CHARACTERISING THE EJECTA SPECTRA OF LONAR CRATER, INDIA IN HYPERION IMAGE – IMPLICATIONS FOR LUNAR STUDIES.

S. Vijayan[1], K. Vani[1] and S. Sanjeevi[2], [1]Department of Computer Science and Engineering, Anna University, Chennai, India. [2]Department of Geology, Anna University, Chennai, India, vijayansiva@gmail.com, vanirrk@yahoo.com, sanjeevigeo@gmail.com.

Introduction: Lonar crater, which was formed on the Deccan Basalt [1] ~50,000 years ago, with a radius of ~900m, is comparable to lunar Mare craters because of the similar target rock (basalt). The distribution pattern of ejecta around the crater was studied by [2] and it was observed that it is spread out for greater than the radius of the crater. Ejecta mapping (exact boundary) around the crater region is difficult because of the heterogeneous mixture of the materials. The heterogeneity is caused not only due to the distribution of different grain sizes but also due to degradation by erosion processes. Hence, fresh ejecta is difficult to find. During the impact, the heavier material falls near the rim, whereas, the finer particles will be thrown away from the rim. Some of the finest particles also fall near the rim thus making the ejecta material a heterogeneous (various grain sizes). Spectral mapping of ejecta will reveal any possible variation within the ejecta. To spectrally distinguish the ejecta types, hyperspectral images are useful. Hence, in this study the Lonar crater ejecta was examined using the spectra derived from Hyperion image to discriminate the variations within the ejecta.

Hyperion Dataset: The Hyperion hyperspectral image of 13 February 2007 (Fig. 1) was used in this study. It consists of 220 bands with a wavelength range of 0.4nm to 2.5nm and with a spatial resolution of 30m.

Hyperion image correction. The Hyperion dataset consists of several zero-band and strip error. Such images are removed from the dataset prior to analysis. The FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) correction was performed to remove the atmospheric effects and the MNF (Minimum Noise Function) was performed to eliminate the noise in the images. The water absorptions bands ~1400nm and ~1900nm were also removed. After performing the above mentioned corrections, the final dataset contains 151 bands.

Spectral Variation of Ejecta: Due to the heterogeneous nature, identification of pure ejecta is difficult. Moreover, the resolution of the Hyperion image is 30m which leads to mixed (pixel) spectra. Thus, to minimize the limitations due to heterogeneity around the crater, the following steps were carried out:

First, in the Hyperion image, the range of ejecta flow considered for this study is equivalent to one crater radius (~900m). This was done because the ejecta beyond this range is difficult to be distinguished. Second, the hindrance due to vegetation cover on both, inner and outer region of the crater was minimized using the NDVI approach. NDVI was computed using the appropriate wavelengths, and vegetation was delineated. The NDVI values < 0.2 were chosen for the analysis and all other regions were masked. The third limitation is the bunds in the agricultural fields over the crater region. These were not considered for this study.

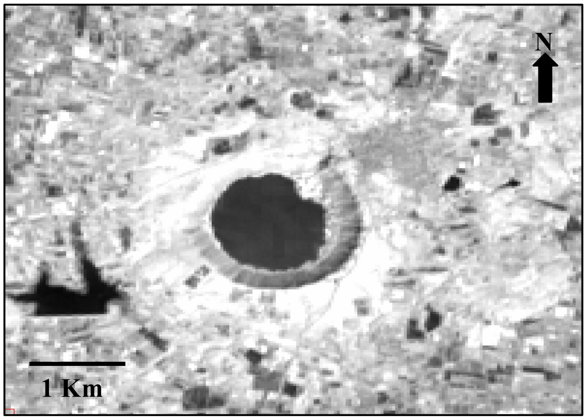

Fig. 1. Hyperion hyperspectral image of Lonar crater and it environs.

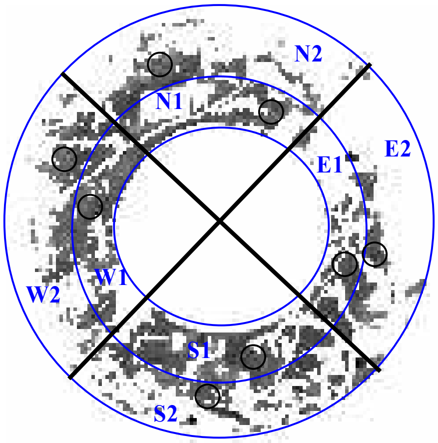

Fig. 2. Region of ejecta spread and the sub-zones considered for separability analysis.

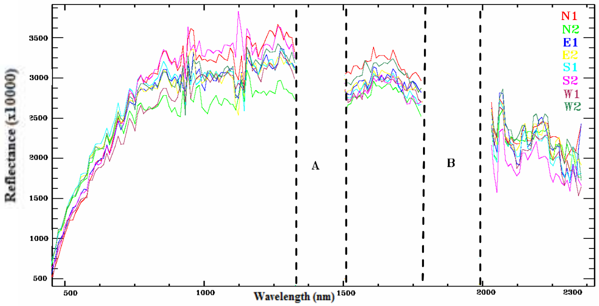

Fig. 3. Average Spectra of 8 classes as of ejecta in Hyperion image. A & B are water absorption bands.

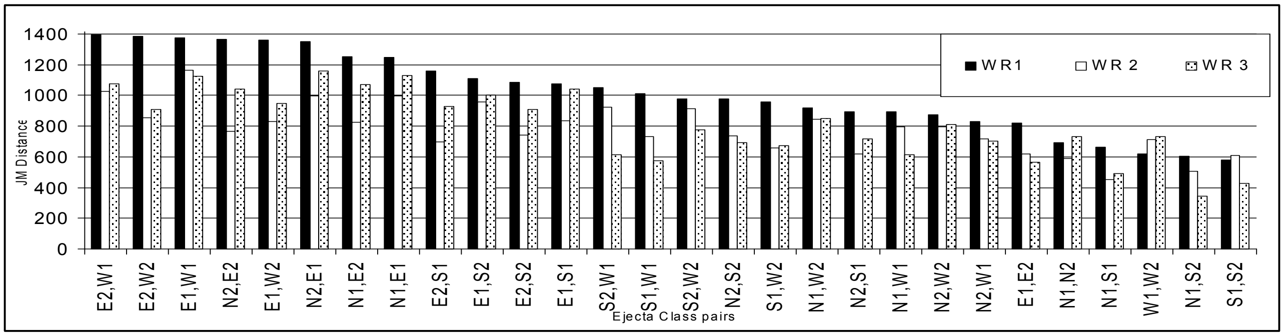

Fig. 4. Spectral separability (in decreasing order) amongst various ejecta classes in Hyperion wavebands (see Table 1).

After overcoming the above mentioned limitations, the crater ejecta available for this study shown in Fig. 2. To find out the characteristics variation around the Lonar region, the ejecta were divided into 4 zones (N,E,S,W). Each zone is again split into two with a range of ½ of the crater radius, expanding outward from the crater rim. Thus 8 zones of ejecta for the analysis were named as N1,N2,E1,E2,S1,S2,W1&W2. The reason for categorising the ejecta into zones is to check whether there is variation in the ejecta radially. Analysing the ejecta will reveal the variation within it.

The spectral variation was calculated using the Jeffries-Matusita Distance approach (*JM*)[3]. It is the average distance between the two class density functions. JM distance performs better as a feature selection criterion for multivariate normal classes than the Divergence method. The JM distance has upper and lower bounds that vary between 0 and 1414, with the higher values indicating the total separability of the class pairs in the bands being used [4].

Results: The JM separability analysis was performed to find the possible separability between ejecta and the optimal number of bands to distinguish between the ejecta variations. The computation time for the JM measure is high and the complexity of calculation increases if the number of bands increases. To overcome this limitation, the 151 bands were separated into three parts Wavelength Range1 (WR 1: bands 1-53), Wavelength Range2 (WR 2: bands 54-102) & Wavelength Range3 (WR 3: band 103-151). The training classes for spectral separability analysis where chosen from the 8 zones (Fig. 2 circled regions) and compared with each other to find the spectral separation between them. Their corresponding average spectra is shown in Fig. 3. The separability is compared between the zones. The calculated separability is shown in Fig. 4. Spectral separability under each range and the appropriate wavelength regions are given in Table 1.

Table 1. Appropriate wavelengths with best Separability

Wavelength Range (nm)	Hyperion Bands	Appropriate wavlengths (nm)
WR1=426-952	1-53	528, 701, 752, 874
WR2=962-1578	54-102	1104, 1174, 1275,1568
WR3=1588-2355	103-151	1638, 1699, 1739

Inner Zone. In the inner zone (class N1,E1,S1,W1), the computed separability shows that class E1 & W1, ie ejecta on East and West are spectrally distinct. On the other hand, classes N1 & S1 are similar. The E1 class in the eastern part of the ejecta is spectrally distinct compared to all other classes.

Outer Zone. In the outer zone (class N2,E2,S2,W2) the classes S2 & W2 show high separability, whereas classes N2 & S2 shows less separability.

Conclusion: The Lonar crater target material (basalt) was converted into ejecta during the impact. The impact itself generated heterogeneity in the ejecta. There are separable classes within the ejecta, as seen from the Fig. 4. This spectral separability may be due to the different grain sizes of basalt over the zones. This study shows the appropriate wavelengths to distinguish the ejecta in the hyperion hyperspectral image both in visible and infrared regions. These appropriate wavelengths indicate the probable separation in ejecta and can be used for further classification. This also reduces the volume of hyperspectral data by choosing the appropriate bands for the ejecta mapping.

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References: [1] Fredriksson, K., Dube, A., Milton, D. J., & Balasundaram M. S.(1973) *Science*,180,862-864 [2] Ghosh, S. & Bhaduri, S. K. (2003) *Indian Minerals* 57, 1-26 [3] Swain, P. H. & Davis, S. M.(1978) in *Remote Sensing: The Quantitative Approach,* McGraw Hill [4] Richards, J. A. & Xiuping Jia. (2006) in *Remote sensing digital image analysis,* Springer-Verlag, Berlin.