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Review

The Kokchetav Massif, Kazakhstan: "Type locality" of diamond-bearing UHP metamorphic rocks

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ABSTRACT

After the discovery of metamorphic coesite in crustal rocks from the Western Alps (Italy) and the Western gneiss region (Norway) in the mid 1980s of the last century, metamorphic diamond was observed only a few years later "*in situ*" in the Kokchetav Massif (Kazakhstan). Findings of such coesite- and diamond-bearing ultrahigh pressure metamorphic (UHP) rocks with protoliths formed or embedded in crustal levels and subsequently experienced PT-conditions within or even higher than the coesite stability field have dramatically changed our geodynamic view of orogenetic processes. These occurrences provide evidence that crustal rocks were subducted into mantle depths and exhumed to the surface. Recent studies even suggest continental subduction to depths exceeding 300 km. These rocks have been extensively studied and many new and important observations have been made. Thus far, more than 350 papers have been published on various aspects of Kokchetav UHP rocks.

The Kokchetav Massif of northern Kazakhstan is part of one of the largest suture zones in Central Asia and contains slices of HP and UHP metamorphic rocks. Classical UHP rocks mainly occur in the Kumdy Kol, Barchi Kol and Kulet areas, and include a large variety of lithologies such as calcsilicate rocks, eclogite, gneisses, schists, marbles of various compositions, garnet–pyroxene–quartz rocks, and garnet peridotite. Most of them contain microdiamonds; some of which reach a grain size of 200 μm. Most diamond grains show cuboid shapes but in rare cases, diamonds within clinozoisite gneiss from Barchi Kol occur as octahhedral form. Microdiamonds contain highly potassic fluid inclusions, as well as solid inclusions like carbonates, silicates and metal sulfides, which favour the idea of diamond formation from a C–O–H bearing fluid. Nitrogen isotope data and negative $\delta^{13}C$ values of Kokchetav diamonds indicate a metasedimentary origin.

PT-estimates of Kokchetav UHP rocks yield peak metamorphic conditions of at least 43 kbar at temperatures of about 950–1000 °C. Some zircon separates show inherited Proterozoic cores and 537–530 Ma UHP metamorphic mantle zones. Several Ar–Ar-ages on micas scatter around 529–528 and 521–517 Ma and reflect different stages of the exhumation history. Migmatization occurred during exhumation at about 526–520 Ma.

Isotopic studies on calcsilicate rocks confirm a metasedimentary origin: $\delta^{18}O$ values of garnet and clinopyroxene of a layered calcsilicate rock rule out the possibility having a primitive mantle protolith. Similar studies on eclogites indicate their basaltic protolith having experienced water–rock interaction prior to UHP metamorphism.

A number of unique mineralogical findings have been made on Kokchetav UHP rocks. K-feldspar exsolutions in clinopyroxene demonstrate that potassium can be incorporated into the cpx-structure under upper mantle pressures. Other significant observations are coesite exsolutions in titanite, quartz-rods in cpx, the discovery of K-tourmaline as well as new minerals like kokchetavite, a hexagonal polymorph of K-feldspar and kumdykolite, an orthorhombic polymorph of albite.

The Kokchetav UHP rocks represent a unique and challenging stomping ground for geoscientists of various disciplines. From crystallography, petrology and geochemistry to geophysics and geodynamics/geotectonics – it concerns all who are interested in the diverse metamorphic processes under upper mantle conditions.

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Contents

1. Introduction

About 25 years ago, the burial and exhumation of crustal rocks into and from mantle depths of more than 100 km were thought to be an "exotic feature". However, in the present days, such mantle-depth metamorphic "event" represents a well-accepted and common process. The importance of such ultrahigh-pressure (UHP) metamorphic rocks is documented today in more than 25 recognized UHP terranes worldwide.

The commencement of the geodynamical revolution was initiated by Chopin (1984), who discovered metamorphic coesite in pyrope-quartzites of the Dora-Maira Massif, Italian Western Alps. In the same year, Smith (1984) described coesite from eclogites of the Western Gneiss Region in Norway. The term UHP metamorphism was born as a result of these coesite occurrences; which indicate that supracrustal rocks formed or embedded at shallow levels of the continental or oceanic lithosphere have experienced recrystallization at PT-conditions above the low-*P* stability limit of coesite.