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# Survival of Brown Colour in Diamond During Storage in the Subcontinental Lithospheric Mantle

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Brown is the most common colour of natural diamond. This colour is generally associated with plastic deformation of the crystal structure, which is imparted during residence in the mantle. Dislocation movement generates vacancies, which aggregate into clusters of perhaps 30–60 vacancies. The resulting electronic configuration leads to the broad, featureless absorption pattern associated with common brown colour.

It is well-established that the common brown colour can be removed by high-pressure–high-temperature (HPHT) treatment. The process involves pressures and temperatures in the range of 5–9 GPa and 1800–2700 ˚C, respectively. The treatment may take several minutes or hours.

It has been suggested that the same colour removal process operates continuously in the subcontinental lithospheric mantle, causing any brown diamonds in the diamond window to quickly lose their colour. The present study examined the validity of this suggestion. Temperature is the important difference between HPHT conditions and diamond window conditions. Higher temperatures result in faster colour removal. HPHT treatment occurs at 1800–2700 ˚C, whereas inclusion thermometry places most lithospheric diamonds in the range of 900–1400 ˚C.

Destruction of the brown colour centre involves breaking up vacancy clusters. How quickly this can be done depends on the concentration of clusters as well as the rate constant. The rate constant is changes with temperature, according to the Arrhenius equation. The key to this relationship is the activation energy required for the breakup of a vacancy cluster. This activation energy can be estimated as the energy of an isolated monovacancy, minus the energy per vacancy of the cluster, plus the vacancy migration energy. A value of 7.7$\pm$0.3 eV is obtained using data from recent literature.

For any given brown diamond, the rate constant determines the time needed to remove a certain amount of colour. The Arrhenius equation can be rearranged to show how this reaction time varies with temperature. Thus, the activation energy can be used in conjunction with experimental HPHT data to extrapolate reaction times from HPHT temperatures to lithospheric mantle temperatures. For a certain reduction in brown colour produced by HPHT ($T_1$, $t_1$), the equation below shows the time required ($t_2$) to produce the same reduction at a different temperature ($T_2$):

$\ln(t_2) = \ln(t_1) + (E_a/k)(1/T_2 - 1/T_1)$

where $E_a$ is activation energy, $k$ is the Boltzmann constant, and temperatures are in kelvins. The error in activation energy causes large, increasing error as the temperature difference between $T_1$ and $T_2$increases.

Nevertheless, the time required to destroy brown colour in the lithospheric mantle is significant at the scale of geological time. Brown diamonds should easily maintain brown colour during cooler mantle storage at or below 1000 ˚C. Warmer temperatures toward the base of the lithosphere may be able to reduce or eliminate brown colour within a reasonable geological time frame. However, the survival of brown colour in the lithospheric mantle does not *require* the colour to be formed late in the storage history nor does it *require* metastable storage in the graphite stability field.

Additionally, preliminary measurements of diamond crystal strain suggest that brown colour removal in the lithospheric mantle is, at least, not a common occurrence. Mosaic spreading was gauged in 18 untreated natural dia-

monds using micro-X-ray diffraction ($\mu$XRD) $\chi$-dimension peak widths. None of the colourless diamonds examined have a large residual mosaic spread, as should be expected for a diamond that has been deformed and turned brown, but later lost its brown colour. Despite the limited sample size, the results support some capacity for the survival of brown colour in the mantle.