Paleozoic Basement Structure of Northwest Anatolia (an Approach)

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Summary:

The principle Paleozoic basement structure of NW-Anatolia is that of large-scaled linear segments, which have undergone different structural and sedimentary evolutions. The segments are composed of either high-grade metamorphic rocks or ultramafitites, being mantled by low-grade metasedimentary strata. The ultramafitite includes harzburgite, lherzolite, dunite with various grades of serpentinization, subordinate hypabyssal intrusions of gabbro, norite, diorite, and rodingites. Textural and compositional criteria suggest them to have suffered metamorphic processes. The over-all distribution pattern and contact relationships to disconformably overlying metamorphic and non-metamorphic rock units involve the fact that the ultramafitite is a differentiated mantle portion to constitute a simatic crust. Its emplacement dates Pre-Ordovician (or Precambrian). High-grade greenschist facies metamorphic rocks crop out in isolated polygonal masses surrounded by ultramafitite into clear-cut faulted boundaries. The rock succession can be generalized into augen-gneiss, banded gneiss, schist and marble. The gradational contacts and interlayers of different rock types indicate the parent rocks to be mainly clastic sediments. It is suggested that the high-grade metamorphic rocks constitute a sialic crustal layer underlain by a simatic layer (= differentiated mantle portion). The low-grade metasedimentary rocks occur within five distinct stratigraphic units, in ascending order: lawsonite-albite schist facies rocks, low-grade greenschist facies metaclastics, metacarbonates, metavolcanics and glaucophanitic greenschist facies metaclastics-metavolcanics. The units, interrupted by disconformities, overlie the erosional surface of the ultramafitite, and superimpose the high-grade metamorphics. A Pre-Ordovician age is assigned the low-grade metamorphics.

During the Ordovician-Permian time interval two coeval depositional belts were existed in Northwest Anatolia: marginal belt and medial belt, which were extended further eastward. The marginal belt is characterized by marine and paralic, orderly stratified "miogeosynclinal" sequences. A basement of high-grade and low-grade metamorphic rocks is inferred. It formed, at the beginning of Ordovician or earlier, an E—W-trending subsided fault block with a northward tilt, located on the southern periphery of a northerly lying sialic crust. The southernmost part of the tilted block raised as a—marginal—belt that was southerly fault-bounded. The first deposits were tectonic arkose and conglomerates succeeded by orthoquartzite-graywacke-shale association. During the Late Ordovician, at the western part, it is cross-segmented into a structural high bordered by basins. In the basins the younger deposits exhibit conformable and gradational successions, whereas on or near the structural high thining out, marginal discordances, and onlap relationships. The medial belt includes at its southwestern part Early and Late Paleozoic strata of "miogeosynclinal" character and, at its northeastern part, Late Paleozoic strata mainly of "eugeosynclinal" composition. The infill of the belt

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appears to have been deposited on ultramafitite or low-grade metamorphic rocks underlain by ultramafitite.

The fault southerly bounding the marginal welt is virtually a tectonic division between a sialic crust and prevalently simatic crust lying on the north and south, respectively. The spatial coincidence of the western end of the North Anatolian fault with the old tectonic division may have a genetic significance.

Geological Setting

The Paleozoic rocks of northwest Anatolia are underlain by Pre-Ordovician (Precambrian) basement rocks comprising low-grade metamorphic rocks, high-grade greenschist facies rocks and ultramafitite. The low-grade metamorphic rocks originally form a sedimentary cover on ultramafitite and superimpose the high-grade greenschist facies metamorphics. The latter crop out in "crystalline massifs" being isolated by surrounding ultramafitites. Virtually the high-grade metamorphics have been underlain by ultramafitite (Kaya, in prep.). The principle Paleozoic structure of the nothwest Anatolia (Fig. 1) is that of large-scaled linear segments, which have undergone different structural and sedimentary evolutions. The integrated depositional segments, classified to their prevalent structural behaviour, sediment content and infrastructure, are: (1) Paleozoic marginal belt consisting of a trough and a welt with "miogeosynclinal" infill (Istanbul-Zonguldak), (2) Paleozoic medial belt with predominantly "eugeosynclinal" infill (Chios-Şarköy-Gemlik-Orhaneli and further east). The marginal belt with a sialic basement on the north and the medial belt with a prevalently simatic on the south are juxtaposed along a structural division (Şarköy-Gemlik-Sapanca and further east).

Earlier contributions for Regional Synthesis

Kaaden v. d. (1959, 1971) dates the "meso- and kata-zonal" metamorphic rocks Pre-Variscan, the "epi-dynamometamorphic" rocks Early Paleozoic. The writer, firstly considered the "serpentinized peridotitic rocks" to be the "initial basic phase," contributed by the earlier stages of Variscan mountain-building. He classifies the "glaucophane-bearing greenschist facies rocks" and "greenschist facies rocks" as rock units and concludes a Paleozoic age for the deposition and metamorphism. Ketin (1966) records "the gradual transition from metamorphic series to the ophiolitic Upper Cretaceous". To the writer the West Anatolian "metamorphic-crystalline massif is not an intermediary massif of Paleozoic or of Precambrian age; but, on contrary it is Alpine range formed during the Alpine orogeny". Brinkmann (1968) established "the North Anatolian crystalline swell" as a roughly 150 km wide zone consisting mainly of epizonal rocks and small massifs of gneisses and granitoid intrusions, such as Kazdağ, Uludağ. In 1976, he redefined it "the North Anatolian welt", "composed partly of pre-Variscan rocks which were metamorphosed in early Paleozoic or Cryptozoic time, and partly of metamorphites and magmatites which were formed during the Variscan tectogenesis". To Brinkmann (1974) the Ordovician marine transgression came from south whereas the continental deposits were derived from the northerly lying "Pontian landmass". The landmasses were not existing during the Devonian. The two Late Carboniferous-Permian facies zones, a northern zone with continental sediments, and a southern one with "graywacke flysch (Orhanlar graywacke) containing intercalations of diabase and tuffs", were indication of the sediment deriviation from "north—that, is, from an uplifted area in the center of the Black Sea". BRINKMANN (1976) concluded the emplacement of the ultramafitites to have occured during the Early Mesozoic. BINGÖL (1974) established the Triassic „Karakaya formation" into "a belt consisting of metaspilite and metagraywackes, containing large blocks of limestone and green schist". In northwest Anatolia the belt covers the entire areas between Manisa, Edremit, Erdek, Bilecik, Eğrigöz Dağ. "The occurrence of limestone blocks is attributable to the ingression of Permo-Carboniferous or older blocks to the depression areas, resulting from tensional stresses, which affected the Tethys region after beginning of Lower Triassic." The depositional mechanisms were related to the "development of an ocean-floor located assumingly on the north and northwest of Menderes massif".

ULTRAMAFITITES

The ultramafic rock association is composed of harzburgite, lherzolite, and dunite with various grades of serpentinization, and serpentinites. Small-sizes hypabyssal intrusions of gabbro, norite, diorite and rodingites of different deriviations are common. Ultramafitites could be classified to their textural and compositional peculiarities into following main types: (1) Porphyroidal peridotite is built up of large orthopyroxenes up to 20 mm in size, and olivine which are embedded in a mesostasis-like mosaic of orthopyroxene, olivine and subordinate clinopyroxene. The larger crystals appear to be the relicts of the older generation which were undergone to deformation, partial melting, and recrystallization. The large orthopyroxenes may show, most peculiarly, parallel orientation and elongation (up to 5 cm) into a gneissoid structure. (2) Equigranular peridotite—or dunite—consists of a mosaic of mostly subhedral olivine and orthopyroxene with interstitial smaller crystals of same species but younger generation. In both of the above types, (a) the deformation and larger-scale corrosion of the large orthopyroxene and olivine, (b) the younger generations of olivine filling either the joints, cavities of the orthopyroxenes or interstitial spaces, (c) the subsequent formation of new, small crystals of orthopyroxene, located in comparable sites, are evidences indicating the ultramafitite to have subjected to metamorphic processes. (3) Metaserpentinite includes, in a network of fibrous and lamellar serpentine minerals (lizardite, clinochrysotile, antigorite) the relicts of above types and chlorite, antophyllite, tremolite, and talc. These minerals account for a low-grade greenschist facies metamorphism.

The over-all distribution and contact relationships of the ultramafitite indicate it to be a mantle portion (KAYA, 1972 a, b). The consideration of (a) porphyroidal peridotites with, in most cases, gneissoid structure, (b) metaserpentinites, (c) nonconformably overlying low-grade greenschist facies and blueschist facies metamorphics, (d) metamorphic gradation from metasedimentites into ultramafitite involve the fact that the ultramafitite is a differentiated mantle portion, constituting a simatic crust.

HIGH-GRADE METAMORPHICS

High-grade greenschist facies metamorphic rocks crop out in massifs, such as, Menderes, Kazdağ, Uludağ, Istranca. They are isolated polygonal bodies, surrounded by ultramafitites into clear-cut faulted boundaries. Close structural association extends to the inner parts of the massifs (Uludağ, Menderes Massif, Kazdağ: Bingöl, 1971) the massifs have certain similarities in respect to succession of rock types, metamorphic facies, tectonic attitude, and radiometric ages. The massifs[1]), in a generalized way, include all or part of the three major sequences. In ascending order: coarse-grained augen-gneiss, banded gneiss, schists and marble. The first two may closely be associated with migmatites (Gördes: Ayan, 1973). Typical mineral assemblages of these units are: (1), (2) quartz, muscovite, biotite, albite-oligoclase, K-feldspar; (3) quartz, muscovite, biotite, albite-oligoclase, K-feldspar, almandine weighted garnet, kyanite, sillimanite as products of exsolution, calcite, diopside. On the northern part of the Menderes Massif the coarsegrained augen-gneiss grades upward into fine-grained banded gneisses (Kaya, in prep.). In the transitional interval the coarse-grained varieties occur as interlayers in the fine material. The banded gneiss consists of alternating dark and light colored layers of different thicknesses, a result of the amount and arrangement of mica types, and includes marble and metaquartzite interbeds. It appears that the gneisses were derived from parent prevalently clastic sediments (cf. Dora, 1969; Başarir, 1970), with subordinate carbonates. In Uludağ, the banded gneiss, although predominantly light colored, grades into a thick and uniform marble (Kaya, in prep.). The schists are variable in composition and lithology. Coexisting kyanite and exsolutions of sillimanite in feldspat, quartz, and micas suggest the metamorphic phase to have reached to the metastable triple point of the Al_2SiO_5 system (cf. Dora, 1975). In consideration the superimposing low-grade metamorphics, which have been affected by two metamorphic stages (Kaya, 1972a), the latter the lower-grade, the high-grade metamorphics appear to have suffered regionally, at least, three metamorphisms.

The absence of representative successions of the facial gradations into low-grade greenschist facies metasedimentary rocks involves a postmetamorphic erosion. The oldest radiometric dates available are 490 + 90 and 529 m. y. for augen-gneisses (cit. Brinkmann, 1976) and 304 + 31 m. y. for the "metabasalts" underlying the "gneisses" in Kazdağ (Bingöl, 1969). The former corresponds nearly the Ordovician/Cambrian boundary, the latter the Late Carboniferous.

Metasedimentites

The low-grade metamorphic sequences of NW-Anatolia re made up of metasedimentites including subordinate metavolcanics. In a generalized way, the metasedimentites are divided into five large units, in ascending order: (1) lawsonite-albite schist facies rocks, (2) Barrowian type low-grade greenschist facies (quartz-albite-muscovite-chlorite) metaclastics, (3) metacarbonates, (4) metavolcanics and (5) glaucophanitic greenschist facies of metaclastics. Throughout their extensions the units display uniform mineralogical compositions, facies, and stratigraphic relationships. They are bounded from base and top either by abrupt contacts or disconformities.

The ultramafitite constitutes the basement on which all the metasedimentary units are deposited (Kaya, in prep.). The criteria involved are as follows: (a) Undisturbed stratigraphic contacts between the metasedimentites and metamor-

[1]) In special reference to those except the Istranca massif and southern part of Menderes massif.

phosed ultramafitites. (b) The high chlorite, Mg-amphibole and magnesium content of the basal contact intervals of the metasedimentites on the metamorphosed ultramafitites and their gradual decrease upwards. (c) Presence of angular fragments of differentiated ultramafitites in the basal intervals. (d) Tectonic slices of ultramafitites into parent sediments which were metamorphosed concomitantly. (e) Parallelism in the schistosity, and tectonic attitude.

The metasedimentary rocks, particularly those of greenschist facies, superimpose the high-grade metamorphics (Armutlu, Iznik, Kazdağ, Uludağ, Eğrigöz Dağ). They are overlain by Early Paleozoic (Mudurnu: Abdülselamoğlu, 1959) and Late Paleozoic (Gemlik, Bandırma, Kınık, Tırmanlar) non-metamorphic strata. A Pre-Ordovician age is assigned for the metasedimentites on the basis of following criteria: (a) The Ordovician epiclastics include metasedimentary rock fragments, ranging in size from pebble to coarse blgck. (b) Closely distributed outcrops of metasedimentites (Manisa, Izmir, Oinoussai) and non-metamorphic Ordovician-Silurian (Karaburun, Chios) strata. (c) Closely spatial association of the metasedimentites with quartzose, feldspar-bearing sandstones and conglomerates (Gemlik) comparable with those of Ordovician in Istanbul.

Paleozoic Marginal Belt[2])

The Paleozoic marginal belt consists of orderly stratified epiclastic carbonate, and siliceous rocks. Towards NW the belt is bounded by the Istranca Massif, towards S southerly by a structural line (Şarköy, Gemlik, Sapanca) defining northermostly the ultramafinite. The belt can be divided into (1) a northern marginal trough (Çatalca-Istanbul-Zonguldak), (2) a southern marginal welt (Gemlik-Iznik-Sapanca). The sedimentary infill of the trough ranges in age from Ordovician to Permian. The integrated thickness exceeds 6500 m in Istanbul and 4500 m in Zonguldak regions. The welt includes small patches of sedimentary rocks resembling to those of Ordovician (Armutlu) and Early Paleozoic (Gemlik, Akçat) strata of the trough.

The sedimentary-tectonic framework, successions and composition of the Ordovician rock associations suggest a competent and structurally uniform basement for the marginal trough. The inferred depositional morphology is that of an E—W-trending subsided fault block with a northward tilt, located on the southern periphery of a northerly lying sialic crust. The southermost part of the tilted block was raised as a welt that was southerly faultbounded. High-grade and low-grade greenschist facies metamorphic rocks on the northern half of the Armutlu Peninsula (Akartuna, 1968) constitute the welt and represent the sialic basement of the marginal trough. In Istanbul region, in the Late Ordovician, the marginal trough was cross-segmented by hinge lines in fairly straight, S—N-trending line, and poorly developed SW—NE-trending line. Intermittently positive structure is called the Ordovician structural high. On the hinge lines slump folds, abrupt change in thickness, and marginal disconformities sporadically punctuating the successions are common. In Zonguldak region, the northerly trending isopachs of four important coal seams (Tokay, 1962) may suggest diagonally aligned sags controlled by comparable structure.

[2]) Special reference is made to Istanbul region.

ORDOVICIAN: Arkose association, as the oldest sedimentary record, occupies the entire Kocaeli Peninsula and extends eastward being even more obscured. It is mainly composed of reddish tectonic arkose and polymictic conglomerate with shale interbeds. The coarse clasts include, notably, low- and high-grade metamorphic and acidic to basic plutonic rocks, and extrusives. The bulk lithology of the upper part differentiates southwards into submature arkose-subarkose with shallow water sedimentary features. Marine origin is suggested in respect to conformably overlying strata.

Orthoquartzite association consists of marine lithosomes of orthoquartzite, greywacke and shale. The orthoquartzite, which is volumetrically small but the most prominent rock type, occurs as sheets, lenticular and domal masses. The graywackes and shales do not have the textural and structural attributes of turbidity deposition. The shales locally contain chamosite-ooid beds rich in *Conularia* of Middle Ordovician age (SAYAR, 1969). All the lithosomes conformably and immediately succeed the arkose association. They are time-transgressive units, and are closely related to the energy distribution in depositional environment than the time elements. The association undergoes a marked facies change from east to west: the progressive diminution of grain size, the sharp decrease of proportion of graywacke to shale, the change of dome-shaped orthoquartzite lithosomes to those of sheet-shaped, increasing compositional uniformity to vitreous megaquartz mosaic, decreasing bedding-frequency etc.

In the western end of Armutlu Peninsula the subgraywacke, orthoquartzite and quartz-rich polymictic conglomerates seem to be correlable, in respect to lithology and stratigraphic position, with those of arkose and orthoquartzite associations in Istanbul.

SILURIAN: Random reef association is composed of patch reefs, detrital limestones of inter-reef facies and epiclastic lithosomes. In patch reefs tabulate corals (esp. favositids and *Halysites*) and stromatoporoids predominate over the organic content. The subarkose and calcareous graywacke occur as blanket deposits to define the repeatedly alternating patch reef horizons. The association disconformably overlies the Ordovician structural high on the bordering hinge lines. Basinwards it constitutes a conformable sequence on the orthoquartzite association.

LOWER DEVONIAN: lower limestone is thin-bedded to laminated, sparsely bioclastic and remarkably uniform. On the hinge lines it onlaps the random reef association onto Ordovician structural high. Away from the high it conformably overlies the Silurian carbonates through a marked pebbly to sandy basal horizon.

The shale-graywacke unit corresponds the classical "Pendik Series", composed of regularly stratified shale, graywacke with bioclastic limestone interbeds. The high carbonate content and abundant benthic fauna exhibit uniformity throughout the extension of the unit. At the west of Bosporus, sporadical turbidities punctuate the sequence. On the hinge lines it onlaps the lower limestone onto Ordovician structural high. The deposition of this mainly epiclastic sequence corresponds the time of a rather rapid subsidence of the marginal trough and an extensive transgression on the metamorphic borderlands.

Upper limestone is thickly bedded and bioclastic. Its transgressive attitude on the Ordovician structural high delineates a pre-depositional large-scaled regressive phase.

MIDDLE-UPPER DEVONIAN: Shale is calcareous and arenite-free. Nodular limestones are continually carbonate-rich facies of the shale. The lydite horizon regionally interrupts the nodular limestone section. All of the units indicate a condensed pelagic sedimentation under considerably reduced environmental conditions. Most significantly on the S—N-trending hinge line, each unit transgresses on the deeply unroofed Ordovician structural high. Closely spaced marginal unconformities between the units delineate an exactly straight hinge line. Basinward the sequences become more or less homogenized.

TOURNAISIAN: Lydite conformably overlies the nodular limestone. Across the hinge lines, it constitutes an extensive transgressive sequence on the Ordovician structural high. It is formed under shallow pelagic conditions. Bedding is basinward increasingly contorted into intrastratal folds of disordered geometry. The deformation is concomitant with the gradual formation of flysch basin of Visean time.

VISEAN

In a generalized way, the shales and graywackes represent an orderly stratified flysch. The carbonate lithosomes define the flysch succession from base and top. The early strata are composed of calcareous shales with foraminiferal limestone interbeds. They conformably overlie the lydite. Later strata have the highest proportion of graywacke to shale and include sporadically pebbly mudstones, and polymictic conglomerates. All are turbidity deposits and the individual beds extend laterally over great distances. The clasts, ranging from fine pebble to small blocks, are rounded and include large quantities of metamorphic, plutonic rocks and, specifically, lydite. The coarsening of the clasts, tool and current marks indicate a northerly lying landmass. The plant fragments are abundant (KAYA, 1971). Dictyodora-type ichnococoenoses marks deep Nereites-facies. On the hinge lines the flysch strata onlap the lydite onto Ordovician structural high. Lithologically correlable strata occur on the marginal welt, spatially coinciding with gneisses (Akçat).

The latest strata are predominantly shale although turbidities and fluxorturbidities occur as well. The shale is locally calcareous and has a fairly rich benthic fauna. Northward, it is increasingly calcareous, pebbly and rich in algae. The Late Visean limestone is a large-scaled lenticular body. Isolated syringoporoids, rugose corals, large productids, and non-fusulinid foraminifera are common. In the uppermost part it is composed of large crinoidal-reef detritus and intercalated with Mn-, Fe-rich tuffs.

POST VISEAN: The strata are restricted to the western side of Bosporus. Lydite and siliceous shale, being lateral equivalents, disconformably overlie the flysch strata and the Late Visean limestone, on the north and south, respectively. The quartzose graywacke unit, unlike the Visean graywackes, has highest proportion of graywacke to shale and contains significant amounts of feldspar. The coarse clasts include large quantities of lydites and granitoid rocks. The lower subgraywacke is moderately sorted, and thickly bedded. The limestone is, mainly, regularly bedded, fine-grained, and includes intraclastic intervals. The upper subgraywacke is poorly sorted, pebbly, and contains coalified plant fragments. The unit, with locally exposed reddish shale and graywacke interbeds, is the latest deposit of Paleozoic in Istanbul and represents the first introduction of the limnic facies in the western end of marginal belt.

Paleozoic Medial Belt

On the medial belt the rocks and stratigraphic successions differ from their counterparts on the marginal belt. The marine epiclastic, ophiolitic and carbonate rocks unconformably rest on a basement mosaic composed prevalently of ultramafitite and low-grade metasedimentites, which overlie the ultramafitite. The belt is defined from north by the northermost outcrops of the ultramafitite on the Şarköy, Erdek, Gemlik, İzmit line, and from south nearly by the northern boundary of the Menderes Massif. The belt comprises relatively thick non-carbonate sedimentary and submarine volcanic fills. Diagonally oriented, SW—NE-trending deep troughs are delineated by (a) the sites of maximum accumulation of ophiolitic (Brinkmann, 1971 b) and (b) disorderly deposited epiclastic rocks, (c) the onlap of latest carbonate sequences the extremely thinned out non-carbonate sequences onto basement rocks, (d) spatial coincidence in the distributions of the Early and Late Paleozoic strata on the south (Karaburun-Bergama). The most prominent trough of about 100 km extends from Karaburun to Bursa. In the trough the basements gradually come closer to the surface and at least the metasedimentites emerge first around the Kınık and Tırmanlar, and ultramafitite around Bursa.

Early Paleozoic

The Early Paleozoic strata, consisting of predominantly epiclastic and carbonate rocks, are restricted to the most southeastern part of the belt (Chios: Besenecker et al., 1968; Karaburun: Höll, 1966, Lehnert-Thiel, 1969). These strata are either very thin or absent northeastward to Bergama, where Late Paleozoic rocks disconformably rest on the metasedimentites. This condition may be the result of following processes: (a) no deposition, (b) erosion subsequent to deposition, or (c) gradual development of the trough structure. The pebbles (Brinkmann et al., 1970) and exotic blocks in Devonian age included by Early Carboniferous epiclastic strata around Bergama-Balya suggest that the two last processes operated together.

Late Paleozoic

The Late Paleozoic rocks are difficult to distinguish from Early Paleozoic strata by other than paleontological reasons. The Carboniferous carbonate beds are established in Karaburun (Gümüş, 1971), Balya (Dessauvagie and Dağer, 1963) and epiclastic beds in Danişment. The Late Permian carbonates have been subjected to detailed studies in Bergama (Çakıroğlu, 1969), Balya (Aygen, 1956), Bursa (Erk, 1942). The criteria used to distinguish the Late Paleozoic sequences, in other localities, are: (a) lithological correlations with known Late Paleozoic sections, (b) presence of turbidites and ophiolitic materials, (c) absence of lydite, (d) spatial relationships. Along these criteria the rocks in Keşan (Mecidiye), Gelibolu (Karaburgaz), Şarköy are suggested to be Late Paleozoic in age until more definite information is available. Additionally, (e) the presence of isolated bodies of Late Paleozoic carbonates (lenticular or allochthonous) support Late Paleozoic assignment for the mainly non-carbonate sequence in Yenice, Bayramiç (Kısacık), Zeytindağ, Bandırma, Gemlik, Iznik (Adliye, Sığırhasan), M. Kemalpaşa.

In a generalized way the Late Paleozoic is composed of three distinct sequences, which are highly variable, both laterally and vertically: (1) flysch, (2) ophiolite[3]), and (3) carbonate. The flysch sequence is formed by a succession of epiclastic material including graywacke, feldspar-rich graywacks, arkose, polymictic conglomerate, pebbly mudstone, and shale, which are deposited mainly by turbidity processes. In respect to (a) the magnitude of contemporaneous deformation, (b) allochthonous bodies, and (c) ophiolitic constituents the flysch sequences could be classified into disorderly and relatively orderly deposited types. The disordered flysch sequences have higher proportion of sandstone to shale. In general, the beds neither have lateral continuity nor form any fixed stratigraphic succession. Bedded chert slide sheets, olistholiths and exotics of mafic submarine lavas, pyroclastics, sandstones and carbonates are common. For the most part, both the lithology, size and orderliness of olistholiths and exotics are zoned stratigraphically. The ordered flysch sequences have the traceable beds, thick sections of shale associated with turbidities, frequent lenticular limestones, intraclasts and small-sized olistholiths of graywackes and carbonates. The basal intervals may include subordinate ophiolitic material. Disordered flysch sequences occur on the axial part of the belt (Yenice, Bergama, Balya, Bursa), where they closely associate with ophiolitic material. Ordered flysch sequences are found on the north (Gelibolu, Şarköy, Armutlu, İznik) and south (Karaburun, Zeytindağ).

The ophiolite is composed of successive submarine basalt lava, pillow lava, tuff, coarse pyroclastics, reddish to greenish bedded cherts; which usually interfinger with disordered flysch strata. Scattered olistholiths and exotics of varied basaltic rocks, cherts, bioclastic and recrystallized limestones exist to float in pyroclastic and volcanoclastic matrix.

The carbonate sequences are developed either as uniform and large masses or lenticular bodies embedded in calcareous epiclastics. In both cases they include low relief biostromes with abundant fusulinids, corals and algae, and thickly bedded, sparsely bioclastic limestones. The epiclastics, unlike those of flysch sequences, are texturally submature, calcareous, and include quartzose graywacke, subgraywacke, polymictic rounded conglomerate.

For the most part, the flysch and ophiolite are interfingering sequences. *Siphonophyllia* sp., at first recognized in the shale-like matrix of an exotic-olistholith zone of flysch (Danişment), indicates, at least, an Early Carboniferous age for the non-carbonate strata. The widely distributed carbonate sequences range in age from Middle to Late Permian. Based on (a) abrupt textural change of the epiclastics, (b) presence of rounded epiclastic conglomerate defining the lower part

[3]) The practical conclusion stemming from the author's work in NW-Anatolia, is that an ophiolite is composed of mafic submarine volcanics, including massive lava, pillow lava, tuff, coarse pyroclastics and volcanoclastics; bedded cherts; shales as halmyrolytic products of the tuffs; recrystalized limestones; exotic and olistholiths of above and different types of rocks; subordinate terrigenous shale and thinly bedded graywacke. Spilitization of the volcanics is a common process. The olistholiths and exotics are zoned stratigraphically. The ophiolite may spatially associate with a basement of ultramafitite or not. A close association may have existed with flysch, but, in general, the sedimentary-tectonic framework of ophiolite works independently. Metamorphic rock assemblage with an ophiolitic composition is not part of a nonmetamorphosed ophiolite, but an earlier cyle of formation (Pre-Ordovician) — so that, it may be included as exotic blocks in a younger ophiolite sequence. For the use of ophiolite as an operating map unit and for the genetic interpretations, the ultramafinite, flysch, and partial metamorphism must be excluded from the concept the ophiolite.

of the sequence, and (c) exotic ophiolitic material along with Late Permian Carbonate olistholiths, and (d) lacking paleontologic evidence for Early Permian may suggest an erosional stage spanning part of the Late Carboniferous-Early Permian time.

The sequences of flysch and ophiolite, being nearly time equivalents, rest in depositional contact upon the ultramafitite and metasedimentite. Chlorite-rich, arenite-free shales (Şarköy, İznik), fine-grained serpentinite-conglomerate (Şarköy, Gemlik) and pebbles of ultramafitite, gabbro, norite (Gemlik); submarine basaltic tuff with reddish chert interbeds and (Keles) define the basal contact intervals on the ultramafitite. The basal ophiolitic (Yenice, Yenişehir, İzmir) and flysch strata (M. Kemalpaşa) spatially associated with fault-sliced ultramafitites support the contact relationships. The disordered flysch sequences with basal feldspar-rich graywacke (Tırmanlar), sandy shale and graywacke (Kınık) disconformably rest on the metasedimentes.

Conclusions

In the northwest Anatolia the low-grade metamorphics overlie both the high-grade metamorphics and the ultramafitite. The infrastructure of NW-Anatolia seems to be determined before the deposition of the low-grade metamorphics. The distribution-pattern and the metamorphic gradation from ultramafitite to metamorphic rocks (Kaya, in prep.) indicate that the ultramafitite (= differentiated mantle portion) were a simatic basement for the parent rocks of the metamorphic successions. It follows that the infrastructure of NW-Anatolia is the outbuilding of a lower simatic (= differentiated mantle portion) and an upper sialic (stratigraphic units of high-grade metamorphics) crustal layer, Fig. 3. In the medial belt concomitant with the prevalence of the ultramafitite as a sole crustal element, connected with undifferentiated mantle, is an increase in the magnitude of contemporaneous deformation and ophiolitic development.

The fault, bounding the marginal belt in the south is virtually a tectonic division between a sialic crust and prevalently simatic crust lying on the north and south, respectively. The main differences in non-metamorphic rocks on the two sides of the tectonic division is more pronounced and evident in Late Paleozoic. Actually it represents the northernmost limit of the ultramafitite.

The diagonally oriented SW—NE elongated basins, high and troughs are striking structural features of the Pre-Paleozoic and Paleozoic terrain of NW-Anatolia. They are formed by tensional tectonic and arranged en echelon, and seem to result from the relative (dextral) strike-slip displacement in major faults bounding the linear segments of the belts. The spatial coincidence of the western part of North Anatolian fault with the old tectonic division may have a genetic significance.

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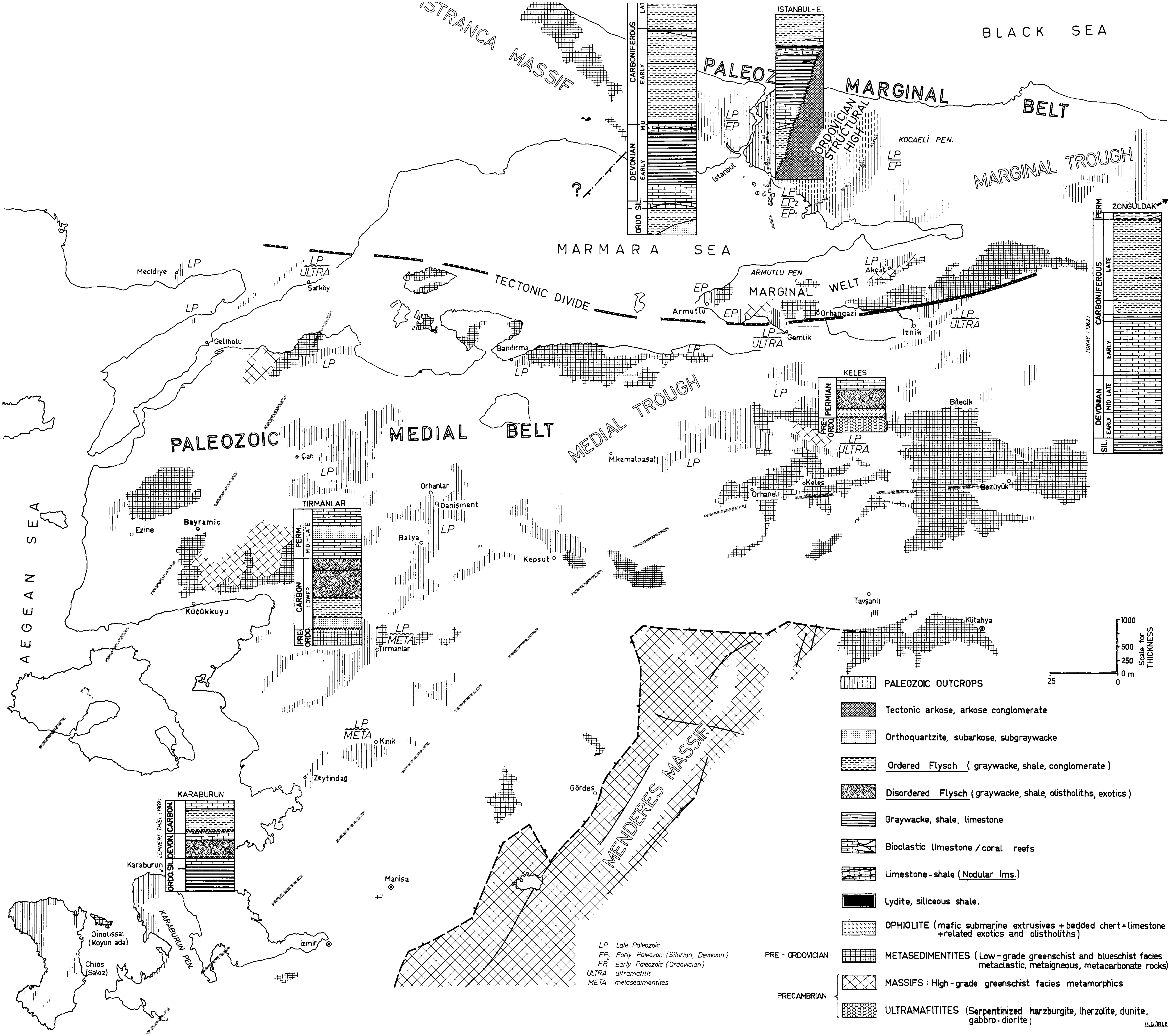


Fig. 1: Distribution of the Paleozoic strata and Pre-Ordovician metamorphic rocks. The younger deposits, ultramafititites and intrusive bodies are not included. The map depends on author's own areal investigations and local observations. The rock boundaries based essentially on MTA 1:500000 geologic map of Turkey.

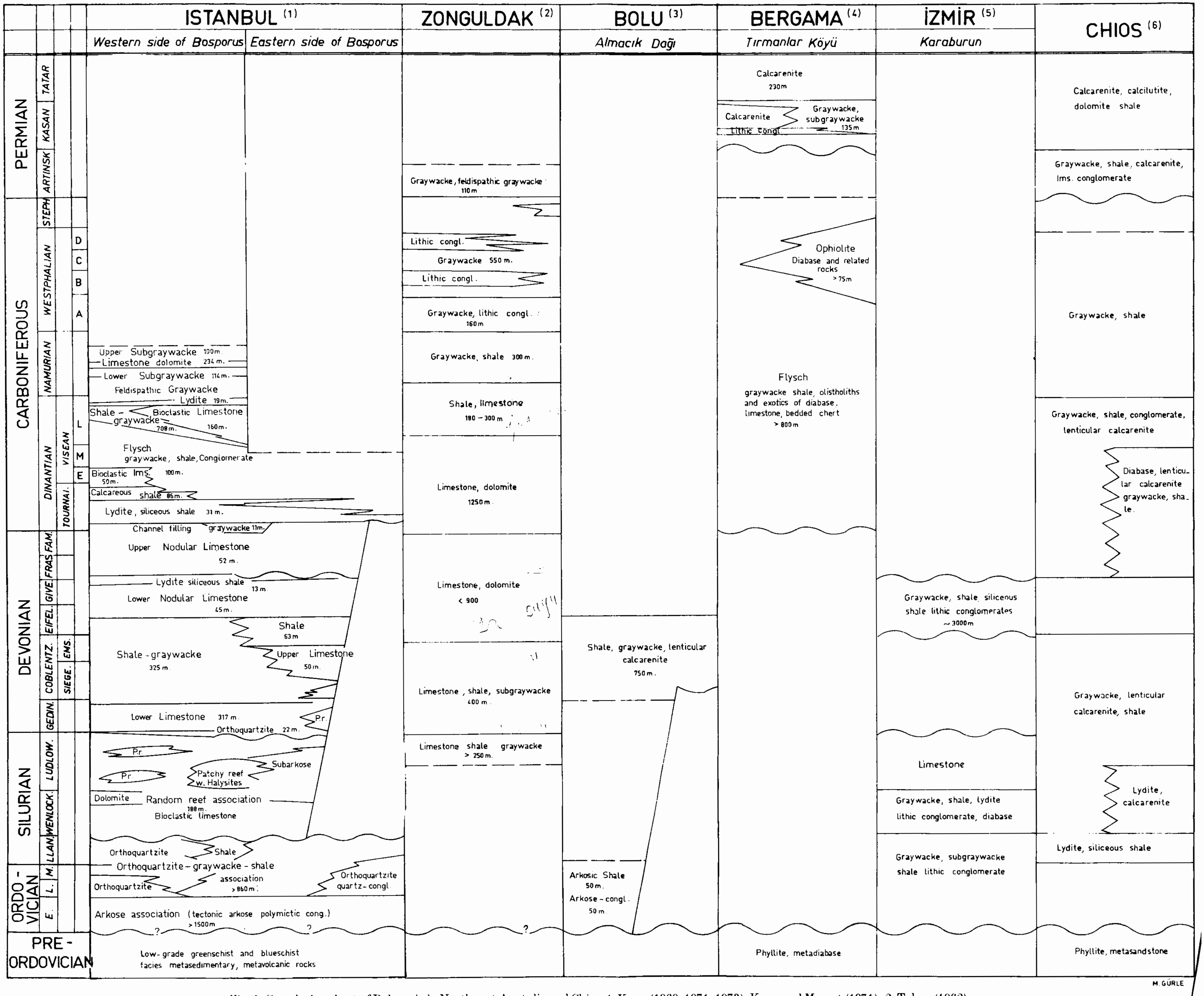
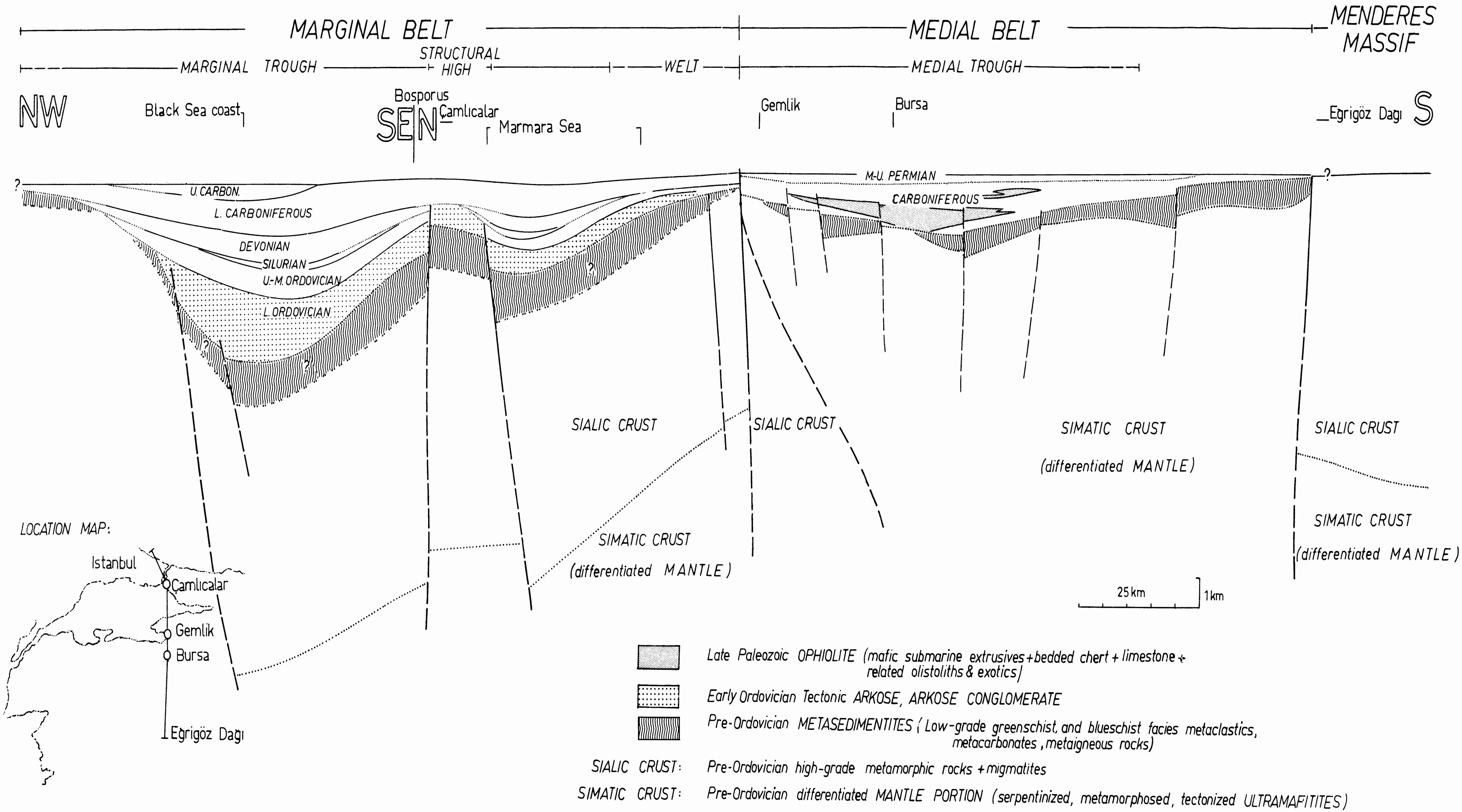


Fig. 2: Correlation chart of Paleozoic in Northwest Anatolia and Chios. 1. Kaya (1969, 1971, 1973). Kaya and Mamet (1971); 2. Tokay (1962), Patijn (1953/54); 3. Abdüsselamoğlu (1963); Çakıroğlu (1969), Kaya (in prep.); 5. Lehnert-Thiel (1969); 6. Besenecker et al. (1968).


MARGINAL BELT
MEDIAL BELT
MENDERES MASSIF
MARGINAL TROUGH
STRUCTURAL HIGH
WELT
MEDIAL TROUGH
NW
Black Sea coast
Bosporus
SEN
Çamlıcalar
Marmara Sea
Gemlik
Bursa
Eğrigöz Dağı
S
M-U. PERMIAN
U. CARBON.
L. CARBONIFEROUS
CARBONIFEROUS
DEVONIAN
SILURIAN
U-M. ORDOVICIAN
L. ORDOVICIAN
SIALIC CRUST
SIALIC CRUST
SIMATIC CRUST
(differentiated MANTLE)
SIALIC CRUST
SIMATIC CRUST
(differentiated MANTLE)
SIMATIC CRUST
(differentiated MANTLE)
25 km
1 km
LOCATION MAP:
Istanbul
Çamlıcalar
Gemlik
Bursa
Eğrigöz Dağı
Late Paleozoic OPHIOLITE (mafic submarine extrusives + bedded chert + limestone + related olistoliths & exotics)
Early Ordovician Tectonic ARKOSE, ARKOSE CONGLOMERATE
Pre-Ordovician METASEDIMENTITES (Low-grade greenschist and blueschist facies metaclastics, metacarbonates, metaigneous rocks)
SIALIC CRUST: Pre-Ordovician high-grade metamorphic rocks + migmatites
SIMATIC CRUST: Pre-Ordovician differentiated MANTLE PORTION (serpentinized, metamorphosed, tectonized ULTRAMAFITITES)