GeoSpectral Imaging

www.geospectral.co.za info@geospectral.co.za

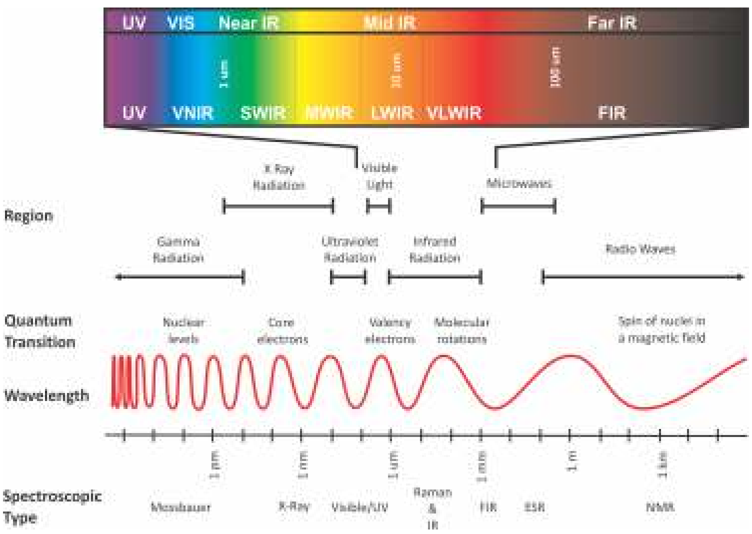
+27 (0)11 675 7092

Mineral Detection in the Infrared using Reflectance Spectroscopy

Infrared and Mineral Detection

Reflectance spectroscopy is a passive, non-destructive analytical technique that only requires illumination of the sample for measurement. Measurements can be made on samples with little preparation, therefore the method is suitable for in-situ sample analysis. The technique measures reflected light from the sample and is considered a surface measurement technique.

The infrared is considered a good mineral detection technology because of the wide range of minerals that it can identify. Minerals have characteristic features across different wavelength ranges resulting from the electronic and vibrational processes associated with bonded elements within them. The value of each wavelength range is determined by its mineral detection capabilities, thus the use and development of technology measuring in that wavelength will be determined by its ability to measure target minerals. This is significant as the individual wavelength regions generally require their own spectrometer and illumination source for detection. To cover the full infrared region a series of spectrometers designed for detection across each wavelength range would be required, coupled with the requirement of a changing illumination source for these infrared reflectance measurements.



Schematic representation of the electromagnetic spectrum indicating wavelength ranges with the capability of or potential for mineral detection.

Region	Infrared Range	Code	Approximate Range (microns)
Ultraviolet	Ultraviolet	UV	0.2-0.4
Visible	Visible-Near Infrared	Vis	0.5-0.7
Near-Infrared		vnir	0.4-1
	Short-Wave Infrared	SWIR	1-2.5
Mid-Infrared	Mid-Wave Infrared	MWIR	3-6
	Long-Wave Infrared	LWIR	6-14
	Very Long-Wave Infrared	VLWIR	14-30
Far-Infrared	Far Infrared	FIR	30-1000

The near-infrared (0.4 - 2.5 *µm)* is considered developed technology where applications have and are being explored. In contrast, the mid-infrared (3 - 30 *µm)* is an emerging technology, where applications and sensors for imaging reflectance spectroscopy are being developed.

The importance of Different Regions of the Infrared

The detection capabilities of the VNIR, SWIR and LWIR are illustrated in the summary table of mineral classification. These are the wavelength ranges where the most mineral detection capabilities are achieved.

The VNIR has limited mineral detection capabilities on its own, but provides valuable undetected identification of minerals when measured across other wavelength ranges.

The SWIR, however, is fundamental in identifying and discriminating between micas, chlorite, carbonates and clay minerals, through its ability to detect hydroxyl and carbonate bond related vibrations. This is the wavelength range most commonly used, as well as that for which the most technology has been developed.

The LWIR provides identification of the tectosilicates, amongst others, providing a near complete suite of mineral detection capabilities. In combination, the SWIR and LWIR ranges have the potential to provide a powerful mineral detection system.

The MWIR is not included in this summary table as reflectance data across this region is only becoming possible with current instrument developments. This is the region in which many fundamental absorption features related to the OH bonds in minerals occur. It provides similar data to that obtained in the SWIR, where development has been easier to implement, mainly due to the illumination source.

In the SWIR solar radiation can be used as an illumination source, and as such has been included in remote sensing applications. This has led to the current development of the SWIR over the MWIR in infrared reflectance measurements. The MWIR does not significantly expand mineral detection capabilities when added to the VNIR-SWIR combination.

The LWIR is, however, much more significant as it adds identification of minerals not seen in the NIR. As such the LWIR is a more targeted wavelength range. The MWIR can provide support to the SWIR and LWIR in assisting detection when mineral mixtures complicate identification. This region also has the potential to add value for niche applications. One area of potential is the suitability of the MWIR for CH_4 detection, which has applications in the measurement of coals and oils.

The VLWIR has been little explored for mineralogical applications, primarily due to the limited instrument development. This region has the potential to address some of the oxide and sulphide identification challenges not possible through the other regions of the infrared.

Value of Combined Infrared Wavelength Ranges

A review of the mineral detection capabilities in the summary table below indicates that similar minerals are often detected over several different wavelength ranges. The value of this so called duplication is that when mineral combinations obscure identification in one region, the identification or confirmation of mineral presence can be obtained through review of the adjacent wavelength ranges. This highlights the importance of integrating the mineralogical data of the different wavelength ranges to generate a complete mineral map. Certain wavelength ranges provide important mineral detection and combining these ranges significantly increases the mineral detection capabilities of the technology (e.g. SWIR and LWIR).

Sensor resolution is an important factor for mineral detection and in most instances hyperspectral image data is required to resolve the different mineral species. Higher spectral resolution allows more subtle mineralogical variations to be observed in the spectral signatures. Compositional variations within a mineral species are often recorded through wavelength shifts of the mineral bands in the spectral signatures.

	Structure	Mineral Group	Example	VNIR Response	SWIR Response	LWIR Response
Silicates	Inosilicates	Amphibole	Actinolite	Non-Diagnostic	Good	Moderate
		Pyroxene	Diopside	Good	Moderate	Good
	Cyclosilicates	Tourmaline	Elbaite	Non-Diagnostic	Good	Moderate
	Nesosilicates	Garnet	Grossular	Moderate	Non-Diagnostic	Good
		Olivine	Forsterite	Good	Non-Diagnostic	Good
	Sorosilicates	Epidote	Epidote	Non-Diagnostic	Good	Moderate
	Phyllosilicates	Mica	Muscovite	Non-Diagnostic	Good	Moderate
		Chlorite	Clinochlore	Non-Diagnostic	Good	Moderate
		Clay Minerals	Illite	Non-Diagnostic	Good	Moderate
			Kaolinite	Non-Diagnostic	Good	Moderate
	Tectosilicates	Feldspar	Orthoclase	Non-Diagnostic	Non-Diagnostic	Good
			Albite	Non-Diagnostic	Non-Diagnostic	Good
		Silica	Quartz	Non-Diagnostic	Non-Diagnostic	Good
Non-Silicates	Carbonates	Calcite	Calcite	Non-Diagnostic	Moderate	Good
		Dolomite	Dolomite	Non-Diagnostic	Moderate	Good
	Hydroxides		Gibbsite	Non-Diagnostic	Good	Moderate
	Sulphates	Alunite	Alunite	Moderate	Good	Moderate
			Gypsum	Non-Diagnostic	Good	Good
	Borates		Borax	Non-Diagnostic	Moderate	Uncertain
	Halides	Chlorides	Halite	Non-Diagnostic	Uncertain	Uncertain
	Phosphates	Apatite	Apatite	Moderate	Non-Diagnostic	Good
	Hydrocarbons		Bitumen	Uncertain	Moderate	Uncertain
	Oxides	Hematite	Hematite	Good	Non-Diagnostic	Non-Diagnostic
		Spinel	Chromite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic
	Sulphides		Pyrite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic

Green – Minerals that are well characterized in the infrared region.
Yellow – Minerals that can be identified in the infrared region. These minerals may not have high contrast responses or are not easily distinguished from some minerals if the system measurement resolution is low.
Grey – Non-diagnostic responses observed for these minerals across the specific infrared regions.
White – Uncertain responses for these minerals across these regions of the infrared.