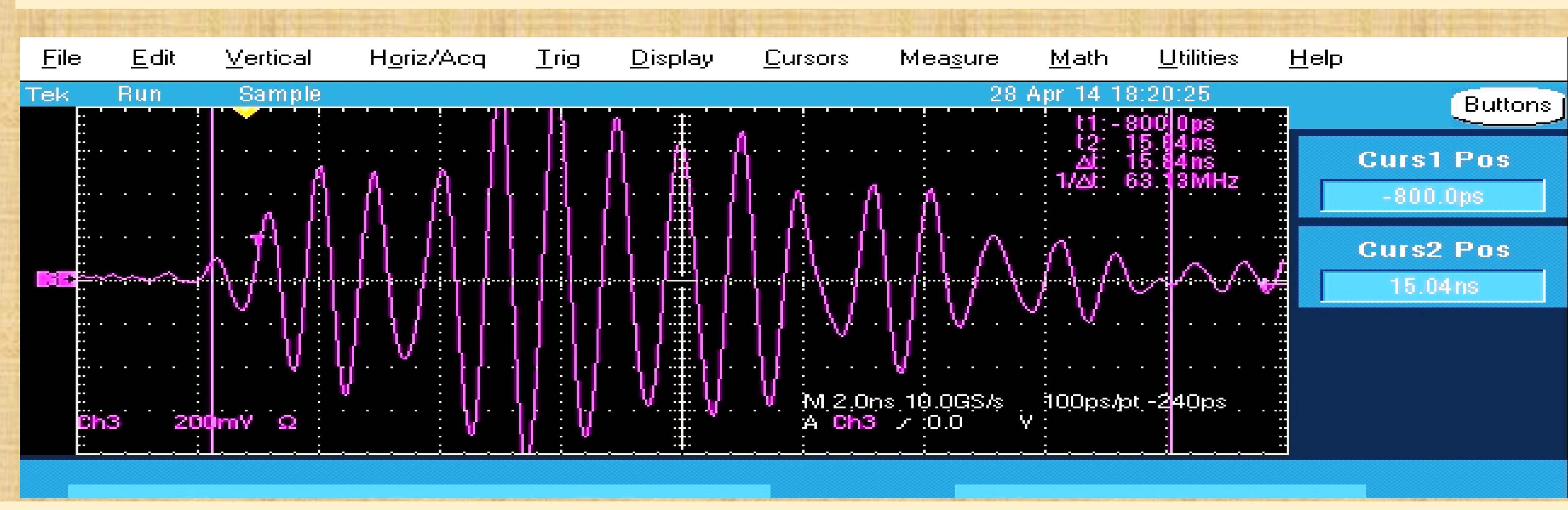
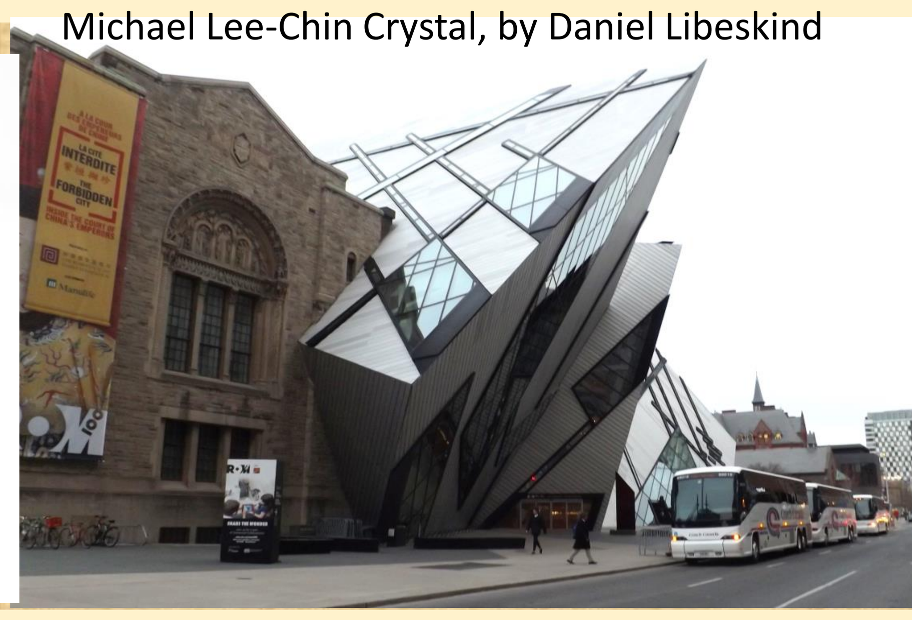
Dr Ronnie Gallagher, Eirini Kardara & Dr G. Colin Stove, © Adrok, 49-1 West Bowling Green Street, Edinburgh, EH6 5NX
rgallagher@adrokgroup.com www.adrokgroup.com

Can Microwave Frequencies be Used to Differentiate Between Rock Types?

Introduction: Despite a variety of innovations in exploration of the sub-surface of the earth, the majority of surveys still use seismic. Seismic surveys can be very disruptive and damaging to the environment. This use of destructive technologies makes prospecting and monitoring of the sub-surface problematic in many areas. Moreover, the results derived from these surveys can be misleading, resulting in very costly further exploration, which proves fruitless. Our company seeks to use Electromagnetic technologies to better understand what is in the sub-surface. These technologies have a negligible environmental impact and have been used in a wide variety of locations throughout the world. As well as trying to define strata within the earth we want to try and find a method to help identify what the strata are made of. In an effort to reach our goal we undertook laboratory experiments in collaboration with the Royal Ontario Museum, Toronto, Canada.



Michael Lee-Chin Crystal, by Daniel Libeskind



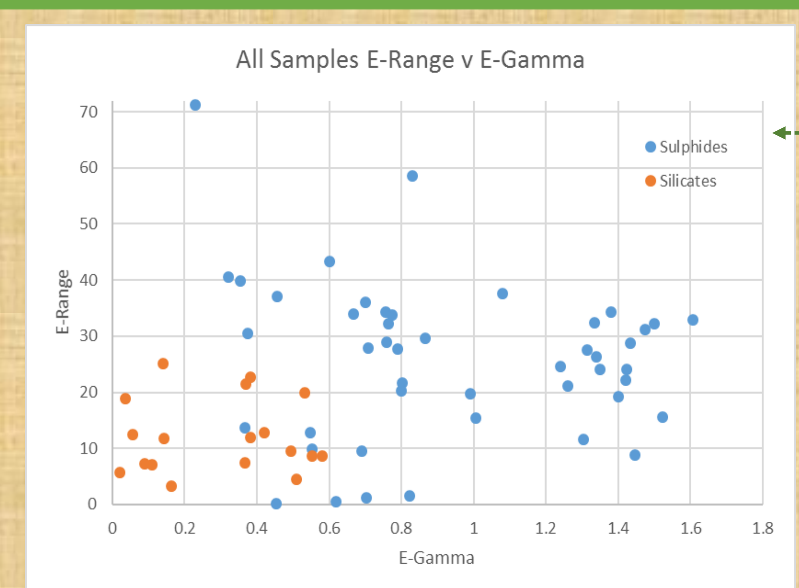
Background: We use a variety of wavelengths in microwave and radio wave ranges to interrogate individual objects and geological formations. The basic concepts grew out of ground penetrating radar (GPR), with further processing of GPR images leading to the realisation that there is more information available than initially thought. In these experiments we used a chamber 125cm x 16cm x 16cm with a transmit (Tx) and receive (Rx) antenna built into one end transmitting a signal of 1Ghz. The chamber opens by means of a hinged lid and has a space measuring 30cm x 16cm x 16cm for putting specimens into. The received signal is captured as an image and processed using proprietary software.

Aims: We want to differentiate between economically important mineral-bearing rocks from those rocks which have low, or no, economic value. if this can be achieved, the methodology could then be transferred to a field setting to provide a means of identifying important areas for potential exploration. To this end we analysed 18 Silicate and 47 Sulphide rock samples. These consisted of the following:

Sulphides: Galena (9), Chalcocite (4), Sphalerite (13), Bornite (5), Covelite (3), Chalcopyrite (9), Pyrrhotite (4) (Total 47).
Silicates: Orthoclase (3), Enstatite (3), Hornblende (3), Marcasite (3), Phlogopite (3), Quartz (3) (Total 18).

Results: Using a Fast Fourier Transform to derive frequency and energy information from the original images, we analysed these outputs in a variety of ways. Although we use frequency information, the results presented here show how we can use energy measurements to classify materials.
The energy outputs we use are E-Gamma (Range/Mx+Mn), E-Range (Mx-Mn) and E-Ratio ($\overline{x}$:sd), these outputs are considered over a range of frequencies. *Note. Only values for E-Gamma and E-Range are displayed here.* The energy over the range of frequencies can be combined into a single number and this is then graphed as a scatter plot. Furthermore, these individual point scores can be used for statistical analysis. The statistical analysis shows that the two groups of samples can be separated at a value of P<0.01 using a two-tailed unpaired t-test.

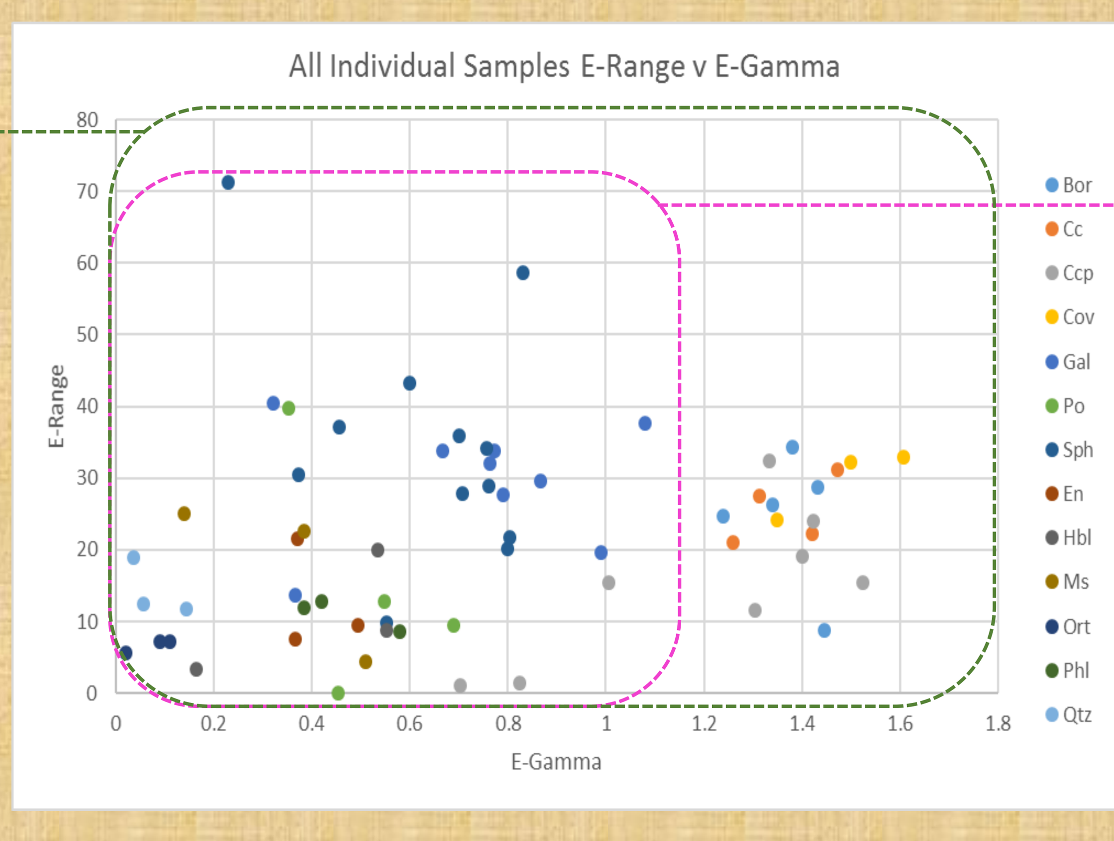
Statistical Comparison of all Silicates v all Sulphides



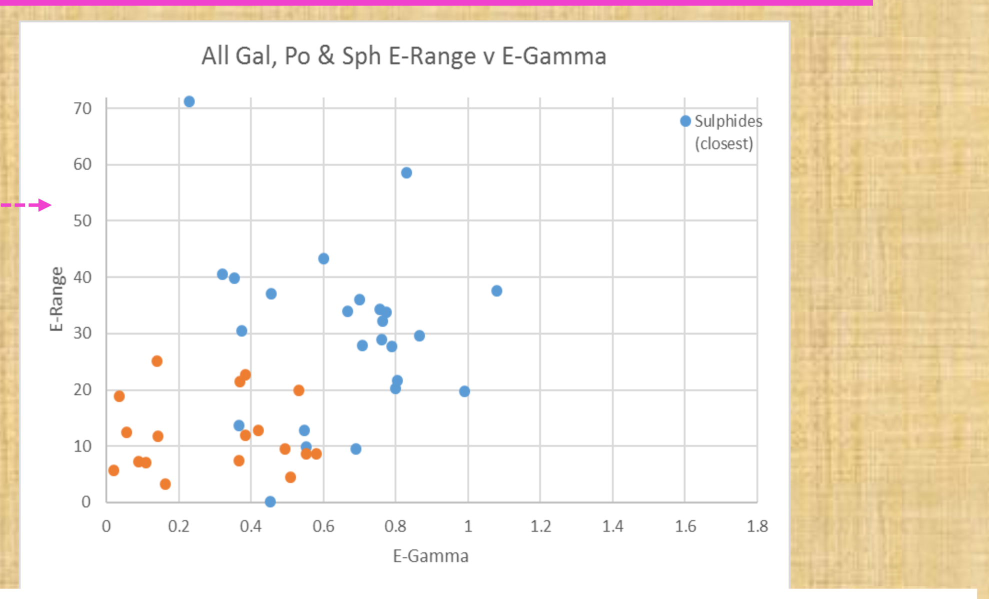
Unpaired t test results for each individual sample: Gamma
P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.
Confidence interval:
The mean of Group One minus Group Two equals -0.63538219075
95% confidence interval of this difference: From -0.82981971460 to -0.44094466689

Intermediate values used in calculations:
t = 6.5302
df = 63
standard error of difference = 0.097
Review your data:

Group	Silicates	Sulphides
Mean	0.29851851844	0.93390070919
SD	0.19732598752	0.39289543241
SEM	0.04651018129	0.05730968891
N	18	47



Statistical Comparison of all Silicates v closest Sulphides

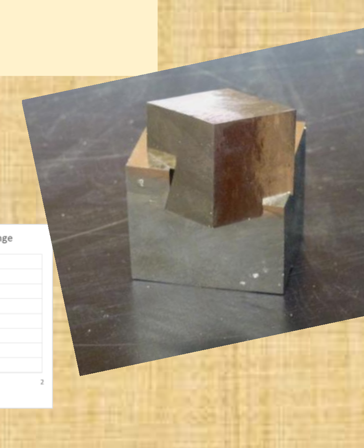


Unpaired t test results using only the Sulphide groups closest to the Silicates (Gn, Po & Sph):
Gamma P value and statistical significance:
The two-tailed P value is less than 0.0001
By conventional criteria, this difference is considered to be extremely statistically significant.
Confidence interval:
The mean of Group One minus Group Two equals 0.35913580256
95% confidence interval of this difference: From 0.23244326610 to 0.48582833901

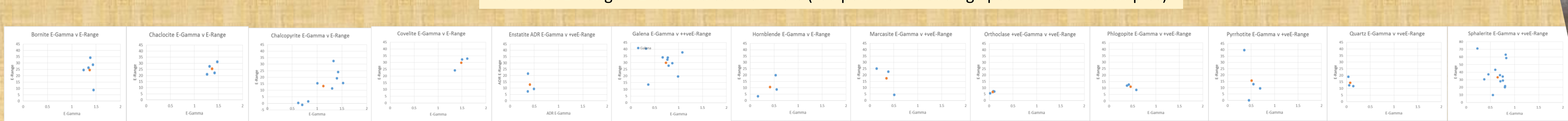
Intermediate values used in calculations:
t = 5.7167
df = 43
standard error of difference = 0.063
Review your data:

Group	Silicates	Sulphides
Mean	0.29740740733	0.65654320989
SD	0.19881858754	0.21129733879
SEM	0.04686199049	0.04066419181
N	18	27

Conclusion: In a controlled laboratory environment we can differentiate between two different rock types using energy measurements derived from FFT and proprietary software. This separation can be shown to be at statistically significant levels, when taking into account factors such as volume and weight.



Individual E-Range v E-Gamma Scatter Plots (red point is the average position for the samples)

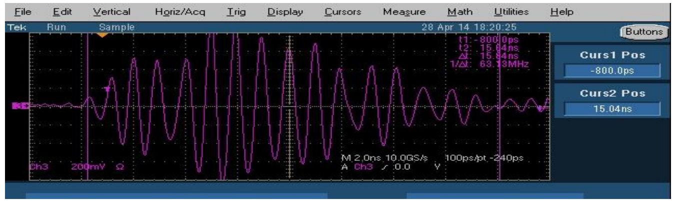


Acknowledgements: Royal Ontario Museum, Toronto, Canada & Ian Nicklin of the ROM

Dr Ronnie Gallagher

Can Microwave Frequencies be Used to Differentiate Between Rock Types?

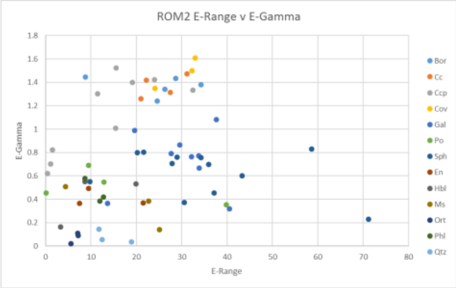
The idea: use microwaves to help identify materials in the ground that are of interest to industry (minerals, water, etc.).



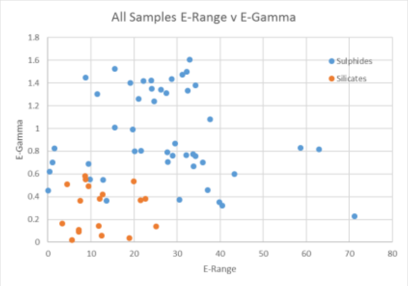
The experiment: lab-based with partners at the Royal Ontario Museum (Toronto, Canada) who gave us access to a large range of rock types. Use one of our chambers to scan the samples and analyse the results for frequency and energy content using proprietary software.

Sulphides: Galena (9), Chalcocite (4), Sphalerite (13), Bornite (5), Covelite (3), Chalcopyrite (9), Pyrrhotite (4) (Total 47).
Silicates: Orthoclase (3), Enstatite (3), Hornblende (3), Marcosite (3), Phlogopite (3), Quartz (3) (Total 18).

Michael Lee-Chin Crystal, by Daniel Libeskind

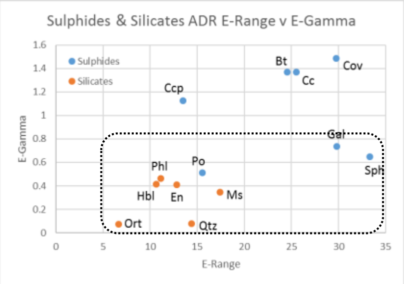


All Samples



Samples separated into Sulphides and Silicates

Unpaired t test results for each individual sample: Gamma
P value and statistical significance:
The two-tailed P value is less than 0.0001



Samples combined into groups and closest matches checked

Unpaired t test results using only the Sulphide groups (Gn, Po & Sph [total 27]) closest to the Silicates: Gamma
P value and statistical significance:
The two-tailed P value is less than 0.0001

Result: Sulphides can be separated from silicates using energy measurements derived from FFT at statistically significant levels.

Acknowledgments: Ian Nicklin, ROM

Dr Ronnie Gallagher © Adrok, 49-1 West Bowling Green Street, Edinburgh, EH6 5NX
rgallagher@adrokgroup.com www.adrokgroup.com