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INVERSELY PILED METAMORPHIC SUCCESSIONS OF THE PHYLLITE-QUARTZITE SERIES OF THE SOUTHERN PELOPONNESUS.- STRUCTURAL AND GEODYNAMIC IMPLICATIONS.

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ABSTRACT

The nappe of the Phyllite-Quartzite Series in SE Laconia consists mainly of 3 successions, different in lithology, petrography, metamorphism and deformation. All these successions are tectonically overlain by the Tripolitza Series resp. the Tyros Beds.

During nappe emplacement parts of successions of higher metamorphic grade are thrust over the succession of lower metamorphic grade.

Emplacement and structural development of the Phyllite-Quartzite Series is considered to be caused by underplating processes within a subduction-accretion complex analogously to a model presented by PLATT (1986).

INTRODUCTION

In the External Hellenides of the Peloponnesus and Kithira nappes of metamorphic rocks - the Phyllite-Quartzite Series and the Plattenkalk Series - are exposed on great horst and anticlinal structures extending parallel to the Hellenic Arc.

The Mesozoic/Tertiary Tripolitza carbonates and their basement, the anchimetamorphic Tyros Beds that stratigraphically reach from Permian to U.Triassic, are tectonically overlaying the Phyllite-Quartzite Series (= Arna Unit, PAPANIKOLAOU & SKARPELIS, 1987/88) which is biostratigraphically dated in Crete from U.Carboniferous to U.Triassic (KRAHL et al. 1983).

The Phyllite-Quartzite Series (PQS) is underlain by the Plattenkalk Series, stratigraphically reaching from Triassic to Oligocene, and the Kastania Phyllites of unknown age at their base (KOWALCZYK & DITTMAR 1991).

The lithological inventory of the PQS on the southern Peloponnesus contains metaclastics, metavolcanics and very rare metacarbonates.

The metamorphic conditions the PQS have suffered, have been determined as 450±30°C, 17±4 kbar for the Peloponnesus, for Eastern and Central Crete 300-350°C, 8-10 kbar and for Western Crete 400±50°C, 10±3 kbar (THEYE & SEIDEL 1991). In the northern Peloponnesus (Feneos Area) the peak P/T-conditions are not as high as in the south according to DORNSIEPEN et al.(1986).

Deformation of the PQS took place polyphasically with early isoclinal and later tight to open folds.

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Parts of the PQS of SE Laconia have been investigated by KATAGAS (1980), SEIDEL et al. (1982), BRAUER (1983), DOERT et al. (1985), THEYE (1988) and BLUMÖR (1991). Key literature about the PQS of the whole southern Peloponnesus can be found in THIEBAULT (1982), THIEBAULT & TRIBOULET (1984), PAPANIKOLAOU & SKARPELIS (1987/88), JACOBSHAGEN (1986).

Our paper is based on geological mapping and investigation of the SE Laconian Peninsula carried out by the working group of Frankfurt/Main and on current research.

SUCCESSIONS OF THE PQS IN SE LACONIA

The complex of PQS of SE Laconia is essentially built up by three successions (fig. 1), different in lithology, petrography, metamorphism and deformation.

Succession 1 is a monotonous alternation of light metaquartzites and dark phyllites more than 100 m in thickness. Primary sedimentary bedding textures reach from several cm to several meters in thickness.

Microtextures of the metaquartzites are characterized by detrital quartz grains (mostly 0.1-0.5 mm ⌀), often flattened, within a fine grained matrix of recrystallized quartz and sericite.

Within the phyllites and quartz-phyllites a slaty cleavage has been developed, in parts with a separation of quartz- and sericite-rich layers, which is overprinted by a fracture or a crenulation cleavage. Within phyllosilicate-rich layers changing amounts of albite, chlorite and (now replaced or altered) biotite have grown pre-kinematically (less often also synkinematically) in respect to the development of the last cleavage.

For the whole of succession 1, the prograde mineral paragenesis

quartz + sericite + albite ± chlorite ± biotite

is characteristic. High-P-indicators are not detectable within this succession.

Typical deformation features of succession 1 are open, tight and isoclinal folds in the order of centimeters to several 10's of meters in scale. Folded quartz filled veins are common.

The B-axis are generally gently dipping with maxima in NNE to ENE, NE and NW.

Succession 2, more than 150 m in thickness, consists predominantly of glaucophane-chloritoid-schists, chloritoid-schists, metaquartzites and basic metavolcanics, additionally tourmalinites occure. The metavolcanics, the tourmalinites and metaquartzites with detrital quartz pebbles up to 1 cm ⌀, are intercalated in the upper part of this succession.

The characteristic mineral parageneses are:

quartz + muscovite/phengite + chloritoid + glaucophane (metaclastics) and

epidote + chlorite + albite + glaucophane/crossite (metavolcanics).

These metavolcanics are quite similar to the basic metavolcanics described from the Arna area in SE Taygetos (Arna-Unit, PAPANIKOLAOU & SKARPELIS 1987/88).

Only in the upper parts of this succession was aegirinejadeite detected.

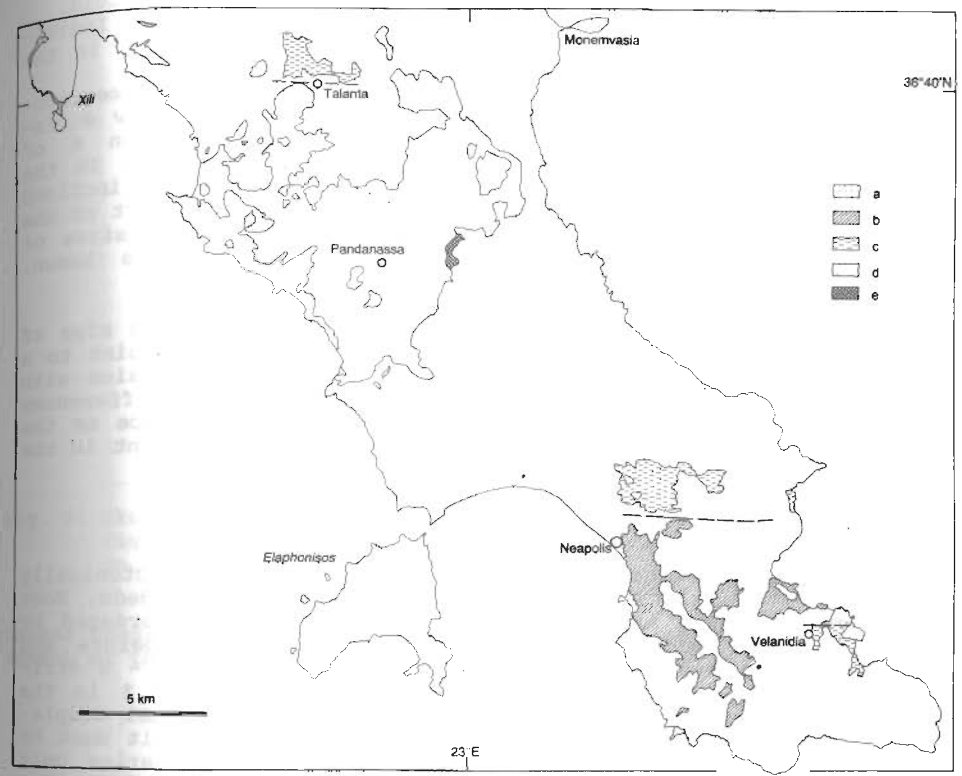

Fig. 1. Regional distribution of the Phyllite-Quartzite Series of SE Laconia.
a - succession 1; b - succession 2; c - succession 3; d - PQS unclassified / resp. retrograde; e - superposition of succession 2 and 3 on succession 1.

On the southern Mani Peninsula, only exposures of succession 2 of the PQS have been identified. The lithology and lithostratigraphy of the succession here is in good conformity with that of SE Lakonia. Also the abundance of tourmalinites is remarkable (BLUMÖR 1991).

The deformation of succession 2 shows early kinematic open to tight, moderately inclined and recumbent megascopic folds. Fold axes are generally gently, but locally also steeply, inclined, and plunge mostly to NNE to ESE, however the plunge varies strongly. Succession 2 forms large scale syn- and antiforms.

Succession 3 predominantely contains garnet-glaucophane-mica-schists and metaquartzites, also at least 100 m in thickness. Its characteristic prograde mineral paragenesis is:

quartz + muscovite/phengite + glaucophane + garnet ± chloritoid.
Garnet is detectable in all parts of this succession. Individual grains of garnet show a high content of spessartine in the center decreasing to the edge.
Succession 3 is intensively deformed in the micro- to megascopic scale by at least two generations of folds which show different axial orientation. However, in a coastal section W of Velanidia the fold generations are developed homoaxially. In the complete section, axial planes are upright or only gently inclined - an orientation which is not known from the remaining part of the PQS in SE Laconia. Also from this section, the largest sizes of porphyroblasts within the PQS of the Peloponnesus are known. Glaucophane reaches a length up to 4 cm.

In conclusion, the differing mineral parageneses, the size of white mica growths and the recrystallisation of quartz point to a weaker metamorphic overprint of succession 1 in comparision with succession 2 and 3. In addition to lithological differences succession 2 and 3 can be differentiated by the occurence or the absence of garnet, which is caused by different Mn content in the protoliths.

SPATIAL RELATIONSHIPS

All above mentioned succesions of the PQS are tectonically overlain by the Tripolitza carbonates resp. the Tyros Beds. Most of the distribution areas of these 3 succesions are bordered by steeply dipping fault zones which have been active before and after the nappe movements. This is demonstrated by a E - W striking fault zone NE of Neapolis, separating succession 2 in the south from succession 3 in the north (fig. 1). A vertical displacement of the PQS of several hundred meters by this fault must be assumed. The overlaying carbonates of the Tripolitza Series only show a throw of some 10's of meters, deduced from the altimetric level of the thrust plane on both sides of the fault zone.
E of Pandanassa, sheets of garnet-glaucophane-micaschists, glaucophane-chloritoid-micaschists and metavolcanics - parts of succession 2 and 3 - are thrust over metaquartzites and phyllites of succession 1, and form an inversely piled stack of metamorphic rocks (fig. 2). The PQS is overthrust in this place by carbonates of the Tripolitza Series with flakes of Tyros Beds at their base. The thrust sheets of succession 2 and 3 are separated from each other by cataclastic zones up to several meters in thickness. The development of this imbrication was associated with the overthrusting of the Tripolitza Series upon the PQS.
These observations lead to the assumption that large scale vertical displacements of the PQS took place already before the emplacement of the Tripolitza Nappe.

Based on the above mentioned observations it can be concluded:
The PQS of SE Laconia is not a uniform and homogeneous unit, but consists of several (at least three) successions which differ in lithology, metamorphism and deformation. These different successions are placed today either in superposition or in juxtaposition, separated from each other by subhorizontal thrust planes and vertical fault zones. In some places an inverse metamorphic piling of the successions can be observed. The processes which

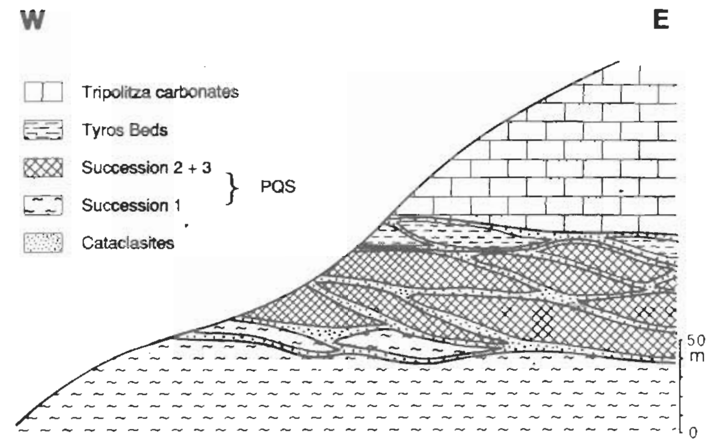

Fig. 2. Sketch of the section east of Pandanassa (location s. fig. 1) showing the superposition of succession 2 and 3 on succession 1.

caused these spatial relationships started before the final emplacement of the overlaying Tripolitza Nappe.

THE PQS WITHIN THE GEODYNAMICAL DEVELOPMENT OF THE PELOPONNESUS

The interpretation of the development and emplacement of the PQS must be based on the present structural and geological situation of the Peloponnesus:
Numerous existing data on the neotectonics and geophysics of the Peloponessus (e.g. LYBERIS & LALLEMENT 1985, MARIOLAKOS et al. 1985, LYON-CAEN et al. 1988, ZELILIDIS et al. 1988, HATZFELD et al. 1989, 1990) show that uplift and extension are the dominating tectonic processes within the upper crustal level of the Peloponnesus since nappe emplacement of the external Hellenides in the Middle to Upper Miocene.
This nappe pile which is most complete preserved in the southeastern Peloponnesus consists of (cf. KOWALCZYK 1986):

"Pelagonian" shallow water carbonates (Anisian)

Ophiolithes, ophiolithic mélange (? - Norian - Jurassic)

Olonos-Pindos Series (Triassic - U.Eocene)

Tripolitza Series (U.Triassic - L.Miocene)
including Tyros Beds (Permian - U.Triassic)

Phyllite-Quartzite Series (? - Carnian - ?)

Plattenkalk Series (U.Triassic - Oligocene)
with Kastania Phyllites at their base.

The extent of the neotectonic movements is obvious by the uplift of the Plattenkalk Series which is at the highest elevations of the Peloponnesus (Taygetos 2404 m). The extension within the upper crustal levels caused the dissection of the nappe pile in numerous fault blocks. During the exhumation of the lower nappe units the upper ones have been removed by erosion and especially by gravitational dismembering.

Off the westcoast of the Peloponnesus the western part of the Hellenic Trench runs NW - SE and forms the margin of the African plate were it is gently subducting under the Aegean plate in the east. The crust in the area of the Ionian Sea is formed by Mesozoic to recent sediments, 10 km thick, probably covering a basaltic basement. Upper mantle seismic velocities are reached at a depth of 19 km without a break of velocity (MORELLI 1985). The sedimentary cover in front of the trench has been detached and forms imbricated formations extending as far as the Mediterranean chain (FINETTI et al. 1990). East of the trench a frontal accretionary complex is developed (BERCKHEMER 1977) followed by the Westhellenic Nappe Complex. The eastern margin of the Peloponnesus and the area of the adjoining Myrtoan Sea is dissected by large scale, east dipping normal faults. The existing data on the structure of the Peloponnesian crust show, that the Peloponnesus is part of an island arc, which can be characterized according to its form and geodynamics as an orogenic wedge s. PLATT (1986).

Metamorphic units are usually rather uncommon in the external parts of an orogen. In the external Hellenides, high-P/low-T metamorphic units are only known from areas, that are underthrust by a plate subducting from the Hellenic Trench (Peloponnesus, Kithira, Crete).

In this areas units, elsewhere preserved unmetamorphous, are present as metamorphic successions. For example, the Ionian Series is known from the southern Peloponnesus and Crete only as the metamorphic Plattenkalk Series (following THIEBAULT 1982, the same is valid for the Preapulian Series). The location of submergence must be placed west of the Tripolitza Series.

According the P/T conditions presented by THEYE & SEIDEL (1991) at least parts of the PQS of the Peloponnesus must have been submerged to at least a depth of 50 km. For the Plattenkalk Series lower values have been calculated (THEYE 1988, BASSIAS 1988, MANUTSOGLU 1991).

The features mentioned above lead to an alternative model of the geodynamic evolution of the PQS of the Peloponnesus (fig. 3) which differ from those proposed before (THIEBAULT 1981, PAPANIKOLAOU 1984, PAPANIKOLAOU & SKARPELIS 1987/88), but reconsider suggestions made by JACOBSHAGEN et al. (1978).

Because of its present position, its stratigraphic extent (only to U.Triassic), its metamorphism and deformation, we consider probable a palinspastic position of the PQS beneath the Mesozoic carbonate successions in the west of the Tripolitza Series, i.e. the region of the Ionian Zone (and, if existing in this region, the Preapulian Zone).During the subduction of the Ionian Series, the carbonate successions, with parts of their basal rocks, were detached from the submerging plate and accreted at a shallow depth while the remaining parts of the unit were attached to the upper plate at deeper levels (i.e. underplated at greater depth). The underplating processes are continuing today by subduction of the north drifting African plate. Continously

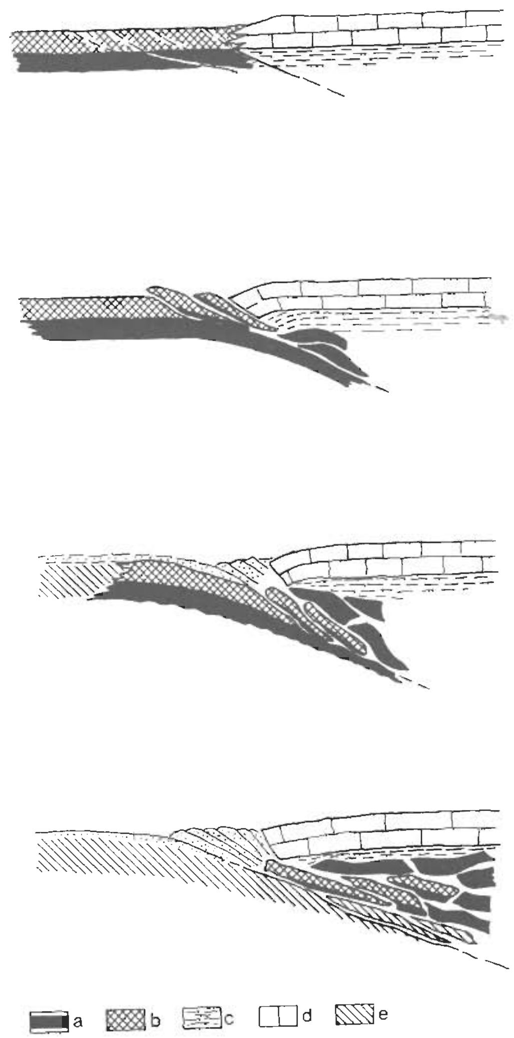

Fig. 3. Cartoon (not to scale) illustrating the model of the Late Alpine development and the emplacement of the PQS. Crust in the Ionian/Preapulian realm:
a - clastics/volcanics (becoming the PQS)
b - carbonates (becoming the Plattenkalk Series).
Crust in the Tripolitza realm: c - clastics/volcanics
d - carbonates.
e - Younger sedimentary cover.

underplating, analogous to the concept presented by PLATT (1986), explains the uplift and the lack of thermal equilibration of the high-P/low-T metamorphic PQS as well as the extension and the uplift in the area of the Peloponnesus as part of an island arc (fig. 4).

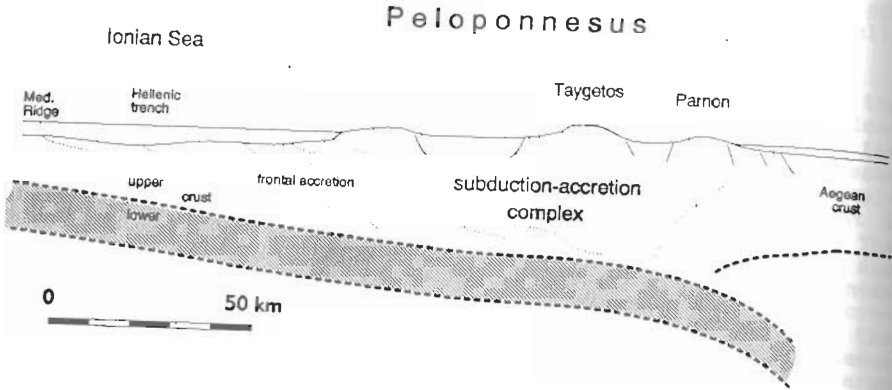

Fig. 4. Model of the present tectonic setting of the Peloponnesus region. (Geophysical data obtained from BERCKHEMMER 1977).

The results and the model, this paper presents, are based on the most up-to-date investigations on ongoing research concerning the structure and the geodynamic evolution of the lower nappes of the southern Peloponnesus. Further work on this project is in preparation.

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