

# Vibrational Spectroscopy of Calcic Amphiboles - From Mineral Physicochemistry to Applications in Mineral Exploration

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Amphiboles are common alteration minerals in a number of mineral systems (e.g. orogenic Au deposits, Yilgarn, Australia; Fe-oxide Cu-Au deposits, Mount Isa Inlier, Queensland, Australia). The identification of amphiboles and distinct amphibole species provides insights into regional and contact metamorphic processes as well as mineralization related hydrothermal events (Laukamp et al., 2011), which are important for mineral exploration. Routine measurements of amphibole abundance and composition using commercially available non-lab based technologies, such as field (e.g. ASD FieldSpec<sup>TM</sup>) and automated drill core logging techniques (e.g. HyLogging<sup>TM</sup>), mainly operate in the visible and near-infrared wavelength range (0.4 - 2.5  $\mu\text{m}$ ). However, the understanding of absorption bands related to amphiboles in this range is quite limited.

This paper addresses the application of near-infrared reflectance spectroscopy as a tool for rapid determination of amphibole species in mineral exploration, based on the review of the physicochemical constraints of amphibole related absorption bands. The hydroxyl stretching vibrations in the actinolite-series for example occur in the 3700 – 3600  $\text{cm}^{-1}$  range, with one absorption band in the case of tremolite and up to 4 bands in ferro-actinolite (Strens, 1974; Makreski et al., 2006). A shift of the OH-frequency to longer wavelengths is attributed to increasing occupation of  $\text{Fe}^{2+}$  cations in the octahedral sites. Band assignments in the 700 – 400  $\text{cm}^{-1}$  range are discussed controversially in literature, but it is assumed that near-infrared absorption features of calcic amphiboles positioned at around 4320  $\text{cm}^{-1}$  (2.31  $\mu\text{m}$ ) and 4200  $\text{cm}^{-1}$  (2.38  $\mu\text{m}$ ) are due to the combination of hydroxyl stretching and bending fundamentals. Compared to actinolite the increased chemical complexity of hornblende leads to broadening, weakening and possibly long shift of the stretching and bending combinations to longer wavelengths. Rock samples containing calcic amphiboles were collected from various localities in Australia and vibrational spectroscopic results were compared with SEM and electron microprobe work, to correlate the spectral signatures with the chemical composition of calcic amphiboles. Based on a multiple feature extraction method (Cudahy et al., 2008; Laukamp et al., 2010), algorithms were developed to estimate the relative abundance of amphiboles and their composition in large datasets (e.g. drill core logging, remote sensing). Albeit the multiple possible combinations of fundamental absorption features in amphiboles and overlapping signatures with other minerals, our study suggests that routine compositional mapping of calcic amphiboles in the near-infrared is possible.

## References:

Cudahy, T., Jones, M., Thomas, M., Laukamp, C., Caccetta, M., Hewson, R., Rodger, A., Verrall, M. (2008), CSIRO report P2007/364, 161pp.

Laukamp, C., Cudahy, T., Caccetta, M., Chia, J., Gessner, K., Haest, M., Liu, Y.C., Rodger, A. (2010), AIG Bulletin, 51, 73-76.

Laukamp, C., Cudahy, T., Cleverley, J., Oliver, N., Hewson, R. (2011), GEEA, 11, 3-24.

Makreski, P., Jovanovski, G., Gajovic, A. (2006), Vibrational Spectroscopy, 40, 98-109.

Strens, R.G.J. (2004), in: V.C. Farmer (Ed.), Mineralogical Society, London, UK, 1974, 305-330.