# METAMORPHIC EVOLUTION OF DIAMOND-BEARING ROCKS AND ECLOGITE FROM THE KOKCHETAV MASSIF, N. KAZAKHSTAN

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**Introduction:** Diamond of metamorphic origin in supracrustal rocks was first discovered from the Kokchetav Massif in the Caledonides of northern Kazakhstan. Microdiamond-bearing rocks include biotite gneiss, garnet mica schist, pyroxene marble, and garnet pyroxenite; no diamond has been reported in the associated metabasaltic eclogitic rocks (e.g., Sobolev & Shatsky, 1990). We have selected 3 eclogites, 5 garnet-bearing gneisses and 2 pyroxene marbles collected from Kumdikol of the northern Kokchetav Massif during the 1994 field season for detailed study for two purposes: (1) to determine whether or not the microdiamonds were formed within the diamond stability field; and (2) to delineate the retrogressive P-T path.

**Mineral Parageneses:** Eclogites consist of the assemblage garnet + omphacite (or sodic augite) + rutile + coesite/quartz ± kyanite ± zoisite (Shatsky et al., 1995; Dobrzhinetskaya et al., 1994, and our observations); garnet contains inclusions of zircon, rutile, mica, and feldspar. Omphacite is replaced by symplectitic intergrowths of hornblende and plagioclase, and rutile by ilmenite and titanite. Diamond-bearing dolomitic marble consists of dolomite (>70 vol.%), garnet, diopside, but lacks quartz; garnet has inclusions of diamond and dolomite (the latter contains graphitized diamond inclusions and is rimmed by calcite). Garnet is overprinted by phlogopite. Dolomite has exsolved calcite lamellae and diopside encloses minute garnet granules. Diamond-bearing gneiss and schist contain variable amounts of minerals including coesite/quartz, plagioclase, K-feldspar, garnet, biotite, zoisite/clinozoisite, chlorite, tourmaline, calcite and minor apatite, rutile and zircon. Abundant inclusions of diamond, graphite + chlorite (or calcite), muscovite, clinopyroxene, feldspar, phlogopite/biotite, rutile, titanite, calcite, and zircon occur in garnet. Inclusions of quartz pseudomorphs after coesite with radial fractures were identified in garnet of both eclogites and diamondiferous gneisses. Consistent occurrences of coesite pseudomorphs and microdiamond inclusions in single sample of these rocks and reported findings of coesite and microdiamond as inclusions in zircons (Sobolev & Shatsky, 1990) suggested that the microdiamonds crystallized within the diamond stability field.

On the basis of textural relations and mineral stabilities, we have established three distinct stages of metamorphic recrystallization of diamondferous genisses, dolomitic marble and associated eclogites; these mineral paragneses are shown in Fig. 1. The peak UHP metamorphic stage I assemblage is characterized by diamond + coesite together with garnet + clinopyroxene ± K-feldspar ± phlogopite in gneissic rocks, and diamond + diopside + dolomite + garnet ± magnesite in dolomitic marbles.. Stage I eclogites are devoid of elemental carbon, hence do not carry diamond. Stage IIa decompression is represented by the replacement of diamond by graphite and coesite by quartz. Further pressure-drop, stage IIb is reflected by amphibolite facies conditions with the paragenesis amphibole + plagioclase + biotite + titanite. Final reequilibration, stage III, under greenschist facies conditions resulted in formation of minor chlorite ± actinolite.

**Mineral Compositions:** New microprobe analyses indicate that garnets in metabasaltic eclogites and diamond-bearing gneisses and dolomitic marble contain 0.02-0.14 wt.% $Na_2O$; most show retrograde zoning with pyrope decreasing and spessartine increasing from core to rim. Garnet in dolomite is characterized by high grossular (~46 mol%) and pyrope (~40 mol%)

components; garnets from other rocks are rich in almandine. Eclogitic clinopyroxenes contain only 2.5 - 3 wt. % $Na_2O$, fall in the field between sodic augite and omphacite, and have negligible $K_2O$. Diopside in studied marble has 0.08-0.59 wt.% $K_2O$, and contains less Fe than salitic clinopyroxene in gneissic rocks. Phlogopite-biotite micas of the diamond-bearing rocks are distinctly different in composition; those inclusions within garnet are phlogopite [$100Mg/(Fe + Mn + Al^{VI} + Ti + Fe^{3+}) > 70$] or between phlogopite and Mg-biotite [$100Mg/(Fe + Mn + Al^{VI} + Ti + Fe^{3+}) = \sim 65$], whereas matrix micas are Mg-biotite.

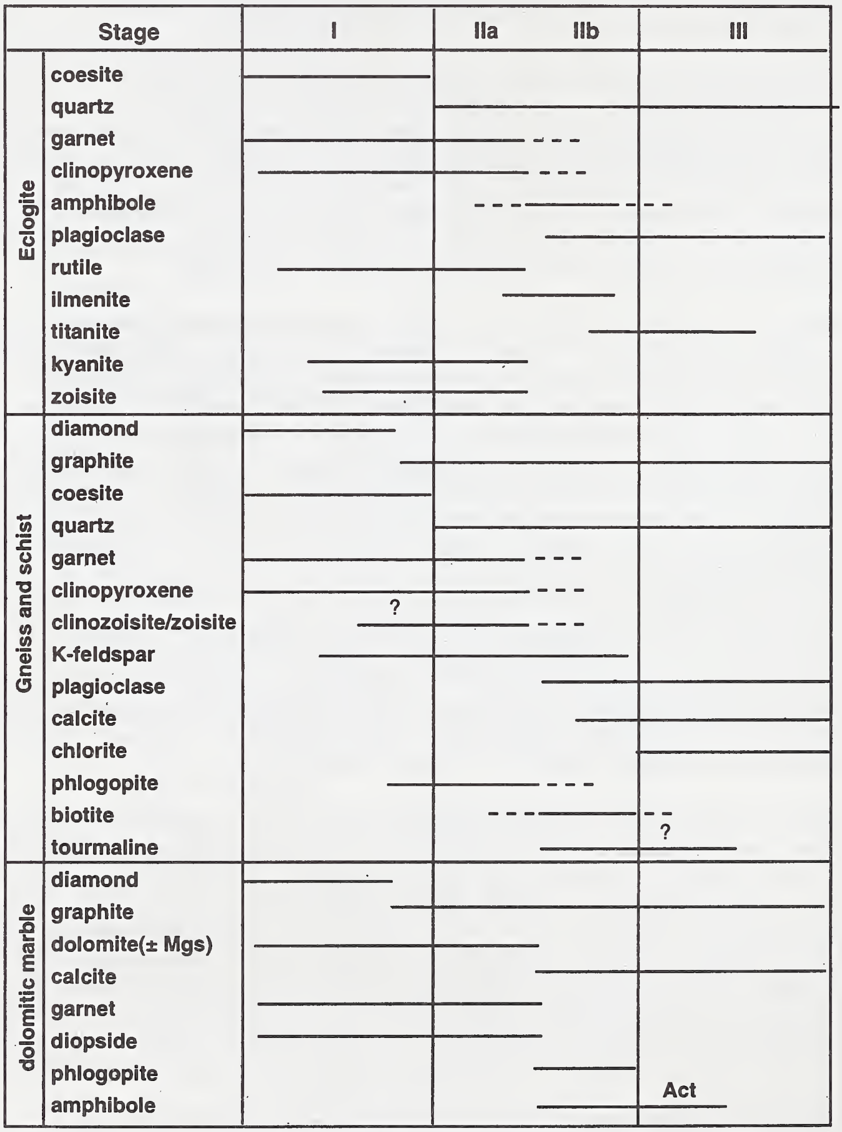


**Fig. 1 Parageneses of minerals from diamond-bearing rocks and eclogite**

**P-T Evaluations:** These UHP rocks exhibit at least 2-3 stages of metamorphic recrystallization; the estimated P-T conditions are shown in Fig. 2. The Fe-Mg partitioning between coexisting clinopyroxene and garnet yields a peak T of ~780°C at P > 28 kbar for eclogite, and 900-1000°C at P > 40 kbar for diamond-bearing dolomitic marble and gneiss; these P-T estimates are consistent with those by Sobolev & Shatsky (1990) and Shatsky et al (1995). The formation of symplectitic plagioclase and amphibole after pyroxene, replacement of garnet by biotite, amphibole, or plagioclase marks retrograded amphibolite-facies recrystallization at 650-680 °C. The exsolution of alkali feldspar to Kfs + Ab and of dolomite to Cal + Dol, and development of matrix chlorite and replacement of amphibole by chlorite imply greenschist facies overprint at ~350-420°C. A clockwise P-T path related to deep subduction of continental crust was constructed based on these P-T estimates (Fig. 2). Apparently, supracrustal sediments together with basaltic lenses were subjected to UHP metamorphism within the diamond stability field, and were subsequently retrograded through amphibolite to greenschist facies during exhumation.

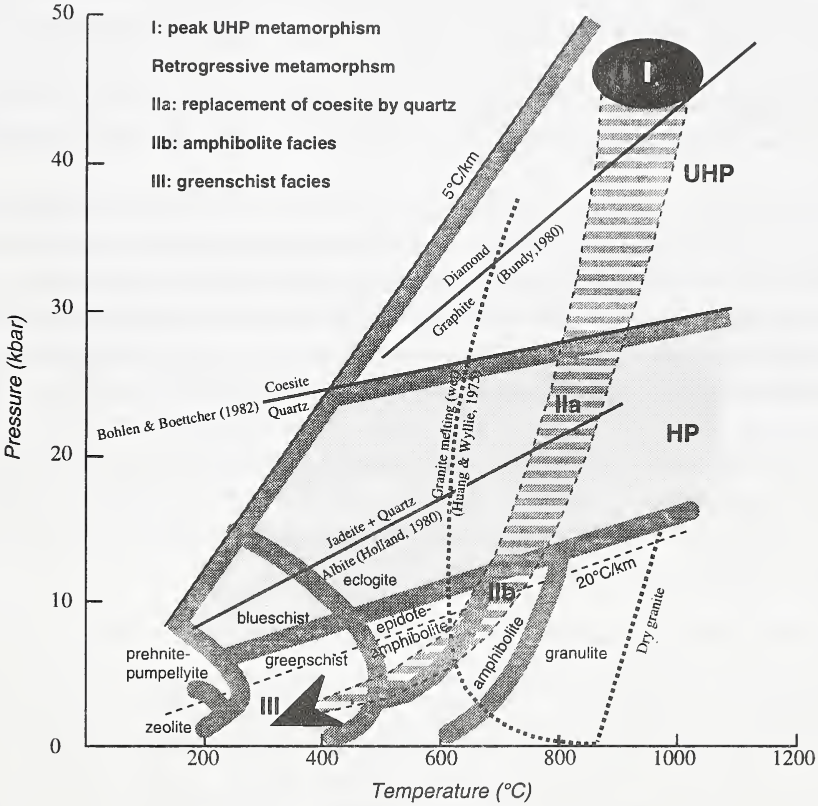


Fig. 2 P-T path of diamond-bearing rocks and eclogite

Dobrhizhinetskaya, L. F., Braun, T. V., Sheshkel, G. G. & Podkuiko, Y. A. 1994. *Tectonophysics*, **233**. 293-313.
Sobolev, N. V. and Shatsky, V. S. 1990. *Nature* , **343**, 742-746.
Shatsky, V. S., Sobolev, N. V. & Vavilov, M. A. 1995. in Coleman, R. G. & Wang, X. (Editors), Ultrahigh-pressure metamorphism, Cambridge press. 427-455.