Definition of high-temperature alteration zones with PIMA: an example from the Panorama VHMS district, central Pilbara Craton

David L. Huston[1], Julienne Kamprad[1], & Carl Brauhart[2]

The Panorama volcanic-hosted massive sulphide (VHMS) district in the central Pilbara is an ideal natural laboratory to test newly developed exploration techniques, as it is perhaps the best exposed, least deformed district of its type in the world. Our studies there show that PIMA (portable infrared mineral analyser) analysis effectively defines local-scale alteration zones, and complements alteration mapping as an exploration tool. The depth ratio of Al–OH to Fe–OH absorption features in PIMA spectra corresponds to sericite–chlorite ratios, and effectively maps alteration facies.

The Sulphur Springs deposit is the largest of several VHMS deposits that occur at or near the top of the 3.24-Ga Kangaroo Caves Formation in the Panorama district. The Kangaroo Caves Formation consists of andesitic to rhyolitic volcanic rocks, and has been intruded by the polyphase, subvolcanic Strelley Granite (Fig. 9a). The granitic and volcanic rocks are overprinted by three main alteration assemblages in the Sulphur Springs area (Fig. 9b):

- chlorite–quartz–albite ± carbonate ± pyrite, the regional background alteration assemblage;
- chlorite–quartz, which forms a pipe-like zone below the deposit and a semiconformable zone at the base of the andesite; and
- feldspar–sericite–quartz, which occurs mainly in dacite lateral to the deposit (Brauhart et al. 1998: Economic Geology, 93, 292–303).

Methodology

The PIMA is a spectrometer that measures the infrared (1300–2500-nm wavelength) radiation reflected from illuminated geological samples. Light interacting with the molecular bonds of a sample is absorbed at wavelengths that characterise the sample and causes a spectral response. These characteristic absorption features can be used to identify minerals, particularly hydrous minerals commonly formed during hydrothermal alteration.

PIMA spectra (e.g., Fig. 10) were collected from 63 fresh-rock powders from the Sulphur Springs area that were also analysed for oxygen isotopes (Huston et al. 1998: AGSO Research Newsletter, 29, 14–16) and whole-rock geochemistry. Before they were interpreted, the raw spectra were transformed to remove curvatures caused by major absorption features outside the spectral range of interest (e.g., a hull transformation). The resulting spectra were then classified by shape into spectral groups, and the depth and position of the peak within the Al–OH (2180–2220 nm) and Fe–OH (2230–2295 nm) absorbance bands were measured for each spectrum.

Results

Qualitative examination indicates that most spectra are dominated by chlorite and/or sericite. The spectrum of one diorite sample indicated the presence of actinolite–tremolite, and several spectra indicated the presence of minor kaolinite.

The PIMA spectra did not detect carbonate minerals, even though background-altered andesite contains significant ankerite/calcite. This apparent inconsistency results from the requirement for a high abundance of carbonate minerals before PIMA will detect them. The PIMA spectra do not indicate the presence of other hydrous minerals in the samples analysed. All the spectra and a more detailed analysis of the results are presented in Huston et al. (1997: AGSO Record 1997/14).

The depth (D) of a peak in the Fe–OH and Al–OH absorbance bands for each sample may be expressed as a ratio ($D_{[2230–2295]}/D_{[2180–2220]}$), which approximates closely the chorite/sericite ratio (e.g., Huston et al. 1997: op. cit.). According to the spatial variation of this ratio (Fig. 9c), high $D_{[2230–2295]}/D_{[2180–2220]}$ values (>0.5) correspond broadly to the chlorite–quartz alteration zone (Fig. 9b). The highest values (>2.0) occur in the andesite directly below the Sulphur Springs gossan and extend west to a major dolerite dyke. A smaller, stratiform zone of high values (>2.0) corresponds to the southeastern extension of the chlorite–quartz alteration zone at the base of the andesite. PIMA analysis also indicates the presence of a 300–400 m wide, stratiform zone with higher $D_{[2230–2295]}/D_{[2180–2220]}$ values (0.5–2.0) in the upper part of the background alteration zone southeast of the chlorite–quartz pipe; field mapping has not revealed a corresponding change in alteration mineralogy in this region. Low $D_{[2230–2295]}/D_{[2180–2220]}$ values (<0.5; generally 0.0) are restricted to sericite-dominant alteration zones, to the granite and mafic intrusive complex, and to the lower part of background-altered andesite. Whereas most changes in $D_{[2230–2295]}/D_{[2180–2220]}$ are sharp, those between sericite-altered dacite and the upper part of background-altered andesite are gradational.

Variations in the wavelength of the Fe–OH and the Mg–OH absorption bands can be used as a qualitative indication of chlorite composition. In this study, we used the Fe–OH absorption band (2240–2260 nm; Fig. 9d) because the Mg–OH absorption band (2320-2360 nm) was poorly defined for many samples. Low-wavelength values indicate Mg-rich chlorite, whereas higher values indicate Fe-rich chlorite (Pontual et al. 1997: 'Spectral analysis guides for mineral exploration', 7). Most Fe–OH absorbance peaks around Sulphur Springs are between 2255 and 2257 nm, which indicates Fe-rich chlorite. Values below 2255 nm are restricted to the northwestern part and the southeasternmost extension of the chlorite–quartz alteration zone. Values greater than 2257 nm are restricted to a small part of background-altered andesite with high $D_{[2230–2295]}/D_{[2180–2220]}$.

Exploration applications and further work

The PIMA parameters discussed are potentially useful as vectors in semiregional to deposit-scale exploration. The most effective parameter is $D_{[2230–2295]}/D_{[2180–2220]}$, which is a measure of the chlorite/sericite ratio. Variations in relative chlorite and sericite abundances are common in many VHMS districts, in which chlorite generally is enriched in alteration zones proximal to deposits whereas sericite is enriched distal to deposits (cf. Franklin et al. 1981: Economic Geology, 75th Anniversary Volume, 485–627). The PIMA results at Sulphur Springs are consistent with this generalisation. This zonation occurs over a distance of a kilometre or more, which suggests that this ratio can be used as a semiregional exploration guide. However, variations in the wavelength of the Fe–OH peak, which reflect systematic compositional variations, are not as useful.

The results presented here also have implications for hyperspectral remote sensing as a tool for defining exploration vectors at the regional scale in well-exposed terrains. AGSO is presently a contributor to a project (funded by MERIWA, the Minerals & Energy Research Institute of Western Australia, and operated by CSIRO) designed to assess the applicability of the hyperspectral HYMAP remote-sensing method to mineral and alteration mapping in the Panorama VHMS district.

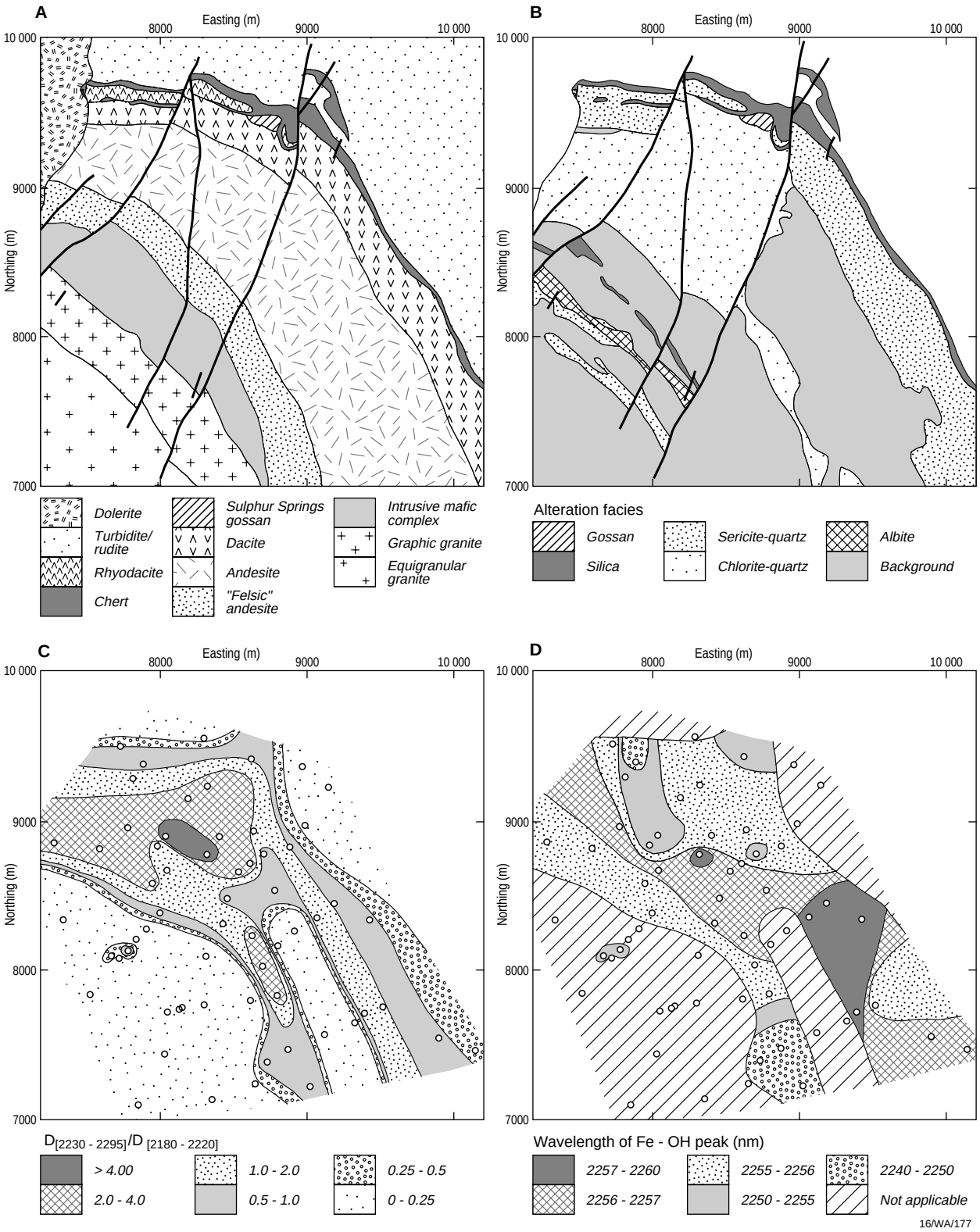

Fig. 9. Plans of the Sulphur Springs area showing: (a) geology, (b) alteration assemblages, (c) variation in the depth ratio of the Fe–OH to Al–OH absorption features, and (d) variations in the wavelength of the Fe–OH absorption feature. Open circles represent sample locations.

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[1] Minerals Division, Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601; tel. +61 2 6249 9577 (DLH), +61 2 6249 9274 (JK); fax +61 2 6249 9983; email David.Huston@agso.gov.au, Julie.Kamprad@agso.gov.au

[2] Centre for Strategic Minerals, University of Western Australia, Nedlands, WA 6009; tel. +61 8 9380 1871; fax +61 8 9380 1178; email cbrauhar@geol.uwa.edu.au

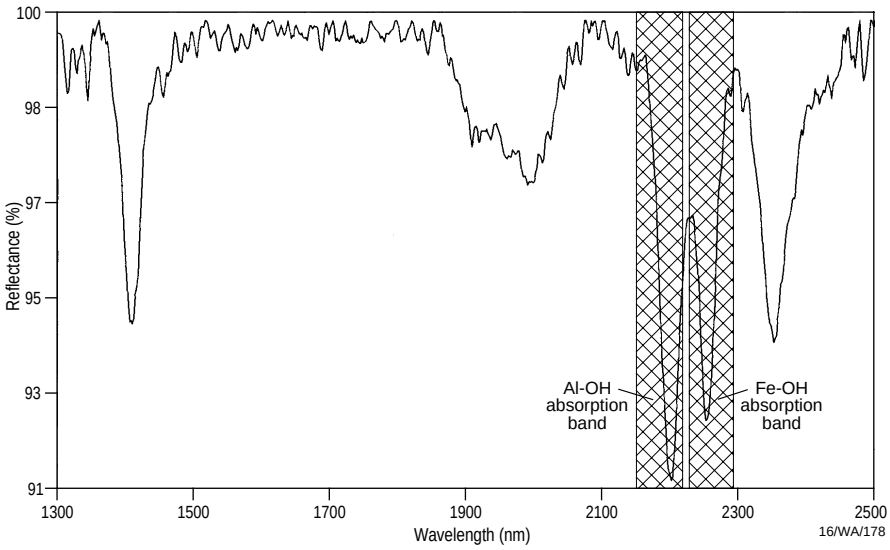

Fig. 10. PIMA spectrum for sample 207497 showing the Al–OH and Fe–OH absorption bands (cross-hatched areas). This sample has a $D_{[2230-2295]}/D_{[2180-2220]}$ of 0.87.