GEOCHEMICAL EXPLORATION FOR SKORPION STYLE OXIDE ZINC DEPOSITS

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Introduction

The Skorpion Zinc mine in southern Namibia is located 22km to the north east of the Rosh Pinah VMS Zn-sulphide mine and 40km to the NE of the Orange River marking the international border with South Africa. The deposit is a unique style of Zn-oxide mineralisation comprising sauconite, hemimorphite and smithsonite as the principle Zn minerals of economic interest hosted by arkosic metasediments. The deposit was exhumed by erosion and subsequently buried under an average of 20 meters of Namib Desert sands and gravels post 21Ma (Borg, Karner, Buxton, et al, 2003), resulting in the orebody having no surface outcrop prior to pre-stripping. Given the non-conductive oxide nature of the orebody, lacking electrical, magnetic or gravity contrast with the host, rendering it essentially invisible to direct detection geophysical techniques; and given the complete burial of mineralization beneath younger cover; the deposit proved an obvious target to evaluate the potential to detect mineralization through transported overburden.

In 2000 during the final resource-drilling phase and prior to stripping of the overburden, Anglo American undertook an orientation survey comprising 4 lines of surface geochemical samples across the buried orebody. Initial encouraging results prompted additional profile sampling from surface to bedrock in the first pre-stripping open cuts exposing the ore body. In addition detailed centimeter scale sampling of the surface profile was undertaken to evaluate potential surface contamination.

Profile sampling clearly indicated the presence of an often silcrete cemented zone at the base of the gravels elevated in base metals as a result of both chemical transport and clastic transport from the paleo-eroding body. This horizon was determined to be a considerably more robust material that could be applied at a regional scale in the exploration for additional resources. Subsequent drilling campaigns in the Skorpion exploration camp consistently sampled this horizon in addition to the more conventional bedrock sampling.

Figure 1. Preserved surface environment at the time of Phase 1 sampling. Looking east across the orebody between the central two sample lines. Note the presence of 5 drill rigs and 1 of 2 metallurgical test pits in the background. *(Credit: P. A. Winterburn).*

Exploration and Mining History

The Skorpion Zinc Oxide deposit in southwestern Namibia represents a genuine geochemical discovery. The deposit was discovered in 1976 in the “Sperrgebiet” restricted zone that had been opened for exploration the previous year in a joint venture between Anglo American and De Beers. Follow-up to stream sediment anomalies of 115ppm Zn and 250ppm Pb against typical backgrounds of 30-40ppm in this arid desert environment identified a barite gossan to the west of a sediment filled basin assaying up to 4% Zn, 2.9% Pb, 0.3% Cu and 50ppm Ag (Corrans *et al*, 1993). Initial drilling through the basin targeted deep sulphide VMS style mineralization, however, fortuitous analysis of the bland rock above the sulphide zone resulted in the ultimate discovery of the zinc oxide deposit. The initial drilling program resulted in a measured and indicated resource of 8.3Mt @ 10.9% Zn in oxide. As a result of metallurgical extraction problems Anglo mothballed the project and subsequently formed a joint venture with Reunion Mining in 1996. Between 1996 and 1998 the resource was more than doubled to 17.5Mt @ 10.4% Zn and a technological solution found to the Zn recovery. Anglo American purchased Reunion Mining in 1999 to become sole owner and commenced mining in 2002 of the orebody as an open pit with a resource of 24.6Mt @ 10.6% Zn (Mining Journal, 2000). Anglo American sold the Skorpion Zinc Mine along with its remaining zinc assets to Vedanta Resources in 2010. Remaining total resources and reserves amount to 11.4Mt @ 9.5% Zn with a projected life of mine to 2017 (Vedanta Resources, 2014).

Phase 1 sampling - 2000.

Four sample lines were initially taken across the deposit oriented perpendicular to the strike of the orebody. The northern and southern most lines being “off mineralisation”. Samples of unconsolidated windblown sand were collected at a constant depth of 30cm and dry screened in the field to 125microns. Material was submitted for a variety of analytical techniques including Aqua-Regia digest ICP-OES and ICP-MS, Enzyme Leach and MMI. Whilst sample lines were located to avoid drill holes (both RC and DD), the sampling was undertaken in an area that had undergone intermittent drilling over a 30 year period. At the time of sampling 5 drill rigs were active on the orebody (Figure 1).

Initial geochemical results produced a positive response above and adjacent to the mineralisation in Zn and Pb (Figure 2 and 3), however with peaks effectively at only 2*background. Not surprising, however, given the level of drilling that had been undertaken, coupled with the open wind swept environment; concerns were raised over the viability of the surface sample and whether the surface had been contaminated.

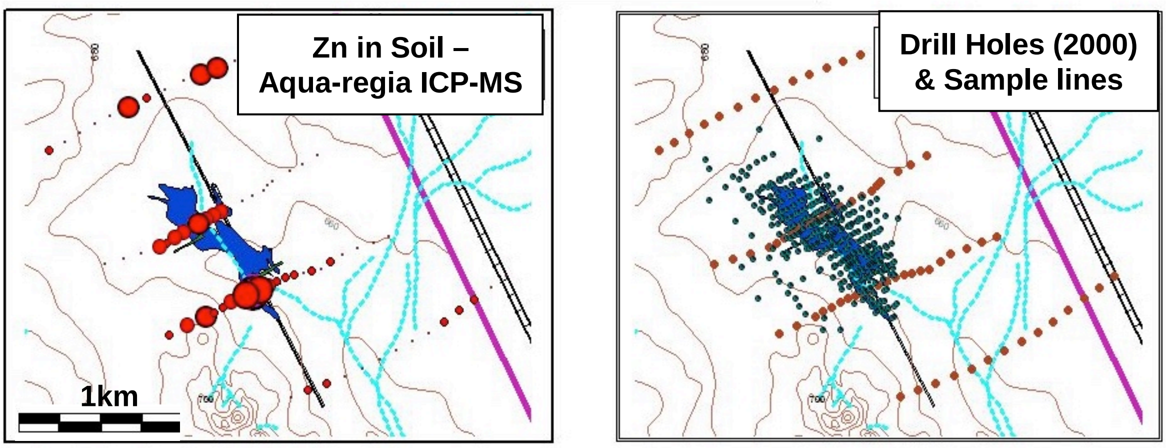

Figure 2. a- Zn results in soil by aqua-regia ICP-MS. Symbols are scaled from small Zn (30ppm) to large (65ppm). b- Sample positions relative to the drill pattern as of mid 2000 when the sampling was undertaken. Solid blue represents the sub-surface outcrop of the orebody at >1% Zn.

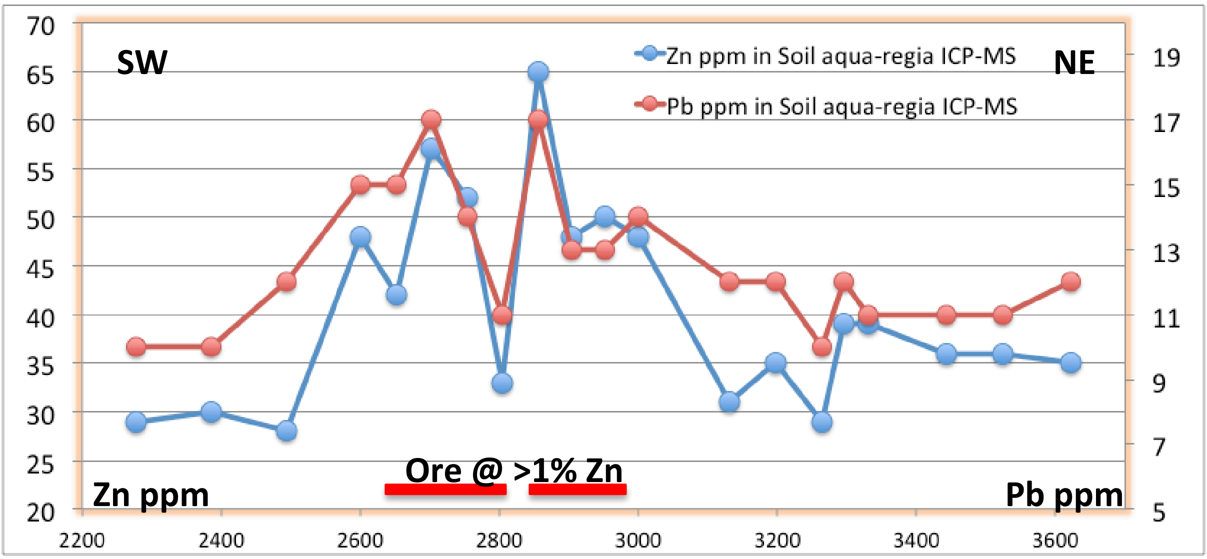

Figure 3. Profile for Zn and Pb in soil above the ore body (line 2 from the NW).

Phase 2 sampling – 2001.

In 2001 several large pits were cut through the gravel for bulk sampling, exposing the mineralisation. These provided an opportunity to sample the complete profile from surface to bedrock (Figure 4) with the intention to identify evidence of vertical migration of metals from mineralisation to the surface. This was supplemented with centimetres scale sampling of the near surface soil profile in a shallow 1.5 m pit excavated by hand. Of particular value was a line of rubble in the pit wall identifying the original surface at the time of the drilling in the 1970's which has subsequently been actively buried under the moving surface dune sands. Anything sampled above this anthropogenic rubble line could potentially be affected by drill contamination. Sampling strategy in both materials followed that in the initial program with a sub-125micron fraction being collected from the gravel beds at discrete intervals and analyzed by Aqua-Regia digest with ICP-MS finish.

Analysis of the material in the shallow pit at 10cm intervals, (Figure 5) indicated a high probability of surface contamination with the material above the rubble line being strongly enriched with the same chemical signature as the ore. Notably the Zn/Cd ratio in the near surface material is closer to the ore material than the Zn/Cd ratios in the overburden profile beneath a layer of calcrete lat ~1.5m. Zn and Cd were separated from an original sphalerite source during formation of the oxide ore-body and currently sit in different mineral phases in the oxide ore (Karner 2006).

Profile chemistry down the newly excavated pit walls to bedrock indicated a high probability that vertical movement of metal had been or still was occurring. In addition the results also clearly indicated highly anomalous values in the gravel material immediately above the bedrock interface (Figure 6). This observation resulted in the proposal to routinely sample the gravel level immediately above the unconformable contact with the bedrock on the basis that material had both travelled vertically as well as laterally from the deposit as a mixture of both clastic and hydromorphic transportation. Lateral dispersion of this material would potentially significantly increase the footprint of the deposit and thus aid in the exploration for further mineralized bodies of a similar nature.

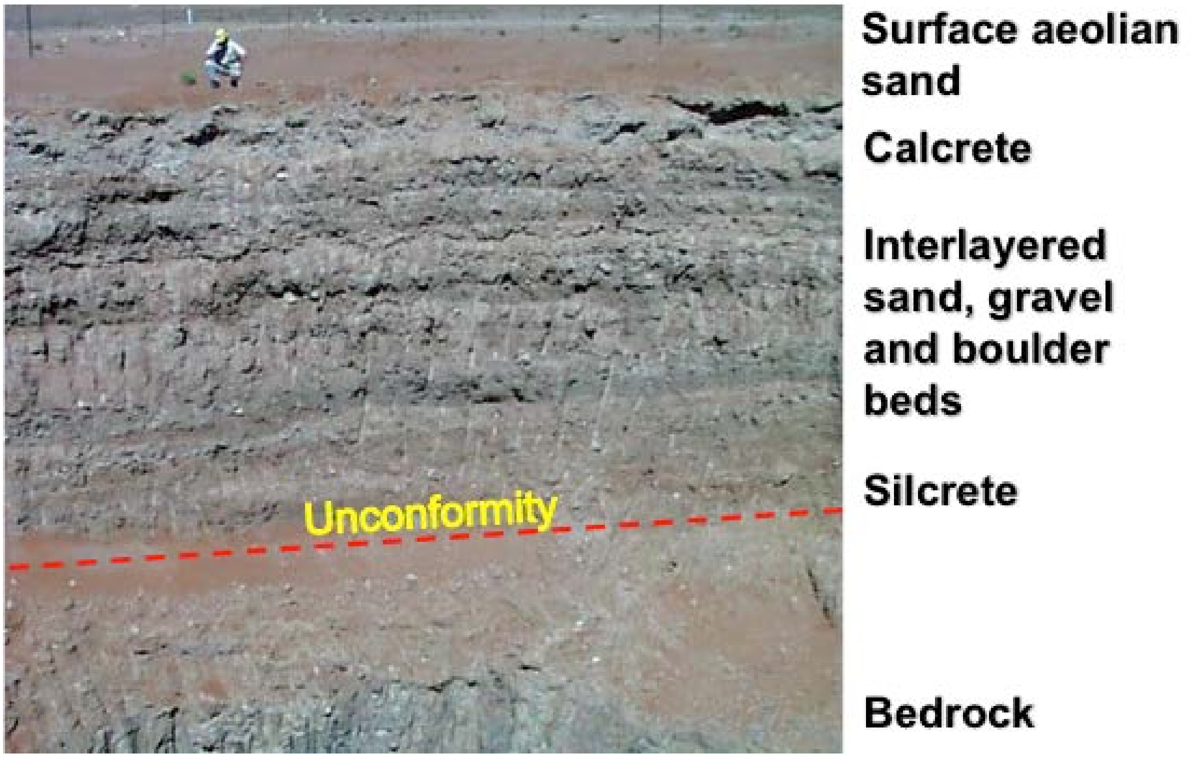

Figure 4. Profile through the exotic overburden to bedrock. Cover is approximately 10m thick.

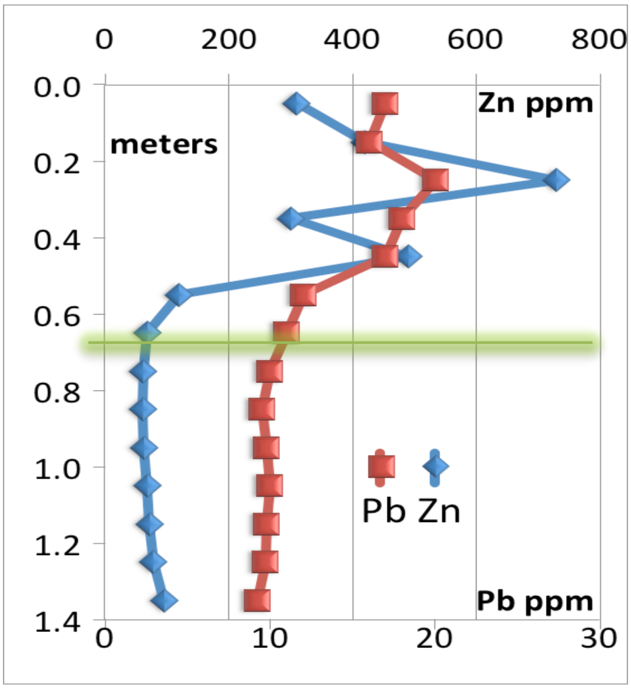

Figure 5. Zn and Pb results in the shallow pit sampled at 10 cm intervals. The position of the rubble line within the sands demarcating the original pre-drilling surface is indicated in green. Note this pit does not expose mineralization penetrating the upper aeolian sand layer only to the calcrete horizon.

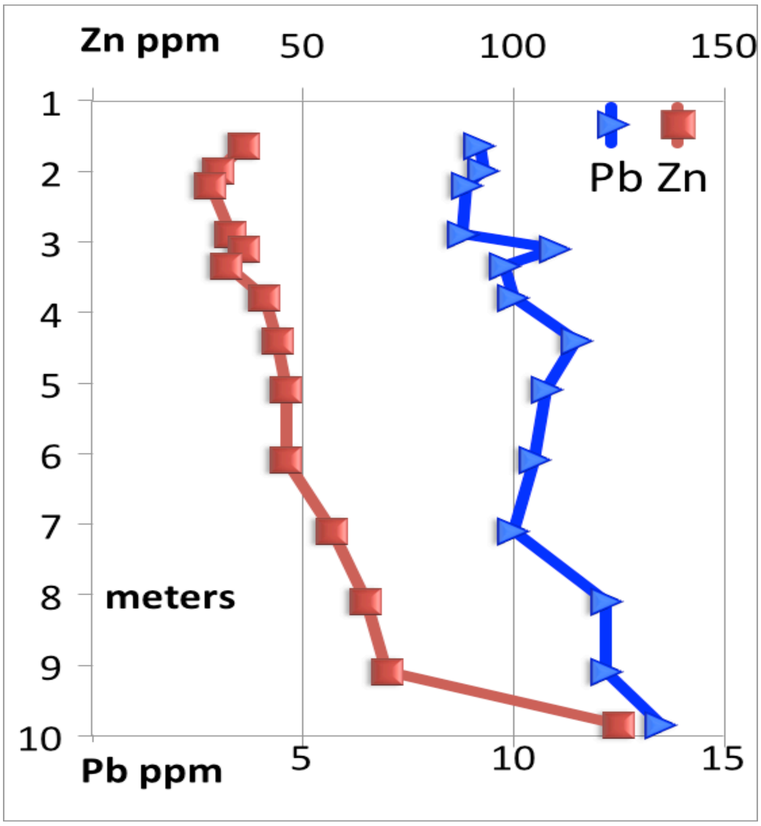

Figure 6. Profile for Zn and Pb in the pit wall from below the calcrete to the unconformity. Ore grade mineralization is not present at the base of this pit.

Phase III Sampling - 2003.

In 2003, the exploration group at the Skorpion Mine commenced a regional scale drilling program using RAB to sample bedrock as a primary geochemical and geological exploration medium. Twenty six of these holes with elevated levels of Zn in bedrock and for which the complete overburden material had been retained were subsequently submitted for analysis of the complete overburden profile using 2m composite samples. As this material had been collected by RAB, it represented a total pulverised sample rather than a fines extract as had been previously used during the profiling orientation in 2002.

Geochemical results from the 2m-interval gravel sampling confirmed the presence of a surface geochemical response as well as a deeper response at the unconformity with the bedrock. The surface response, often subtle, variable and inconsistent included the elements Zn, Tl, U, W, Y, Mn, Sb, Te, S, Mo, Cu, Hg, Ag, As, Au and Ba, all of which are present in the ore material at various concentration levels. However given the concerns of surface contamination; active mining of the ore material was now in progress; and given the variable depth of the overburden; confidence that a robust consistent signal would be generated on the surface was not strong.

Geochemical results (Figure 7) from Aqua-Regia digest ICP-MS analysis from the last 2 meters of gravel above bedrock produced a geochemical response in a similar suite of elements to that at the surface. Simple statistical evaluation of the data using non-parametric statistics and excluding elements reflecting a lithological rather than mineralisation control resulted in the generation of an empirical geochemical index – the Skorpion Index. Analytical results for the element suite being simply summed following normalisation to the 50th percentile relative to that of Mn to accommodate for differences in the absolute concentration ranges.

Active Exploration - post 2003.

The results of the research and development exercise were subsequently actively applied during the regional scale exploration program in the Skorpion District (Schaefer 2008). The standard application procedure developed utilises the field portable XRF to screen the lower 10m of overburden for elevated base metal contents. From this initial screening, selected 2m composite intervals are submitted for multi-element Aqua-Regia digest, ICP-MS analysis. These results are evaluated both using the Skorpion Index as well as individual elements to take cognisance of different detailed signatures and distribution patterns. This is applied in conjunction with paleo-topographic information and underlying geology to identify targets or vectors for further follow up exploration (Figure 8). This information is supported by other lithogeochemical techniques such as VHMS proto-ore alteration, and rhyolite fertility (Bork, Karner and Winterburn 2002)

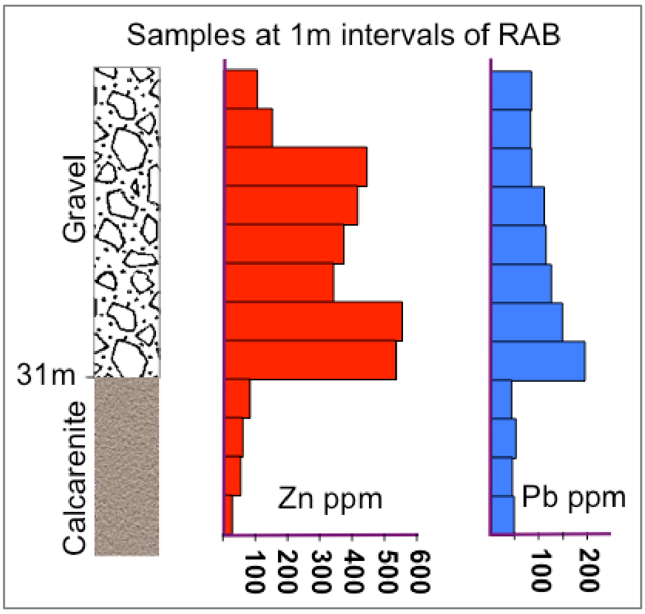

Figure 7. Example data from the regional RAB drilling program. Following initial screening by FP-XRF highlighting anomalous Zn and Pb values immediately above the unconformity contact. The final 2m samples would be composited and submitted for multi-element analysis. Modified from Schaefer (2008)

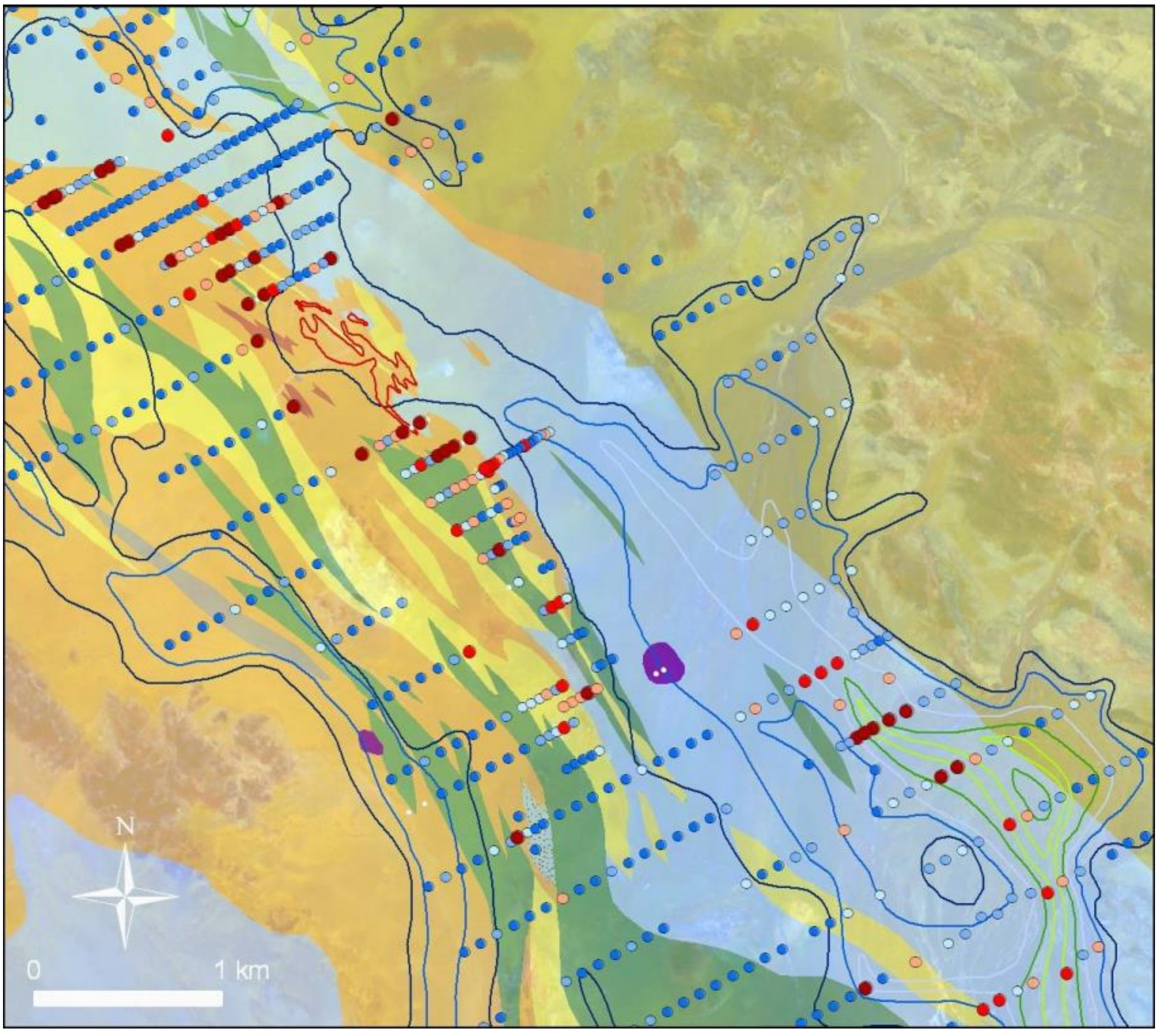

Figure 8. Combined model used for final follow-up target selection. This comprises subsurface geology, palaeotopography at the unconformity surface (blue lines) and calculated Skorpion index from the overburden geochemical results (coloured dots Blue low ranking to red high ranking). The >1% Zn contour of the Skorpion ore body is outlined in red. (Schaefer, 2008).

Conclusions

Surface contamination from previous drilling (and recent mining activities) in the vicinity of the Skorpion Zn-oxide ore-body, limits the application of surface geochemical sampling. Evaluation of the basal units of the transported overburden indicate that geochemical dispersion, of certain elements, from bedrock has occurred, this is believed to comprise vertical and lateral transport, the latter probably focussed along the unconformity. Distance of this transport appears different for different elements implying de-coupling of the chemistry during element migration. RAB drilling and direct sampling of bedrock and lower transported gravel units remains the most robust sampling method.

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