Methods for exploration under cover, with emphasis on ionic leach surveys, Roberts Creek project as example

By M. Claiborne Newton, III

American Metals Exploration Corp.

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SLIDES with text

Figure 1. The Gold Bar Carlin-type gold deposits of McEwen Mining occur spread out in an arcuate geometry in and adjacent to the Roberts Mountains in Eureka County, Nevada. American Metals Exploration Corp.'s (**"AmMetEx"**) Roberts Creek Project lies under alluvium just off the range, on a gravity high that presumably extends the bedrock geology of the range into the basin. In pediment exploration, range geology should always be mapped and structures projected into the basin. In Figure 1 below, several mapped faults have been projected from the range that may intersect in the Roberts Creek project area. Additionally the central Gold Bar deposits in the range are in a thrust window exposing Devonian carbonate rocks surrounded by structurally higher upper-plate Vinini Formation. Such windows in Nevada are commonly eroded on structural highs and this one appears to be on a south-plunging anticline, the possible hinge line of which is shown as a green line in the following figures.

Figure 1

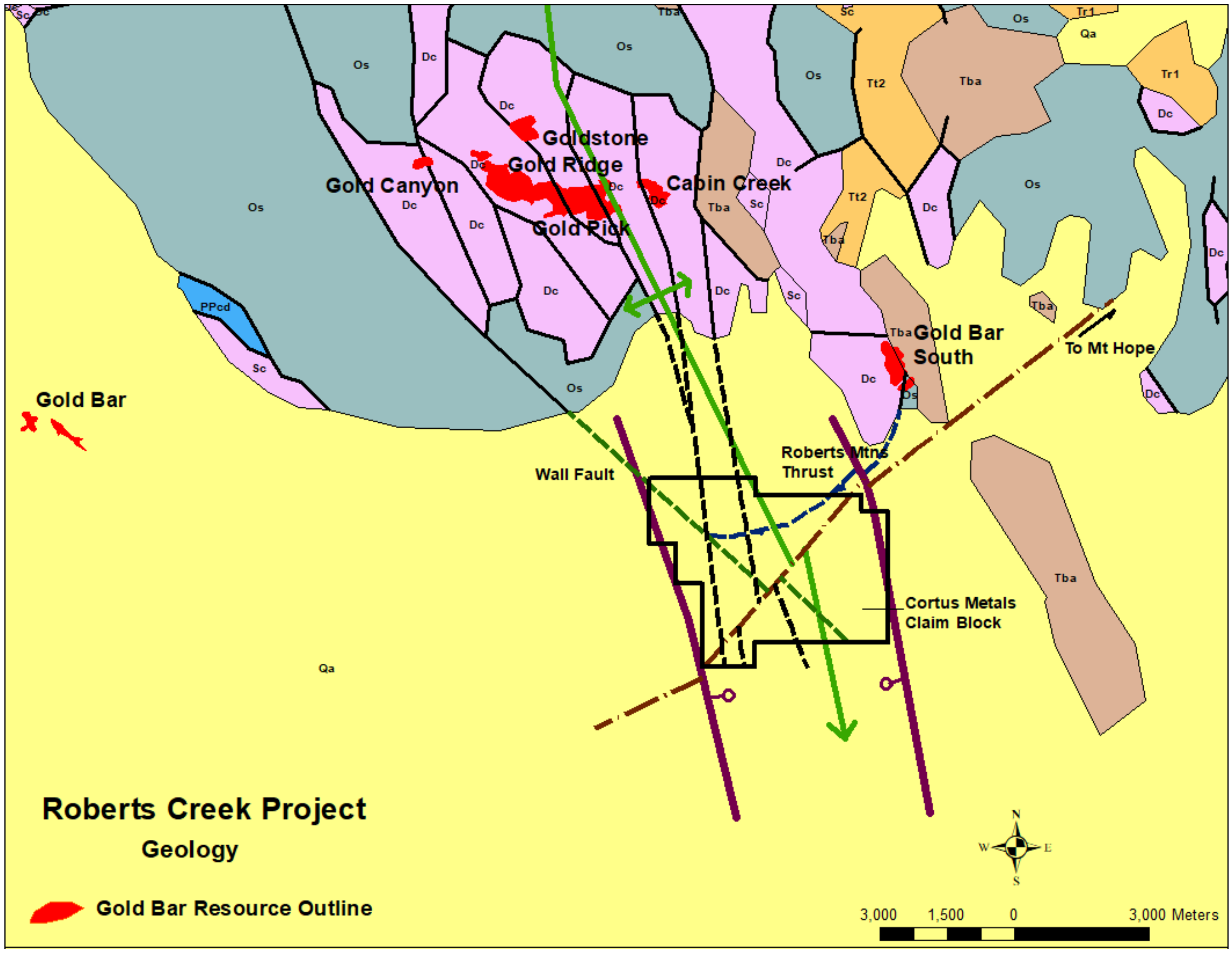


Figure 2. A possible analogue for the Roberts Creek project is the 20-million ounce gold Pipeline deposit. It is located at the intersection of 3 trends of faults under alluvium just off the range where Gold Acres is a satellite deposit. It is possible that the Gold Bar deposits are similarly small satellite deposits peripheral to a big deposit buried at the edge of the basin.

Figure 2.

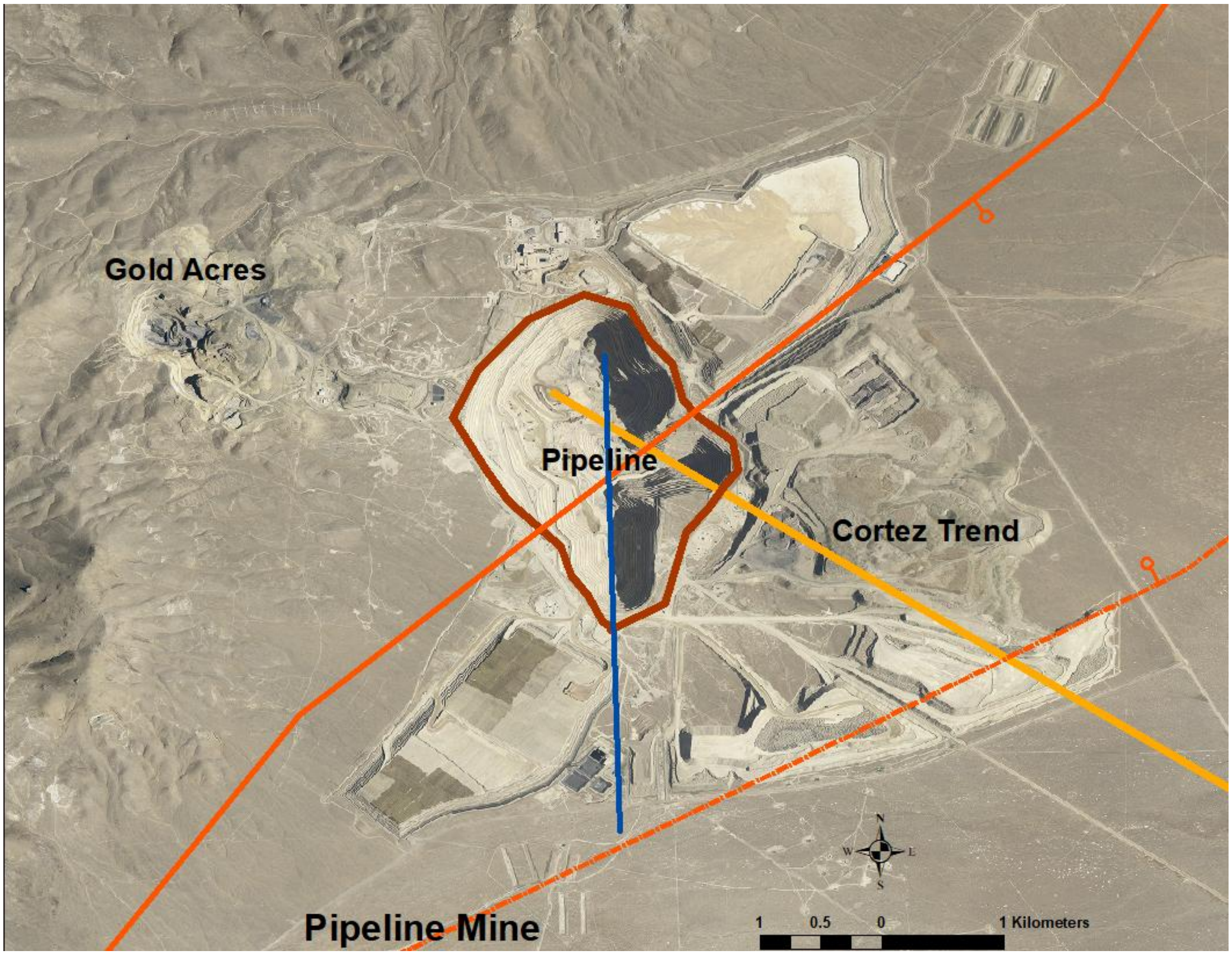


Figure 3. Several geophysiscal and geochemical techniques are important in basin exploration. AmMetEx routinely employs gravity, ground magnetic and ionic leach soil surveys over pediment targets. Detailed gravity surveying is essential to define the geometry of bedrock. In the detailed gravity survey shown in Figure 3 (red/pink higher gravity, blue lower gravity), a gravity high at the edge of the basin suggests the extension of range lithologies and structures beneath alluvium. The possible extent of the buried gravity is outlined in Figure 3 by the dot-dashed purple line. Additionally the gravity high has a central N-S trending low zone that suggests a trough, possibly an apical graben along the crest of the anticline, a common feature

in Nevada geology. In the figure, the outline of the Pipeline pit is shown “to scale” in brown, just to show how such a giant deposit could fit into this small space.

Figure 3.

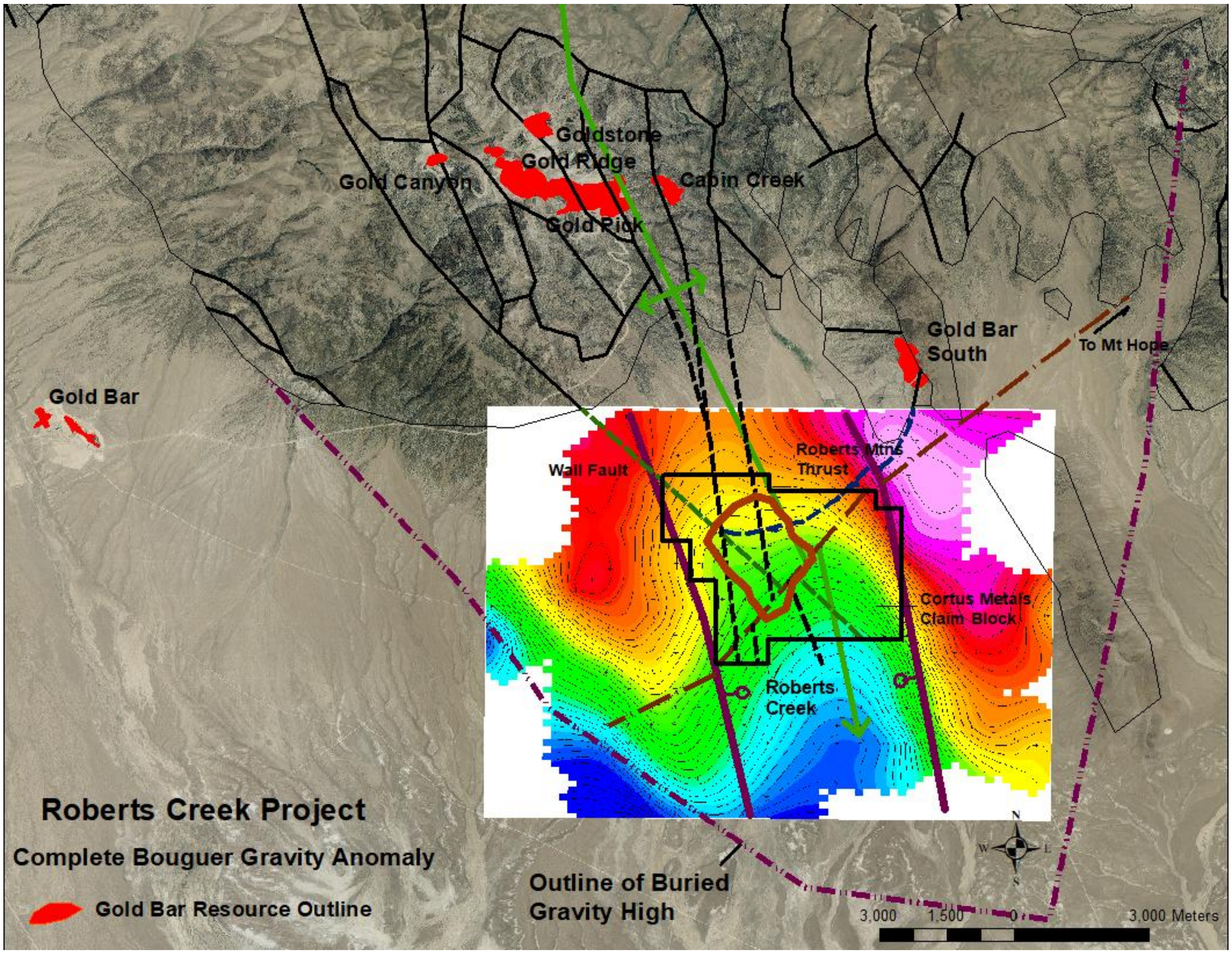
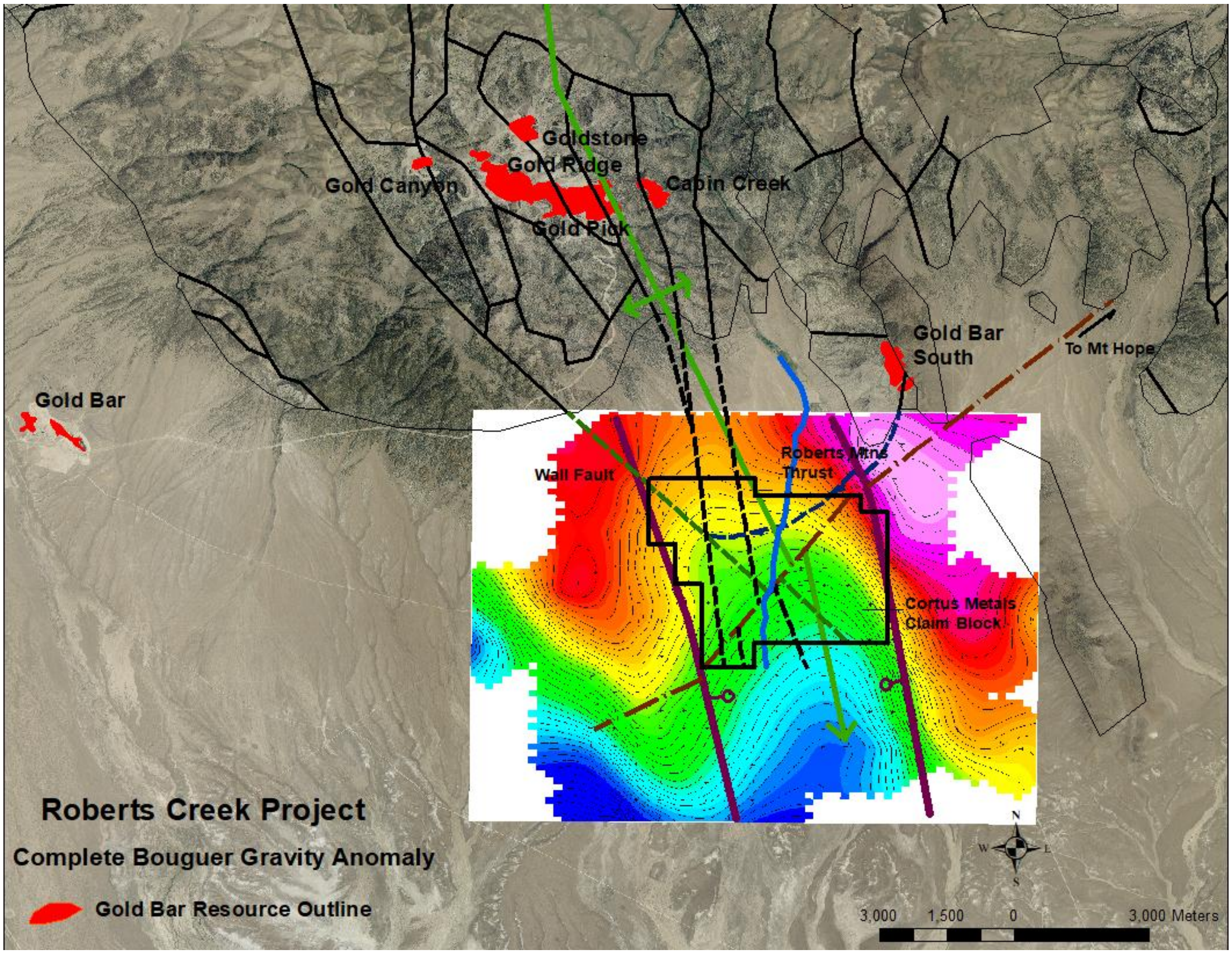


Figure 4 shows the previous slide with the current position of Roberts Creek as a blue line. This feature drains the Roberts Mountains where gold deposits have been exposed for 25 years, and is an important source of potential soil contamination at the Roberts Creek project that will be addressed below.

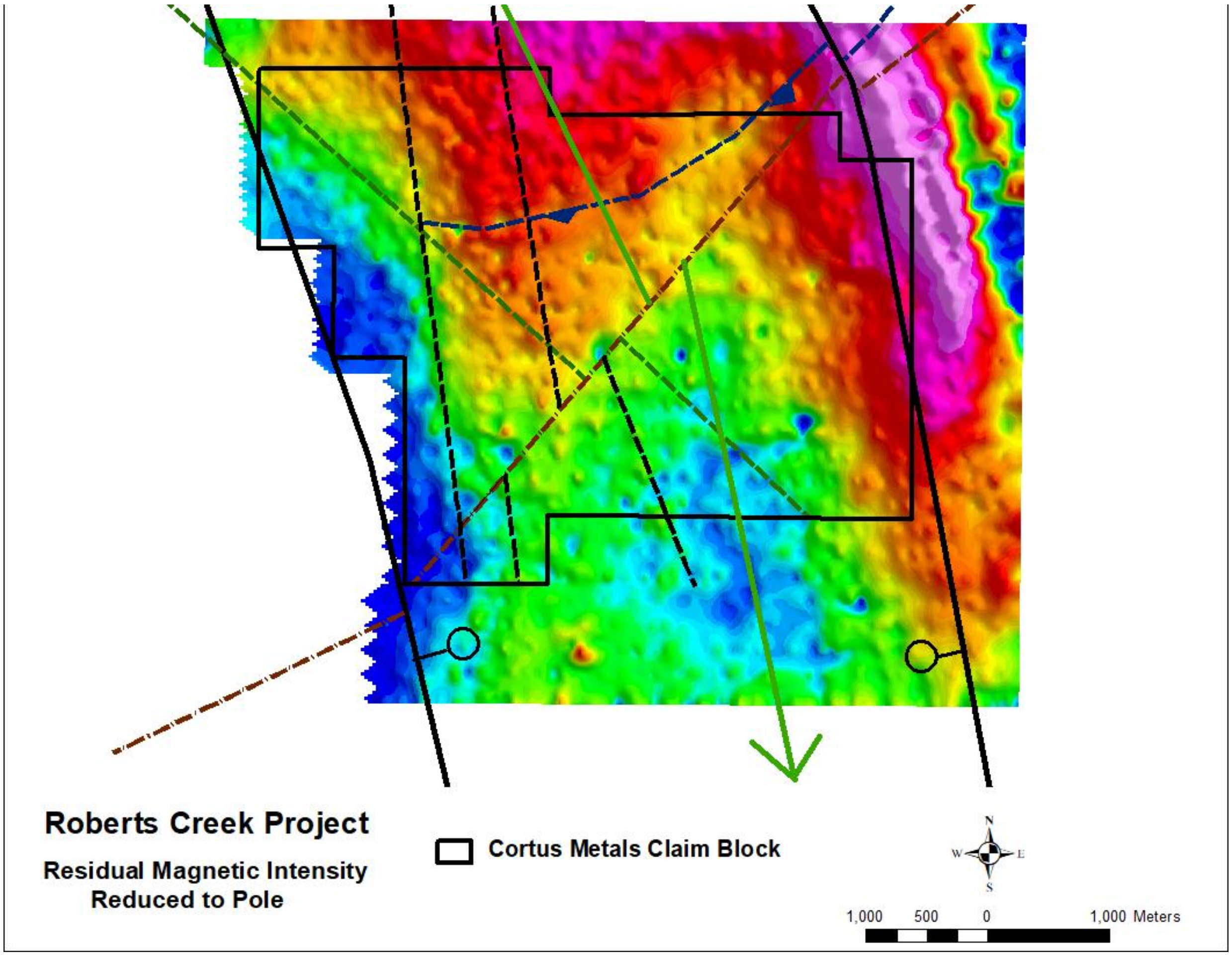
Figure 4.



Goldstone
Gold Ridge
Gold Canyon
Cabin Creek
Gold Pick
Gold Bar South
To Mt Hope
Gold Bar
Roberts Mine Thrust
Wall Fault
Cortus Metals Claim Block
Roberts Creek Project
Complete Bouguer Gravity Anomaly
Gold Bar Resource Outline
3,000 1,500 0 3,000 Meters

Figure 5. Figure 5 displays the results of a ground magnetic survey. The red/pink zones are probably volcanic rocks, dark blue zones may be non-magnetic bedrock such as carbonate rocks. Several linear structural trends that parallel projected fault trends are easily discernible.

Figure 5.



The rest of the talk will be concerned with the interpretation of ionic leach soil results at Roberts Creek. Soil surveying is another option to biogeochemical or ground water chemistry surveys that have been discussed earlier. A possible advantage of analyzing soils is that the soils may have been evolving in-place for thousands of years collecting rising ions, whereas the period of accumulation over a point source is far less for the life-cycle of plants or for moving groundwater. Ionic leach, offered by ALS, is just one of several weak leach methodologies available, including MMI and Enzyme Leach. The theory of the weak leach techniques is that the very weak reagents used only strip off ions adsorbed onto the outside of soil grains, so that the substrate which would represent the original rock which came from somewhere on the range, is not leached. In theory, the elements derived from buried mineralization rose to the surface by mechanisms such as vapor phase ascent, capillarity, evapotranspiration and fluctuating groundwater tables. In the arid environment, evapotranspiration is probably the most important mechanism. Sampling techniques vary widely, from surface shovels to deep holes, and sometimes extraction of the sample with plastic tools to minimize metal contamination. The reality of sampling in rocky or caliche-rich soil however is that big metal tools wielded by strong people are the best bet. AmMetEx digs down to below the root zone to where there is a change in soil color and degree of induration, because this is the top of the zone of strong evaporative precipitation. In the survey reported here, 500 soil samples were taken at 400 foot intervals (~120 meters) along east-west lines 1,000 feet apart (~300 meters). It is important to get the samples into the lab as soon as possible to minimize loss of volatile elements, such as mercury and arsenic. It is also advantageous to take and submit all samples from a single survey period, for reasons such as vagaries of sample quality taken by different people and instrument drift common to ICP-MS labs. Data presented below were krigged and gridded, which is the best way to show the map patterns of interest. With gridding, outlier very-high values can obscure the visibility of lower abundance samples, and in such cases, AmMetEx uses a cap of around 2 standard deviations above the mean to enhance the visibility of lower values. Although screamer high values may be important, and definitely should be looked at, it is probably more important to see the patterns of anomalies, and for that purpose, presence rather than abundance is important.

Three types of anomalies possibly related to subsurface mineralization are recognized with ionic leach – halo, apical within halo and highs along faults. The other types of common anomalies are surface-related, such as stream deposition or contamination from mineralized material at the surface. Halo anomalies are a priority to recognize as they may outline a mineralized body at depth and concentric halos by different elements can sometimes be recognized, which can help in vectoring to the center of the hydrothermal system. An early theory for a halo anomaly was that the mineralized body was behaving as an electrochemical cell driving up ions along the edges where the positive and negative terminals of a battery would be. A more realistic idea is that a sulfide or weathering oxide/hydroxide mineralized body behaves much like a heap leach pile containing preg-robbing carbon. In such a heap, gold might be leached by cyanide and travel a few centimeters before it is snatched up again by a carbon molecule and never gets out of the pile. Similarly, metals in the probable low-pH local environment of a sulfide or weathering oxide/hydroxide ore body never move far. The only place they can escape is around the edges of the body, hence the overlying halo. Alteration elements, such as K and Tl, may behave the same way with clays or micas, etc. constantly retrapping them.

An apical anomaly within a halo is obviously important as a drill target as it might directly overly mineralization. But apical anomalies in weak leach soil surveys don't appear to be too common. An exception is over Carlin-type ore bodies where calcium-related elements such as strontium, derived by carbonate dissolution, may form highs within halos. Such elements may also form inner halos, in which case the best drill target is probably the window of low values inside the halo.

A third type of common anomaly is local highs along faults. Three elements in particular have been noted as forming high anomalies directly over faults – Fe, Zn (and its associate Cd) and Ba. These anomalies are due to water flowing up along the faults. This may also cause apical anomalies within halos.

One of the problems to overcome is differentiating possible subsurface-related anomalies from surface stream deposition. Figures 6, 7 and 8 show some elements (Au, Ag and Tl) that by their spatial association with the current position of Roberts Creek (bold blue line in center of map) are probably related to stream deposition. Multiple stream channels are shown as blue lines in the following figures. On the east side of the maps, it can be seen that Roberts Creek is actually a distributary stream system, much like the deltaic mouth of a river. The eastern half of the maps is essentially a flood plain of Roberts Creek. In contrast the west half of the maps is dominated by small tributary streams.

Figure 6.

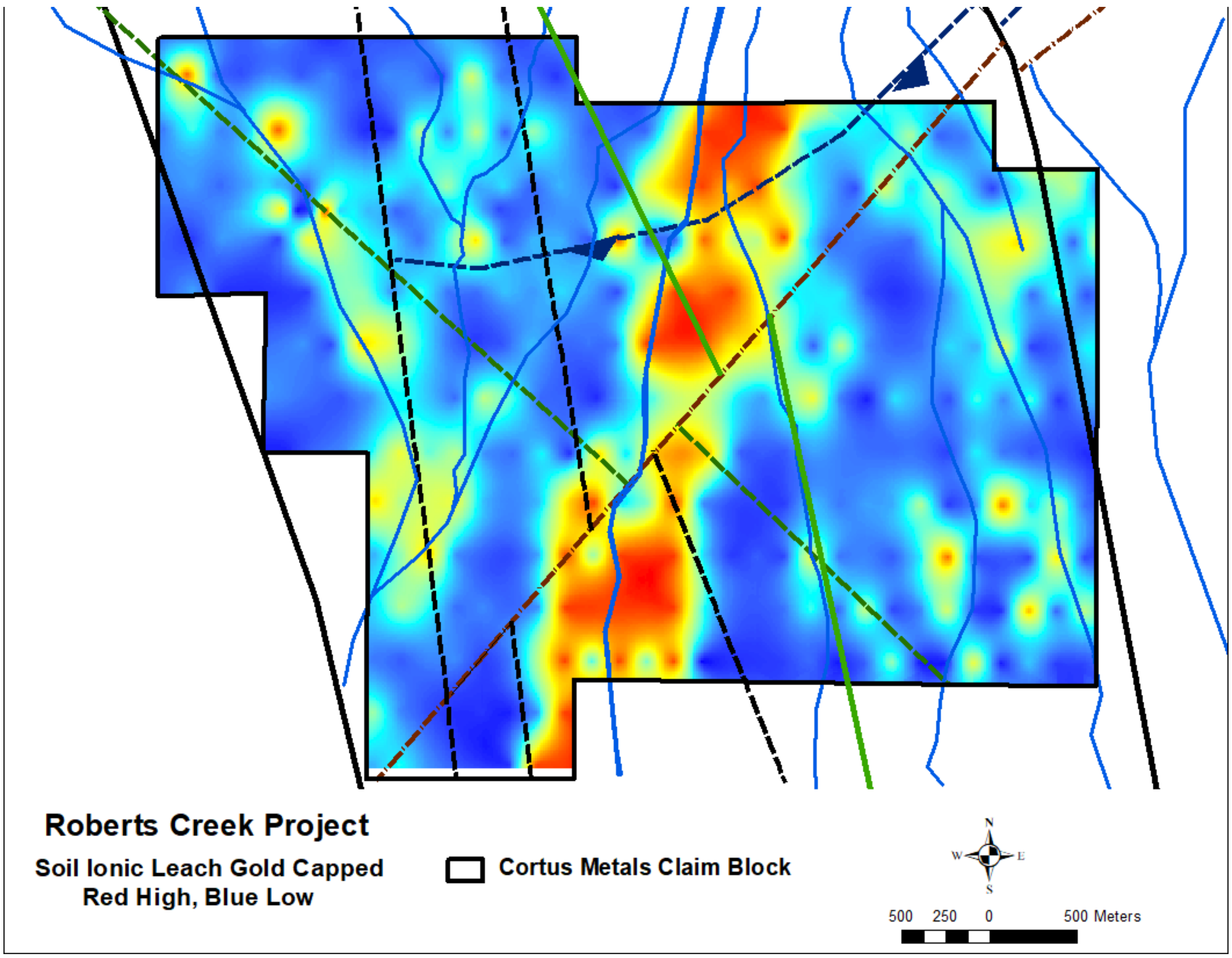


Figure 7.

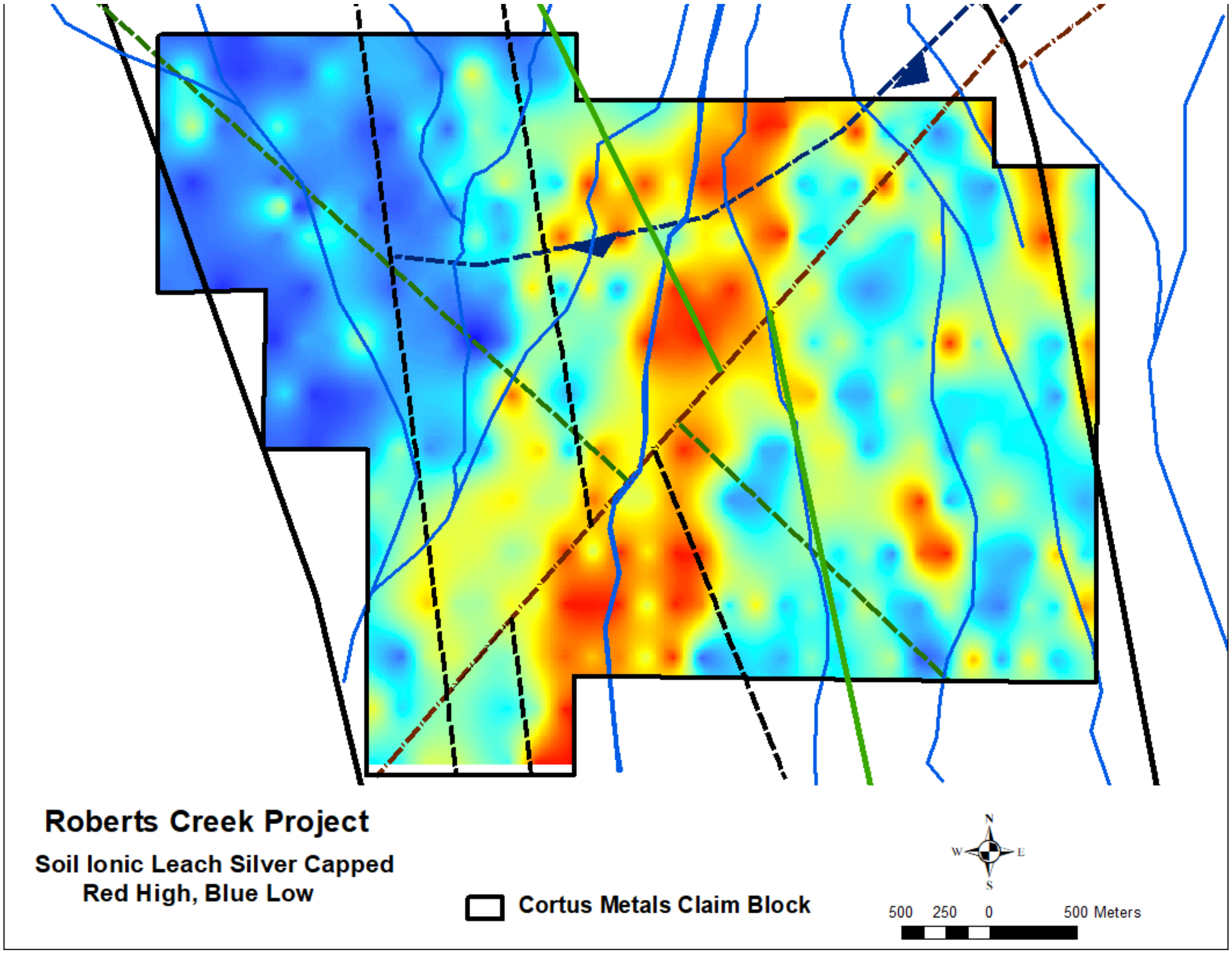
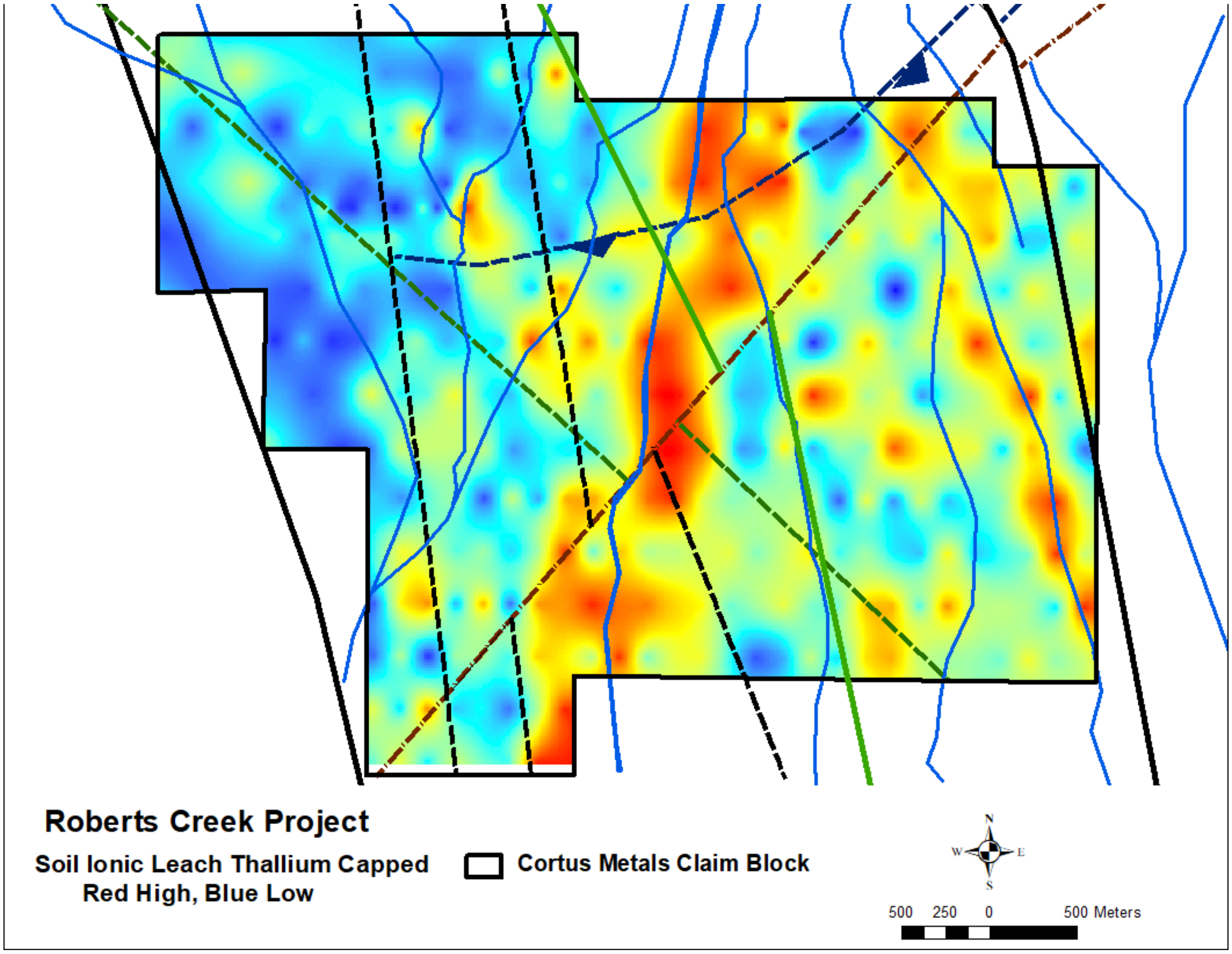

Roberts Creek Project
Soil Ionic Leach Silver Capped
Red High, Blue Low
Cortus Metals Claim Block
N
W
E
S
500
250
0
500 Meters

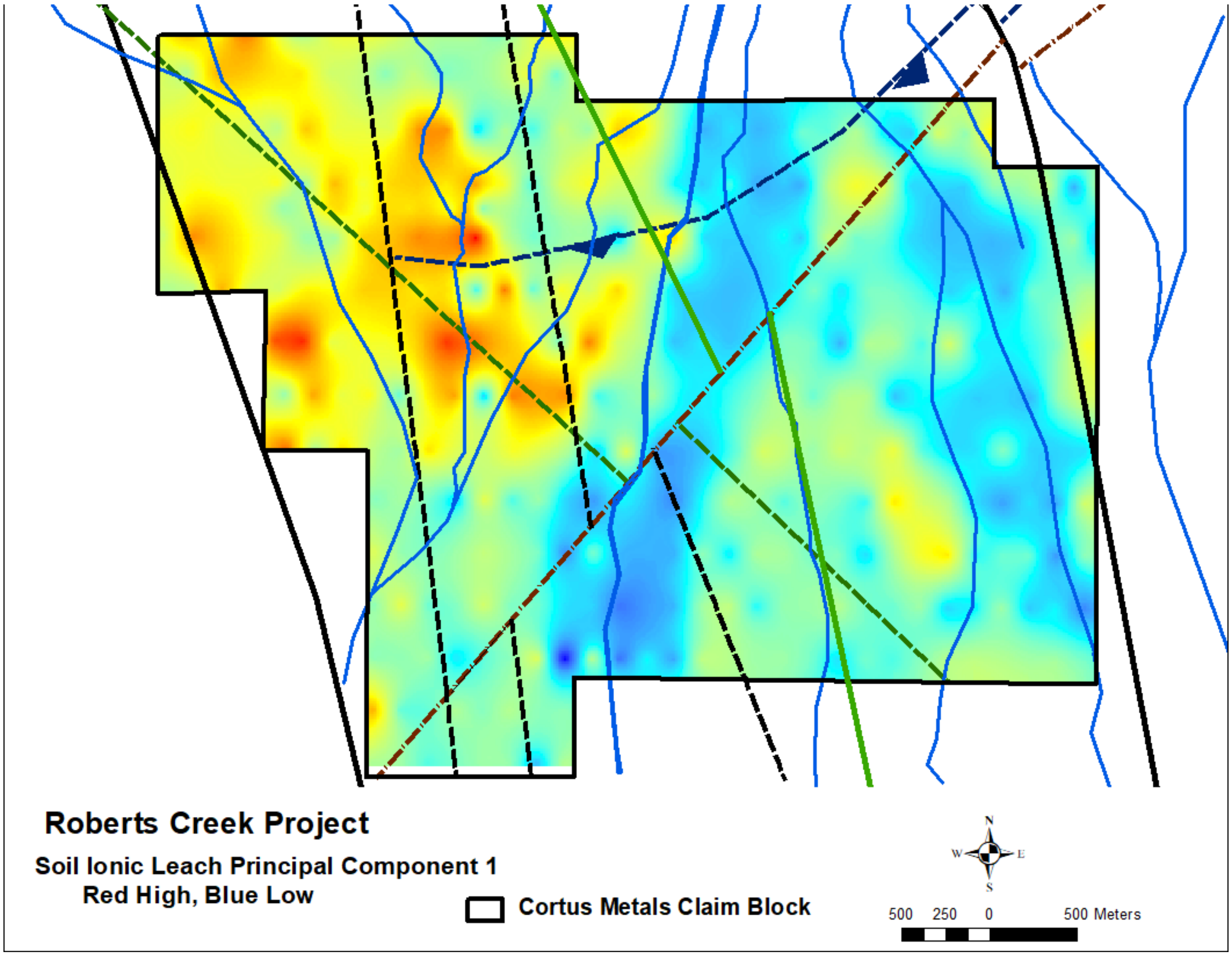
Figure 8.



So we found Roberts Creek with our soil survey. But that is not what we're looking for, and for those who tend to focus on drilling the gold-in-soil anomalies, it could be an expensive failure. That being said, of course the stream could be there because it was controlled by a mineralized fault which is forming the anomaly. How can we distinguish a valuable anomaly from one that is not?

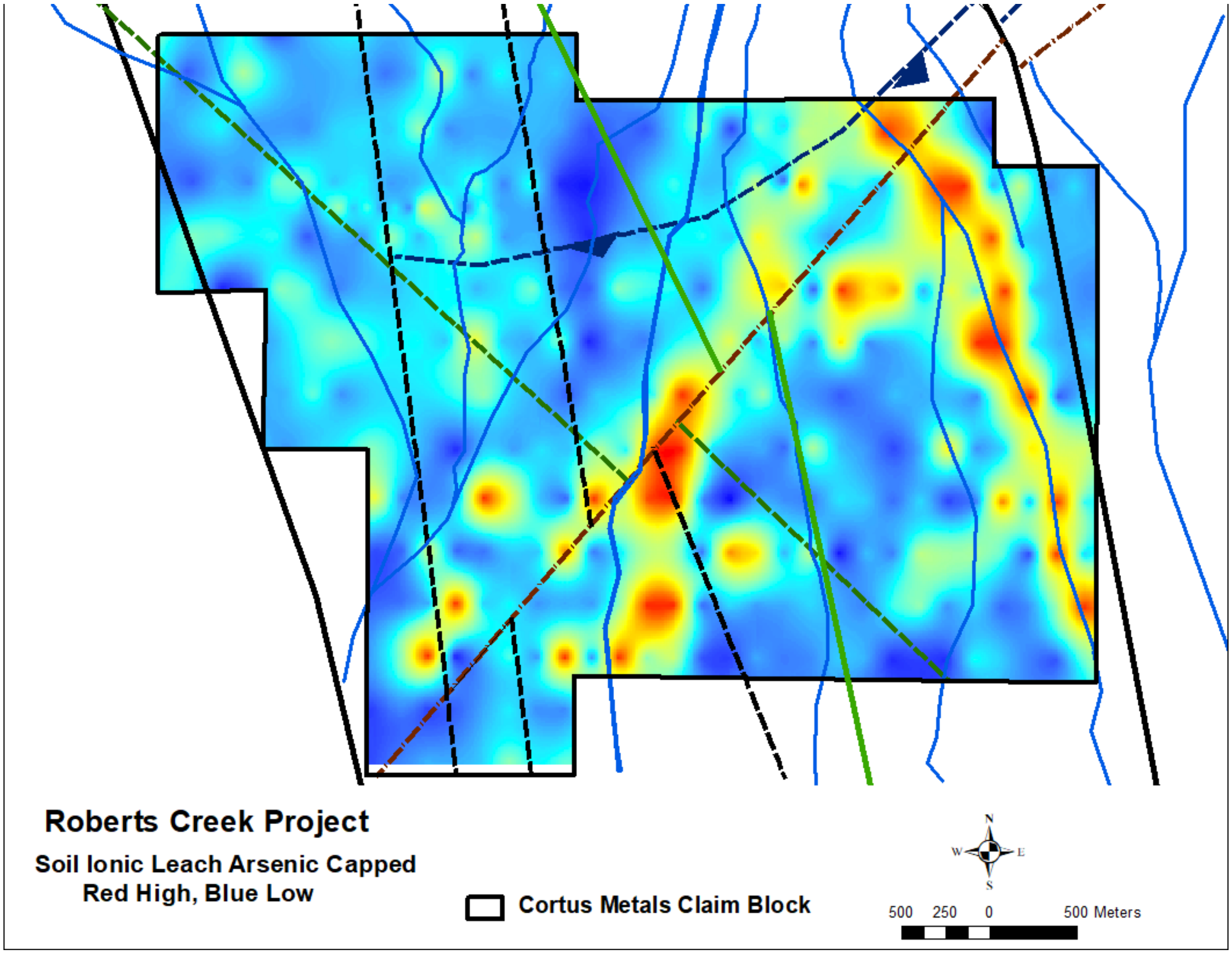
Principal component analysis is a method that helps with this. Principal component analysis is a multivariate technique where all elements (around 50 with ionic leach) are examined together to ascertain how suites of elements vary together. The correlations can be either positive or negative for a particular component. Each component defines a certain proportion of the cumulative variance and each element in each component is assigned a score indicating the strength of its correlation. In this dataset, principal component 1, shown in Figure 9, accounted for 40 % of the variance. Positively correlated elements included Ba, Cd, Fe, Ga, Ge, Li, Mn, Mo, Ni, Pb, Pd, Rb, REE, Sr, Th, U and Zn. Negatively correlated elements included Ag, As. Au, Br, Cs, Cu, Hg, I, Mg, Nb, Re, Sb, Se, Tl, V and W. In map view, it can be seen that the negatively correlated elements (blue-colored zones) are along stream drainages and concentrated on the east side of the map, in the flood plain. The northwest side of the map shows a zone of high (positively correlated values) seemingly unrelated to stream location. There are also zones of moderate lows (light blue colors) on both sides of the map, that are basically in interfluve areas as opposed to the deep blue colors along the streams. These moderate low zones are candidates for the holes of low values within halos.

Figure 9.



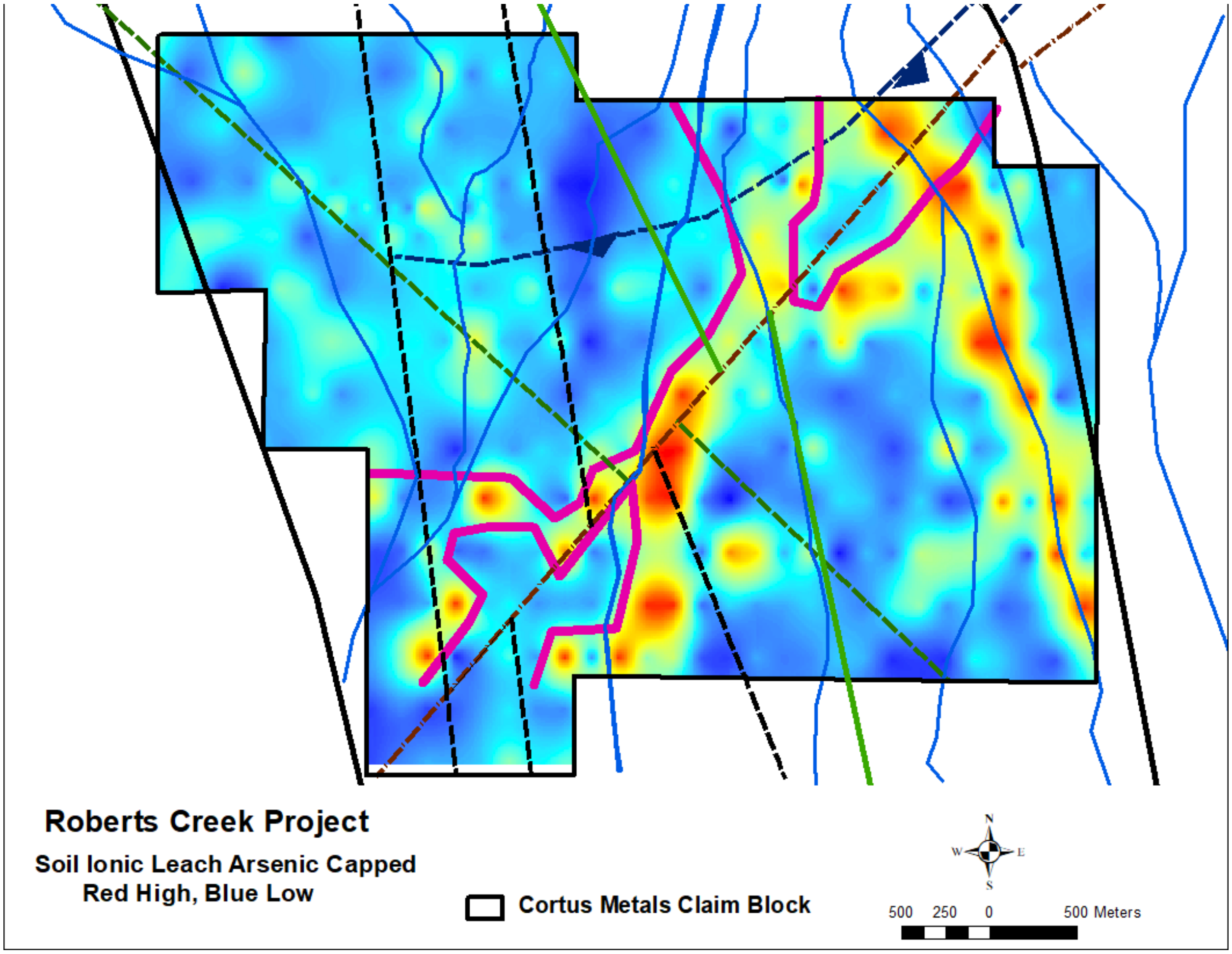
But some elements may be elevated both by stream deposition and subsurface ascension. Arsenic for example (Figure 10) is elevated along some stream segments but not all. And along the northeast-trending fault, it shows small halo anomalies with the low holes along the fault. The northwest side of the arsensic map is essentially devoid of arsenic and an arcuate border between the zones of high and low values can be drawn.

Figure 10.



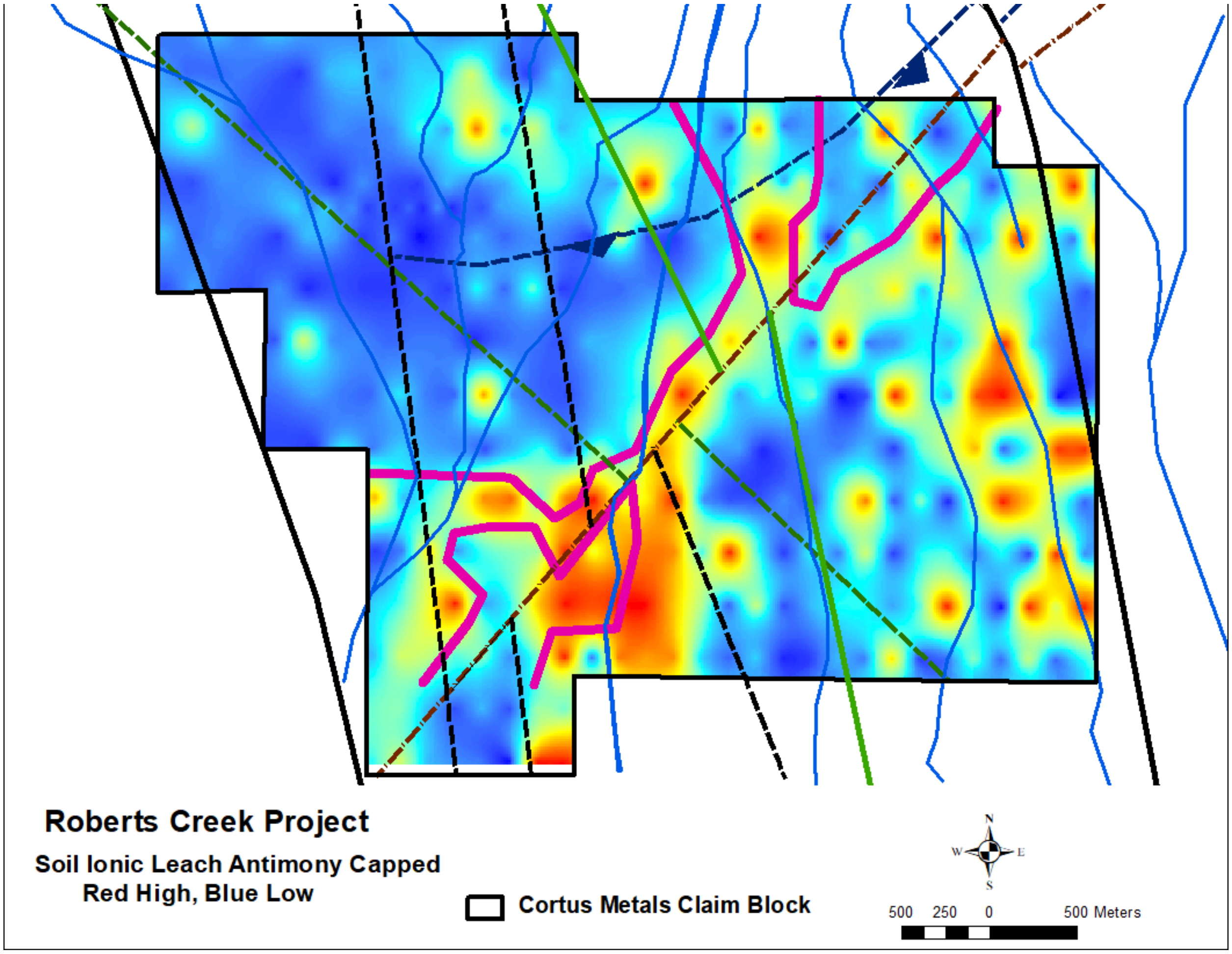
Roberts Creek Project
Soil Ionic Leach Arsenic Capped
Red High, Blue Low
Cortus Metals Claim Block
N
W
E
S
500 250 0 500 Meters

Figure 11.



Antimony shows a similar pattern to arsenic and Figure 12 displays antimony with outlines in pink from the arsenic anomalies. In the northeast-most anomaly, the stream cuts through the anomaly outline with high values right along the stream. In this case those high values are deemed related to the stream and are disregarded in outlining a possible subsurface anomaly.

Figure 12.



Among the elements making up the positive part of principal component 1, the two highest scoring elements are respectively Ge and Ga, statistically unrelated to stream deposition. These two elements are important indicators of hydrothermal alteration. Figure 13 is the periodic table showing the location of Ga and Ge. Gallium in an ionic leach survey is a proxy element for aluminum and germanium is a proxy for silicon. Gallium substitutes for aluminum in minerals like clays and micas, but it is much more mobile than aluminum. Its presence at the surface may indicate argillization at depth and germanium may indicate silicification.

Figure 13.

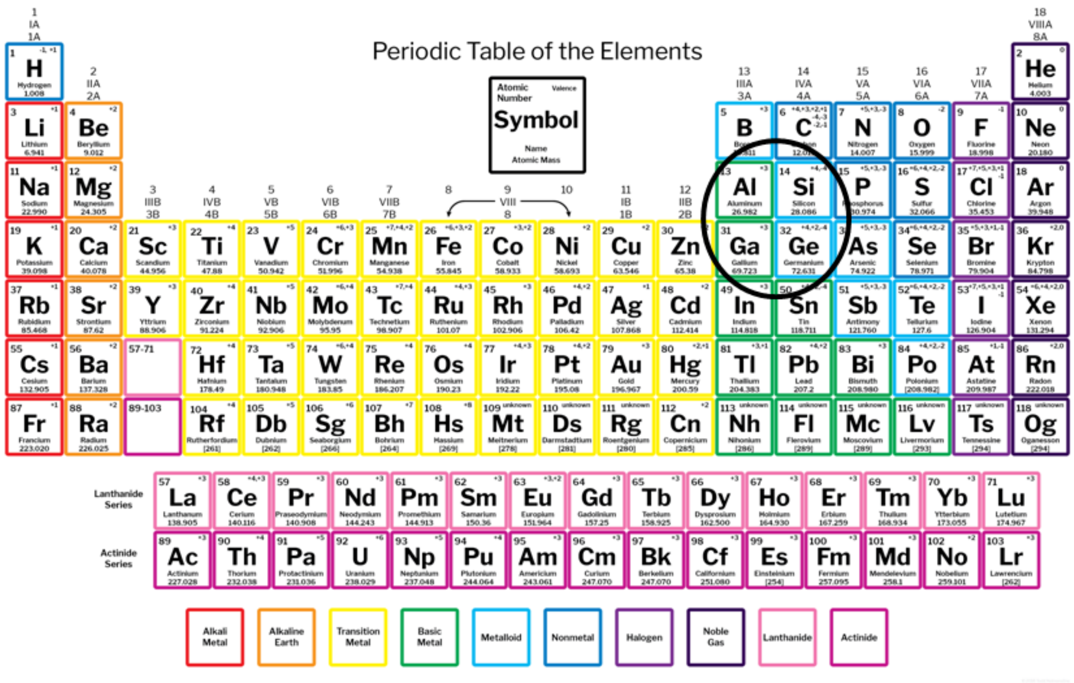
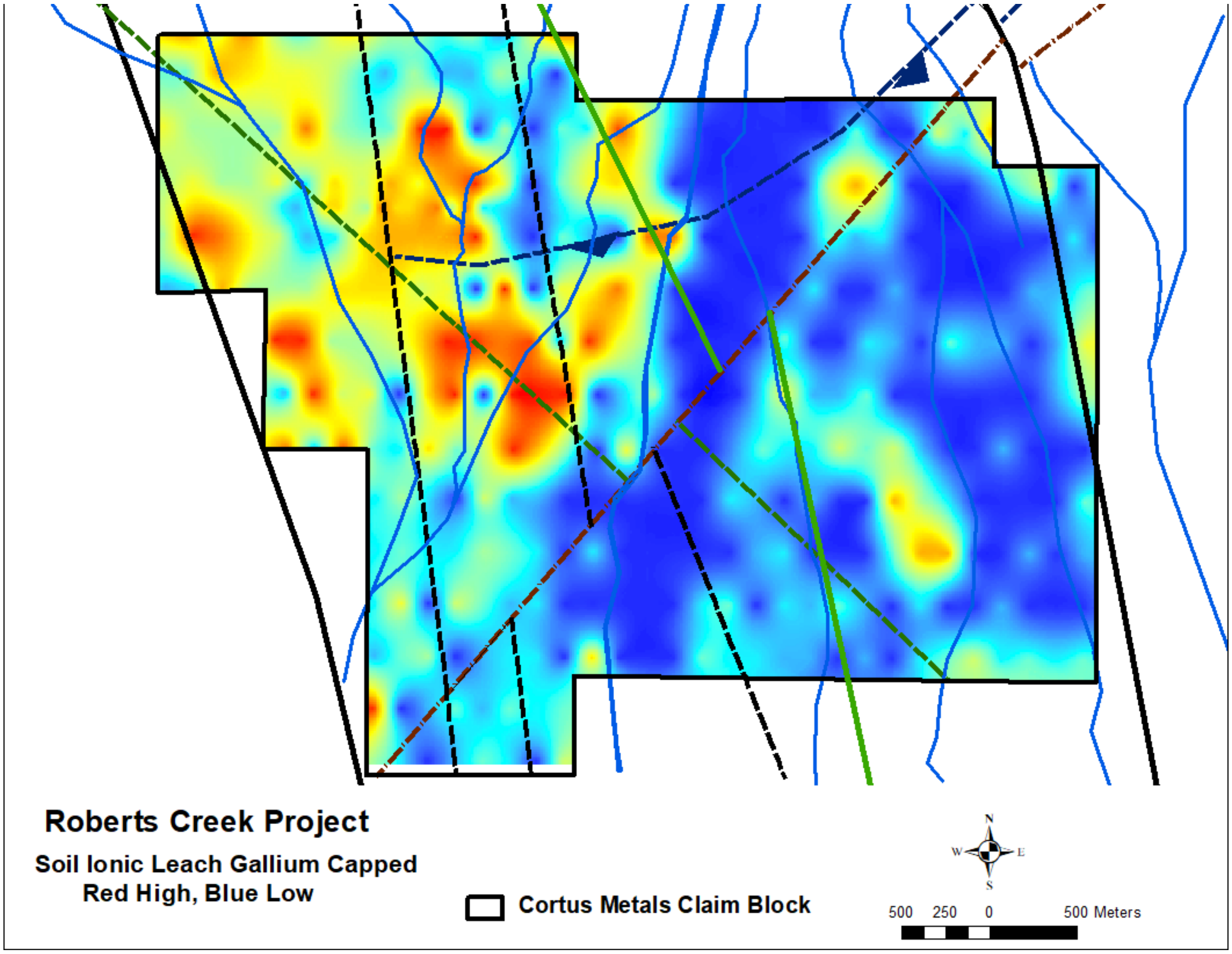


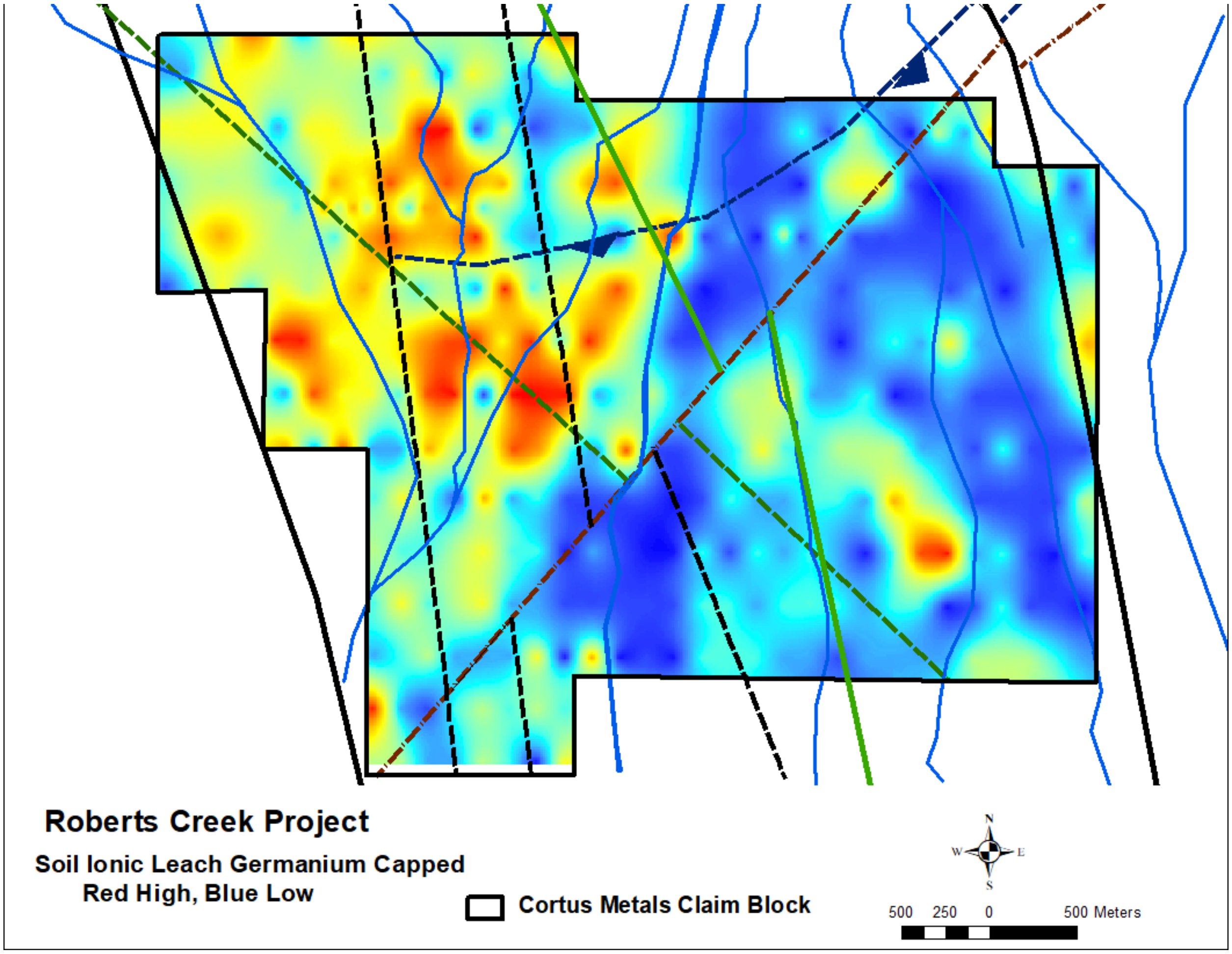
Figure 14 is a plot of gallium and figure 15 is a plot of germanium. Figure 16 is the Germanium plot with zones of Ge highs outlined in thick black lines, Ge lows outline in thinner brown lines and the arsenic halo outlines in pink. It can be seen that in the northwest corner of the map, Ge forms an inner halo to arsenic (and antimony). A similar germanium high zone could probably be outlined in the southeast part of the map but is obfuscated by lows in the proximity of streams. The low zones along streams may be due to the fact that germanium, and many other elements, form salts, which either didn't form or were flushed out due to abundant flowing fresh water. It is also important to note here that salts rather than Mn or Fe-oxide coatings may be a main scavenger of elements in the arid environment. Note also that the germanium and gallium windows in the northwest part of the map are in interfluve areas and would not likely be due to stream processes.

Figure 14.



Roberts Creek Project
Soil Ionic Leach Gallium Capped
Red High, Blue Low
Cortus Metals Claim Block
N
W
E
S
500 250 0 500 Meters

Figure 15.



Roberts Creek Project
Soil Ionic Leach Germanium Capped
Red High, Blue Low
Cortus Metals Claim Block
N
W
E
S
500 250 0 500 Meters

Figure 16.

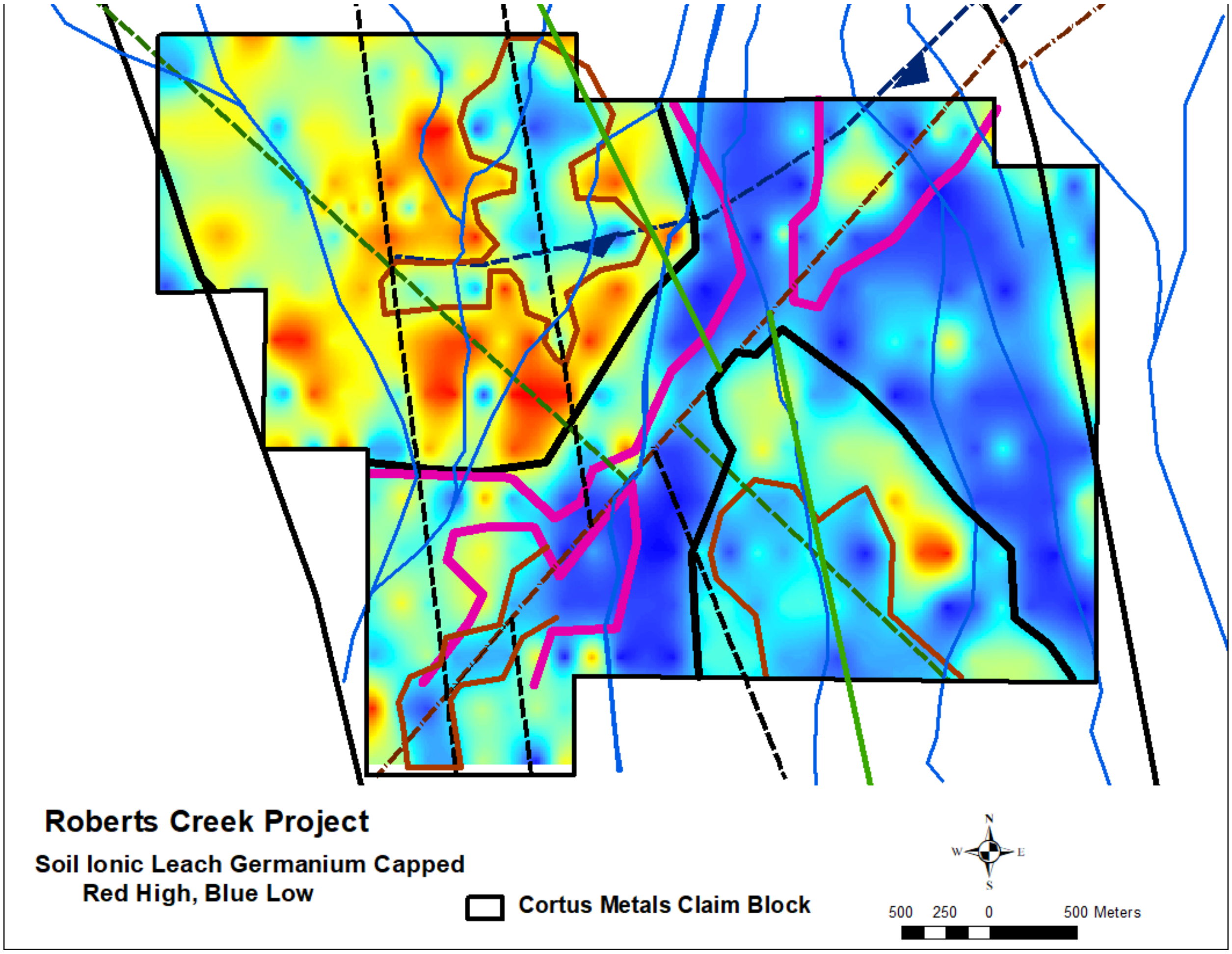
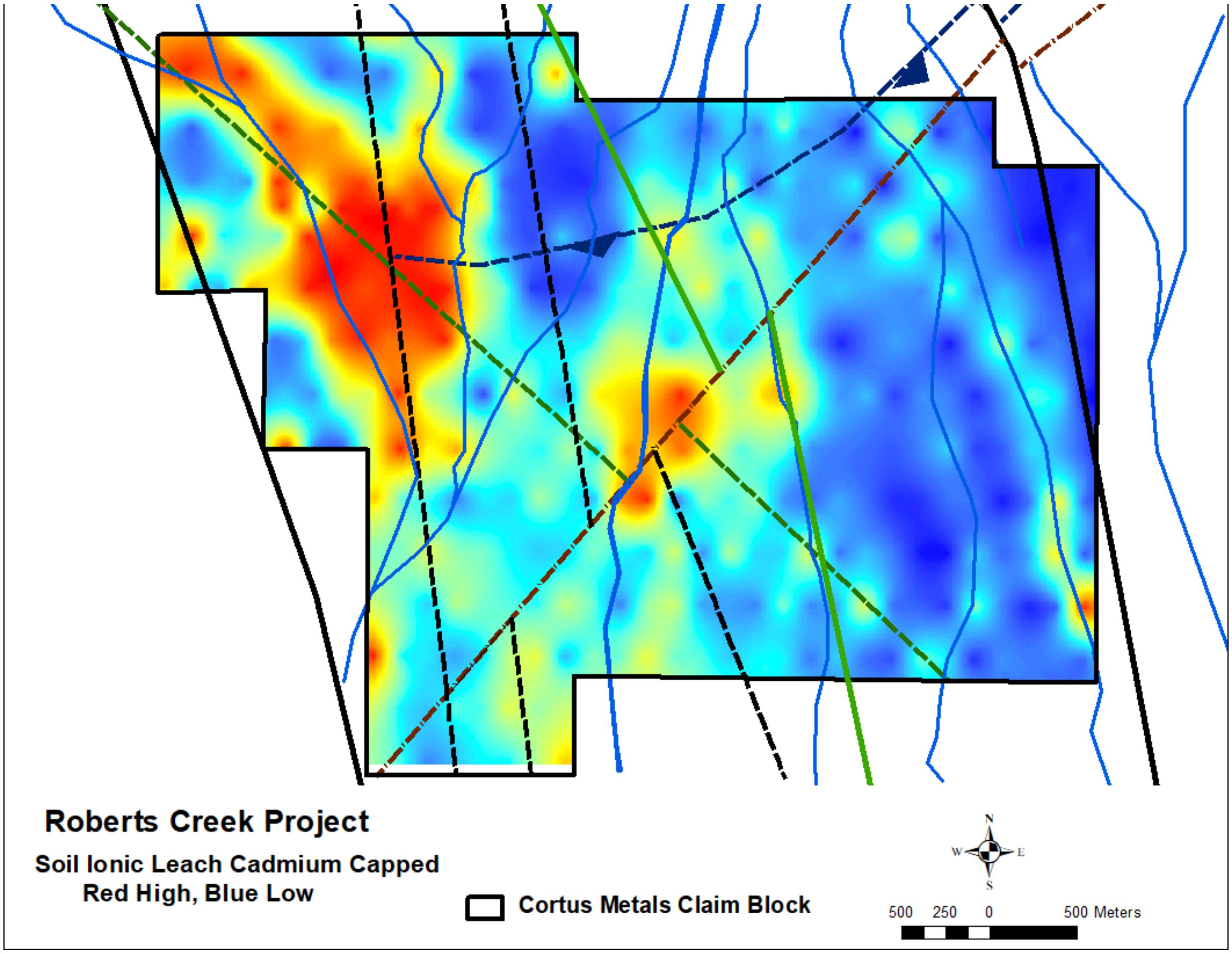


Figure 17. High anomalies, particularly in Fe, Zn, Cd and Ba, can occur along faults, from water traveling up the faults. As shown for cadmium in Figure 17, zinc in Figure 18 and iron in Figure 19, these elements can form large high anomalies extending in multiple directions along intersecting faults. Figure 19 shows an outline around the zone of high values.

Figure 17.


Roberts Creek Project
Soil Ionic Leach Cadmium Capped
Red High, Blue Low
Cortus Metals Claim Block
N
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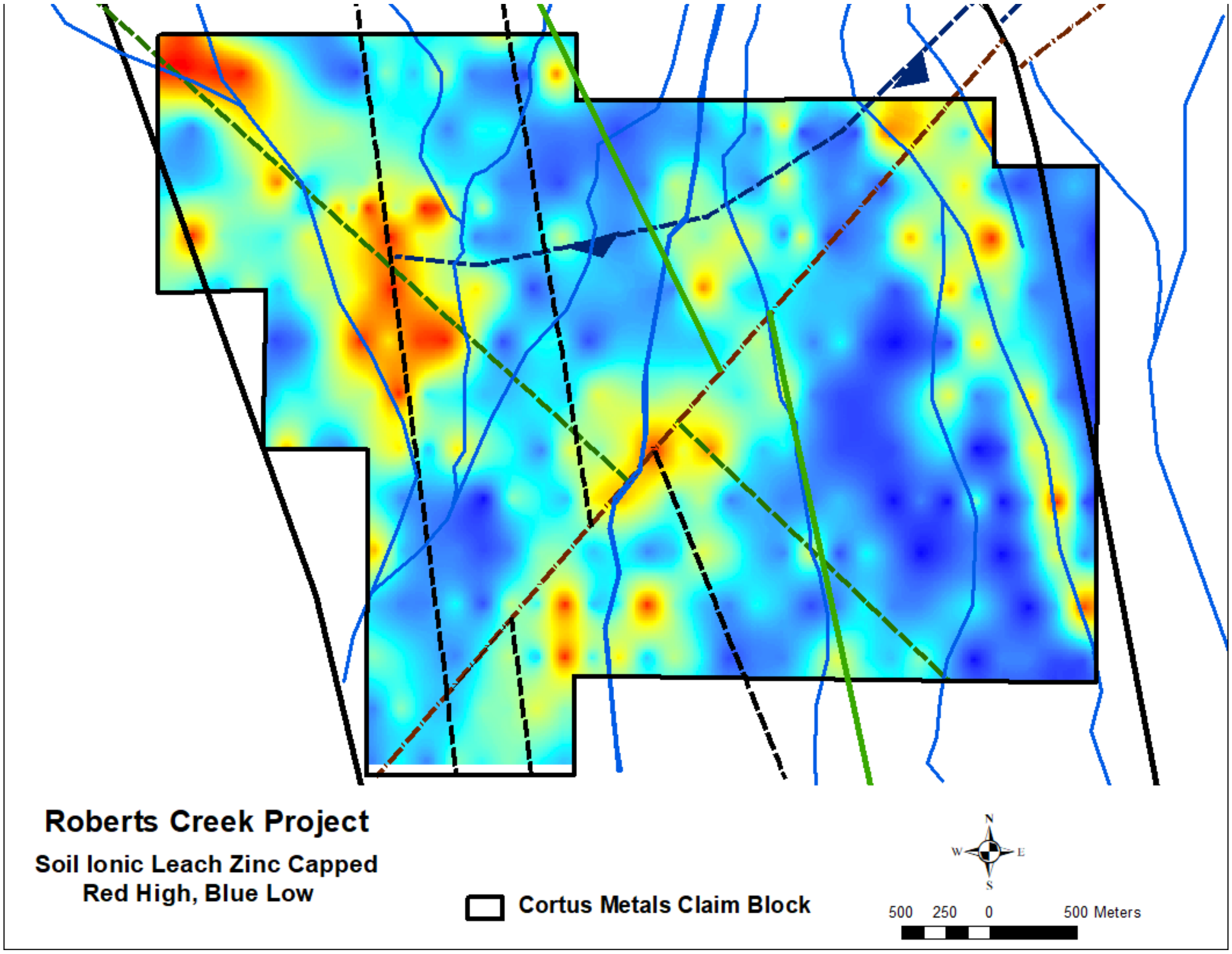
500 250 0 500 Meters

Figure 18.


Roberts Creek Project
Soil Ionic Leach Zinc Capped
Red High, Blue Low
Cortus Metals Claim Block
N
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500 250 0 500 Meters

Figure 19.

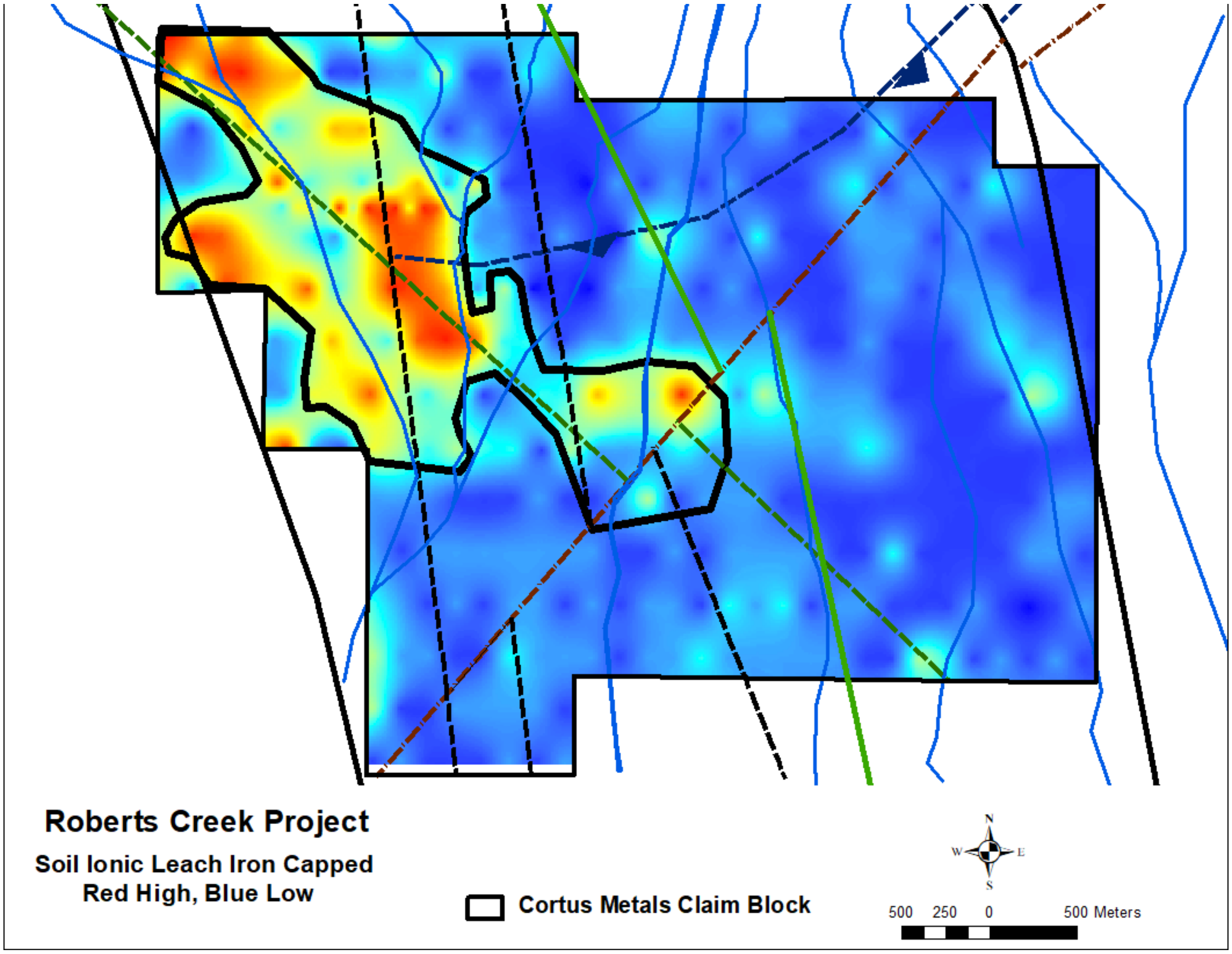
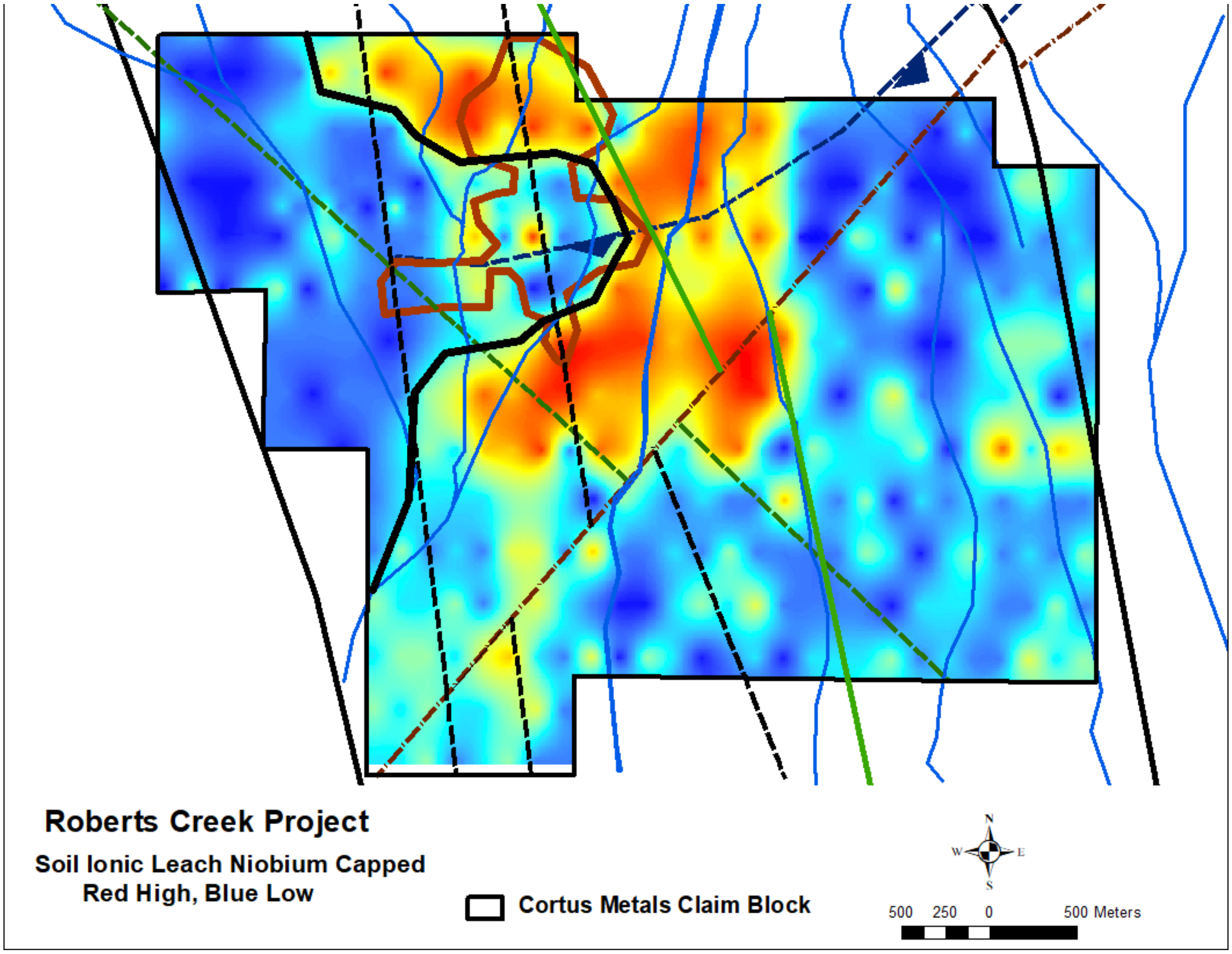


Figure 20 shows niobium, which, because of its high positive charge it is extremely incompatible with most rock-forming minerals and is an indicator of hydrothermal alteration. It has been noted to be elevated in the wall rocks of Carlin-type deposits. The zone of strong Nb values in the central part of the map outlines a halo of low values to the west that crosses both the Ga and Ge windows and the Fe, Zn and Cd high zones (see Figure 21). The preferred anomaly outline shown in Figure 22 suggests a target for a large buried Carlin-type deposit, whereby the faults to the west, which dip east, were avenues for fluids coming up from a mineralized body within the halos of Ge, Ga and Nb to the east.

Figure 20.



Roberts Creek Project
Soil Ionic Leach Niobium Capped
Red High, Blue Low
Cortus Metals Claim Block
N
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500 250 0 500 Meters

Figure 21.

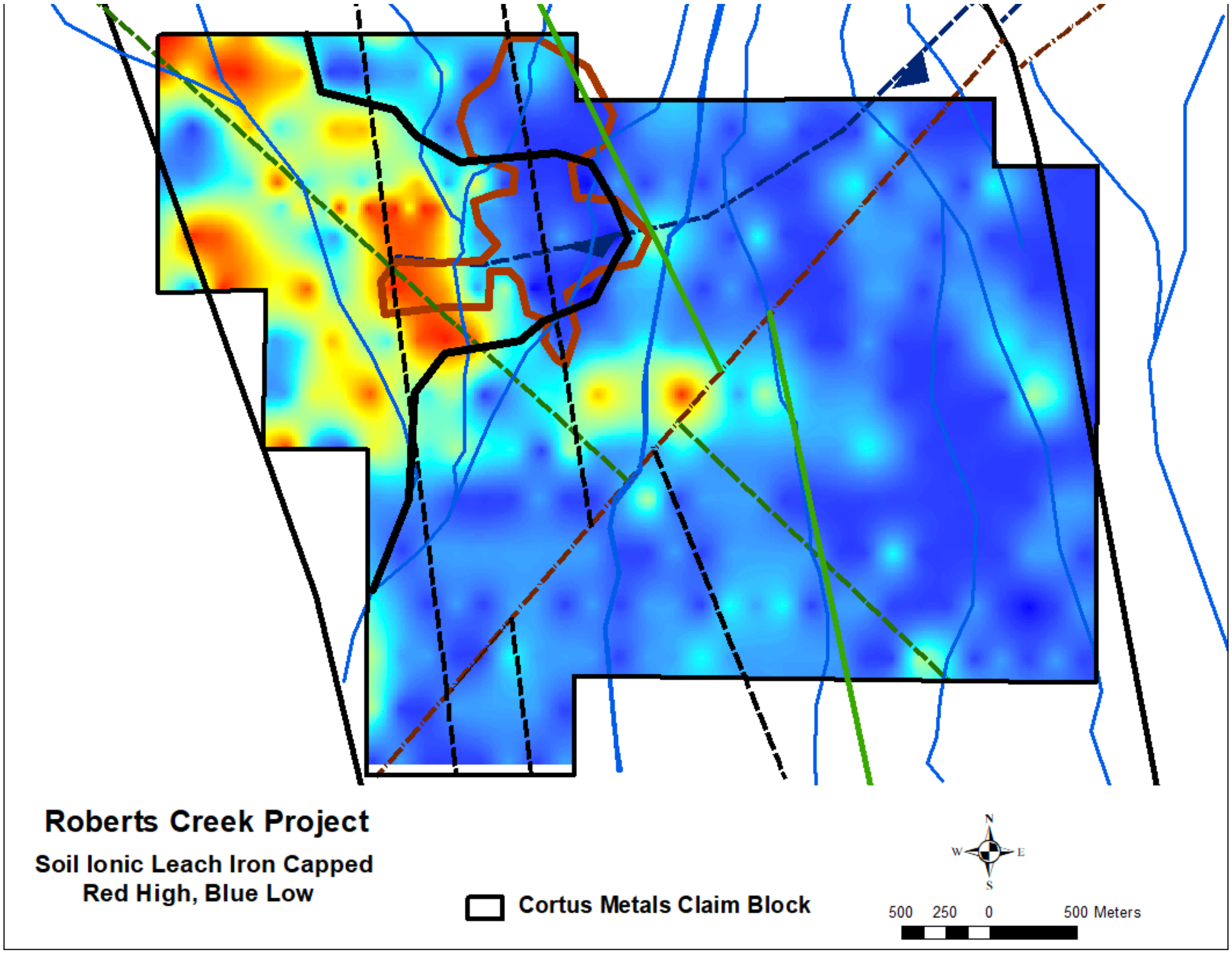

Roberts Creek Project
Soil Ionic Leach Iron Capped
Red High, Blue Low
Cortus Metals Claim Block
N
W
E
S
500 250 0 500 Meters

Figure 22.

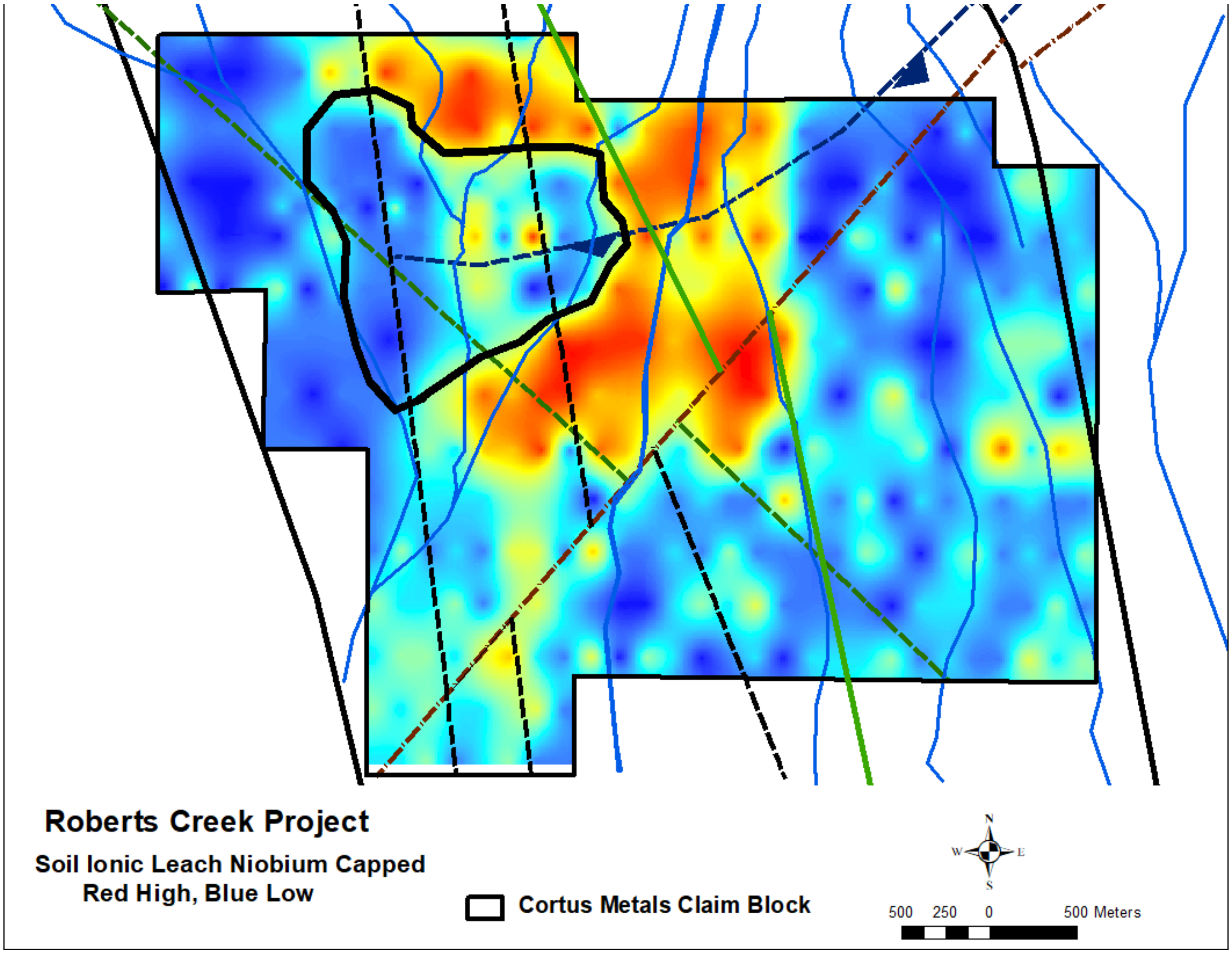
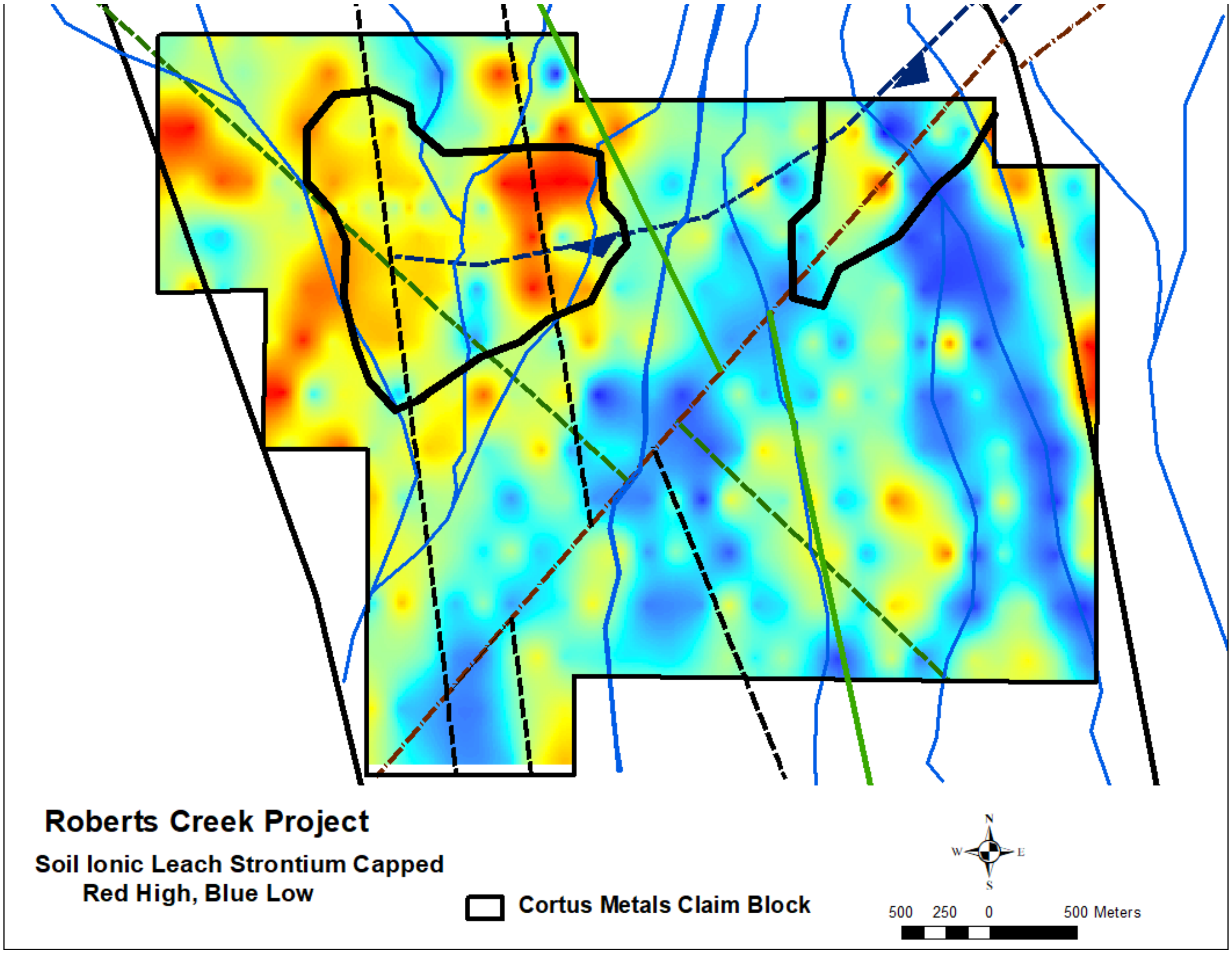


Figure 23 displays gridded strontium values which show high values inside several of halos, most notably the Ga-Ge-Nb windows in the northwest. This may be an example of an apical anomaly, suggesting carbonate dissolution at depth.

Figure 23.



Figures 24 and 25 shows the preferred soil geochemical anomaly outlines superimposed respectively on the gravity and magnetic maps. Proposed first-pass drill sites are also shown.

Figure 24.

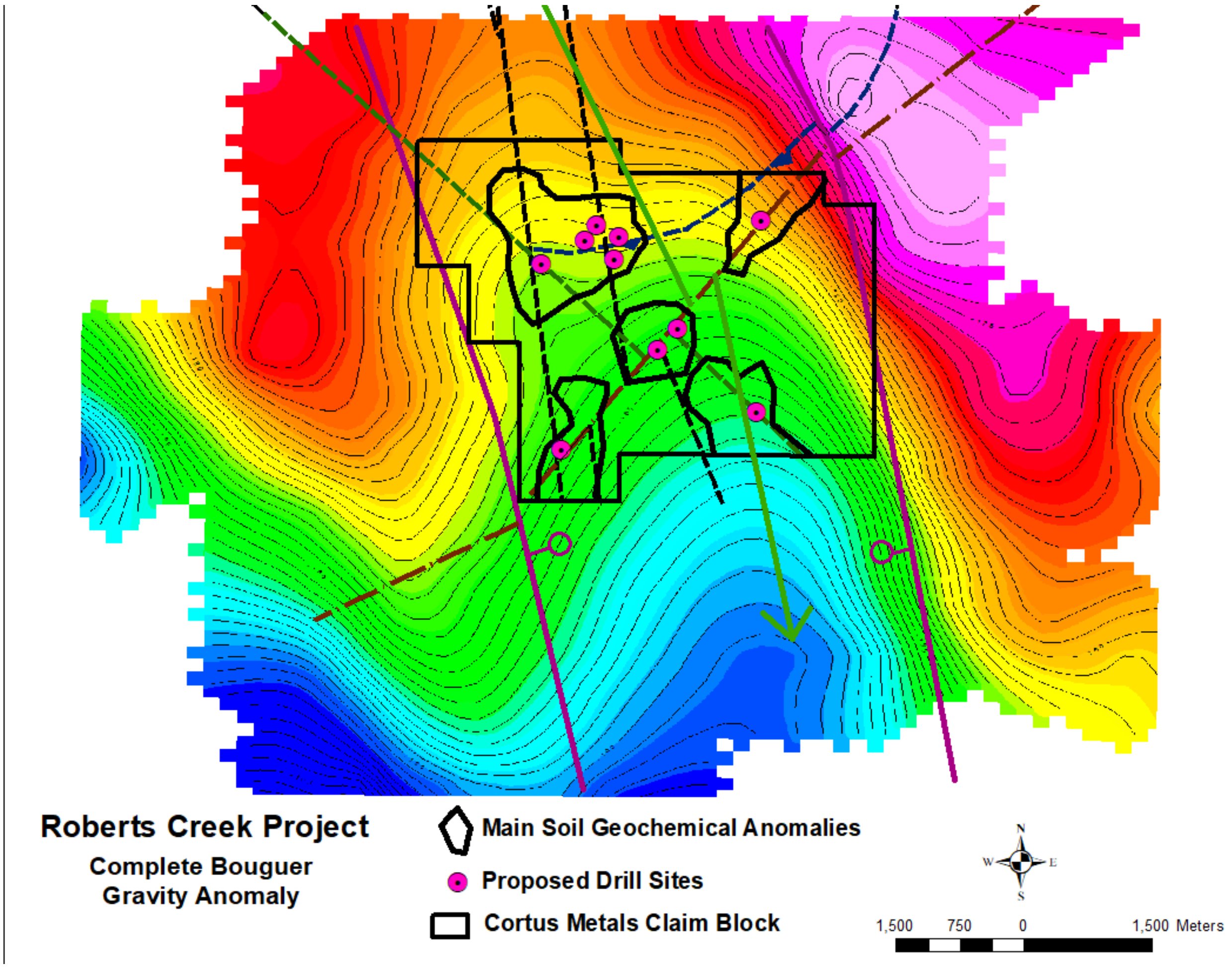
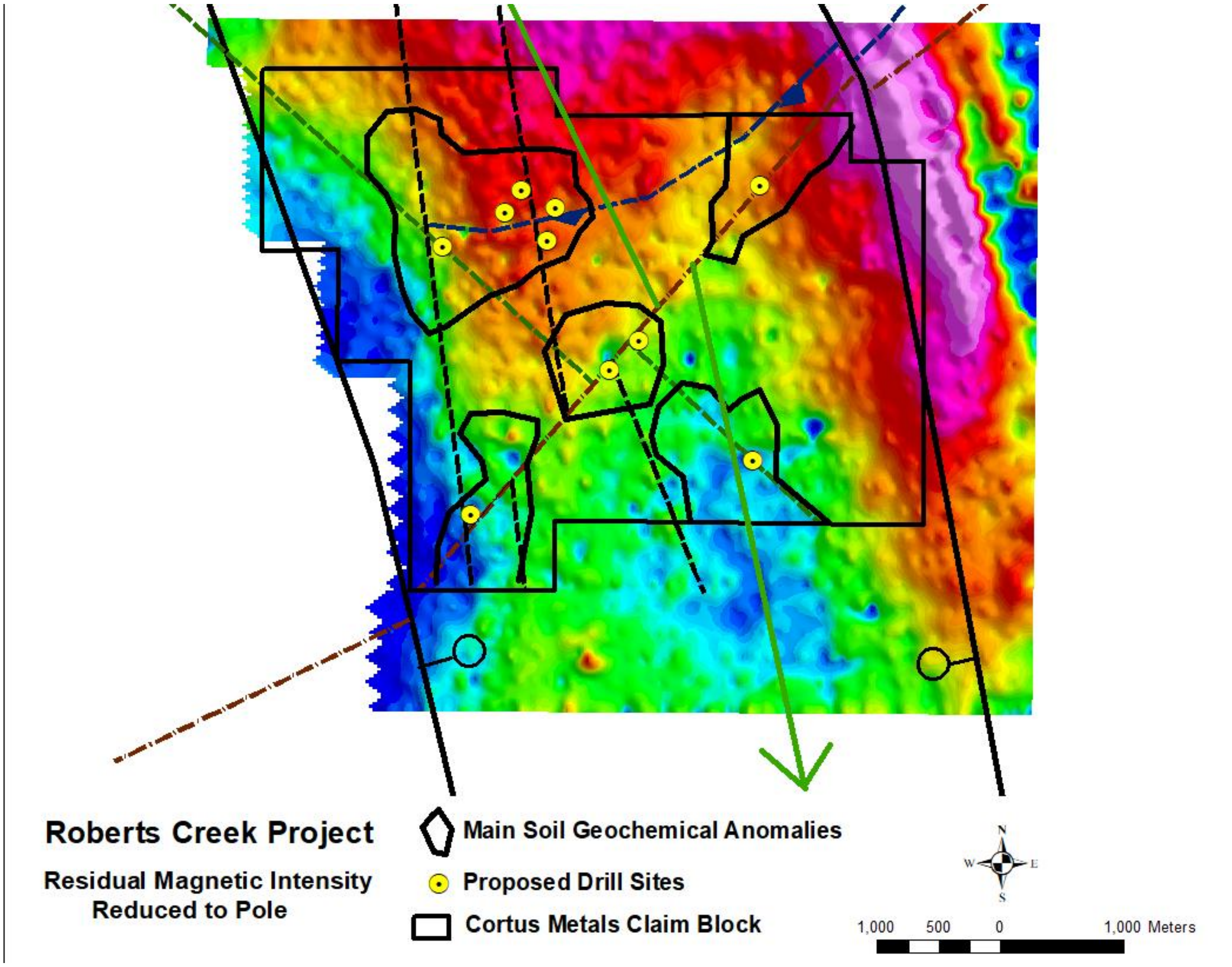

Roberts Creek Project
Complete Bouguer
Gravity Anomaly
Main Soil Geochemical Anomalies
Proposed Drill Sites
Cortus Metals Claim Block
N
W
E
S
1,500
750
0
1,500 Meters

Figure 25.



In summary, soil geochemical analysis by ionic leach suggests several anomalies within a possible apical graben in the core of a south-plunging anticline, which hosts the central Gold Bar deposits. The largest anomaly is in the northwest part of the claim block, along and down-dip of the intersection of the Wall fault and a fault through the Cabin Creek deposit, projected under alluvium. The pattern of concentric halos by different elements appears to be outlining a large hydrothermal cell, within which strong examples of all 3 types of weak leach soil anomalies are present – halo, apical within halo and highs along faults.