The impact of igneous intrusions on coal, cleat carbonate, and groundwater composition

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THE IMPACT OF IGNEOUS INTRUSIONS ON COAL,
CLEAT CARBONATE, AND GROUNDWATER
COMPOSITION

A thesis submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy

from

The University of Wollongong

by

Alexandra Golab, BSc. (Hons)

School of Geosciences

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Abstract

Igneous intrusions affect the safety, productivity and economic viability of many coal mines due to thermal and geochemical alteration of the coal, alteration of groundwater chemistry, and the production of methane and carbon dioxide, which elevates the threat of spontaneous combustion and outbursting. In addition, the intrusions themselves commonly create difficult and expensive mining conditions and the nearby coal is coked, rendering it useless.

Dartbrook Coal mine is located in the Upper Hunter Region, on the boundary between the Sydney and Gunnedah Basins, NSW, Australia. This thesis has investigated the impact that two major dykes have had on the coal of the Late Permian Wynn seam, cleat carbonates, and groundwater composition at the mine. Samples of coal were collected in transects, starting close to the intrusions and extending away from the intrusions. Vitrinite reflectance, mineralogy, and geochemistry were analysed on the coal samples to determine the extent of thermal alteration. Additional coal samples were collected throughout the mine-lease and the cleat carbonate was extracted. The mineralogy, $\delta^{18}$O and $\delta^{13}$C composition were analysed on the cleat-infill to determine the source of the dominant carbonate. Groundwater samples were also collected throughout the mine-lease and the geochemistry, $\delta^{34}$S and $^{87}$Sr/$^{86}$Sr composition were analysed to determine if groundwater can be used to detect the intrusions.

The vitrinite reflectance, mineralogy, and geochemistry of the coal seams intruded by dykes change dramatically approaching the intrusions. Proximal to the igneous intrusions, the coal changes through four alteration zones comprising normal coal ($R_o$ max = 0.8), slightly thermally altered coal ($R_o$ max = 1.8), brecciated coke ($R_o$ max = 2.5 to 5.0), and natural coke ($R_o$ max = 7.0). The greatest alteration occurs between the fingers of the dyke but the pattern of alteration is not uniform; the outer dyke finger caused the most alteration by far, because it acted as a conduit for subsequent intrusions of magma and hydrothermal fluids. Geochemical data for the coal indicate that elements exhibit affinities for minerals (e.g. Na, Al, and Si for aluminosilicate minerals) and display trends of accumulation and depletion.
approaching the contact depending on those affinities. The majority of elements (e.g. Ca, Mg, Mn, and Fe) are enriched at the coal/intrusion contact.

The dominant cleat carbonate is dawsonite (NaAlCO$_3$(OH)$_2$), with $\delta^{13}$C$_{PDB}$ values between -1.7 and +2.4‰ (standard deviation = 0.7‰) and $\delta^{18}$O$_{SMOW}$ values between +13.6 and +19.8‰, and a narrow standard deviation (1.7‰). The narrow range of $\delta^{13}$C values and the occurrence of major igneous activity at Dartbrook indicates that the carbon in the dawsonite has a magmatic source, whereas the broad range of $\delta^{18}$O values reflects the direct or indirect impact of local intrusions. The dawsonite formed at a late stage by the interaction of Na$_2$CO$_3$- or NaHCO$_3$-rich solutions with hydroaluminosilicates present in the coal.

The groundwater composition displays spatial variations near the two major dykes. The $\delta^{34}$S values range from –0.3 to +63.8‰ (average = +22.8‰), while the $^{87}$Sr/$^{86}$Sr values range from 0.704984 to 0.706647. The $^{87}$Sr/$^{86}$Sr data indicate that the igneous influence is all-pervasive in the study area. The groundwater chemistry exhibited a localised igneous signal near one dyke, which was detected using the products of potassic alteration of K-rich feldspars (weathering products from the dyke).

The finding that igneous intrusions can be detected using groundwater composition indicates that the technique can be used during mining exploration. The advantage to early-detection of intrusions is that they can be avoided during mining and a better estimate of the size of the recoverable coal reserves can be made.
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