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Cathodoluminescence of diamond as an indicator of its metamorphic history

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Diamond displays a supreme resistance to chemical and mechanical weathering, ensuring its survival through complex and prolonged crustal processes, including metamorphism and exhumation. For these reasons, volcanic sources and secondary and tertiary collectors for detrital placer diamonds, like Ural or Bingara diamonds, may be difficult to determine. If metamorphic processes leave their marks on diamond, they can be used to reconstruct crustal geologic processes and ages of primary diamondiferous volcanics.

Four diamond suites extracted from metamorphic rocks have been characterized using optical CL, infrared and CL spectroscopy, and photoluminescence at the liquid nitrogen temperature. The studied diamonds are from the ~2.7 Ga sedimentary conglomerate and lamprophyric breccia metamorphosed in the greenschist facies (Wawa, Northern Ontario, Canada) during the 2.67 Ga Kenoran orogeny, and from the ultra-high pressure (UHP) terranes of Kokchetav (Kazakhstan) and Erzgebirge (Germany) exhumated in the Paleozoic. Wawa diamonds (Type IaAB and Type II) displayed green, yellow, orange, and red CL colours controlled by the CL emittance at 520, 576 nm, and between 586 and 664 nm. The UHP terranes diamonds show much weaker CL; few luminescent stones display CL peaks at 395, 498, 528 nm and a broad band at 580-668 nm. In contrast, most common diamonds found in unmetamorphosed rocks, i.e. octahedrally grown Type IaAB stones, luminescence blue emitting light at ~415-440 nm and 480-490 nm. There is a noticeable difference between cathodoluminescence of these diamonds and diamonds in metamorphic rocks. The studied diamonds that experienced metamorphism show a shift of CL emission to longer wavelengths (above 520 nm) and to green, yellow and red CL colours.

Photoluminescence has the high resolution necessary to assign luminescence to specific optical centers of diamond. Diamonds in metamorphic rocks contain H3 (pairs of substitutional nitrogen atoms separated by a vacancy) and NVo optical centers (neutrally charged complexes of a vacancy and a single nitrogen). We ascribe the effect of metamorphism on the diamond CL to low-T, low-P deformation that creates lattice dislocations and vacancies. These combine with substitutional N to make and enhance optical centers. The metamorphism-induced CL anneals when diamonds are stored at high-T mantle conditions, as the mobility of dislocations at T>750oC quenches the luminescence. Indeed, all studied diamonds that displayed unusual green, yellow and red CL were found in low and medium grade metamorphic rocks, i.e. Wawa greenschists (T<350oC and P< 3 kb) and Kokchetav and Erzgebirge UHP terranes retrograded in the amphibolite facies (T<750oC, P<14 kb)

Our study suggest that a low abundance of octahedrally grown Type IaAB diamonds with blue CL colours among detrital diamonds may indicate that the stones may have once been a part of a low- or medium-grade metamorphic terrane. The CL characteristics superimposed by metamorphism could survive through billions of years of the geological history if not annealed by a high -T process. The discovered record of metamorphism in the diamond crystal lattice provides an opportunity for a better reconstruction of the crustal history and provenance studies of diamond.