-Tethyan branches has controlled the present distribution of these terranes. The Turkish orogenic collage can be divided into a number of tectono-stratigraphic units or terranes trending in E-W direction (Figure 1). These units, corresponding with various tectonic settings, such as an active and passive continental margins, arc and suture complexes, were generated as a result of the closure of three main oceanic basins: Pan-African, Hercynian and/or Paleo-Tethyan and Neo-Tethyan. The terranes related to the Pan-African and Hercynian and/or Paleo-Tethyan cycles are represented by disrupted and metamorphosed tectono-stratigraphic units within the alpine terranes (Göncüoğlu et al., in print).

In this paper, I will briefly describe the distribution and lithologies, tectonic settings and assemblage of the Lower Paleozoic units in the alpine terranes, correlate them with the adjacent areas and try to summarize their possible paleogeographic reorganization.

STRATIGRAPHY OF LOWER PALEOZOIC ROCKS

Well-defined Lower Paleozoic successions are mainly met in the İstanbul Terrane, Tauride Subunit of the Tauride-Anatolide Terrane and the SE Anatolian Autochtonous Terrane (Figure 1). The presence of the Lower Paleozoic units in the metamorphic terranes such as the Istranca, Sakarya and Anatolide terranes are indeed known, but their stratigraphy as well as their distribution is not yet well documented.

Lower Paleozoic of the İstanbul Terrane

İstanbul Terrane consists of a Pre-Cambrian? basement, unconformably covered by a well-developed sequence, extending without any major unconformity from Ordovician to the Lower Carboniferous. This anchi-metamorphic Paleozoic section, represents a southward facing Atlantic type passive continental margin (Şengör, 1984). It is unconformably overlain with Lower Triassic continental clastics, which pass upwards to an alpine-type Triassic sequence and finally unconformably covered by Upper Cretaceous-Paleocene carbonates.

Pre-Lower Paleozoic Rocks

Limited outcrops of meta-gabbros, high-Mg schists (metaserpantinites), ortho-amphibolites and amphibole-gneisses are reported from basement of the İstanbul Terrane, which is named as the "Basement Complex" (Göncüoğlu et al., in print). Discontinuous bands of

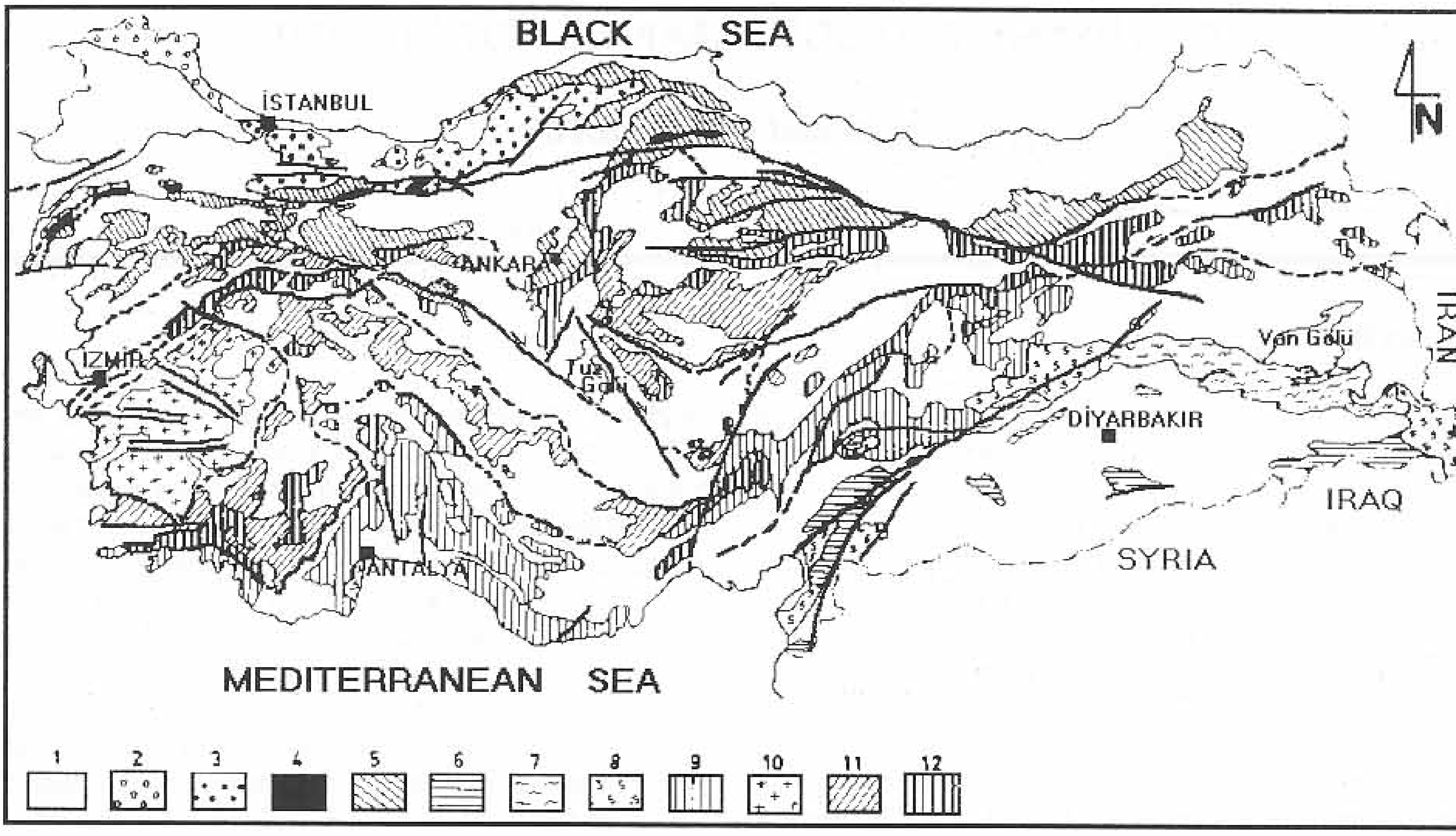

Figure 1. Distribution of prealpine and alpine terranes in Turkey. 1) Cenozoic cover, 2) Istranca Terrane, 3) İstanbul Terrane, 4) Intrapontide Ophiolite Belt, 5) Sakarya Composite Terrane, 6) Southeast Anatolian Zone, 7) Bitlis Zone, 8) Southeast Anatolian Ophiolite Belt, 9) Taurides, 10) Menderes Terrane, 11) Kütahya Bolkardağ Belt, 12) North Anatolian Ophiolite Belt (simplified from Göncüoğlu et al., in print).

bioite gneisses and biotite bearing para-amphibolites are observed as thin interlayers. Blasto-myionitic alkali-feldspar granites and quartz-monzonites are common intrusive ingredients of the Basement Complex (Arpat et al., 1978). This Basement Complex has common features with the Pre-Cambrian ophiolites and Cambrian island-arc associations of the Balkan Terrane, which were described by Haydoutov (1989).

Lower Paleozoic Rocks

In the western (İstanbul-Pendik) area (Figure 2), in the lowermost interval of the sequence, Ordovician is characterized by shallow-marine quartzites and conglomerates Haas, (1968) indicate that the sediment transportation is from north. They are overlain by a succession of black, Graptolite bearing shales that are followed by Lower Silurian shales and siltstones. Limestone lenses from the lower interval of the Silurian sequence yielded Early Llandoverian fossils. In Early Wenlockian a carbonate deposition began and was followed by Devonian crinoidal and nodular limestones with shale, silty shale and siltstone interlayers, passing conformably into Lower Carboniferous radiolarian cherts. The Ordovician-Silurian period is characterized by the formation of local N-S trending highs (Kaya, 1978). The depositional features of Devonian and Carboniferous units suggest a further subsidence and formation of deep-shelf to slope sediments. In the central part of the İstanbul Terrane (Çamdağ area, Figure 2) and farther in the East (Kastamonu area) Cambro-Ordovician variegated shales and sandstones with Trilobites and primitive Brachiopods rest with an angular unconformity on the Basement Complex (Aydın et al., 1987). In contrast to the western part Ordovician and Silurian are represented by deep basinal siliciclastic sediments. Stratigraphy and fauna of the Lower Paleozoic in this area are described in detail by Dean et al. (1995 and this volume). The disconformity between older units and Devonian platformal carbonates in this part also contrasts with the western areas.

Regional transgressions of ?Late Ordovician-Early Silurian and Early Devonian age in the eastern part and the Early Devonian disconformity in the central part of the İstanbul Terrane (Aydın et al., 1987) were ascribed to local uplifting events (Kaya, 1978; Gedik, 1988).

Detailed biostratigraphical work yet available on the uppermost interval of the Silurian in western İstanbul area (Haas, 1968) does not mention the presence of Pridoli but suggest a transition between Silurian and Devonian strata in the western İstanbul Terrane. In the case that a disconformity is confirmed by further studies also in the western area, the unconformity at Silurian-Devonian transition may indicate a Caledonian event rather than a local uplifting.

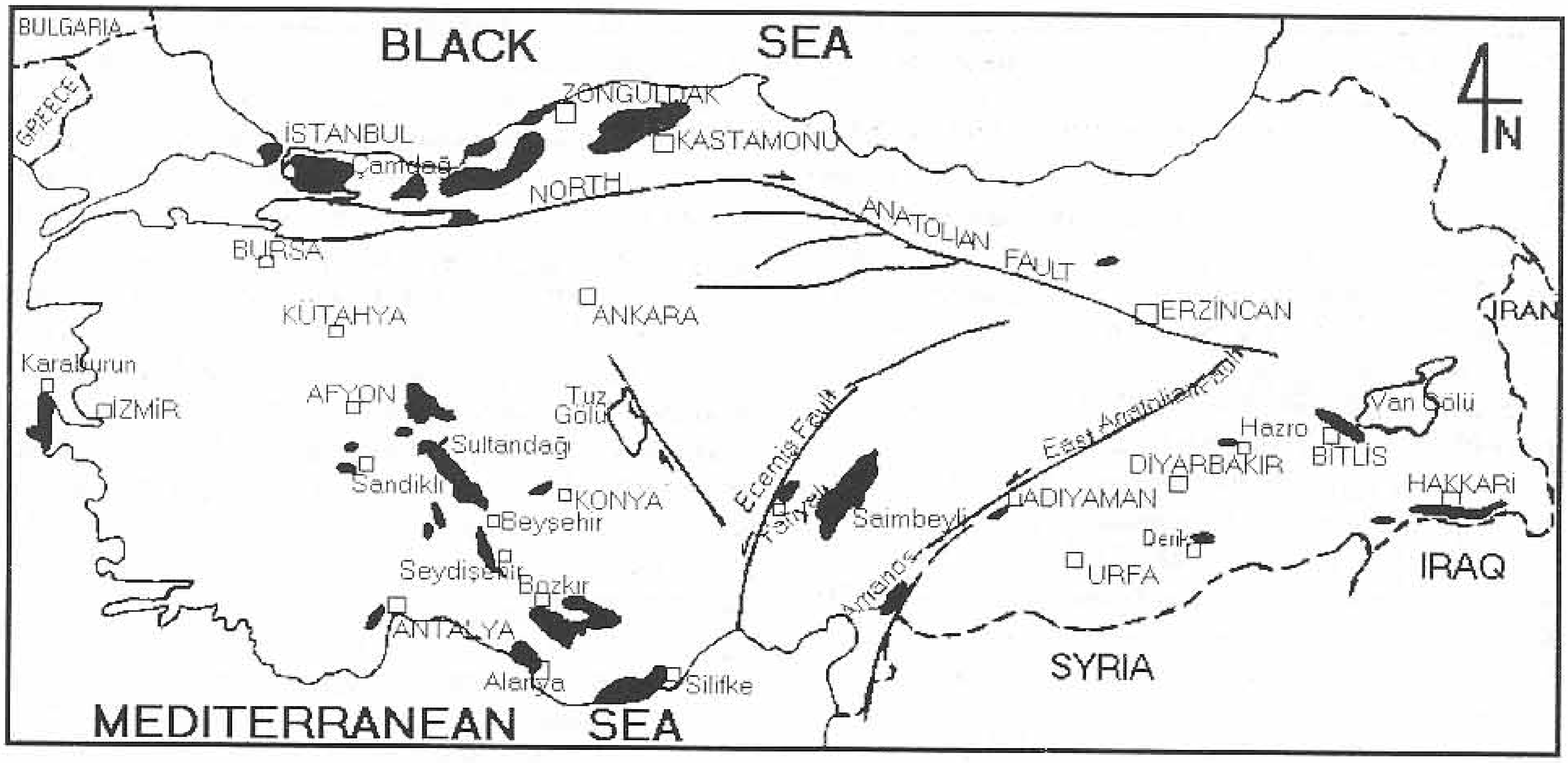

Figure 2. Areas of Lower Paleozoic rocks in Turkey.

Lower Paleozoic of the Tauride-Anatolide Composite Terrane

Tauride-Anatolide Composite Terrane represents the continental platform between the Neo-Tethyan İzmir-Ankara-Erzincan Ocean to the north and the southern branch of Neo-Tethys to the south. It comprises three groups of structural units. From north to south these are Kütahya-Bolkardağ Belt, representing the northern margin of the platform, Menderes subunit, representing the metamorphic central part and Tauride Belt (s.s.), a package of mainly non-metamorphic nappes.

Tauride Belt (s.s.): Taurides or the Tauride Belt is represented by an Infra-Cambrian basement and its non-metamorphic Paleozoic-Mesozoic cover made of mainly platformal sediments. The Late Cretaceous closure of the northern and southern branches of Neo-Tethys gave way to a double-verging napped structure, which consists of a number of tectono-stratigraphic units with distinctive stratigraphic and structural features characterizing different depositional environments of the platform. Based on Özgül's (1976) palinspastic restoration these units are arranged from north to south as: Bozkır Unit, Bolkar Dağı Unit, Aladağ Unit, Geyikdağı Unit, Antalya Unit and Alanya Unit.

Infra-Cambrian units

Limited outcrops of mildly metamorphosed Infra-Cambrian rocks are reported from the Bolkar Dağı and Geyikdağı units of the Taurides (Kozlu et al., 1995; Kozlu and Göncüoğlu, this volume). The relatively well studied areas are located in Sandıklı Area and Anamur-Silifke Region in Central Taurides and Saimbeyli-Feke Area in Eastern Taurides (Figure 2).

The Infra-Cambrian sequences in the Eastern Taurides (Emirgazi formation) consist of members. The lowermost member is characterized by an alternation of red-green-gray colored arkoses and shales that is very probably deposited in a periodically subsiding shallow-marine environment. Upwards follow the middle member with varicolored stromatolitic and cherty limestones interlayered with sandstones and shales. The depositional environment is interpreted as sabkha deposits. The lower and middle intervals of the unit contain basic-intermediate volcanics and highly altered tuffites. Where the volcanics dominate they are generally accompanied by bands and lenses of brecciated quartz-conglomerates and black shales. Depositonal features such as ripple marks and lamination, and large scale cross bedding in the upper member indicates to a shallow marine depositional environment. Emirgazi formation in the Eastern Taurides is disconformably covered by Cambrian quartzites and nodular limestones.

In Sandıklı area (Figure 2) highly sheared and mylonitized porphyroids unconformably covered by Early Middle Cambrian clastics and limestones yielded xenocryst single zircon ages about 550 Ma suggesting the presence of a Late Pan-African igneous activity (Kröner and Şengör, 1990) in the basement rocks of the Taurides.

Cambrian units

Stratigraphy and faunas of the Cambrian formations (Hüdai/Feke and Çal Tepe formations) in the Tauride

Bcit has been recently reviewed by Dean et al. (1991) and Dean and Özgül (1994). The lower interval of the Cambrian (Hüdai formation in the Central Taurides and Feke quartzites in the eastern Taurides) consists of a thick sequence of cross-bedded quartz-arenites, which are interpreted as beach deposits. It is transgressively overlain by the Çal Tepe formation. At its type-locality in Seydişehir area (Figure 2) the Çal Tepe formation is subdivided from bottom to top into: the dolomite member, black limestone member, lightgray limestone member and red nodular limestone member. Reliable ages are mainly obtained from the last member indicating to middle Lower Cambrian to Late Middle Cambrian. Dean et al. (1991) consider the dolomites at the lower interval of the succession as the first Paleozoic transgression onto the Gondwanean Platform. The nodular limestones at the top, on the other hand, mark the sudden change from platformal to deep marine conditions indicating the presence of a deepening basin to the north of the platform.

A very thick siliciclastic unit, known as Seydişehir formation succeeds the Çal Tepe carbonates. Its age is middle Middle Cambrian to Late? Arenig. Dean et al. (1991) indicates that the unit comprises a monotonous succession of quartzites and alternating micaceous shales. Late Middle Cambrian siliciclastics are mainly restricted to the north whereas bands and lenses of nodular limestones were described in the south. Late Cambrian strata are generally absent or greatly reduced in thickness. The only locality where Late Cambrian is well developed is the Sultandağ area (Figure 2). In most of the tectonic slivers in this area, in the lower interval of the Seydişehir formation silty shales and quartzitic sandstones alternate with rare bands of pink nodular limestone that contain middle Late Cambrian trilobites and acritarchs.

Dean et al. (1991) emphasize that the Late Cambrian-Early Ordovician contact is not precisely known, but the space available for the latest Cambrian strata is very limited. They suggest a combination of a general regression with weak topographic differentiation at the end of Cambrian in this part of NW Gondwana.

Ordovician units

The main body of the Seydişehir formation in the Central Taurides is represented by Tremadoc shales and siltstones with alternating quartzites and rare nodular limestones. In southern Turkey the unit was dated by trilobites, graptolites and acritarchs (Dean et al., 1991). The uppermost interval of the Ordovician units (Sobova formation) in Sobova Valley to the south of Beyşehir consists of pink and gray limestones with ecinoderm fragments followed by reefal limestones with trilobites and gray shales with acritarchs. Trilobites and associated conodonts indicate Upper Arenig age (Dean and Monod, 1985). Arenig deposits are interpreted as deep-water siliciclastic deposition in a northfacing basin.

The monotonous deposition within the Seydişehir formation indicates that no important changes in the depositional environment between Late Cambrian and Lower Ordovician units had been generated. Towards the end of Lower Ordovician the reefal limestones in the Sobova formation may, however, suggest a shallowing upward sequence at the end of Arenig.

A widespread hiatus separates the Early Ordovician from Late Ordovician in the Central Taurides.

Upper Ordovician is only described from Silifke-Işıklar area in the Central Taurides (Figure 2), where a succession of coarse-grained sandstones, siltstones and silty shales (Şort Tepe formation) unconformably overlie the Seydişehir formation. Dean et al. (1991) reported poorly preserved acritarchs and sporomorphs of Caradoc-Ashgill age from this unit.

Both in the northern and southern areas the Ordovician units are unconformably overlain by Lower Silurian coarse clastics.

The stratigraphic hiatuses, unconformities and irregular distribution of the Ordovician units in the Tauride Subunit may be ascribed to glacioeustatic sea level changes of the Late Ordovician in the NW Gondwana-margin.

Silurian units

Well-dated Silurian rocks were described only from a few localities in the Tauride Subunit and are in general restricted to the southern part of the Taurides. Lower Silurian, wherever described, unconformably overlies Seydişehir formation. In the Silifke area (Figure 2) it starts with red colored, cross-bedded conglomerates and coarse-grained sandstones. The coarse-grained lower interval contains well-rounded granitic and metamorphic pebbles indicating to a source area made up of crystalline basement rocks. The clastic-dominated lower member grade upward into a gray shale-sandstone interbedding, followed by laminated Graptolite-bearing black shales with rare Orthoceras-bearing limestone interlayers. The upper interval of the unit comprises bioturbated shales alternating with siltstones (Gül, 1995). From the black shales in the upper interval of the unit in Silifke area Dean et al. (1991) report ages that range from Llandovery to Wenlock, based on graptolites and acritarchs.

In the Antalya nappes at the Isparta Angle, Şenel et al. (1992) described two further occurrences, which differ from the former locality by the presence of dolomites. Based on conodont findings (Göncüoğlu and Kozur, in prep.) a Lower Silurian age has been assigned to these occurrences.

In the Eastern Taurides in Saimbeyli area (Figure 2) the Silurian sequence also begins with coarse-grained clastics and contains Lower Silurian graptolites (Özgül et al., 1973) and Lower and Middle Silurian conodonts in its shale-dominated upper interval (Göncüoğlu and Kozur, in prep.). The lower interval unconformably overlying an erosional surface is represented by coastal deposits. The overlying black shales with graptolites and Orthoceras limestones indicate a deepening of the basin and reducing conditions. The upper interval of the sequence is characterized by features resembling distal tempestites of the foreshore region.

During the November 1995 field-excursion the members of the IGCP Project 351 identified in Silifke area fine grained, laminated mudstones and siltstones with dropstones in the gray shale-sandstone interbedded interval, that follow the coarse-grained basal clastics. The presence of diamictites in this interval very probably indicates that the lower interval of the Silurian sequence also includes Hirnantian.

Late Silurian rocks are described from the Antalya Nappes (Şenel et al., 1992), Silifke area (Demirtaşlı, 1984) and Eastern Taurides (Özgül et al., 1973). In these localities Late Silurian-Early Devonian deposits conformably cover the Early and/or Middle Silurian strata and are mainly represented by an alternation of black limestone and shale, grading into clastics and platform carbonates of Lower Devonian age.

Late Silurian deep-water fauna is further described from Karaburun area (Figure 2) to the west of Menderes Massif (Kaya and Kozur, in print) and from the northern Tauride nappes in Konya area (Özcan et al., 1987). This data indicates that the Taurides were still facing to a deep (oceanic?) basin (Rheic Ocean) to the north of the Tauride Subunit.

It is not clear whether the irregular distribution of the Silurian in the southern Tauride Unit is related to the presence of smaller basins separated by highs or by an uplifting in the internal areas represented by shallowing upward sequences at the end of Silurian.

Post-Lower Paleozoic units

A widely distributed shelf-type carbonate deposition dominated in the Tauride Unit, which started in Lower Devonian and rested until the end of Upper Devonian. Further development of the NW-Gondwanean realm is irrelevant to this presentation and will be discussed in a separate paper (Göncüoğlu, in prep.).

Lower Paleozoic rocks in further subunits of the Tauride-Anatolide Composite Terrane are mainly found in the Kütahya-Bolkardağ to the South of Afyon (Figure 2), Central Anatolian and Menderes Subunits. The scarcity of detailed biostratigraphical work as well as post-Lower Paleozoic (?Late Paleozoic and alpine) metamorphism that widely erased the fossil record prevents a reliable interpretation of the Lower Paleozoic assemblages in these subunits. However, it should be noted that especially in the less-metamorphic successions of the Kütahya-Bolkardağ Belt, very similar sequences to the Tauride Subunits are represented.

Lower Paleozoic of the SE Anatolian Autochthonous Terrane

Southeastern Anatolia is located in the northern periphery of the Arabian Platform, so that the depositional features of the Pre-Cambrian-Lower Paleozoic sedimentary units of this area play an important role to understand the geological evolution of the northwestern margin of Gondwanaland.

Lower Paleozoic units of SE Anatolia have been studied relatively well and reviewed recently (Dean et al., 1981; Bozdoğan et al., 1996; Bozdoğan and Ertuğ, this volume), so that in this paper only a brief summary will be given and the paleogeographic framework will be emphasized.

Infra-Cambrian units

The lowermost unit (Telbesmi formation) in SE Anatolia consists of submarine lavas and pyroclastics of intermediate composition, which alternate with red epiclastics and shales of presumably Infra-Cambrian age.

The outcrops of the Telbesmi formation are mainly described from the Derik type-area in the Mardin-Kahta High (Figure 2). This unit comprises red-green colored volcanics, agglomerates and tuffs, including pillow-lavas of andesitic-spilitic composition, alternating with shales and sandstones. The volcanics and volcaniclastics reach up to 350m in thickness and are highly altered. The red-green sandstone and mudstone interlayers are 2-30m thick. The amount of volcaniclastic and sedimentary rocks gradually increase towards the top of the formation.

The rock-units in Amanos (Eğribucak) and Adıyaman (Meryemuşağı and Kaplandere areas) regions (Figure 2) slightly differ from those in the Derik Region where volcanics are missing and an alternation of green-dark gray volcanogenic sandstones and shales dominates. The sandstones are thin-medium bedded, rich in mica and silica cemented. Transitions to pure quartzites and a well-developed slaty cleavage in the shales are common features.

In Derik region (Figure 2) Telbesmi formation is represented by intracontinental sediments related to alluvial fan and fluviatile depositional environments. The presence of some coastal sediments and pillow-lavas indicate to a contemporaneous shallow-marine deposition. In Adıyaman and Amanos regions, however, Telbesmi formation is deposited completely in intracratonic shallow-marine conditions.

This lowermost interval of the succession interpreted as the product of a Late Pan-African arc-related volcanic event that is confirmed by radiometric age data (Kröner and Şengör, 1990; Loss and Reischmann, 1995).

Cambrian units

The Derik Group starts with Lower Cambrian deposits (Sadan formation) which are characterized by continental clastics, grading into Middle Cambrian shelf-type carbonates (Koruk formation) and Middle-Upper Cambrian shallow marine clastics (Sosink formation).

The lowermost formation is composed predominantly of sandstones alternating with gray-red colored sandy limestones and shales (Ketin, 1966).

In Derik type-area Sadan formation starts with 30-40m thick basal conglomerates unconformably covering the Telbesmi formation, which are followed by an interval consisting of sandstone, sandy limestone, shale and siltstone alternations. At the top, the unit is represented by coarse grained and hummocky-type cross-bedded sandstones with quartz conglomerates.

The deposition of the basal part is characterized by a shallow-marine transgression, transitional to coastal tidal-flat deposits of the middle part. The upper part of the sequence is interpreted as the regressive product of an eolian environment. In the type area no fossils were found. The entire data is from limestone interlayers in the Hakkari region, where Dean et al. (1981) noted Archaeocyathus fragments of Lower Cambrian age.

The limestone-dominated Koruk formation is a key-unit in SE Anatolia, because of its homogenous distribution and diachronous nature. The lower interval of the formation is composed of gray, thin-medium bedded sandy-clayey dolomites, followed by a middle part of thick-bedded dolomites with chert nodules. The upper interval consists of a 20-30m thick interval represented by greenish-reddish nodular limestones.

The rock-units of this formation is interpreted as products of a marine transgression and a stable platform deposition, reaching up to 150-200m in thickness. The limestones in the upper part of the sequence are rich in trilobites, brachiopods and acritarchs, yielding a Middle Cambrian age (Dean et al., 1981; Bozdoğan, 1982).

A diachronous younging towards east suggests that the transgression during Middle Cambrian was from west to east.

The Sosink formation starts at its base with an interlayering of nodular limestone and shale and continue with alternating shale, siltstone and sandstone. Towards the top the proportion of sandstones progressively increases.

The micacous sandstones are greenish-gray colored, thin-medium bedded, and silica-cemented. They display ripple-marks and cross-ripple lamination. The basal pink-greenish colored nodular limestones, alternating with reddish-greenish shales are rich in trilobites, brachiopods and crinoids. It is implied that the deposition has started in a slowly deepening environment followed by basinal deposition. The upper part of the sequence, however, is turbiditic and interpreted as the product of a regressive delta complex (Bozdoğan et al., 1996).

Detailed paleontological studies (Bozdoğan, 1982 and the references herein) indicate a Middle Cambrian age. In Hakkari region (Figure 2), where Upper Cambrian fossils are reported, the carbonate deposition is dominating.

Ordovician units

The Ordovician deposition in the central SE Anatolia is mainly controlled by the Mardin-Kahta High, which changed the paleogeographic distribution in the study area. The Lower Ordovician sandstones and shales (Seydişehir formation), dominating in the eastern and western parts, unconformably cover the Derik Group. Middle to Upper Ordovician marine clastics (Bedinan formation) conformably overlying Seydişehir formation, however, is not represented in the Mardin-Kahta High.

The Seydişehir formation contains in its lower interval green-gray shales and siltstones interlayered with quartz-arenites. The upper interval is represented by an alternation of quartz-sandstones with ripple-marks and worm-tubes and thin-bedded dark shales.

The deposition has started in shallow-marine and continued in deep-marine environment. In Mardin-Kahta High the formation is not represented. In Amanos and Hakkari areas, the formation conformably overlies the Sosink formation. In the Urfa region the subsurface data indicate to a reduction of the thickness. It is assumed that the variations in the thickness are mainly controlled by erosion and paleotopography.

Fossil data from the surface and subsurface evidences a Tremadoc-Arenig depositional age for the formation.

The distribution and deposition of the Bedinan formation are mainly controlled by the Mardin-Kahta High. It is mainly composed of alternating dark shales and siltstones in the lower interval, sandstones and shales with local submarine lavas in the middle and upper intervals. In Amanos region Dean and Monod (1985) infer that the lowermost layers of the Bedinan formation, conformably overlying the Arenig strata of Seydişehir formation is Karadoc in age, which would indicate to a non-depositional period during Middle Ordovician. The subsurface data from the central SE Anatolia (Urfa region) however, contrasts with this suggestion. In Hakkari region Seydişehir formation is unconformably covered by the Bedinan formation that starts with Ashgil. These differences in the depositional age together with the variations in the thickness are very probably related to the uneven paleotopography during Middle-Upper Ordovician (Bozdoğan et al., 1996).

The topmost interval of the formation in Amanos area constitutes poorly sorted conglomerates with siltstone and mudstone interlayers. This interval is implied as glacial deposits.

It is suggested that the deposition has started during Middle to Late Ordovician with platform-type shallow-marine conditions which is followed by regres-

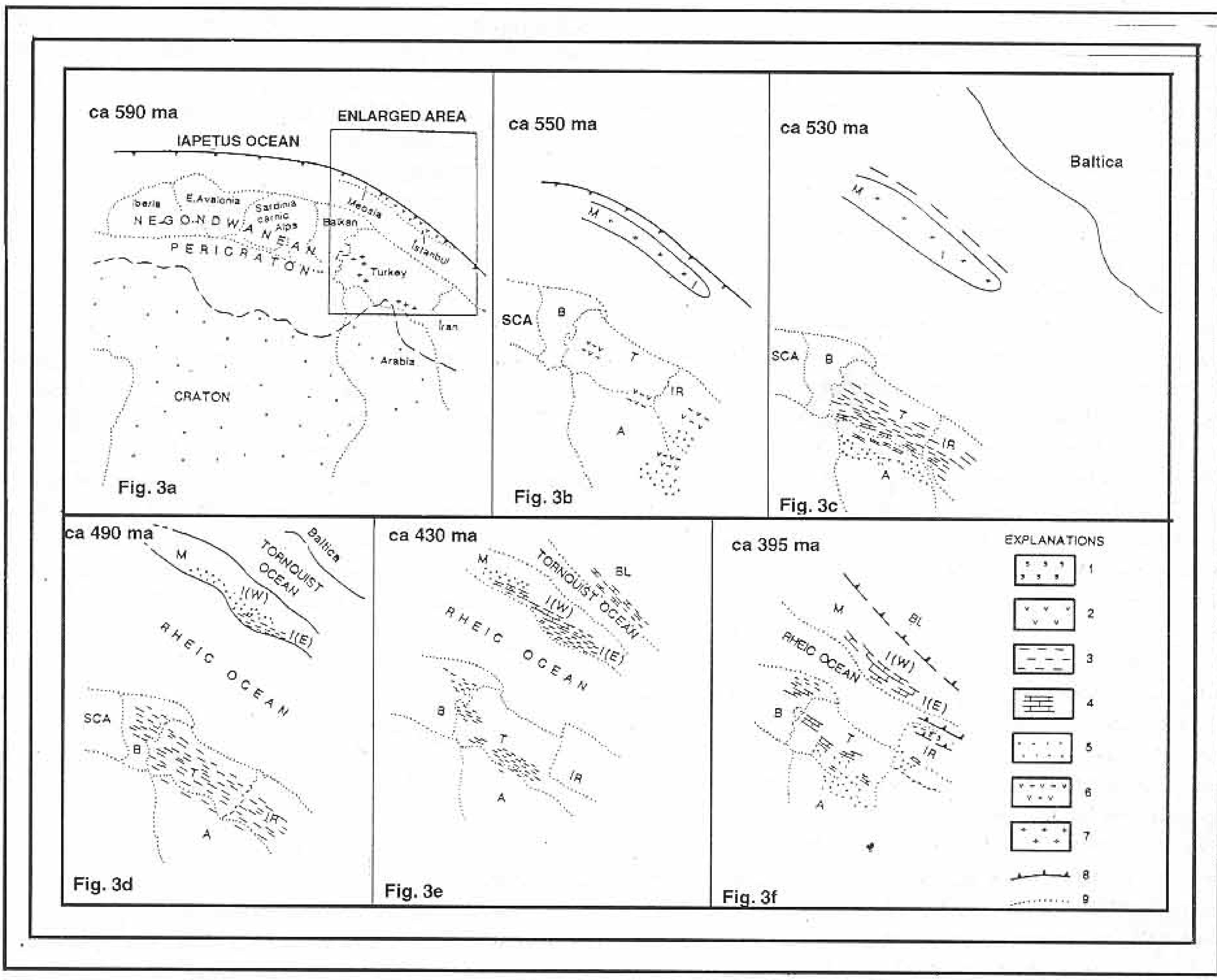

Figure 3. Palinspastic paleogeography reconstruction of the Turkish terranes. A: Arabia, B: Balkan, Bl, Baltica (Laurasia), I: Istanbul (IW: Western Istanbul, IE: Eastern Istanbul), IR: Iran, M: Moesian, SCA: Southeast European Terranes. Explanations: 1- oceanic crust, 2- Island arc magmatics, 3- deep marine siliciclastics, 4-carbonates, 5- continental sediments, 6- rift volcanics and sediments, 7- arc magmatics, 8- subduction, 9- boundaries.

sive sequences representing deltaic environments. The upper part of the unit is again characterized by shallow-marine deposits.

Silurian units

A regional depositional break during Early Silurian is followed by the Late Silurian-Late Devonian deposition (Diyarbakır Group) which is restricted to the central part of SE Anatolia. Lower Silurian-Lower Devonian dark shales (Dadas formation) of restricted marine environment are followed by tidal-dominated clastics of Lower Devonian (Hazro formation) and the deposition is terminated with Middle-?Upper Devonian evaporite bearing dolomites and shales (Kayayolu formation) representing a regressive (fluvial) cycle.

In the periphery of the SE Anatolian platform, however, the Ordovician clastics are unconformably overlain by coastal to shallow marine sediments of Upper Devonian-Lower Carboniferous age (Zap Group).

PALEOGEOGRAPHIC CONSTRAINTS

The geodynamic evolution of NW Gondwana in the Mediterranean area mainly involves rifting and accretion of continental microplates to one of the neighboring macroplates. This event has been repeated several times during the geological history. In the Anatolian realm at least three orogenic events (Late Paleozoic, Early Mesozoic and Late Mesozoic events) have greatly obliterated the original signatures of the main pre-Late Paleozoic geodynamic evolution. The information on which our reconstructions (Figure 3) are based is generally derived from "composite terranes" including fragmentary data.

The paucity of detailed studies on Lower Paleozoic paleomagnetism, litho- and biostratigraphy and biogeography are a further complication for the paleogeographic reconstructions in the Turkish area. So that it should be noted that our introductory palinspastic reconstruction is highly hypothetical.

Outcrops of Pre-Cambrian units occur only in the basement of the İstanbul terrane and very probably in some alpine and post-alpine exhumated metamorphic cores such as Menderes-Central Anatolian and Bitlis subterranes. It is obvious that the tectonic setting of the İstanbul terrane in the North greatly differs from the southern areas. A possible Pre-Cambrian geodynamic scenario is proposed in Göncüoğlu and Turhan (this volume) that involves a southern zone (Taurides, SE Anatolian-Arabian, and Central Iranian terranes) and a northern zone (Carpato-Balkan, İstanbul and Main Range terranes) representing remnants of a Pre-Cambrian orogenic collage with oceanic, arc-type and continental elements (Figure 3a).

Infra-Cambrian-Early Cambrian sequences in Turkey were described only from the Tauride and SE Anatolian terranes. During this period extensive volcanism and very similar successions of continental deposition dominate the NW Gondwanean pericratonic margin. In the relatively eastern part of this margin in Turkey as well as in Iran, Oman and Pakistan the Infra-Cambrian-Early Cambrian period can be ascribed to the formation of Red Sea-type rifting on the Pan-African consolidated basement by back-arc extension or transtension.

In the north, in the basement of the İstanbul terrane only granitoids intruding an ophiolitic assemblage have been reported (Göncüoğlu et al., in print). Lack of radiometric age data prevents a reliable reconstruction. However, we correlated this magmatic event with the evolution of SE European areas (Haydoutov, 1989). We have suggested that the Late Pre-Cambrian-Early Cambrian period is represented by intra-oceanic subduction and formation of an ensimatic arc (Göncüoğlu and Sassi, 1993) in the İstanbul terrane (Figure 3b). This assumption further indicates that İstanbul terrane was attached to the SE European-Balkan terranes and not to the Baltic terrane as supposed by Pickering and Smith (1995).

Late Lower Cambrian-Upper Cambrian period is designated by a regional transgression. Dean et al. (1991) emphasize the diachronous younging of platform-deep marine carbonates towards southeast suggesting a rapid subsidence in the area to the northwest of Arabian-Tauride platform (Figure 3c). Trilobite fauna in the Taurus area indicates an affinity with the well-known Mediterranean biofacies (Shergold and Sduzy, 1984; Dean and Özgül, 1994; and the references herein). In İstanbul area in the north the only record of Cambrian strata (Arpat et al., 1978) has not been confirmed by recent investigations (Dean et al., 1995 and this volume).

Latest Cambrian sea-level fall and the unconformity in this level in the Middle East (Fortey, 1984) are supported by Dean et al. (1991)'s suggestions for the northern Taurides.

Early Ordovician in the Taurus area is characterized by a monotonous deposition similar to that of Late Cambrian. Towards the end of Early Ordovician shallowing upward sequences noticed in the southern Taurus area.

In SE Anatolia the Early Ordovician deposition is mainly controlled by the formation of Mardin-Kahta High, which extends towards south to the Dar-ez-Zor High.

A prevalent hiatus separates the Early Ordovician from Late Ordovician in the Central Taurides. Middle-Late Ordovician successions with patchy distribution unconformably overlying earlier strata are reported from the southernmost Taurides and SE Anatolia. The stratigraphic hiatuses, unconformities and irregular distribution of the Ordovician units in the Taurides and SE Anatolia may be ascribed to glacio-eustatic sea-level changes of the Late Ordovician in the NW Gondwana-margin (Figure 3d, e).

The coarse-grained, basement derived conglomerates and glacio-marine sediments attached to the bottom of Lower Silurian sequence in Silifke area, together with the poorly sorted conglomerates with siltstone and mudstone interlayers in topmost Seydişehir formation in Amanos area (Bozdoğan et al, 1996) are clear indications of latest Ordovician glaciation in the Turkish area.

Rifting of further microcontinents (e.g., Iranian microcontinent; Stampfli et al., 1991 or East-Avalonian microcontinent; Paris and Robardet, 1990) from the southern zone and the opening of the Rheic basin farther north that developed to an oceanic basin later in Silurian may have further complicated the overall picture.

In the northern zone, in İstanbul terrane, Lower Ordovician siltstones and quartzites mark the beginning of the transgression on a peneplained crystalline basement. The succeeding dark shales with Arenig-Llanvirn trilobites of Welsh affinity (Dean et al., 1995 and this volume) may indicate that İstanbul Terrane was in a closer position to the East-Avalonian microplate than the Tauride-Arabian plate, which in turn suggests the presence of an intervening deep basin between the northern and southern terranes.

Lower Silurian period in the Tauride unit is characterized by a transgression on the Early Ordovician, represented by clastics followed successively by the development of graptolitic black shales. Local volcanic activity is recorded in the southwestern and eastern Taurides.

In SE Anatolia, Lower Silurian is a period of nondeposition or erosion.

In İstanbul Terrane Lower Silurian strata rest on Late-Middle Ordovician and are characterized by graptolitic black shales indicating to deep-marine deposition. The Lower Silurian sequence in İstanbul area is the first unit that lithologically correlates to the southern zone (Figure 3e). Detailed work on biogeography is missing, so that a reliable faunal correlation with the southern zone is not possible.

Upper Silurian-Lower Devonian period is characterized by a well-established regression characterized by shallowing upward sequences and a transition from slope-deep platform to restricted shelf deposition both in the Taurides and SE Anatolia.

In the eastern İstanbul Terrane, the black shale unit of Wenlock age is unconformably overlain by Lower Devonian carbonates, whereas formation of local N-S trending highs were reported from the western part. Considering that İstanbul terrane was attached to the northerly located microcontinents; the facial differences, formation of ridges and the unconformity mentioned above may be related to the buffered effects of the closure of the Ligerian Ocean (Pickering and Smith, 1995) between the Baltica and E Avalonia (Laurussia). An alternative suggestion may be the closure of the Tornquist Ocean and the gentle docking of the Iberian-South European-Balkan Terranes to Laurussia (Figure 3f).

The effect of this closure may also be suspected in the Taurus and SE Anatolian terranes where a regional uplifting and an important unconformity are noticed at the Late Silurian-Early Devonian transition.

During the Lower Devonian an extensive platform carbonate deposition is observed in both the Tauride-SE Anatolian and İstanbul areas. Faunal affinities of this period between the northern and southern areas have not yet been studied in detail. Consequently, it is not clear, whether the intervening deep basin between the northern and southern terranes was totally eliminated or remained as a narrow basin that closed later during the Hercynian orogeny. The absence of Lower Devonian deep-marine sediments can be used as a parameter for the former suggestion. The lack of an intense deformation, the non-existence of accreted or overthrusted oceanic materials, etc., on the other hand argue for the latter. The augmenting carbonate deposition suggests that both the southern and northern zones were located in similar lower latitudes. This is a further indication for the narrowing of the intervening basin

The post-Devonian history of the Anatolian part of NW Gondwana will be the topic of an other paper and hence is irrelevant for this discussion.

CONCLUDING REMARKS

Repeated rifting and re-assemblage of continental microplates during the geological history of the Anatolian realm have greatly obliterated the original signatures of the Early Paleozoic geodynamic events. The lack of detailed paleomagnetic, litho- and biostratigraphic and biogeographic studies on Lower Paleozoic rocks in this area are a further dilemma for the paleogeographic reconstructions.

Even if our reconstructions are based on fragmentary data derived from "composite terranes" and the palinspastic reconstruction is highly hypothetical they may give a first insight into the paleogeography of the study area and constitute an assumption for further discussions.

The distribution of the Pre-Cambrian rock-units suggests a northern zone (Carpato-Balkan, İstanbul and Main Range terranes) and a southern zone (Taurides, SE Anatolian-Arabian, and Central Iranian terranes) representing remnants of a Pre-Cambrian orogenic assemblage with oceanic, arc-type and continental elements. They were very probably formed during the early southward subduction of the Eastern Iapetus Ocean.

During the Infra-Cambrian-Early Cambrian time in the southern zone the Pan-African consolidated NW Gondwanean pericratonic margin was rifted by back-arc extension or transtension. Whereas in the northern zone the intra-oceanic subduction and formation of an ensimatic arc (Göncüoğlu and Sassi, 1993) lasted until ?Late Cambrian.

Late Lower Cambrian-Upper Cambrian period in the southern zone is designated by a regional transgression from northeast suggesting a rapid subsidence in the area to the northwest of Arabian-Tauride platform and hence opening of a relatively deep basin in the North.

Early Ordovician in the southern zone is characterized by a monotonous deposition. Towards the end of Early Ordovician shallowing upward sequences and formation of NW-SE trending highs were noticed. The stratigraphic hiatuses, unconformities and irregular distribution of the Ordovician units in the southern zone may be ascribed to glacio-eustatic sea-level changes of the Late Ordovician in the NW Gondwana-margin that may be further complicated by rifting of additional microplates from the pericratonic NW Gondwanean margin. In the northern zone during the Early Ordovician the peneplained island-arc was subsided, transgressed from south and covered by deep marine sediments.

The Lower Silurian deepening in both zones is very probably related to the relatively rapid global sea-level change, which is reported from different parts of NW Gondwana (McKerrow and Scoetese, 1990).

The regression in the Taurides and SE Anatolia and the unconformity in the northern zone at the Upper Silurian-Lower Devonian transition is very probably related to the closure of the Tornquist Ocean (Pickering and Smith, 1995) between the Baltica and E Avalonia (Laurussia) or alternatively the closure of the Ligerian Ocean and the accretion of the Iberian-South European-Balkan Terranes to the Laurussia.

During this event the Rheic basin has probably narrowed, but remained open until the Early Carboniferous when it closed by southward subduction. This narrowing is further demonstrated by deposition of similar carbonates in the northern and southern zones.

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