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Evaluation of shock induced effect on rock-forming minerals from Ries Crater using cathodoluminescence spectroscopy

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Cathodoluminescence (CL) spectroscopy and microscopy provide important information on the existence and distribution of defects and trace elements in materials which is related to shock metamorphism. CL of silica minerals and feldspar in Lunar and Martian meteorite has been applied to examine the textures formed by shock metamorphism such as Planar Deformation Features (PDFs) and to clarify high-pressure minerals (e.g., maskelynite). A few CL studies on these minerals in shocked rock samples from impact crater, however, have been reported so far. In this study, the CL of quartz, alkali feldspar and plagioclase from the Ries Crater have been measured to characterize their CL features related to shock metamorphism.
Quartz, alkali feldspar ($Or_{84-91}Ab_{9-15}An_{0-1}$) and plagioclase ($Or_{2-4}Ab_{66-81}An_{17-31}$) in the drilling core samples between 601 and 602 m depth from the surface in the Ries Crater were used for CL measurements. CL spectroscopy was obtained in the range from 300 to 800 nm using a SEM-CL system, which is comprised of a secondary electron microscope (JEOL: JSM-5410) combined with a grating monochromator (OXFORD: Mono CL2). CL images were collected with a MiniCL (Gatan) equipped with a SEM-CL. Operating conditions of SEM-CL and MiniCL imaging system were set at 15 kV (accelerating voltage) and 1.0 nA (beam current).
CL spectra of quartz exhibit emission bands at around 390 and 650 nm in blue and red region. Blue CL emission is related to Ti^{4+}or $[AlO_4/M^+]^0$(M^+: H^+, Li^+, $Na^+$and K^+) defect center. An emission band at 650 nm is attributed to oxygen vacancy center. CL images of quartz at room temperature show a homogeneous distribution of intensity, whereas those at -130 °C indicate thin dark lines superimposed on more brightly luminescent background. These thin dark lines are corresponding to PDFs by impact-shocked metamorphism observed under an optical microscope (open nicol). Interference shock wave with high pressure might cause structural destruction with parallel array along wave front, resulting in non-luminescence in PDFs. This fact indicates that CL imaging at low temperature can be used to detect PDFs in shocked quartz.
The euhedral alkali feldspar has CL emissions at around 430 and 720 nm in blue and red-IR spectral region. The blue and red-IR CL emissions are attributed to $Al-O^--Al$ defect and Fe^{3+} impurity center, respectively. CL spectra of isotropic alkali feldspar under optical microscope (crossed nicol) consist of an emission band at around 380 nm, which has been reported in CL spectra of maskelynite and diaplectic glass. This emission band might be responsible for shock-induced defect center, which can be detected in maskelynite and diaplectic glass changed from plagioclase in the meteorites.
CL spectra of the plagioclase show five emission bands at around 330, 400, 430, 580 and 740 nm, which can be assigned to Ce^{3+}, Eu^{2+}, $Al-O^--Al$ defect, $Mn^{2+}$and Fe^{3+}centers, respectively. Similar emission bands have been extensively observed in terrestrial plagioclase, whereas they do not involve an emission band at 380 nm assigned to shock-induced defect center in shocked plagioclase and maskelynite. Post-shock temperature effect in the Ries Crater might eliminate shock-induced defect center in plagioclase because of absence of emission band at around 380 nm. Consnsequently, CL microscopy and spectroscopy is a powerful tool to study the degree of shock

metamorphism in not only confirmed but also probable meteorite craters.

Keywords: cathodoluminescence, quartz, alkali feldspar, plagioclase, Ries Crater, shock metamorphism