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RETROGRADED ECLOGITE FROM THE KŐRÖS COMPLEX (EASTERN HUNGARY): RECORDS OF A TWO-PHASE METAMORPHIC EVOLUTION IN THE TISIA COMPOSITE TERRANE

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ABSTRACT

A characteristic feature of the NE part of the Tisia is the occurence of high pressure relics in the Variscan metabasic rocks. A new eclogite sample, brought to the surface by the Szarvas-16 borehole contains garnet, clinozoisite, kyanite, rutile and phengite as HP relict grains in a symplectitic material. As the most significant secondary phase, amphibole occurs. Chemical composition and zoning tendencies of these minerals as well as the PT path modelled by different prograde and retrograde parageneses result in a two stage metamorphic evolution. In good agreement with earlier data, the B-type eclogite sample broke down under greenschist facies condition and recrystallized in the amphibolite facies afterwards.

INTRODUCTION

Current models on the Pre-Alpine evolution of the Tisia microplate show that it should have been a part of the southern margin of Europe during the Variscan and early Mesozoic and broke off the continent due to late Jurassic (Bathonian) movements. Not only the Post-Variscan sediments show close relationship, but there are also similarities between the Carboniferous anatectic granite of the Mecsek Mountains and that of the Moldanubian part of the Bohemian Massif (BUDA, 1985) suggesting the possibly common metamorphic evolution of the two regions during the Variscan orogeny. No satisfactory data exist, however, on petrological similarities between other parts of the crystalline basement of the Tisia and the Bohemian Massif. When distinguishing parts of the Bohemian Massif usually the geochemical characteristics of the metabasic rocks as well as the metamorphic evolution of the high pressure samples are studied (e.g. PIN, 1990), because both features show significant differences from place to place. In order to clarify the Variscan paleotectonic setting of the Tisia an analogous approach should be followed.

Crystalline basement of the Tisia may be characterized lithologically by barrovian type (MP-MT) metamorphic rocks developed during the Variscan orogeny. Some textural relics in metabasic rocks from the south-western (RAVASZ-BARANYAI, 1969) as well as from the north-eastern part (M TÓTH, 1994a, 1995, 1996) of the unit, however, have been interpreted as high pressure rocks. These relict samples had possibly formed prior to the thermal peak.

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Physical conditions characteristic of the evolution of the first eclogite sample are not known, while samples from the north-eastern part (Kőrös Complex) all indicate low to medium temperature. This paper presents a probable metamorphic evolution of a new eclogite sample from the same region.

GEOLOGICAL SETTING

The present make-up of the basement of the Pannonian Basin is a result of horizontal microplate movements due to the Alpine tectogenesis. According to recent reconstruction studies (HAAS et al., 1995 and referencies therein) diverse fragments of the basement were situated in different parts of the northwestern Tethys realm during the Paleozoic and Mesozoic time. The big blocks got side by side during the Paleogene-Miocene period and at present are separated by the Mid-Hungarian lineament and other strike slip faults. Tisia (also called Tisza, South Pannonian) Unit is located south from this line and in addition to Hungary it may also be traced in Romania, Yugoslavia, Croatia and Slovenia.

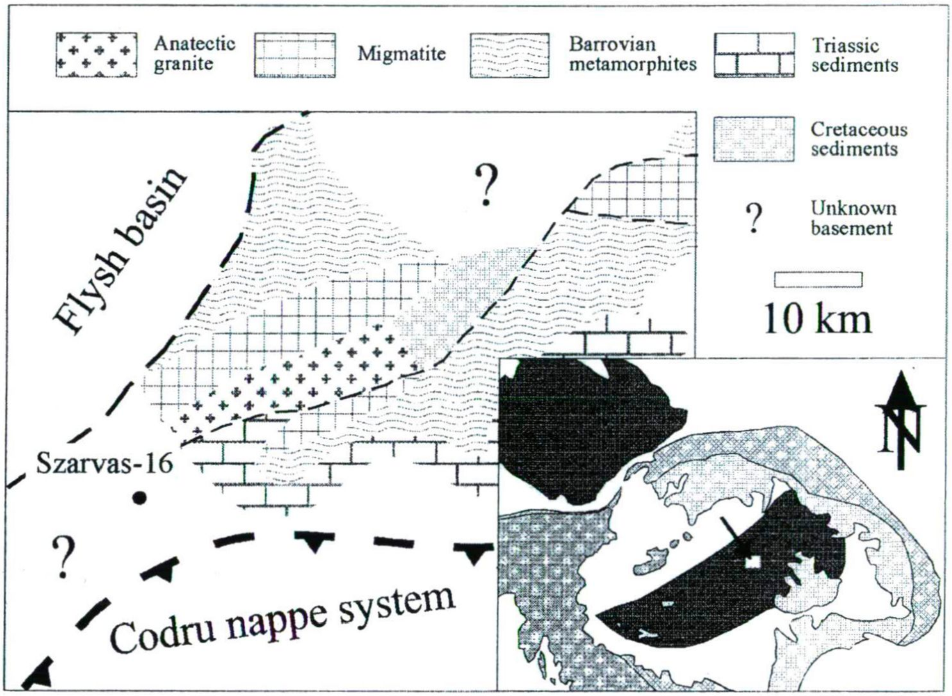

Fig. 1. Current geological map of the pretertiary basement of the Kőrös Complex and the position of the Szarvas-16 borehole.

The rather complicated building of the crystalline basement of the Tisia is a result of subsequent tectonic events from the almost totally unknown Pre-Variscan history up to the extension of the Pannonian Basin which took place in the middle Miocene. Present studies

(SZEDERKÉNYI, 1996, KOVÁCS et al., 1996) exhibit the microplate as a "composite terrane" of diversely developed blocks and fragments. Based on these current distributions the area studied (Kőrös Complex, KC *fig. 1.*) belongs to the "Mecsek-North Plane subterrane" of the so-called "Para-Autochton" terrane. The name shows that this part of the basement did not possibly take part in the Alpean nappe tectonics.

At present KC forms a basement high (strictly speaking a set of smaller highs) developed probably during the Miocene extension of the Pannonian Basin. This tectonic evolution may be explained by the metamorhic core complex theory (TARI et al., 1992) described first in the western USA (LISTER and DAVIS, 1989) and worldwide later. The intensive extension and the rapid uplift of parts of the basement may so be responsible for the occurence of high grade rocks (gneiss, amphibolite) as well as granite and migmatite in the axis of these highs. Although, a lot of data speak for the existence of core complexes in this region, no satisfactory petrological evidence confirms this idea yet.

Geochemical studies on the metabasic rocks suggest a one-time (Pre-Variscan) back-arc basin basalt origin of the protolith (M. TÓTH, 1994/a), while rocks of sedimentary origin show a chemical composition similar to greywacke (SZEDERKÉNYI, 1984). The most characteristic metamorphic event was a barrovian type MP-MT one (5.5-6 kbar, 550-600 °C, SZEDERKÉNYI, 1984, SZEDERKÉNYI et al., 1991, M. TÓTH, 1994/b). Its age was previously considered to be Precambrian, while more recent geochronological data (K/Ar on amphibole and biotite) suggest an age of about 330-350 Ma (SZEDERKÉNYI, 1996 and referencies therein). Traces of a high pressure event prior to the barrovian one as well as retrograted eclogite samples are reported by M. TÓTH (1995, 1996). No granulite facies relics have been reported.

The eclogite sample reported in this paper was found in the southern slope of the complex (Szarvas-16 borehole) about 2000 m below the surface. From the same well no more metamorphic cores are known. Boreholes which penetrated to the basement close to it exposed common mica schist as well as amphibolite but no more high pressure samples were found.

ANALITICAL METHODS

Major and trace element composition of the sample studied was measured at the XRF laboratory of Johannes Gutenberg University in Mainz (Germany) on a Philips PW1453 XRF machine by using Sc-Mo tube. In addition to the major elements the following set of traces were also determined: V, Cr, Co, Ni, Zn, Cu, Ga, Rb, Sr, Zr, Y, Nb, Ba, Th, U, Pb. Microprobe analysis of minerals was performed on the Cameca SX-50 (accelerating voltage: 15 kV, sample current: 20 nA) electron microprobe at the University of Berne (Switzerland) by using natural standards (DIAMOND et al., 1994).

PETROGRAPHY, GEOCHEMISTRY

The sample studied consists of high pressure relict minerals and others formed possibly due to the breakdown of the HP paragenesis. The original constituents are garnet, clinopyroxene, kyanite, clinozoisite, rutile and phengite. Although, the sample has significantly transformed to symplectite due to overprint by succeeding events, the original texture is still able to be oserved (Plate I/1). The most common relict phase is garnet which gives about 30 v% of the whole rock. Usually inclusion free, but small rutile and kyanite inclusions occur. Garnet grains are usually enclosed by a radial corona of plagioclase and tiny amphibole. Clinopyroxene is almost entirely replaced by symplectitic intergrowth of amphibole, chlorite and plagioclase, only a very few grains could survive the breakdown of the original HP assemblage. Kyanite and phengite are surrounded by fine grained margarite (Plate I/2), while rutile is partially replaced by titanite. Clinozoisite is almost completely replaced by minerals not able to be identified under the microscope (Plate I/3).

The most characteristic secondary phase is amphibole that occurs in two different textural positions. It either growths independently in the symplectitic matrix (Plate I/4), or forms poikiloblastic intergrowth with the garnet. Also in this latter case, however, garnet is surrounded by the fine grained plagioclase corona first. No optical zoning has been observed. The sample contains no primary plagioclase. Feldspar occurs only as a corona-forming mineral around garnet and as a newly forming phase together with the matrix amphibole. Ilmenite does not occur even as a secondary Ti-phase.

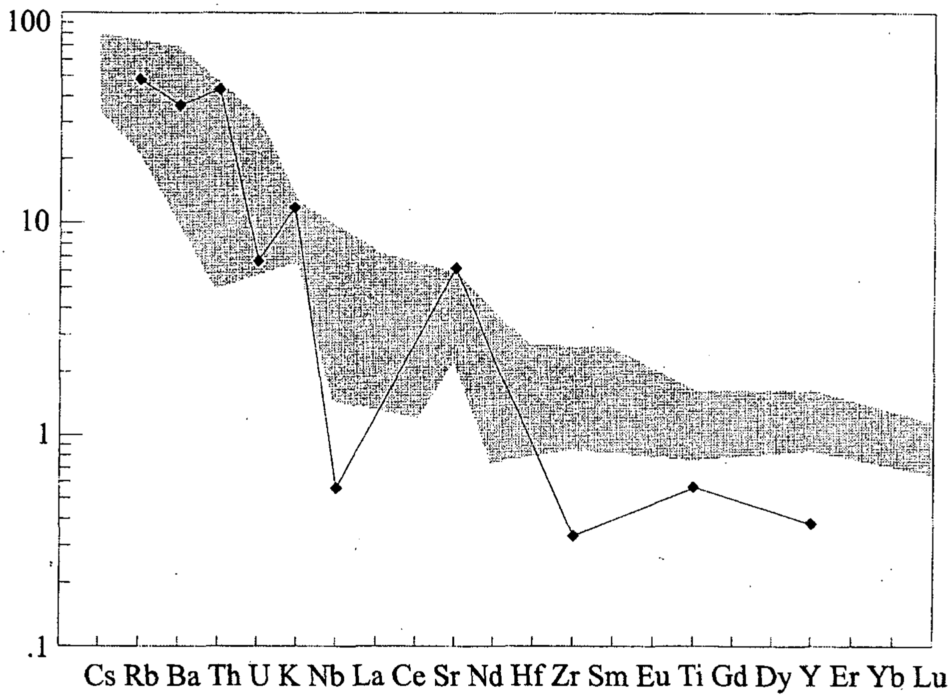

Fig. 2. N-MORB normalized spidergram for the eclogite sample. Shaded area is characteristic for the Körös Complex amphibolite.

Geochemically the eclogite sample is subalkaline basalt based on the discriminating method of WINCHESTER and FLOYD (1977) with as low as 0.15 Nb/Y ratio. Similarly to the KC amphibolite samples also the eclogite is tholeiitic rather than calc-alkaline in composition ($FeO^{tot}/MgO-SiO_2$, MIYASHIRO, 1974; Cr-V, MIYASHIRO and SHIDO, 1975, not presented). It also exhibits a considerable LIL element enrichment as plotted on the N-MORB normalized spidergram (*fig. 2.*) and falls roughly into the typical range defined by the KC amphibolite. The graph, however, also shows that the sample owns a significant depletition on Nb, Zr and Y.

MINERAL CHEMISTRY

Primary phases

Garnet composition has been calculated by the MINFILE software (AFIFI and ESSENE, 1988) assuming full octahedral site occupancy. The grains measured have a rather uniform composition (Table 1.) ($Alm_{35-40}Prp_{35-40}Grs_{15-20}Adr_{0-5}Sps_{0-2}$), without any significant chemical zoning. Calculated garnet end-members are plotted in *fig. 3.* No clinopyroxene of the original HP composition has remained. Minute pyroxene inclusions in the recrystallyzing amphibole grains are diopside in composition (MORIMOTO et al., 1988) with as much as 25-30 % hedenbergite in them. Only a very little amount of jadeite has been calculated ($Di_{70-75}Hd_{25-30}Jd_{0-3}$) (Table 1.).

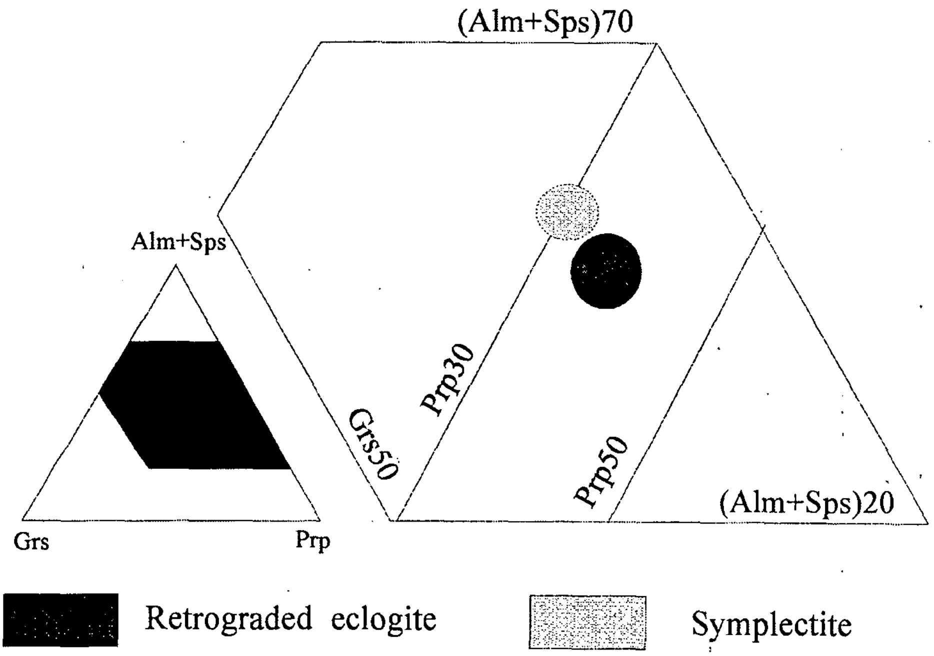

Fig. 3. Garnet shows a uniform composition on the Ca-Mg-(Fe+Mn) diagram. Typical garnet composition of the Körösladány eclogite (symplectite) is also shown.

Kyanite commonly occurs as a matrix grain, but also forms minute inclusions in garnet. It is rather homogenous in composition, analysis reveals only small amount of Fe as an impurity. Phengite, the dominant high pressure white mica phase is magnesian (Mg/Fe≈1,.5), low in Ti and Na as well as in Si (6.5-6.7 p.f.u. for 22 oxygens) (Table 1.). Rutile is near pure TiO_2.

Secondary phases

Amphibole is actinolitic hornblende after LEAKE's system (LEAKE 1978; LEAKE et al., 1997). It shows only a slight but characteristic zoning. From the core towards the rim the continuous increase of Al^{IV} and $(Na+K)^A$ while decrease of Si, Al^{VI} and Na^{M4} are the most significant changes (*fig. 4/a., b.;* table 1.). Sphene is low in Al, so can be regarded as pure $CaTiSiO_5$ (RIBBE, 1980).

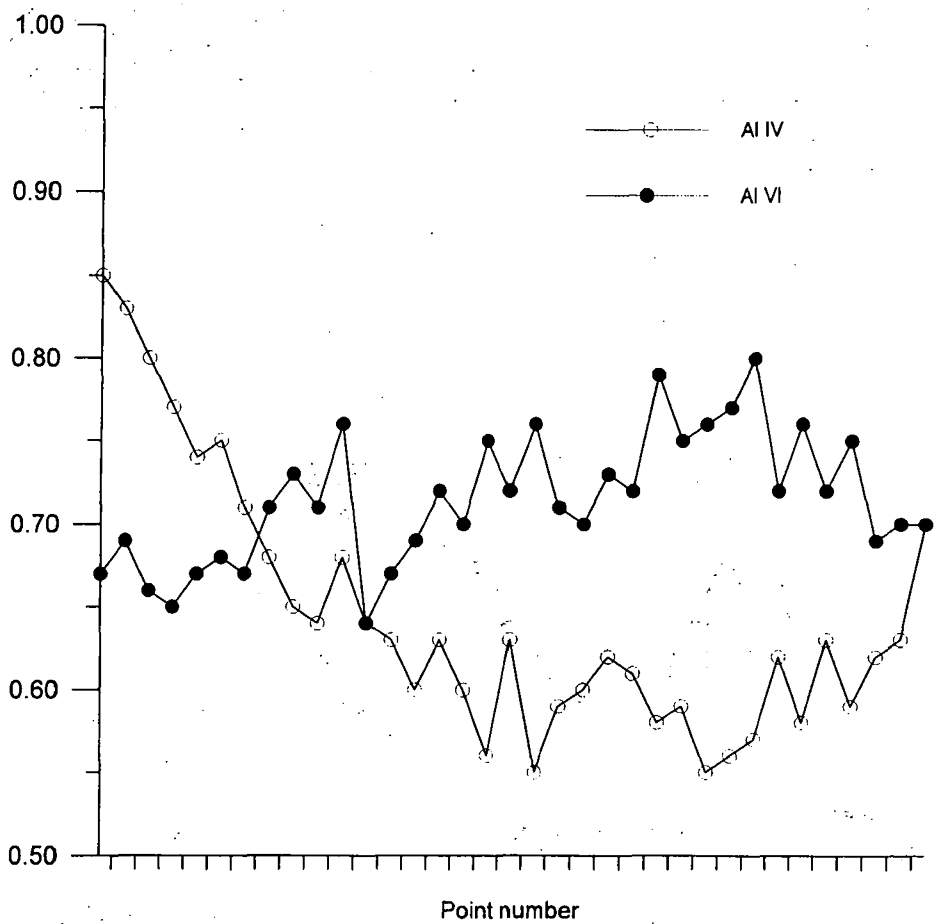

Fig. 4/a. Selected rim-to-rim sections of a secondary amphibole grain (Al^{IV}, Al^{VI}; each lag equals to 10 μm). The amphibole composition has been calculated based on the assumption ∑Ca=15.

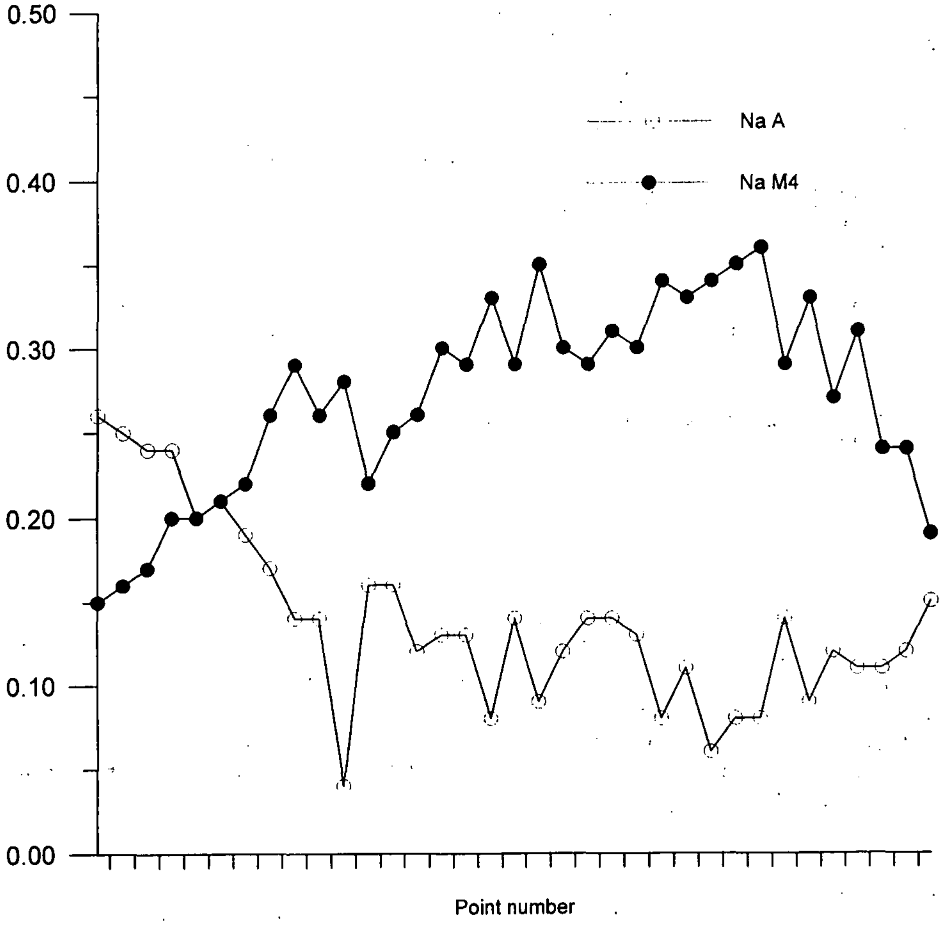

Fig. 4/b. Selected rim-to-rim sections of a secondary amphibole grain (Na^A, Na^{M4}; each lag equals to 10 μm). The amphibole composition has been calculated based on the assumption $\sum Ca=15$.

PT CONDITIONS

In the absence of any stable HP paragenesis the peak conditions of the eclogite facies metamorphism may only roughly be estimated. Because no original pyroxene composition is available, the most commonly used garnet-pyroxene Fe-Mg exchange reaction (ELLIS and GREEN, 1979; KROGH, 1988) can not be applied. So, the core compositions of the garnet and phengite will be utilized. Medium pyrope content of the garnet is characteristic for B type eclogites (COLEMAN et al., 1965). Assuming temperature not higher than 650 °C is consistent with this datum. In this case the Si-content of phengite suggests 10-12 kbar as a minimum pressure (MASSONE and SCHREYER, 1987). Assuming this pressure interval when applying different garnet-phengite thermometers (GREEN and HELLMAN, 1982; KROGH and RAHEIM, 1978) for the core parageneses, a 600-650 °C temperature interval can be calculated systematically. For both higher and lower pressures the temperature data scatter significantly. Although, both the estimated P and T intervals are rather wide (10-12 kbars; 600-650 °C), they are consistent with each other and so can be accepted.

Characterization of the breakdown path of the eclogite by using different retrograde parageneses commonly occuring in the sample seems valid. To do this the following two cases are examined:

[1] garnet+rutile+kyanite+sphene+plagioclase+quartz,

[2] kyanite+clinozoisite+margarite+quartz.

The paragenesis [1] may often be identified in thin section. Garnet usually contains rutile and rarely also kyanite inclusions. Matrix rutile grains are always rimmed by sphene while garnet has a plagioclase rim around it. Possible reactions in this paragenesis may be described in the SiO_2 - Al_2O_3 - FeO - TiO_2 - CaO system, and the following linearly independent reactions exist:

(1) grossularite+2 kyanite+quartz=3 anorthite,

(2) anorthite+rutile=sphene+kyanite,

(3) grossularite+3 rutile+quartz=3 sphene+kyanite,

(4) grossularite+2 rutile+quartz=2 sphene+anorthite.

The other paragenesis needs the SiO_2 - Al_2O_3 - CaO - H_2O system and there is only one possible reaction:

(5) 5 kyanite+2 clinozoisite+3 H_2O=4 margarite+3 quartz.

All listed minerals are suitable for thermobarometric calculation and most of them need no special activity models. Rutile, kyanite, margarite and quartz are assumed to be ideal just as sphene. In this latter case the low Al-content of the mineral allows leaving solution model calculations out. Activities of garnet end member components were calculated using the model of GANGULY and SAXENA (1984), while in the case of plagioclase the model of FUHRMAN and LINDSLEY (1988) was applied. Thermodynamic calculations were performed with a TWQ software using the JUN92.GSC internally consistent thermodynamic database of BERMAN (1988).

Phases specified as paragenesis [1] are all in equilibrium with each other, where reactions (1)-(4) intersect on the PT space. This point represents one step of the breakdown history. The intersection of the four reactions has been calculated in the case of five inclusion-bearing garnet grains. Composition of only garnet and plagioclase has been measured, all the other minerals were assumed to be ideal. To get the position on the P-T space where the system is in equilibrium the program INTERSX contained in TWQ (BERMAN, 1991) were used. P-T results proved very similar in each case, T is 500-520 °C, while P is in the range of 8.0-8.9 kbar (*fig. 5.*).

Application of the paragenesis [2] and namely the reaction (5) for estimating the breakdown conditions is rather uncertain because of the significant role of H_2O. Depending on whether the activity of H_2O is high or low, the equilibrium may vary in a wide range. Theoretically, an eclogitic remnant may be preserved in a relatively dry environment, thus a low H_2O content may be postulated. Equilibrium in the case of two possible activities (0.3, 0.5) of H_2O were calculated by TWQ (BERMAN, 1991) using the database of BERMAN (1988). Results are plotted on *fig. 5.* On this graph one can see that the retrograde path of the eclogite goes likely down to the greenschist facies. Although, the physical conditions of this low temperature phase cannot be modelled exactly, the lowest temperature is definitely below the stability field of the amphibolite facies overprint.

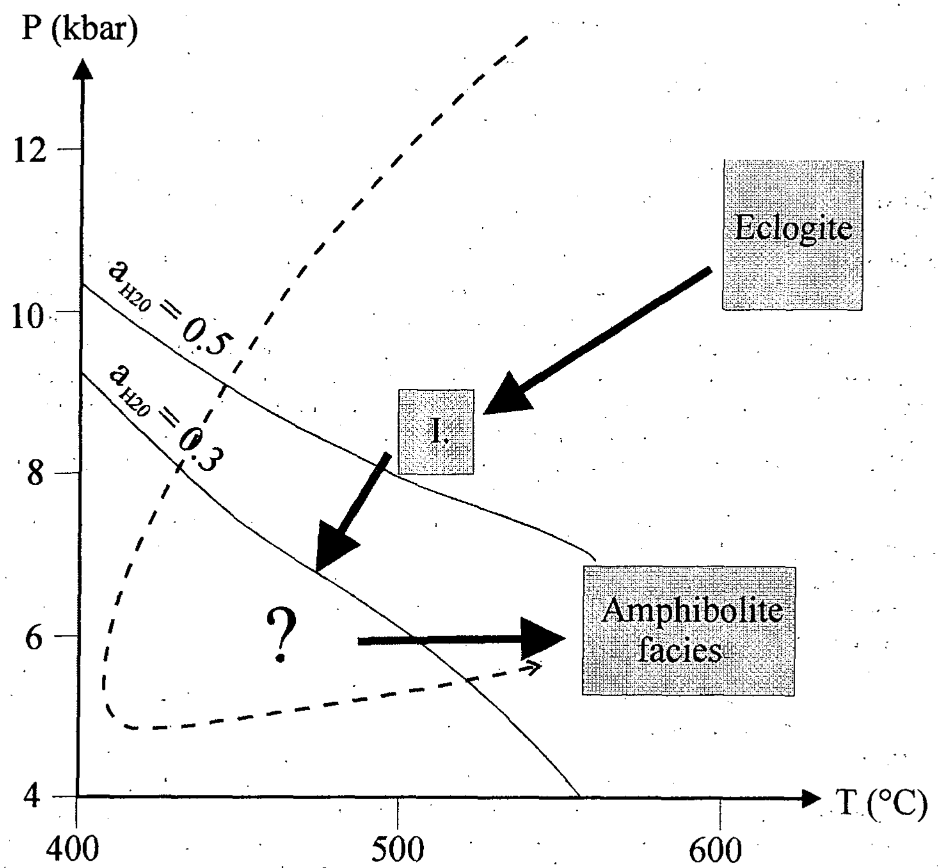

Fig. 5. Estimated PT evolution of the Szarvas eclogite sample. Broken line reminds of the evolution of the retrograded eclogite from Kőrösladány-5 borehole (M TÓTH, 1995).

Even garnet grains which are overgrown by the secondary amphibole have the plagioclase corona around, indicating that the breakdown of the HP rock preceded the appearance of the amphibole. The nature of the chemical zoning of the secondary amphibole grains is similar in both textural positions discussed above. All the characteristic changes, the increase of Al^{IV} and $(Na+K)^{A}$ suggest that amphibole grew due to increasing temperature (BARD, 1970; SPEAR, 1981). These data suggest that the breakdown of the HP rock was followed by an amphibolite facies overprint.

CONCLUSIONS

Similarly to the other metabasic rocks of the KC, also the eclogite sample studied is tholeiitic basalt. The characteristic light element enrichment (*fig. 2.*) relative to N-MORB suggests evolution on destructive plate margin. In contrast, however, to the other samples the retrograded eclogite exhibits a depletition in Nb, Zr and Y. Based on this composition this rock may be considered to be island arc basalt rather than back-arc basin tholeiite, which has been documented for the majority of other amphibolites from the region. There is, however, no tectonic reason to suppose that the eclogite represents a different igneous series.

The estimated HP conditions and the further metamorphic evolution of the eclogite sample are in good agreement with the development of other high pressure relics from the KC (M. TÓTH, 1995, 1996) and especially with the other eclogite sample (*fig. 5*). All these rocks evolved on low to medium temperature, no HT samples have been detected. The peak conditions were followed by retrograde evolution down to the greenschist facies and a progressive amphibolite facies overprint afterwards. The identical two-stage evolution can be seen also in the case of the current eclogite sample. Diminishing of both P and T after the eclogite facies peak are indicated by the estimated pyhysical conditions of the two retrograde parageneses [1] and [2], respectively (*fig. 5.*). This retrograde evolution was followed by the progressive barrovian type overprint exhibited by the chemical zoning of the secondary amphibole grains. Their rim composition is comparable to the amphiboles common in the KC amphibolites. Based on the detailed examination of several HP relics, this two-stage metamorphic evolution seems characteristic in the KC.

Occurence of a HP relict (RAVASZ-BARANYAI, 1969) and several ultramafic bodies (SZEDERKÉNYI, 1974; GHONEIM and SZEDERKÉNYI, 1979; BALLA, 1983) in the Transdanubian part of the Tisia as well as the eclogite samples in the KC gave way to the assumption that the two regions may geologically belong together (SZEDERKÉNYI, 1996). A narrow zone is assumed and interpreted as a remnant of a Pre-Variscan suture. There are, however, significant diferences between the metamorphism of the two eclogite types. The Görcsöny eclogite sample is interpreted as a high temperature eclogite, it contains orthopyroxene as a retrograde phase. In this case amphibole also appears as a retrograde mineral in contrast to all the HP samples from the KC. The metamorphic evolution of the HP rocks in the two regions is fundamentally different, so they probably formed in different tectonic situations. Additionally, although, in the Transdanubian part occurence of ultramafic bodies is rather common, in the KC no one has been found so far. Consequently, the Pre-Variscan connection of the two eclogite-bearing parts of the Tisia composite terrane seems questionable and needs further investigations.

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REFERENCES

AFIFI, A. M.; ESSENE, E. J. (1988): MINFILE: A microcomputer program for storage and manipulation of chemical data on minerals. American Mineralgist, **73**, 446-448

BALLA, Z. (1983): A Dél-dunántúli ultrabázitok lemeztektonikai értelmezése (Tectonic interpretation of South-Transdanubian ultramafics). (In Hungarian) Földtani Közlöny, **113**, 39-56

BARD, J. P. (1970): Compositions of hornblendes during the Hercynian progressive metamorphism of the Aracene metamorphic belt (SW Spain). Contrib Mineral Petrol, **28**, 117-134

BERMAN, R. G. (1988): Internally-consistent thermodynamic datafor stoichiometric minerals in the system Na_2O-K_2O-CaO-MgO-FeO-Fe_2O_3-Al_2O_3-SiO_2-TiO_2-H_2O-CO_2. J. Petrol., **29**, 445-522

BERMAN, R. G. (1991): Thermobarometry using multi-equilibrium calculations: a new technique with petrological applications. Can. Mineral., **29**, 833-856

BUDA, GY. (1981): Genesis of the Hungarian granitoid rocks. Acta Geol. Acad. Sci. Hung., **24/2-4**, 309-318

BUDA, GY. (1985): Variszkuszi korú kolliziós granitoidok képződése Magyarország, Ny-Kárpátok és a Központi Cseh-masszívum granitoidjainak példáin. (Genesis of collision type Variscan granitoides in Hungary, Western-Carpatians and in the Bohemian Massif.) Ph.D. thesis, ELTE Budapest, in Hungarian

COLEMAN, R. G.; LEE, D. E.; BEATTY, L. B.; BRANNOCK, W. W. (1965):Eclogites and eclogites: their differences and similarities. Geological Society of America Bulletin, **76**, 483-508

DIAMOND, L. W.; SCHMATZ, D.; WÜRSTEN, F. (1994): „Standard library": A relational database for the management of electron microprobe standards. Computers and Geosciences, **20**, 585-595

ELLIS, D. J.; GREEN, D. H. (1979): An experimental study of the effect of Ca upon garnet-clinopyroxene Fe-Mg exchange equilibria. Contrib. Mineral. Petrol., **71**, 13-22

FUHRMAN, M. L.; LINDSLEY, D. H. (1988): Ternary-feldspar modeling and thermometry. American Mineralogist, **73**, 201-215

GANGULY, J.; SAXENA, S. K. (1984): Mixing properties of alumosilicate garnets: constraints from natural and experimental data, and applications to geothermo-barometry. American Mineralogy, **69**, 88-97

GHONEIM, M. F.; SZEDERKÉNYI, T. (1979): Petrological rewiev of the Ófalu serpentinite, Mecsek Mountains, Hungary. Acta Miner., Petr., Szeged, **24/1**, 5-18

GREEN, T. H.; HELLMANN, P. L. (1982): Fe-Mg partitioning between coexisting garnet and phengite at high pressure, and comments on a garnet-phengite geothermometer. Lithos, **15**, 253-266

HAAS, J.; KOVÁCS, S.; KRYSTYN, L.; LEIN, R. (1995): Significance of Late Permian-Triassic facies zones in terrane reconstructions in the Alpine-North Pannonian domain. Tectonophysics, **242**, 19-40

KOVÁCS, S.; SZEDERKÉNYI, T.; ÁRKAI, P.; BUDA, GY.; LELKES-FELVÁRI, GY.; NAGYMAROSY, A. (1996): Explanation to the terrane map of Hungary. Report of the IGCP project. No. 276. Athen, in press

KROGH, E. J. (1988): The garnet-clinopyroxene Fe-Mg geothermometer - reinterpretation of existing experimental data. Contrib Mineral Petrol, **99**, 44-48

KROGH, E. J.; RAHEIM, A. (1978): Temperature and pressure dependence of Fe-Mg partitioning between garnet and phengite, with particular reference to eclogites. Contrib. Mineral. Petrol. **66**, 75-80

LEAKE, B. E. (1978): Nomenclature of amphiboles. American Mineralogist, **63**, 1023-1052

LEAKE, B. E.; WOOLEY, A. R.; ARPS, C. E. S.; BIRCH, W. D.; GILBERT, M. C.; GRICE, J. D.; HAWTHORNE, F. C.; KATO, A.; KISCH, H. J.; KRIVOVICHEV, V. G.; LINTHOUT, K.; LAIRD, J.; MANDARINO, J. (1997): Nomenclature of amphiboles: Report of the Subcommittee on Amphiboles of the International Mineralogical Association Commission on New Minerals and Mineral Names. Mineralogical Magazin, **61**, 295-321

LISTER, G. S.; DAVIS, G. A. (1989): The origin of metamorphic core complexesand detachment faults formed during Tertiarycontinental extension in the northern Colorado River region, U.S.A. J. Struct. Geol., **11**, 65-94M TÓTH, T. (1994/a): *A Tiszai egység amfibolitjainak premetamorf fejlődéstörténete és metamorfózisa* Szeghalom környékén. (Premetamorphic origin and metamorphic evolution of amphibolites of the Tisia in the vicinity of Szeghalom.) Ph.D. thesis, JATE, Szeged, in Hungarian

M TÓTH, T. (1994/b): The geochemical character of amphibolites from Tisza Unit on the basis of incompatible trace elements. Acta Miner., Petr., Szeged, **XXXV**, 27-38

M TÓTH, T. (1995): Retrograded eclogite in the crystalline basement of Tisza Unit, Hungary. Acta Miner., Petr., Szeged, **XXXVI**, 117-129

M TÓTH, T. (1996): *Magas nyomású metamorfózis nyomai a Tiszai Egység amfibolitjain* (Traces of high pressure metamorphism on the metabasic rocks from the Tisia, Eastern Hungary). Földtani Közlöny, **126/1-2**, 37-52

MASSONE, H. J.; SCHREYER, W. (1987): Phengite geobarometry based on limiting assemblage with K-feldspar, phlogopite and quartz. Contributions to Mineralogy and Petrology, **96**, 212-224

MIYASHIRO, A. (1974.): Volcanic rock series in island arcs and active continental margins. American Journal of Science, **274**, 321-355.

MIYASHIRO, A.; SHIDO, F. (1975): Tholeiitic and calc-alcalic series in relation to the behaviors of titanium, vanadium, chromium and nickel. American Journal of Science, **275**, 265-277

MORIMOTO, N.; FABRIES, J.; FERGUSON, K.; GINZBURG, I. V.; ROSS, M.; SEIFERT, F. A.; ZUSSMAN, J.; AOKI, K.; GOTTARDI, G. (1988): Nomenclature of pyroxenes. American Mineralogist, **73**, 1123-1133

PIN, C. (1990): Variscan oceans: Ages, origins and geodynamic implications inferred from geochemical and radiometric data. Tectonophysiscs, **177**, 215-227

RAVASZ-BARANYAI, L. (1969): Eclogite from the Mecsek mountains, Hungary. Acta Geol. Ac. Sci. Hung., **13**, 315-322

RIBBE, P. H. (1980): Orthosilicates. (Reiews in Mineraology vol. 5.). Mineralogical Society of America, pp 450

SPEAR, F. S. (1981): An experimental study of hornblende stability and compositional variability in amphibolite. American Journal of Science, **281**, 697-734

SZEDERKÉNYI, T. (1974): Paleozoic magmatism and tectogenesis in Southeast Transdanubia. Acta Geol. Ac. Sci. Hung., **18**, 305-313

SZEDERKÉNYI, T. (1984): Az Alföld kristályos aljzata és földtani kapcsolatai. (The crystalline basement of the Great Hungarian Plane and its geological connections.) Academic doctor theses, Hungarian Academy of Sciences, Budapest

SZEDERKÉNYI, T. (1996): Metamorphic formations and their correlation in the Hungarian part of the Tisia megaunit (Tisia megaunit terrane). Acta Miner., Petr., Szeged, **XXXVII**, 143-160

SZEDERKÉNYI, T.; ÁRKAI, P.; LELKES-FELVÁRI, GY. (1991): Crystalline groundfloor of the Grat Hungarian Plain and South Transdanubia, Hungary. Serbian Academy of Sciences and Arts, Academic Conferences, **62**, 261-273

TARI, G.; HORVÁTH, F.; RUMPLER, J. (1992): Styles of extension in the Pannonian Basin. Tectonophysics, **208**, 203-219

WINCHESTER, J. A.; FLOYD, P. A. (1977): Geochemical discrimination of diferent magma series and their differentiation products using immobile elements. Chemical Geology, **20**, 325-343

TABLE 1.

Representative analysis of the primary and secondary phases of the eclogite sample

	garnet	clinopyroxene	phengite	amphibole core	amphibole rim	margarite
SiO_2	39.01	52.16	49.51	49.70	46.70	28.09
TiO_2	0.13	0.22	0.00	0.25	0.25	0.00
Al_2O_3	23.42	1.16	28.25	5.31	8.51	50.82
FeO	18.78	8.41	2.13	13.58	14.04	0.56
MnO	0.66	0.50	0.00	0.26	0.24	0.00
MgO	9.50	12.79	3.05	13.88	12.71	0.55
CaO	8.52	24.69	0.06	10.90	10.31	12.57
Na_2O	0.00	0.26	0.05	0.47	0.87	0.48
K_2O	0.00	0.00	10.35	0.14	0.22	0.13
Total	100.20	100.18	93.39	94.49	93.85	93.20

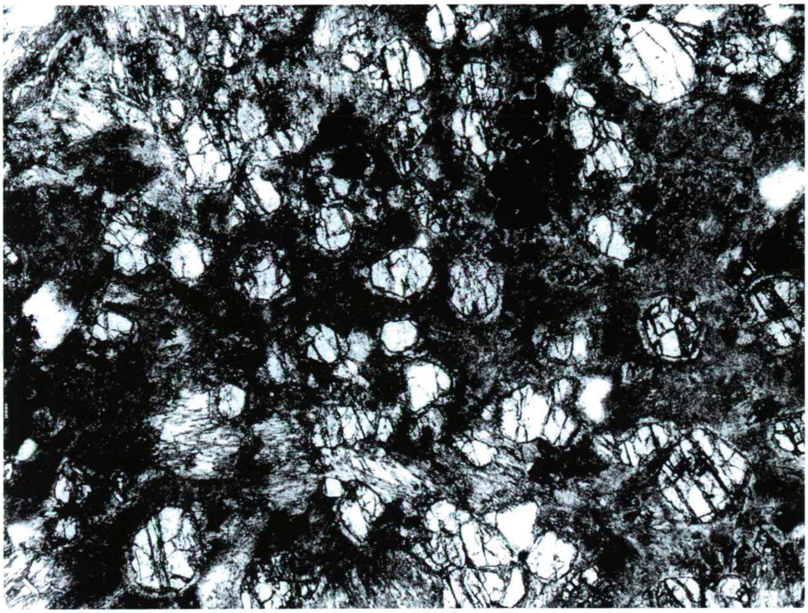

Plate I/1.
Very fine grained symplectitic texture of the Szarvas-16 eclogite with erroded garnet grains.

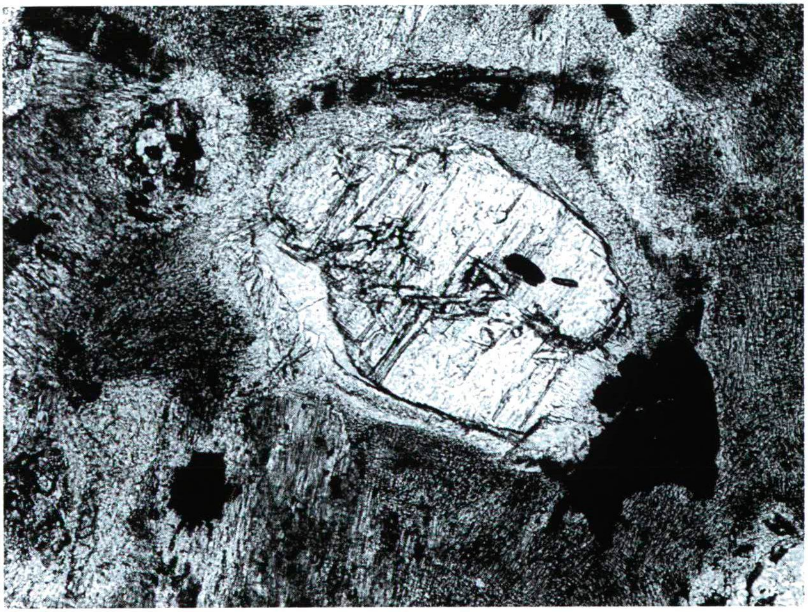

Plate I/2.
Primary kyanite is enclosed by margarite. Also see the fine grained pseudomorphs after pyroxene.

Plate I/3.
The cluster of elongated clinozoisite grains is replaced by undefinable set of secondary minerals

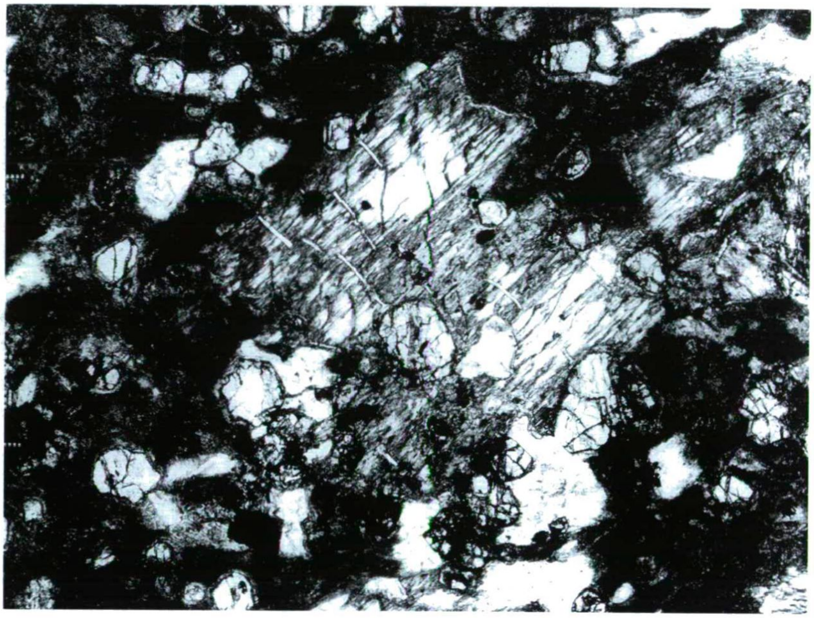

Plate I.4.
Secondary amphibole intergrows with the eclogite garnet. Note that the garnet is surrounded by a fine grained plagioclase-amphibole corona.