Determination of stream sediment background concentrations in mineralised catchments impacted by mining using Tellus data from Northern Ireland

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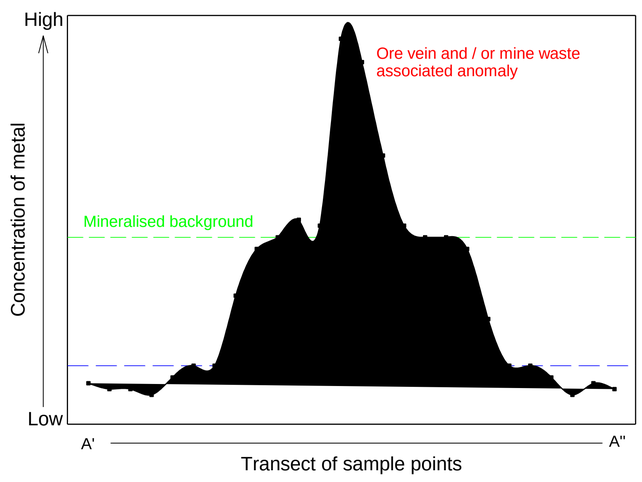
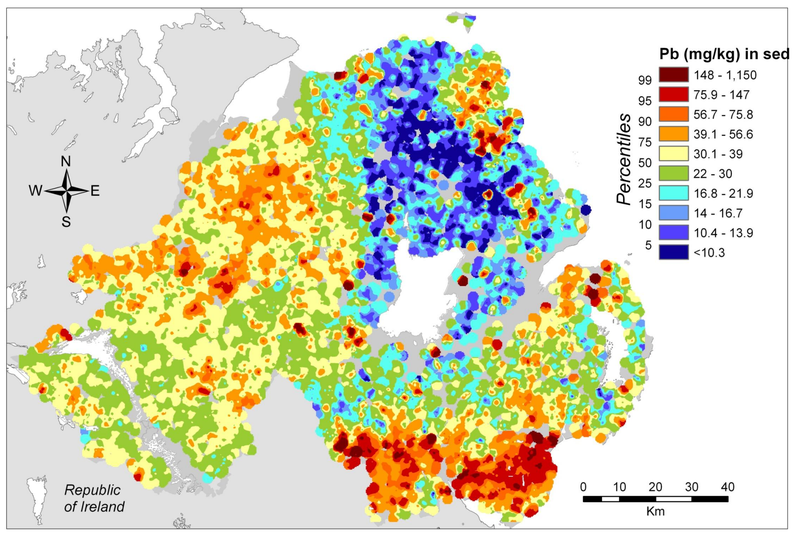
Introduction

The naturally elevated background concentrations of metal(loids) in stream sediments and water from mineralised catchment can be retrospectively discriminated from the impacts of ore extraction and processing by using geochemical survey data.

We present a methodology to derive baseline data using a subset of the Tellus geochemical stream sediment survey database.



Stream sediment concentrations are expected to increase, if local rocks are mineralised. This will be further enhanced if there has been historic mining.



Stream sediment lead (Pb) concentrations from the Tellus survey.

The most widespread high concentrations are found in southern Counties Armagh and Down.

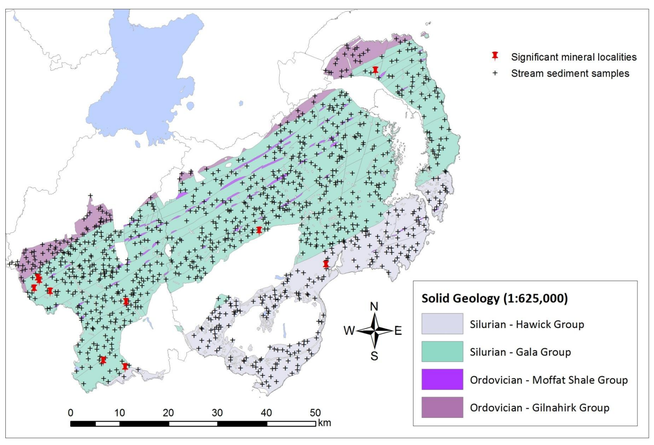
Requirement for baseline data

Distinguishing natural versus mining-related water and sediment quality degradation will:

- ❑ Improve assessment of the environmental pressures due to mining to inform the implementation of the European Mine Waste Directive and the Water Framework Directive.
- ❑ Increase understanding of what restoration goals are achievable in mining impacted catchments.
- ❑ Provide a reference against which changes can be measured and can be used in future mine applications.

Method: data exploration

Stream sediment sample data were selected where they overlie Ordovician or Silurian sediments, coincident with many of the high Pb concentrations shown above. This area has had historic mining activities, especially those of the south Armagh – Monaghan mining district.

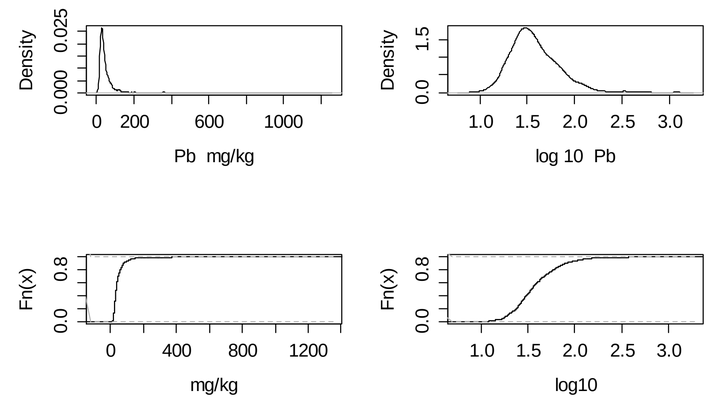


Variable	PEL	minimum	25th	50th	75th	maximum
			percentiles			
	(mg/kg)					
Lead (Pb)	91.3	8	25	35	54	**1245**
Zinc (Zn)	315	32	124	172	257	**3162**
Cadmium (Cd)	3.5	0.3	0.3	0.6	1.2	**56**
Antimony (Sb)	none	0.3	0.6	0.8	1.2	7.4
Arsenic (As)	17	0.9	7.3	11	**17**	**357**
Copper (Cu)	197	7	30	37	48	**260**
Chromium (Cr)	90	16	**127**	**146**	**185**	**407**
Nickel (Ni)	35.9	4	**52**	**64**	**83**	**250**

The table above shows the summary concentrations of the data for the sites mapped to the left. These shown the full range, interquartile range (25th and 75th percentiles) and the median (50th percentile).

In the absence of sediment quality guidelines, comparison of the selected dataset is made to the Canadian sediment Predicted Effects Level (PEL) – where statistical values exceed the PEL these are highlighted in bold.

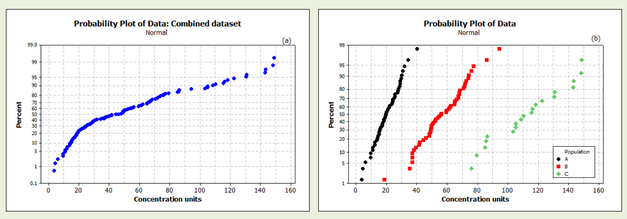
For each element studied, the statistical properties, such as the shape of the distribution shown below, help inform as to whether the data appear to be a single normally distributed data population or not. We find that lead (Pb) approximates a normal distribution after a $\log_{10}$ transformation, as shown below.



Method: using statistical data properties to separate data populations

The theory:

Where a dataset is comprised of more than one statistical population, shown in an example dataset in (a), these can be separated out into their component data populations, as has been done in (b).



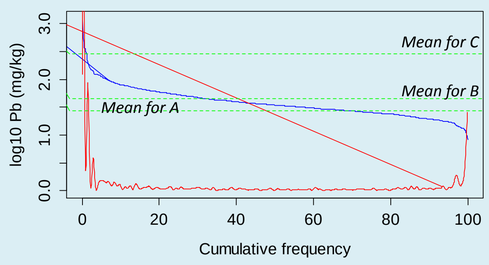
References:
Sinclair, A.J., 1976. Applications of probability graphs in mineral exploration. The Association of Exploration Geochemists, Vancouver, BC, Canada.
Stanley, C.R., 1987. PROBPLOT. An interactive computer program to fit mixtures of normal (or log-normal) distributions with maximum likelihood optimization procedures. The Association of Exploration Geochemists, Vancouver, BC, Canada.

In order to 'un-mix' data populations from real datasets, the 'ProbPlot' methodology of Sinclair and Stanley has been used as a basis. However, we have implemented the methodology using R-scripts.

This allows the earlier algorithms to be implemented in a more modern programming language, which is freeware and thus universally accessible.

Examples of outputs are shown for stream sediment lead (Pb) background concentration calculations.

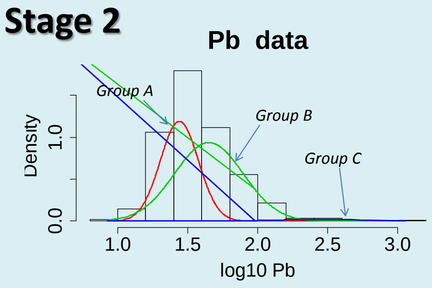
Stage 1



A cumulative frequency plot (blue) is overlain with the arithmetic mean values of three sub-populations (green) modelled in the lead data.

The identification of the higher concentration populations is supported using a derivative plot (red) showing maximum slope changes in the data plot (blue).

Stage 2



The distribution of the data, here shown as density plots for each population, is used to assess the model outcome. These data populations are also compared with location information, and mapped in GIS software.

Arithmetic mean lead (Pb) concentrations for each of the unmixed background populations are: Group A 23 mg/kg; Group B 40 mg/kg; and Group C 290 mg/kg.

The use of baseline concentration

Systematically sampled regional geochemical data can be used to derive local background concentrations, related to the bedrock composition and specific catchments. This may provide guidance on feasible restoration targets where there is localised contamination.

TELLUS BORDER

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