Are all models created equal? Finding targets from early-stage exploration data

Charlie Moon
University of Leicester
England

Modelling

- Spatial correctness of data

Catchmentising stream sediment data

- Models

Comparing well established with less established

- Examples

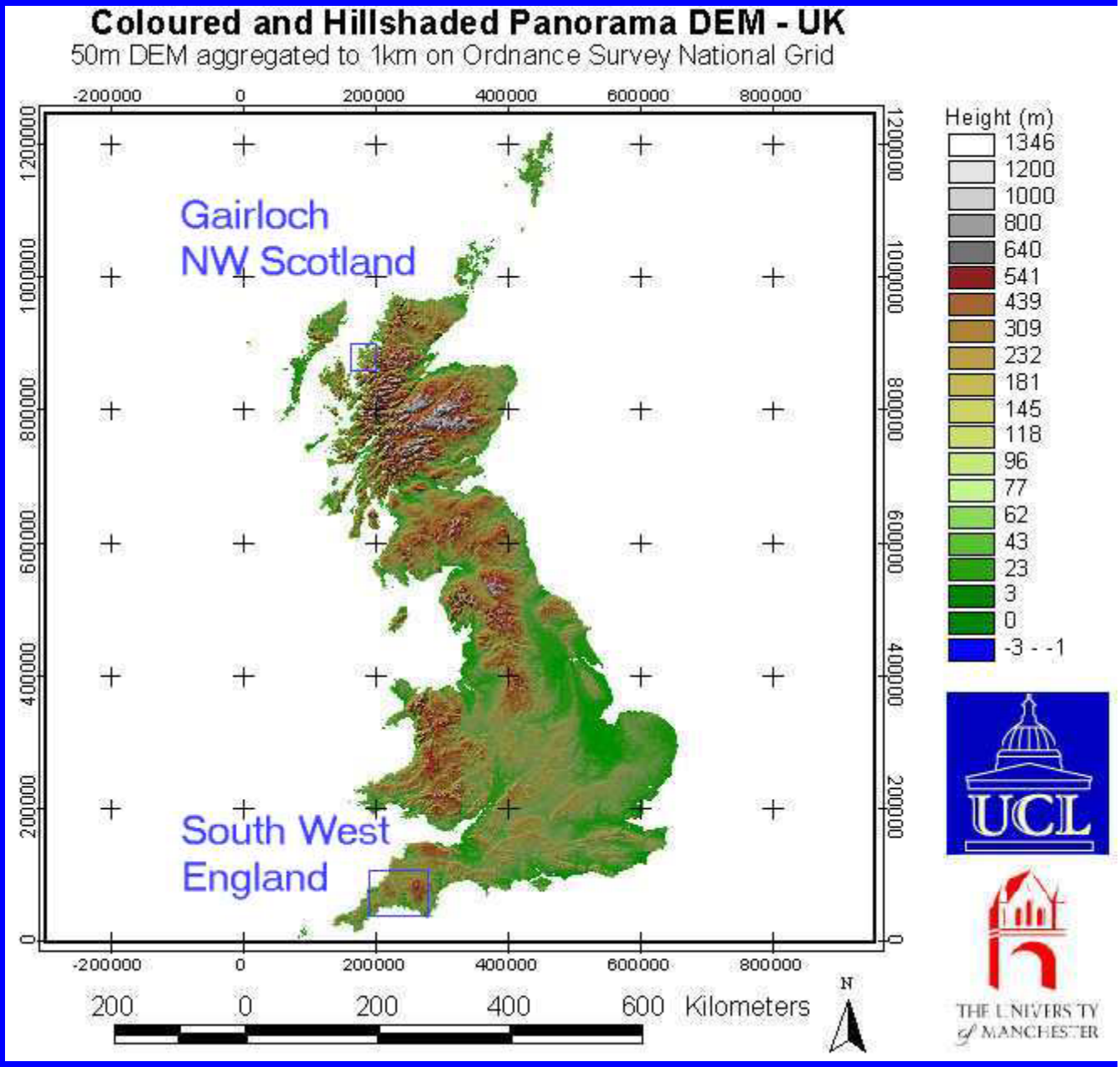
S W England Au

What has changed since 1990

- Widespread inexpensive Digital Elevation Models
- Digital geological coverages
- ICP-MS data (often >50 elements)

- More user friendly software

Examples


Coloured and Hillshaded Panorama DEM - UK
50m DEM aggregated to 1km on Ordnance Survey National Grid
-200000
0
200000
400000
600000
800000
1200000
1000000
800000
600000
400000
200000
0
Gairloch
NW Scotland
South West
England
Height (m)
1346
1200
1000
800
640
541
439
309
232
181
145
118
96
77
62
43
23
3
0
-3 - -1
200
0
200
400
600
Kilometers
N
UCL
THE UNIVERSITY of MANCHESTER

Options

- Representation of regional data

points

contours

catchments

- Extraction of Geological Information
- Relation of soil and stream sediment data

Productivity (Solovov1990)

Generation of Catchments

- Hand generated or automated
- Problems (see review: Jones, 2002) Computers and Geosciences
- Not good in flat areas
- Need to fill pits

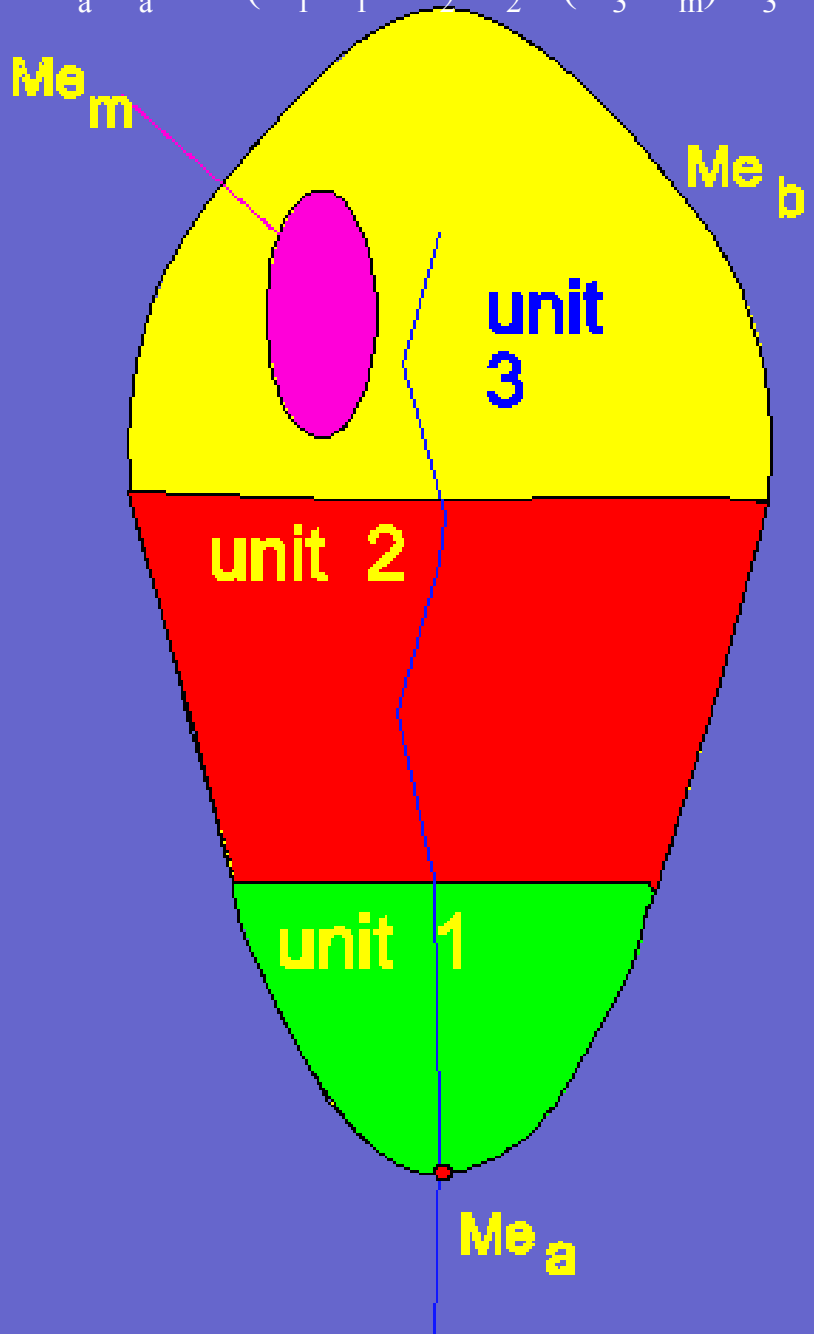
Methodology

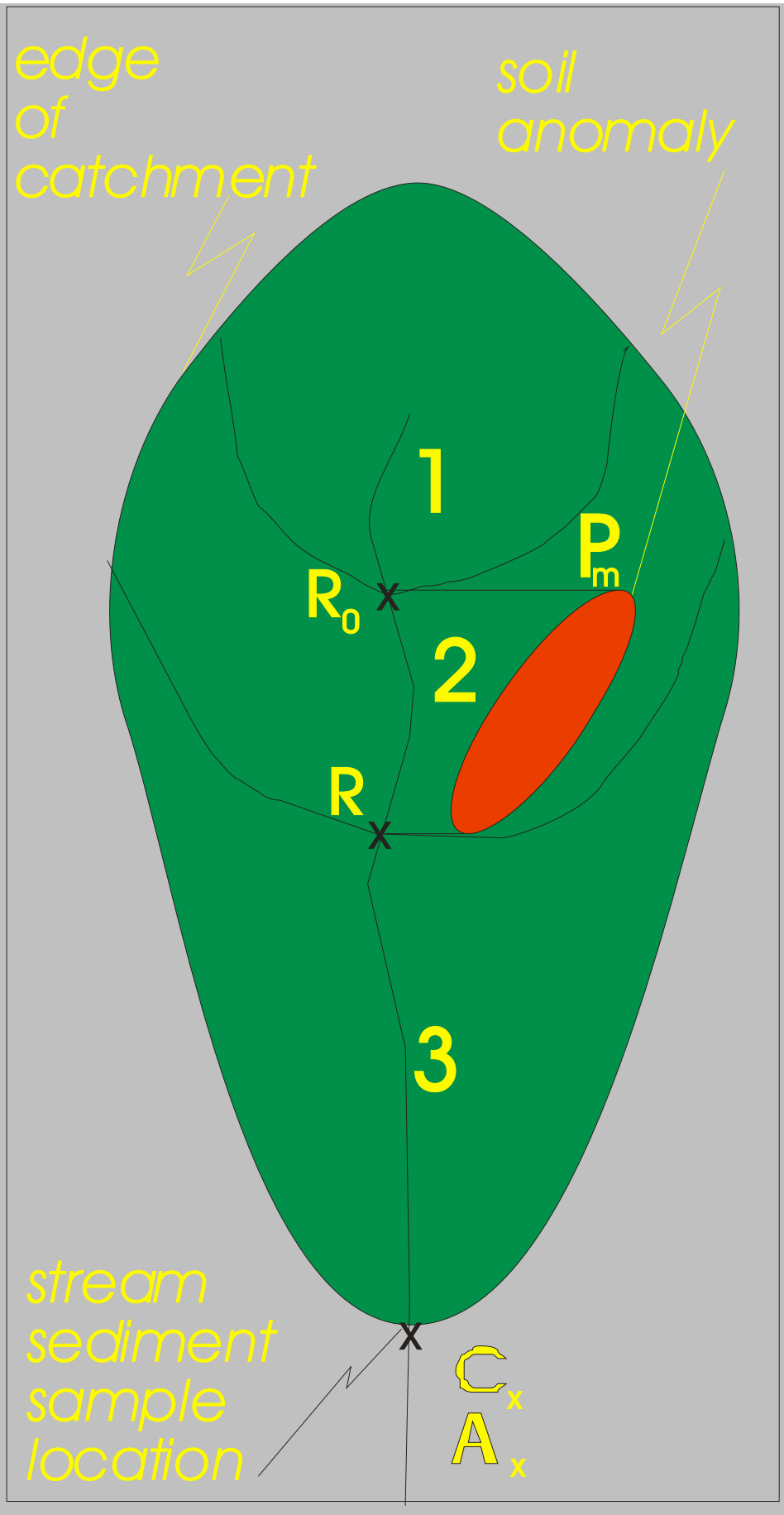
- DEM as Arc grid
- Fill pits using Hydromodeler
- Generate individual catchments using Basin1
- Clean, build and edit in Arcedit
- Link with geochemical data

Modified Dilution Formula

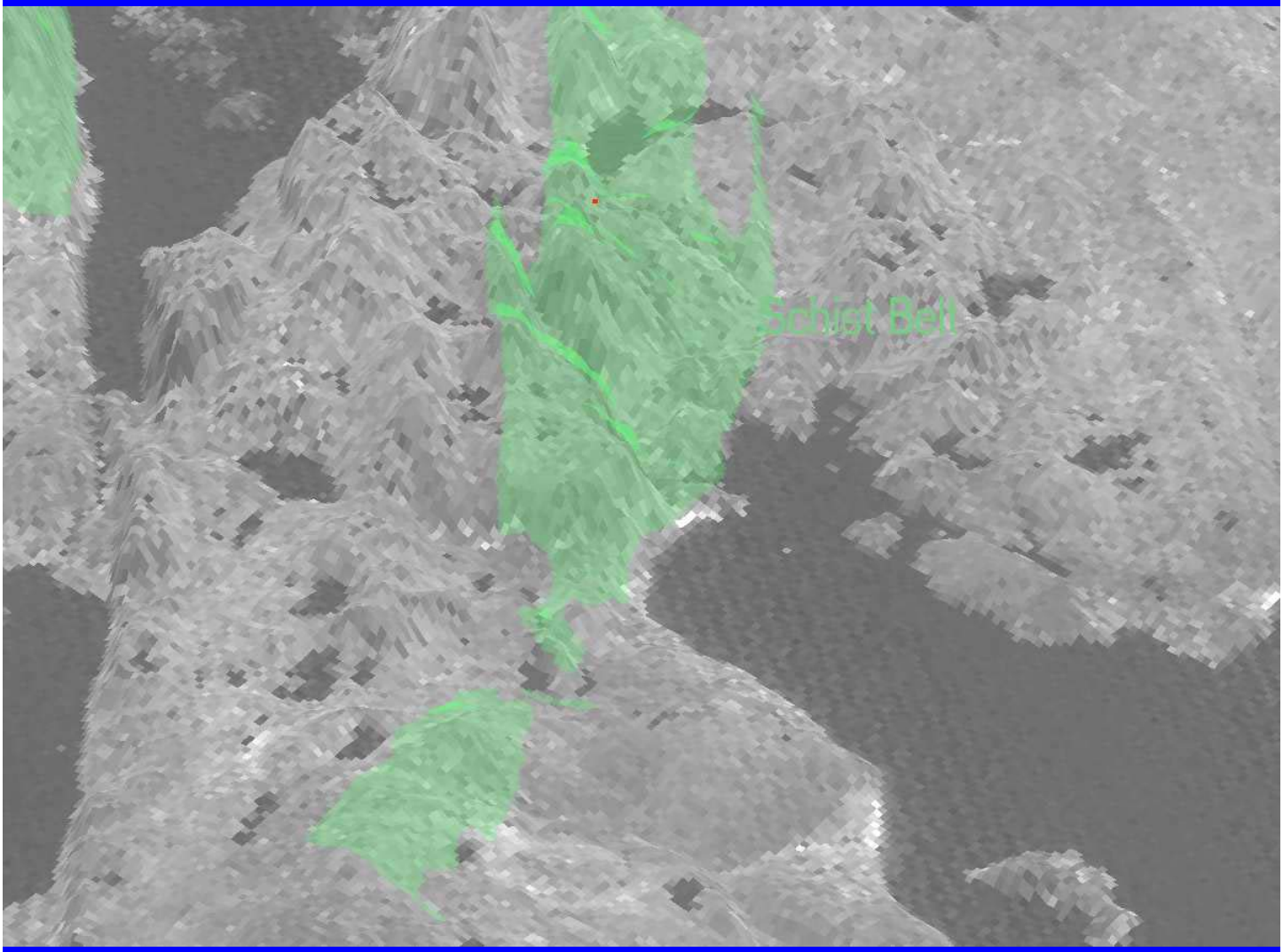
Original $Me_a A_a = Me_b (A_a - A_m) + Me_m A_m$

New $Me_a A_a = \Sigma (A_1 M_1 + A_2 M_2 + (A_3 - A_m) M_3 + A_m M_m)$

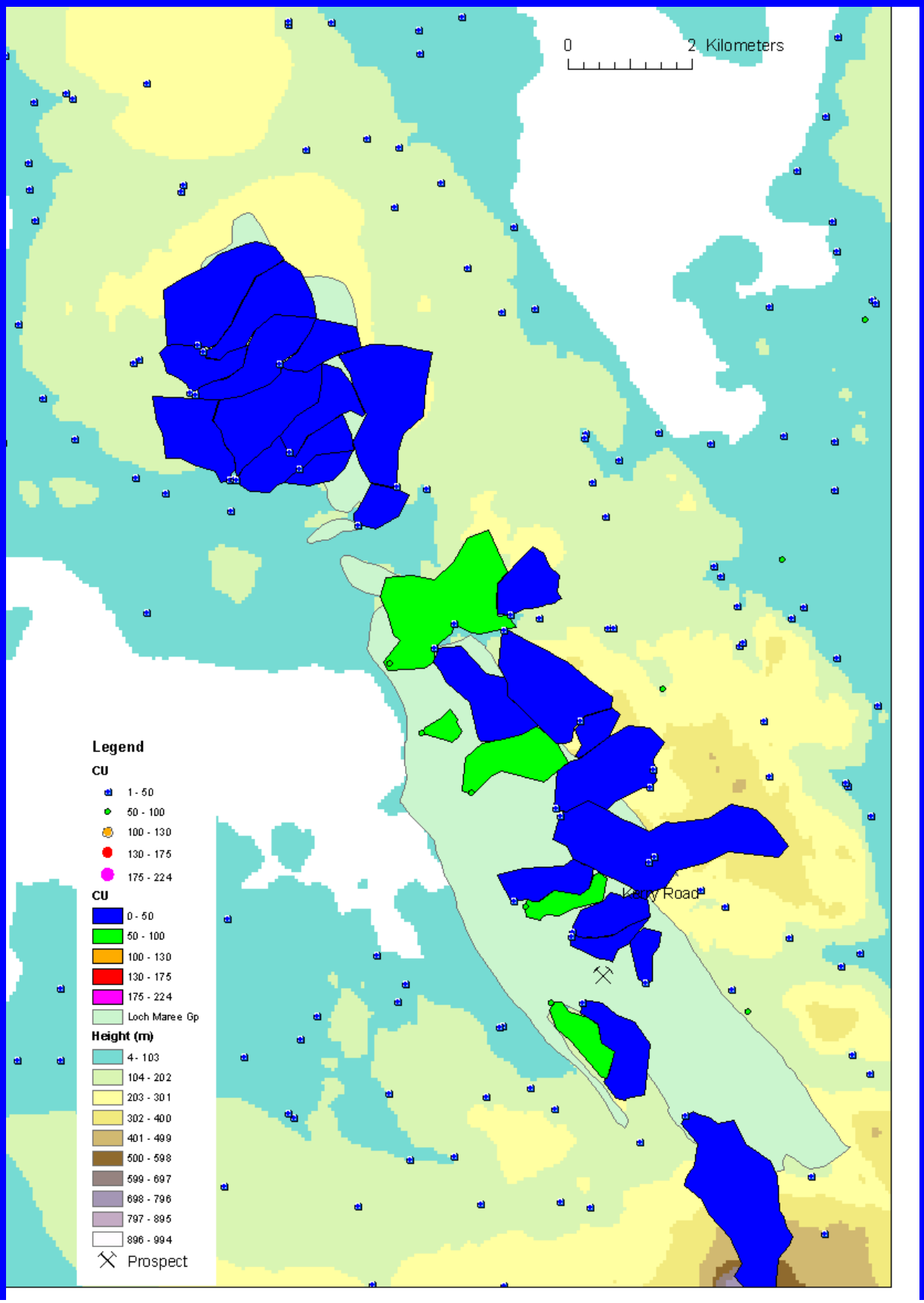



edge
of
catchment
soil
anomaly
1
2
3
P_m
R_0
R
stream
sediment
sample
location
C_x
A_x

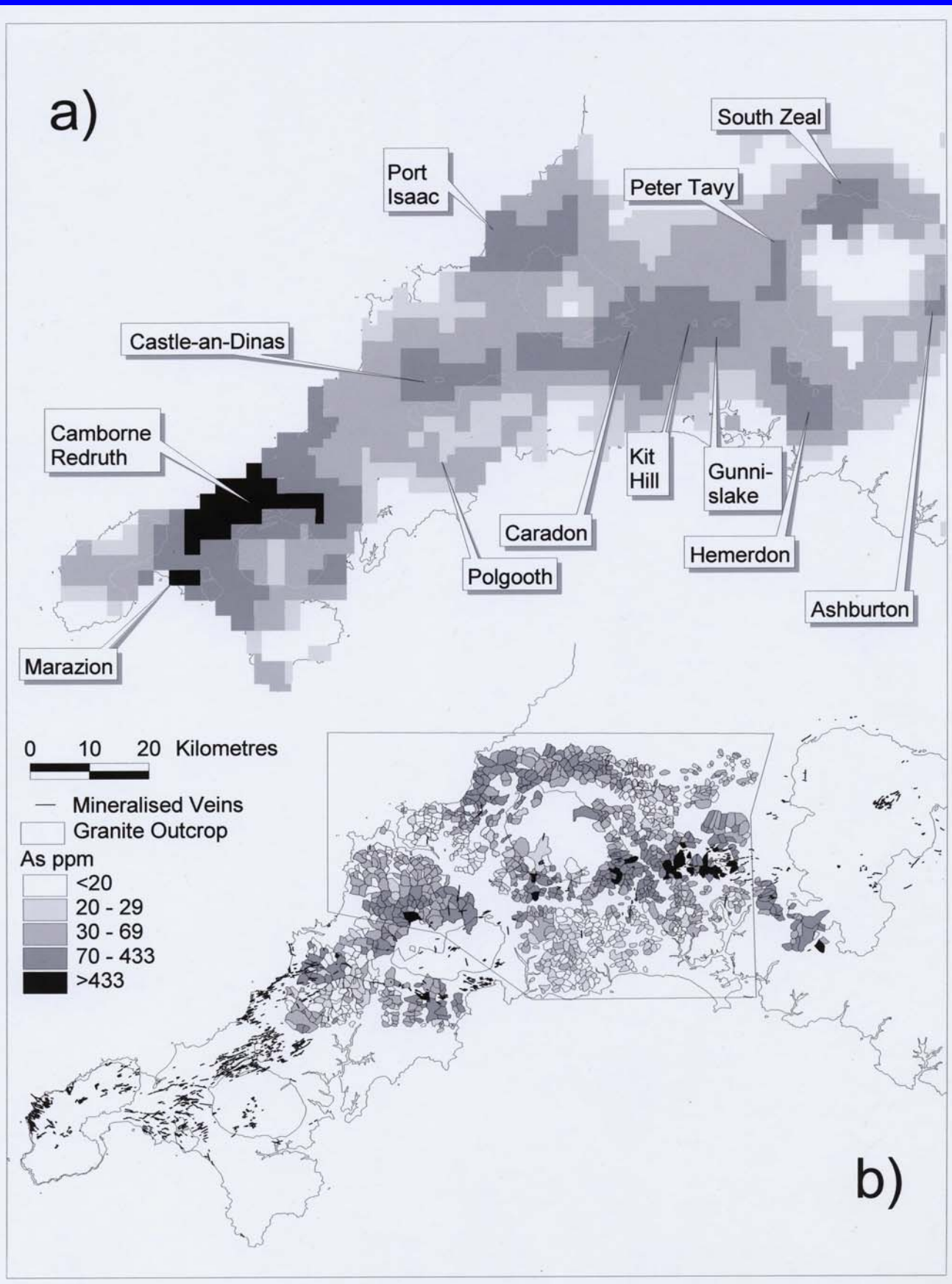
Gairloch



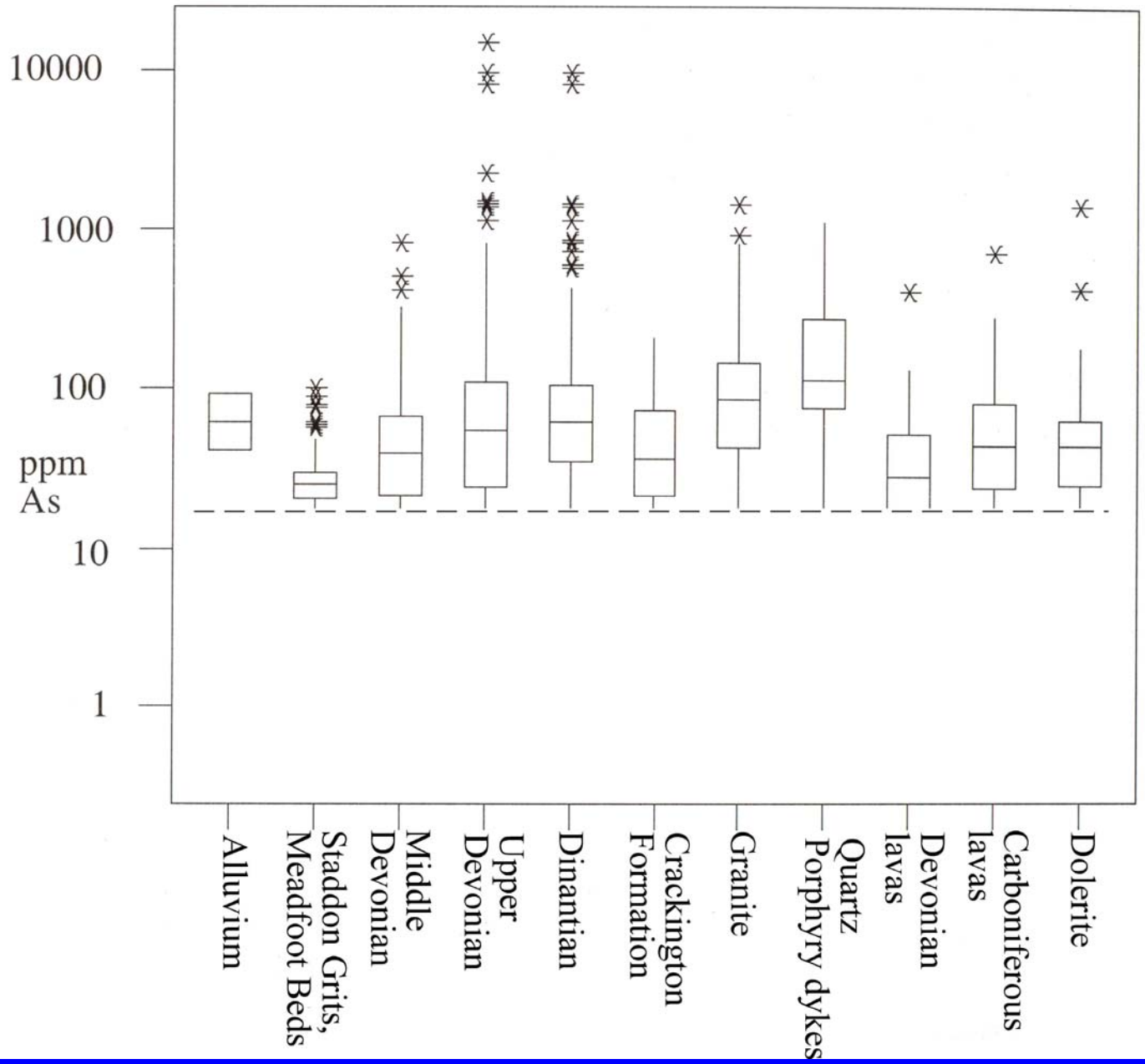
Catchments from BGS Data on Loch Maree Group



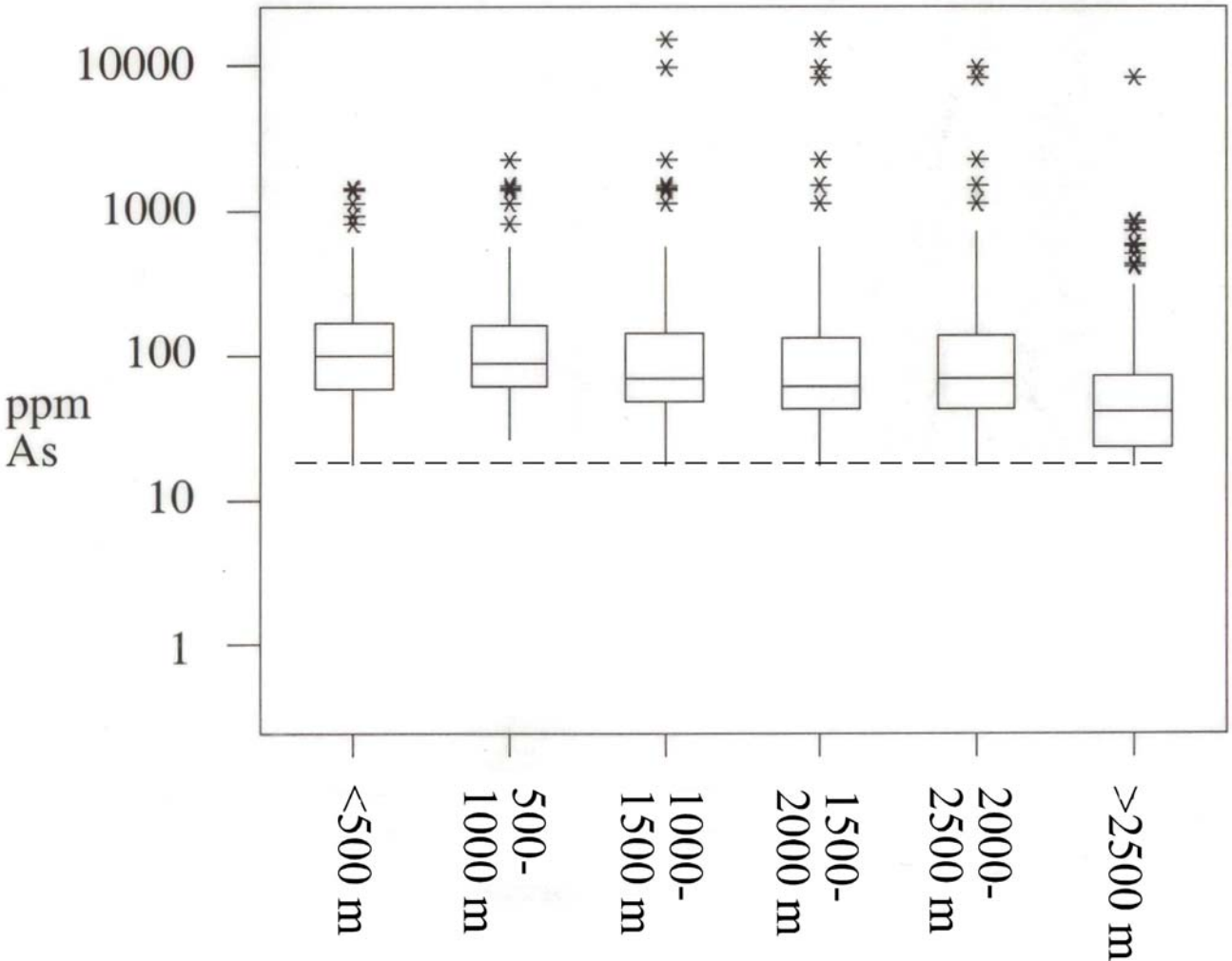
Arsenic Data Cornwall



Background As



Distance from granite



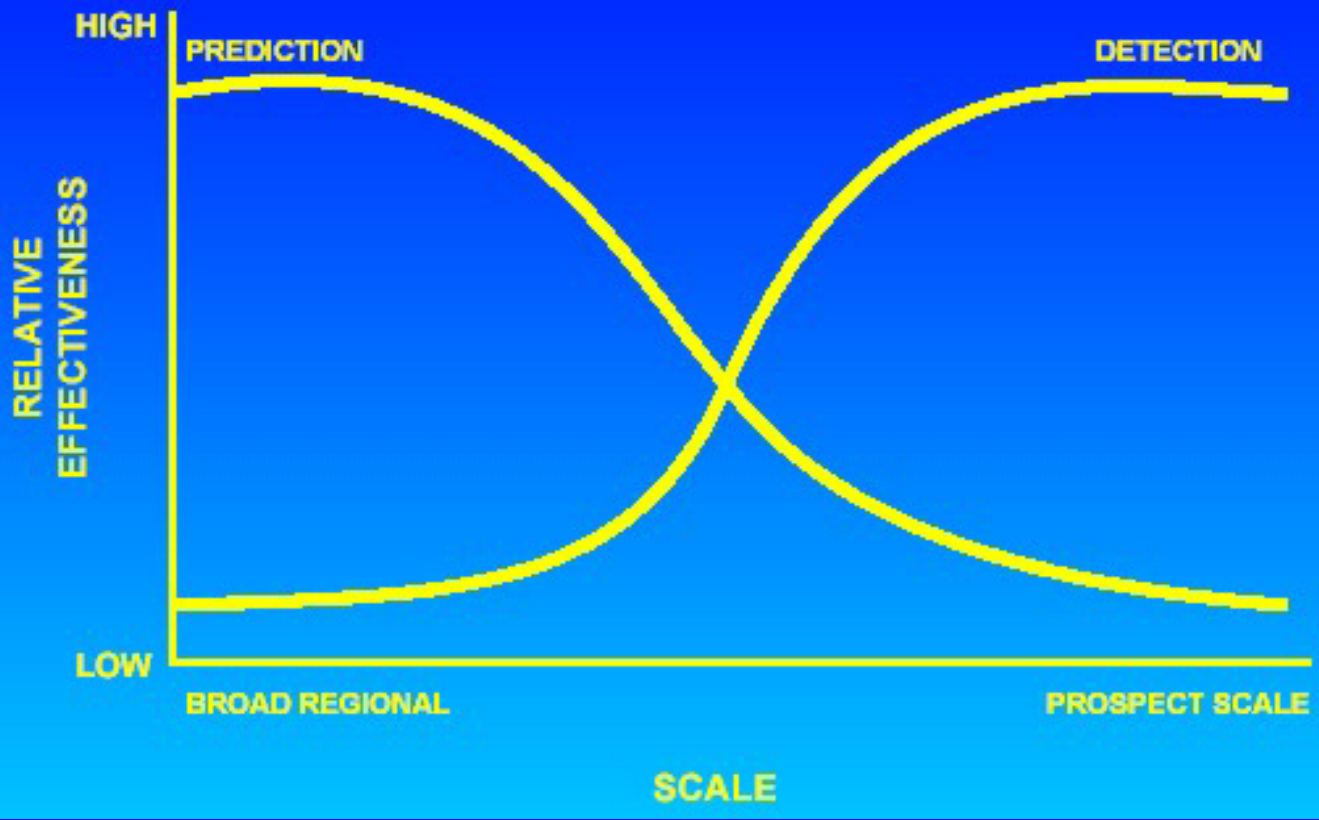
Catchmentisation

- The quick approach of data integration, using points and grids is very cost efficient
- This can misrepresent data
- The catchment approach is costly, 100 samples per day

Mineral Potential Mapping

EXPLORATION

At smaller scales, the Targeting Process (Prediction) gives way to Direct Detection



Source (Hronsky, 2003)

www.wmc.com

Mineral Deposit Models

- Sources of models

Cox and Singer

Eckstrand

- Example: Prospector 2

Linking Cox and Singer mineral deposit models to real data

Math. Geol. 26 917-936

- Mine Match

Prospector 2

Table 1. A Portion of the Original Descriptive Model of Sn Greisen Deposits Taken from Reed (1986)

Description: Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenized granite

Age Range: May be any age; tin mineralization temporally related to later stages of granitoid emplacement

Rock Types: Specialized biotite and/or muscovite leucogranite (S-type); distinctive accessory minerals include topaz, fluorite, tourmaline, and beryl

Texture/Structure: Exceedingly varied, the most common being disseminated cassiterite in massive greisen, and quartz veinlets and stockworks; less common are pipes, lenses, and tectonic breccia

Alteration: Incipient greisen (granite); muscovite +/− chlorite, tourmaline, and fluorite. Greisenized granite; quartz-muscovite-topaz-fluorite, +/− tourmaline. Massive greisen; quartz-muscovite-topaz +/− fluorite +/− tourmaline

Mineralogy: General zonal development of cassiterite + molybdenite, cassiterite + molybdenite + arsenopyrite + beryl, wolframite + beryl + arsenopyrite + bismuthinite, Cu-Pb-Zn sulfide minerals + sulphostannates, quartz veins +/− fluorite, calcite, pyrite

Geochemical Signature: Specialized granites enriched in Sn, F, Rb, Li, Be W, Mo, Pb, B, Nb, Cs, U, Th, Hf, Ta, and most REE

Table 3. A Portion of the Numerical Model for Sn-greisen Deposits in Prospector II

scription: Disseminated cassiterite, and cassiterite-bearing veinlets, stockworks, lenses, pipes, and breccia in greisenized granite

ologic-Ages: Precambrian, Phanerozoic

ck Types: Felsic-plutonic (5 −5), Granite (5 −5), Leucogranite (4 −4), Muscovite-leucogranite (3 −2), Biotite-leucogranite (3 −2)

rm-Structure: Greisen, Veinlets, Stockwork

teration: Greisenization (5 −2), Albitization (5 −2), Tourmalinization (3 −2)

inerals: Cassiterite (4 −5), Molybdenite (4 −5), Arsenopyrite (3 −5), Topaz (4 −2), Tourmaline (4 −2), Beryl (2 −4), Wolframite (2 −3), Bismuthinite (2 −2), Fluorite (4 −3), Calcite (1 −3), Pyrite (2 −4)

ochemical-Elements: Sn (4 −5), F (5 −5), B (5 −4), Mo (2 − 5), Rb (2 −4), Cs (2 −4), Be (2 −3) REE (2 −4), U (2 −4), Th (2 −4), Nb (2 −4), Ta (2 −4), Li (2 −4), W (2 −3), As (2 −4), Bi (2 −3)

Prospector 2

Table 2. Quantization Levels for Presence–Absence

State	Level	Verbal description of the attribute
Degree of sufficiency		
Presence	5	Most highly suggestive
	4	Highly suggestive
	3	Moderately suggestive
	2	Mildly suggestive
	1	Weakly suggestive
Degree of necessity		
Absence	−1	Infrequently present
	−2	Occasionally present
	−3	Commonly present
	−4	Most always present
	−5	Virtually always present

Types Of Data Merging

- Data Driven

Index Overlay

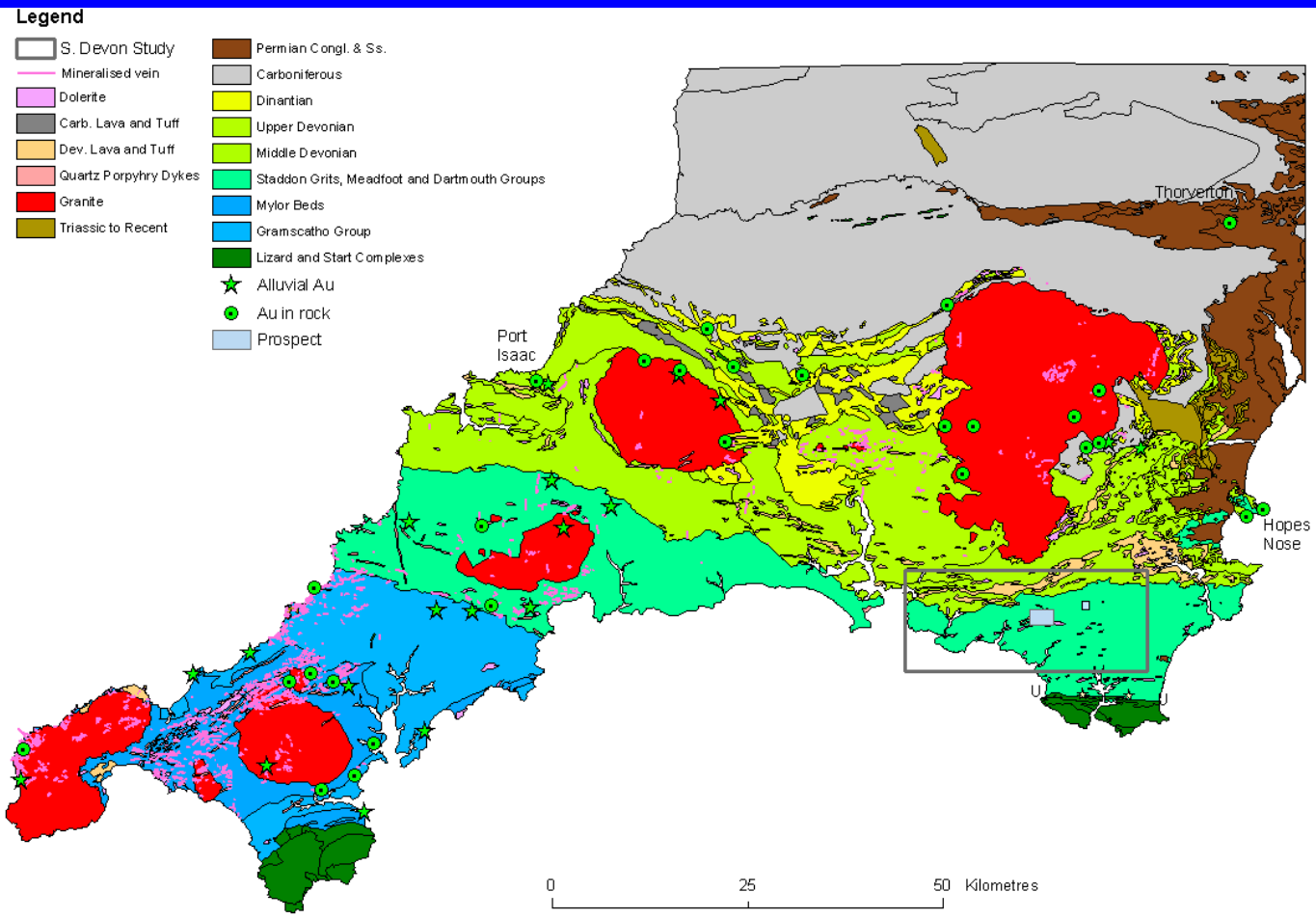
Weights of Evidence

Logistic Regression

- Model Driven

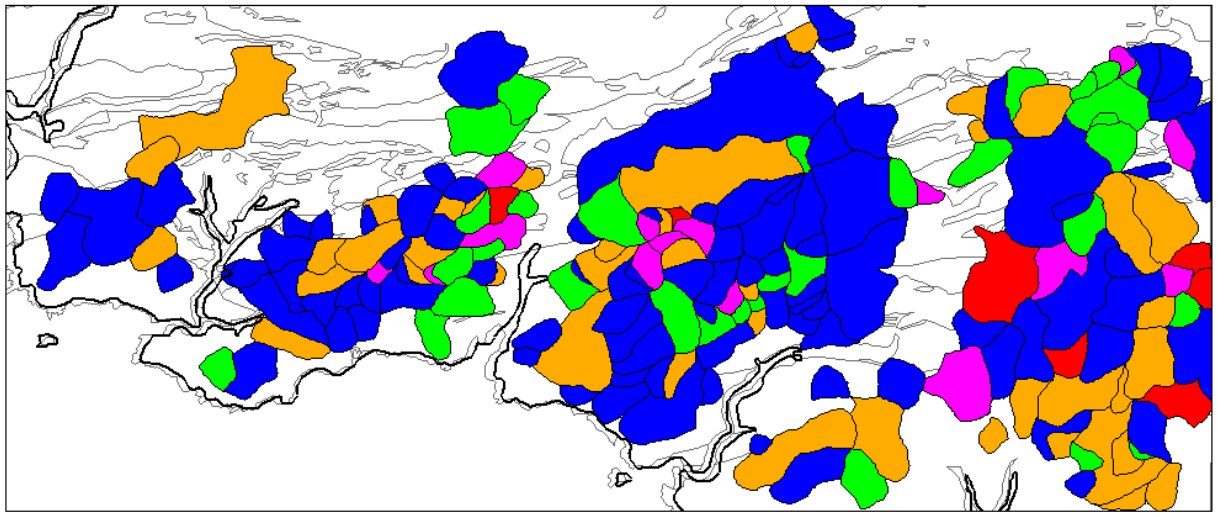
Dempster Shafer

Fuzzy Logic


Legend
S. Devon Study
Mineralised vein
Dolerite
Carb. Lava and Tuff
Dev. Lava and Tuff
Quartz Porpyhry Dykes
Granite
Triassic to Recent
Permian Congl. & Ss.
Carboniferous
Dinantian
Upper Devonian
Middle Devonian
Staddon Grits, Meadfoot and Dartmouth Groups
Mylor Beds
Gramscatho Group
Lizard and Start Complexes
Alluvial Au
Au in rock
Prospect
Port Isaac
Thorverton
Hopes Nose
0
25
50 Kilometres

South Devon

- New Gold Area
  mainly BGS work
- Much Alluvial Gold
  with Pd and Sn
- Geology Poorly Exposed
- 4 Main Shows
  contrasting settings
- Limited Drilling



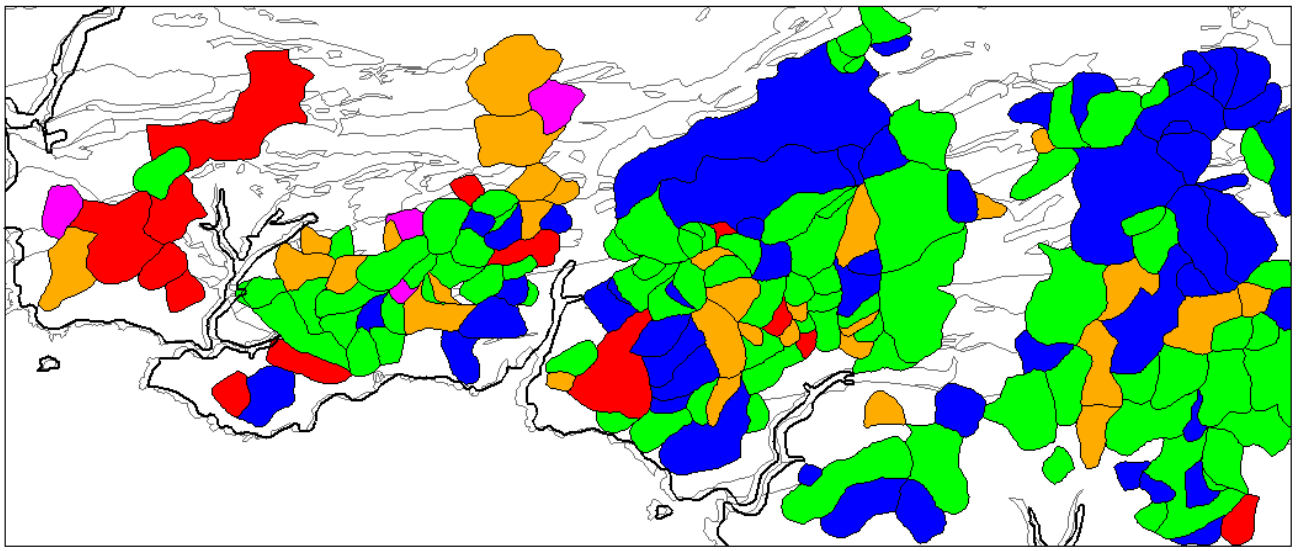
Legend

AU ppb

- 0.5 - 5
- 6 - 50
- 51 - 500
- 501 - 1000
- 1001 - 14500

0 2 4 8 Kilometers

BGS Panned Concentrate Data Catchmentised Au ppb



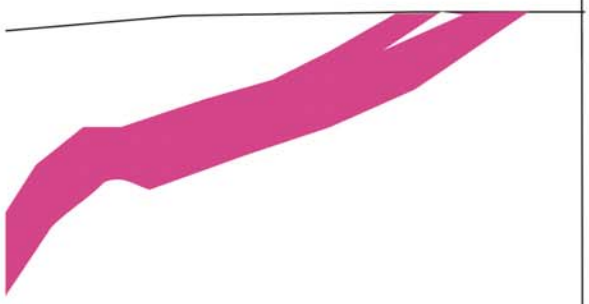
Legend

SN

- 1 - 100
- 101 - 500
- 501 - 1000
- 1001 - 5000
- 5001 - 13495

0 2 4 8 Kilometers

BGS Panned Concentrate Data Catchmentised Sn ppm



Volcanogenic Model

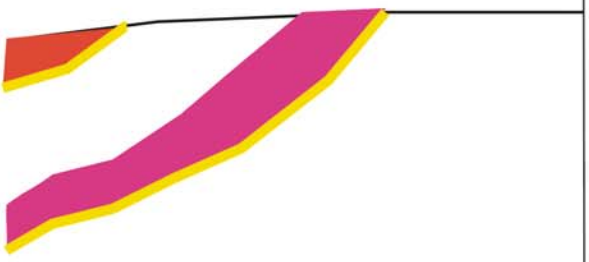
Host: Devonian acid- Int. Volcanics

Geoch: Linear Ba,As,Sb,Mn,Zn,Cu

Landsat: Local Hematite

Geophys: EM, I.P.

Example: Ugborough area



Thrust Model

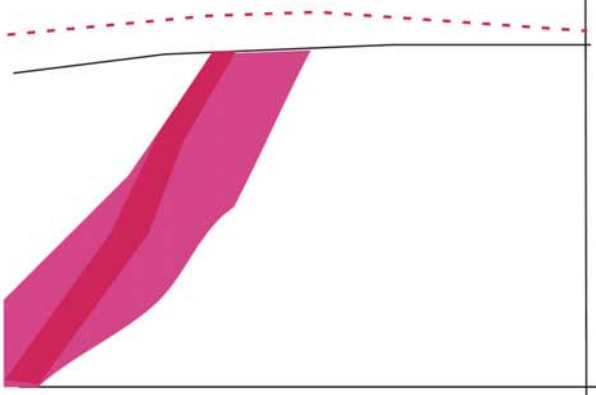
Host: Contacts of Volcs,ss

Geoch: As,Sb,Pb,Ag

Landsat: Local Linears

Geophys: VLF

Example: Port Isaac



Permian Model

Unconformity and Epithermal

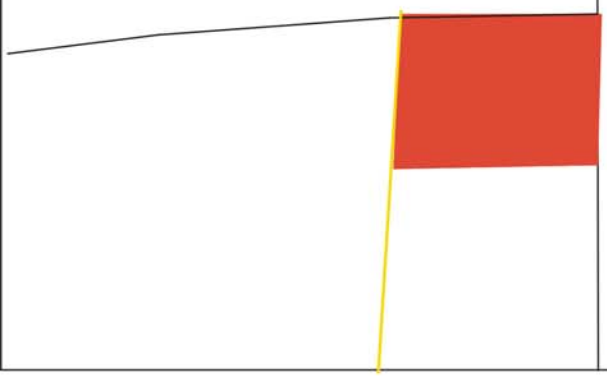
Host: Near Unconformity

Geoch: Pd,Se,Cu

Landsat: Extensive Hematite

Geophys: None

Example: ?Whympston, Modbury



Wrench Fault Model

Host: Any

Geochem: Pb,Ba,Cu,Ag,Sb

Landsat: Long Linears

Geophys: E.M.

Example: Loddiswell

Devonian Volcanics

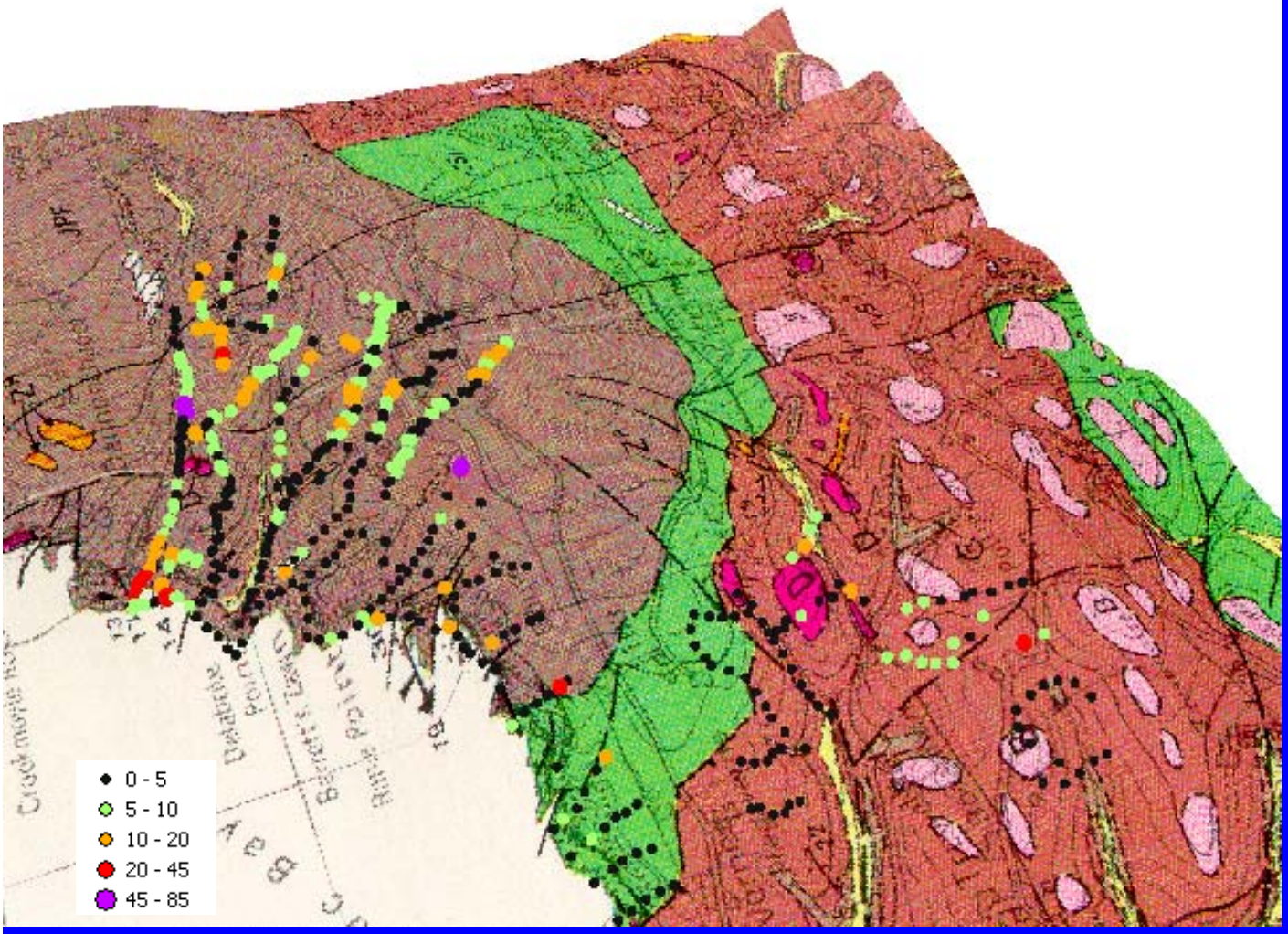
Permian Volcanics

Sandstone

Data types

	Influence/ precision
Geology (BGS maps)	25m
Topography	50m
Mineral Occurrences	100m
(Geophysics)	50m
Geochemistry	10m- 500m
S. seds, Pan Conc.	
Leicester, BGS	
Landsat TM	30m

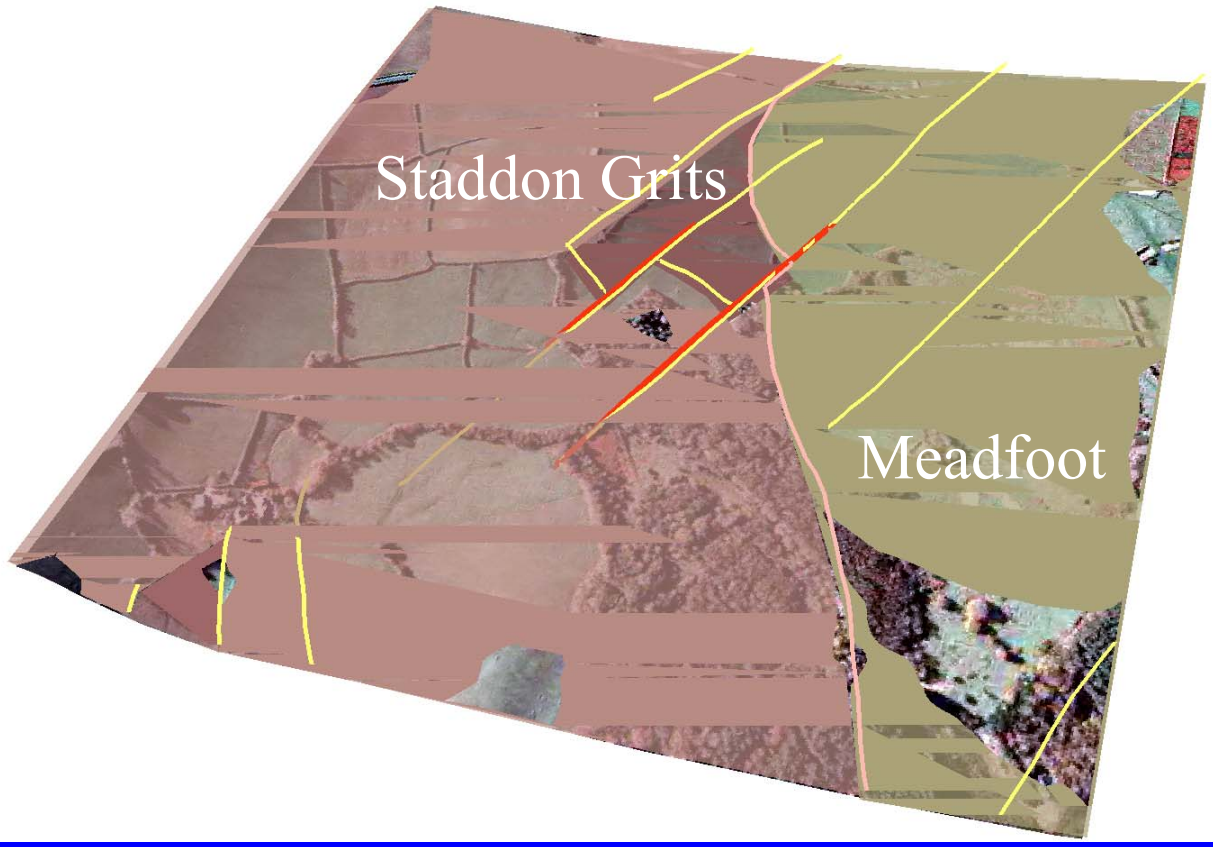
Port Isaac



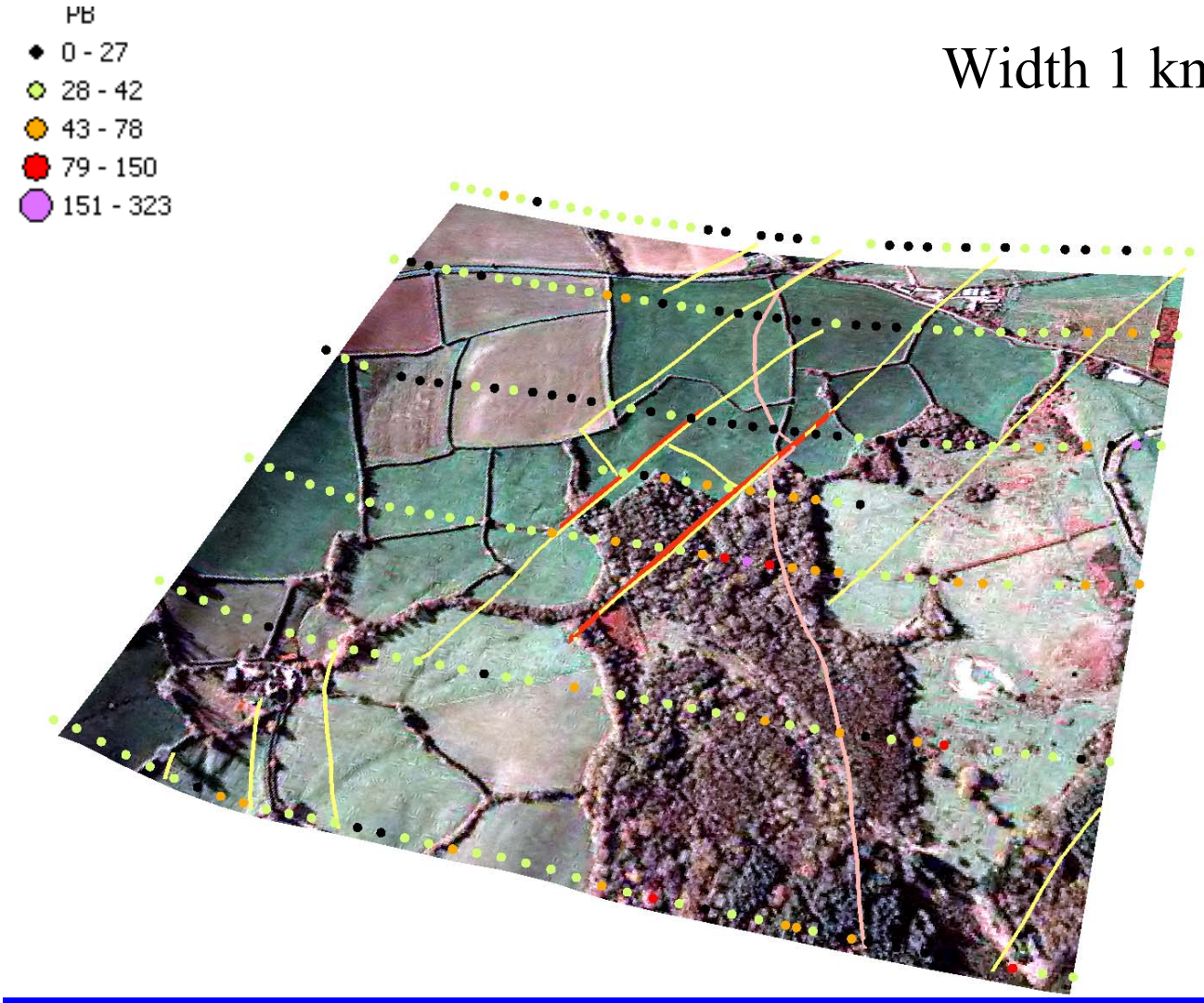
Draped Image of soil Au (Major 1985)

On published BGS 1:50000 map

Loddiswell Geology (James et al., 1990)

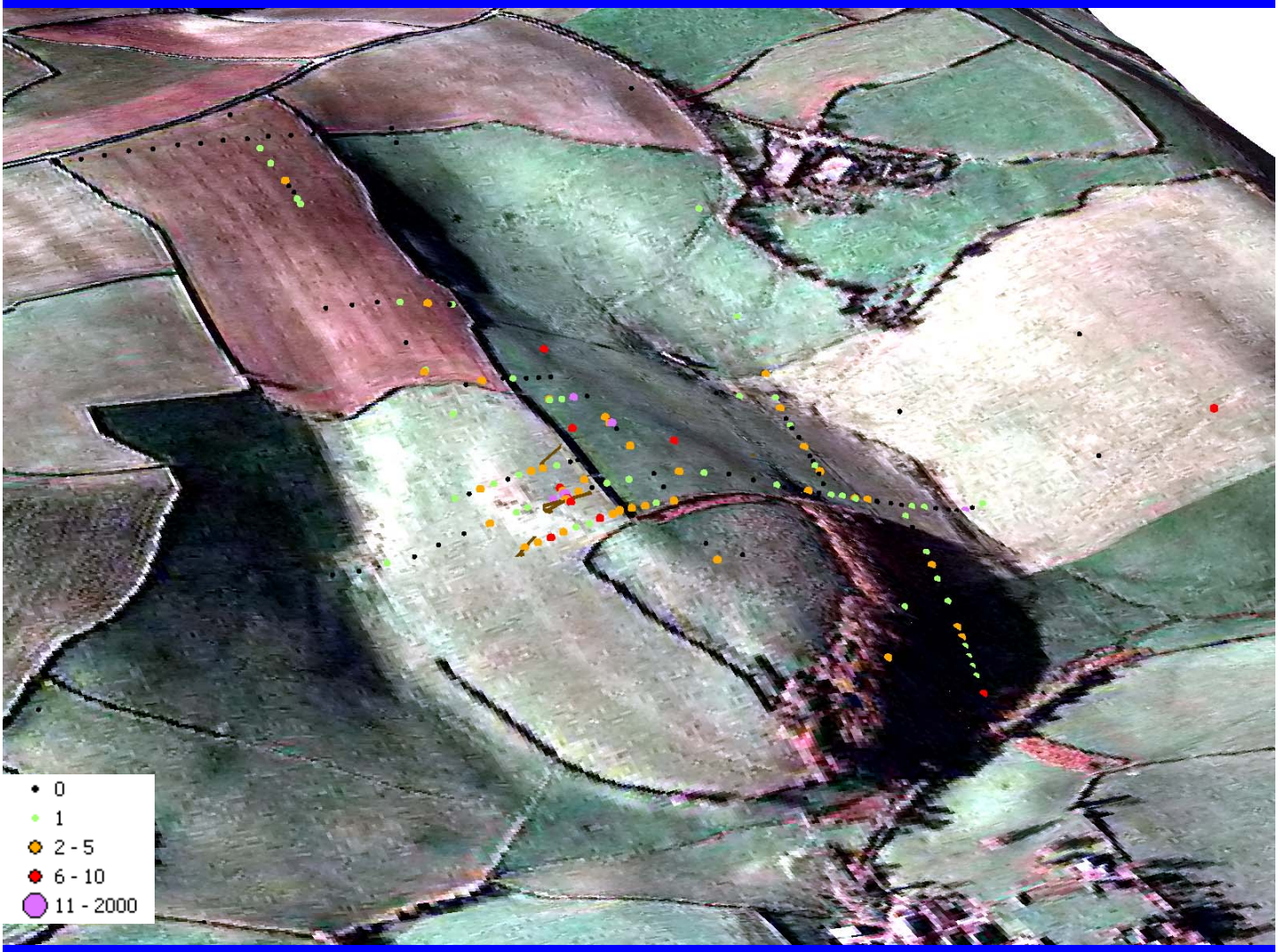


Loddiswell Pb

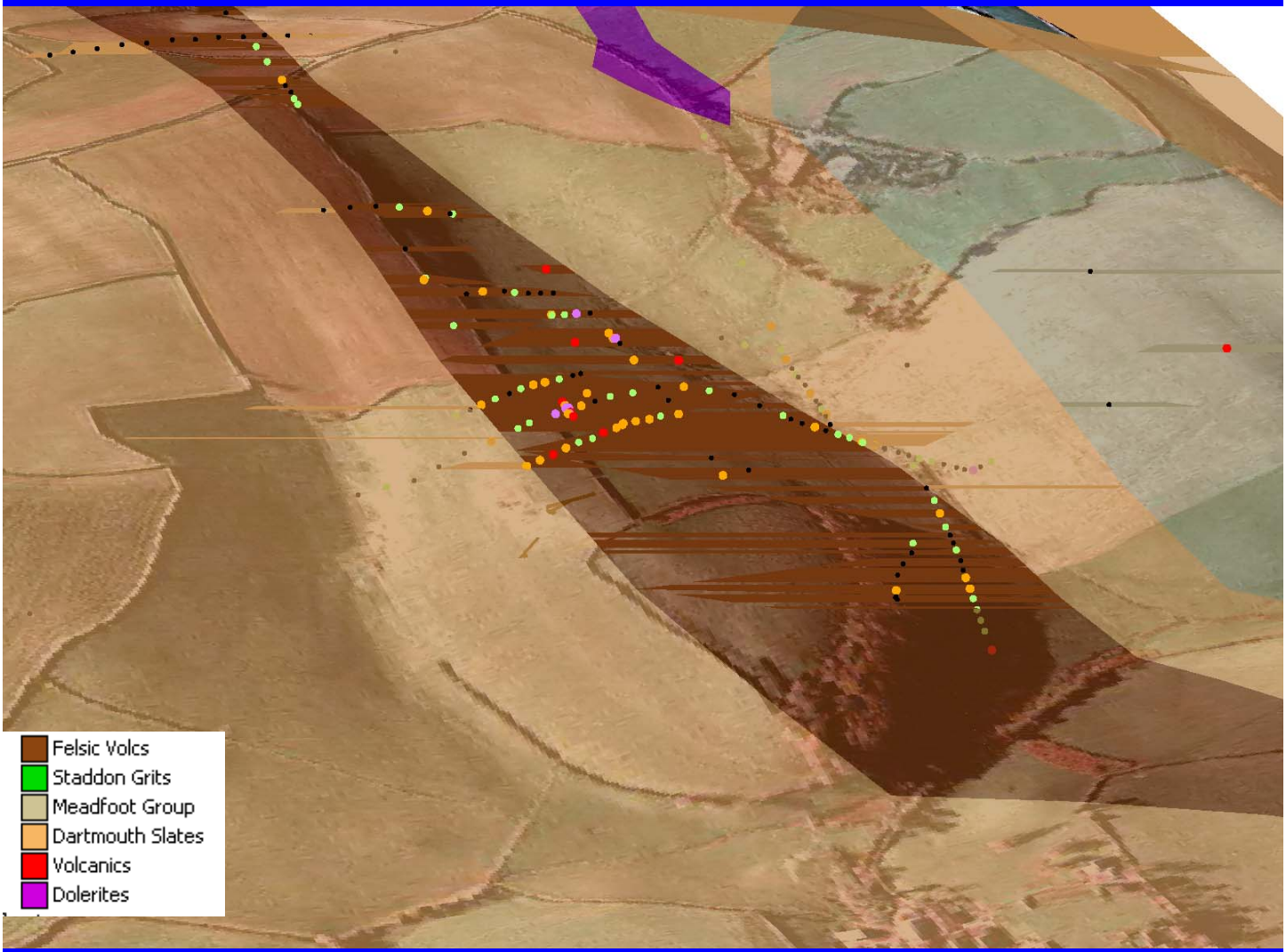


Width 1 km

Whympston Au grains (BGS data)



Original Geology (Ussher ~1900)



Comparison In South Devon

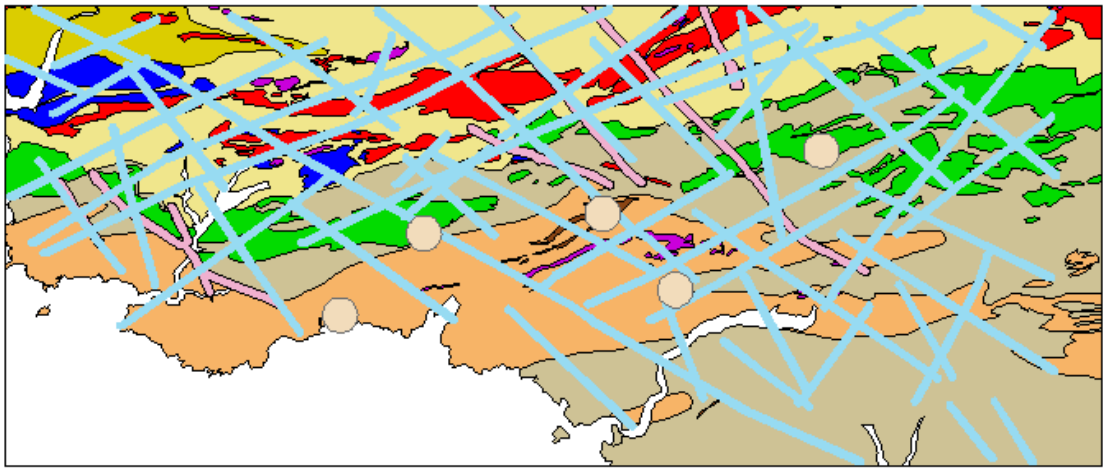
- Weights of Evidence
- Dempster-Shafer
- Fuzzy Logic
- Index Overlay

➢ 'Shows'

➢ Gold anomalies

Based on

- Lithologies
- 250, 500, 750 and 1000m buffers around major structures
- Geochemistry



0 5 10 20 Kilometers

Legend

- Au occurrences
- lineament
- fault buff
- sea
- Dolerites
- Volcanics
- Dartmouth Slates
- Meadfoot Group
- Staddon Grits
- Mid Devonian Slates
- Mid Devonian Lst
- Upper Devonian
- Felsic Volcs

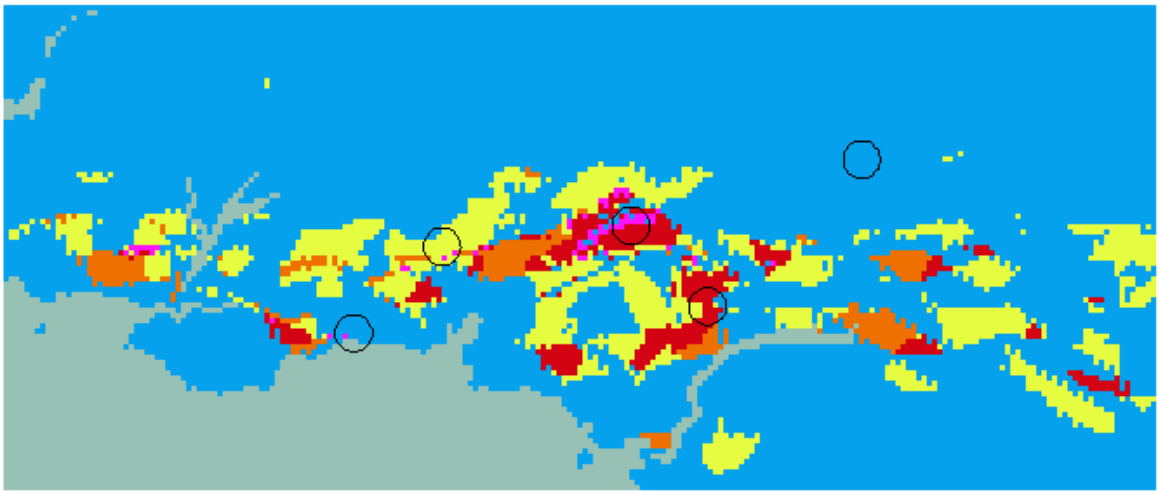
Index map for Wof E Analysis

Results of W of E Au occurrences

	W+	W-	contrast
Lineaments 1km NW	0.26	-0.34	0.60
Dart- Mead 2 km	0.63	-0.74	1.37
Mead-Stadd 750m	0.55	-0.20	0.75
Mead- Mdev 750	0.61	-0.08	0.69
Thrust 250	0.78	-0.06	0.85
Dolerite	1.18	-0.02	1.20
Dartmouth slate	1.05	-0.62	1.67
Felsite	3.74	-0.06	3.79
Au)5 ppb	0.84	-0.69	1.53

Results of W of E Panned Au >1 ppm

	W+	W-	contrast
Lineaments 1km NW	0.29	-0.40	0.69
Dart- Mead 2 km	0.55	-0.57	1.12
M Dev-Stadd 250m	0.26	-0.01	0.26
Thrust 250	0.32	-0.01	0.34
Dolerite	0.48	-0.01	0.49
Meadfoot	0.38	-0.29	0.68
Staddon Grit	0.23	-0.02	0.26
Felsite	2.02	-0.01	2.04



Legend

Au shows

Post. Prob.

sea

0 - 0.025

0.025 - 0.075

0.075 - 0.125

0.125 - 0.175

0.175 - 0.9

Comparison of W of E
based on Occurrences (upper)
and
(lower) catchments > 1 ppm Au

4 2 0 4 Kilometers

Legend

Post. Prob

sea

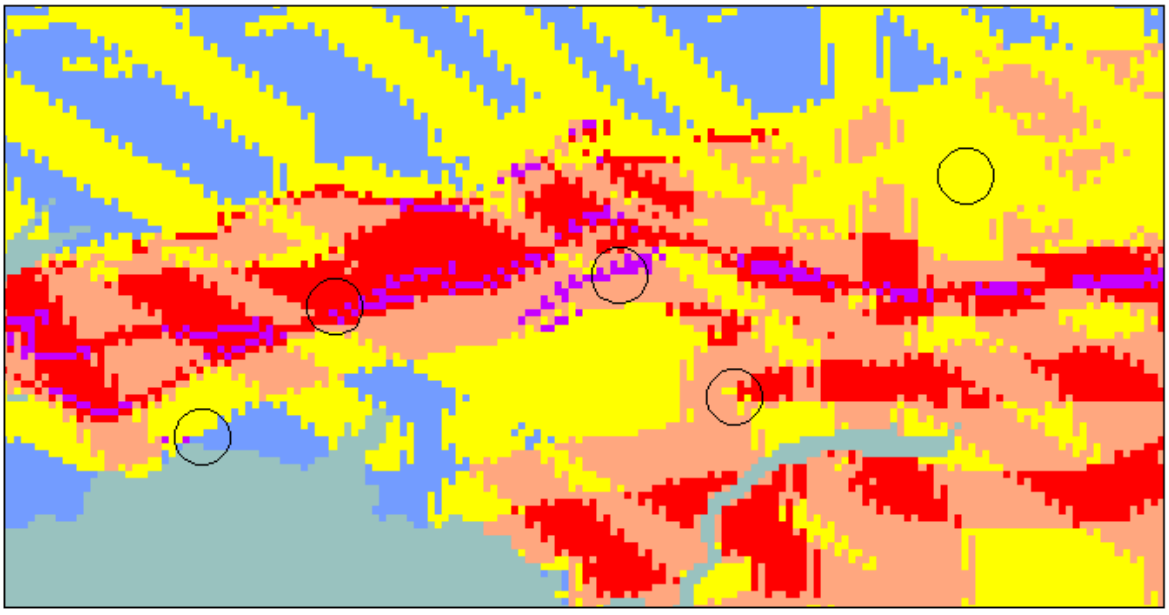
0 - 0.010

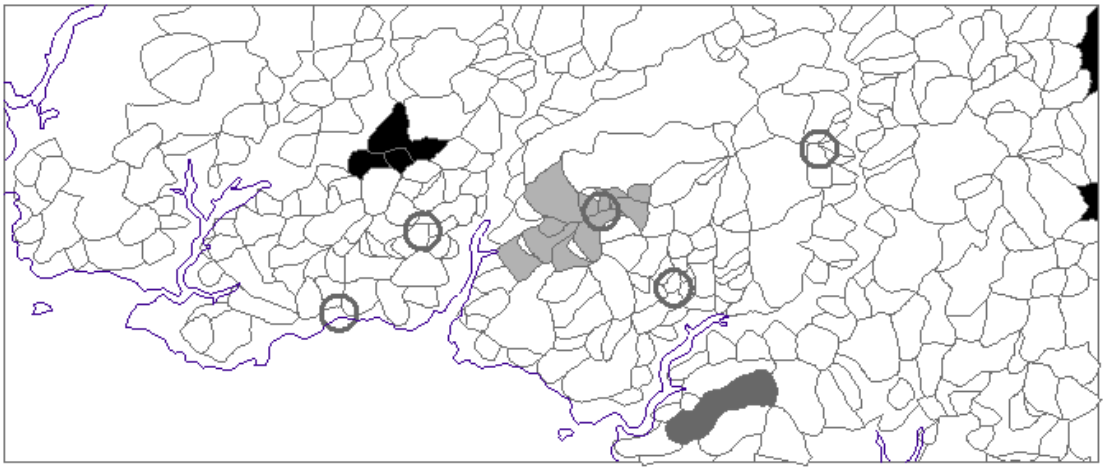
0.010 - 0.030

0.030 - 0.050

0.050 - 0.07

0.070 -0.250





Legend

shows

Summary

none

models 1+2+3 +4

models 1+3

model 1+ 6

Logistic regression: Summary of 6 models (above) model 1 (below)

Legend

Probability

0.00 - 0.07

0.08 - 0.15

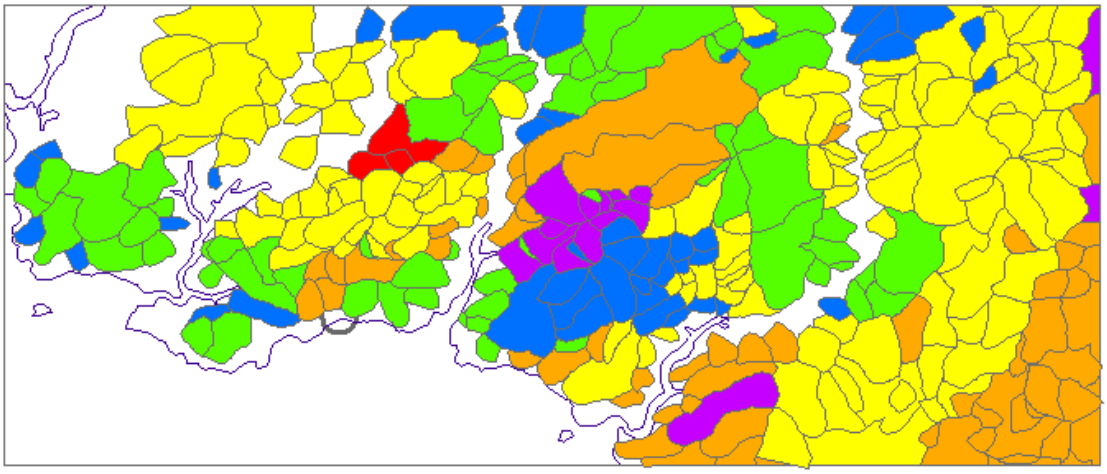
0.16 - 0.25

0.26 - 0.30

0.31 - 0.50

0.51 - 0.60

0.61 - 0.86



Comparison of different approaches

- Results are scale dependent

Prospect scale indicate feliste as main control

Regional geochemistry more emphasis on linears and thrusts

- Over all results are similar for different data driven methods
- Little evidence for unconformity related unless felsite is Permian

BGS Model
(from Colman 2000)

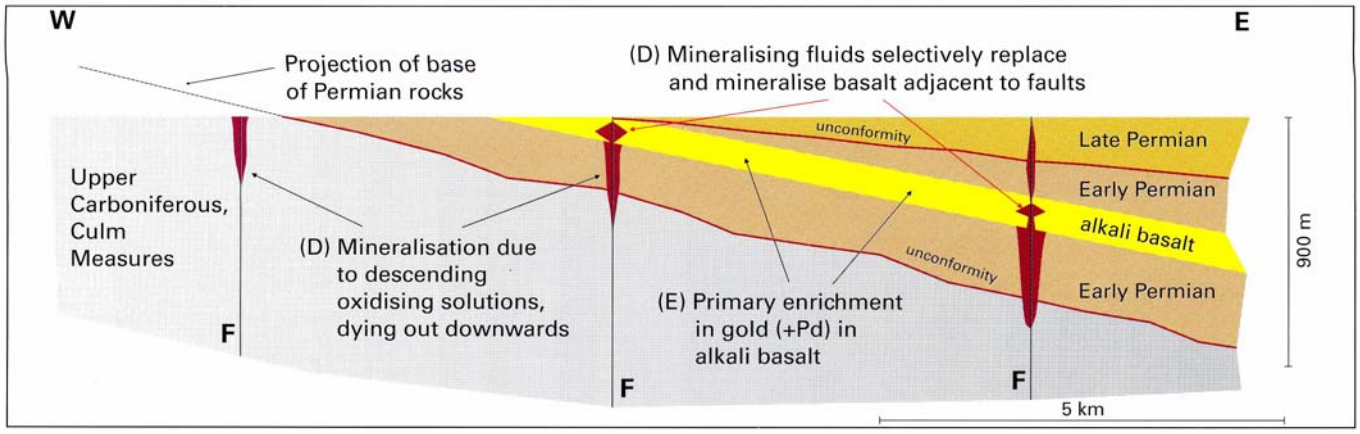


Figure 9 Model for unconformity-related gold mineralisation in Permo-Triassic red-beds.

Tests for Unconformity Model

- Distance from unconformity

Reddening

Valley shape

Projection of surface

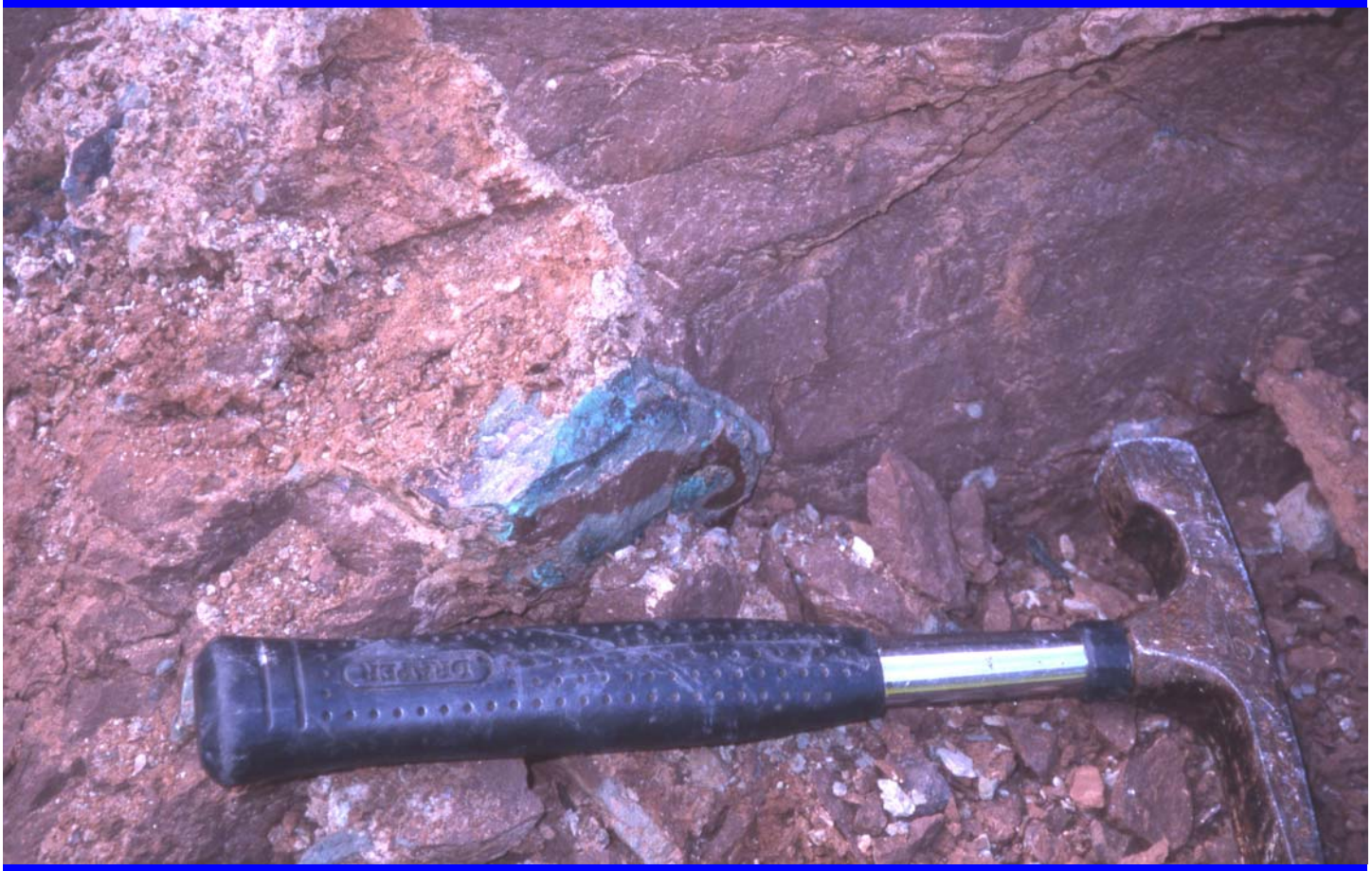
- Geochemistry

Pd, Se, U (Cu)

Unconformity
(Bardon, Leics)

Veining
Bardon

Cu Mineralisation



Crediton Trough

- Similar geochemistry
- Au confirmed in basalt

3.6g/t gold over 0.9m, 3.9 g/t over 1.91m , and 4.9 g/t over 0.44m in vertical carbonate veins

- Unconformity untested although Au rich in places

Conclusions from S. Devon study

- Models such as unconformity model are difficult to test
- Quantitative approaches dependent on data availability and known occurrences although does provide discipline