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RETROGRADED ECLOGITE IN THE CRYSTALLINE BASEMENT OF TISZA UNIT, HUNGARY

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ABSTRACT

Crystalline basement of Eastern part of Tisza Unit in Hungary has been said to be built up of amphibolite facies rocks. However, some samples of these contain relics of an earlier high pressure event and sporadically eclogitic remnants also occur. A symplectitic rock from borehole Kőrösladány-5 includes garnet fragments (Py ≈ 30%), phengite, rutile and also pseudomorph after alkali pyroxene. These traces corresponding to other mineralogical observations imply a one-time B or C type eclogitic material.

INTRODUCTION

Crystalline basement of Tisza Unit (Pannonian Basin) consists of mica schist and gneiss as the most common metamorphic rocks. There are also some amphibolite bodies forming thin intercalations in the other metamorphites. The mineralogical composition and textural features of these rocks refer to a Barrow type metamorphism with a peak condition of medium pressure and temperature. In the southern part of the Unit (Codru nappe) andalusite bearing metamorphites occur as well, suggesting a LP phase of metamorphic history (SZEDERKÉNYI, 1984). There has also been very little data of high pressure metamorphism in the northern part of Tisza Unit. The first information on HP rocks was an eclogitic sample found in the borehole Görcsöny-1 (RAVASZNÉ BARANYAI, 1969). This rock is retrograded and contains only pseudomorph after garnet and pyroxene referring to the preceding quality of it. In addition to this sample some relict parageneses were found in amphibolitic rocks in the eastern part of Biharian Autochthonous, which point to an earlier high pressure metamorphic phase (M. TÓTH, 1995a). As a result of a microscopic work both traces of eclogite and blueschist facies metamorphism were found. However, since all samples are sufficiently altered, only a detailed mineralogical study may confirm the existence of the earlier HP metamorphism.

In the near past I was allowed to measure significant minerals of an altered eclogite sample by electron microprobe at the University of Berne in Switzerland. The purpose of this paper is presentation of this sample and interpreting its significance in the crystalline basement of Tisza Unit.

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GEOLOGICAL SETTING

Tisza Unit is located in south and south-east Hungary and also may be traced in Rumania, Serbia and Croatia. In the Palaeozoic time it was a part of the European basement and got to its present setting due to Alpine movements. During Alpine orogenesis a complicated nappe structure formed in the Tisza Unit. The subsequent nappes differ from each other petrologically and may be traced on the surface in the Apuseni Mountains. In Hungary the existence of "Biharian Autochthonous" and Codru nappe has been inferred so far (SZÁDECZKY–KARDOSS, 1970; SZEDERKÉNYI, 1984; BALÁZS et al., 1984). Since metamorphic rocks in the Hungarian part of Tisza Unit are covered by more than 2000 m thick young sediments, only crystalline rocks from borecores may be examined.

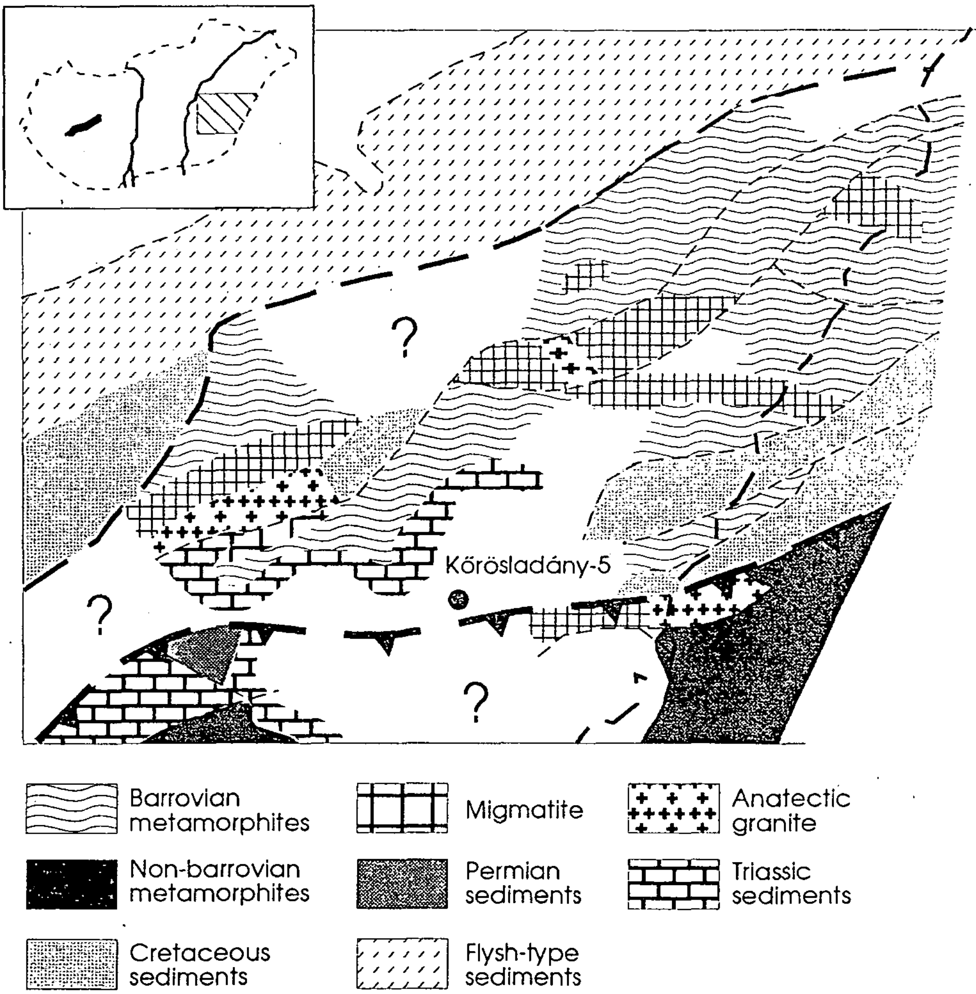

Fig. 1. Simplified geological map of Eastern Tisza Unit and location of borehole Kőrösladány-5

The sample in question came from borehole Kőrösladány-5 (*Fig. 1*) which is in the area of Biharian Autochthonous (SZEDERKÉNYI, 1984) not far (about 10 km-s) from the border of Codru nappe. Surrounding borecores consist mainly of micaschist and gneiss. Relative to other parts of Tisza Unit, in this small sub-area, amphibolite is also a frequent rock type. Detailed geochemical examination showed the protolith of these metabasic rocks back-arc basin type tholeiite (M. TÓTH, 1994). Further geochemical and multivariate mathematical methods inferred that amphibolite samples preserve subsequent stages of a former-tholeiitic differentation trend (M. TÓTH, 1995b). Amphibolite samples from boreholes in question all represent a primitive or partially differentiated T-MORB basalt. Petrologically all these metamorphosed basalt samples, but one, have equilibrium texture and consist of minerals of common amphibolite paragenesis (LAIRD, ALBEE, 1981): Ca-amphibole, plagioclase, with or without garnet, epidote, quartz. However, these samples also suggest uncertain signs of previous high pressure (M. TÓTH, 1995a). Hornblende often contains a big quantity of albite rimmed inclusions of magnetite referring to a reaction product of an earlier sodic amphibole (YARDLEY, 1982). Mica schist and gneiss have not been reported yet to show any relict high pressure paragenesis, though these rock types have not been investigated in detail yet.

There is only one sample which contains high pressure minerals and relict textural characteristics referring to an earlier eclogite facies metamorphism.

MINERALOGICAL FEATURES OF THE RETROGRADED ECLOGITE SAMPLE

The sample is characterized by a conspicuous duality. The bigger part of it has symplectitic texture (*Fig. 2/a*). Mineralogical composition of a pseudomorph is fairly difficult to recognize under microscope. It consists of a set of very fine grained amphibole, plagioclase and white mica. As amphibole is almost colourless its composition must be close to tremolite. Sometimes chlorite and epidote may be identified. All of these symplectites have a zoned structure. The fine grained core is rounded by coarser grains of plagioclase. Between these relics of earlier minerals newly formed amphibole occurs forming a duality of a rock (*Fig. 2/a*). These amphibole grains have a pale green colour opposite to those in the pseudomorphous part of the rock. Occasionally small garnet grains occur in this rock with many opaque minerals (magnetite, ilmenite) and also some biotite around them (*Fig. 2/b*). The frequency of this secondary paragenesis suggests that the rock before the alteration may have contained conspicuous amount of big garnet grains.

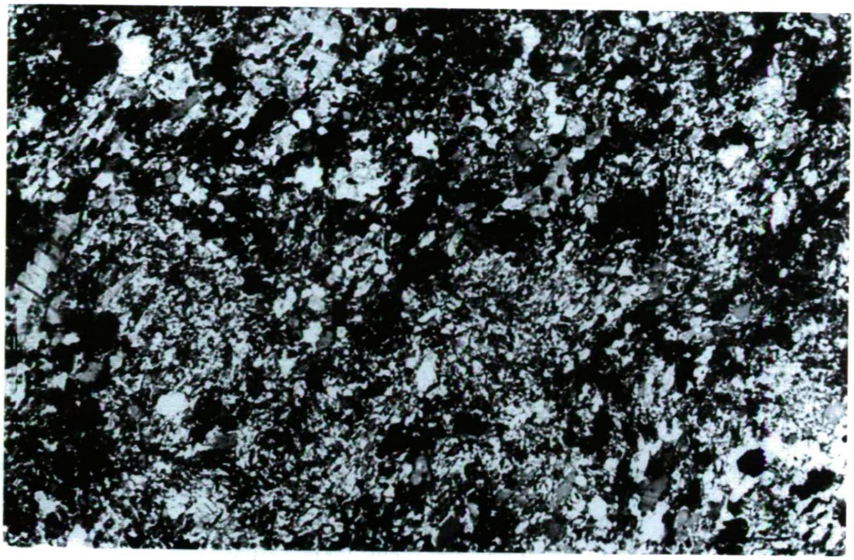

Fig. 2. (a) Secondary amphibole and plagioclase around fine grained symplectite of tremolite, albite and white mica.

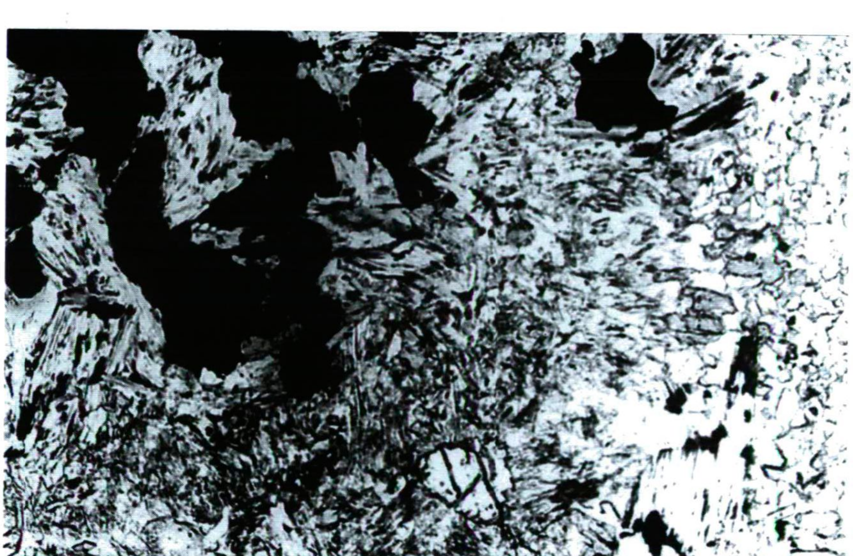

Fig. 2. (b) Small garnet relict as well as secondary biotite and opaque minerals

GARNET

The rock sample studied contains only a very few garnet grains, all small in size. However, garnet is always surrounded by the minerals mentioned above implying that these garnet fragments are the remains of a previously larger grain existed in an earlier stage of metamorphic history. Relict garnet grains are not zoned chemically, and they all have a very similar composition. Representative garnet analyses are given in Table 1, while calculated end-members are plotted in *Fig. 3*. The relatively high pyrope content (about 30%) of garnet shows that this mineral may have formed under eclogite facies. The typical composition of garnet examined belong to the border of B and C type eclogite fields (COLEMAN et al., 1965).

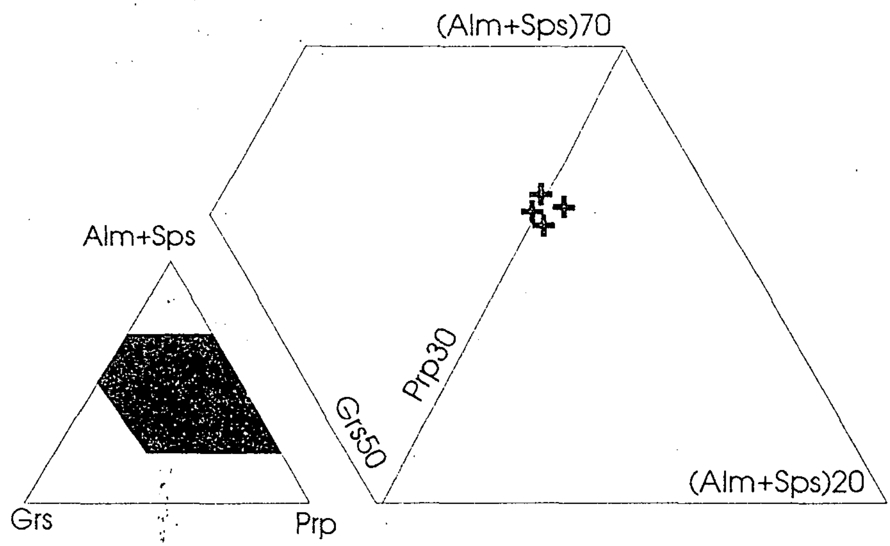

Fig. 3. Garnet analyses plotted in the (Alm+Sps)–Prp–Grs triangular diagram of COLEMAN et al. (1965)

TABLE 1

Representative chemical analysis of characteristic minerals

	Garnet	Amphibole$_1$	Amphibole$_2$	White mica	Ilmenite
SiO_2	39.06	49.70	40.55	49.51	0.00
TiO_2	0.04	0.25	0.49	0.00	60.34
Al_2O_3	22.60	5.31	15.29	28.25	0.00
FeO	20.59	13.58	15.45	2.13	36.84
MnO	0.40	0.26	0.26	0.00	2.51
MgO	7.74	13.88	9.45	3.05	0.00
CaO	8.65	10.90	10.44	0.06	0.18
Na_2O	0.00	0.47	1.65	0.05	0.00
K_2O	0.00	0.14	0.61	10.35	0.00
Total	99.08	94.49	94.19	93.40	99.88

AMPHIBOLE

Amphibole has two typical occurences in the sample examined. There are colourless amphibole paths very small in size in the symplectitic part of the rock forming the first amphibole generation. There is also a secondary generation of amphiboles around the margins of symplectites. These latter grains are strongly pleochroic, and differ from symplectite amphiboles in both shape and size. Representative amphibole analyses of both types are given in Table 1. Different important parameters are plotted on *Fig. 4.* This figure suggests that the two kinds of amphibole from an exact series of development. In general, symplectitic ones are close to tremolite in composition. These grains are magnesian and have little tetrahedral alumina, they contain essentially no sodium in the M4 site and only few alkalies in the A site. This composition may be expected for a low pressure and relatively low temperature phase (LAIRD, 1982). Secondary amphiboles, however, are pargasites and the diagrams on *Fig. 4.* clearly show the development of

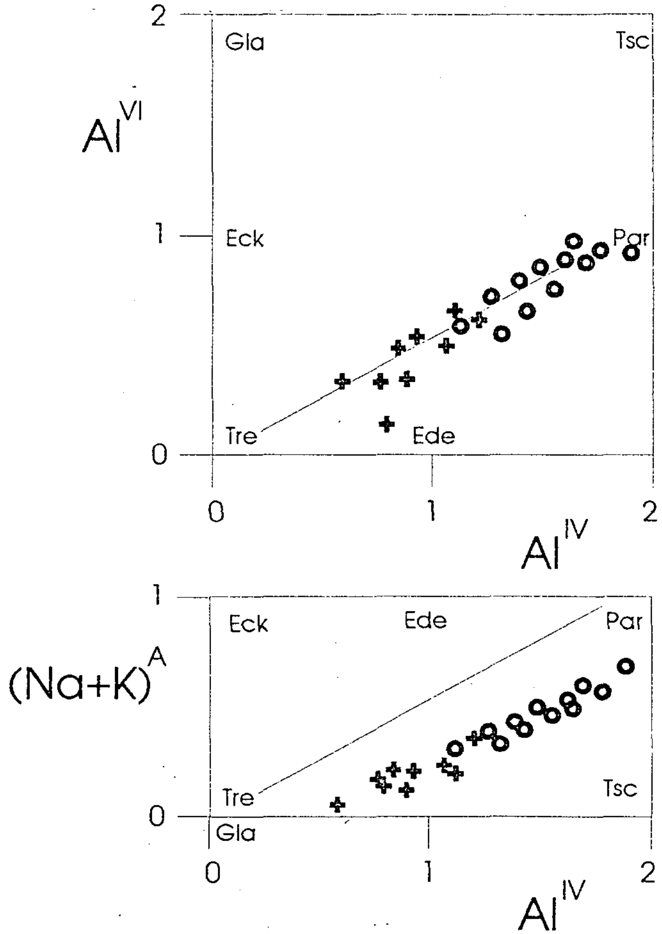

Fig. 4. Plotting of amphibole analyses in Al^{IV}–Al^{VI} and Al^{IV}–$(Na+K)_A$ diagrams. Evolutional trends suggest the significance of tschermak and edenite substitution. Sign "+" represents sypmlectitic grains while sign "o" secondary grains

amphibole grains from tremolitic towards the near pargasitic composition. That is, tschermak (Mg_{-1} Si_{-1} Al^{IV} Al^{VI}) and edenite (λ_{-1} Si_{-1} Na^{A} Al^{IV}) substitution must have played a significant role in change of amphibole composition, refererring to increasing temperature during metamorphic history (BANNO, 1964; BARD, 1970; HIETANEN, 1974).

PLAGIOCLASE

Both fine grained symplectite and the secondary part of the rock contain plagioclase in significant amount. Symplectites always contain plagioclase and most of these relict structures are surrounded by plagioclase grains yielding a zoned building of them. Plagioclase also occurs together with pargasitic amphiboles as secondary mineral. Chemically two discrete groups of feldspar are present, albite (An < 5%) and a more Ca-rich face (35% < An < 45%) (Fig. 5.). Though this distinction is evident, the tendency of their occurrence in space is obscure. As a secondary mineral only the An-rich plagioclase can be found, however, symplectites contain grains of both compositions. Probably, albite forms the original symplectitic face, while An-rich plagioclase occurs due to increasing temperature of metamorphism.

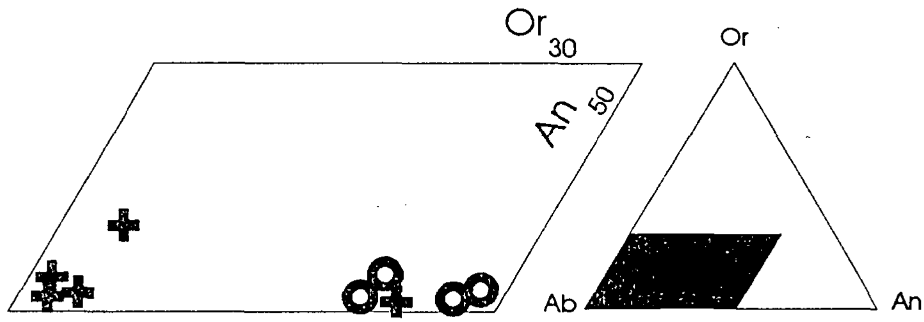

Fig. 5. Plagioclase analyses plotted on Ab–An–Or triangular diagram. Sign "+" represents symplectitic grains while sign "o" secondary grains

OTHER MINERALS

In addition to tremolite and albite, symplectites also contain different amounts of white mica. These grains are muscovites with a various phengitic component, silica in tetrahedral position differs between 3.2 and 3.3 with one outstanding value (3.46) (Fig. 6.). The high phengite content of the white mica may imply this mineral to be an eclogitic remnant. Na-content of the mica (paragonite) is low, < 15%.

The breakdown of garnets, presented in detail above, yielded biotite and ilmenite. Biotite is magnesian (X_{Fe} < 0.5) and relatively poor in Ti (0.17–0.22). Ilmenite occurs always in intergrowth with very fine-grained rutile needless suggesting that the original garnet, as eclogitic garnets commonly do, contained rutile inclusions. Mn-concentration in ilmenite (pyrophanite) is rather high (MnO > 2.5%).

The sample examined also contain a small amount of chlorite, epidote, tremolite and magnetite forming small symplectites together with albite.

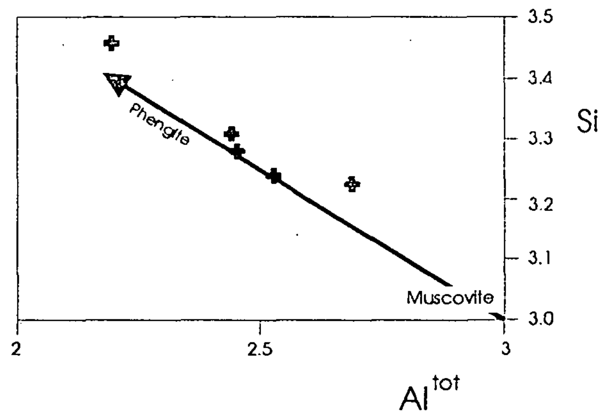

Fig. 6. Evolution of white mica on the Altot–Si diagram

THERMOBAROMETRY

Since, not even a little part of the examined sample shows an equilibrium texture, neither of possible geothermometers or geobarometers (garnet-biotite, plagioclase-amphibole, GRISP, etc.) may be applied. However, the compositional change of different relict and newly formed minerals may let us estimate the physical conditions of the metamorphic history. Chemical composition of the few garnet fragments suggests that the original metamorphic rock before any retrograde alteration may have been a B or C type eclogite (*Fig. 3.*). Theoretically, the temperature border between the two varieties is at 550 °C as an initial temperature of metamorphism may only be accepted approximately. Estimation of pressure in low temperature eclogite is problematical even in the case of stable eclogite (GHENT, STOUT, 1994). Supposed white mica (phengite) is also a relict eclogitic mineral, its chemical composition may give more information about the initial conditions of the eclogite facies metamorphism. The low paragonite-content of white mica implies temperature not lower than 450 °C based on diagrams of SASSI et al. (1994). Presuming the temperature about 500 °C, the Si-content of phengite yields pressure in the range of 10–13 kbar (MASSONE, SCHREYER, 1987).

The occurence of the tremolite+epidote+magnetite+albite+chlorite paragenesis in the retrograded eclogite may point to the previous existence of crossite as original component of eclogite (BROWN, 1977; YARDLEY, 1982; MARUYAMA et al., 1986). Assuming the appearance of alkali amphibole as initial high pressure constituent one can confirm that eclogite was metamorphosed under low to medium temperature (< 550 °C) (MARUYAMA et al., 1986 and references therein).

Although the sample examined contain no pyroxene grain, the previous existence of this mineral may be assumed. The first step of retrograde breakdown of eclogitic pyroxene is the formation of a less jadeite-rich pyroxene and a Na-rich plagioclase. Later, the secondary pyroxene grains are substitued by amphibole, white mica and more plagioclase. These processes result in a symplectitic intergrowth of amphibole and plagioclase (O'BRIEN, 1993).

The fact that no orthopyroxene formed in the place of original eclogitic clinopyroxene as a secondary mineral suggests that retrogression may have been characterized by decreasing temperature (O'BRIEN, 1993). This estimated tendency of breakdown history is confirmed also by the chemical character of garnet replacing minerals: ilmenite and biotite. The Mn-content of ilmenite (proportion of pyrophanite) is higher the lower the metamorphic temperature of formation is (POWNCEBY et al., 1987a, 1987b). This value in the ilmenite grains from our sample is much higher than it would be expected in the realm of amphibolite or granulite facies. The low content of titanium in biotite implies the greenschist grade formation of it (GUIDOTTI, 1984) verifying the low breakdown temperature of the original eclogitic garnets. All these things considered, the breakdown of the original eclogite was controlled by decreasing both pressure and temperature.

Therefore, the mineral assemblage of symplectites, mainly tremolite and albite, represents the lowest P and T phase of metamorphic history. The appearance of these two significant minerals refers to the conditions of greenschist facies. The temperature of this phase must not have been higher than 450–480 °C and assumed pressure not higher than 5 kbar (*Fig. 7.*).

The only fresh minerals in the sample are Ca-amphibole with high pargasite content and plagioclase (An_{35-45}) representing physical conditions of amphibolite facies. Both tschermak substitution in amphibole and Ca enrichment in feldspar infer that greenschist facies was succeeded by increase of temperature. The stable amphibole-plagioclase paragenesis corresponds to that of amphibolite common in surrounding borecores. Metamorphic condition of these metabasic rock is calculated to be 580–600 °C and 4–6 kbar (SZEDERKÉNYI, 1984).

A sketch of the three subsequent phases of estimated metamorphic development of the retrograded eclogite sample is given in *Fig. 7*.

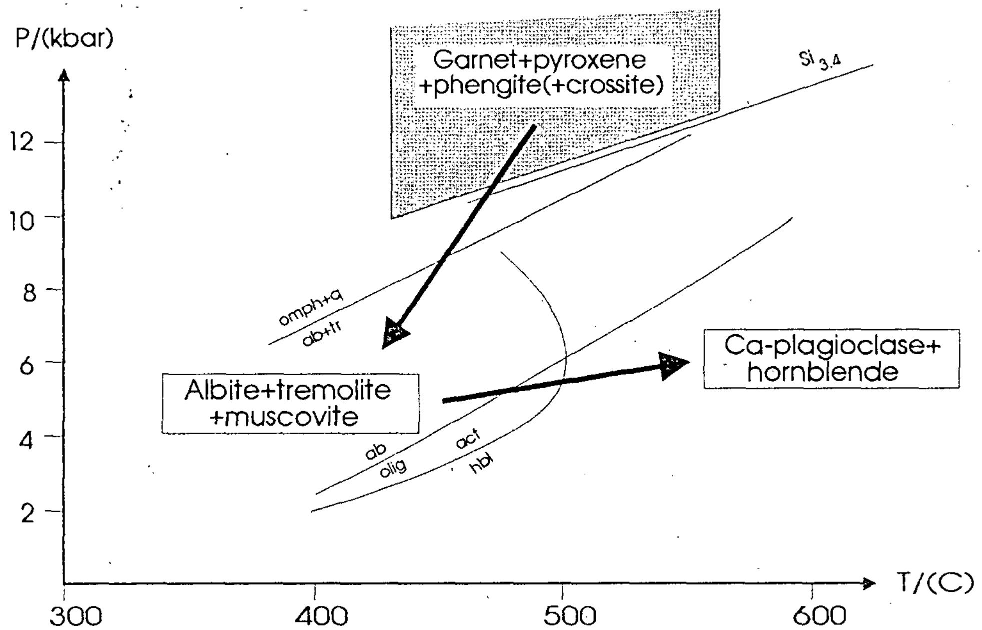

Fig. 7. Estimated PT-path of the eclogite from borehole Kőrösladány-5, stability fields of subsequent mineral parageneses and boundaries of important reactions. Albite-oligoclase and actinolite-hornblende transitions (MARUYAMA et al., 1983); isopleth of Si in phengite (MASSONE, SCHREYER, 1987); omphacite+quartz = albite+tremolite (NEWTON, 1986)

CONCLUSIONS

Based on detailed mineralogical investigation the retrograded eclogite sample from the borehole Kőröskladány-5 proved to be a B or C type eclogite. Unfortunately, the rock contain no stable high pressure paragenesis, so only the estimation of the physical condition of development is possible. Based on it, the rock was formed under low to medium temperature (450–550 °C), while the evaluated pressure was as least 10–13 kbar. The breakdown of the eclogite was controlled by decreasing temperature yielding vermicular symplectites of tremolite, albite and white mica in the place of previous clinopyroxene. The last progressive metamorphic effect was an amphibolite facies overprint corresponding to other metabasic rocks in the surrounding boreholes.

Previous works inferred that the protolith of amphibolite and other metabasic rocks from the investigated area was tholeiitic basalt formed in a back-arc basin (M. TÓTH, 1994). Recent papers on metamorphic as well as exhumation development of back-arc basins showed a special cooling history of such regions (*Fig. 8.*) (JOLIVET et al., 1994 and references therein). In the case of Naxos and Corsica the typical P-T path is characterized by low peak temperature (about 450 °C) and not very high peak pressure (lower than 14 kbar). The original HP-LT associations broke down to greenschist facies parageneses.

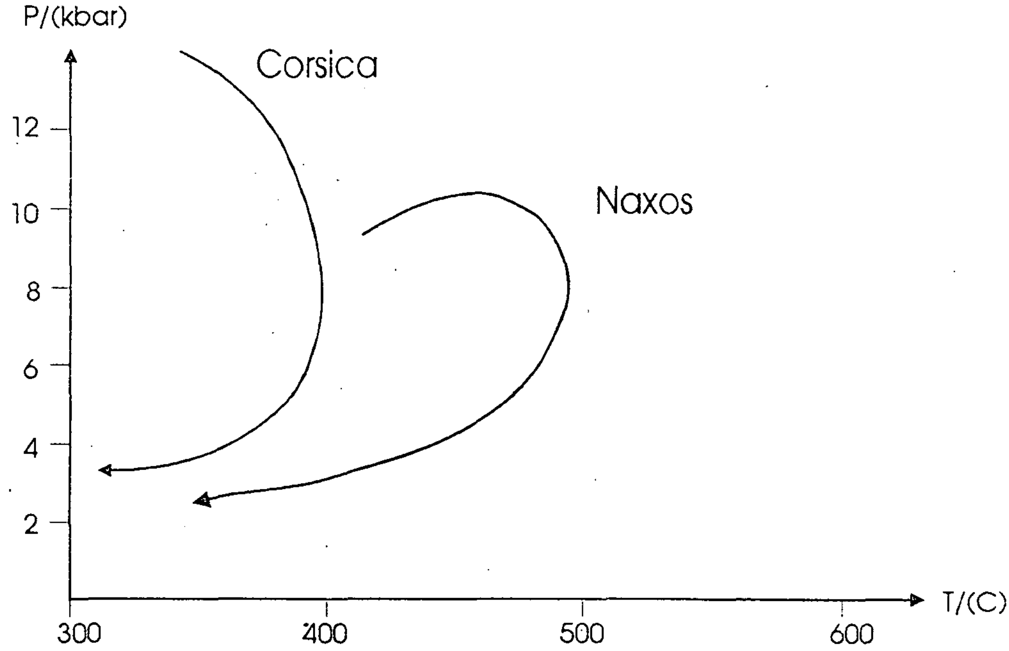

Fig. 8. Metamorphic development and cooling history of back-arc basins during exhumation (after JOLIVET et al., 1994).

All these features are similar to those were concluded from the retrograded eclogite from borehole Kőröskladány-5. Therefore, the metamorphic evolution of this sample corresponds to the previous findings that the investigated area of Tisza Unit belonged to a one-time marginal basin.

There are some papers as well as unpublished data which call attention to similar petrological, chronological etc. characteristics between Tisza Unit and the eastern part of European Variscides, especially Bohemian Massif. In addition to investigation of these correspondences the comparison of metamorphic evolution of HP rocks in the two areas seems important. In the Bohemian Massif the peak pressure and temperature of eclogitic rocks as well as the breakdown temperature of them decreases from south to north (O'BRIEN, 1993, MEDARIS et al., 1995). This tendency yields the common occurrence of granulite facies rocks in the Moldanubian part of the massif, while in Sudetes C-type eclogite (SMULIKOWSKI, SMULIKOWSKI, 1985) and in Lugicum also blueschist occurs (GUIRAUD, BURG, 1984). Supposed the Tisza Unit the eastern continuation of European Variscan Belt, based on the similar characteristics of HP rocks, the small area examined in this paper may have belonged to the northern part of Bohemian Massif.

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