MODAL ANALYSIS AND PHASE IDENTIFICATION IN METEORITE THIN SECTIONS USING "FREEWARE" FOR PC. [1]D. van Niekerk, [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, Honolulu, Hi 96822, dionysos@higp.hawaii.edu.

Introduction: Automated mapping and determination of mineral modes in thin sections have been the subject of various publications [1-6]. Automated techniques have advantages that include denser sample counts, speed, and potential elimination of biases in mineral identification. Many of these studies however, have presented techniques based on specialized or expensive software, as well as software that, due to logistical reasons, may not always be widely accessible. A previous study at the University of Hawaii [7] developed a technique for automated mapping and modal analysis of meteorite thin sections, using image processing software. Here I present an extension to that technique that makes it more accessible to a wider range of users, by replacing specialized software with free software for the Windows environment.

Background to the technique: For this study, elemental X-ray maps were imported into *Multispec©* and manipulated to identify minerals, in order to produce maps that were subsequently used for modal analysis by extrapolating procedures in [7]. X-ray maps of thin sections that were collected by Hicks [7] on a Cameca SX 50 Electron Microprobe (EMP) were used in this study, in order to provide control on the accuracy of the results obtained from studying Shergotty, NWA 733, and a schist. *Himax* software supplied with the EMP was used to collect the individual elemental maps, which were subsequently exported as TIFF files. The reader is referred to Hicks et al. [6] for details concerning the procedures for collecting the X-ray maps, as well as the fundamentals underlying the procedure of modal classification of thin sections by use of remote sensing software.

Multispec© [8], which is a copyrighted software program developed by the Purdue Research Foundation, was used to classify the mineralogy of the images and determine the modes. It is distributed free of charge and can be downloaded from http://dynamo.ecn.purdue.edu/~biehl/Multispec. An original Mac version is also available, and includes some features not yet transposed to the PC version.

Software functionality applied to thin section processing: X-ray maps can be imported into *Multispec©* and linked to produce a multi-element file, from which further classification and statistical manipulation may be performed. There are two philosophical end members in approaching the processing of the resultant file - one where it is assumed that the phases are unknown, and one where the researcher is aware of all the phases present. The latter scenario is perhaps a more realistic one, since petrographical work and knowledge of the rock mineralogy in advance of compositional mapping is almost assured.

Unsupervised classification of the resultant file is possible, however, if one assumes the first scenario, and a number of algorithms are available to this end.

In a case where advance knowledge of the mineralogy of the thin section is assumed, supervised classification through various algorithms may be performed. This involves visually and statistically identifying different minerals in combined image maps, and then training the processor to recognize all similar pixels. To aid in the identification of unknown phases that appear in a particular multi-layer image, the elemental composition of pixels in a user-defined area may be viewed in the form of a graph plot – a kind of spectral signature characteristic to each phase. Two-and-three element maps (Figure 1) are also useful in indentifying phases, as are single element maps in the linked file. The resultant output file contains statistics that present modal estimates of the predefined classes/phases, and may represent either the entire image or a subset as defined by the user.

A detailed reference manual may be downloaded from the software website, and may serve as a guide to the customized application of *Multispec©* to thin section processing.

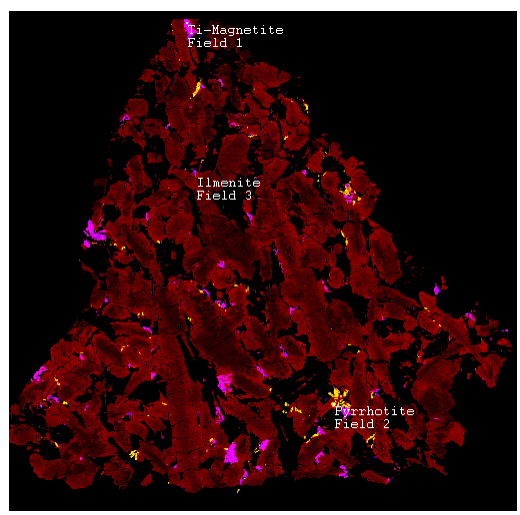

Figure 1: Bi-variate (two element) map used to classify pixels belonging to iron-bearing minerals.

Results and conclusions: The technique developed by Hicks [7] calls for avoiding compression of data when exporting X-ray maps from Himax as TIFF files. She presents a solution that involves data extraction and recompilation in a specialized IDL application. Despite the use of TIFF files in the current study on NWA 733 and schist samples, mineral maps and modes are in agreement with that of the specially manipulated data in the Hicks study. This indicates that precompilation of data through a specialized IDL application is not imperative. A critical factor controlling the accuracy of the mineral maps and the subsequently calculated modes, is the number of elemental maps used versus the diversity of phases. Major phases may be easily distinguished and accurately counted with a small number of maps, whereas this will produce inaccurate results for minor phases. A further factor to be taken into account is the resolution of the X-ray maps versus the size of the smallest phases. Although the technique has obvious advantages, great care must be taken to produce as accurate a mineral map as possible, through thorough and know- ledgeable use of the available software features.

An example of results obtained in this study are listed in Table 1, and is in good agreement with previous studies. The mineral map produced through supervised classification, and used to obtain the modes in Table 1, is presented in Figure 2 and has been color coded so as to be comparable to that of [6], in Figure 3.

With informed use, *Multispec©* provides a welcome alternative for those who do not have access to commercial programs designed for image processing of remote sensing data. Basic step-by-step instructions for using *Multispec©* to start processing of thin sections will be posted at http://www.higp.hawaii.edu/~dionysos/LPSCMultispec.pdf, from March 2003 to May 2003.

	A	B [6]	C [9]	D [10]	E [11]	F [12]
Pyroxene	67.1	67.8	70.5 / 69.1	68.9	70	67
Maskelynite	25	25.1	23.9 / 22.7	24	20	24
Mesostasis	2.5	2.3	2.8 / 5.2		3	3
Phosphates	2	2	tr / tr	1.3	1	2
Ti-magnetite	1.4	1.1	2 / 2.5	2.3	2	2
Silica	1	1				0.5
Pyrrhotite	0.6	0.5	0.3 / 0.2			0.4
Ilmenite	0.4	0.3	0.5 / 0.3	1.8	0.5	0.2

Table 1: Modal analysis of Shergotty in this study (A) compared to others (B-F).

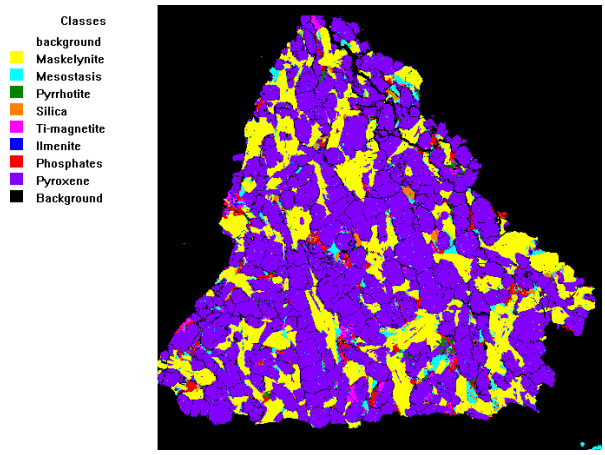

Figure 2: Mineral map of Shergotty, based on associating unique pixels with phases (produced in *Multispec©*).

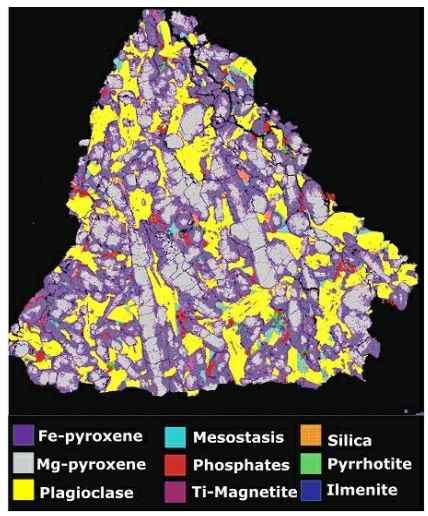

Figure 3: Mineral map of Shergotty from [6] (produced in *ENVI©*).

References:

[1] Bowman L. E. et al. (1997) *MAPS, 32,* 869–875. [2] Chambers J. G. et al. (1995) *JGR, 100 (E7),* 14391-14401. [3] Cossio R. (1998) *Comp. and Geosci.,* 24, 805-814. [4] Elliot B. A. (1999) *Bull. Geol. Soc. Finland, 71(2*), 233-241. [5] Taylor L. A. et al. (1996) *Icarus 124*, 500-512. [6] Hicks T. L. et al. (2002) *LPSC XXXIII,* Abstract # 1055. [7] Hicks T. L. (2002) *MS Thesis*, Univ. of Hawaii at Manoa 115pp. [8] Biehl L. and Landgrebe D. (2002) *Comp. and Geosci*, 28, 1153-1159. [9] Stolper E. M. and McSween H.Y. Jr. (1979) *GCA*, 43, 1475-1498. [10] Duke M. B. (1968) In *Shock Metamorphism of Natural Materials*, 612-621. [11] Smith J. V. and Hervig R. L. (1979) *Meteoritics*, 14, 121-142. [12]Stoffler D. et al. (1986) *GCA*, 50, 889-913.