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Low-resolution VNIR spectra of AP and AT landmines
Some examples

R.W. Herring
Defence Research Establishment Suffield

Technical Memorandum
DRES TM 2000-212
December 2000

National Defence Défense nationale

Canada

Low-resolution VNIR spectra of AP and AT landmines

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Abstract

Low-resolution (up to 9 bands) optical spectra of 13 anti-tank and 13 antipersonnel landmines over the visual and near infrared (VNIR) range (400-950 nm) are presented. It is suggested that further measurements at higher spectral resolutions would be useful.

Résumé

On présente les spectres optiques à faible résolution (jusqu'à 9 bandes) de 13 mines terrestres antichars et de 13 mines antipersonnel dans le domaine spectral visible et proche infrarouge (VNIR) (400-900 mm). On propose qu'il serait utile d'effectuer d'autres mesures à des limites de résolution spectrale plus élevées.

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Executive summary

One of the many ways proposed for the detection of anti-tank and anti-personnel landmines has been the use of optical sensors in the visual and near infrared (VNIR) spectral region (400–950 nm wavelength). There currently exist remote sensing devices that are capable of producing multispectral images by means of which, in some instances, it appears to be possible to detect the presence of landmines.

In this Technical Memorandum, the *casi* compact airborne spectral imager has been used to produce low-resolution spectra of 13 available anti-tank and 13 available anti-personnel landmines, with a view to making available representative spectra. These results, when viewed in a larger context of the spectra of expected background soils and vegetation (not considered here), should serve to reveal whether or not the optical spectra of typical mine materials are sufficiently unique to be distinguishable from such background.

Although the results presented here lack the necessary context, it is suggested that, because of the coarseness of the resolution of the spectra presented, it would be useful to repeat these measurements at a higher spectral resolution.

R.W. Herring. 2000. Low-resolution VNIR spectra of AP and AT landmines. DRES TM 2000-212. Defence Research Establishment Suffield.

Sommaire

Un des nombreux moyens qu'on propose pour détecter les mines terrestres antichars et antipersonnel consiste à utiliser des capteurs optiques dans le domaine spectral (longueur d'ondes de 400-950 nm) visuel et proche infrared (VNIR). Il existe actuellement des dispositifs de télédétection capables de produire des images multibandes qui permettent, dans certains cas, de détecter la présence de mines terrestres.

Dans l'étude exposée par le présent document technique, on s'est servi de l'imageur spectrographique compact aéroporté ou *casi* pour obtenir des spectres à faible résolution de mines terrestres dont on disposait, soit 13 antichars et 13 antipersonnel. Le but était d'assurer la disposition de spectres typiques. Vus dans un contexte plus vaste des spectres de fond formé par les sols et la végétation envisagés (spectres non considérés par l'étude), ces résultats devraient servir à faire connaître si les spectres optiques typiques des matériaux constituant les mines sont suffisamment distinctifs pour ressortir de ce fond.

Les résultats exposés dans ce document n'ont pas été obtenus dans le contexte voulu, mais à cause du faible pouvoir de résolution des spectres présentés, on a proposé qu'il serait utile de reprendre les mesures à des limites de résolution spectrale plus hautes.

R.W. Herring. 2000. Low-resolution VNIR spectra of AP and AT landmines.
DRES TM 2000-212. Centre de Recherches pour la Défense Suffield.

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Acknowledgements

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1. Introduction

The Defence Research Establishment Suffield (DRES) has been researching various electromagnetic methods for the detection of landmines and unexploded ordnance (UXO) since 1975. These methods range from electromagnetic induction to thermal neutron activation — in other words, essentially from DC to gamma rays. One method with potential for the airborne detection of exposed mines lying on the surface of the ground is hyperspectral imagery [1] – [4]. In support of DRES's research into hyperspectral imagery, in June 1998 the optical spectra in the visual and near infrared (VNIR) range (in the present instance, 400–950 nm) for several available specimen landmines were measured. These mines are listed in Table 1 below. Four sets of data, comprising a total of 98 spectral images, were recorded. These data sets were obtained using the *casi* Compact Airborne Spectrographic Imager, manufactured by ITRES Instruments Inc. [5] and, for these trials, operated for DRES under contract by ITRES Research Ltd. of Calgary, Alberta.

Table 1: *List of specimen landmines*

Anti-Tank Mines	Anti-Personnel Mines
FFV 028	Butterfly
M15	Cuppmisr (D)
M21	FFV013
Mk-7	M16A2
PT Mi-Ba III	M18A1
SA-10 (D)	OZM-3 (D)
TM-46 (D)	PMA-1A
TM-62M	PMA-2
TMA-3	PMA-3
TMA-4	PMN-6 (D)
TMA-5	Valamara 69
TMRP-6	VS-50
Woodmine	VS-Mk2
(D) denotes surrogate mine	

2. Methodology

As mentioned in the Introduction, four sets of data were obtained. For two of the data sets, the mines were illuminated by artificial light within the confines of a building; for the other two, the mines were placed outdoors under direct sunlight. In all cases, a reflectance panel, comprising two regions having uniform 10% and 90% reflectance over the VNIR range, was included in the *casi* imagery. Data from the two regions of the panel was used to calibrate the mine image hyperspectral data and convert it from luminance to reflectance, by means of a simple linear interpolation algorithm.

Since the *casi* is a 'push-broom' system, it was mounted on a tilt-head tripod, which was then tilted up and down so as to simulate the along-track motion necessary to generate a raster image. A sample image from a single band of a *casi* image is shown in Figure 1.

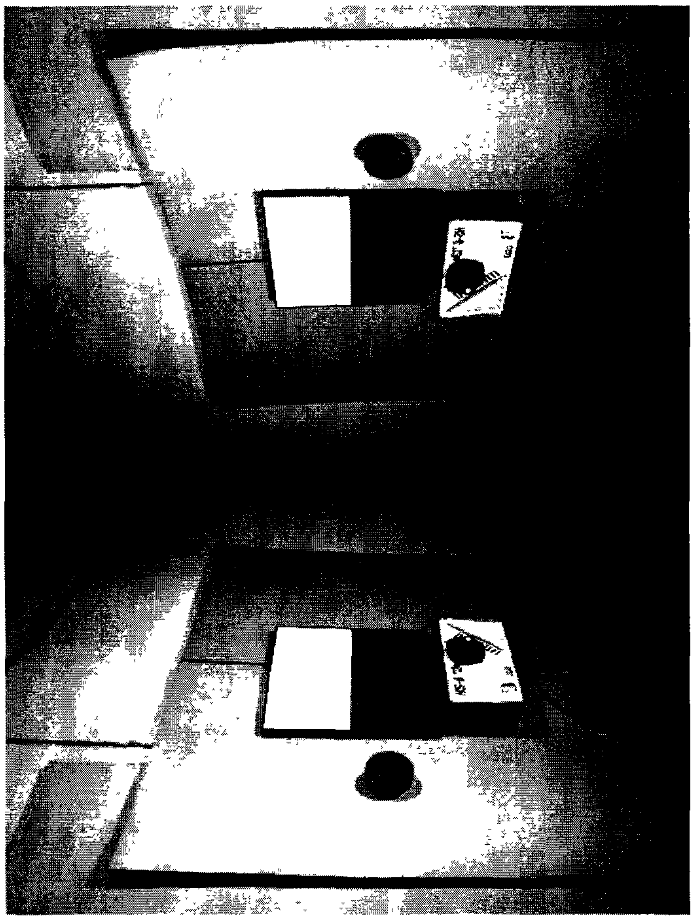

***Figure 1:** Sample* casi *image*

Within Figure 1 can be seen two apparently mirror images of the mine and the reflectance panels. This mirror effect is an artefact of the 'up and down' scanning technique. The light and dark coloured panels are the 90% and 10% reflectance panels mentioned above. The anti-personnel mine in this particular image is a PMA-2. The four sets of data are denoted as follows: **d15cm2, d20cm2**, **dspat1** and **dspat2**. The sets **d15cm2** and **d20cm2** were recorded indoors; the sets **dspat1** and **dspat2** were recorded outdoors. The combinations of *casi* spectral rows and resultant wavelength bands for each of the four data sets are given in Tables 2–5 below.

The raw mine images were provided to DRES as uncalibrated multiband radiance images in PCI (*.pix) file format. Each image was converted to a reflectance image by means of the ENVI image processing software package [6]. Specifically, a 'Region of Interest' (ROI) from each of the 90%- and 10%-reflectance panels was defined, and mean radiance for each spectral band for each panel was extracted. A custom-written ENVI script was then used to linearly rescale the magnitude of the intensity of each spectral band of the entire image to fall in the range 0 to 10^6. In effect, a value of 0 then corresponds to a reflectance of 0% in the processed image, and a value of 10^6 corresponds to a reflectance of 100%.

In order to produce the spectra shown in the Results chapter of this Memorandum, the 'reflectance' images were used. One or more ROIs of the specimen mine were defined, and the mean spectrum was extracted from each ROI using the ENVI spectral tool 'Spectral Library Builder'. The resultant mean spectrum was then extracted to a text file using the 'Output Data to ASCII File' feature of the ENVI spectral tool 'Spectral Library Viewer'. Each spectral text file was converted to a Microsoft Excel file, which was used as input to the 'Grapher 2' program [7] to produce the final spectral plots.

Table 2: *casi bands for* ***d15cm2*** *data*

Band Number	Centre Wave-length	Width	Row Numbers	
	(nm)	±*(nm)*	*Start*	*End*
1	453.2	44.9	241	288
2	542.2	45.6	193	240
3	633.1	46.1	145	192
4	724.5	46.4	97	144
5	816.4	46.6	49	96
6	908.5	46.6	1	48

Table 3: *casi bands for* ***d20cm2*** *data*

Band Number	Centre Wave-length	Width	Row Numbers	
	(nm)	±*(nm)*	*Start*	*End*
1	438.3	30.0	257	288
2	497.5	30.4	225	256
3	557.4	30.6	193	224
4	617.8	30.9	161	192
5	678.6	31.0	129	160
6	739.7	31.2	97	128
7	801.1	31.2	65	96
8	862.5	31.2	33	64
9	923.8	31.2	1	32

Table 4: casi *bands for* ***dspat1*** *data*

Band Number	Centre Wave-length	Width	Row Numbers	
	(nm)	±*(nm)*	*Start*	*End*
1	517.2	35.1	212	248
2	569.6	18.5	193	211
3	605.5	18.5	174	192
4	641.5	18.6	155	173
5	677.7	18.7	136	154
6	713.9	18.7	117	135
7	750.3	18.7	98	116

Table 5: casi *bands for* ***dspat2*** *data*

Band Number	Centre Wave-length	Width	Row Numbers	
	(nm)	±*(nm)*	*Start*	*End*
1	551.0	50.3	186	238
2	650.2	50.0	134	185
3	750.3	51.3	81	133

3. Results

For ease of reference, the Results are divided into two sections, Anti-tank mines and Anti-personnel mines. The specimen mines are listed in Table 1. The spectral results below are given in the same (alphabetical) order.

3.1 Anti-tank mines

3.1.1 FFV 028

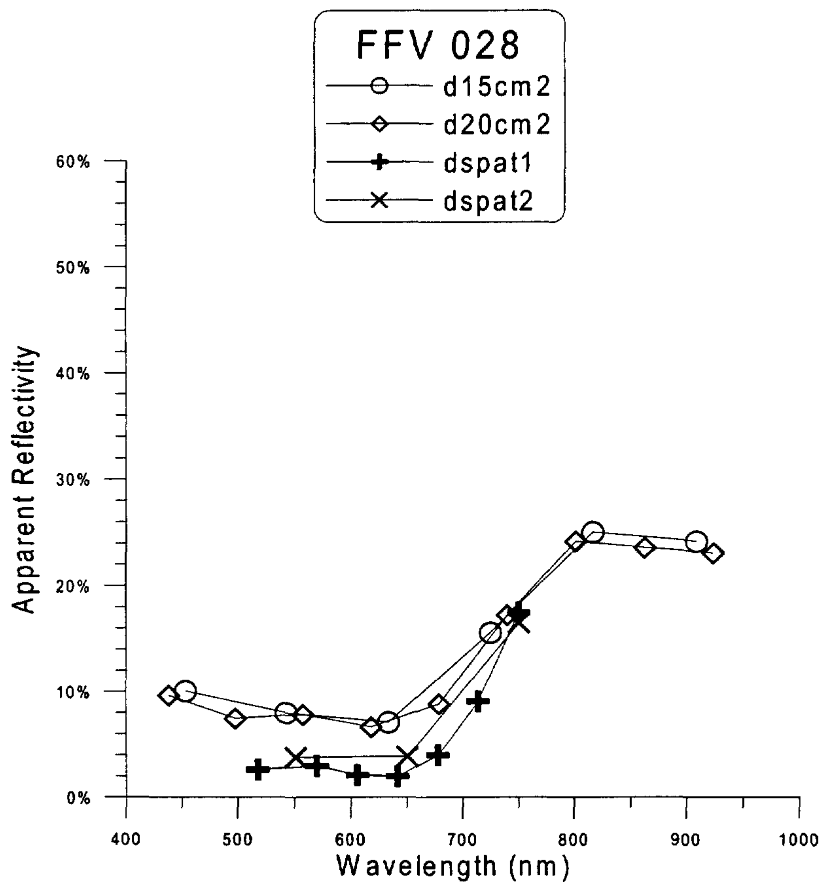

Figure 2: *Spectra of FFV 028 AT Mine*

3.1.2 M15

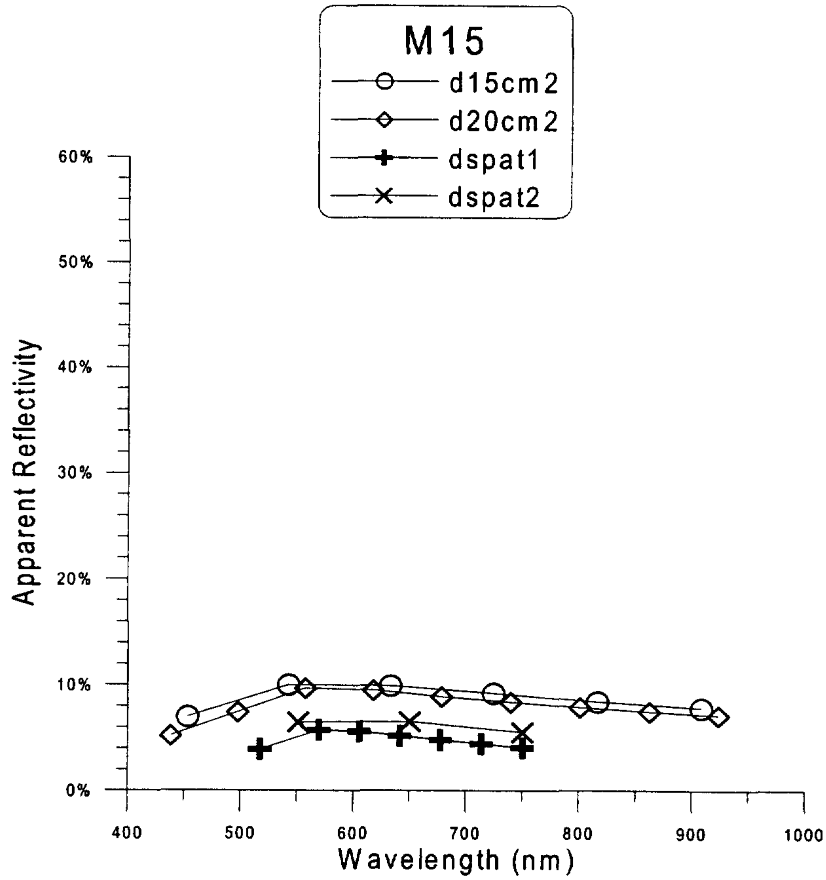

Figure 3: *Spectra of M15 AT Mine*

3.1.3 M21

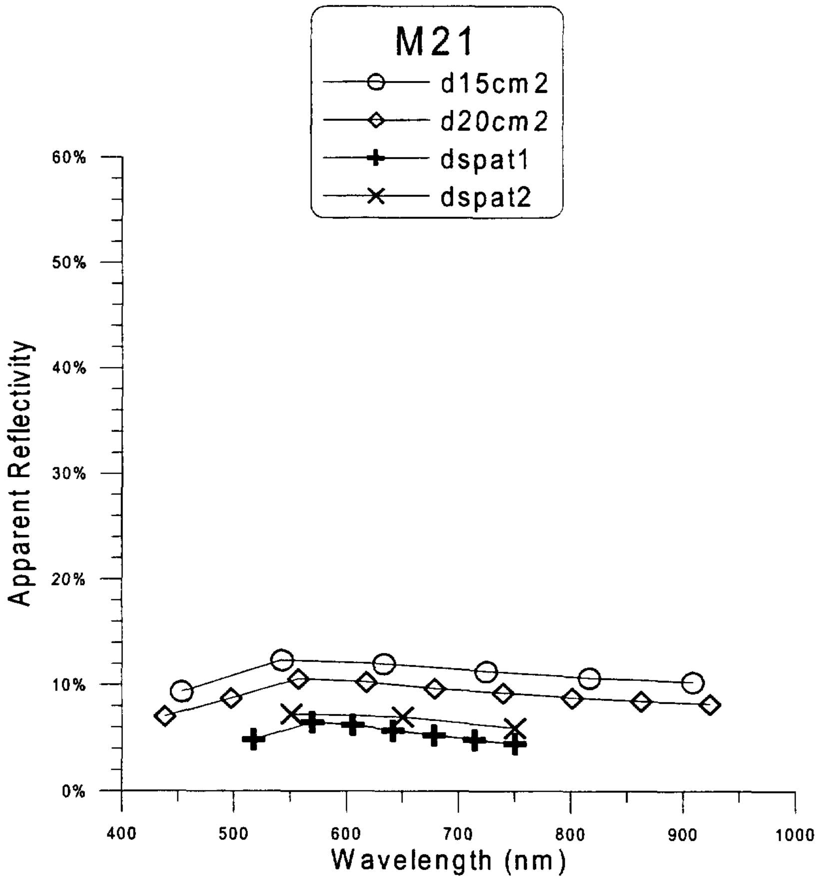

Figure 4: *Spectra of M21 AT Mine*

3.1.4 Mk-7

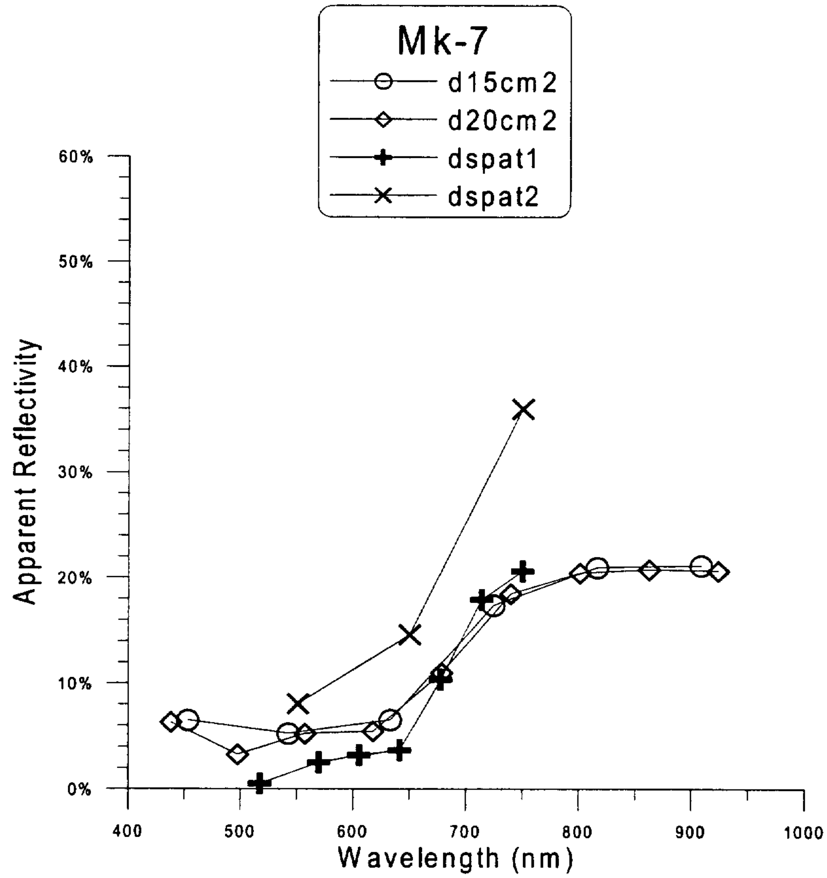

Figure 5: *Spectra of Mk-7 AT Mine*

3.1.5 PT Mi-Ba III

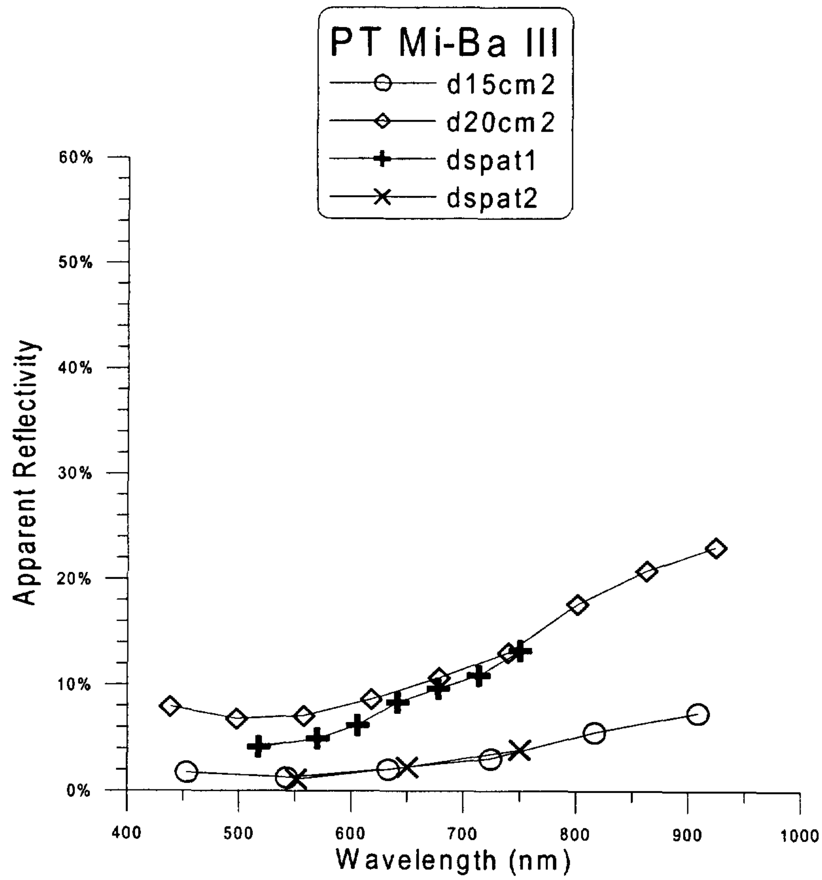

Figure 6: *Spectra of PT Mi-Ba III AT Mine*

3.1.6 SA-10 (D)

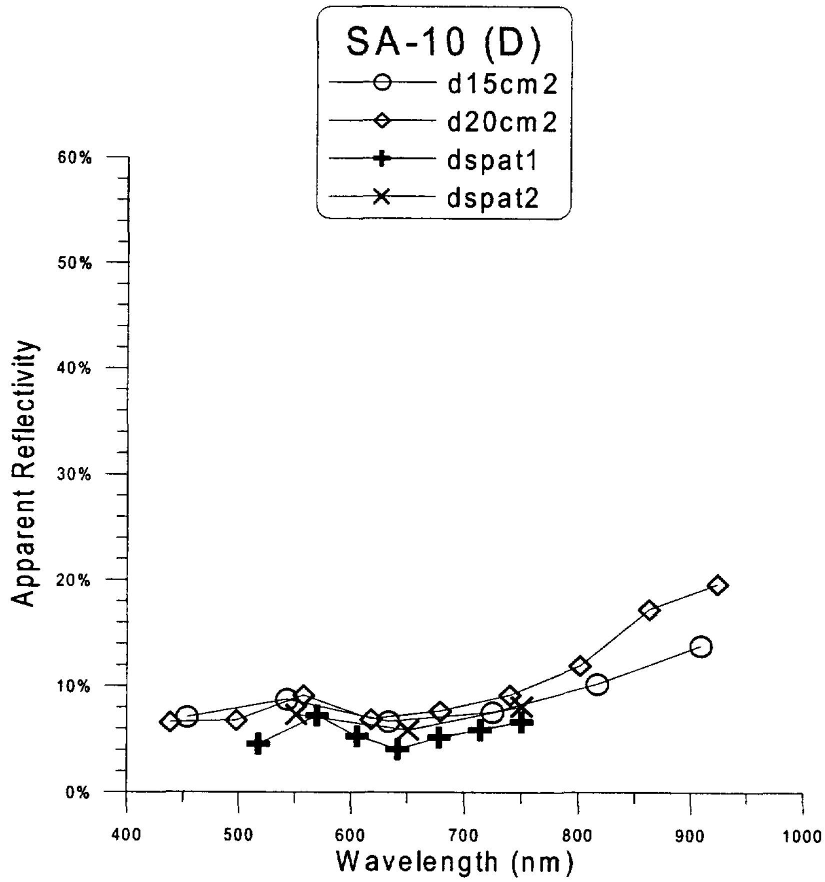

Figure 7: *Spectra of SA-10 (D) AT Mine*

3.1.7 TM-46 (D)

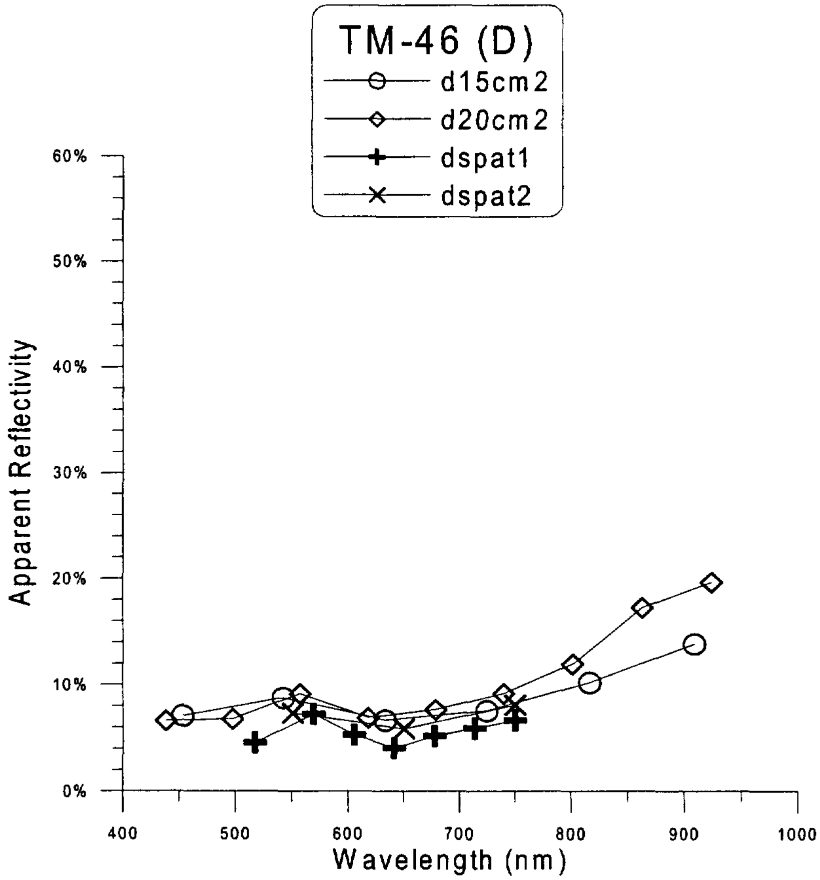

Figure 8: *Spectra of TM-46 (D) AT Mine*

3.1.8 TM-62M

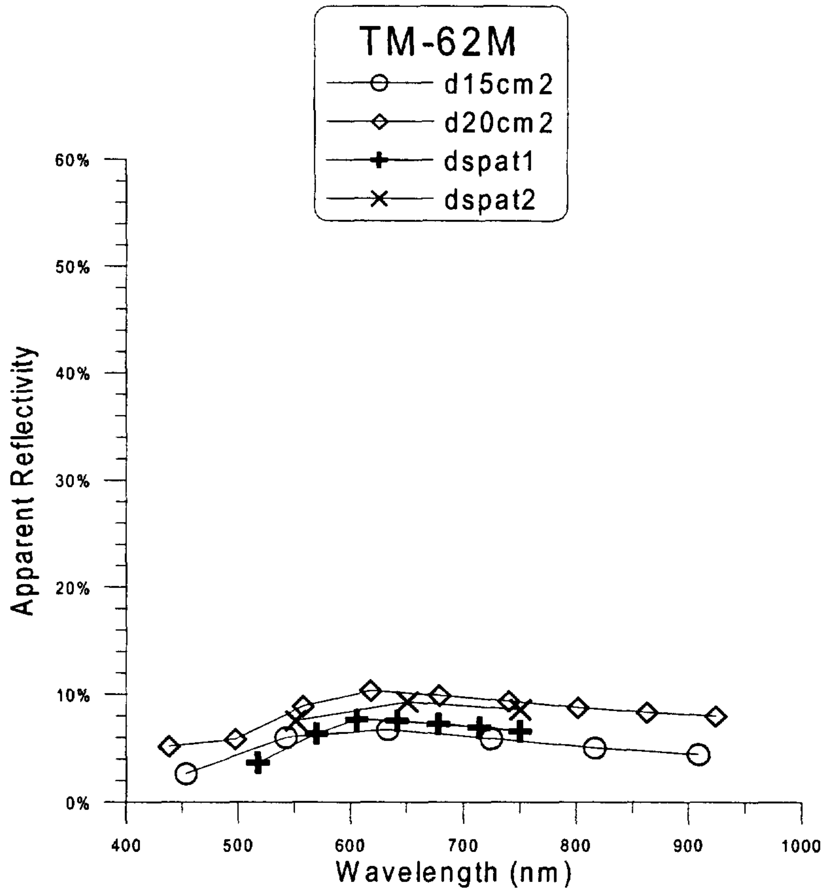

Figure 9: *Spectra of TM-62M AT Mine*

3.1.9 TMA-3

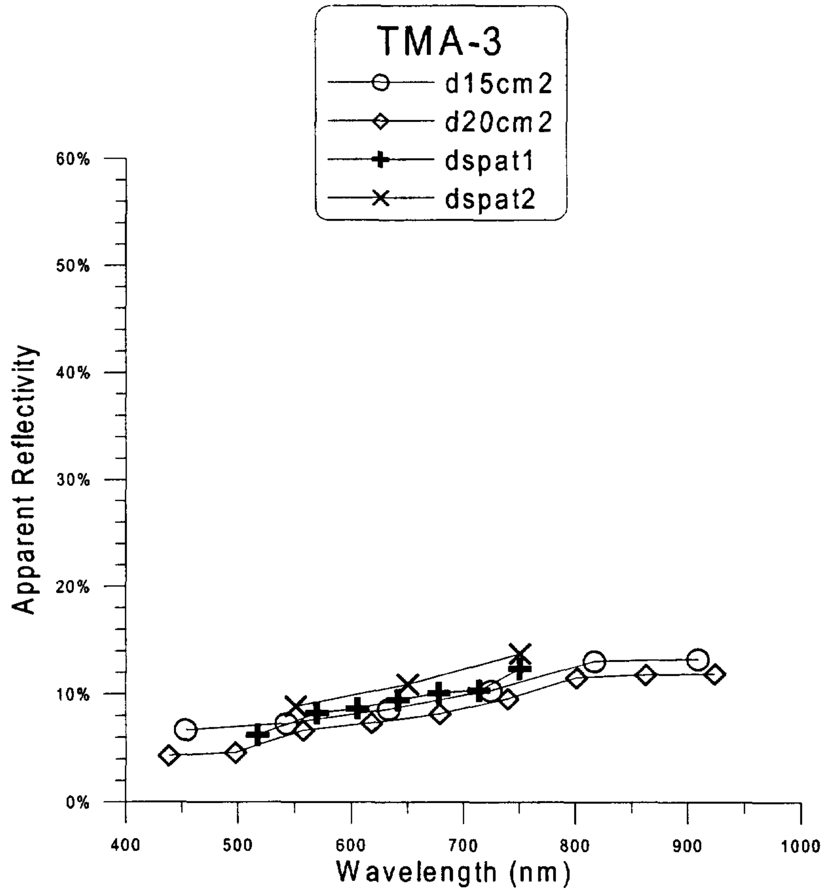

Figure 10: *Spectra of TMA-3 AT Mine*

3.1.10 TMA-4

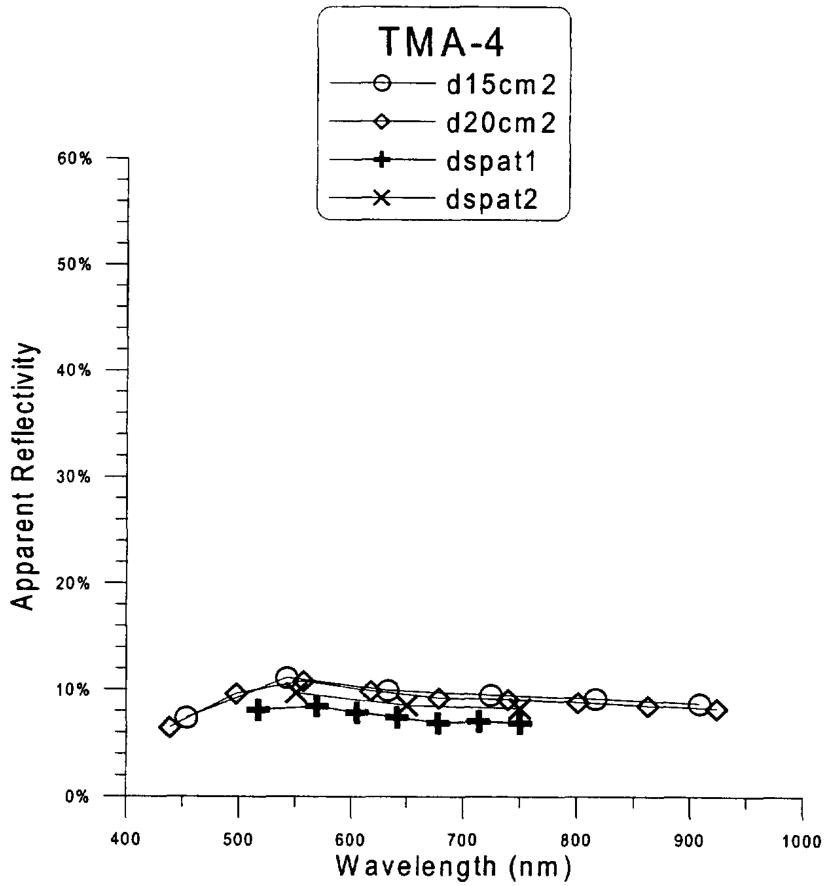

Figure 11: *Spectra of TMA-4 AT Mine*

3.1.11 TMA-5

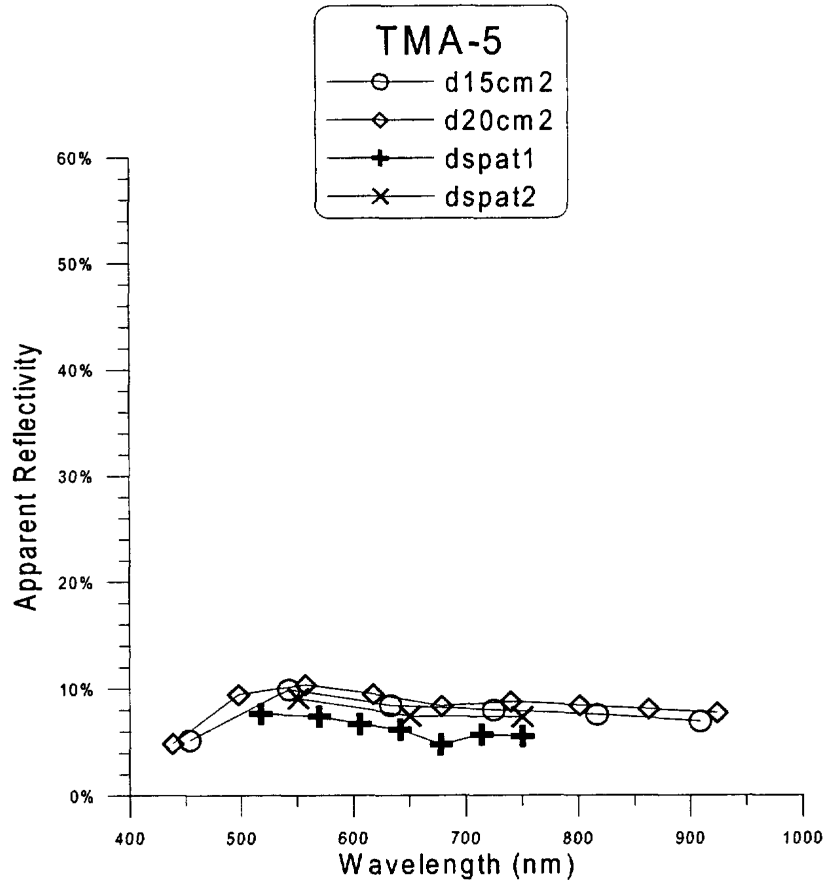

Figure 12: *Spectra of TMA-5 AT Mine*

3.1.12 TMRP-6

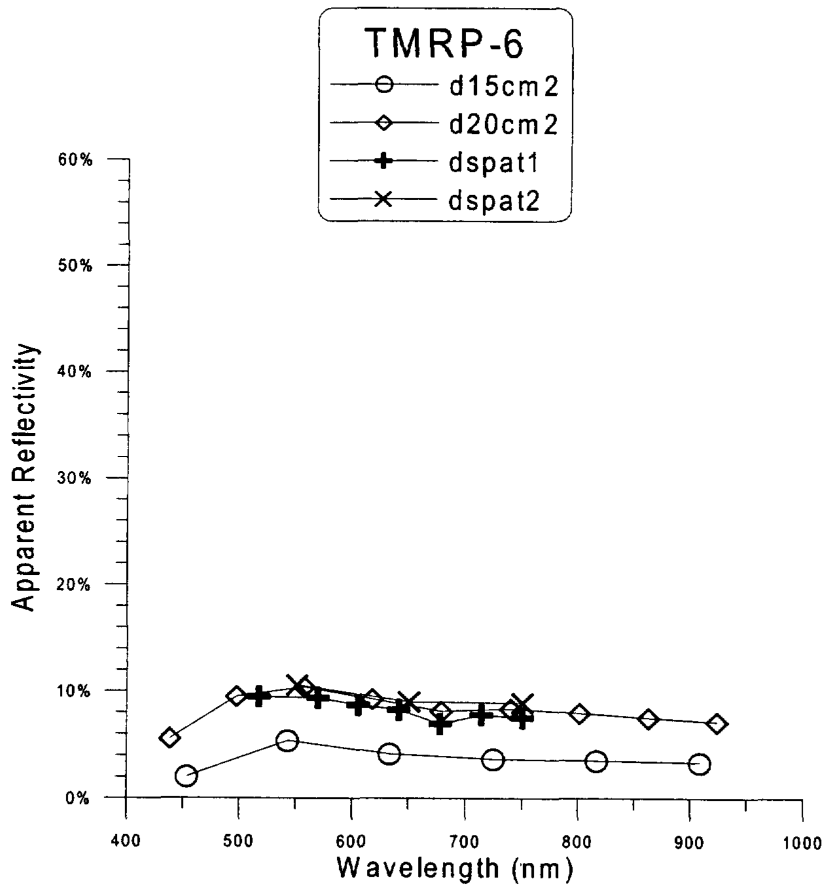

Figure 13: *Spectra of TMRP-6 AT Mine*

3.1.13 Woodmine

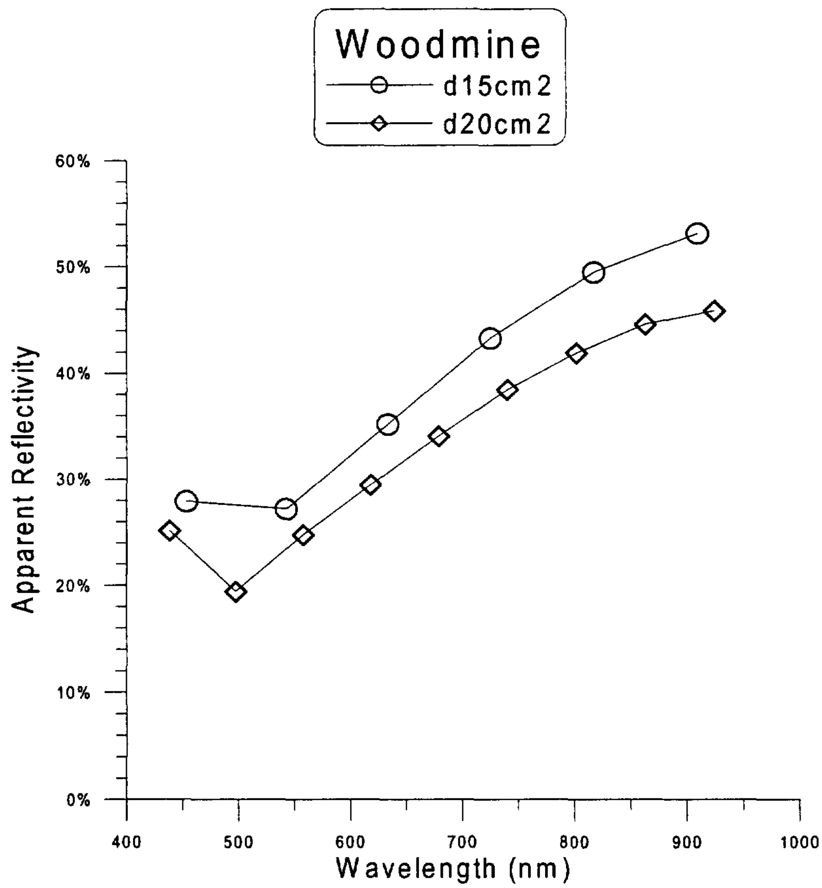

Figure 14: *Spectra of Woodmine AT Mine*

3.2 Anti- personnel mines

3.2.1 Butterfly

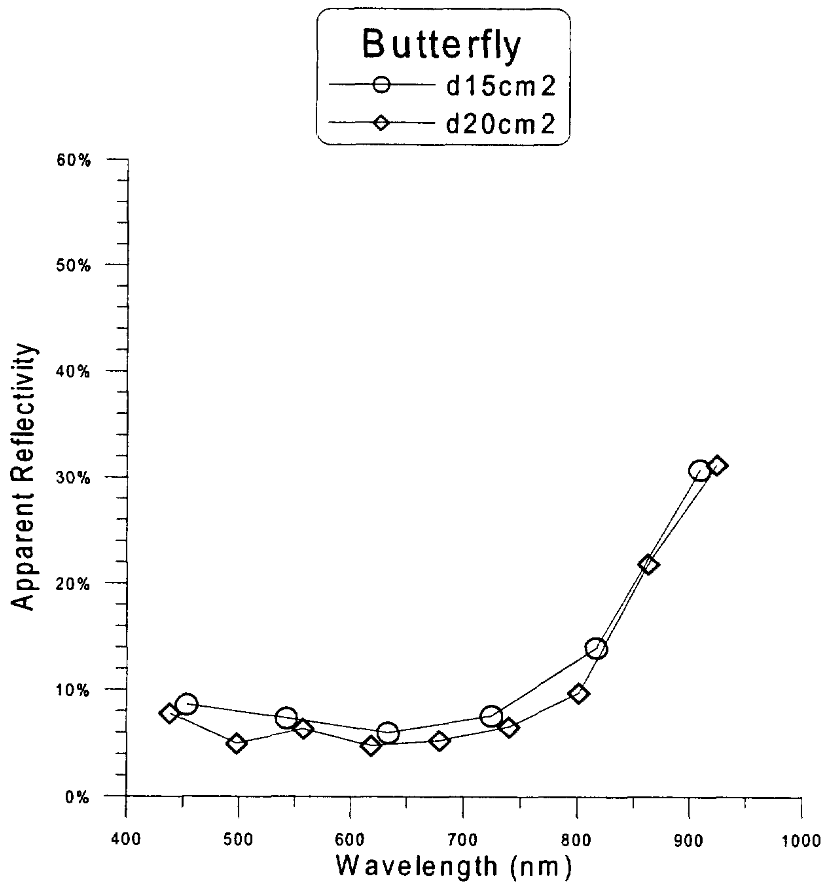

Figure 15: *Spectra of Butterfly AP Mine*

3.2.2 Cuppmisr (D)

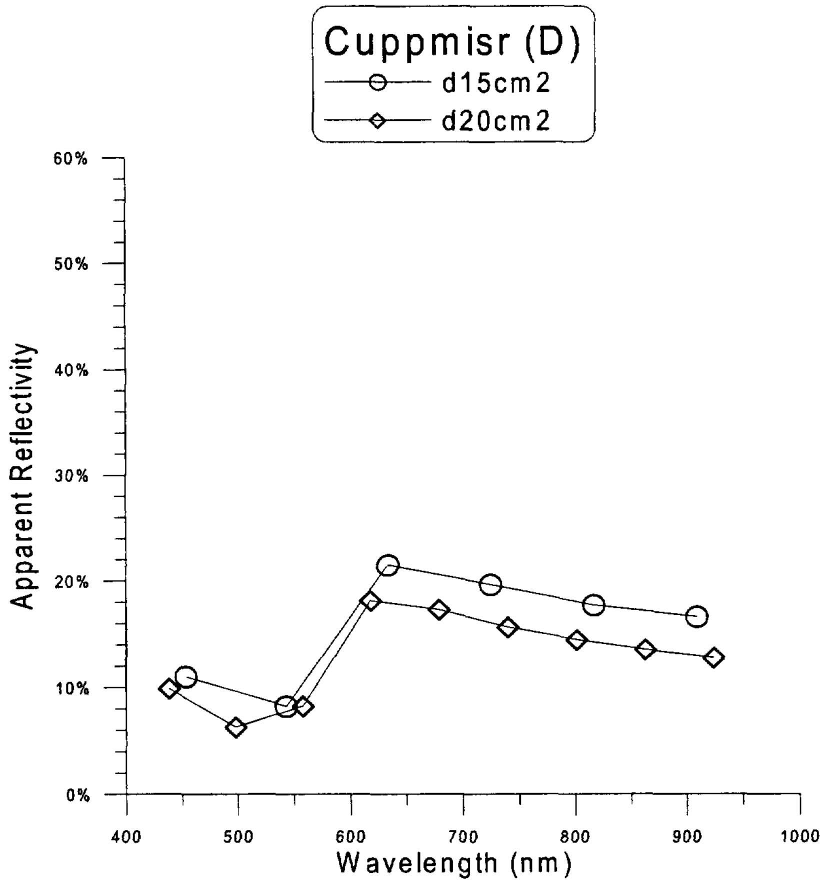

Figure 16: *Spectra of Cuppmisr (D) AP Mine*

3.2.3 FFV 013

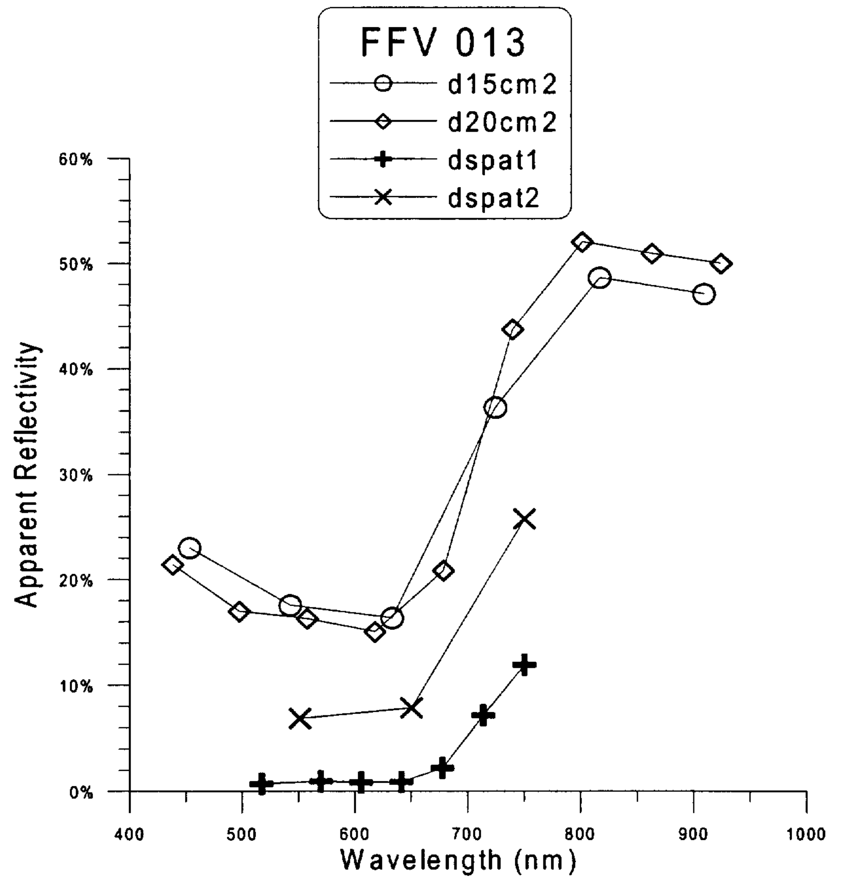

Figure 17: *Spectra of FFV 013 AP Mine*

3.2.4 M16A2

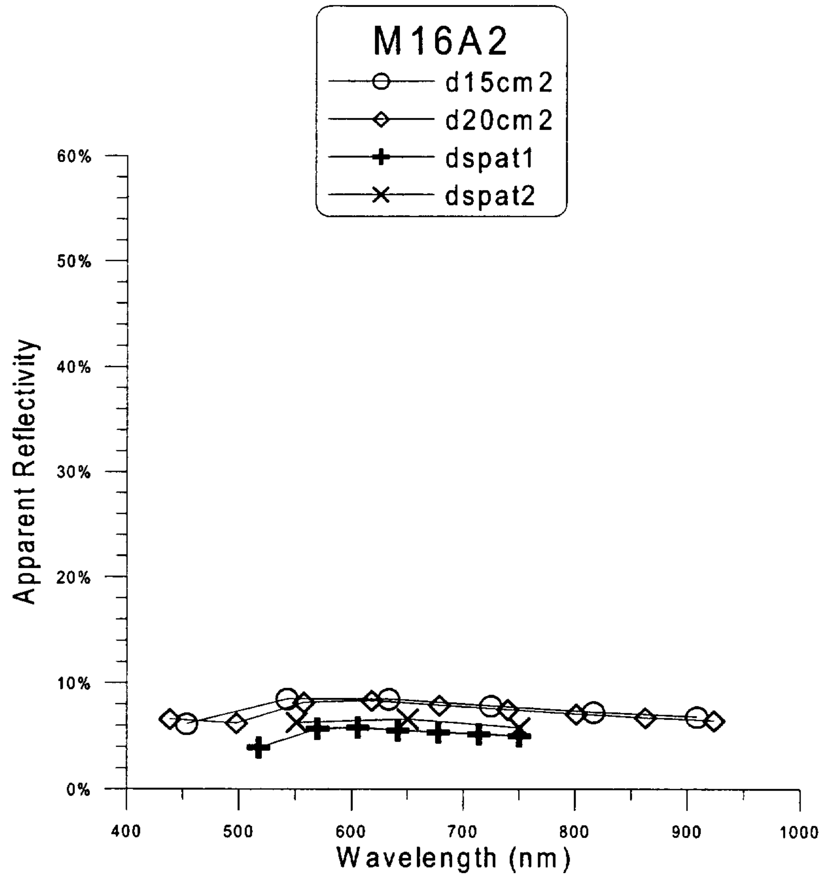

Figure 18: *Spectra of M16A2 AP Mine*

3.2.5 M18A1

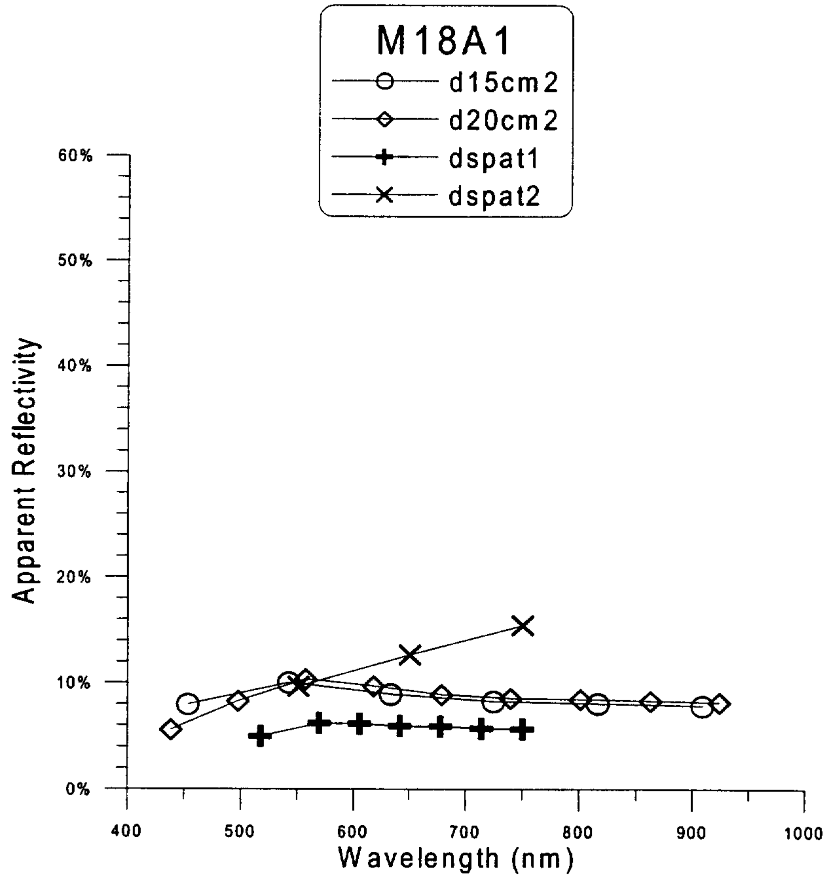

Figure 19: *Spectra of M18A1 AP Mine*

3.2.6 OZM-3 (D)

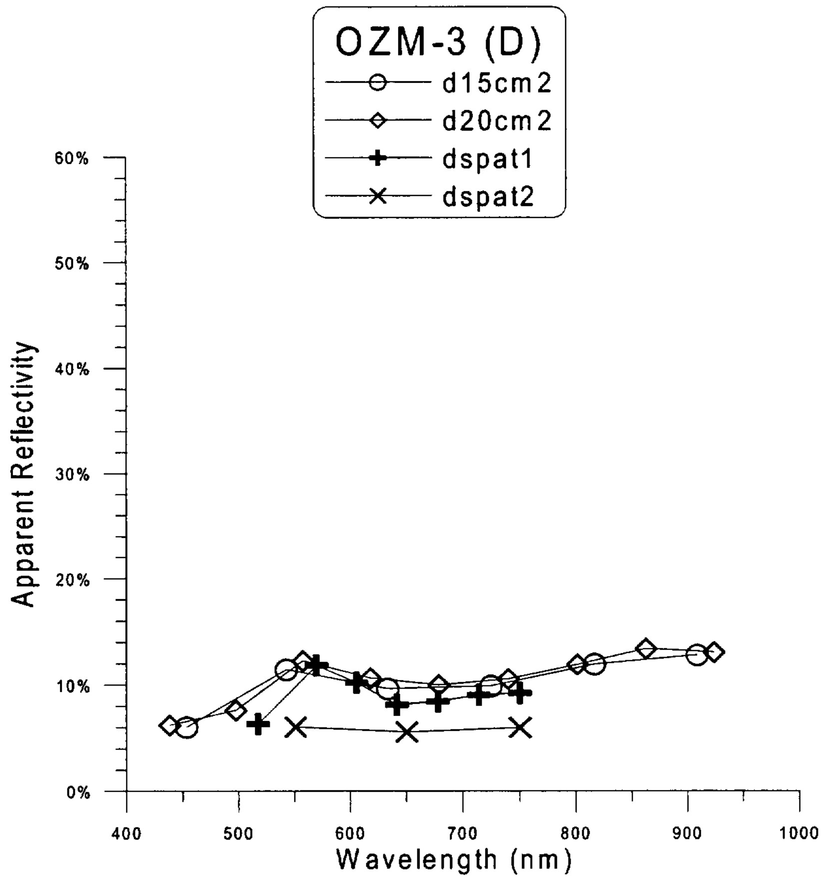

Figure 20: *Spectra of OZM-3 (D) AP Mine*

3.2.7 PMA-1A

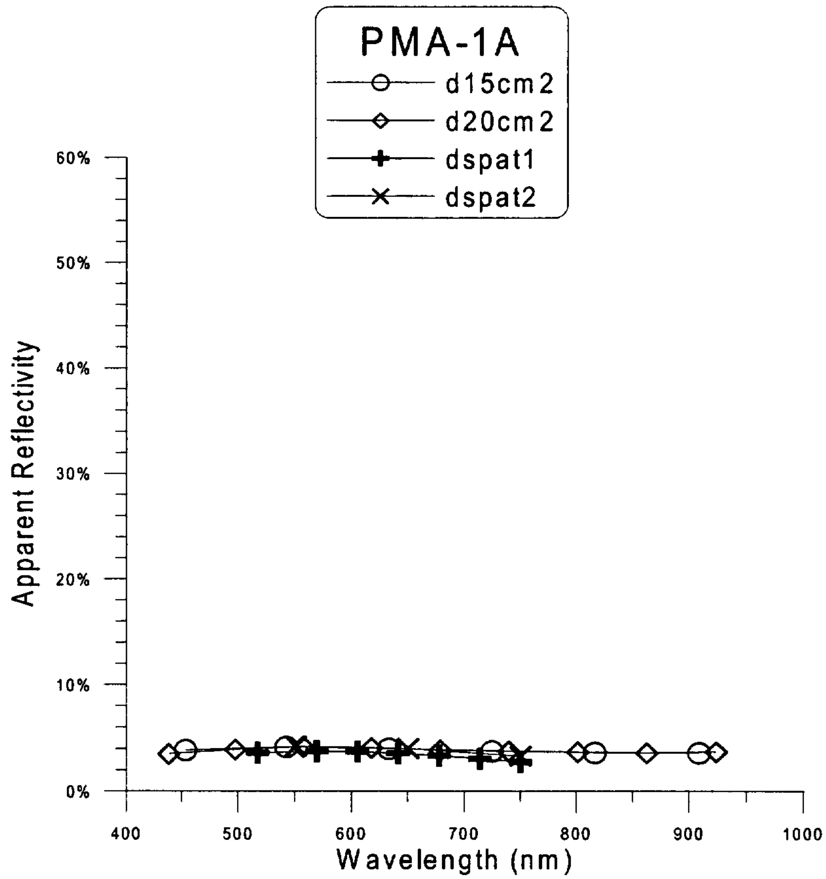

Figure 21: *Spectra of PMA-1A AP Mine*

3.2.8 PMA-2

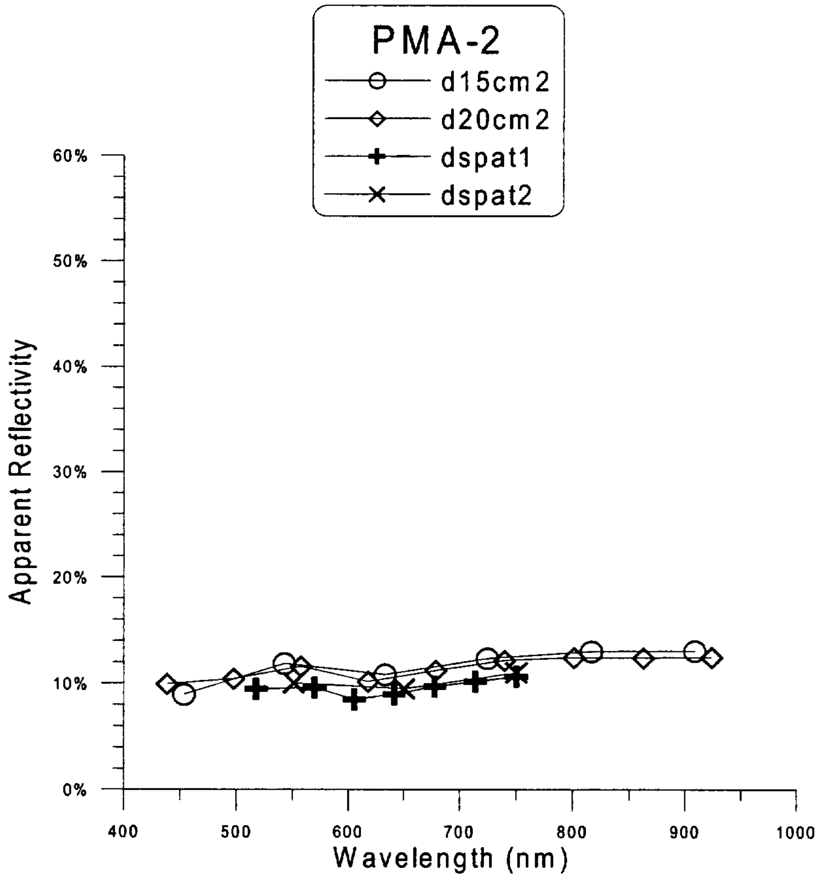

Figure 22: *Spectra of PMA-2 AP Mine*

3.2.9 PMA-3

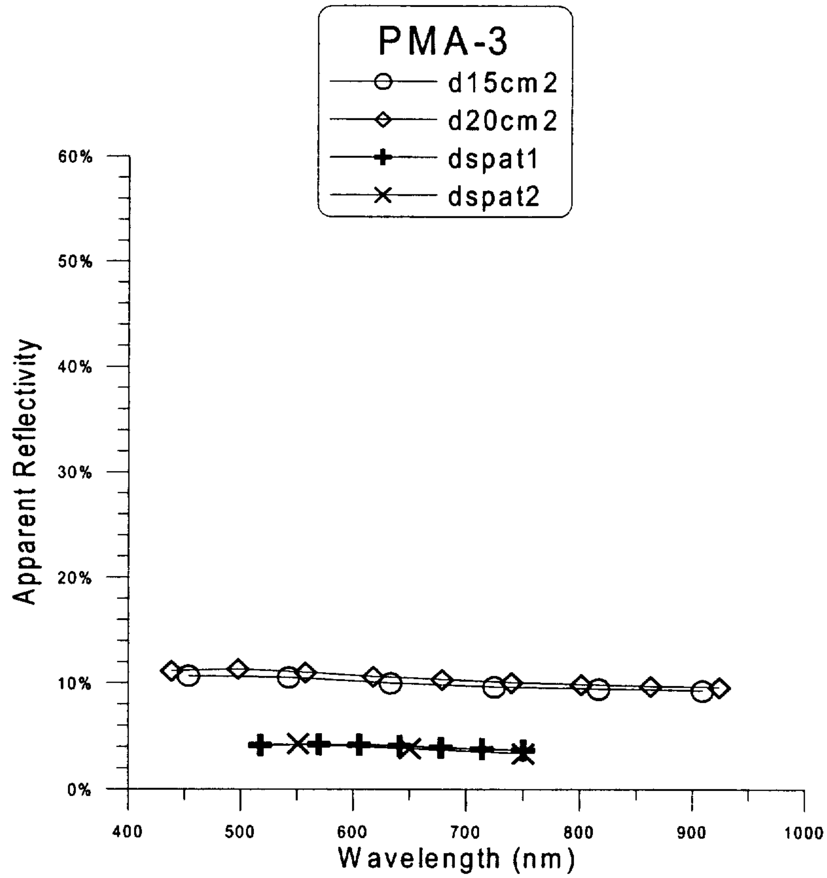

Figure 23: *Spectra of PMA-3 AP Mine*

3.2.10 PMN-6 (D)

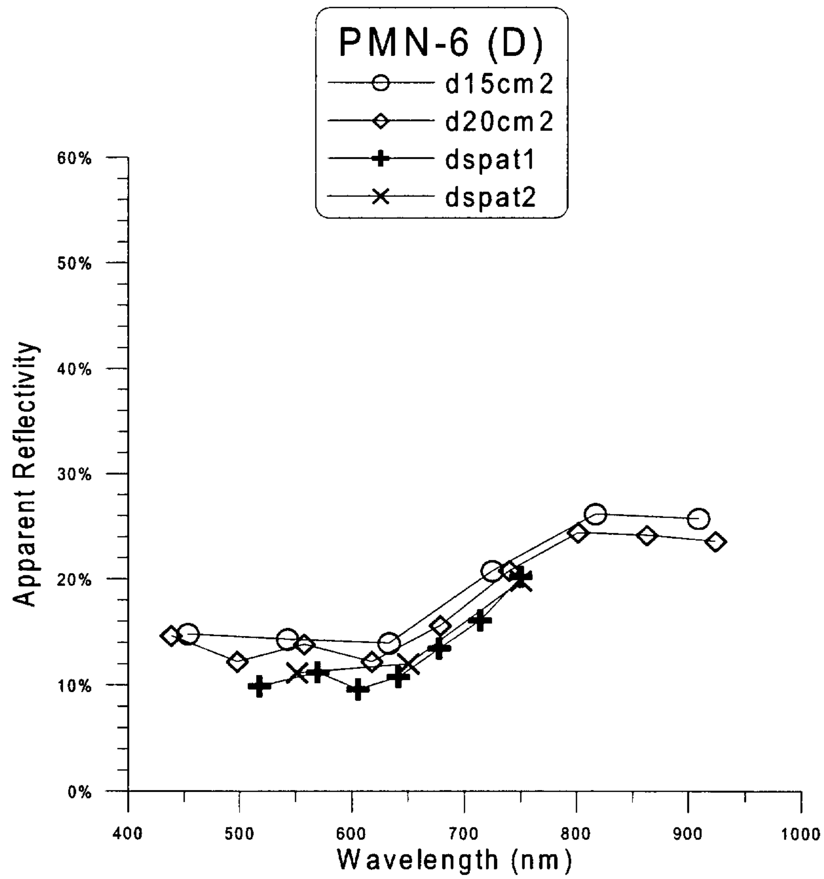

Figure 24: *Spectra of PMN-6 (D) AP Mine*

3.2.11 Valamara 69

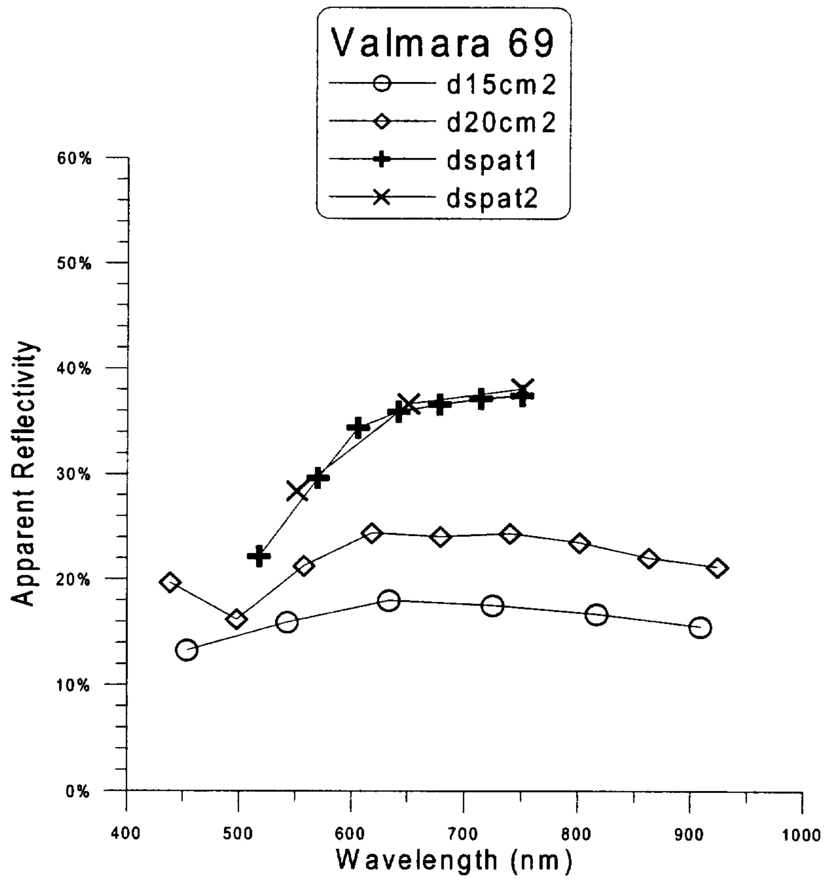

Figure 25: *Spectra of Valamara 69 AP Mine*

3.2.12 VS-50

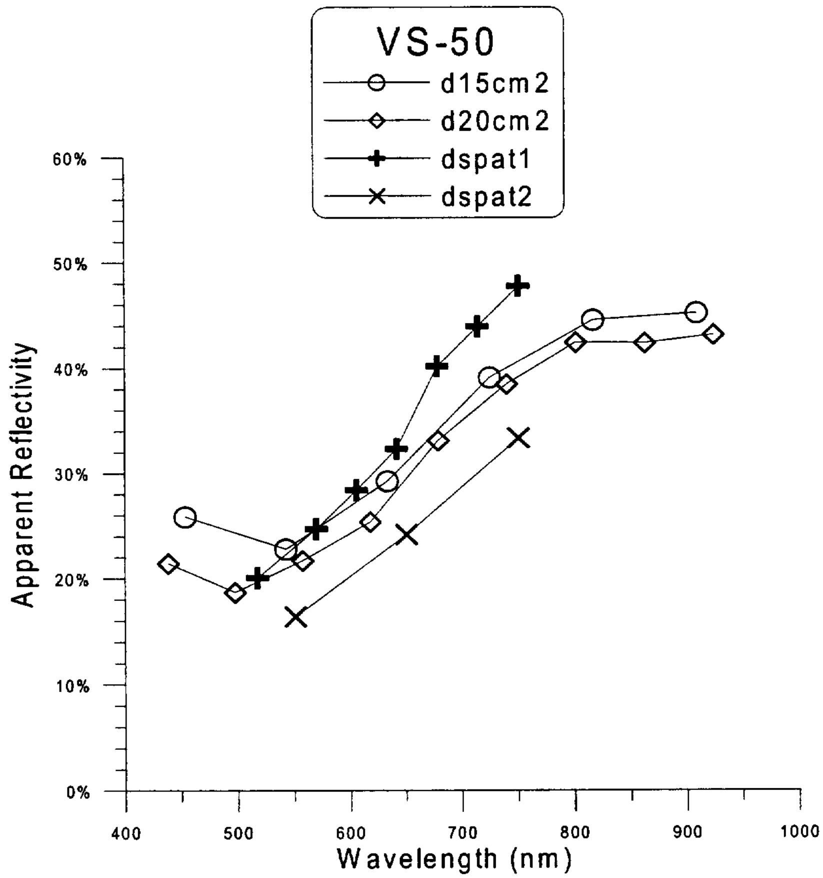

Figure 26: *Spectra of VS-50 AP Mine*

3.2.13 VS-Mk2

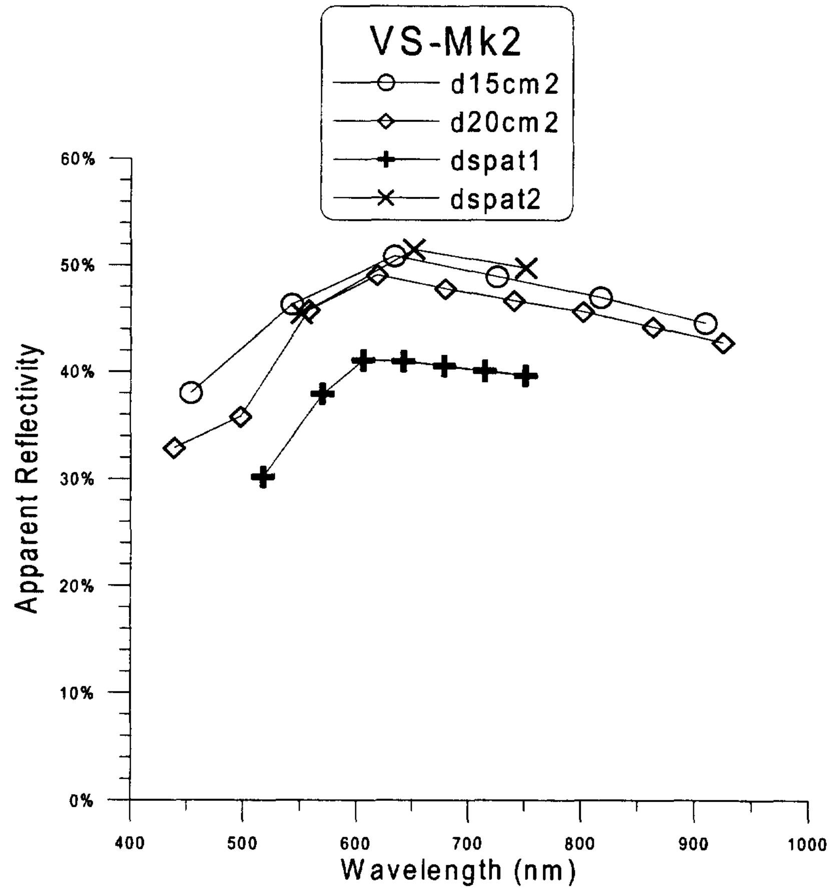

Figure 27: *Spectra of VS-Mk2 AP Mine*

4. Discussion

There are several observations that can be made regarding the general characteristics of all the sets of spectra for all the mines. Some of these observations pertain more to the characteristics of the spectral shapes; others relate to apparent systematic measurement problems. Systematic measurement problems will be discussed first.

4.1 Systematic inconsistencies

For many of the sets of spectra, it can be seen that the results for the natural and the artificial light spectra do not coincide. Nevertheless, in almost all cases there appears to be a characteristic spectral shape for each mine that is consistent to within an offset and/or a scaling factor. This degree of consistency indicates that a basic characteristic spectral shape for each mine has been captured. Typically, the **d15cm2** and **d20cm2** spectra, which were recorded indoors under artificial light, have reasonable self-consistency and show a higher measured reflectivity than the **dspat1** and **dspat2** spectra, which were recorded outdoors under sunlight and also have reasonable self-consistency. The exceptions are noted below.

The non-uniform illumination provided by the artificial light used to measure the **d15cm2** and **d20cm2** spectra provides a partial explanation for the discrepancies between some of these pairs of spectra, and also for the lack of coincidence with the **dspat1** and **dspat2** spectra measured outdoors. Of course, this does not explain the lack of coincidence between the **dspat1** and **dspat2** spectra for individual mines, notably the Mk-7, the PT Mi-Ba III, the FFV-013, the M18A1, the OZM-3 (D), the VS-50 and the VS-Mk2. As well, there is lack of self-consistency for the PT Mi-Ba III, the TM-62M (slight), the Woodmine (slight), the FFV 013, the M18A1 and OZM-3 (particularly the **dspat2** spectra) and the Valmara 69.

4.2 Characteristic spectral shapes

The spectral shapes for the various mines display different characteristics, and there is no particularly outstanding feature that unites them. For example, the spectra of the FFV 028, the Mk-7, the FFV 013 and the PMN-6 (D) have a strongly sigmoidal shape with a rise in reflectivity occurring over the range from 600 nm to 800 nm. The VS-50 also has spectra of a similar shape, but with the rise occurring over the range 500 nm–800 nm. This appears to be an attempt to mimic the chlorophyll red edge. The outstanding characteristic of all these mines is that they are more highly reflective in the 800-900 nm region than at visible wavelengths. The Butterfly mine exhibits a sharp increase in reflectivity above 850 nm, and the reflectivity of the woodmine also increases as a function of increasing wavelength.

The PT Mi-Ba III, the SA-10 (D), the TM-46 (D) and the TMA-3 all show a small increase in reflectivity as a function of increasing wavelength. The spectra of the

SA-10 (D) and the TM-46 (D) are virtually identical, which indicates that these two surrogate mines were fabricated from the same material. Many of the remaining mines have spectra that are essentially flat, or have only minor fluctuations in their reflectivity as a function of wavelength. Most of these mines have reflectivities of about 10% or less, if the calibration of the data is accurate.

It is not apparent from the present data whether the coarseness of the spectral resolution has masked finer structure which could be used to discriminate mines from their background, or whether the VNIR spectra of the materials from which modern anti-tank and anti-personnel mines are fabricated are inherently smooth. For this reason, it is suggested that further measurements at higher spectral resolutions should be made.

5. Conclusions

A set of 98 VNIR low-resolution spectra of modern anti-tank and anti-personnel landmines has been presented. It has been shown that these spectra, in and of themselves, have no particularly unique characteristics, and have a smoothly varying dependency of reflectivity at the relatively coarse resolutions of these measurements.

It is suggested that future measurements should be made at higher spectral resolution.

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4. Achal, S.B., Anger, C.D., McFee, J.E., and Herring, R.W. (1999). Detection of surface-laid mine fields in VNIR hyperspectral high spatial resolution data. In Dubey, A.C., Harvey, J.F., Broach, J.T., and Dugan, R.E., (Eds.), *Proceedings SPIE Conference on Detection and Remediation Technologies for Mines and Mine-like Targets IV*, Vol. 3710, pp. 808–818. Orlando, FL, USA.

5. *casi* User's Manual. http://www.itres.com/.

6. ENVI User's Guide, Version 3.2. http://www.rsinc.com/.

7. Grapher 2 is a product of Golden Software, Inc. of Golden, Colorado. http://www.goldensoftware.com/.

List of symbols/abbreviations/acronyms/initialisms

casi	Compact Airborne Spectrographic Imager, a product of ITRES Instruments Inc. of Calgary, Alberta.
DND	Department of National Defence
DRES	Defence Research Establishment Suffield
ENVI	The environment for visualizing images. ENVI® is a registered trademark of Better Solutions Consulting Limited Liability Company.
ROI	Region of Interest
VNIR	Visual and Near Infra-Red

DOCUMENT CONTROL DATA SHEET

1a. PERFORMING AGENCY DRES	2. SECURITY CLASSIFICATION UNCLASSIFIED -
1b. PUBLISHING AGENCY DRES	

3. TITLE

(U) Low-resolution VNIR spectra of AP and AT landmines: Some examples

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14. ABSTRACT

(U) Low-resolution (up to 9 bands) optical spectra of 13 anti-tank and 13 antipersonnel landmines over the visual and near infrared (VNIR) range (400-950 nm) are presented. It is suggested that further measurements at higher spectral resolutions would be useful.

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