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SUPERGENE GOLD DISPERSION IN THE REGOLITH AT THE CLEO DEPOSIT, WESTERN AUSTRALIA.

D.J. Gray and A.F. Britt

CRC LEME OPEN FILE REPORT 224

November 2008

(CRC LEME Restricted Report 139R / E&M Report 729R, 2000
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CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, Geoscience Australia, Primary Industries and Resources SA, NSW Department of Primary Industries and Minerals Council of Australia.

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The CRC LEME–AMIRA Project 504 “**SUPERGENE MOBILIZATION OF GOLD IN THE YILGARN CRATON”** was carried out over the period 1998 to 2001. Twelve reports resulted from this collaborative project.

CRC LEME acknowledges the support of companies associated with and represented by the Australian Mineral Industries Research Association (AMIRA), and the major contribution of researchers from CSIRO Exploration and Mining.

Although the confidentiality periods of the research reports have expired, the last in July 2002, they have not been made public until now. In line with CRC LEME technology transfer goals, re-releasing the reports through the **CRC LEME Open File Report (OFR) Series** is seen as an appropriate means of making available to the mineral exploration industry, the results of the research and the authors' interpretations. It is hoped that the reports will provide a source for reference and be useful for teaching.

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OFR 218 – Gold distribution, regolith and groundwater characteristics at the Mt Joel prospect, Western Australia – CG Porto, NB Sergeev and DJ Gray.

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OFR 228 – Supergene mobilization of gold and other elements in the Yilgarn Craton, *Western Australia* – ***FINAL REPORT*** – DJ Gray, NB Sergeev, CG Porto and AF Britt

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PREFACE

The principal objective of CRC LEME-AMIRA Project 504, *Supergene mobilization of gold and other elements in the Yilgarn Craton*, is to determine the mechanisms of supergene/secondary depletion, enrichment and dispersion of Au and other elements, so as to improve selection of drilling targets and further optimize interpretation of geochemical data.

The Cleo ore body, part of the Sunrise Gold Deposit, is located on the eastern margin of Lake Carey, in the Laverton region. This region has saline, but not particularly acidic, groundwaters and is strongly influenced by palaeochannel systems. The Cleo ore body is adjacent to one such palaeochannel. There is an general cover of up to 27 m of transported material thoughout the area with up to 60 m additional sediment infilling the palaeochannel. Mineralization in the residual regolith occurs in the transitional zone (equivalent to saprock) and the lower saprolite. Within the palaeochannel, dispersion has occurred along the unconformity where sediments abut mineralization, and within the sediments as a “blanket” of Au enrichment between 325 and 340 m elevation (approximately 55 – 70 m depth). This situation contrasts with the Argo deposit near Lake Lefroy, Kambalda, which has also been investigated as part of AMIRA P504. Argo is also adjacent to a palaeochannel but dispersion has only occurred in the basal palaeochannel sediments.

The Cleo ore body and surrounding region offer a useful area in which to investigate Au dispersion in both residual and transported regolith, and in an adjacent palaeochannel. Comparisons with study sites of similar bedrock, regolith development and palaeotopography have the potential to further our understanding of the differences in Au dispersion at different sites and thus this study fits well within the objectives of the Project.

D.J. Gray
Project Leader
September 2000

ABSTRACT

The Cleo ore body is located approximately 55 km south of Laverton in the Eastern Goldfields Province of Western Australia, on the eastern margin of the salt playa Lake Carey. Mineralization occurs within volcaniclastic rocks of intermediate composition associated with pyrite replacement. There are commonly at least 25 m transported cover over the main ore body, increasing to 80 m within the adjacent palaeochannel, and hypersaline groundwaters. The present day land surface is at approximately 397 m ASL.

Palaeotopography, regolith stratigraphy and Au geochemistry of the Cleo ore body and Sunrise region are derived using the program Mining Visualization System. Using logging provided by Acacia Resources Ltd (now AngloGold Australasia Ltd), the residual profile at Cleo could be divided into bedrock, transitional zone (equivalent to saprock) and saprolite. Transported material, composed of colluvial, alluvial and aeolian sediments, overlies the entire region. The regolith layers and Au distribution were modelled. The average thickness and Au concentration of each regolith layer was calculated. Gold concentrations were also calculated as a function of elevation and on either side of the base of weathering, the transitional/saprolite boundary and the unconformity.

The logged transitional layer averages 7 m thickness over the ore body and 8 m over the region. Saprolite is the thickest residual layer and averages 46 m over the ore body and 33 m regionally. These layers have formed at the greatest depths beneath the palaeochannel but are thinner there, suggesting a degree of truncation. The transported cover averages 27 m in thickness over the ore body, 34 m regionally and there is up to 80 m of sedimentary infill in the palaeochannel.

Primary Au concentration appears to be quite variable, increasing substantially approximately 10 m below the weathering front and reaching a mean of 188 ppb within 5 m of the transitional zone. This could reflect primary variation and/or weathering occurring along structures below the logged base of weathering. Gold content is generally greatest in the residual regolith developed over mineralization and peaks in the transitional zone and lower saprolite at an elevation of approximately 330 m. Mean Au between 315 and 340 m is at least double primary Au concentrations. Above 340 m elevation, Au is depleted with concentrations steadily decreasing up profile. The upper saprolite is significantly depleted by 360 m elevation with the saprolite containing less than 20 ppb Au. The transported material directly above the ore body (which is away from the deeper palaeochannels) is uniformly barren with less than 10 ppb Au.

Within the palaeochannel sediments, there appear to be two main forms of Au enrichment. Firstly, Au enrichment occurs in patches along the unconformity where it abuts mineralization and, secondly, Au enrichment occurs in the palaeochannel sediments as a “blanket” approximately between 325 to 340 m elevation.

Similar investigations were conducted at the Argo gold deposit, 28 km south-east of Kambalda (Britt and Gray, 1999). Argo is also adjacent to a palaeochannel containing up to 60 m of infill and also has Au enrichment in the basal channel sediments abutting mineralization. Unlike Cleo, however, there is no enrichment “blanket” within the sediments. It is possible that the lignitic sediments and reducing environment in the Argo palaeochannel might account for the disparity.

Both the Au enrichment “blanket” occurring in the Cleo palaeochannel sediments and the depletion front over the ore body occur at around 340 m elevation. Both features are probably a result of groundwater processes. These studies, in conjunction with investigations in Project 504 have demonstrated the importance of regional setting, geomorphology and groundwater chemistry and flow characteristics in controlling the form and magnitude of Au redistribution in the regolith.

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1 INTRODUCTION

1.1 Objective

The principal objective of CRC LEME-AMIRA Project 504, *Supergene mobilization of gold and other elements in the Yilgarn Craton*, is to determine the mechanisms of supergene/secondary depletion, enrichment and dispersion of Au and other elements, so as to improve selection of drilling targets and further optimize interpretation of geochemical data.

Within this framework, this study has investigated the geochemical dispersion of Au at the Cleo deposit using the Mining Visualization System (MVS) program. This program is a useful tool for visualizing the three-dimensional patterns of Au distribution in the regolith and calculating amounts of depletion and enrichment.

1.2 Location

The Cleo ore body is located approximately 55 km south of Laverton in the Eastern Goldfields Province of Western Australia. It is on the eastern margin of the salt playa Lake Carey, at latitude 29° 05' S and longitude 122° 25' E (Figure 1). The deposit is co-owned by AngloGold Australasia Ltd (formerly Acacia Resources Ltd), who call their portion "Cleo", and by the Granny Smith Joint Venture (Placer Pacific Ltd 60% and Delta Gold NL 40%), who call their portion "Sunrise".

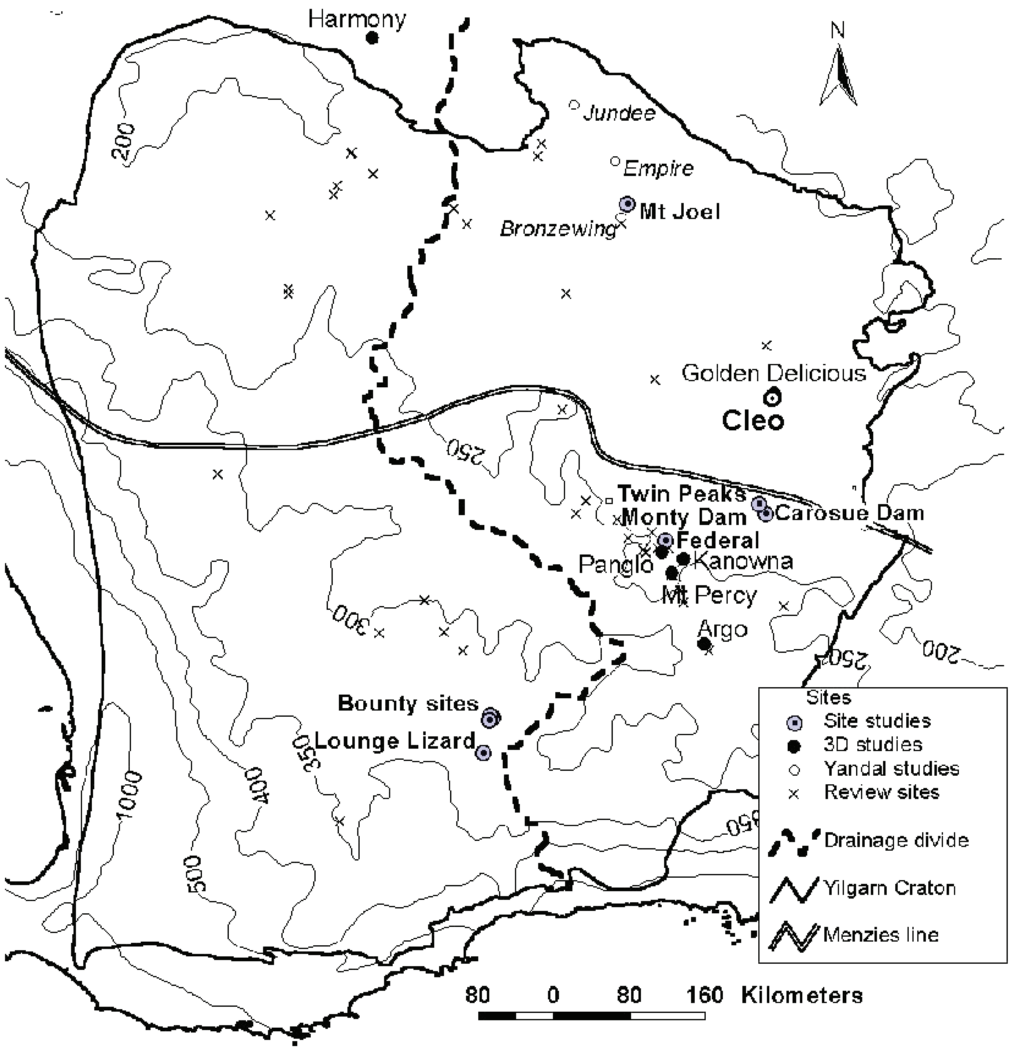

Figure 1: Location of the Cleo Au deposit, and other sites investigated within AMIRA P504, along with the Yilgarn Craton boundary, major N-S drainage divide, Menzies line and rainfall isohyets (courtesy Bureau of Meteorology).

1.3 Climate, vegetation and geomorphology

The climate is semi-arid with highly variable annual rainfall averaging 200-250 mm. Regional vegetation consists of sparse to dense *Acacia* woodland with an understorey of smaller shrubs consisting of *Acacia*, *Cassia* and *Eremophila* (poverty bush) species (Butt et al, 1997).

The area is characterized by low relief typical of the Yilgarn. Apart from a small outcrop of banded iron formation at Sunrise Hill, there is virtually no outcrop in the immediate area. The surface is dominated by sand, gypsiferous dunes, salt pans and sheet wash associated with Lake Carey. In contrast, prior to Tertiary sedimentary infill, local topographic relief was greater than 30 m and a southerly draining stream created a deep palaeochannel trending south to SW through the deposit area (Newton et al., 1998).

1.4 Geology

(Summarized from Newton et al., 1998)

The Cleo deposit is hosted in the Archaean Norseman-Wiluna belt, in the Eastern Goldfields Province. The deposit falls within the structurally complex Laverton Domain, which is characterized by tight folding and thrusting. A number of other gold deposits lie within or near the margins of the Laverton Domain including Laverton, Granny Smith, Red October, Childe Harold, Lancefield and Keringal. Sedimentary rocks host most of these deposits, a distinctive feature of the Laverton region relative to other deposits in the Yilgarn Craton.

The local bedrock consists of shallowly-dipping sequence of interbedded Archaean sedimentary, volcaniclastic and volcanic rocks of acid to intermediate composition. The volcaniclastic rocks are interbedded with BIF facies. In general, they are thick bedded to massive, fining upwards. The BIF units are typically 2 to 10 m thick and commonly grade into magnetite-rich tuffs. A 20 to 40 m thick mafic intrusive postdates the volcaniclastic sequence on the western side of Cleo. Quartz-feldspar porphyries also intrude the sequence, at both Cleo and Sunrise, and, at Cleo, post-date the mafic intrusive. The Archaean sequence is weathered to a depth of approximately 60 to 80 m from the surface.

The Sunrise Shear cuts through the Cleo-Sunrise deposit and shallowly dips north to the NW. This structure is 10 to 20 m thick and the associated carbonate-sericite alteration halo is commonly 30 to 40 m thick. Smaller scale shear zones above the Sunrise Shear are both parallel and discordant to the shallowly dipping Archaean succession. Early recumbent folds have axial planar surfaces that parallel the Sunrise Shear and in cross section the geometry of this deformation is similar to a thrust duplex or imbricate stack. Second phase deformation structures consist of upright to inclined folds with north-striking axial planar surfaces and gently north plunging axes. Quartz veins are abundant throughout the deposit, and regardless of host rock, most are between 0.5-2 cm thick and less than one metre in length.

Transported sediments cover the bedrock and broadly consist of a lowermost unit, 20-60 m thick, consisting of green-grey to white clay interbedded with pisolitic gravel lenses, transported partially-weathered blocks and other materials. An uppermost unit of dune sands is associated with the eastern margin of Lake Carey, and is generally less than 3 m thick. Several ferruginous bands have developed in the sedimentary profile.

1.5 Gold mineralization

(Summarized from Newton et al., 1998)

Within the Archaean rocks, the Sunrise Shear, controlling geometry and mineralization, is thought to have been the main conduit for gold-bearing hydrothermal fluids. Pyrite replacement of BIF accounts for most of the primary mineralization and is well developed where shear zones parallel to the bedding follow the contact of BIF with less competent units. Gold is also associated with quartz-ankerite-pyrite veins and pervasive ankerite, silica, sericite and pyrite alteration of intermediate volcaniclastic host rocks. Thin quartz-carbonate veins also host Au, but are mostly located in the Sunrise part of the deposit. Supergene mineralization has developed within the transported cover and the weathered bedrock.

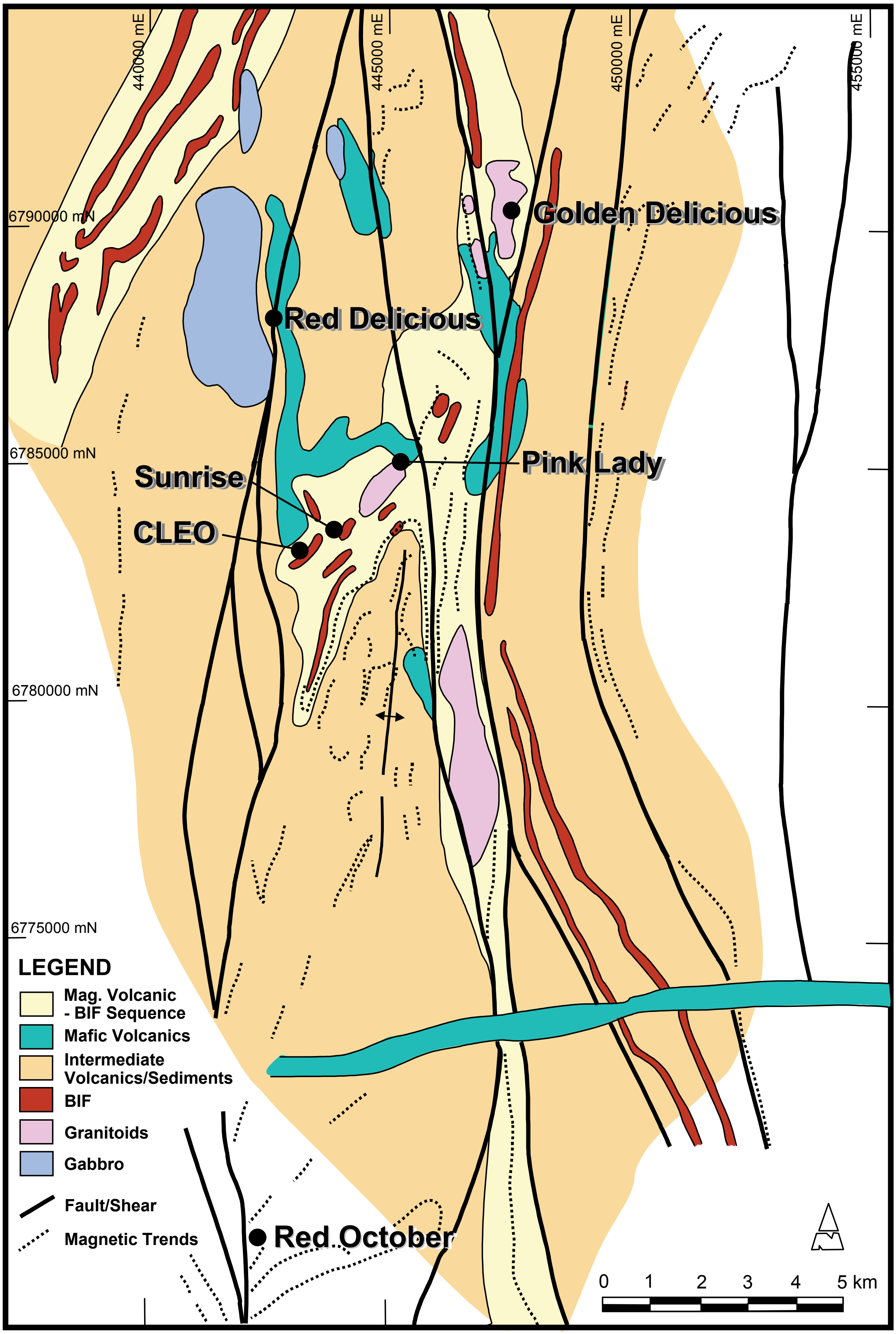

Figure 2: Local geology of the area around the Cleo deposit.
After Bristow et al., 1996, courtesy Acacia Resources Ltd.

2 METHODS

2.1 Data manipulation and modelling

Acacia Resources Ltd supplied geological/regolith logging and geochemical data for up to 206 bore holes, with some 13218 Au analyses. From this data, bedrock and the logged regolith divisions of transitional zone, saprolite and transported cover could be distinguished. The transitional zone is equivalent to saprock. The distributions of these regolith layers were modelled using the program Mining Visualization System (MVS; © C Tech Corporation). This program grids three-dimensional data by kriging, which is able to take into account variables such as trends and bias.

Output was manually filtered with "point" anomalies individually assessed. In general, data resulting in "large" errors (*i.e.*, major variation in regolith transitions which appeared to be logging errors rather than true variation) were disregarded, though with a bias for including data, rather than removing it and thus losing information. Kriging and filtering took several cycles, with less than 5% of data removed for all regolith layers. Both regolith stratigraphy and Au concentrations were gridded.

Two areas were gridded (Figure 3) and are referred to in this report as the "Sunrise region" and the "Cleo ore body". Table 1 lists the parameters used for each area. The Sunrise region covers approximately 1150 x 620 m and includes the ore body, palaeochannel and immediate surrounds. The second area, 400 x 250 m, covers the ore body only. In both cases the gridding was extended down to 280 mRL, which is approximately 120 m below surface and 35 m below the weathering front.

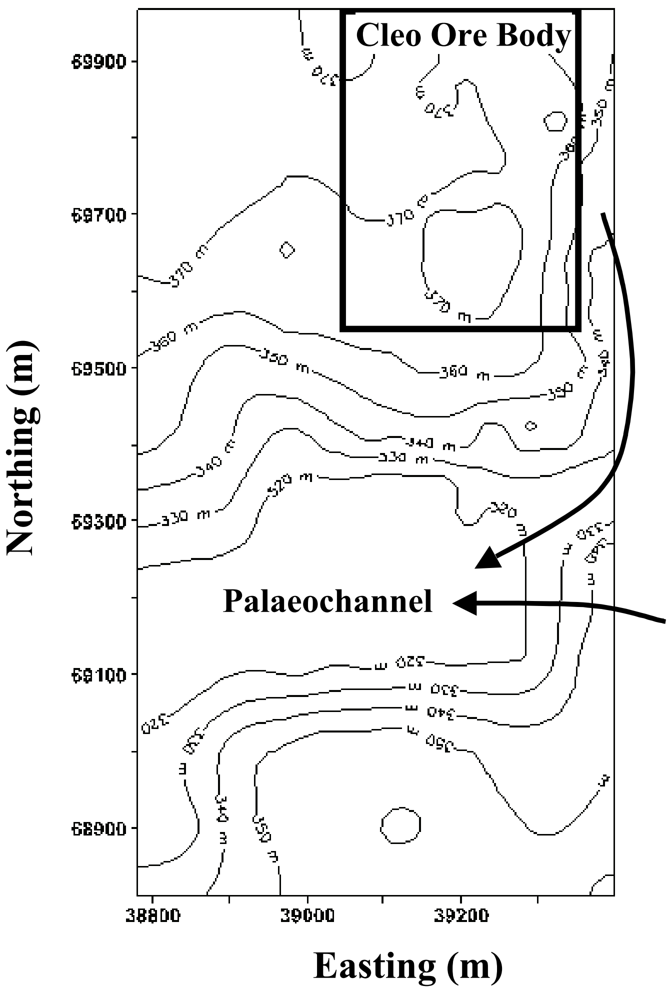

Figure 3: Palaeotopography over the Sunrise region. The entire map area, which includes the palaeochannel, and the smaller area called "Cleo Ore Body" were modelled with MVS. The arrows depict the direction of flow into the palaeochannel.

Table 1: Gridding parameters for the Sunrise region and the Cleo ore body.

		Sunrise Region	Cleo Ore Body
Krig_3D_Geology Parameters			
Kriging	Minimum X	38781	39050
	Maximum X	39398	39350
	Minimum Y	68813	69550
	Maximum Y	69967	69950
	Points	80	80
	X resolution	41	26
	Y resolution	31	41
	Boundary Offset	0	0
	Smoothing	0	0
	Gridding Option	Rectilinear	Rectilinear
Krig_3D Parameters			
Kriging	Minimum X	38781	39050
	Maximum X	39398	39350
	Minimum Y	68813	69550
	Maximum Y	69967	69950
	Minimum Z	280	280
	Maximum Z	402	399
	Points	80	120
	X resolution	46	26
	Y resolution	82	41
	Z resolution	50	121
	Rectilinear Offset	0.05	0
	Horiz./Vert. Anisotropy	2.5	2.5
Post Processing	Clip Minimum	0	0
	Clip Maximum	20	700

2.2 Regolith stratigraphy

The regolith stratigraphy of the Sunrise region was modelled both three-dimensionally and in horizontal cross section. Horizontal cross sections are slices through the earth at nominated elevations. Regolith stratigraphy is represented in the vertical cross sections of Au distribution (along nominated eastings and northings) by a gap between the layers. These diagrams are presented on the enclosed CD and described in Appendix 1.

2.3 Geochemical distribution

Gold distribution at the Sunrise region was modelled in three dimensions and in cross section, the diagrams of which are on the CD (see Appendix 1). The three-dimensional models show those parts of the regolith (coloured by stratigraphy) that contain equal to or greater than a nominated Au value. These diagrams are referred to in this report as “cut-off” diagrams.

Cross sections of Au distribution are along nominated eastings, northings and elevations. They are presented both with and without Au concentration contours. The different regolith layers are indicated by a small gap between units. Additionally, the data were filtered so that all values of 10 ppb and lower were displayed at the low end of the colour scale (blue) and all values of 1 ppm or greater were displayed at the high end of the colour scale (red), creating a greater contrast between mineralized areas and background.

2.4 Gold concentration calculations

The MVS program was used to calculate volume and Au concentration in the bedrock and regolith over both the Sunrise region, the ore body and in the palaeochannel sediments alone. Density data were not provided, so a uniform density was assumed. As the Au concentration data are mass/mass rather than mass/volume, uniform density has only a minor influence on most calculations. However, the calculated concentrations do not compensate for leaching of mobile constituents: if half of the minerals have dissolved and been leached then Au concentration will double because of residual concentration.

Gold concentration was calculated for slices defined either by elevation (e.g., 390-393 mRL) or distance from a regolith interface (e.g., 3-6 m below the unconformity) (Figure 4). Although this method is (arithmetically) correct, it can lead to over- or underestimations as the slices get further from the boundary in question. This is because, ultimately, the slice being analyzed is incomplete. This can be expressed as a reliability factor, which is the mass of the slice divided by the mass of an untruncated slice (Figure 4). A reliability index of 85% indicates that the slice is 15% truncated.

As the reliability index decreases, significant errors can occur. Figure 5 shows the results of Au content measurement for each slice below the unconformity. Though the deeper slices are truncated (Figure 5a), they can still contain mineralized material, as in this example (Figure 4). Thus, a similar mass of Au is being divided by smaller and smaller masses of regolith, which leads to anomalous calculations of Au concentration (Figure 5b). In this example, the results indicate that deepest slice has up to 440 ppb Au even though the “real” Au content is invariant at 80 ppb, except for the depletion zone at the top of the *in situ* regolith.

When all the slices with reliability indices less than 60% are removed, the remaining results can be coded for reliability (Figure 5c). A much clearer picture of Au trends emerges, illustrating depletion towards the unconformity. Note that this example is for the maximum possible overestimation of Au concentration (the maximum overestimation = 100 ÷ reliability: e.g., if reliability is 60%, maximum overestimation is 1.67; if reliability is 90%, maximum overestimation is 1.11). In other cases, underestimation can occur for low reliability samples due to a truncated intersection with mineralization. In summary, samples with reliabilities less than 80% are suspect (but can still be valuable if treated with caution), whereas those with reliability less than 60% should generally not be used.

The mean Au concentration of each regolith layer was calculated for the Cleo ore body. Additionally, Au concentrations were calculated for 3 m slices defined by elevation and slices parallel to the weathering front, the transitional/saprolite interface and the unconformity. For contrast, 3 m thick horizontal slices were used to calculate the vertical changes in Au distribution in the sediments filling the palaeochannel. The bottom 10 m of palaeochannel sediments were not included, so that the results were not affected by any Au concentration at the unconformity. These statistics are discussed in Section 4.

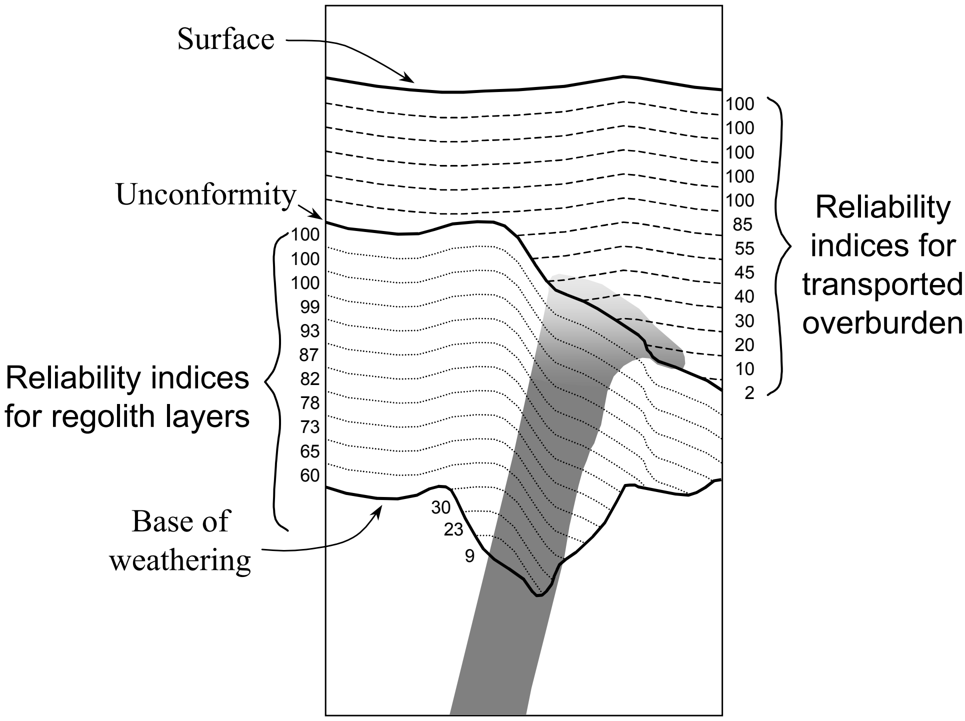

Figure 4: Diagrammatic representation of method for calculating Au concentration from slices defined for the upper surface and for the unconformity. The shaded area represents mineralization, with depletion near the top of the in situ regolith.

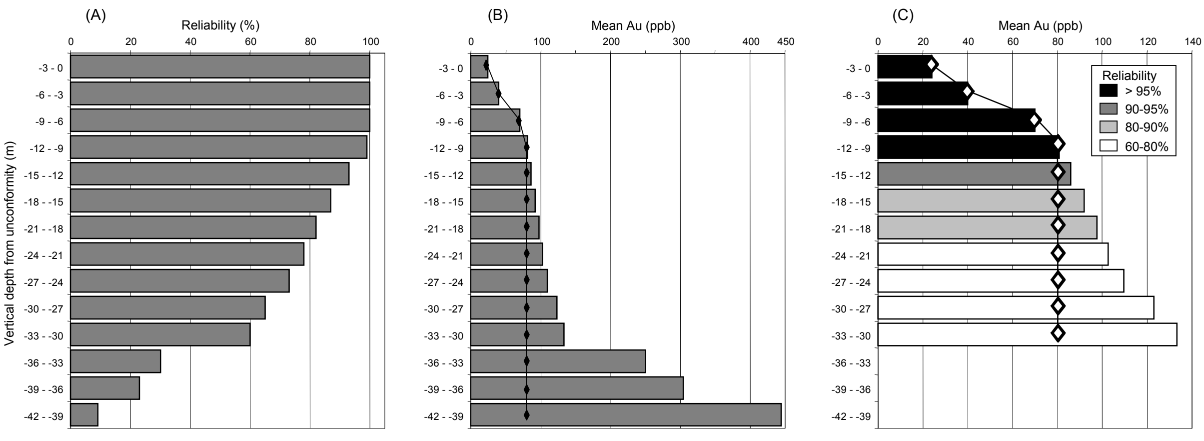

Figure 5: Calculated (a) reliability (b) unfiltered Au concentration and (c) filtered (> 60% reliability) Au concentration, colour coded to reliability, for in situ regolith. Diamonds represent expected Au concentration. Data based on situation represented in Figure 4.

3 REGOLITH STRATIGRAPHY AND PALAEOTOPOGRAPHY

The logging supplied by Acacia Resources Ltd consistently distinguished the three regolith layers – transported cover, saprolite, transitional zone - and bedrock at the Sunrise region and Cleo ore body. The transported cover consists of various aeolian, alluvial and colluvial units, including palaeochannel sediments.

Over the Sunrise region, the transported cover averages 34 m with up to an additional 60 m in the palaeochannel. Saprolite averages 33 m in thickness and the transitional zone approximately 8 m (Figure 6). These layers are at the greatest depths beneath the palaeochannel, but are thinner there, suggesting truncation.

The base of weathering is deepest beneath the palaeochannel and shallowest to the north-west (Figure 7). The geometry of the transitional/saprolite interface is similar (Figure 8). Prior to infill, the Sunrise region had considerable relief with the highest point to the north-west and an east-west trending channel the dominant feature (Figure 9). The ore body is located on the northern rise to the north-east. A smaller palaeochannel runs along the eastern flank of the ore body and feeds into the main palaeochannel (Figure 9).

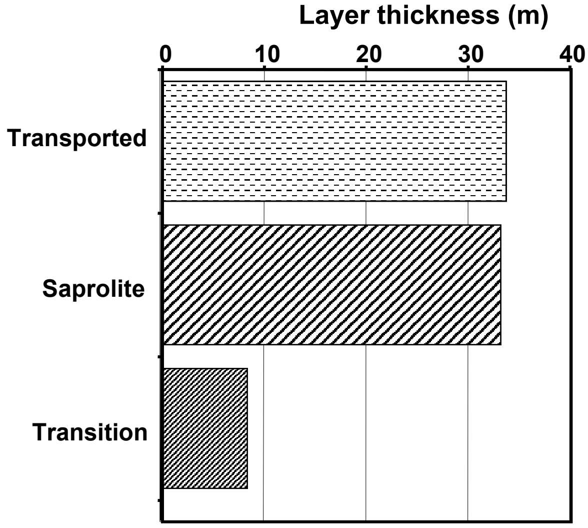

Figure 6: Average thickness of regolith layers over the Sunrise region.

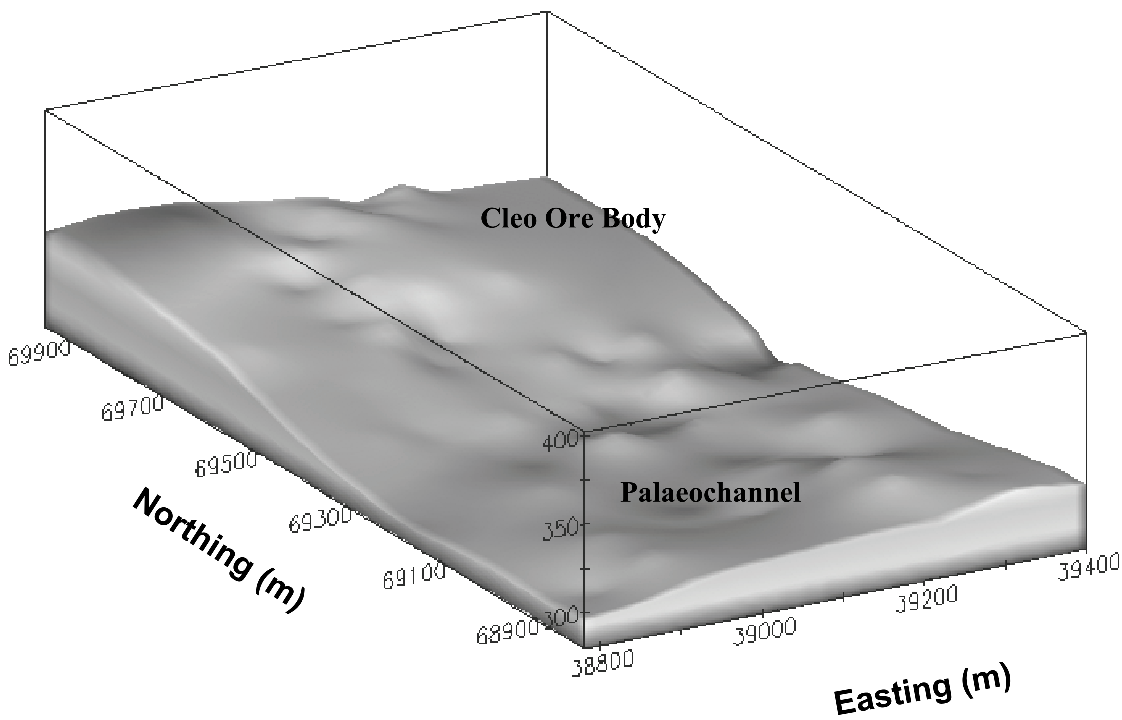

Figure 7: Base of weathering over the Sunrise region.

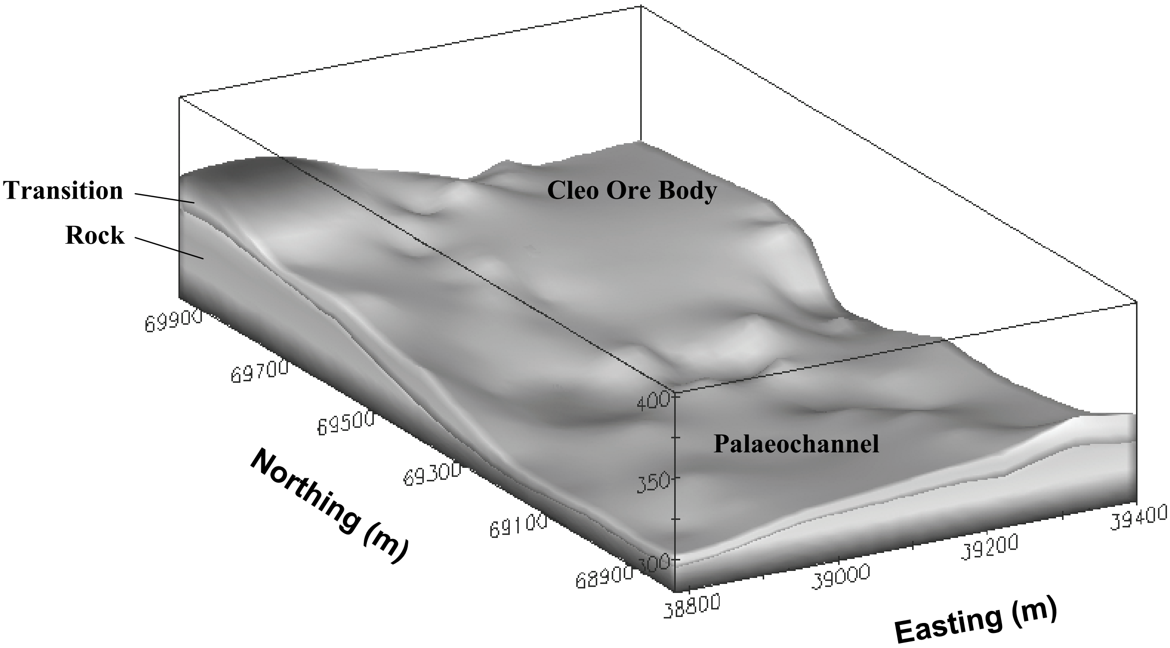

Figure 8: The transitional zone/saprolite interface over the Sunrise region.

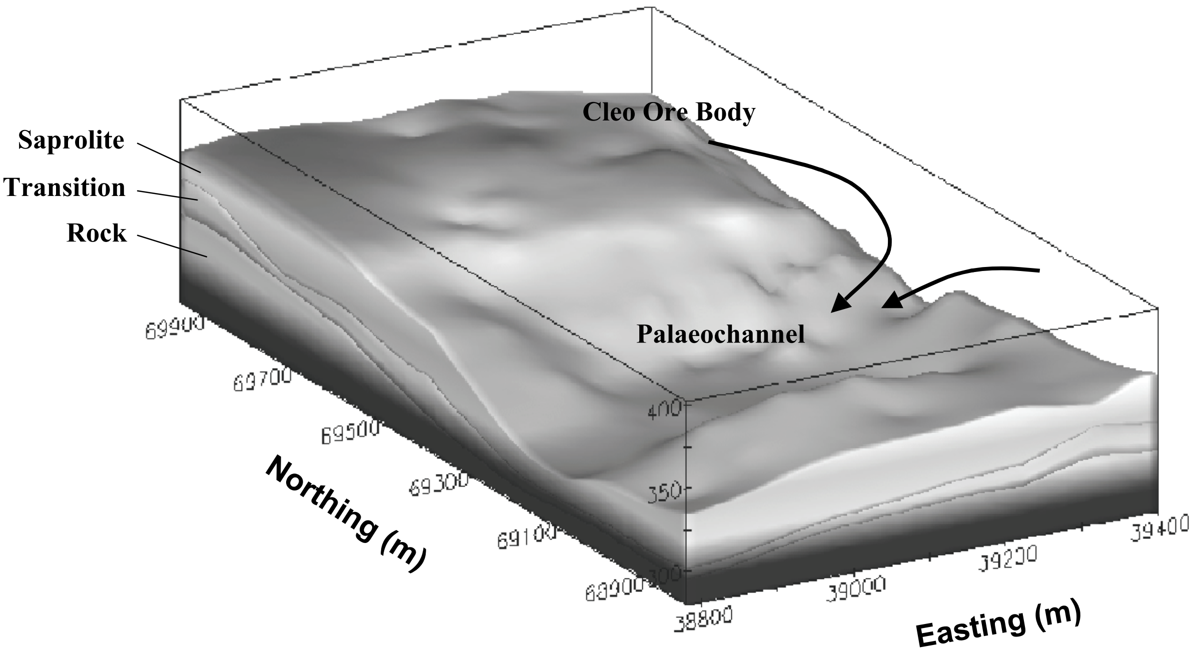

Figure 9: Base of transported overburden in the Sunrise region. See Figure 3 for topographic contours. The arrows represent the directions of flow into the palaeochannel. Of particular importance is the tributary that feeds into the main palaeochannel from the Cleo ore body.

4 DISTRIBUTION OF GOLD IN THE REGOLITH

4.1 Gold distribution at the Cleo ore body

The transitional zone averages approximately 7 m thick at the Cleo ore body (Figure 10), similar to the regional average (Figure 6). Saprolite is the dominant regolith layer at the ore body, averaging approximately 46 m thick. There is also substantial transported material, with a mean thickness of 27 m. The highest mean Au concentrations at the Cleo ore body (200 ppb) are found in the transitional zone (Figure 11). This is approximately twice the mean Au concentration in bedrock (97 ppb). Saprolite also has elevated mean Au concentrations (118 ppb) compared to bedrock. The transported material directly above the ore body is, however, relatively barren with a mean Au concentration of less than 10 ppb.

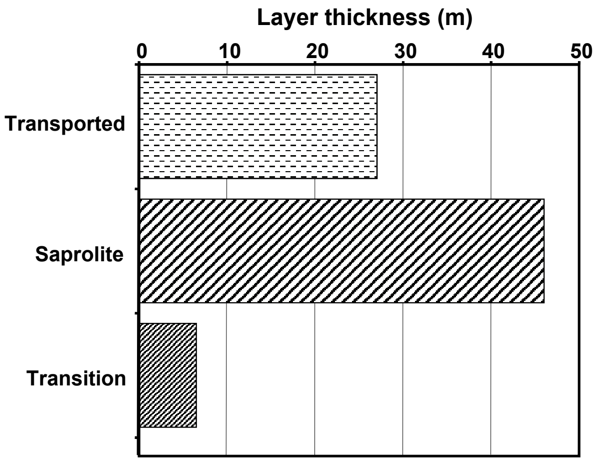

Figure 10: Average thickness of each regolith layer over the Cleo ore body.

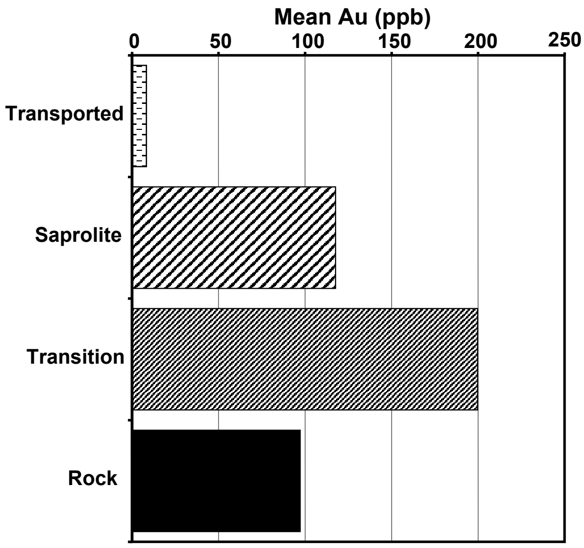

Figure 11: Mean Au concentration in regolith layers and bedrock at the Cleo ore body.

To investigate Au trends within the regolith further, mean Au concentration was plotted against elevation (Figure 12). The Au concentration peaks at approximately 330 m elevation, with mean Au concentrations between 315 and 340 m elevation at least double that found in bedrock. Above 340 m, Au content steadily decreases up profile and by 360 m elevation the upper saprolite is significantly depleted and contains less than 20 ppb Au.

Mean Au concentration was also plotted as a function of distance from the weathering front (Figure 13). Primary Au concentration appears to be quite variable, increasing substantially upwards from less than 100 ppb approximately 10 m below the weathering front to reach a mean of 190 ppb within 5 m of the transitional zone.

Within the regolith, calculations of mean Au trends either side of the transitional/saprolite interface show that this boundary has little influence on the Au distribution (Figure 14). Both the transitional material and the lower saprolite have mean concentrations slightly greater than 200 ppb. However, approximately 12 m above this boundary, Au concentrations in the saprolite start to decrease. Plots of mean Au trends either side of the unconformity (Figure 15) also clearly show the depletion in the upper saprolite, with the top 10 m containing less than 20 ppb Au. Above the ore body, the transported cover is uniformly barren, containing less than 10 ppb Au.

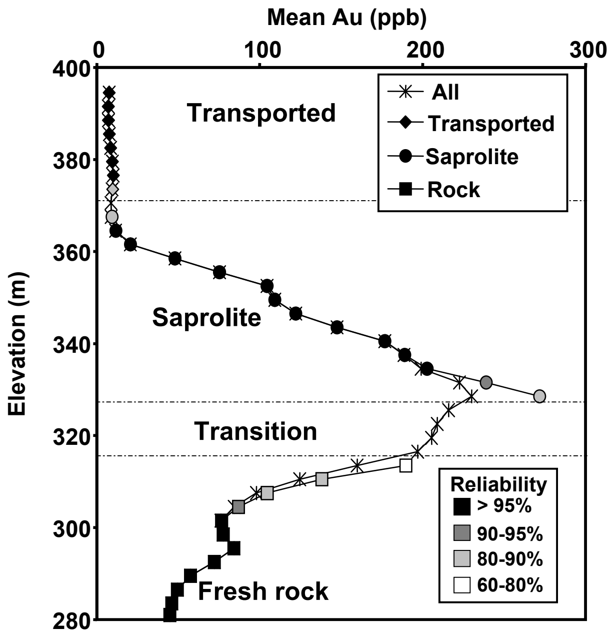

Figure 12: Mean Au concentration plotted against elevation at the Cleo ore body.

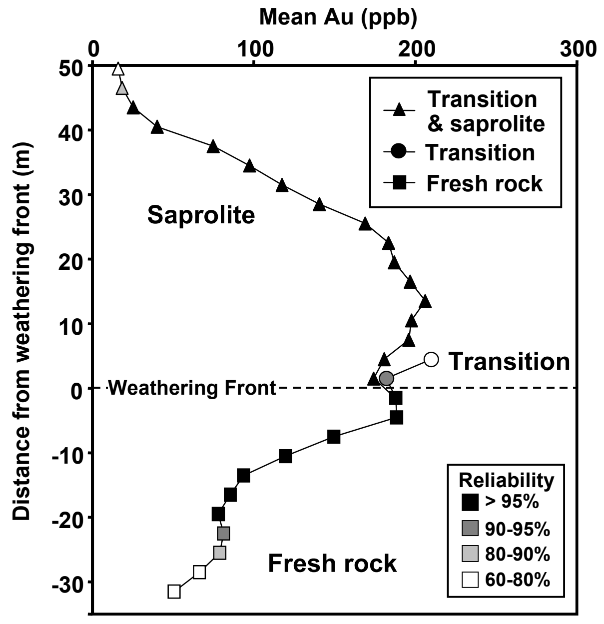

Figure 13: Mean Au concentration trends on either side of the base of weathering, Cleo ore body.

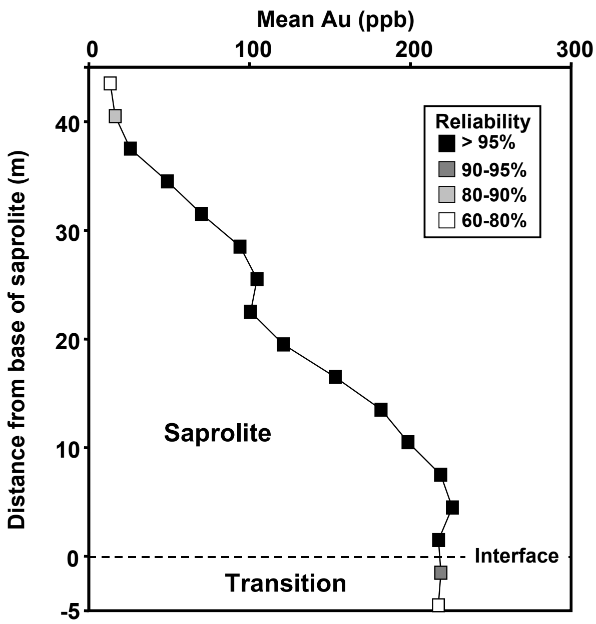

Figure 14: Mean Au concentration trends on either side of the transitional-saprolite interface, Cleo ore body.

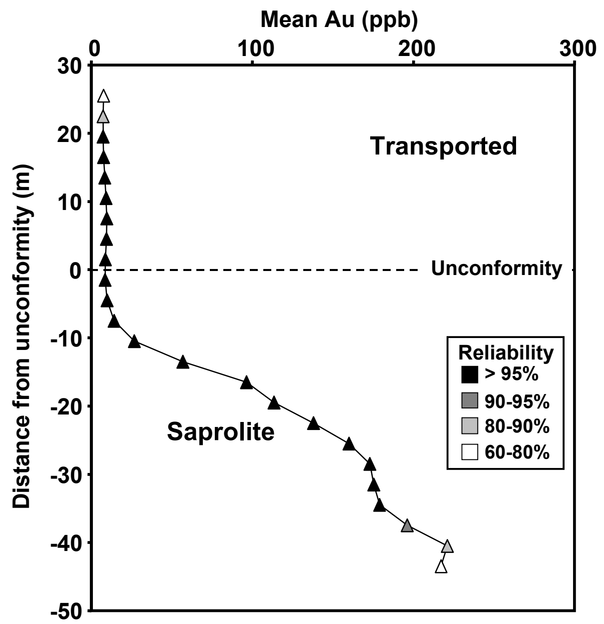

Figure 15: Mean Au concentration trends on either side of the unconformity over the Cleo ore body.

4.2 Gold distribution over the Sunrise region

Gold distributions over the Sunrise region have been visualized as both three-dimensional models and in cross sections, both of which are included on the report CD. Horizontal slices through the region clearly show the Cleo mineralization (in red) to the north-east (Figure 16). These slices also reveal that the palaeochannel sediments immediately to the south of the ore body have variable Au content, in contrast to the transported material overlying the Cleo ore body (Section 4.1). At 340 m elevation, the transported material in nearly all the palaeochannel contains between 50 and 200 ppb (Figure 16A). In contrast, the shallower sediments overlying the ore body have a mean Au concentration of less than 10 ppb. Note that these sediments are above 350 mRL, which is above the depletion front in the residuum (Figure 12). Near the base of the palaeochannel, at 320 m, Au concentrations reach 1 ppm or greater, but are patchy with at least half the channel area containing less than 50 ppb at this elevation (Figure 16B).

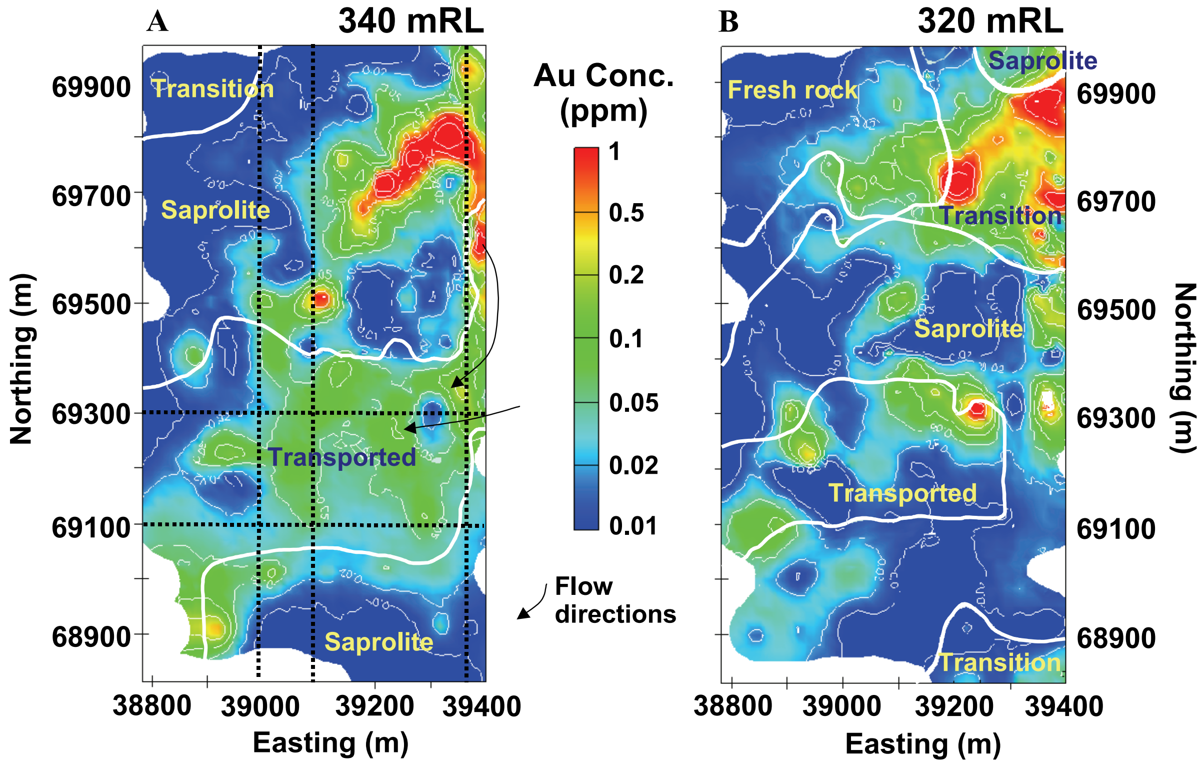

Figure 16: Plans of Au distribution in horizontal slices through the Sunrise region. The slices intersect different regolith zones, as indicated. The Cleo ore body can be clearly seen in the north-east corner (in red). A) Au distribution at 340 m elevation. Gold concentrations between 50 and 200 ppb are widespread in the palaeochannel sediments at this depth. Dotted lines mark the cross sections depicted in Figure 17 and Figure 18. B) Gold distribution at 320 m elevation. The basal palaeochannel sediments have patchy Au content.

Vertical cross sections across the region further reveal the pattern of Au dispersion in the residual regolith and palaeochannel sediments (Figures 17 and 18). The cross sections show that, as the calculations of Au concentration indicate (Section 4.1), Au content is generally highest in the residual regolith developed over mineralization, particularly in the transitional zone and lower saprolite. In areas where the unconformity is shallower (e.g., Figure 17B; northing greater than 69500) cross sections show depletion in the upper saprolite. This is not observed if the unconformity is at elevations below 350 mRL (e.g., Figures 17C).

A

B

C

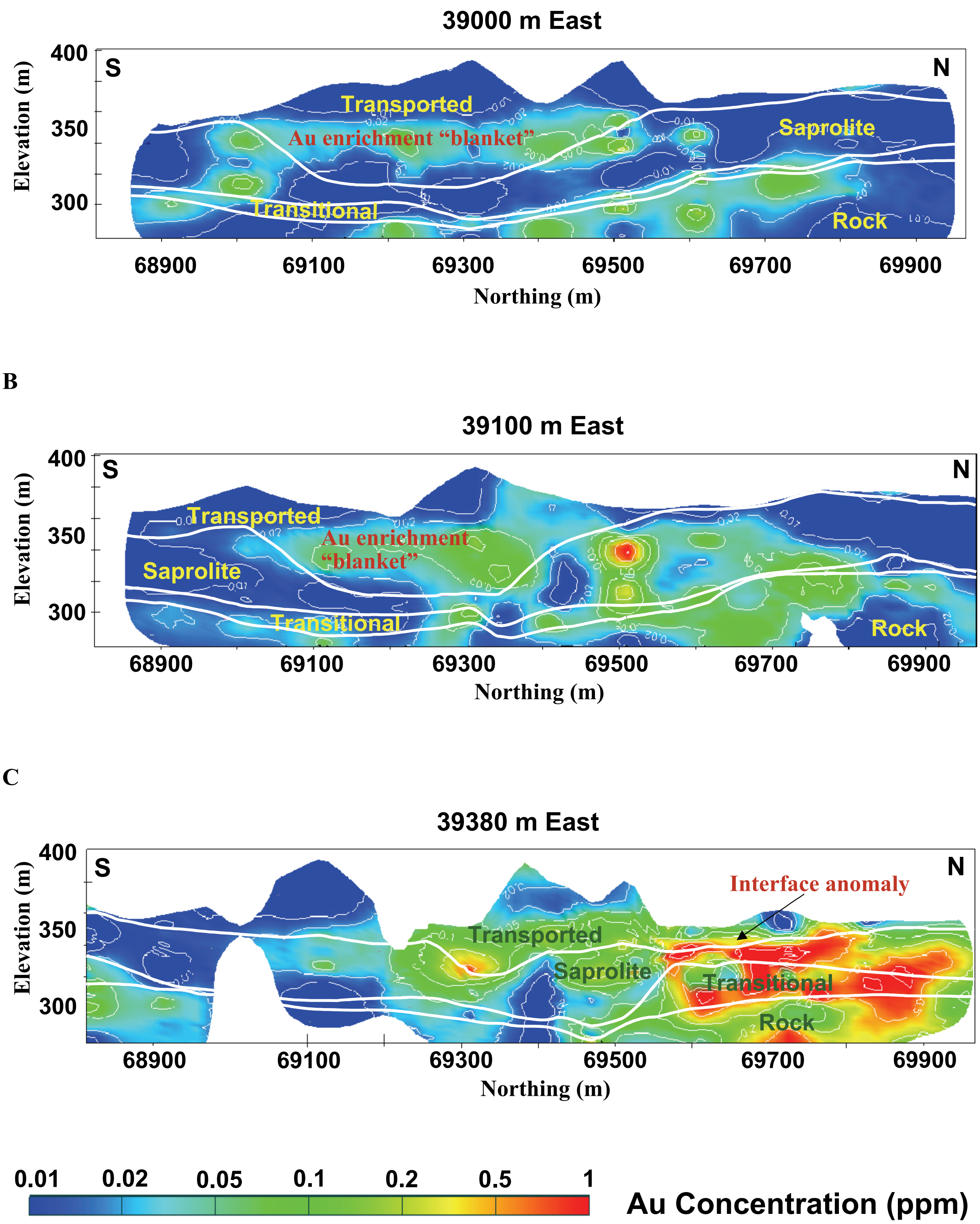

Figure 17: Gold distribution along north-south cross sections of the Sunrise region. See Figure 16 for reference. A) Gold distribution over 39000 m East. B) Gold distribution over 39100 m East. C) Gold distribution over 39380 m East.

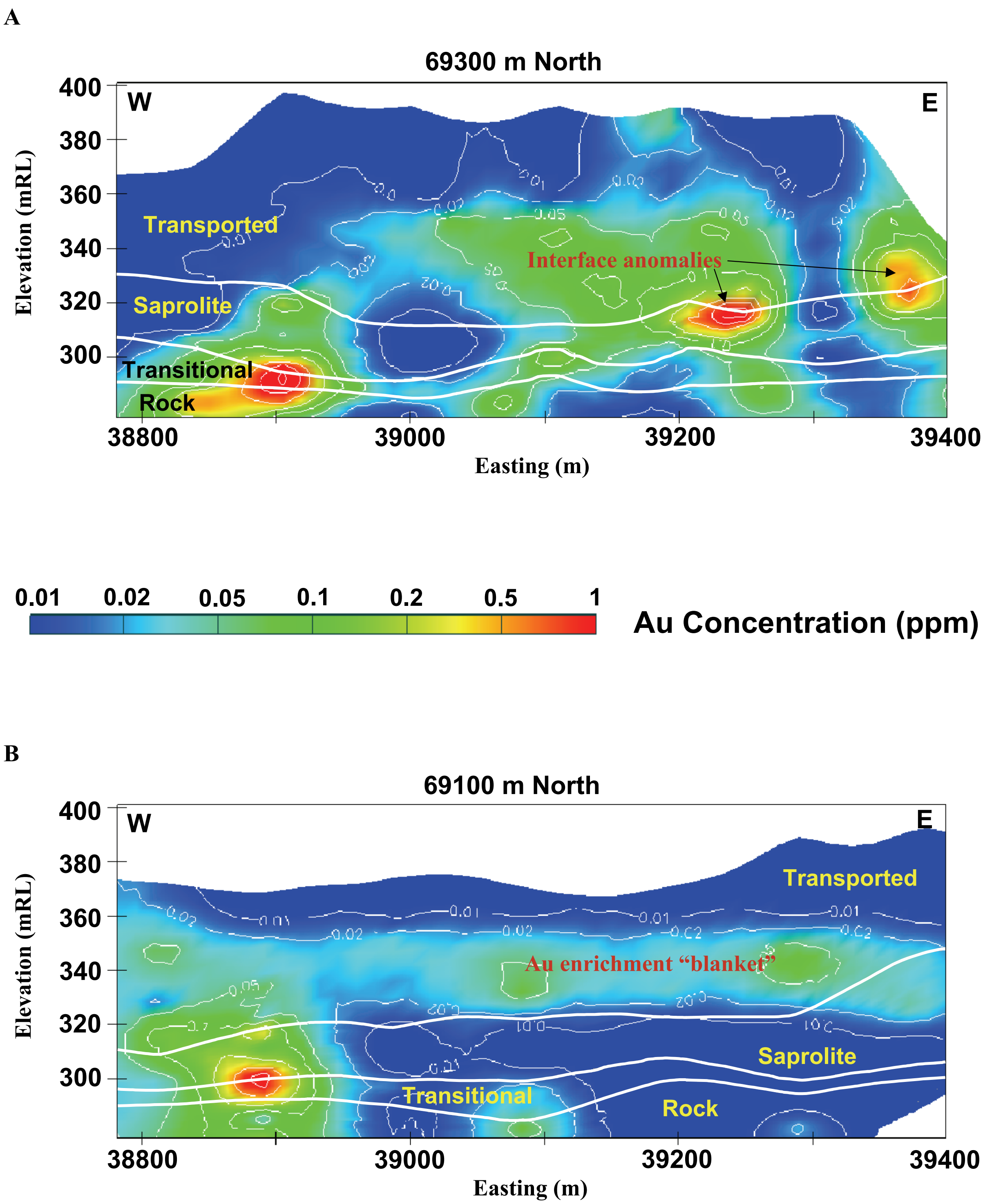

Figure 18: Gold distribution along east-west cross sections over the Sunrise region. See Figure 16 for reference. A) Gold distribution along 69300 m North. Gold is enriched in the sediments where they abut mineralization in the residual profile. B) Gold distribution along 69100 m North. Gold is enriched in the palaeochannel sediments as a "blanket".

Within the palaeochannel sediments, there appears to be two main forms of Au enrichment. Firstly, Au enrichment occurs in patches along the unconformity where it abuts mineralization (e.g., Figure 18A). Secondly, Au enrichment occurs in the palaeochannel sediments as a "blanket" (e.g., Figures 17A and 18B) approximately between 325 to 340 m elevation. In order to assess the degree of enrichment in the Au "blanket", Au concentrations in the palaeochannel sediments were calculated against elevation. The bottom 10 m of the sediments was disregarded so that the basal enrichment was not included in the calculations. The results show that between 325 and 340 m elevation Au concentration averages over 160 ppb and reaches 300 ppb Au (Figure 19).

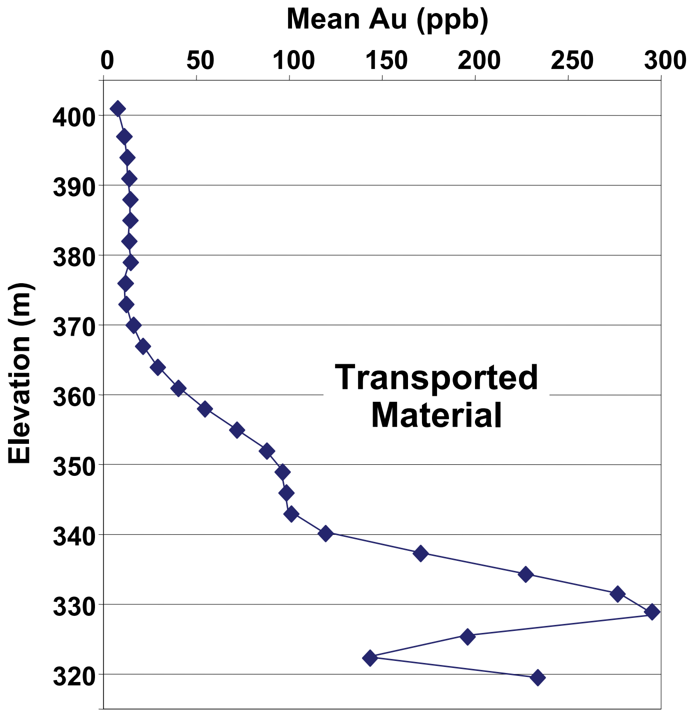

Figure 19: Au distribution in the Cleo palaeochannel, excluding sediment in the first 10 m above the unconformity.

5 DISCUSSION AND CONCLUSIONS

Investigations at the Cleo deposit using MVS indicate that the transitional zone averages 7 m thickness over the ore body and 8 m over the region. Saprolite is the thickest residual layer and averages 46 m over the ore body and 33 m regionally. These layers have formed at greatest depth beneath the palaeochannel but are thinner there, possibly suggesting a degree of truncation. The transported cover averages 27 m in thickness over the ore body, 34 m regionally and there is up to 60 m additional sedimentary infill in the palaeochannel.

Primary Au grades appears to be quite variable, substantially increasing approximately 10 m below the weathering front and reaching a mean of 190 ppb within 5 m of the transitional zone. Thus, the mean Au concentrations within the transitional zone, although the highest in the profile, may simply reflect originally high grades in the primary mineralization. The base of weathering, however, is often difficult to identify accurately, particularly when logging drill cuttings. Discussions with company personnel indicate that the actual base of weathering, as observed in the pit, could be as much as 10 m lower than indicated in the drill logging. Consequently, there is the distinct possibility that the elevated Au concentrations in material logged as upper bedrock (possibly transitional), and in the transitional zone, are actually due to supergene enrichment.

Gold content is generally highest in the residual regolith developed over mineralization and peaks in the transitional zone and lower saprolite at approximately 330 m elevation. Mean Au between 315 and 340 m is at least double the primary Au concentrations. Above 340 m elevation, Au is depleted, with concentrations decreasing up profile, with the upper saprolite above 360 m mRL containing less than 20 ppb Au. The transported material directly above the ore body, is uniformly barren with less than 10 ppb Au.

Within the palaeochannel sediments, there appear to be two main forms of Au enrichment. Firstly, Au enrichment occurs in patches along the unconformity where it abuts mineralization and, secondly, Au enrichment occurs in the palaeochannel sediments as a "blanket" approximately between 325 to 340 m elevation. A conceptual diagram (Figure 20) illustrates the two forms of Au enrichment in the palaeochannel sediments.

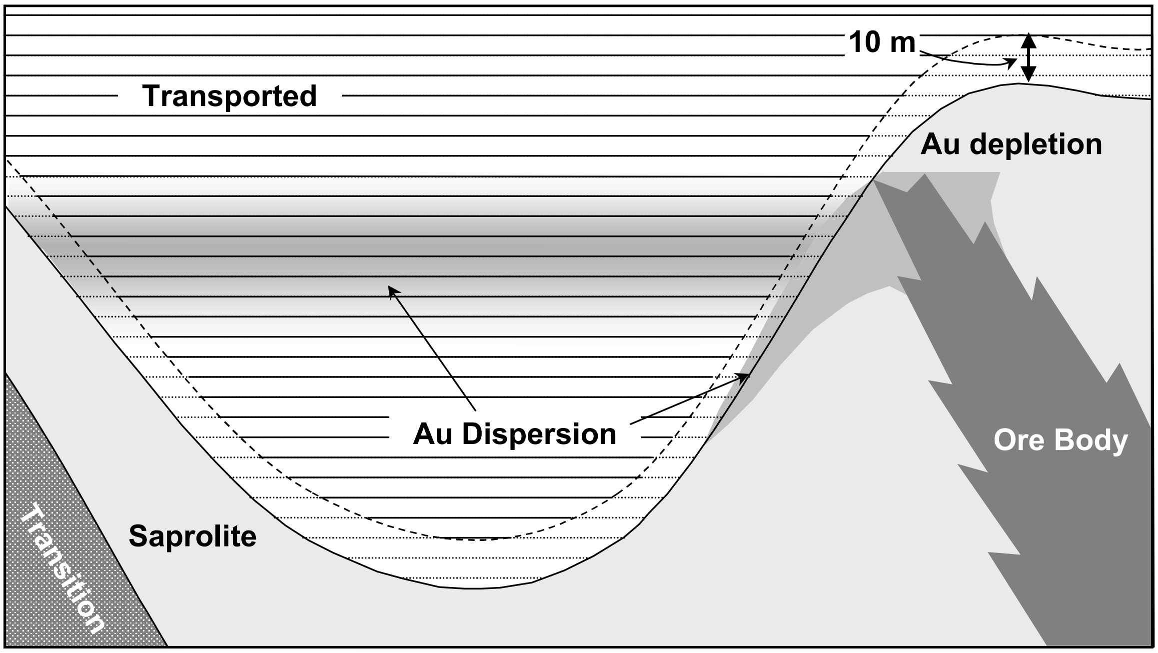

Figure 20: Conceptual diagram for Au dispersion in the Cleo palaeochannel. Gold is dispersed in the basal sediments along the unconformity and as a "blanket" within the sediments. The 10 m line marks the basal sediments excluded from the Au concentration calculations presented in Figure 19.

A critical question unanswered in this study is whether the enrichment blanket in the palaeochannel is chemogenic or physical in origin. The extreme horizontality and general homogeneity in Au concentration throughout the blanket suggests a chemogenic origin, though complete or partial physical transport can not be entirely discounted. Further studies of the regolith material within the enrichment blanket (e.g., presence of pisoliths, etc.) and the form and location of the Au (e.g., presence of primary grains, location within grains or on surface) would probably resolve this ambiguity.

Similar investigations were undertaken at the Argo gold deposit (Britt and Gray, 1999). Argo is located approximately 28 km south-east of Kambalda and 2 km east of Lake Lefroy. It provides an interesting comparison with the Cleo site as it is also adjacent to a palaeochannel containing up to 60 m of infill. Like the Cleo ore body, Argo also has Au enrichment in the basal channel sediments abutting mineralization. Unlike Cleo, however, there is no enrichment "blanket" within the sediments. The Au contents in sediments at Argo, in general, steadily decrease up profile from the basal enrichment.

The difference in Au distribution in these two palaeochannels might lie in the characteristics of the groundwater and the nature of the sedimentary infill. Groundwaters at Argo are typical of the Kalgoorlie region in being highly saline and highly acidic, a combination which should readily dissolve Au. However the groundwaters at Argo contain relatively little Au, suggesting a mature system in which all the available Au has already been removed. The sediments in the Argo palaeochannel are lignitic and it is possible that as Au disperses from the residual profile and enters the reducing environment in the channel it becomes trapped in the basal sediments or within other reduced material abutting the unconformity.

Groundwater data from Cleo are not available but the nearby Golden Delicious deposit (approximately 9 km distant, Figure 2) has groundwaters with high salinity but low acidity (Bristow *et al.*, 1996). They are an order less corrosive than those in the Kalgoorlie region. The palaeochannel sediments at Cleo consist of green-grey to white clays with ferruginous horizons and mottles (Newton *et al.*, 1998) and might, therefore, be less reducing than those found at Argo. Lignite is not observed in the immediate vicinity of Cleo. As such, Au in the Cleo palaeochannel, whilst not as readily dissolved as at Argo, might be more readily dispersed within the sediments.

Both the top of the Au enrichment "blanket" occurring in the palaeochannel sediments and the depletion front over the ore body occur at around 340 m elevation. This is consistent with both features being a result of groundwater processes.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of Acacia Resources Ltd and AngloGold Australasia Ltd, with particular thanks for the provision of the database. Dr Ravi Anand and Mr Melvyn Lintern are thanked for reviewing this report prior to release. Dr Charles Butt provided advice and support during the progress of this study.

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Britt, A.F. and Gray, D.J., 1999. Supergene gold dispersion at the Argo and Apollo deposits, Western Australia. CRC LEME Restricted Report 114R, 53pp.

Butt, C.R.M., Gray, D.J., Robertson, I.D.M., Lintern, M.J., Anand, R.R., Britt, A.F., Bristow, A.P.J., Munday, M.J., Phang, C., Smith, R.E. and Wildman, J.E., 1997. Geochemical exploration in areas of transported overburden, Yilgarn Craton and environs, Western Australia. CRC LEME Restricted Report 36R, 150pp.

Newton, P.G.N., Gibbs, D., Grove, A., Jones, C.M. and Ryall, A.W., 1998. Sunrise-Cleo gold deposit. In: Berkman, D.A. and Mackenzie, D.H. (Eds.). Geology of Australian and Papua New Guinean Mineral Deposits. The Australasian Institute of Mining and Metallurgy, Melbourne, p179-186.

APPENDIX 1 CONTENTS OF ENCLOSED CD

- 3D Au Models
- Plans
  - Au concentrations
  - Au contours
  - Regolith
- Report
- Slices
  - Au concentrations
  - Au contours
- Stratigraphy
- Views

3D Au Models

This folder contains three-dimensional images of Au distribution at particular cut-offs, e.g., a 30 ppb cut-off shows all those parts of the profile that contain 30 ppb or greater Au concentration. The profile is coloured according to regolith stratigraphy.

File:	Depicts:
100ppbAu.bmp	Au distribution with 100 ppb cut-off, looking NNE
1ppmAu.bmp	Au distribution with 1 ppm cut-off, looking NNE
200ppbAu.bmp	Au distribution with 200 ppb cut-off, looking NNE
20ppbAu.bmp	Au distribution with 20 ppb cut-off, looking NNE
2ppmAu.bmp	Au distribution with 2 ppm cut-off, looking NNE
30ppbAu.bmp	Au distribution with 30 ppb cut-off, looking NNE
40ppbAu.bmp	Au distribution with 40 ppb cut-off, looking NNE
500ppbAu.bmp	Au distribution with 500 ppb cut-off, looking NNE
50ppbAu.bmp	Au distribution with 50 ppb cut-off, looking NNE
70ppbAu.bmp	Au distribution with 70 ppb cut-off, looking NNE

Plans

This folder contains three subfolders:

- **Au concentrations**
- **Au contours**
- **Regolith**

The "Plans" folder contains plans of Au distribution and regolith along horizontal slices, at particular elevations, through the Cleo deposit. In the "Au concentrations" and the "Au contours" subfolders, narrow gaps represent regolith boundaries. Additionally the horizontal slices used in "regolith" subfolder match the Au distribution images. The "Au contours" subfolder differs from the "Au concentrations" subfolder in that concentration contours are marked along each plan.

🗁 Au concentrations

File:	Depicts:
280mRL.bmp	Au distribution at 280 m elevation.
290mRL.bmp	Au distribution at 290 m elevation.
300mRL.bmp	Au distribution at 300 m elevation.
310mRL.bmp	Au distribution at 310 m elevation.
320mRL.bmp	Au distribution at 320 m elevation.
330mRL.bmp	Au distribution at 330 m elevation.
335mRL.bmp	Au distribution at 335 m elevation.
340mRL.bmp	Au distribution at 340 m elevation.
345mRL.bmp	Au distribution at 345 m elevation.
350mRL.bmp	Au distribution at 350 m elevation.
355mRL.bmp	Au distribution at 355 m elevation.
360mRL.bmp	Au distribution at 360 m elevation.
365mRL.bmp	Au distribution at 365 m elevation.
370mRL.bmp	Au distribution at 370 m elevation.
375mRL.bmp	Au distribution at 375 m elevation.
380mRL.bmp	Au distribution at 380 m elevation.

🗁 Au contours

File:	Depicts:
280mRLI.bmp	Au distribution with concentration contours at 280 m elevation.
290mRLI.bmp	Au distribution with concentration contours at 290 m elevation.
300mRLI.bmp	Au distribution with concentration contours at 300 m elevation.
310mRLI.bmp	Au distribution with concentration contours at 310 m elevation.
320mRLI.bmp	Au distribution with concentration contours at 320 m elevation.
330mRLI.bmp	Au distribution with concentration contours at 330 m elevation.
335mRLI.bmp	Au distribution with concentration contours at 335 m elevation.
340mRLI.bmp	Au distribution with concentration contours at 340 m elevation.
345mRLI.bmp	Au distribution with concentration contours at 345 m elevation.
350mRLI.bmp	Au distribution with concentration contours at 350 m elevation.
355mRLI.bmp	Au distribution with concentration contours at 355 m elevation.
360mRLI.bmp	Au distribution with concentration contours at 360 m elevation.
365mRLI.bmp	Au distribution with concentration contours at 365 m elevation.
370mRLI.bmp	Au distribution with concentration contours at 370 m elevation.
375mRLI.bmp	Au distribution with concentration contours at 375 m elevation.
380mRLI.bmp	Au distribution with concentration contours at 380 m elevation.

🗁 Regolith

File:	Depicts:
280mRL.bmp	Regolith at 280 m elevation.
290mRL.bmp	Regolith at 290 m elevation.
300mRL.bmp	Regolith at 300 m elevation.
310mRL.bmp	Regolith at 310 m elevation.
320mRL.bmp	Regolith at 320 m elevation.
330mRL.bmp	Regolith at 330 m elevation.
335mRL.bmp	Regolith at 335 m elevation.
340mRL.bmp	Regolith at 340 m elevation.
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355mRL.bmp	Regolith at 355 m elevation.
360mRL.bmp	Regolith at 360 m elevation.
365mRL.bmp	Regolith at 365 m elevation.
370mRL.bmp	Regolith at 370 m elevation.
375mRL.bmp	Regolith at 375 m elevation.
380mRL.bmp	Regolith at 380 m elevation.

🗁 Report

This folder contains the Cleo report.

🗁 Slices

This folder contains two subfolders:

- 🗁 **Au concentrations**
- 🗁 **Au contours**

The "Slices" folder contains slices of Au distribution at particular eastings and northings through the Cleo deposit. The "Au contours" subfolder differs from the "Au concentrations" subfolder in that concentration contours are marked along each slice. Narrow gaps represent the regolith boundaries.

🗁 Au concentrations

File:	Depicts:
38800mE.bmp	Au distribution along a N-S transect at 38800 m East
38900mE.bmp	Au distribution along a N-S transect at 38900 m East
39000mE.bmp	Au distribution along a N-S transect at 39000 m East
39100mE.bmp	Au distribution along a N-S transect at 39100 m East
39200mE.bmp	Au distribution along a N-S transect at 39200 m East
39300mE.bmp	Au distribution along a N-S transect at 39300 m East
39380mE.bmp	Au distribution along a N-S transect at 39400 m East
68820mN.bmp	Au distribution along a E-W transect at 68820 m North

68900mN.bmp	Au distribution along a E-W transect at 68900 m North
69000mN.bmp	Au distribution along a E-W transect at 69000 m North
69100mN.bmp	Au distribution along a E-W transect at 69100 m North
69200mN.bmp	Au distribution along a E-W transect at 69200 m North
69300mN.bmp	Au distribution along a E-W transect at 69300 m North
69400mN.bmp	Au distribution along a E-W transect at 69400 m North
69500mN.bmp	Au distribution along a E-W transect at 69500 m North
69600mN.bmp	Au distribution along a E-W transect at 69600 m North
69700mN.bmp	Au distribution along a E-W transect at 69700 m North
69800mN.bmp	Au distribution along a E-W transect at 69800 m North
69900mN.bmp	Au distribution along a E-W transect at 69900 m North

🗁 Au contours

File:	**Depicts:**
38800mEI.bmp	Au distribution with concentration contours along a N-S transect at 38800 m East
38900mEI.bmp	Au distribution with concentration contours along a N-S transect at 38900 m East
39000mEI.bmp	Au distribution with concentration contours along a N-S transect at 39000 m East
39100mEI.bmp	Au distribution with concentration contours along a N-S transect at 39100 m East
39200mEI.bmp	Au distribution with concentration contours along a N-S transect at 39200 m East
39300mEI.bmp	Au distribution with concentration contours along a N-S transect at 39300 m East
39380mEI.bmp	Au distribution with concentration contours along a N-S transect at 39400 m East
68820mNI.bmp	Au distribution with concentration contours along a E-W transect at 68820 m North
68900mNI.bmp	Au distribution with concentration contours along a E-W transect at 68900 m North
69000mNI.bmp	Au distribution with concentration contours along a E-W transect at 69000 m North
69100mNI.bmp	Au distribution with concentration contours along a E-W transect at 69100 m North
69200mNI.bmp	Au distribution with concentration contours along a E-W transect at 69200 m North
69300mNI.bmp	Au distribution with concentration contours along a E-W transect at 69300 m North
69400mNI.bmp	Au distribution with concentration contours along a E-W transect at 69400 m North
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69600mNI.bmp	Au distribution with concentration contours along a E-W transect at 69600 m North
69700mNI.bmp	Au distribution with concentration contours along a E-W transect at 69700 m North
69800mNI.bmp	Au distribution with concentration contours along a E-W transect at 69800 m North
69900mNI.bmp	Au distribution with concentration contours along a E-W transect at 69900 m North

🗁 Stratigraphy

This folder contains the Microsoft PowerPoint file “layers.ppt” containing 5 slides depicting the palaeotopography, base of weathering, base of saprolite and the regolith stratigraphy in three dimensions.

Slide	Depicts:
1.	Regolith stratigraphy, looking NNE
2.	Regolith stratigraphy, layers exploded, looking NNE
3.	Palaeotopography – the unconformity, looking NE
4.	The base of saprolite, looking NE
5.	The base of weathering, looking NE

🗁 Views

This folder contains three-dimensional images of Au distribution at particular cut-offs, e.g., a 30 ppb cut-off shows all those parts of the profile that contain 30 ppb or greater Au concentration. Additionally, regolith boundaries are displayed by a mesh - green=rock/transition interface (base of weathering), red=transition/saprolite interface and yellow=saprolite/transported interface (unconformity).

File:	Depicts:
100ppb.bmp	Au distribution with 100 ppb cut-off, looking ENE
1ppm.bmp	Au distribution with 1 ppm cut-off, looking ENE
200ppb.bmp	Au distribution with 200 ppb cut-off, looking ENE
20ppb.bmp	Au distribution with 20 ppb cut-off, looking ENE
30ppb.bmp	Au distribution with 30 ppb cut-off, looking ENE
40ppb.bmp	Au distribution with 40 ppb cut-off, looking ENE
500ppb.bmp	Au distribution with 500 ppb cut-off, looking ENE
50ppb.bmp	Au distribution with 50 ppb cut-off, looking ENE
70ppb.bmp	Au distribution with 70 ppb cut-off, looking ENE