# APPLICATION OF FIELD PORTABLE XRF GEOCHEMICAL DATA IN THE BROKEN HILL REGION

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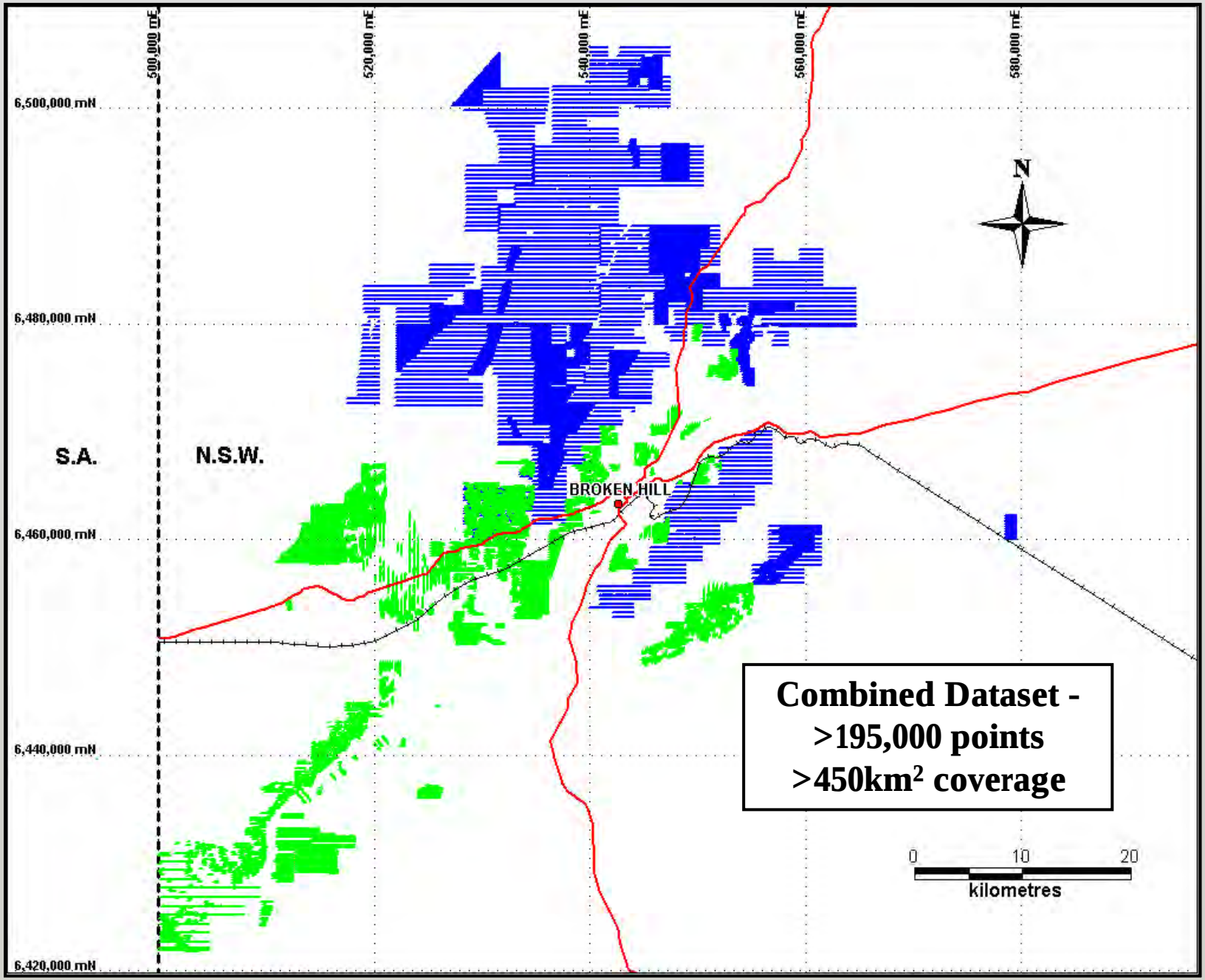
## HANDHELD XRF USERS WORKSHOP & DISCUSSION FORUM

# Outline of Presentation

- Field portable XRF (FP-XRF) data coverage in the Broken Hill region
- Utilisation of FP-XRF surveys in CBH Resources' Regional Assessment Program
- Data collection and quality
- Comparison of FP-XRF with conventional soil analyses
- Selected statistical features of the FP-XRF dataset
- Data treatment and presentation
- Major regional scale features of the CBH dataset
- Potential further work with the FP-XRF datasets

# FP-XRF in the Broken Hill Region

- FP-XRF geochemical data has been extensively collected in the region, most notably by Perilya Ltd. and CBH Resources Ltd. (along with their JV partners)
- Abundant outcrop renders the technique particularly useful in the Broken Hill region
- The FP-XRF geochemical datasets of Perilya and CBH Resources were released as a part of BHEI 2009
  - **The combined datasets contain more than 195,000 individual FP-XRF readings**
  - **Provides coverage to more than 450 km$^2$ of prospective ground surrounding Broken Hill**


500,000 mE
520,000 mE
540,000 mE
560,000 mE
580,000 mE
6,500,000 mN
6,480,000 mN
6,460,000 mN
6,440,000 mN
6,420,000 mN
S.A.
N.S.W.
BROKEN HILL
N
Combined Dataset -
>195,000 points
>450km2 coverage
0
10
20
kilometres

# Why Use FP-XRF Geochemistry in the Broken Hill Region?

## BENEFITS

- Extensive outcrop makes the technique suitable
- **Rapid coverage of large areas**
- Assay of a large element suite (up to 19 elements)
- Immediate display of results
- **Lower cost than conventional soil geochemistry**
- Rapid delineation of drill targets

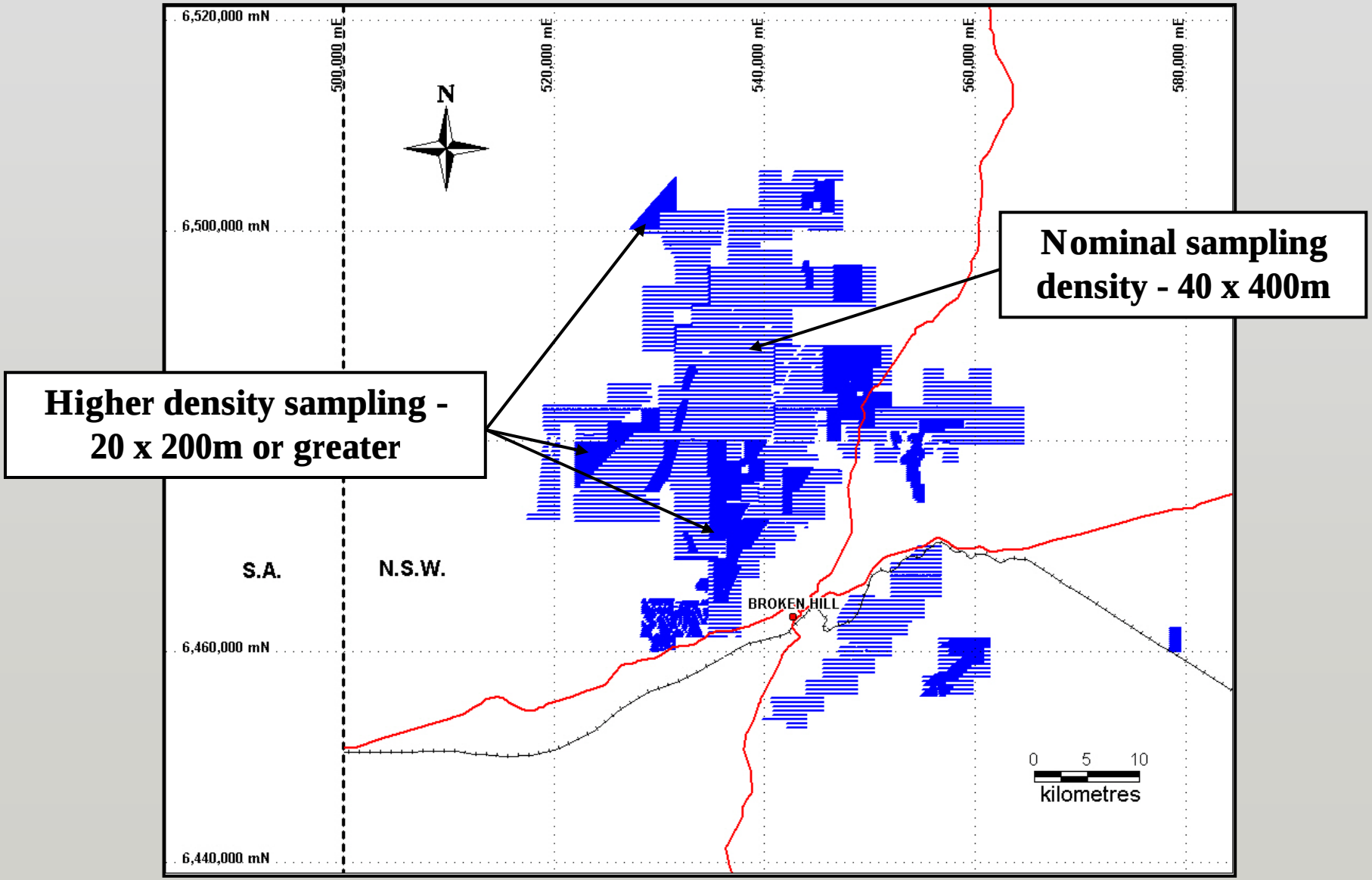
## ISSUES

- Higher detection limits than conventional soil geochemistry
- Not sensitive enough to detect some pathfinder elements
- Limited control on assay medium/soil size fraction
- Reliability can be affected by high temperatures
- Detection of anthropogenic contamination an issue

# The CBH Resources Dataset

- Survey conducted on a nominal grid of 40 x 400 metres, closer infill sampling over many areas (down to 10x10m)
- Readings collected on surface component of soil only
- Reading collection time of 60 seconds per sample
- Up to 19 elements assayed at each point including Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Rb, Sb, Se, Sn, Sr, Zn and Zr
- Best response obtained for **Zn, Pb, As, Cu, Mn, Fe, Rb** and **Sr**
- Instrument regularly checked against a range of standards

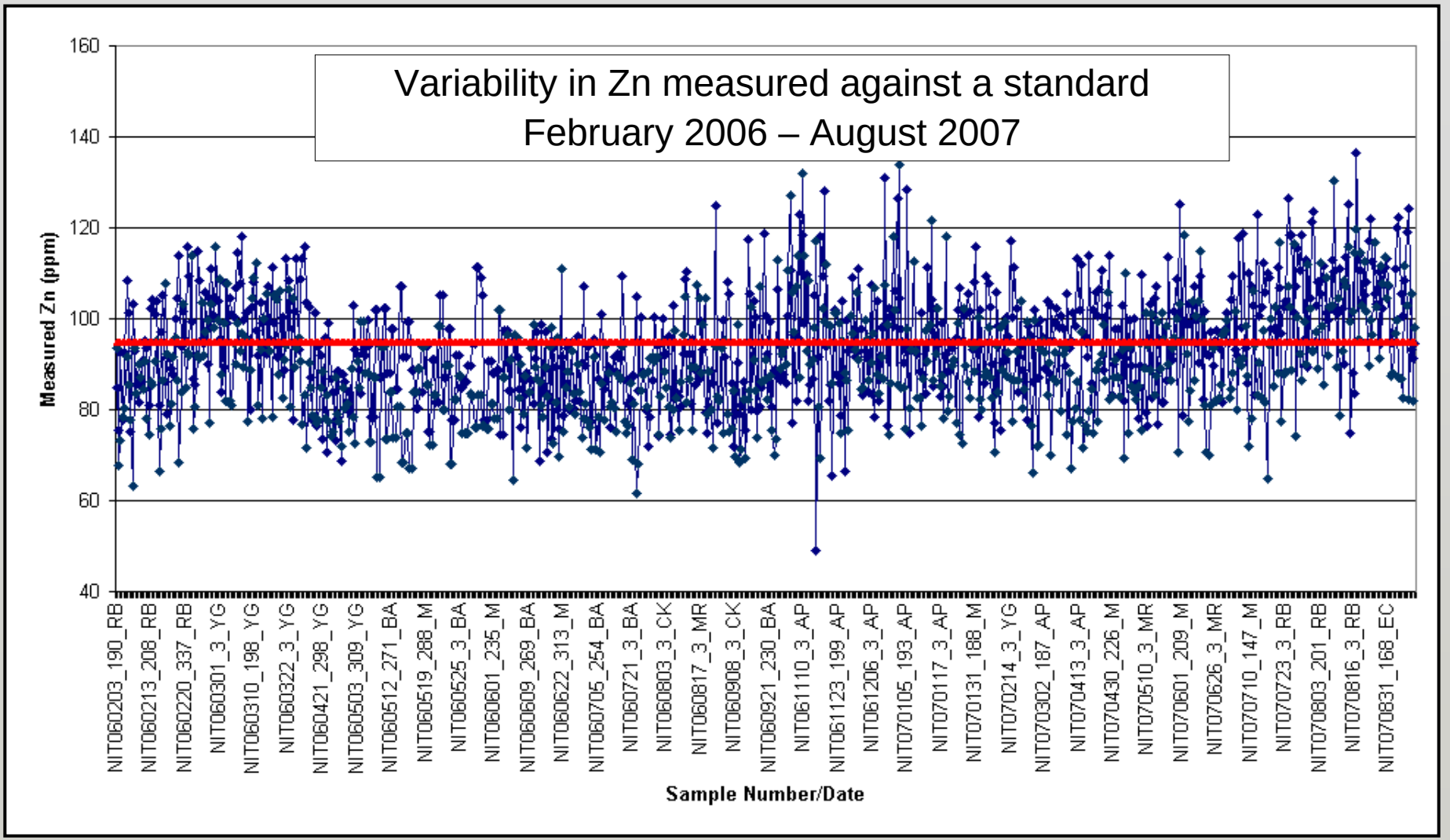
# FP-XRF Sample Density



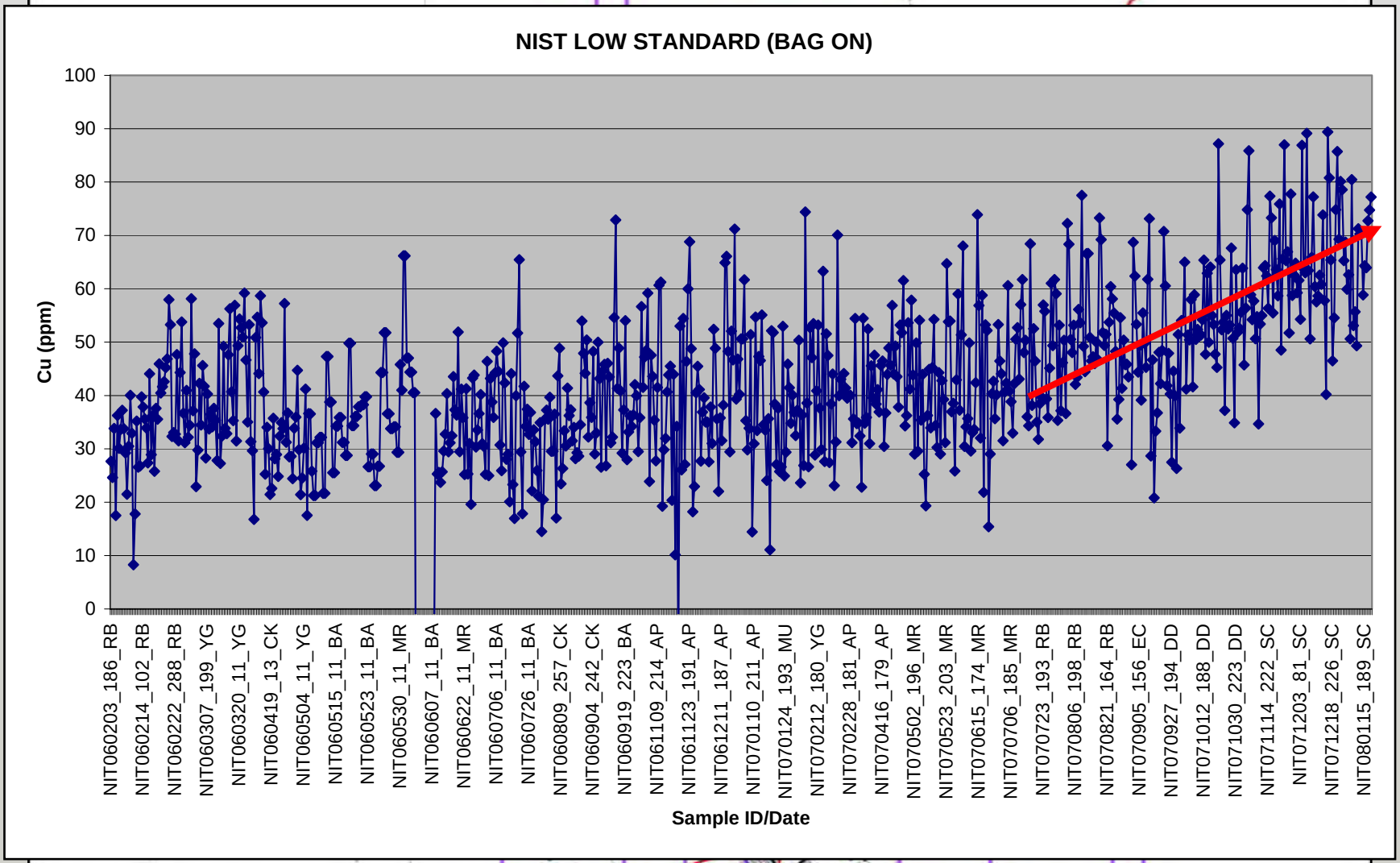
| | Mean | Median | 90th % | 99th % | LLD (SRM)* |
|---|---|---|---|---|---|
| **Ag** | 1.8 | 1.5 | 10.6 | 20.2 | 70 |
| **As** | 7.4 | 5.3 | 14.1 | 44.6 | 20 |
| **Cd** | -6.2 | -7.3 | 8.1 | 27.4 | 75 |
| **Co** | 68.4 | 59.0 | 196.6 | 445.5 | 200 |
| **Cr** | 59.2 | 56.1 | 142.3 | 230.7 | 60 |
| **Cu** | 39.1 | 32.1 | 55.6 | 125.6 | 100 |
| **Fe** | 29323 | 28022 | 39049 | 65878 | 250 |
| **Hg** | 2.2 | 2.1 | 5.5 | 8.8 | 20 |
| **Mn** | 601.4 | 520.6 | 909.6 | 1880.2 | 250 |
| **Ni** | 42.7 | 41.4 | 65.6 | 92.6 | 120 |
| **Pb** | 80.8 | 57.0 | 116.2 | 350.5 | 25 |
| **Rb** | 100.1 | 99.0 | 132.3 | 166.4 | 20 |
| **Sb** | 7.9 | 4.9 | 56.6 | 118.3 | 250 |
| **Se** | 1.2 | 1.1 | 3.7 | 6.2 | 20 |
| **Sn** | -14.1 | -16.4 | 29.4 | 82.6 | 200 |
| **Sr** | 77.7 | 74.3 | 101.8 | 157.0 | 50 |
| **Zn** | 119.2 | 92.2 | 176.4 | 547.3 | 55 |

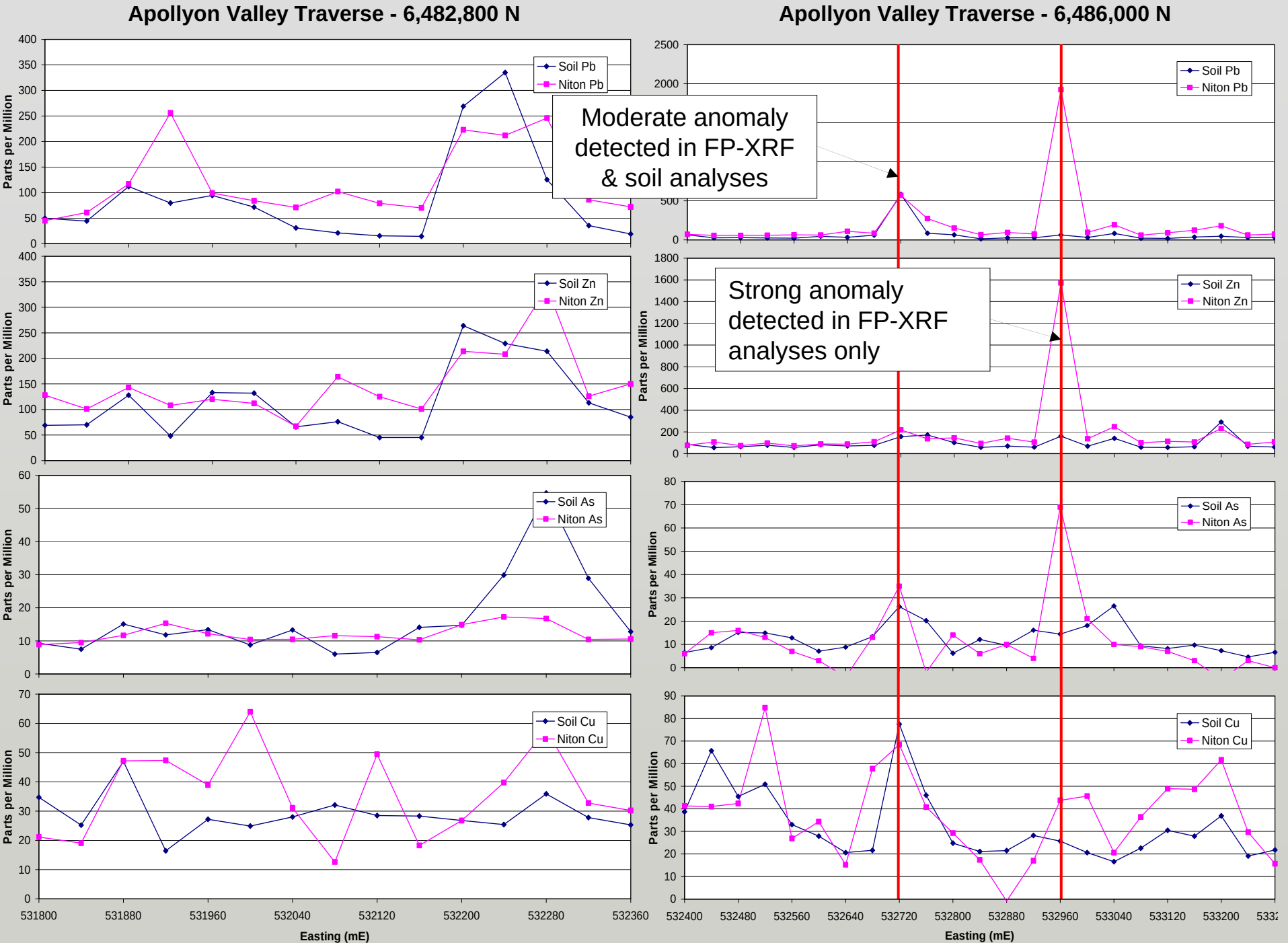
All values in parts per million
*Quoted Lower Limit of Detection for a Standard Reference Material

# Data Quality – Use of Standards

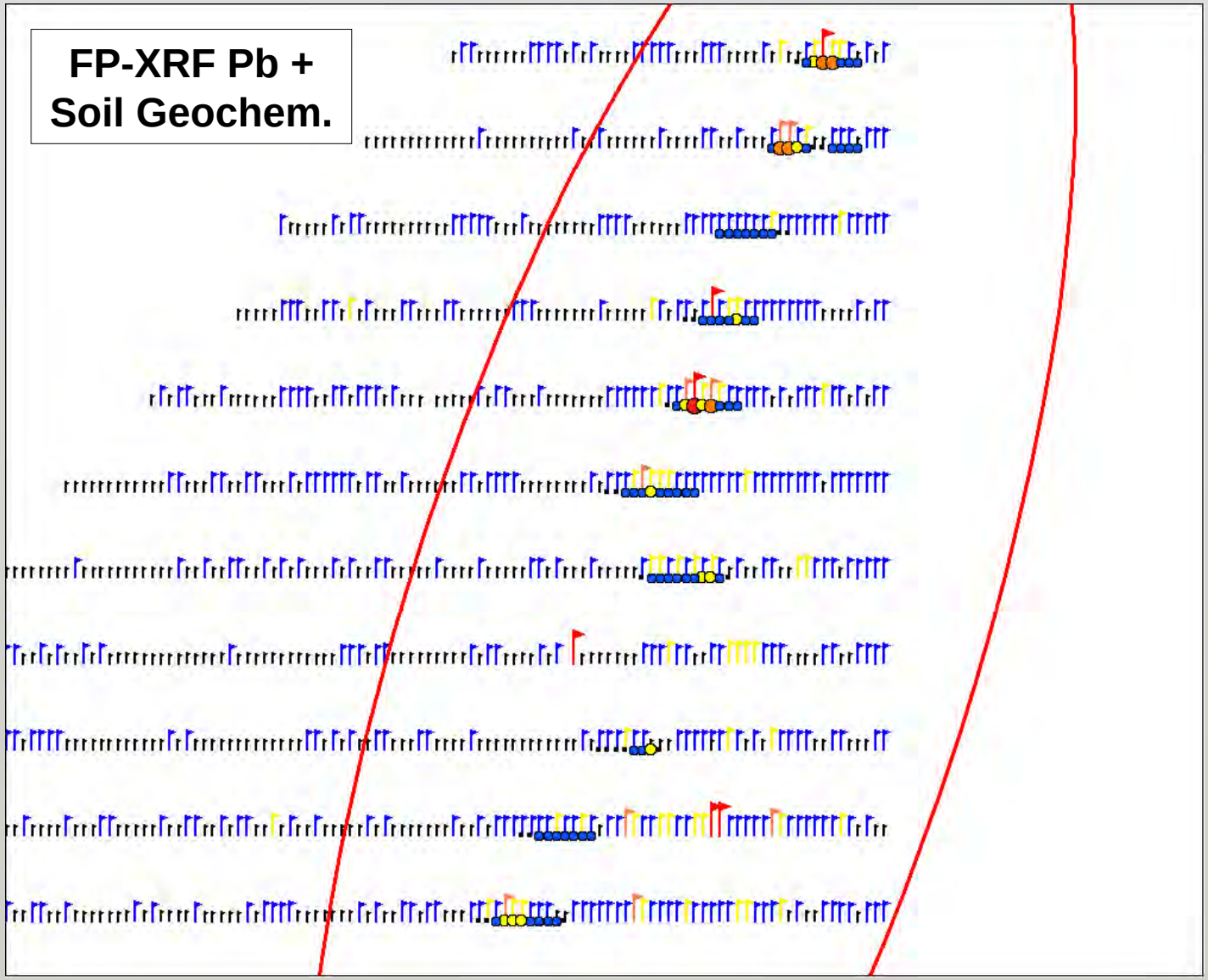


# Data Quality – Variability Over Time




Apollyon Valley Traverse - 6,482,800 N
Apollyon Valley Traverse - 6,486,000 N
Soil Pb
Niton Pb
Soil Zn
Niton Zn
Soil As
Niton As
Soil Cu
Niton Cu
Parts per Million
Moderate anomaly detected in FP-XRF & soil analyses
Strong anomaly detected in FP-XRF analyses only
Easting (mE)
531800
531880
531960
532040
532120
532200
532280
532360
532400
532480
532560
532640
532720
532800
532880
532960
533040
533120
533200

# Data Quality – Comparison with Conventional Soil Geochemistry



# Statistical Analysis - Stratigraphy

| | Pb | Zn | Cu | As | Mn | *n* |
|---|---|---|---|---|---|---|
| **Pb** Bijerkerno Metasediments | 47 | 84 | 33 | 6.8 | 420 | 1201 |
| **Pc** Cartwright's Ck Metasediments | 56 | 94 | 41 | 10.2 | 446 | 1164 |
| **S** Sundown Group | 60 | 99 | 39 | 5.6 | 543 | 11017 |
| **Bh** Hores Gneiss | 80 | 117 | 39 | 5.3 | 647 | 2974 |
| **Bk** Silver King Formation | 58 | 134 | 84 | 10 | 741 | 834 |
| **Bf** Freyers Metasediments | 75 | 118 | 40 | 6.3 | 596 | 10167 |
| **Bp** Parnell Formation | 74 | 120 | 40 | 5.6 | 633 | 13927 |
| **Bs** Purnamoota Subgroup | 61 | 116 | 46 | 6.0 | 614 | 4899 |
| **Ba** Allendale Metasediments | 58 | 100 | 35 | 5.4 | 493 | 19167 |
| **Be** Ettlewood Calc-Silicate | 70 | 165 | 54 | 9.0 | 503 | 423 |
| **Tr** Rasp Ridge Gneiss | 64 | 107 | 41 | 4.2 | 563 | 1893 |
| **Th** Himalaya Formation | 45 | 78 | 30 | 3.8 | 410 | 4324 |
| **Tc** Cues Formation | 63 | 103 | 41 | 5.2 | 539 | 10773 |
| **Tt** Alders Tank Formation | 51 | 81 | 36 | 3.5 | 445 | 317 |
| **T** Thackaringa Group | 45 | 77 | 34 | 5.8 | 405 | 1213 |
| **Ta** Alma Gneiss | 57 | 95 | 39 | 3.3 | 441 | 2702 |
| **rm** Retrograde micaceous schist | 56 | 96 | 36 | 5.9 | 495 | 4171 |
| **All Samples** | **61** | **103** | **38** | **5.4** | **531** | **96113** |

Data presented are median values for each stratigraphic unit. Each point was assigned from the Broken Hill 1:100000 Stratigraphic Sheet

# Statistical Analysis - Stratigraphy

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# Statistical Analysis – Rock Types

## Simplified Rock Type Groups

| | |
|---|---|
| S | Psammite-rich units |
| M | Psammopelite-rich units |
| E | Pelite-rich units |
| SM | Psammite & psammopelite-rich units |
| SE | Psammite & pelite-rich units |
| EM | Psammopelite & pelite-rich units |
| F | Composite gneiss and migmatite |
| B | Quartzo-feldspathic gneisses |
| p | Pegmatite |
| L | Feldspar & quartz-rich rocks +/- pegmatite |
| Pl | Plagioclase & quartz-rich rocks |
| a | Amphibolites and basic granulites |
| c | Calc-silicate rocks |
| q | Massive quartz and/or quartz-rich rocks |
| qg | Quartz-gahnite rocks |
| gq | Garnet-rich rocks |
| t | Tourmaline-rich rocks |
| r | Retrograde rocks and/or schists |
| rm | Retrograde micaceous schists |
| G | Post folding granite intrusives |
| Cz | Cenozoic cover |

# Statistical Analysis – Rock Types

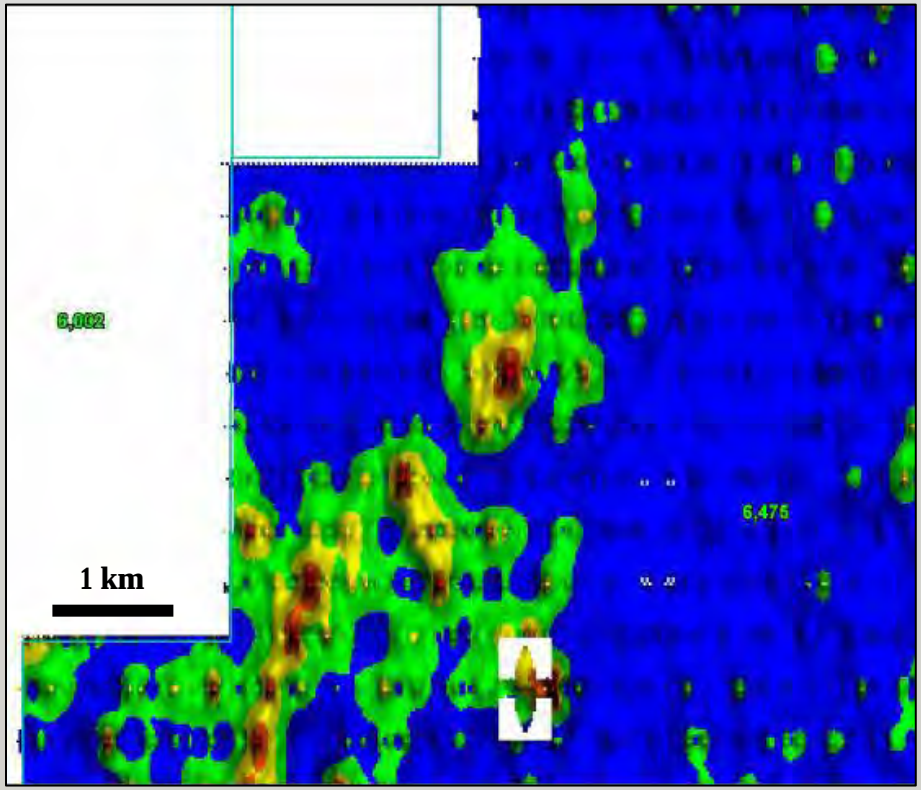
| | | Pb | As | Zn | Cu | Mn | Fe% | *n* |
|---|---|---|---|---|---|---|---|---|
| S | Psammite-rich units | 70 | 6.5 | 117 | 46 | 513 | 2.80 | 1222 |
| M | Psammopelite-rich units | 74 | 6.4 | 121 | 39 | 603 | 2.84 | 2276 |
| E | Pelite-rich units | 65 | 9.1 | 108 | 52 | 543 | 2.89 | 34 |
| SM | Psammite & psammopelite-rich units | 71 | 5.4 | 110 | 39 | 521 | 2.98 | 6901 |
| SE | Psammite & pelite-rich units | 61 | 5.2 | 94 | 33 | 514 | 2.81 | 1792 |
| EM | Psammopelite & pelite-rich units | 70 | 7.2 | 116 | 42 | 572 | 2.89 | 13301 |
| F | Composite gneiss and migmatite | 53 | 5.3 | 89 | 34 | 431 | 2.87 | 3077 |
| B | Quartzo-feldspathic gneisses | 78 | 4.4 | 121 | 41 | 589 | 2.77 | 3745 |
| p | Pegmatite | 59 | 5.9 | 106 | 46 | 485 | 2.61 | 4404 |
| L | Feldspar & quartz-rich rocks +/- pegmatite | 76 | 5.9 | 115 | 36 | 470 | 2.37 | 6339 |
| Pl | Plagioclase & quartz-rich rocks | 46 | 3.4 | 74 | 29 | 369 | 2.50 | 964 |
| a | Amphibolites and basic granulites | 73 | 7.0 | 136 | 53 | 782 | 3.65 | 3466 |
| c | Calc-silicate rocks | 73 | **10.0** | **158** | **53** | 555 | 2.87 | 125 |
| q | Massive quartz and/or quartz-rich rocks | **85** | 5.3 | **125** | 46 | 493 | **3.06** | 147 |
| qg | Quartz-gahnite rocks | **117** | **8.4** | **196** | 42 | **708** | **3.08** | 106 |
| gq | Garnet-rich rocks | **94** | **8.0** | **158** | **61** | **638** | **3.71** | 37 |
| rm | Retrograde micaceous schists | 72 | 6.4 | 116 | 39 | 558 | 2.99 | 4172 |
| G | Post folding granite intrusives | 54 | 4.8 | 83 | 31 | 421 | 2.57 | 892 |
| Cz | Cenozoic cover | 51 | 4.7 | 93 | 37 | 526 | 2.57 | 42939 |
| | **All Rock Types** | **61** | **5.5** | **104** | **39** | **535** | **2.72** | **95939** |

Data presented are median values for each rock type. Each point was assigned from the appropriate 1:25000 Geology Sheet

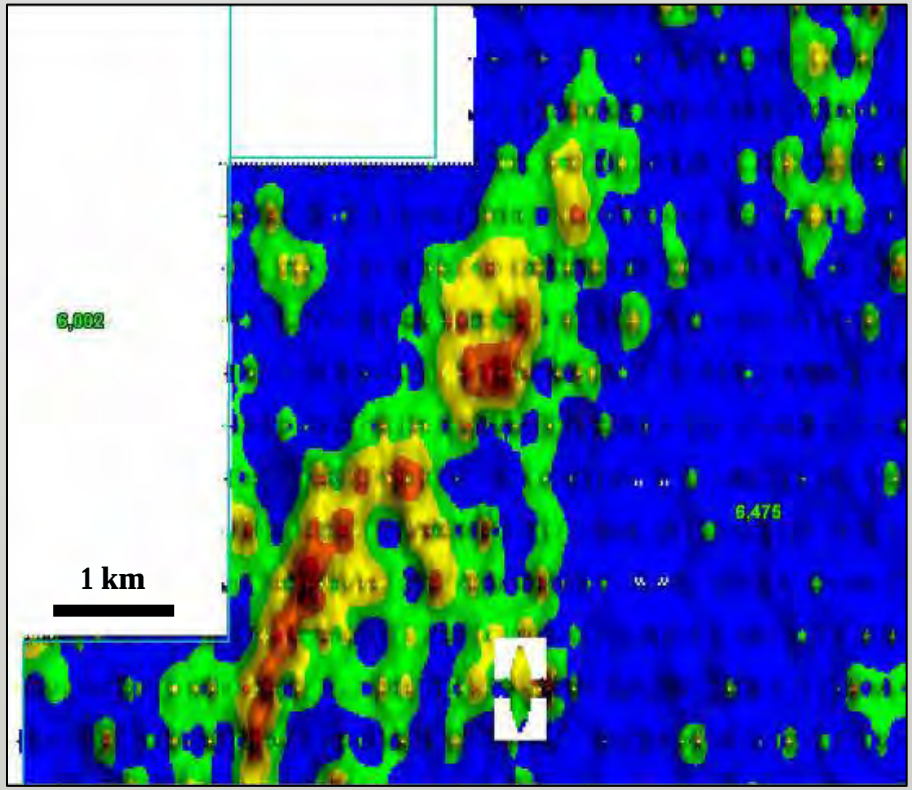
# Regional Scale Data Treatment and Presentation

- To avoid biasing statistical analyses and creation of “false” anomalies, all infill was removed to produce a regular 40 x 400 or 20 x 200m grid
- Multiple normalisation regimes have been trialled, including to stratigraphy, rock type, cover *vs* outcrop and Mn and Fe concentrations
- Data density allows production of high contrast contour plots for each element
- Additive ratio plots are useful for displaying major anomalies and structural features of the dataset
- Ratio of Zn + 2Pb + 10As found to be particularly useful

# Normalisation to Rock Type




Raw Pb+Zn Data

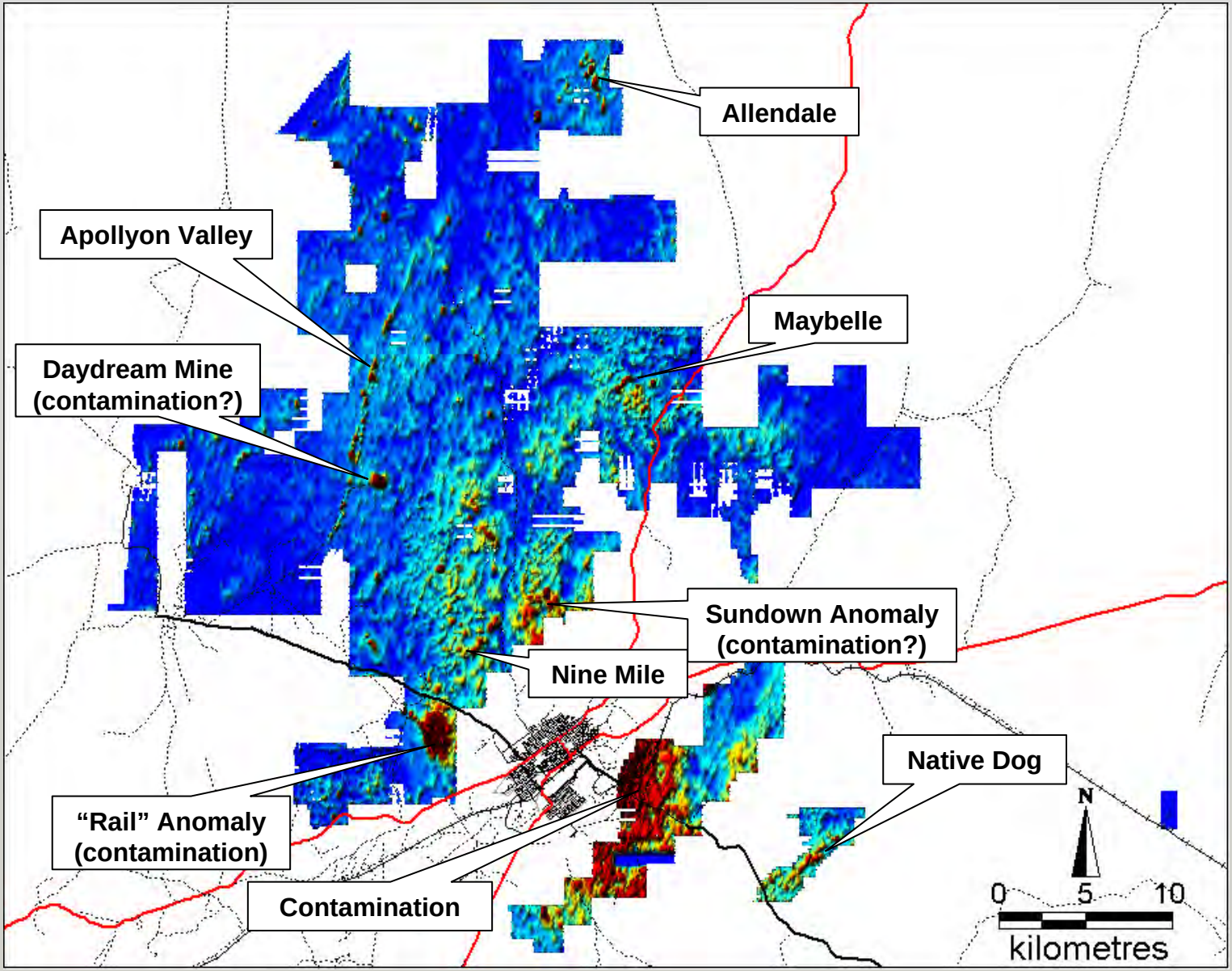



Rock Type Normalised
Pb+Zn Data

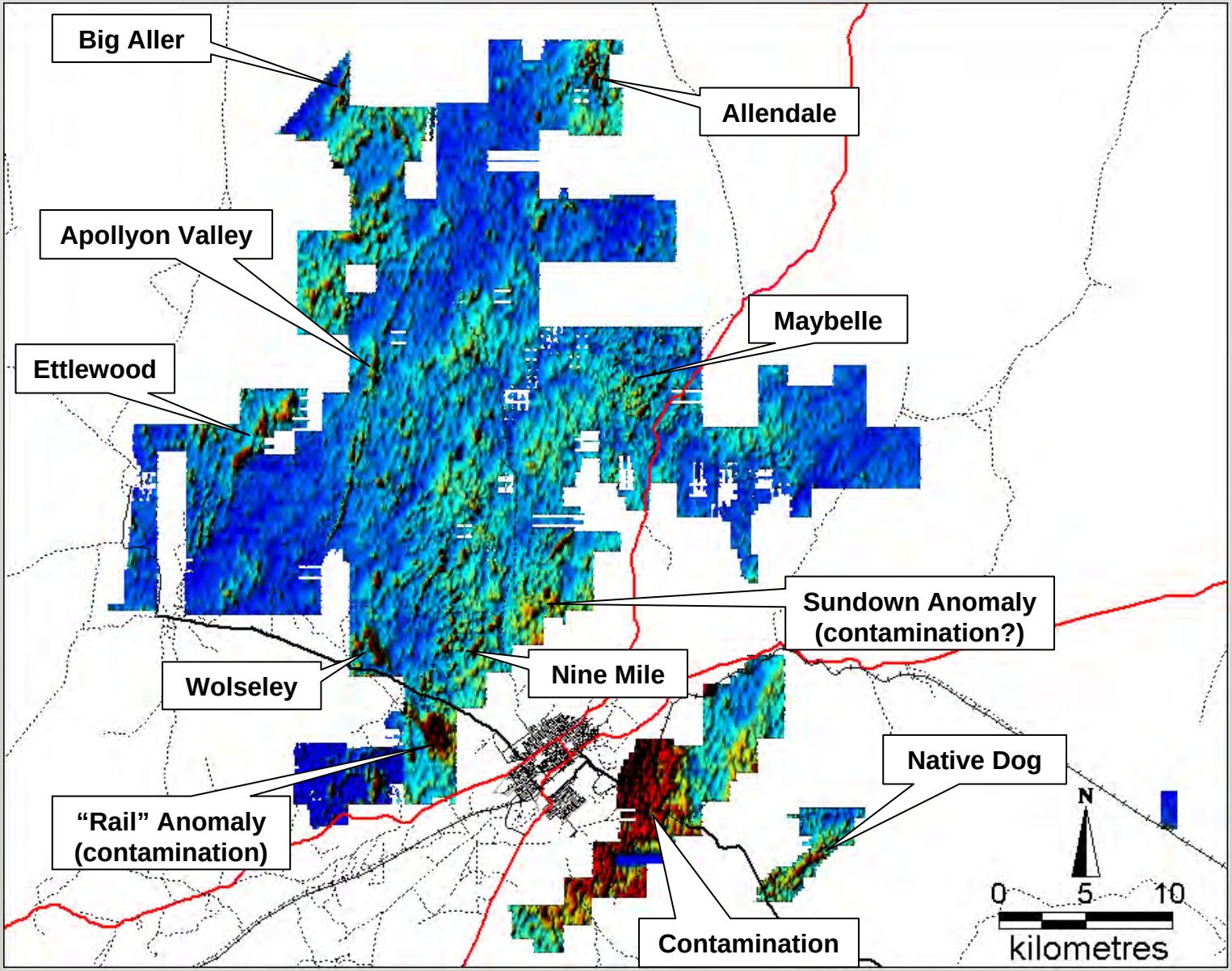
# Anthropogenic Features in the Dataset

- Contamination from historic mining activities form the largest anomalies in the CBH dataset for Pb, Zn, Mn and As
- Biggest anomalies in the dataset to the east and southeast of the Line of Lode; probably due to prevailing wind direction
- Highest values closest to Broken Hill; median values >600ppm for Pb and >1000ppm for Zn.
- Strong circular feature (“rail” anomaly) 2 km west of Broken Hill also due historic ore treatment activities
- Using deeper soil samples may be solution in these areas – yet to be tested

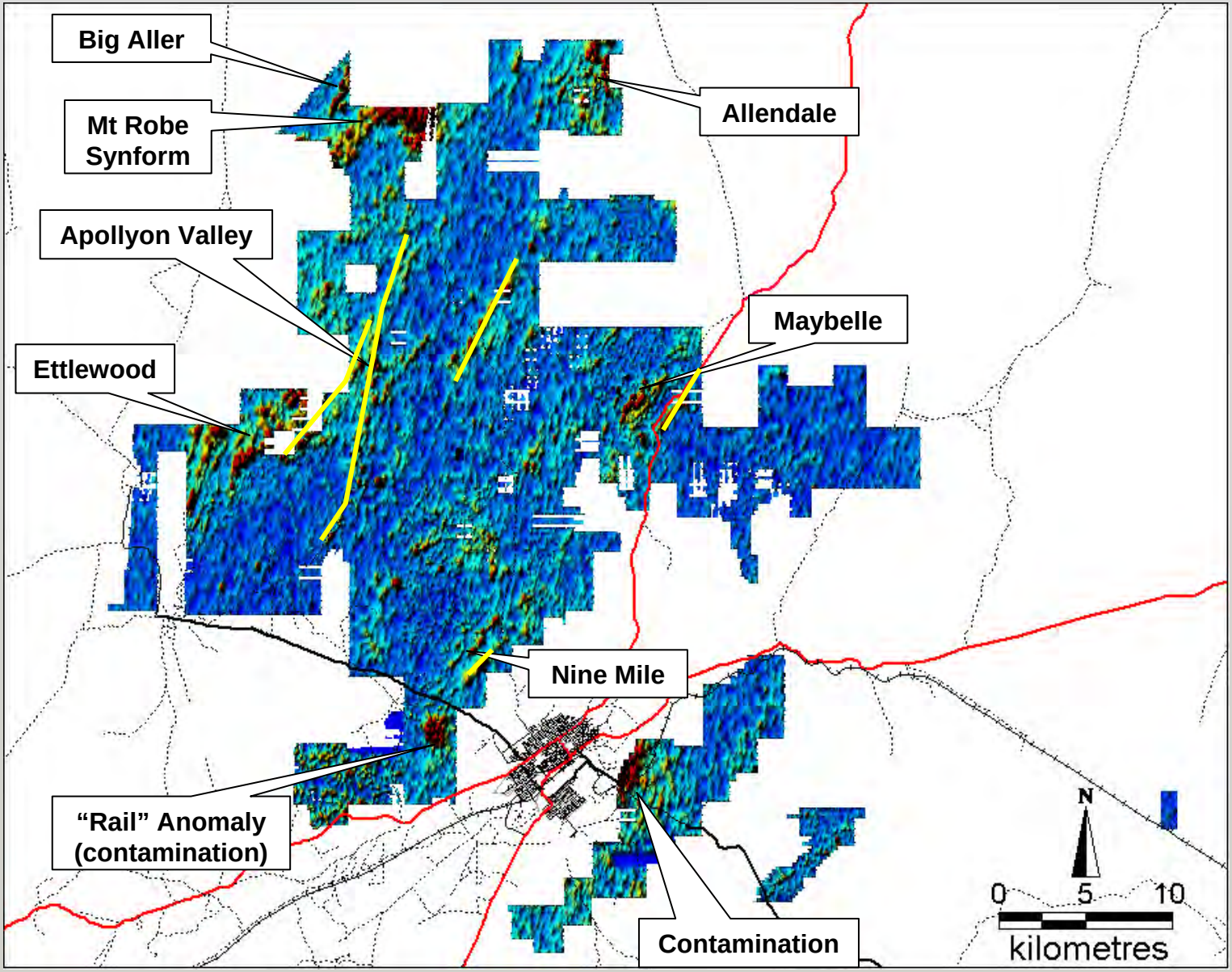
# FP-XRF Regional Scale Features - Pb



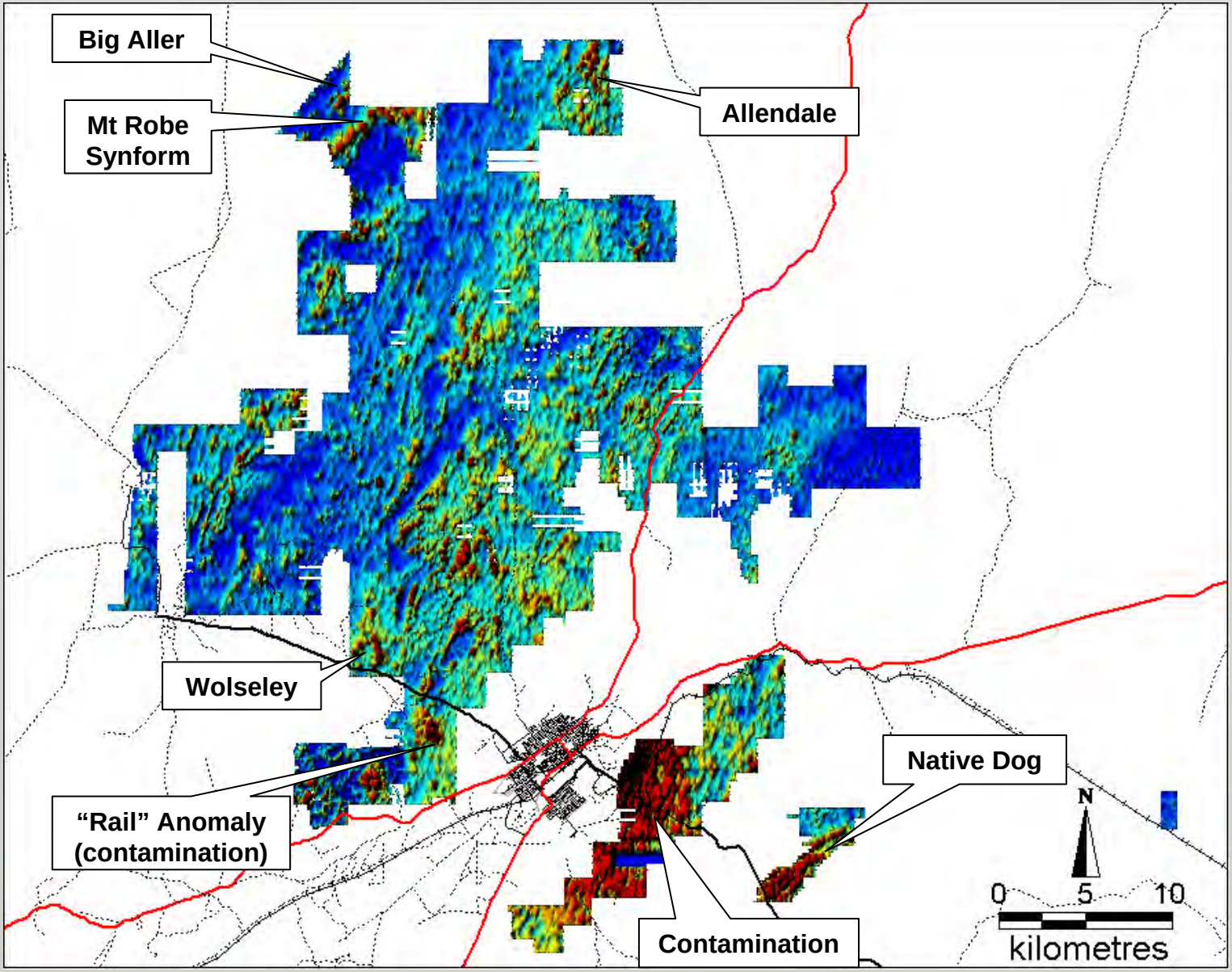
# FP-XRF Regional Scale Features - Zn



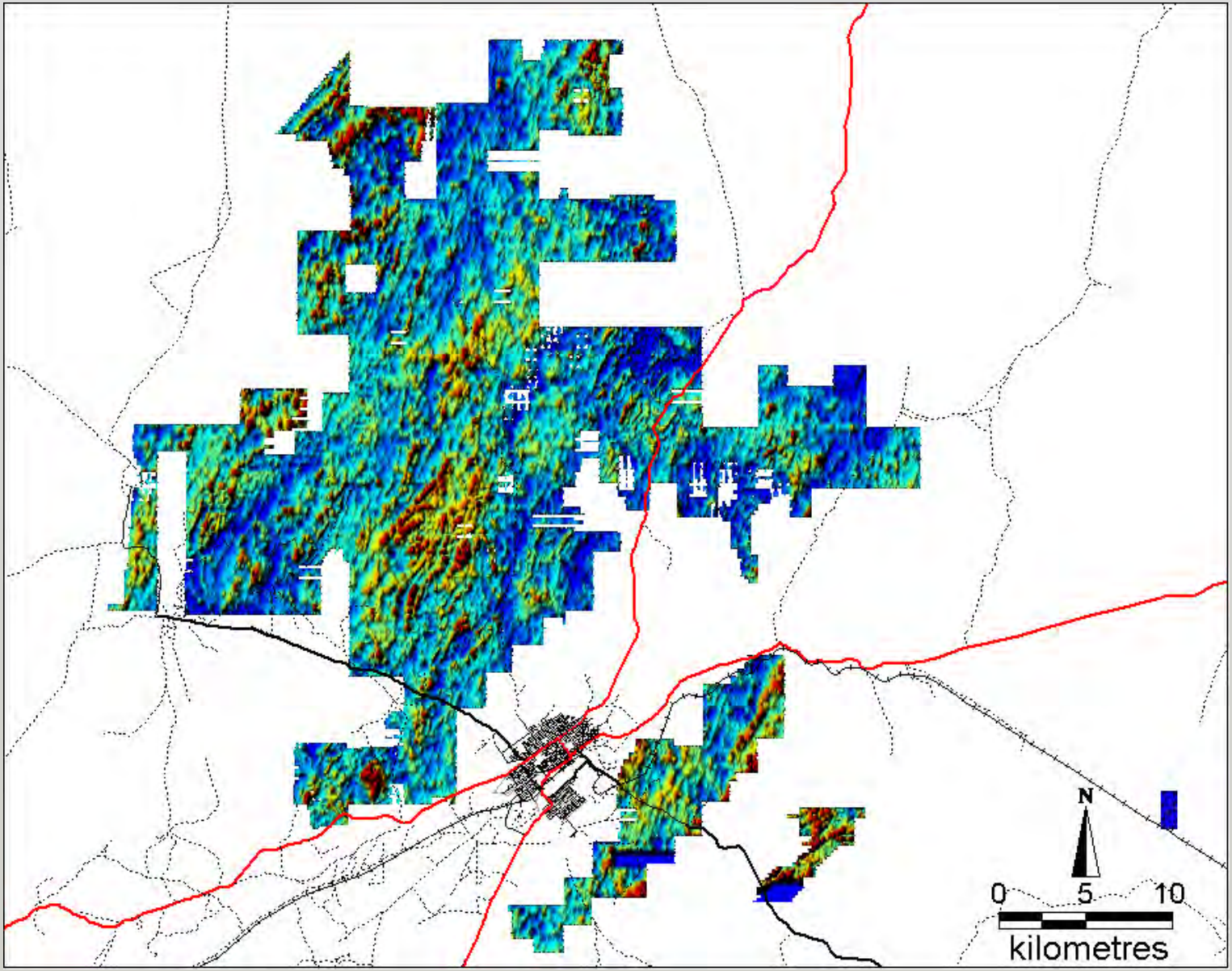
# FP-XRF Regional Scale Features - As



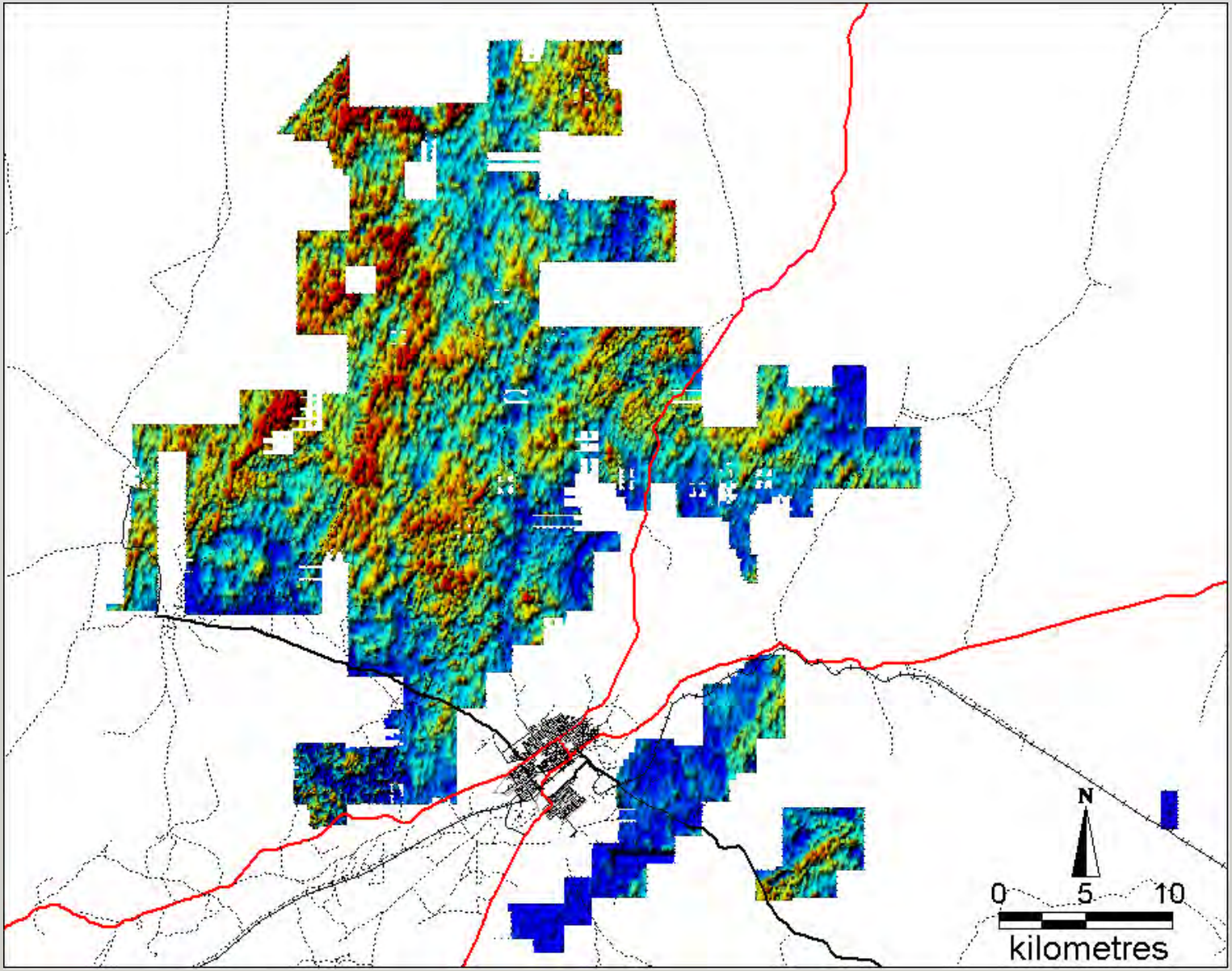
# FP-XRF Regional Scale Features - Mn



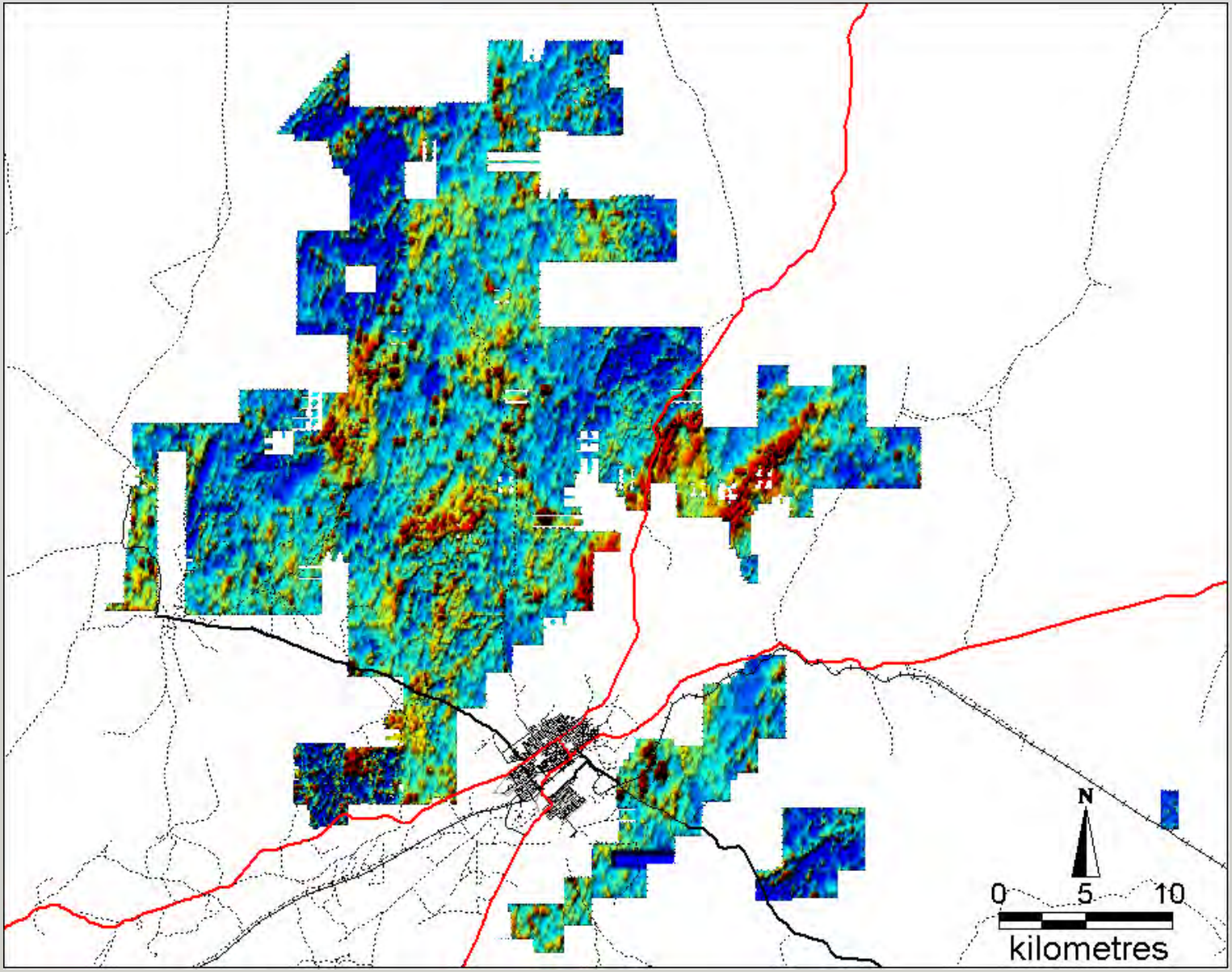
# FP-XRF Regional Scale Features - Fe



# FP-XRF Regional Scale Features - Rb



# FP-XRF Regional Scale Features - Sr



# Potential Further Work

- Integration of PEM and CBH datasets – potential for regional scale FP-XRF geochemistry maps
- Implementation / improvement of levelling and standardisation regimes to improve usability
- Study of regolith controls on FP-XRF responses
- Close-spaced orientation surveys, identification of characteristic responses for BH-type deposits
- Integration of FP-XRF datasets with other exploration data

# Acknowledgements


- CBH Resources Ltd, Perilya Limited and Silver City Mining Ltd (and their JV partners) are thanked for permission to present this work
- Much of this work is derived from Broken Hill Regional Assessment Program conducted by the former CBH Resources exploration team – in particular J. Brigden, G. Jones and J. Randell
- Brian Casey and his team in Broken Hill spent several years and walked immense distances collecting the data presented