

EL PALEOZOICO INFERIOR EN EL NOROESTE DEL GONDWANA

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LOWER PALEOZOIC STRATIGRAPHY OF SOUTHEASTERN TURKEY

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ABSTRACT

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

The lowermost unit (Telbesmi Fm.) in SE Anatolia consists of submarine lavas and pyroclastics of intermediate composition, which alternate with red epiclastics and shales of presumably Precambrian age. This lowermost sequence is interpreted as the product of a Late Pan-African arc-related volcanic event. The Derik Group starts with Lower Cambrian deposits (Sadan Fm.) which are characterized by continental clastics, grading into Middle Cambrian shelf-type carbonates (Koruk Fm.) and Middle-Upper Cambrian shallow marine clastics (Sosink Fm.).

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 (Seydisehir Fm.), dominating in the eastern and western parts, unconformably cover the Derik Group. Middle to Upper Ordovician marine clastics (Bedinan Fm.) conformably overlying Seydisehir Fm., however, is not represented in the Mardin-Kahta High.

A regional depositional break during Early Silurian is followed by the Late Silurian-Late Devonian deposition (Diyarbakir Group) which is restricted to the central part of SE Anatolia. Lower Silurian-Lower Devonian dark shales (Dadas Fm.) 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 Fm.) 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).

The lithostratigraphic features of the Lower Paleozoic sequences in SE Anatolia suggest that the deposition in the northwestern margin of Gondwanaland is mainly controlled by the formation of intracratonic basins which may probably be related to the periodic crustal extension.

INTRODUCTION

Turkey is located in an area where several continental fragments with different geological histories were accreted during the multiple rifting and collision events between Gondwana and Laurasia. SE Anatolian Zone is one of these continental units which constitutes the northern part of the Arabian Plate and had a passive margin setting throughout the Paleozoic and Lower Triassic. The Triassic rifting, related to the opening of the alpine Neotethyan Oceans to the north of this zone caused the separation of some continental microplates from the main Gondwanaen realm. The Late Cretaceous closure of these branches and the Miocene (Fig. 1) compression has resulted in an imbricated structure where the Paleozoic sequences constituting the northernmost edge of the Gondwanaen margin occur only as allochthonous, discontinuous and partly metamorphosed tectono-stratigraphical units. So that the most complete Lower Paleozoic sequences which may reflect the geological evolution of the northern Gondwanaen margin can be adequately well studied only in SE Anatolia.

In this study we will describe the stratigraphy and the depositional features of the Lower Paleozoic units in SE Anatolia in a way that they may be used for interregional correlation within the ambit of IGCP Project No 351.

This descriptive paper is mainly based on the long lasting investigations of the Turkish Petroleum Corp., including published papers as well as unpublished open-file reports (Ketin, 1966; Tuna, 1973; Sungurlu, 1974; Bozdogan and Erkmen, 1980; Dean *et al.*, 1981; Bozdogan, 1982, 1991; Günay, 1984; Bayçelebi *et al.*, 1984; Dean and Monod, 1985, 1990; Köylüoğlu and Erten, 1985; Bozdogan *et al.*, 1986; Perincek, 1990; Perincek *et al.*, 1991) on subsurface and surface geology, biostratigraphy and sedimentology of the region.

STRATIGRAPHY

Based on chrono-stratigraphic successions and paleogeographic distributions for the Lower Paleozoic era, six distinct litho-stratigraphic units have been differentiated in SE Anatolia: Telbesmi Formation (Precambrian), Derik Group (Cambrian), Habur Group (Ordovician), Diyarbakir Group (Silurian-Devonian) and Zap Group (Lower Carboniferous - Upper Devonian).

Telbesmi Formation

The outcrops of the Telbesmi Formation are mainly described from the Derik type-area in the Mardin-Kahta High. 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 volcanoclastics reach up to 350m in thickness and are highly altered. The red-green sandstone and mudstone interlayers are 2-30m thick. The amount of volcanoclastic and sedimentary rocks gradually increase towards the top of the formation.

The rock-units in Amanos (Egribucak) and Adiyaman (Meryemusagi and Kaplandere areas) region slightly differ from those in the Derik Region (Fig.2), where volcanics are missing and an alternation of green-dark gray volcanogenic sandstones and shales dominate. 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.

The basement of the unit is not observed and hence the real thickness is not known. In Derik type-locality the measured thickness is about 2-450m.

Telbesmi Formation is overlain with an angular unconformity by the Sadan Formation, the lowermost unit of the Derik Group.

In Derik region Telbesmi Formation is represented by intracratonic sediments related to alluvial fan and fluvialite depositional environments. The presence of some coastal sediments and pillow-lavas indicate to a contemporal shallow-marine deposition. In Adiyaman and Amanos regions, however, Telbesmi Formation is deposited completely in intracratonic shallow-marine conditions.

Although no radiometric data is available and only some primitive acritarchs have been reported, a Precambrian age has been mostly accepted according to the stratigraphic position of this formation.

Derik Group

Derik Group consists of Sadan, Koruk and Sosink Formations. Biostratigraphic data indicate that all these lithostratigraphical units are Cambrian in age.

Sadan Formation

This lowermost unit of the Derik Group is composed predominantly of sandstones alternating with gray-red colored sandy limestones and shales. The most typical outcrops are in Amanos Mountains (Egribucak area). Adiyaman, Mardin (Derik area) and Hakkari regions.

In Derik type-area Sadan Formation starts with 30-40m thick basal conglomerates unconformably covering the Telbesmi Formation, which are followed by a sequence 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.

Although the subsurface data is limited, it is assumed that Sadan Formation has completely covered SE Anatolia. The maximum thickness (535m) is measured in Derik region, where the unit is progressively overlain by the carbonates of Koruk Formation.

The shales, sandy limestones and siltstones of the type area contain no fossil evidence. The only datum is from similar limestone intercalations in the Hakkari region, where Dean *et al.* (1981) reported a single locality yielding *Archaeocyathus* fragments of Lower Cambrian age.

Koruk Formation

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

The rock-units of this formation are 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; Bozdogan, 1982).

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

Sosink Formation

This uppermost unit of the Derik Group starts at its base with an alternation of nodular limestone and shale and continues with alternations of shale, siltstone and sandstone. Towards the top the proportion of sandstones progressively increase. The thickness of the unit is reduced to 270-1050m due to ?Latest Cambrian erosion.

The sandstones are greenish-gray colored, thin-medium bedded, mica-rich and silica-cemented exhibiting 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. Sosink Formation is conformable with the underlying Koruk Formation. It is assumed that the deposition has started in a slowly deepening environment and transitioned to basinal conditions. The upper part of the sequence, however, is turbiditic and interpreted as the product of a regressive delta complex (Bozdogan, 1982).

From the biostratigraphic point of view, Sosink Formation is relatively well-studied. Detailed trilobite and acritarch studies (Bozdogan and Erkmén, 1980; Dean *et al.*, 1981; Bozdogan, 1982) indicate that the depositional age of the unit is Middle Cambrian. In Hakkari region, where Upper Cambrian fossils are reported, the carbonate deposition is more accentuated.

Habur Group

In SE Anatolia Lower Ordovician Seydisehir and Middle-Upper Ordovician Bedinan Formations are considered as a distinct group. Next to the Cambrian sediments of the Derik Group this unit is really the most extensive lithostratigraphic entity of the region.

Seydisehir Formation

This Formation mainly consists of green-gray colored shales and siltstones alternating with quartz-arenites, rich in trace fossils (Cruziana and Tigillites) in its basal and middle parts. The upper part of the sequence is represented by well-developed alternation of quartz-sandstones with ripple-marks, biogenetic traces such as worm-tubes and thin bedded, dark gray shales.

The deposition of this unit is suggested to start with shallow-marine conditions, and followed upwards by deep-marine sediments. The non-existence of Seydisehir Formation in Mardin-Kahta High is ascribed to the presence of an erosional period. In Amanos and Hakkari areas, where the unit is conformable with the underlying Sosink Formation, the thickness reaches up to 1000m. In the central SE Anatolia, in Urfa region, however, subsurface data show that the thickness is reduced to 167m. Towards the Mardin-Kahta High, the unit is transgressive on the Sosink Formation. This datum indicates that the variations in the thickness are controlled by the paleogeography and erosion, respectively. The upper contact of the Seydisehir Formation is conformable with the Bedinan Formation.

Fossil data from the surface as well as from the wells clearly show that the depositional age of the unit is Lower Ordovician (Tremadoc-Arenig).

Bedinan Formation

The distribution and deposition of this formation is controlled by the Mardin-Kahta High, to the north of which Bedinan Formation is not observed. This unit is mainly represented by an alternation of fossiliferous dark shales and siltstones in the lower part, sandstones and shales with local submarine lavas in the middle and upper parts. Bozdogan *et al.* (1994) subdivided the unit into four members.

In Amanos region Dean and Monod (1985) suggest that the lowermost layers of the Bedinan Formation, conformably overlying the Arenig strata of Seydisehir Formation is Caradoc in age, which would indicate to a non-depositional period during Middle Ordovician. The subsurface data from the central SE Anatolia (Urfa region, Bayçelebi *et al.*, 1984) however, contrast with this suggestion. In Hakkari region, in the east, Seydisehir Formation is unconformably covered by the Bedinan Formation which starts with Ashgîl. These differences in the depositional age together with the variations in the thickness (430-1600m) are very probably related to the uneven paleotopography during Middle-Upper Ordovician.

The uppermost part of the formation (Akcağag Member) in Amanos region consists of poorly sorted conglomerates interlayered with siltstone and mudstone which are interpreted as glacial deposits.

Bedinan Formation is unconformably overlain by the Upper Silurian-Upper Devonian sediments of the Diyarbakir Group.

Considering the general depositional features, it is suggested that the deposition has started with platform-type shallow-marine conditions which is followed by regressive sequences representing deltaic environments. The upper part of the unit is again characterized by shallow-marine deposits.

Biostratigraphical studies (Dean *et al.*, 1981; Bayçelebi *et al.*, 1984; Dean and Monod, 1984 and Bozdogan *et al.*, 1994) have shown that the depositional age of the unit is Middle to Late Ordovician.

Diyarbakir Group

The Upper Silurian to Upper Devonian deposits comprising Dadas, Hazro and Kayayolu Formations in the central part of SE Anatolia are known as the Diyarbakir Group.

Dadas Formation

This formation crops out in the Hazro Anticline and Korudag region. Data from the Diyarbakir area are mainly based on subsurface data. Dadas Formation in its basal parts consists of dark gray, mica-rich organic shales with interlayers of gray, pyrite bearing, chalky and sandy bioclastic limestones. The middle part of the sequence is represented by green-gray colored fossiliferous shales, rich in organic material, which contains bands and lenses of thin-bedded limestone and sandstone. The upper part constitutes of gray-green colored shales with phosphate nodules interlayered with limestones, dolomites and silty, glauconite-bearing sandstones, containing anhydrite nodules.

The depositional environment of the lower part is interpreted as low-energy type inner-shelf, followed by shallow-marine deposition representing the middle part which grades upwards into coastal type deposits of the upper part. The thickness of the unit varies from 140m in Hazro Anticline to 350m to the south of it in subsurface. The Dadas Formation is conformably overlain by the Hazro Formation.

Due to the rich fossil content Bozdoğan *et al.* (1988) and Fontaine *et al.* (1989) have suggested an Upper Silurian to Lower Devonian age for this unit.

Hazro Formation

Hazro Formation crops out at the Hazro Anticline and consists of three members. The lower clastic member is represented by white to gray colored, loosely cemented bar and channel-type quartz-arenites with shale and marl interlayers. It is followed by shales with bands and lenses of sandstones, siltstones and dolomites. The middle unit mainly consists of a sequence characterized by anhydrite bearing gray-beige dolomites which is considered as a marker horizon in SE Anatolia. The upper clastic member is composed of greenish to reddish shales with interlayers of stramatolitic dolomite and evaporites, representing a lagoonal or fluvial delta plain environment.

The sedimentological features of the formation indicate that the lower and middle parts were deposited in coastal, the upper part in deltaic conditions.

Hazro Formation has conformable and transitional contact with the overlying Kayayolu Formation.

The fossil content is quite limited in the lower and middle members. Bozdoğan *et al.* (1988) and Baseens and Schuurman (1990) reported sporomorphs and acritarchs of Lower to Middle Devonian age from the upper member.

Kayayolu Formation

The data on this unit are mainly based on the subsurface information from the Kayayolu oil field, where two members have been described. The lower member consists of clay dolomites with anhydrite nodules, interlayered with sandstones and shales. The upper member comprises light gray, quartz-rich, dolomite cemented sandstones and greenish-reddish sandy shales with interlayers of thin-bedded dolomites and dolomitic marls. Local horizons of white and very fine-grained sandstone are rich in glauconite.

The deposition of Kayayolu Formation started in supra and inter-tidal conditions and continued in a restricted shallow lagoon or flood tidal delta-plain subenvironment.

The subareal distribution of this formation is only limited to Diyarbakir region, indicating to an intensive erosion which also controls the variations in thickness.

Based on palynological studies Bozdoğan *et al.* (1988) have suggested a Middle to early Upper Devonian age for this unit.

Zap Group

The formations of this group comprising Upper Devonian to early Lower Carboniferous deposits are restricted to the eastern and western parts of SE Anatolia. In the Hakkari region to the east Zap Group consists of Upper Devonian Yiginli and Köprülü Formations and Lower Carboniferous Belek Formation. Corresponding units in the western Amanos region are Kirtas and Hasanbeyli Formations.

Yiginli and Kirtas Formations

The outcrops of the former are restricted to Zap Anticline in Hakkari-Cukurca region, where Bedinan Formation is unconformably overlain by the violet to pink colored and cross-bedded coarse clastic basal levels of the Yiginli Formation. To the top, the unit comprises an alternation of variegated shales, sandstones and beige dolomites which grades into carbonates of the Köprülü Formation.

The depositional features indicate to a transgressive shallow marine environment. The maximum thickness in Samurdag type-section is almost 300m (Perincek, 1990).

The dolomites in the upper part of the sequence contain Upper Devonian vertebrate fauna (Janvier *et al.*, 1984).

In Amanos region the red conglomerates and green-red sandstones unconformably overlying the Bedinan Formation and conformably underlying Upper Devonian carbonates of the Hasanbeyli Formation has been described as *Kirtas Formation*, which roughly corresponds to the Yiginli Formation in the east.

Köprülü and Hasanbeyli Formations

The Köprülü Formation in Hakkari region starts with dark gray, thin-bedded, locally sandy and dolomitic limestones followed by black shales with siltstone and sandstone interlayers. To the top the sequence is represented by an alternation of shale and limestone.

The bio- and lithofacies of the formation indicate to a shallow infralittoral depositional environment. In its type-locality the measured thickness is 258m. The unit is conformably overlain by the Early Carboniferous Belek Formation.

The carbonates of the Köprülü Formation is very rich in fossils. Based on foraminiferal assemblages, Köylüoğlu and Erten (1985) have suggested an Upper Devonian to Lowermost Carboniferous age which is further supported by studies on sporomorphs (Simanoglu, 1978).

The Upper Devonian sequence in Amanos region, the *Hasanbeyli Formation* consists of dark gray to brown colored reefal limestones with sandstone and gray shale interlayers and is very similar to the Köprülü Formation.

Belek Formation

The dark gray to brown fossiliferous bioclastic carbonates representing the uppermost unit of the Zap Group are known as the Belek Formation. This formation is restricted to Zap Anticline and characterizes the lagoonal deposits of the inner shelf.

The Zap Group is unconformably overlain by the Permian Tanin Group in the east and by the Middle Triassic to Lower Cretaceous Cudi Group in the west.

DISCUSSION AND CONCLUSION

During the Lower Paleozoic SE Anatolia and its northern promontory, which is now located in allochthonous terranes of the Alpine Orogen, were parts of the Gondwanaen Megacontinent.

The earliest geological records in the Turkish area are from the pre-Cambrian Telbesmi Formation where pillow lavas and spilitic volcanics alternate with volcanoclastics. Perincek *et al.* (1991) suggest that this unit was mainly deposited in marine conditions with a slow transgression from north to south. The geochemistry of the volcanics have not yet been studied in detail, and hence the exact geodynamic setting is not known. It is, however, commonly accepted that this volcanism should be related to a late Pan-African magmatic event.

During the Cambrian shallow-marine deposition in stable platform conditions should have prevailed in SE Anatolia. Minor changes in depositional conditions and that the transgression becomes younger towards east suggests a slow subsidence in the eastern areas.

The transition from the Cambrian Derik Group to the Ordovician Habur Group continued in the western (Amanos) and eastern (Hakkari) areas without any considerable depositional break. In the central area, however, the lower units of the Habur Group either do not exist or unconformably cover the sediments of the Derik Group. These data indicate that the Early Ordovician formation of the Mardin-Kahta High corresponding to the Dar-ez-zor High (Bozdoğan and Erten, 1990) in the south, is the main control in the paleogeography in central SE Anatolia. Bozdoğan *et al.* (1994) suggested that the Mardin-Kahta High has separated two distinct sub-basins which are equivalents of Wıdıyan and Tibuk Basins on the Arabian Plate. The submarine volcanics in the Bedinan Formation as well as the variations in the distribution and deposition of Ordovician sediments in these basins are accounted to an extensional system. The Late Ordovician glacier deposits in Amanos region (Akcağad member of the Bedinan Formation) on the other hand should be related to the closest position of the Arabian Plate to the South Pole during Middle Ordovician (Bambach *et al.*, 1980).

Lower Silurian is generally characterized by a non-depositional period in the studied area. The deposition of Upper Silurian Dadas Formation started with coastal plane, tidal flat and restricted marine conditions and was followed by shallow marine and tidal-dominated clastic deposition, represented by the Lower to Middle Devonian Hazro Formation and terminated with the regressive sequences of Upper Devonian Kayayolu Formation.

Late Devonian to Early Carboniferous deposits (Zap Group) are restricted to the periphery of the central Mardin-Kahta High. In the eastern areas Zap Group began as fluvial and deltaic deposits with some tidal-flat related carbonates (Yiginli Formation) and grade into shallow subtidal carbonates with some reefal build-ups represented by Upper Devonian-Lower Carboniferous Köprülü and Belek Formations. In the western areas, however, the lowermost unit of the Zap Group is transitional to the underlying Diyarbakir Group and is represented by shallow infra littoral deposition. The depositional features suggest that the central Mardin-Kahta High was affected during the Upper Devonian-Lower Carboniferous by marine transgressions both from east and west.

Starting from Middle Carboniferous the entire SE Anatolia was uplifted and remained as a positive area until Late Permian. Geological data from the northerly derived alloctonous units (Göncüoğlu and Turhan, 1984) suggest a Late Carboniferous collision-related magmatic event, probably related to the closure of a Late Paleozoic Oceanic basin to the north of Gondwanaland which may have resulted in the uplifting of SE Anatolia.

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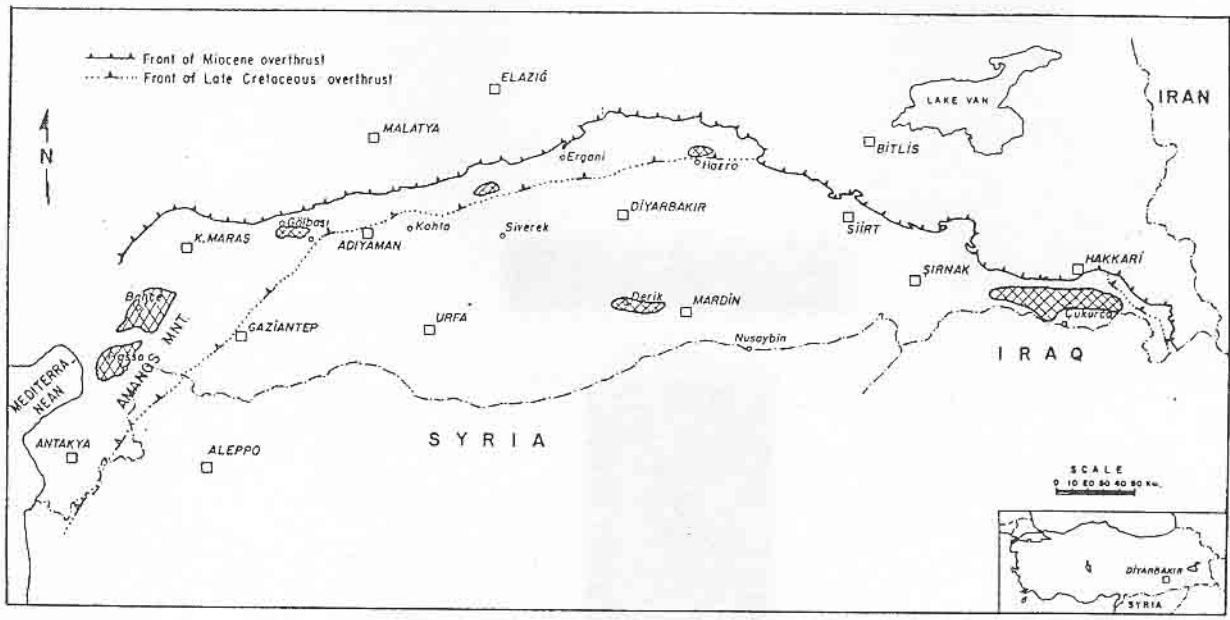


Fig. 1- Location map and outcrops of Paleozoic deposits in SE Turkey.

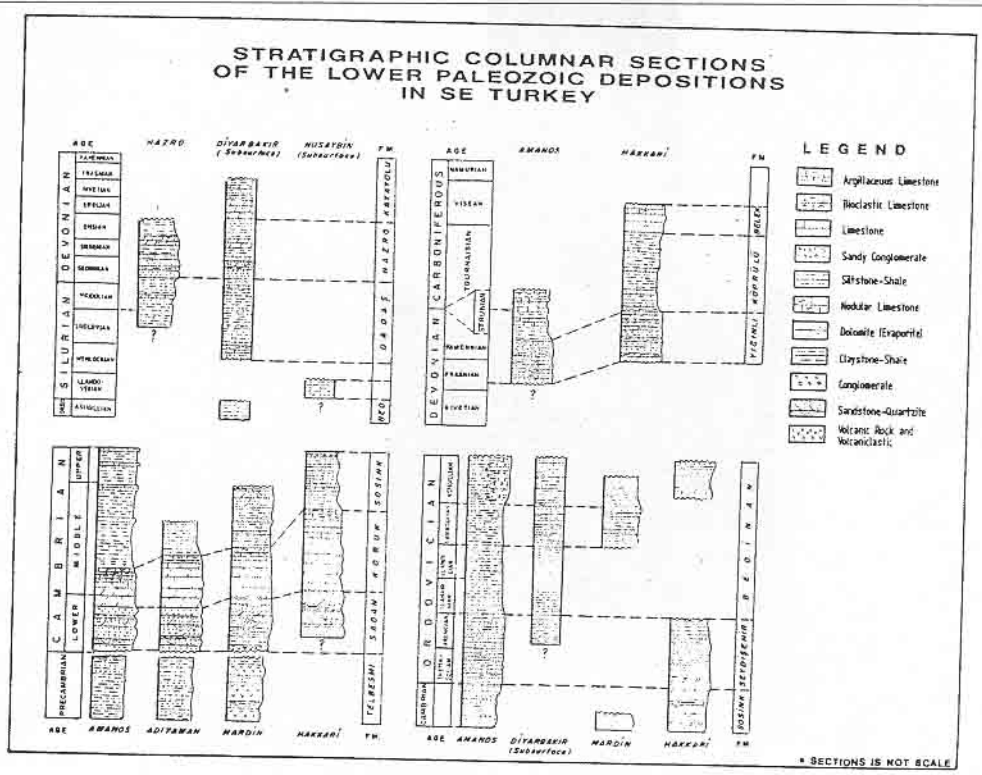


Fig. 2- Stratigraphic columnar sections of the Lower Paleozoic deposits in SE Turkey.