RECENT DEVELOPMENTS IN BIOGEOCHEMICAL METHODS APPLIED TO MINERAL EXPLORATION

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21st IGES, Dublin, 2003

Details of some of the some of the case histories presented during my talk in Dublin, 2nd September, 2003, are confidential at this time, and so have been excluded from the following sequence of slides.

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Acknowledgements

- Alberta Geological Survey
- Anglo Exploration Ltd.
- Anglogold Ltd.
- BHP-Billiton World Exploration Ltd.
- Falconbridge Ltd
- Gold City Industries Inc.
- Natural Resources Canada (GSC & Forestry)
- Uravan Minerals Inc.

OUTLINE

- Rationale + Minerals in Plants
- Ash v dry tissue (losses)
- ICP-MS dry – precision
- Au,Cu,Mo – Amazon; BC
- PGEs – Manitoba; Saskatchewan
- Kimberlite – Alberta; NWT; S.Africa
- Hyperspectral studies
- Future directions

DEMONSTRATE
The use of plant chemistry for:

- Delineating stratigraphy
- Delineating structure/faulting
- Outlining mineralization using different plant species
- Merging data from different plant species

RATIONALE

and new information on Minerals in Plants

Power of Plants

- Complex – 350 million years
- Sophisticated abilities to select elements that they need
- Tolerate other metals
- Store those they don't need (often in extremities such as bark and twig ends and tree tops)

Metals in Primitive Life Forms (*Lepp, 1992*)

	Concentrations (%)			
	Bacteria		Fungi	
Cd	40		3	
Co	25			
Cu	40		1.6	
Pb	49		10.4	
Ni	13			
Ag	35		5.4	

Mineral Phases in Plants
SEMs

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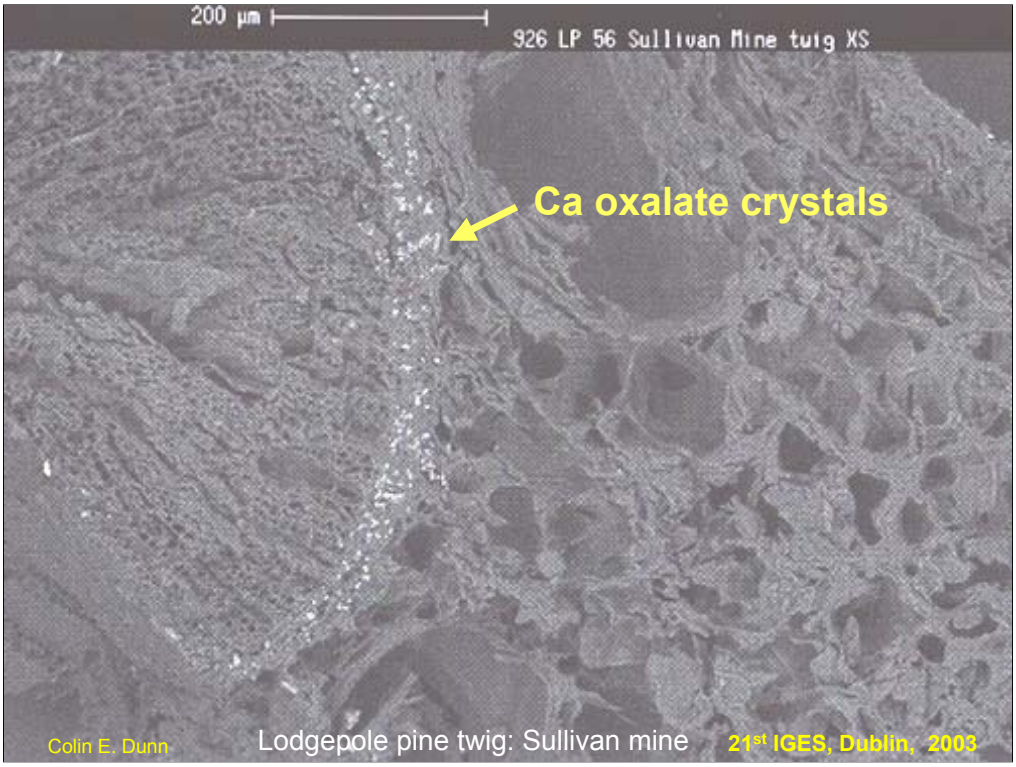
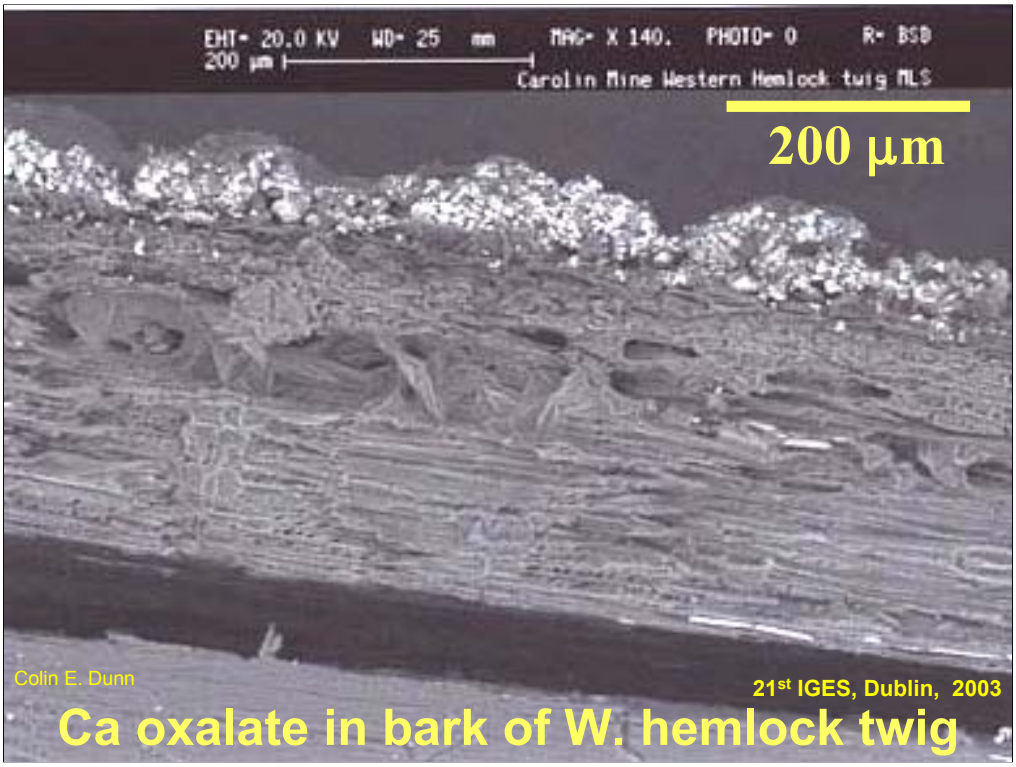


Lodgepole pine twig: Sullivan mine


EHT= 20.0 KV WD= 25 mm MAG= X 140. PHOTO= 0 R= BSD
200 µm
Carolin Mine Western Hemlock twig MLS
200 µm
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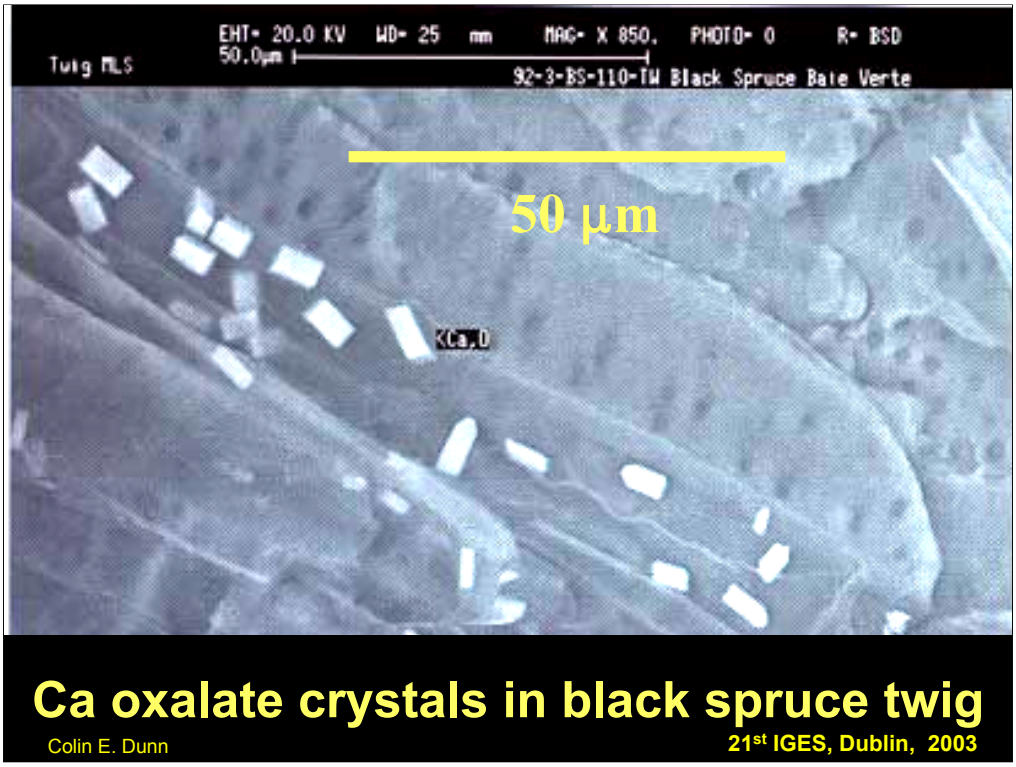
Ca oxalate in bark of W. hemlock twig



Ca oxalate crystals in black spruce twig

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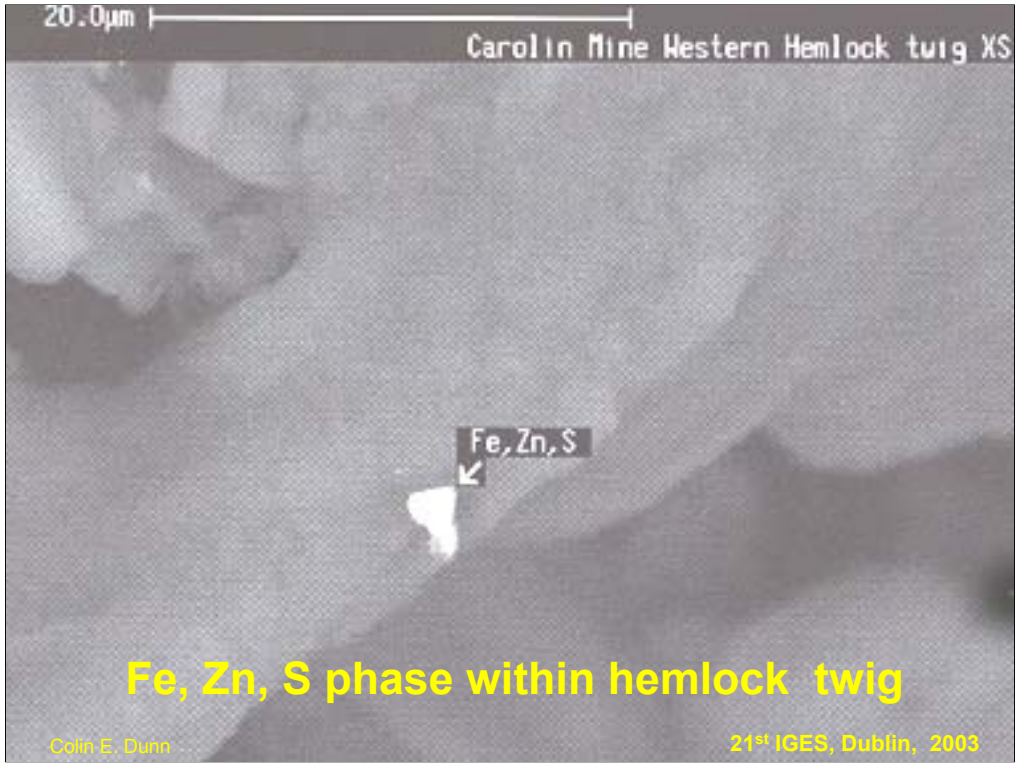
20.0μm
Carolin Mine Western Hemlock twig XS
Fe,Zn,S
Fe, Zn, S phase within hemlock twig
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Manganese phosphate in conifer trunk wood

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Gold within bark

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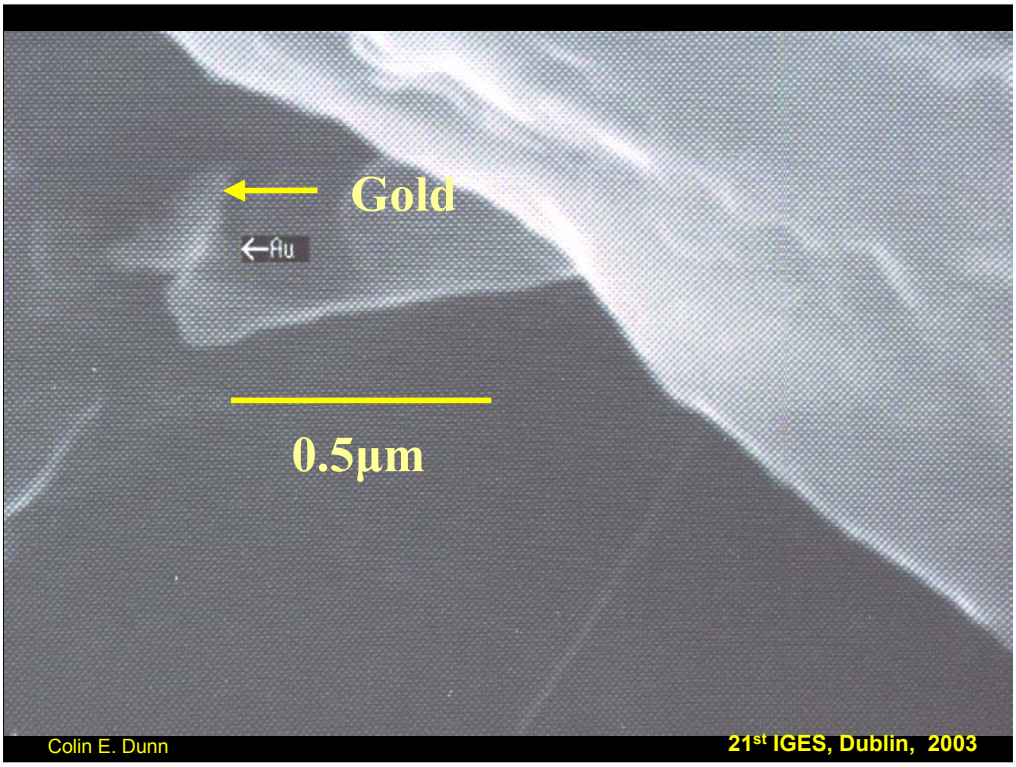
Gold
←Au
0.5µm
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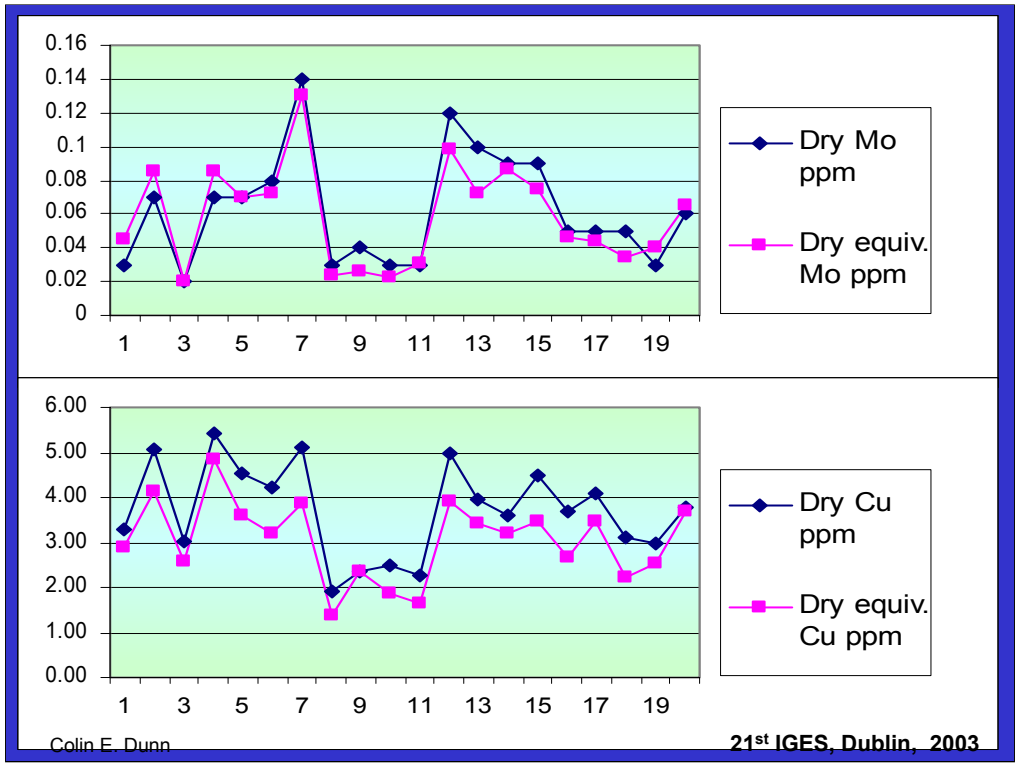
Whether or Not to Ash

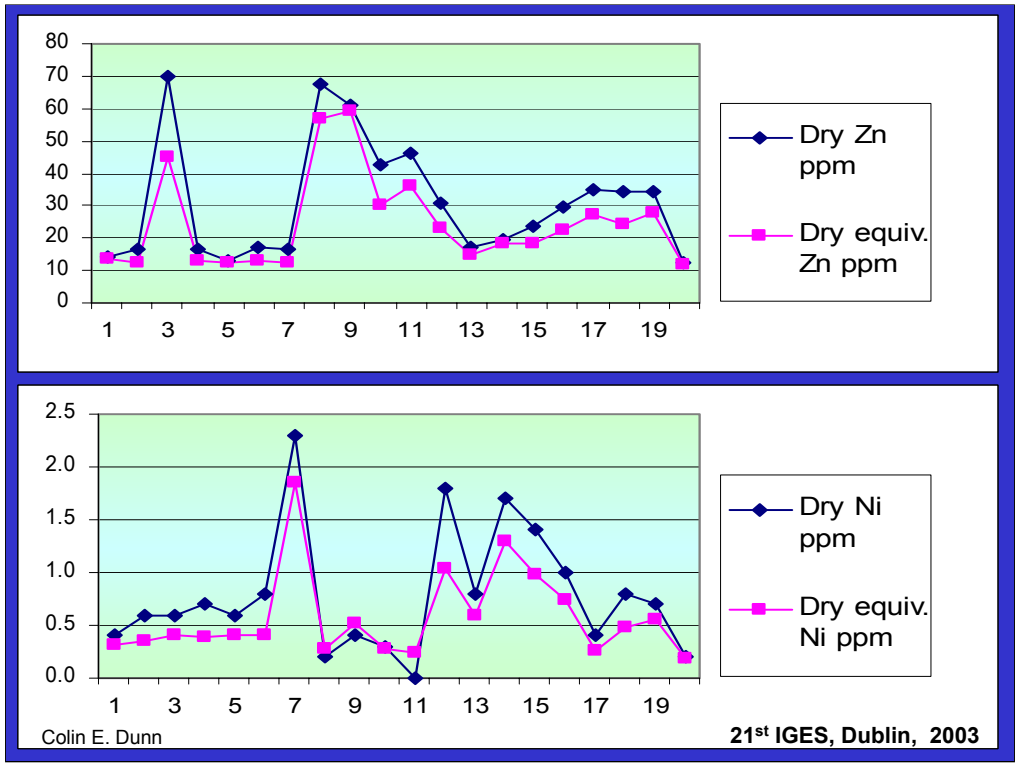
- **Pro:** Reduction to ash permits concentration of elements from large samples
- **Con:** During ashing, some elements (Au, As, Sb) partially volatilize from some species
- ***However,*** *Controlled* ignition results in constant losses, therefore distribution patterns are relevant

Element Losses

Analysis of ash [at 475^{o}C] compared to analysis of dry tissue



Samples split, then analyzed as dry tissue and also reduced to ash and normalized to dry weight.


80
70
60
50
40
30
20
10
0
1
3
5
7
9
11
13
15
17
19
Dry Zn ppm
Dry equiv. Zn ppm
2.5
2.0
1.5
1.0
0.5
0.0
1
3
5
7
9
11
13
15
17
19
Dry Ni ppm
Dry equiv. Ni ppm
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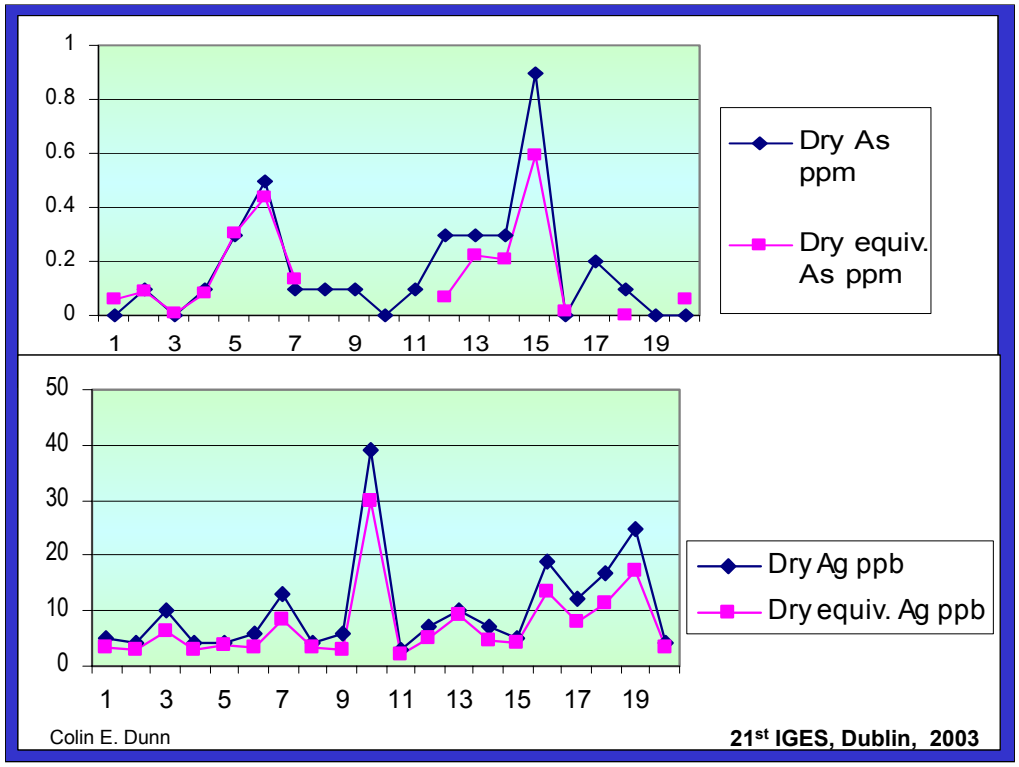
1
0.8
0.6
0.4
0.2
0
1 3 5 7 9 11 13 15 17 19
Dry As ppm
Dry equiv. As ppm
50
40
30
20
10
0
1 3 5 7 9 11 13 15 17 19
Dry Ag ppb
Dry equiv. Ag ppb
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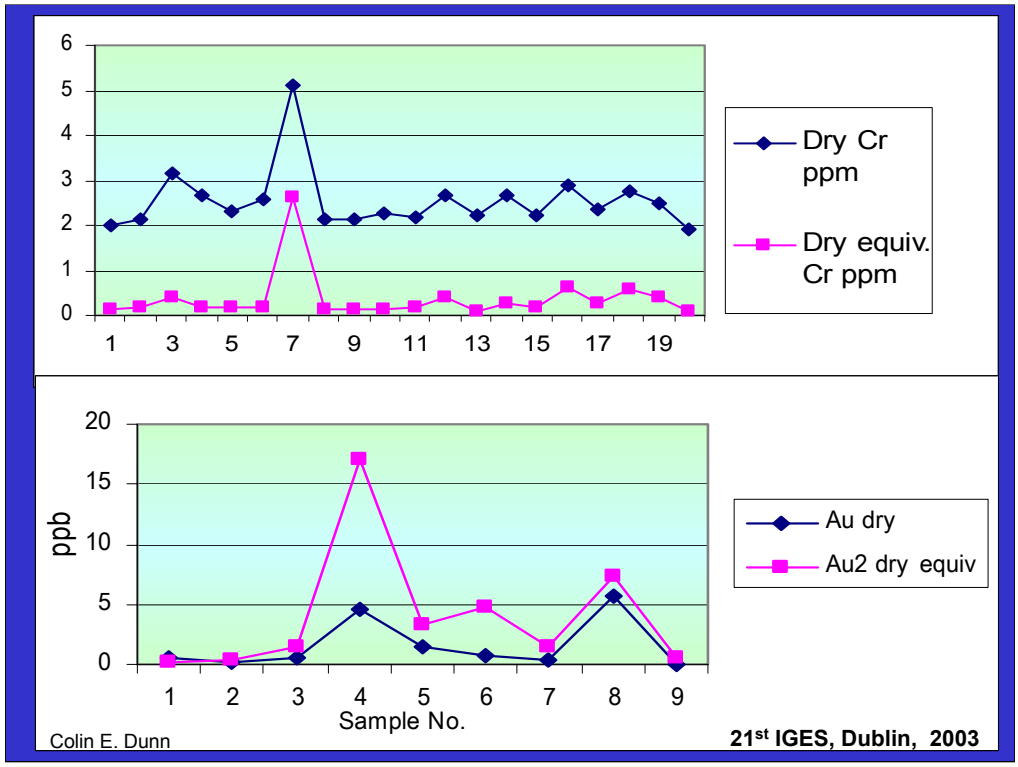


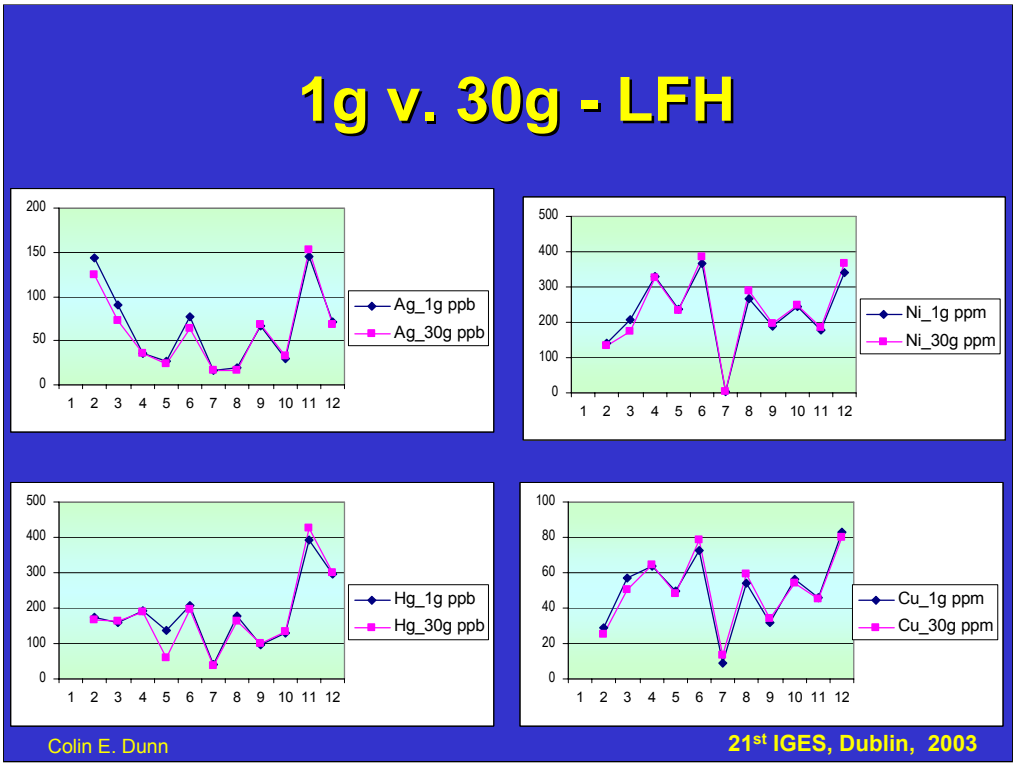
Substantial losss of Cr; Au in dry tissue not all recovered

Correlations: Ash v dry

Perfect or v. good correlations
for most elements except:
Ba, Ge, Hg, Na, S, Se, V, Zr

Elements Typically Only Detected in Ash (ICP-MS) i.e. below detection in dry tissue:

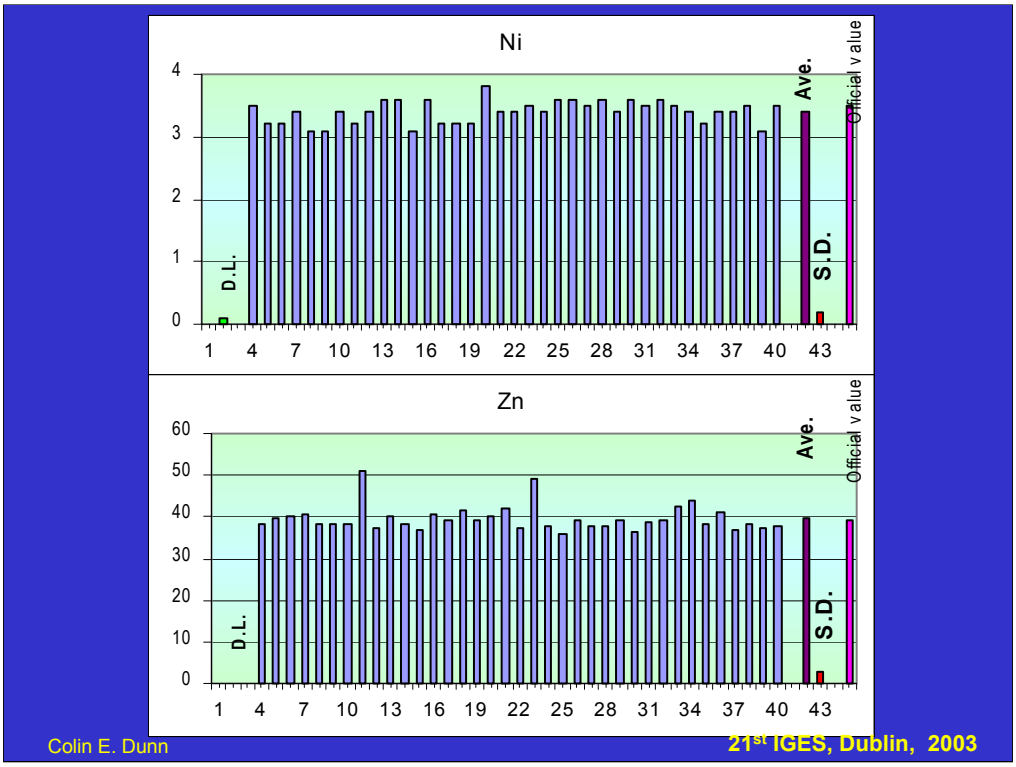
Pt, Pd, Bi, Sb, Se, Te, Tl,
In, Re, Th, U, V, most REE



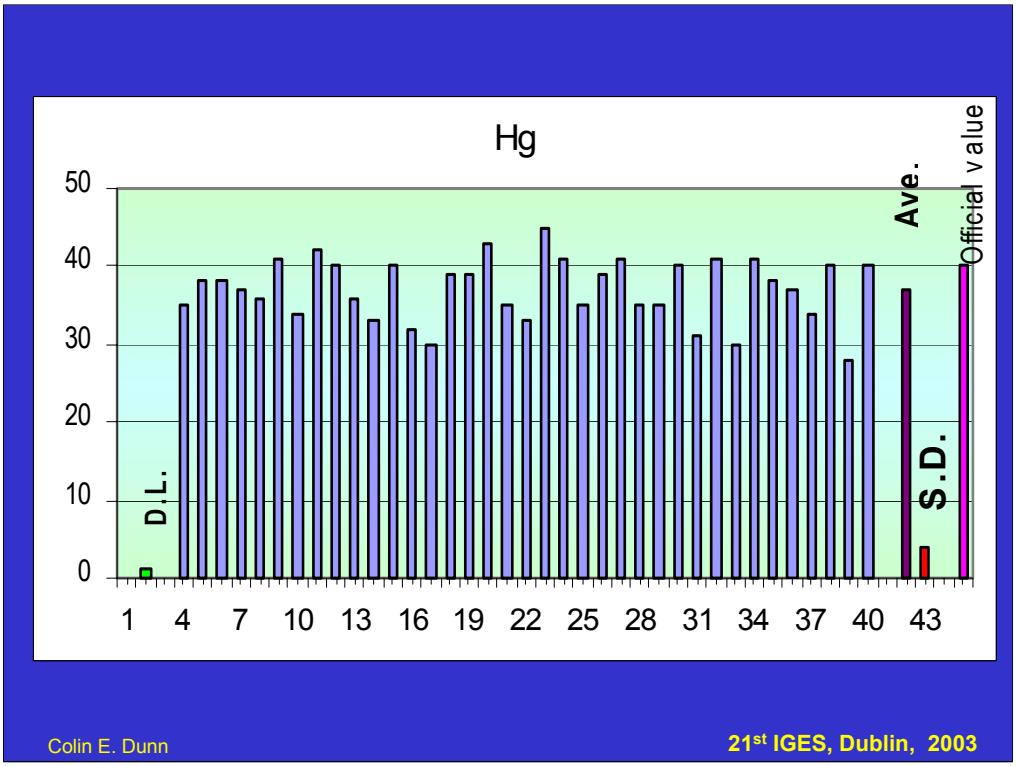
Virtually no difference between 1g and 30g samples

Analytical Precision

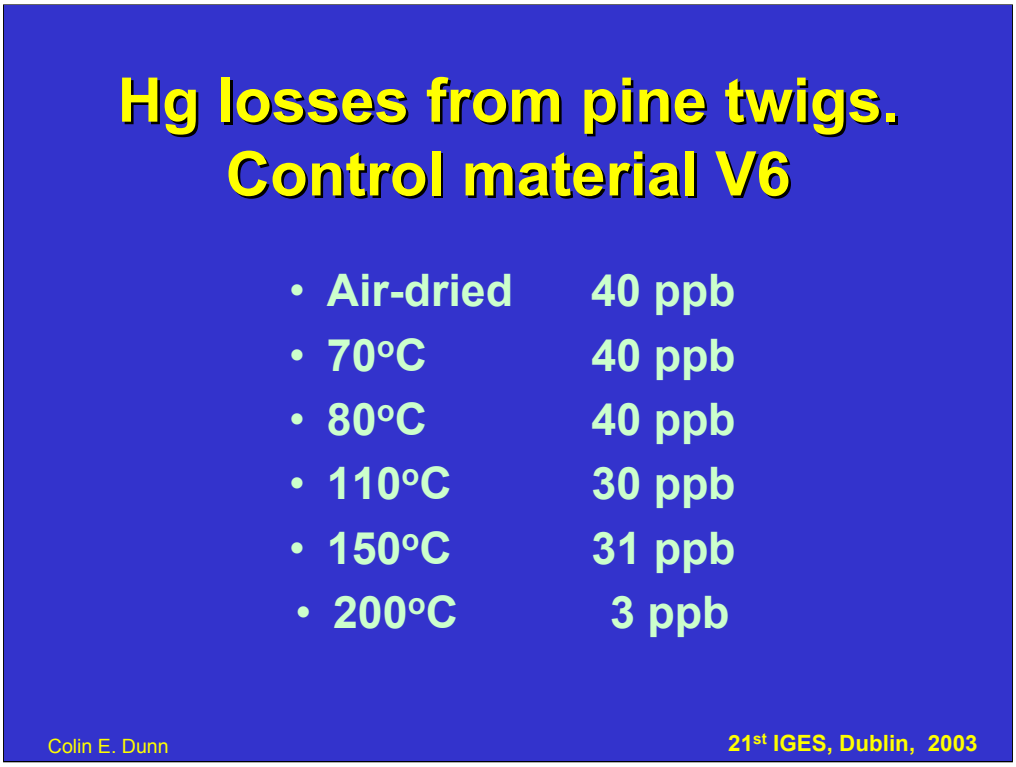
Analysis of 0.5g of dry tissue



Control V6 – analyses within batch of 500 samples



As before – excellent precision



No Hg losses to 80C – most Hg lost between 150-200C

MERCURY and GOLD

Dry Larch and Pine Bark

Gold City Industries
Caramelia Property, Southern BC

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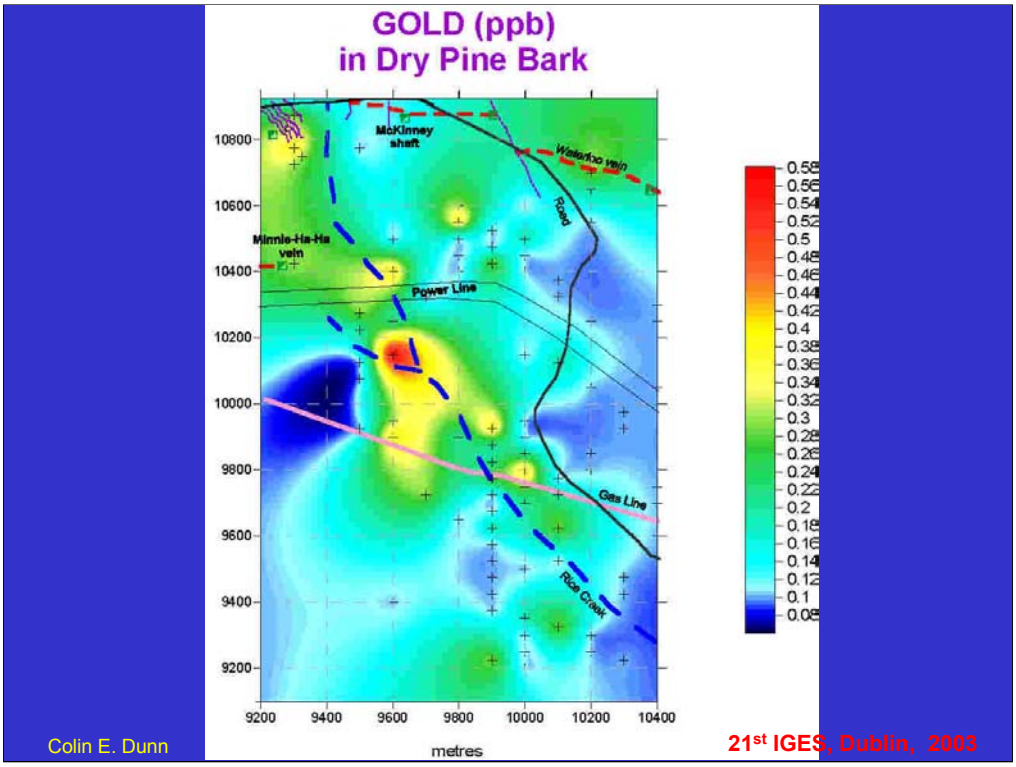
Osoyoos – Okanagan valley. Field area a few km to east



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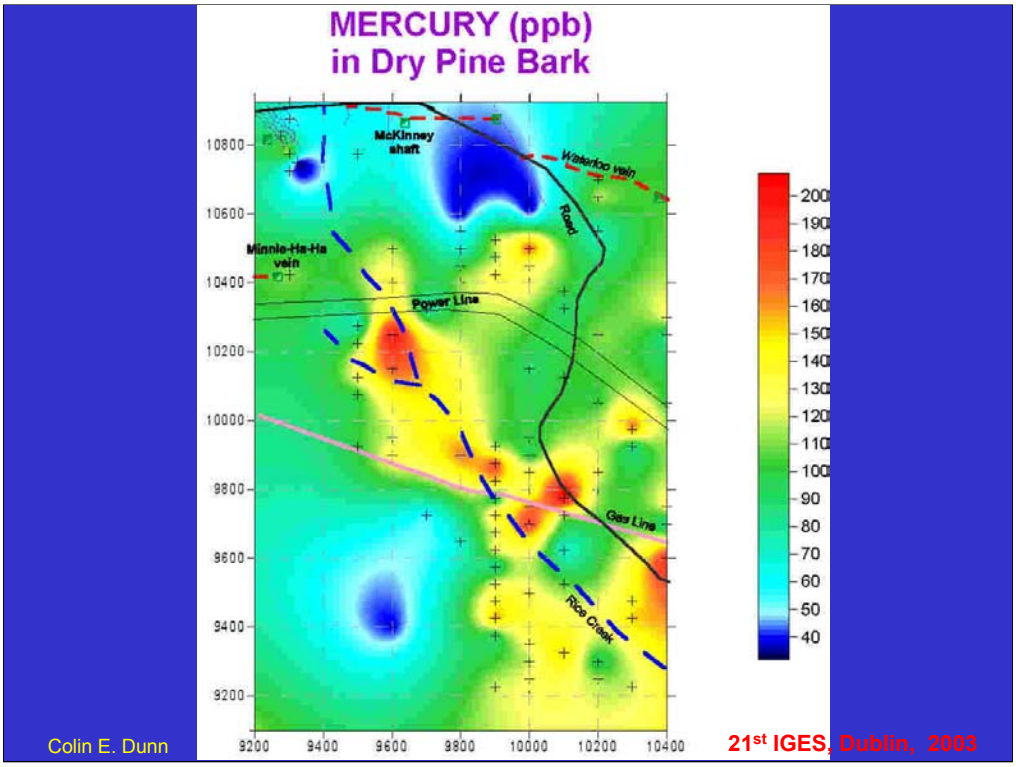
MERCURY (ppb)
in Dry Pine Bark
McKinney shaft
Waterloo vein
Road
Minnie-Ha-Ha vein
Power Line
Gas Line
Rice Creek
10800
10600
10400
10200
10000
9800
9600
9400
9200
9200
9400
9600
9800
10000
10200
10400
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
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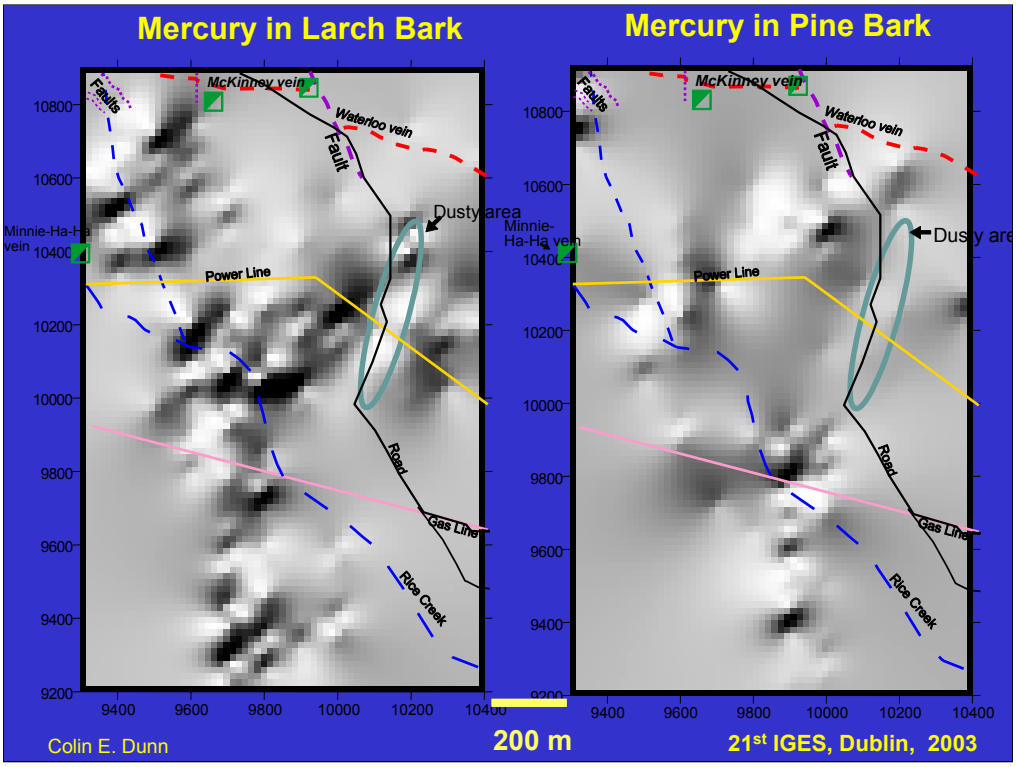
Mercury in Larch Bark
Mercury in Pine Bark
McKinney vein
Waterloo vein
Fault
Faults
Dusty area
Minnie-Ha-Ha vein
Power Line
Road
Gas Line
Rice Creek
10800
10600
10400
10200
10000
9800
9600
9400
9200
9400
9600
9800
10000
10200
10400
200 m
Colin E. Dunn
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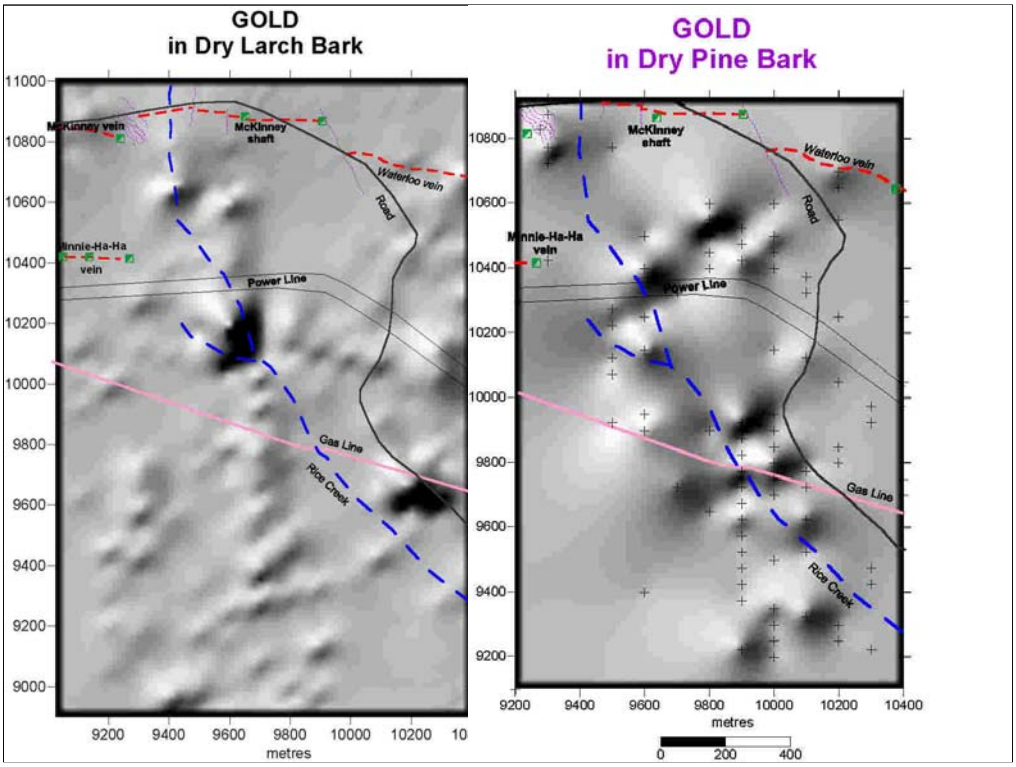
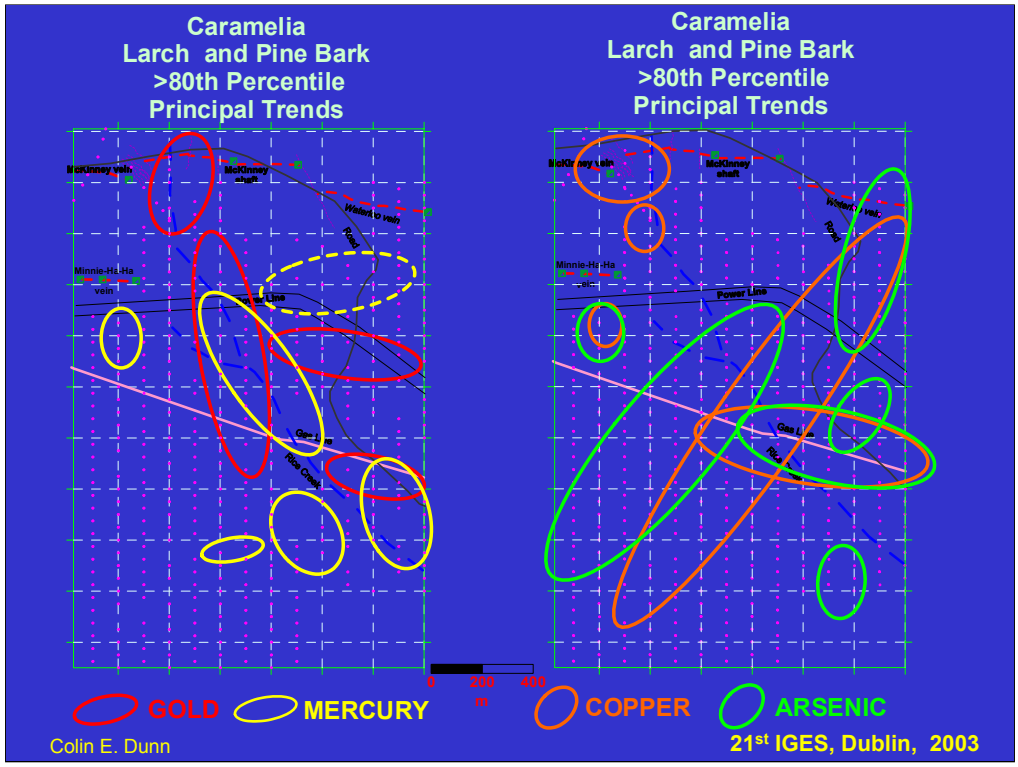
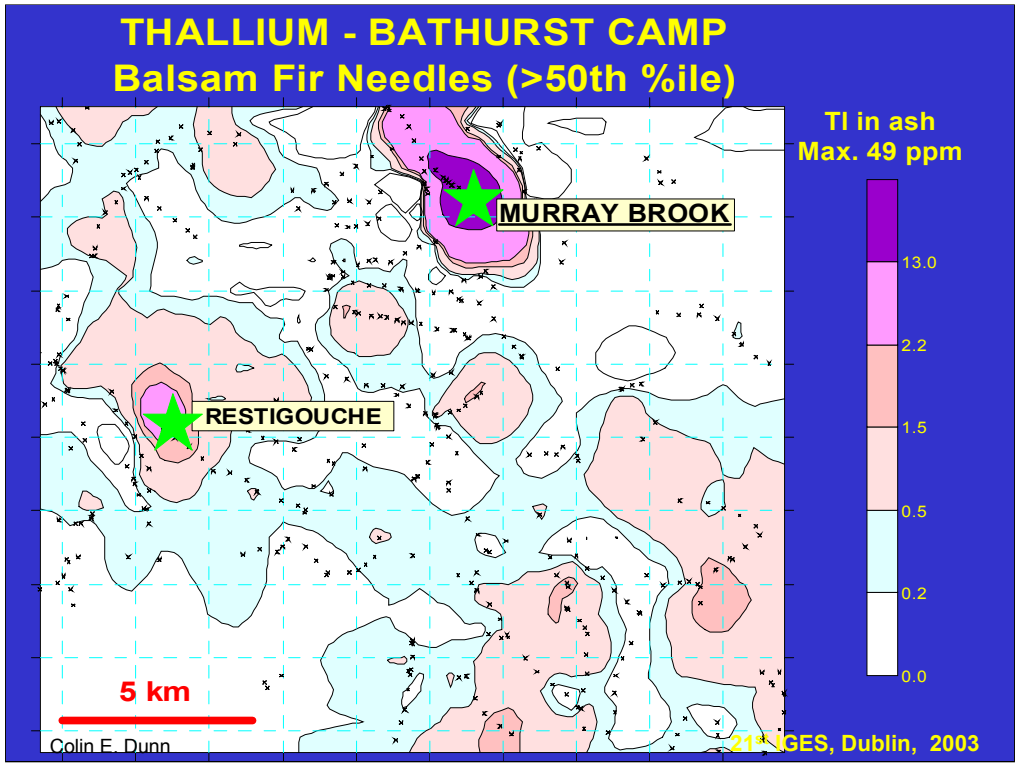

GOLD
in Dry Larch Bark
McKinney vein
McKinney shaft
Waterloo vein
Road
Minnie-Ha-Ha vein
Power Line
Gas Line
Rice Creek
11000
10800
10600
10400
10200
10000
9800
9600
9400
9200
9000
9200 9400 9600 9800 10000 10200 10
metres
GOLD
in Dry Pine Bark
McKinney shaft
Waterloo vein
Road
Minnie-Ha-Ha vein
Power Line
Gas Line
Rice Creek
10800
10600
10400
10200
10000
9800
9600
9400
9200
9200 9400 9600 9800 10000 10200 10400
metres
0 200 400



Trends suggest two phases of mineralization – Au-Hg and Cu-As

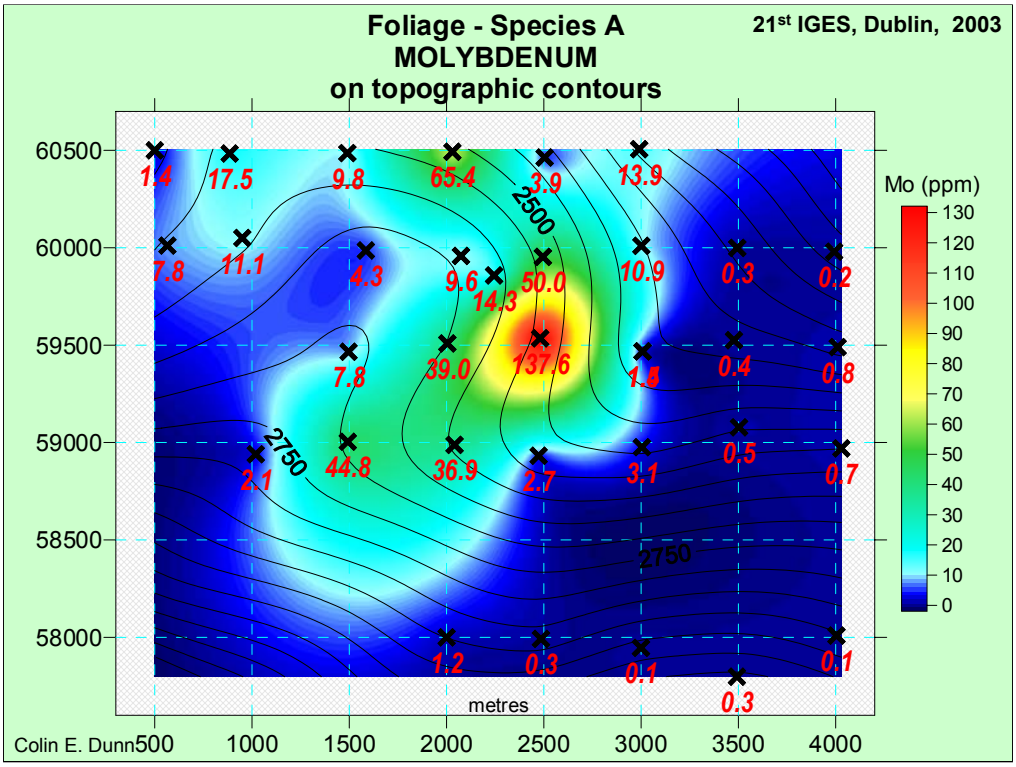


Unusually high Tl values assoc. with Zn,Pb,Au mineralization

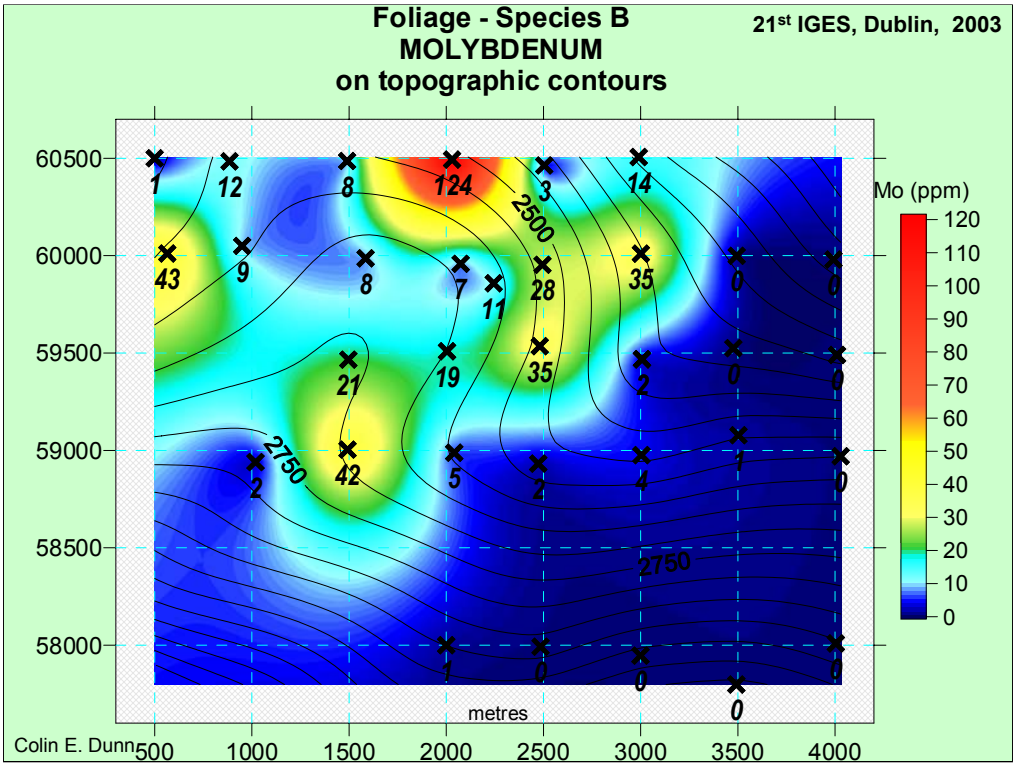
Similar Spatial Patterns from Different Species

Western Amazon

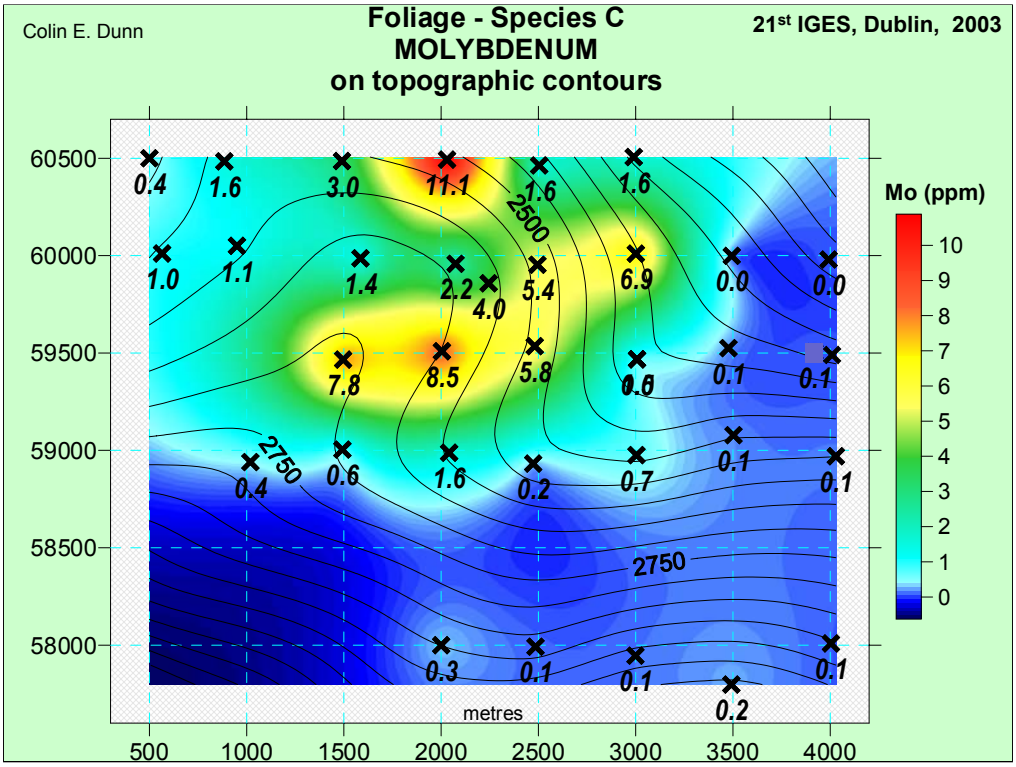
Cu-Mo-Au porphyry



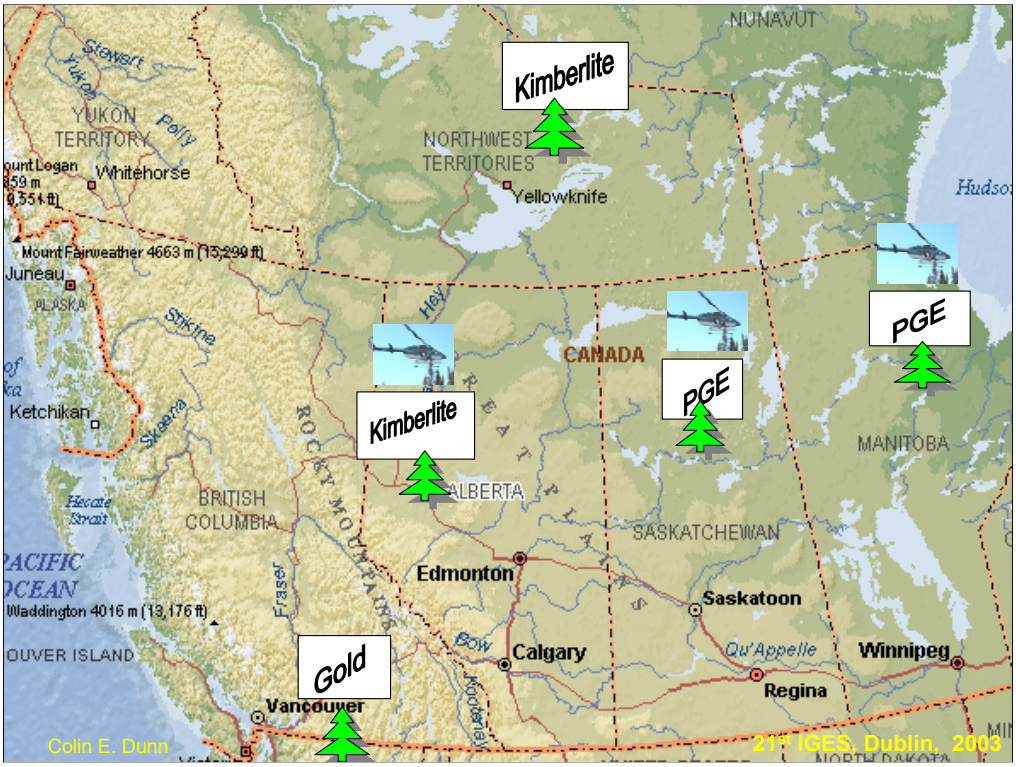
Concentrations in dry tissue



Concentrations in dry tissue



Concentrations in dry tissue



Locations of case history studies in Canada

Preparing to sample treetops from a helicopter

Treetop collection

Pt, Pd, Ni

Rottenstone Deposit

Northern Saskatchewan

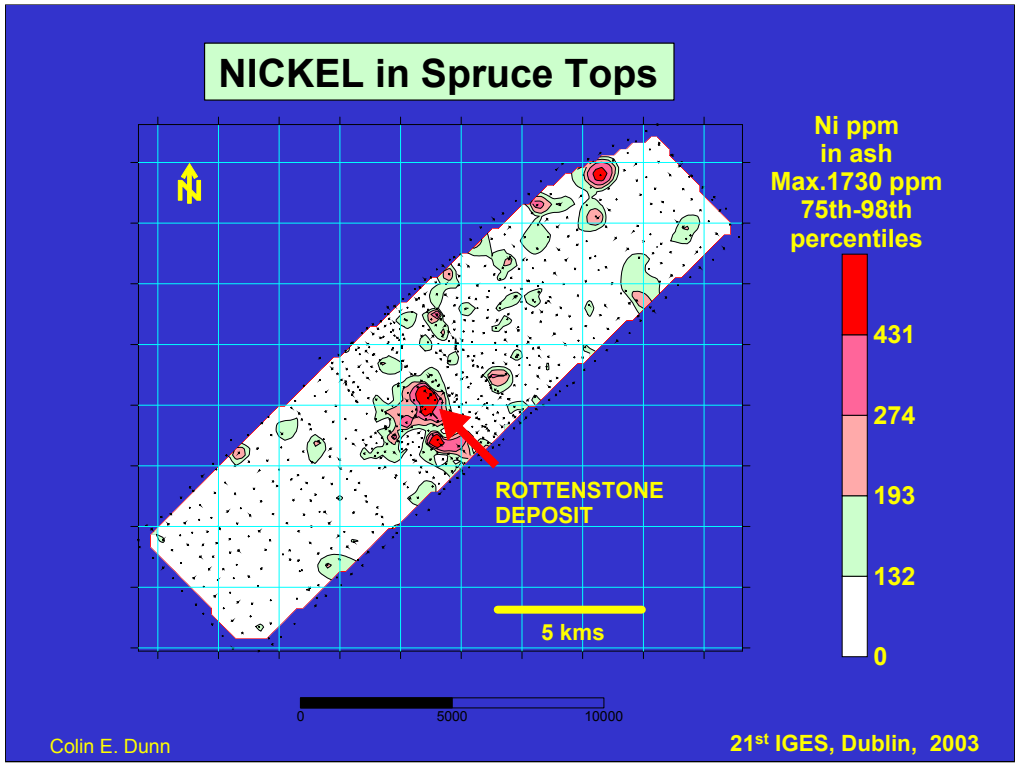
Canada

(Uravan Minerals Inc.)

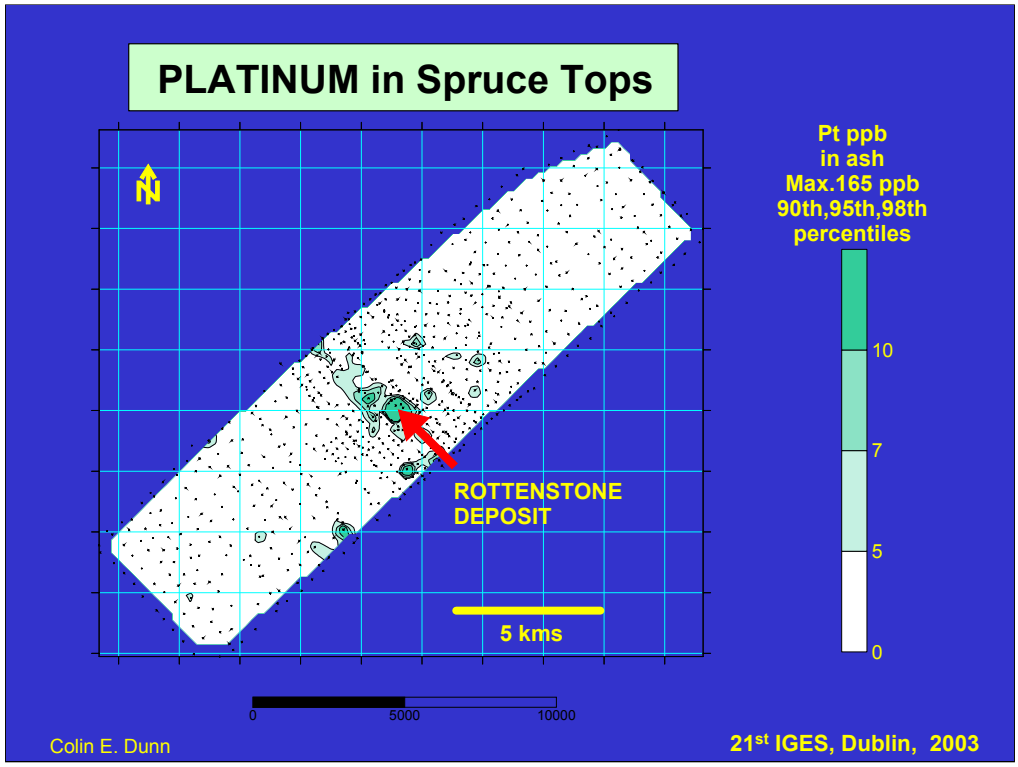
Black Spruce Tops

Boreal forest – N. Saskatchewan

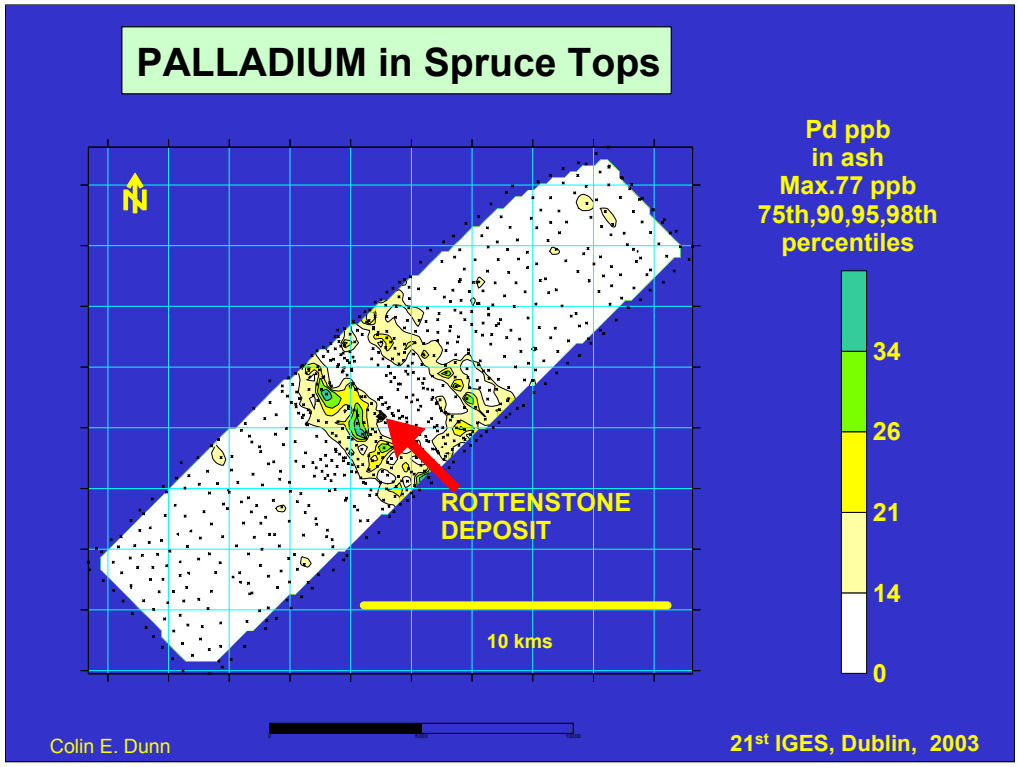
Rottenstone open pit – 1966 (mined out 1968) – courtesy of Jo Brummer



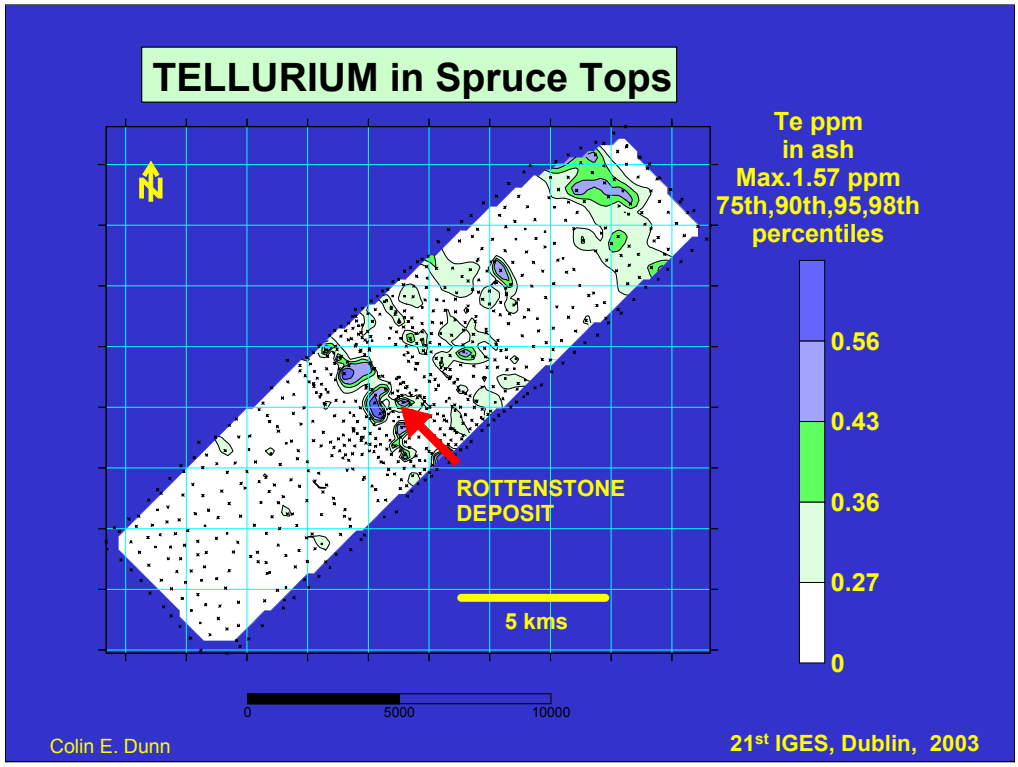
High Ni around Rottenstone and in northeast



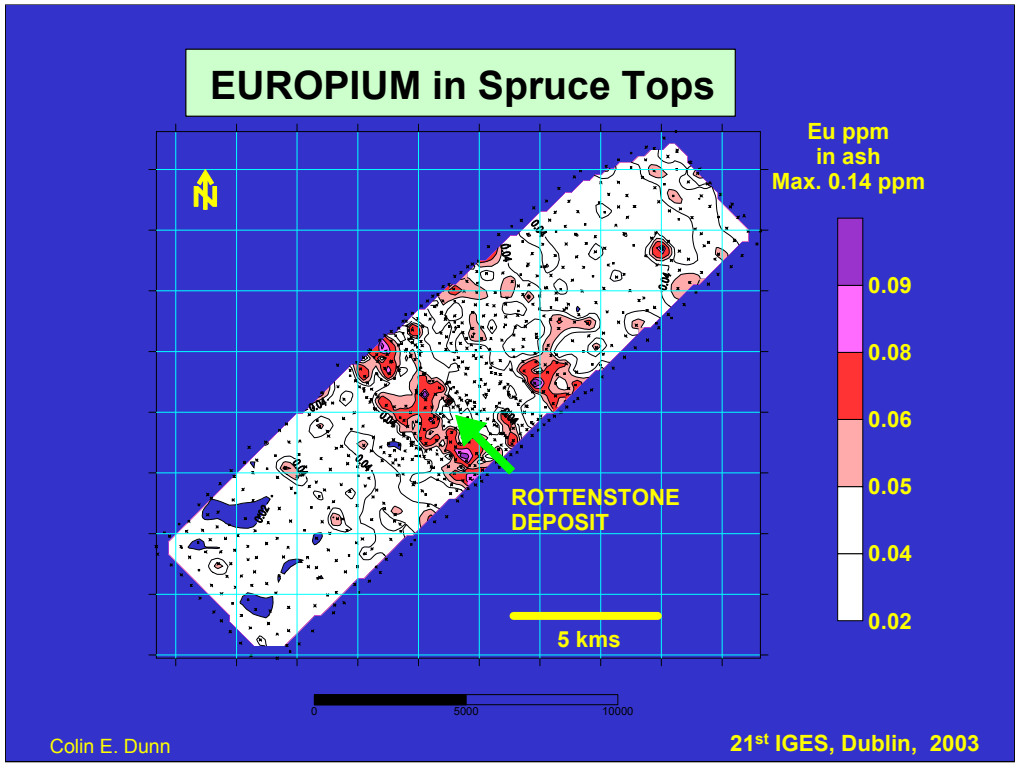
High Pt around Rottenstone



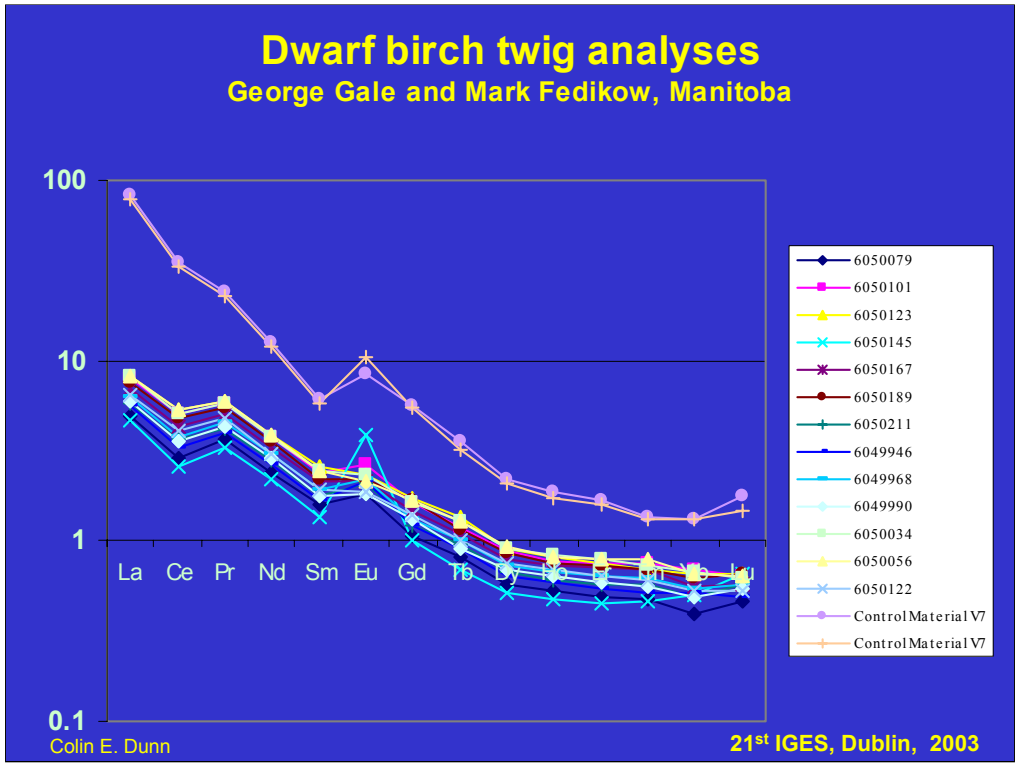
High Pd over and surrounding Rottenstone



Similar pattern to Pd



Similar pattern to Pd



Positive Eu anomalies over mineralization in Manitoba

PGEs, Fox River, Manitoba

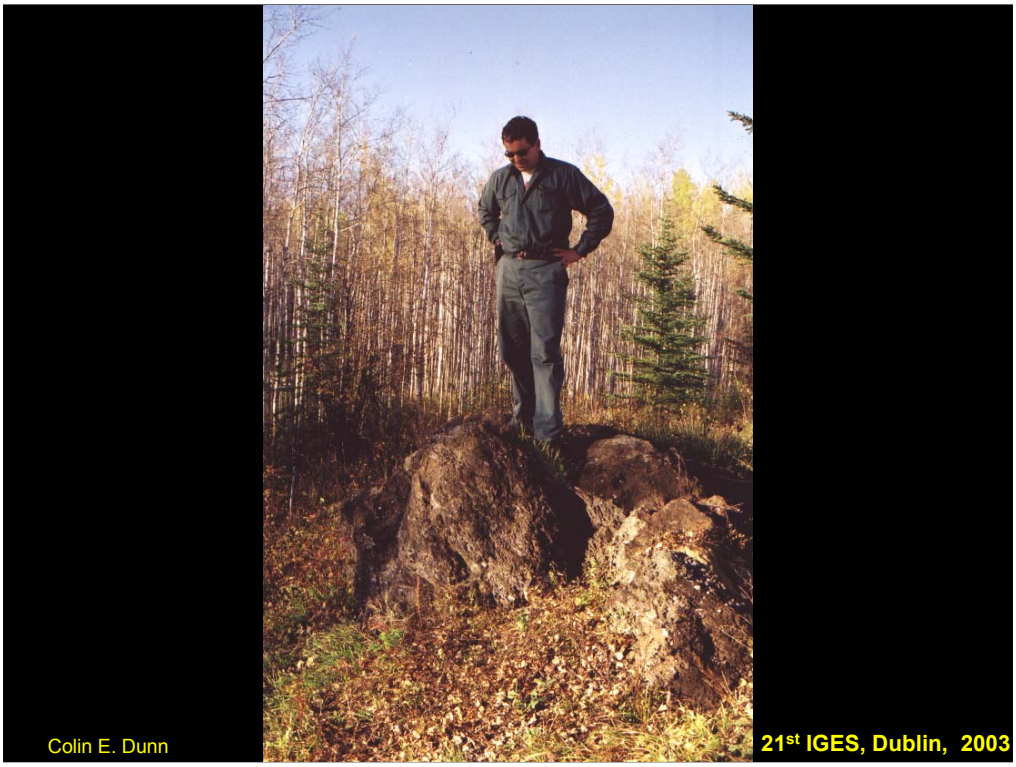
[Falconbridge Ltd.]

Slide sequence omitted - Confidential

KIMBERLITES

ALBERTA KIMBERLITES

- Penetrate 1700 m of Phanerozoic sediments
- Overlain by 0-127 m of glacial overburden
- 23 of 36 discovered are diamondiferous
- Up to 600 x 600 m in extent



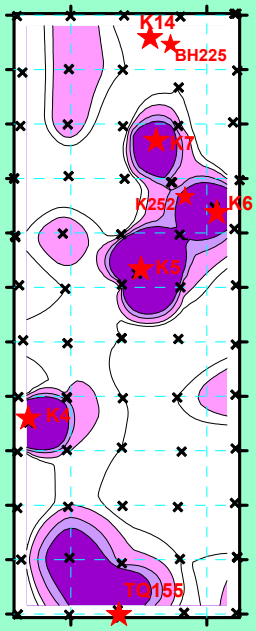
Only kimberlite outcrop

GOLD in ash of White Spruce Top Stems

★ *Kimberlite*

metres

0 2000 4000



Au - Max. 7.8 ppb
Contours at
50, 70, 80, 90th
percentiles

0.9
0.7
0.5
0.4
0.1

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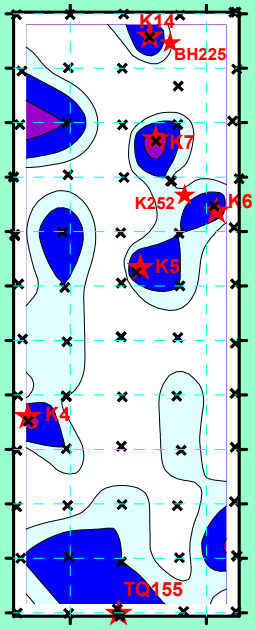
SELENIUM in ash of White Spruce Top Stems

★ *Kimberlite*

metres
0 2000 4000



Se - Max. 0.4 ppm
Contours at
50, 70, 80, 90th
percentiles

0.3
0.2
0.15
0.05

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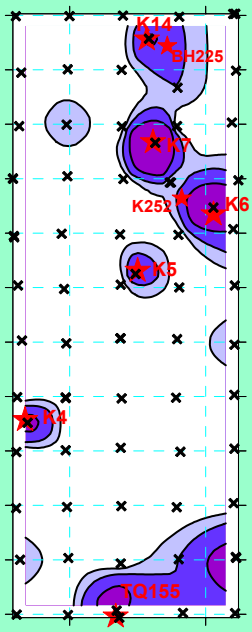
TELLURIUM in ash of White Spruce Top Stems

★ *Kimberlite*

metres

0 5000



Te - Max. 0.09 ppm
Contours at
70, 80, 90th
percentiles

0.03

0.02

0.015

0

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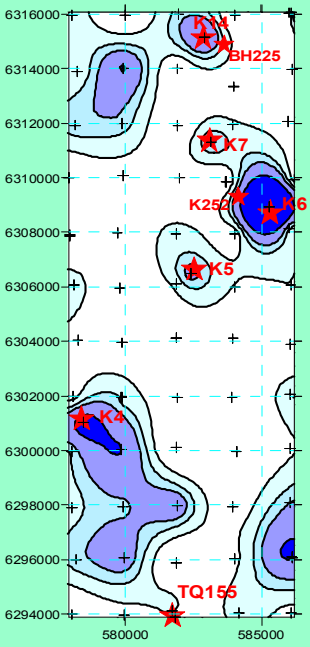
LEAD in ash of White Spruce Top Stems

★ *Kimberlite*

metres
0 2000 4000



Pb - Max. 38 ppm
Contours at
50, 70, 80, 90th
percentiles

5.6
4.4
3.9
3.2
0

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EKATI BLOCK - NWT

BHP-Billiton

Slide sequence omitted - Confidential

ELEMENT ENRICHMENTS IN VEGETATION OVER KIMBERLITES - SUMMARY

- Pb, Au, Li, Se, Te, Hg, Ni, REE, Mo, Sr, Ta, Sn

HYPERSPECTRAL STUDIES

Douglas-fir Needles
Treetops
Vancouver Island

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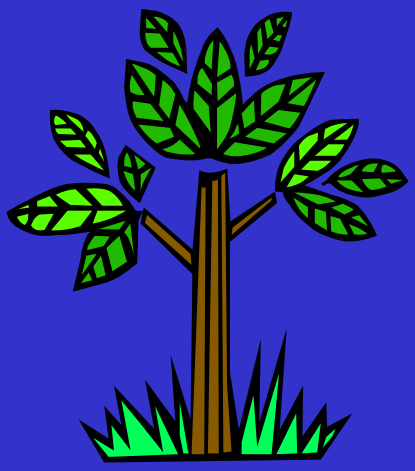
Merging Hyperspectral Data with Canopy Chemistry

D. Goodenough et al., (NRCan. Forestry)

- AVIRIS and Hyperion data acquired from EO-1 flights over Victoria watershed [EVEOSD Project]
- 520 D-fir treetops - 10 in each of 52 plots
- Organic and inorganic content of needles determined

AIMS INCLUDE

- Geochemical mapping
- Focus on spectral wavelength of an element
- Currently resolution is ~10nm
- <1nm is required for detailed work



Future Directions

- Further refinement of analytical technology (esp. PGEs, Se, Te)
- Closer integration of biogeochemical and geophysical data
- Use of bio. data to map stratigraphy, structure, alteration and faulting
- Integration of bio. data with remotely-sensed data