



Original Article

Determining the optimal soil sample grid spacing to explore for epithermal gold deposits in a tropical wet and dry environment: an example from the La India mining district, Nicaragua

L.T.P. English¹

Abstract

Soil sampling is a useful tool for the assessment of large areas of land where low sulphidation epithermal vein mineralisation is known or suspected. It provides a quantitative means of mapping out the geometry of an epithermal system and identifying potentially economic gold concentrations. In this paper gold in soil geochemistry data from the La India gold mining district in Nicaragua is used to model the soil gold signature at different sample grid spacing over known gold resources. The most cost-effective or optimal soil sample grid spacing to explore for epithermal gold deposits in this tropical wet and dry environment is identified. La India gold mining district covers a 50 km² area of fault-fill gold-silver mineralized quartz-adularia veins in western Nicaragua. The distribution of gold veins is well understood with current estimates defining a mineral endowment of over 2.3 Moz gold. The exploration data includes full coverage of the district by a 200 m by 50 m soil survey of fine-fraction B-horizon soil with ultra-trace multi-element analysis. Soil close to the gold veins is enriched in gold at trace level. Gold resources and prospects can be effectively ranked using the soil data with the larger resources correlating to broader, higher-grade soil gold anomalies. The soil gold content can be used to map-out the geometry and distribution of the epithermal vein system. In this study the soil survey data is filtered to create simulated 200 m by 200 m and 400 m by 400 m soil grids. The simulated grids are assessed against the mapped veins, surface rock chip and trench results, and known mineral resources. It is concluded that a 200 m by 200 m soil grid is adequate to discover economic vein gold deposits in the soil type found in the tropical wet and dry zone of western Nicaragua. This grid spacing provides enough resolution to map out vein trends and the overall geometry of an epithermal vein system that is exposed at surface and provides sufficient resolution to rank the gold anomalies by size and grade with confidence that the ranking will broadly correlate with associated gold occurrences. A 400 m by 400 m spaced soil sampling does appear to detect the larger deposits but will miss smaller or partially hidden deeper-seated deposits, and the spacing is too wide to provide any useful information on epithermal vein orientation or network geometry.

Keywords: soil geochemistry; gold; vein; low sulphidation epithermal; La India mining district; Nicaragua

Affiliation Info: ¹ Mina La India, Santa Rosa del Peñón, Dept. León, Nicaragua.

Corresponding Author : English, L, PhD, Professional Geologist; Email: lucenglish@yahoo.com.au.

Citation: English, L.T.P. 2025. Determining the optimal soil sample grid spacing to explore for epithermal gold deposits in a tropical wet and dry environment: an example from the La India mining district, Nicaragua. *Naturalis Scientias*, 2 (1): 377-393. DOI: <https://doi.org/10.62252/NSS.2025.1026>. www.naturalisscientias.com.

Copyright © 2025 by the author. Published by *Naturalis Scientias*. This is an open access article under the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License. (<https://creativecommons.org/licenses/by-nc/4.0/>).



1. Introduction

Soil geochemistry sampling has been successfully used in the exploration and discovery of mineral deposits, including low sulphidation epithermal gold-silver vein deposits for a long time. Soil geochemistry can be used to detect these deposits either by looking for concentrations of the sought after minerals, gold and silver, or by looking for concentrations of other minerals that may be concentrated within the ore veins, the so-called pathfinder elements. If a more extensive suite of elements is analysed, then the soil geochemistry can also be used to help map the host geology and identify areas of hydrothermal alteration that may be associated with the mineralisation.

The soil samples are typically collected at regular intervals on a grid pattern across an area of interest. Several factors are considered when designing the grid pattern used in a soil geochemical survey: geology, vegetation and soil type, terrain and access, budget and time must be considered. In areas with limited soil development or where much of the soil has been covered by a thick transported cover, or restricted access then a regular grid survey may not be possible and practices such as ridge-and-spur sampling may be the best option. In areas where there is widespread soil development and reasonable access then a regular grid pattern is preferred to provide full coverage. Close-spaced samples along traverse lines perpendicular to the dominant regional structural or geological trend and/or the strike direction of any known mineralised veins in the area has been a popular practice. However, recently it has become more common to use an unbiased regular spaced grid pattern such as a square or triangular grid because it is recognised that low sulphidation epithermal vein systems at district-scale often contain a network of veins with two or more oblique strike directions. An unbiased grid pattern is more likely to detect and define the orientation of veins in any direction, whereas a set of soil traverses will bias detection and interpretation to veins that are perpendicular to the traverses and may miss veins that are parallel or at an acute angle.

Soil samples can be analysed in a laboratory, typically using a method that can detect very low concentrations of elements such as inductively coupled plasma mass spectrometry (ICP-MS). Portable X-ray fluorescence spectrometers are a cost-effective and quick alternative for the analysis for many elements, but a laboratory analysis is still required to analyse gold at the low levels of detection required to provide meaningful data.

Soil geochemical surveys are usually constrained by a budget, so once the decision has been made on the analytical technique to be used then the challenge is to design a soil survey grid that covers the area of interest using the least number of samples required to detect and preferably define the orientation of any potentially economic mineralisation.

In this paper the extensive and high-resolution soil geochemistry data that was collected over the La India mining district in Nicaragua is used as a case study to determine the most cost-efficient soil survey grid that would have been required to discover and outline the orientation of all the known potentially economic gold-silver mineralisation in the La India mining district. The existing soil database is filtered to simulate soil geochemistry surveys at different spacing. The simulations are assessed to determine how effective the soil survey is at detecting and ranking the known deposits and prospects and at defining the geometry of the known gold occurrences and vein system. The findings can be used as a guide for

explorers looking for similar low sulphidation epithermal gold-silver deposits in a similar terrain and environment: moderate relief terrain with light woodland in a tropical wet and dry climate.

2. Case study-La India gold-silver mining district

The La India gold mining district in the tropical wet and dry zone of western Nicaragua has an extensive high-resolution soil geochemistry survey dataset over a low sulphidation epithermal gold-vein district which contains multiple past producing mine workings, a development-level open pit mine reserve and several potentially economic gold-silver resources (Figure 1).

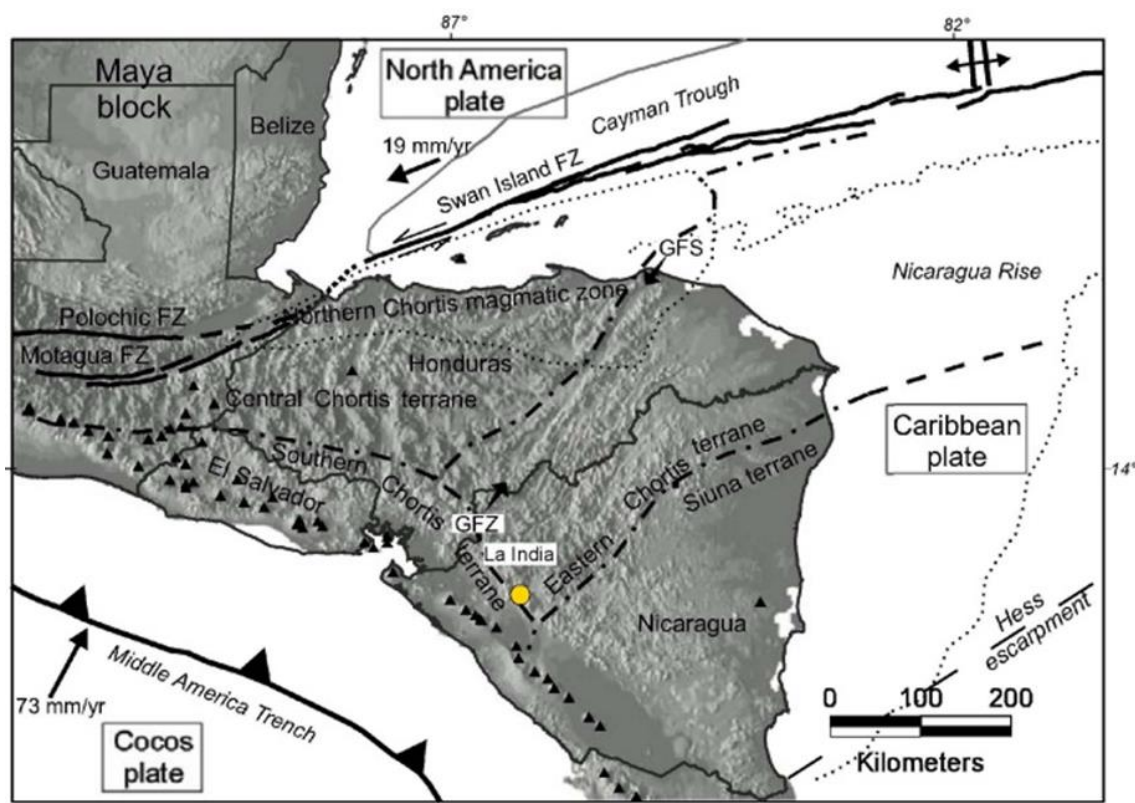


Figure 1. Location of the La India district in western Nicaragua (from Rogers et al. 2007¹)

3. Geology and mineralisation of La India Mining District

The La India gold mining district covers a 50 km² area on the western margin of a Tertiary volcanic arc that runs along the west side of Nicaragua. The district-scale gold-silver mineralisation at La India is found in two adjacent geological settings with distinct mineralization characteristics: (1) an upland area of strongly faulted felsic to andesitic

volcanics where the historic mine workings are located, and (2) an adjacent downthrown graben, the Sebaco Graben, where a thick sequence of andesite is preserved overlying the felsic volcanic sequence (Figure 2). Gold mineralisation is classified as rift margin-type low-sulphidation epithermal gold-silver vein mineralization in fault and fracture-fill veins. In the historic mining area erosion has exposed the top of the high-grade epithermal zone. Minimal erosion in the Sebaco Graben means that the epithermal system is fully preserved and predominantly occurs as deep-seated, partially hidden low sulphidation epithermal mineralization locally associated with hydrothermal sinter outcrops, and also as near surface gold mineralization in a phreatic breccia pipe².

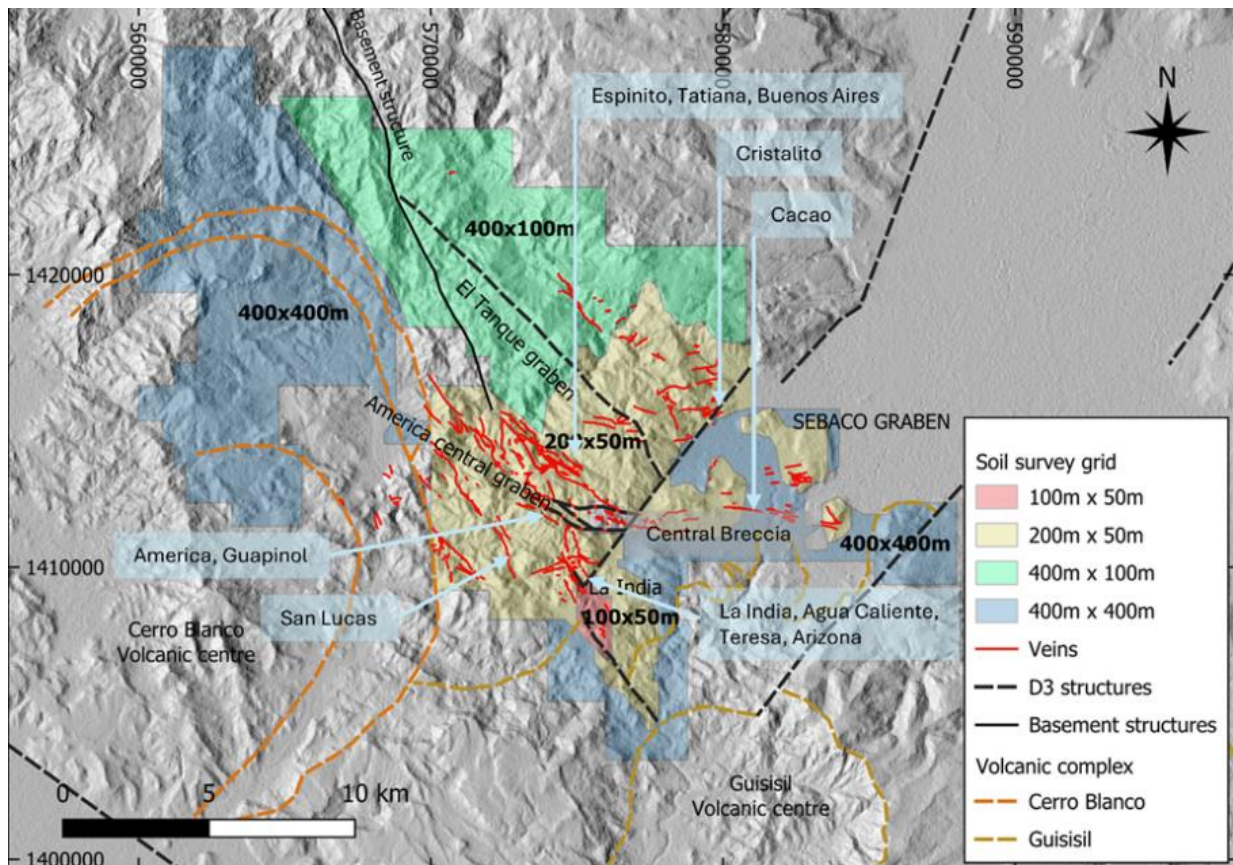


Figure 2. Map showing the soil geochemistry survey coverage at different grid spacing over La India district and the location of the main volcanic complexes and principal geological structural blocks. Digital elevation topographic model background (adapted from English et al.²).

Apart from the one phreatic breccia, the gold-silver mineralisation occurs in quartz veins and breccias that filled brittle faults and associated fractures and fissures. The structures containing the gold-silver mineralisation occur in at least three orientations: (1) a predominant northwest to north-northwest set; (2) secondary but locally extensive east-west, and (3) tertiary shorter and narrower northeast and north-striking veins. The gold-silver mineralisation is best developed where these structures pass through competent felsic

volcanics, welded tuffs and the massive andesite, and is less well developed where the structures pass through less competent unwelded tuffs and volcanic agglomerates².

Historic mining records from a period of underground gold and silver mining in the mid-20th Century, and well-documented modern mineral exploration since the late 1980s has identified 110 kilometres of surficial gold-silver veins, a mineralised breccia pipe and two hidden deep-seated gold-silver veins³. The exploration has been well documented and provides a database of over 4,500 rock chip samples, 1776 trenches for almost 29,000 m of channel samples, and 625 drill holes for over 96,000 m of rock samples, most of which collected continuous samples of rock core, satellite-derived digital terrain models and a 280km² area airborne radiometric and magnetic geophysical surveys, and a grid of over 12,000 soil samples². This extensive dataset has been used to estimate a significant mineral resource in the La India district: the current concession holders have defined a 2.3 Moz gold endowment⁴.

4. Climate, landscape and soil at La India mining district

Climate and terrain play an important role in determining the degree and extent of physical and chemical gold mobilisation in soil. The La India mining district is in an area of moderate to steep relief on the western side of the Central Highlands of Nicaragua, predominantly hills and mesas ranging between 300 m and almost 1000 m altitude and some lowland plains, notably the Sebaco Plain in the east (Figure 3).



Figure 3. Left: Typical moderate relief landscape in the La India mining district which was covered by a regular grid soil geochemistry survey in 2015-2017. Right: Screening a soil sample at <3 mm mesh to sample the fine fraction in the field

The climate is characterised as tropical wet and dry (savannah) according to the Köppen system with an average annual rainfall of 1000 - 1400 mm concentrated in the six months between May and October. The temperature is relatively constant with average year-round temperatures ranging between 20°C and 30°C with cooler weather at higher altitudes.

The upland areas are a mixture of light tropical thorny forest and land cleared for pasture and seasonal crops of corn or beans. The tops of some of the hills at altitudes over 800 m support pine forests. The lowland plains are mostly cleared for pasture, apart from the flattest areas of the Sebaco Plains, beyond of the soil survey area, which are periodically flooded to cultivate rice.

In the upland areas the soil thin with a poorly developed organic horizon. The texture of the residual B-horizon which was sampled in the soil geochemistry survey is determined by the bedrock lithology: a thin sandy horizon where the bedrock is felsic volcanic, a sandy-clayey soil where the bedrock is tuff, and a thicker clayey soil which passes downward into a saprolite where the bedrock is andesite (Figure 4). Soil that has developed on thick transported deposits such as colluvial aprons at the foot of some slopes and alluvial river sediment were not sampled.



Figure 4. Left: Soil sampling thin soil horizon over weathered felsic volcanic bedrock, and (Centre:) trenches revealing the sandy soil developed over tuff and (Right:) the clayey soil over saprolitic andesite

5. Soil geochemistry data at La India mining district

This study uses a database of 12,476 soil samples that were collected on grids ranging between a close-spaced 100 m x 50 m in the historic mining zone to a wide-spaced 400 m x 400 m on outlying regions (Table 1). Samples were collected from the B-horizon, just below the organic A-horizon. Soil was collected with a clean shovel, sieved using a <math><3\text{mm}</math> mesh and any organic particles removed by hand and a 750 g to 1 kg sample collected. The soil samples were then prepared at the certified Bureau Veritas Inspectorate sample preparation laboratory in Managua by drying and screening the <math><180\ \mu\text{m}</math> fraction (-80 mesh). A 200 g sample of the fine fraction was sent for analysis by aqua regia digest and 53-element suite ultra-trace level ICP-MS at the Bureau Veritas (formerly Acme) Laboratory in Vancouver, Canada. The gold value has a stated detection limit of 0.2 ppb⁵.

Table 1. Summary of soil geochemistry survey grid spacing coverage in the La India mining district

Grid spacing	No. of samples	Area (km ²)
50 m × 100 m	320	2
50 m × 200 m	9,257	90
100 m × 400 m	1,476	80
400 m × 400 m	1,423	140
TOTAL	12,476	312

Reviews of the soil geochemistry clearly demonstrated that the soil gold value is the most reliable indicator of gold mineralisation in the bedrock with elevated soil gold results clearly correlating with the mapped veins and supported by rock chip and trench samples collected at surface⁶. The soil gold anomalies are best developed in the upland area where the gold veins are exposed at surface (Figures 5-6). Lower gold values occur over the deeper-seated gold mineralisation in the downthrown Sebaco graben. In these areas where the residual soil has developed from rocks that were located above the level of the epithermal mineralisation then pathfinder elements such as mercury, tellurium, thallium, arsenic and antimony that are associated with the hydrothermal outflow zone above the epithermal system can be used to detect the hidden mineralisation⁷. However, at the La India district exploration for deep-seated hidden and partially hidden deposits is still at an early stage and there is not enough data available to confidently correlate the soil pathfinder element signature to deep-seated gold mineralisation. Therefore, this study only tests the use of soil gold signature as a method of discovering gold vein deposits.

6. Determining the background gold in soil value

In order to identify soil gold anomalies that are associated with vein mineralisation then it is first necessary to establish the background threshold gold value, and to choose higher threshold values to help distinguish low level dispersal of gold in soil, and low level gold occurrences from significant occurrences that may have economic potential. There are several visual and statistical methods that can be used to determine the background gold value. Commonly used methods include using the mean value plus two standard deviations⁸⁻⁹, cumulative graph inflection points, probability graphs¹⁰, arbitrarily application of the 95th percentile value. Jarva et al.¹¹ suggest using the upper limit of the upper whisker line (ULBL) which is based on the 25% and 75% percentile values using the formula $ULBL = P75 + 1.5 \times (P75 - P25)$. In a soil geochemistry survey that has been confined to a gold district where there is widespread dispersal and dilution of gold mineralisation in the soil away from the mineralised veins then there is considerable overlap between the background and mineralised population domains¹². The statistical methods return a wide range of threshold values which can be useful guides to choosing the various thresholds between background, distal and proximal soil dispersion (Table 2).

Table 2. Statistical determination of the gold in soil background threshold using mean plus two times standard deviation, 95th percentile and upper limit of the upper whisker line (ULBL) methods

	No. of soil samples	Mean+2SD Au (ppb)	95 th percentile Au (ppb)	ULBL threshold Au (ppb)
Mining district	9578	254	37	14
All samples	12476	222	30	12

A visual analysis guided by statistics of the soil survey data covering the known mineralisation at La India district can be a more effective way of determining a background value. Pratt and Flindell⁶ suggested that all the known gold veins can be detected using a 10 ppb gold background threshold (Figure 5) which is close to the statistically derived ULBL background threshold.

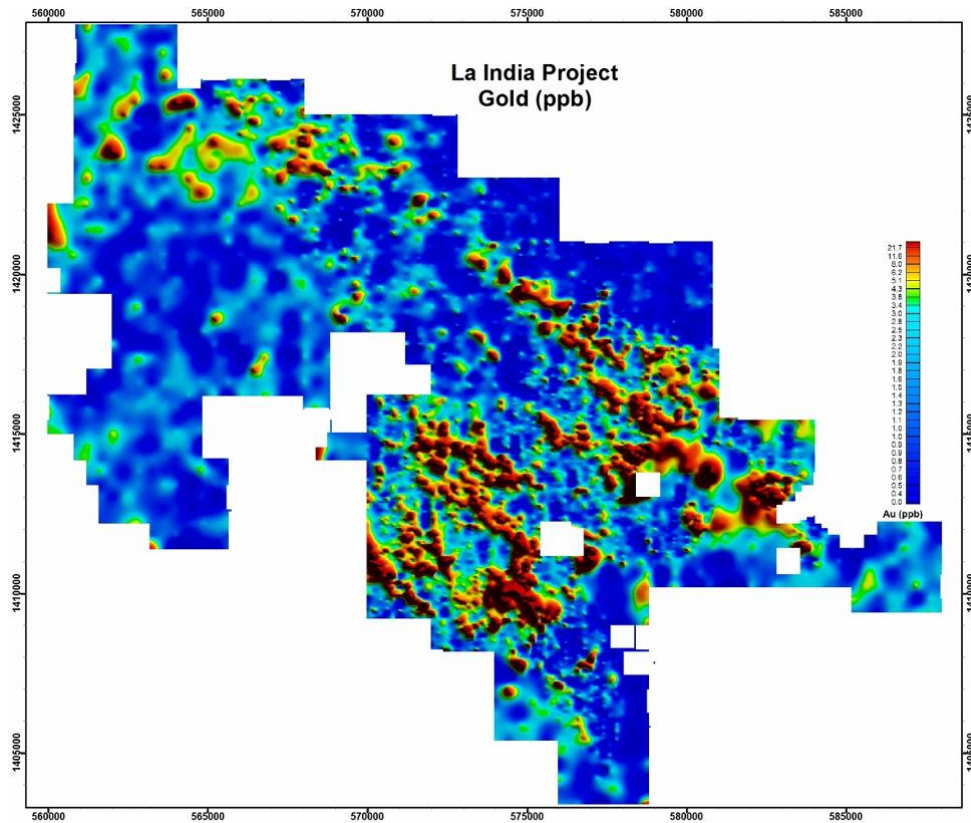


Figure 5. Gold in soil over La India mining district showing a 10 ppb background threshold (yellow-red) clearly defines all known veins (from Pratt & Flindell⁶)

This is also consistent with a compilation of data from unmineralised rocks by Pitcairn¹² which suggests that a background value is typically between 0.5 and 5 ppb. Significant gold mineralisation has a higher threshold. The thirteen veins that currently support gold-silver mineral resources all have at least one sample >25 ppb gold (Figs 5-6). Plans of the soil gold values are presented here with a standardized colour coding built on a 10 ppb gold background with >25 ppb gold considered significant and >250 ppb gold a priority target (Figure 6, Table 3).

Table 3. Comparing the distribution of soil gold values for the soil database with the simulated 200 m by 200 m and 400 m by 400 m soil grids

	200 m × 50 m		200 m × 200 m		400 m × 400 m	
	No.	%	No.	%	No.	%
No. samples	9577	100	2407	25	662	7
< detection	6603	68.95	1665	69.17	451	68.13
>10 ppb Au	1651	17.24	424	17.62	111	16.77
>25 ppb Au	686	7.16	172	7.15	49	7.4
>50 ppb Au	358	3.74	90	3.74	29	4.38
>100 ppb Au	177	1.85	41	1.7	15	2.27
>250 ppb Au	61	0.64	10	0.42	4	0.6
>500 ppb Au	27	0.28	4	0.17	2	0.3
>1000 ppb Au	14	0.15	1	0.04	1	0.15

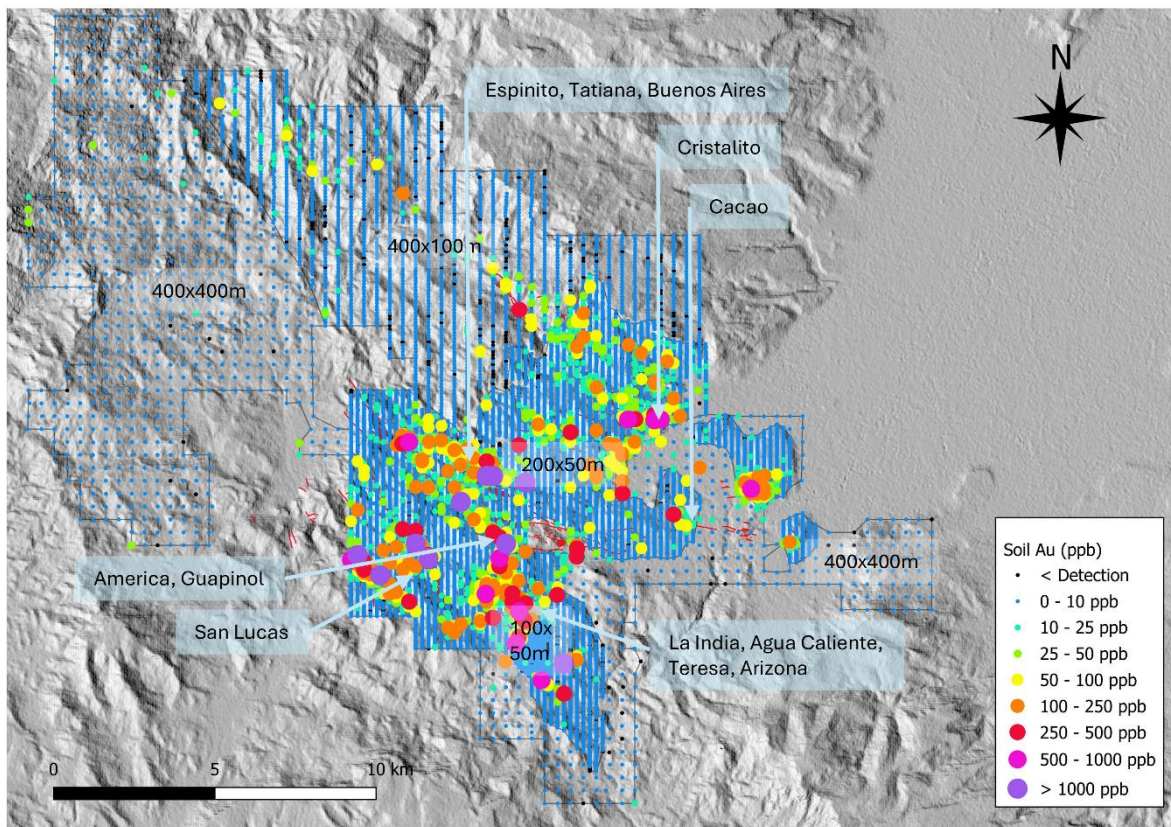


Figure 6. Soil sampling coverage over La India mining district

7. Analytical method

Soil samples in La India mining district were collected on grids ranging between 100 m by 50 m and 200 m by 50 m over the area of known gold vein mineralisation. Outlying areas beyond the known mineralisation was covered by a wider-spaced and 400 m by 400 m grid. This study aims to test the effectiveness of using an unbiased square-grid at different grid spacings over the area of known mineralisation to determine the most cost-effective sample



spacing that would still have discovered all the potentially economic gold veins and still defined the geometry of the vein system. There are two unbiased square grid spacings that can be filtered out of the available data to simulate using a square grid. A 200 m x 200 m square grid can be extracted from the core 92 km² core area which covers most of the mineralisation, and a 400 m x 400 m square grid can be filtered across the entire area, including the core area.

The simulated grids were created by first creating idealised 200 m by 200 m and 400 m by 400 m grids and then filtering the La India soil data using QGIS™ geographic information software 'distance matrix tool'. The filter selects the nearest actual soil sample to each of the idealised grid locations to create the simulated grid with real datapoints, thus simulating the results of sampling on these grid spacings.

The simulated 200 m by 200 m and 400 m by 400 m soil grids were then compared with the known distribution of the gold resources, prospects and occurrences as determined by mapping, surface rock chip, trench sampling and drilling. A comparison with the effectiveness of the actual closer spaced full soil dataset was also made. The effectiveness of each simulated grid is determined by considering: (1) how many of the known resources and mineralised veins could be detected, (2) whether the soil anomalies can be ranked correctly based on the size and maximum grade of the soil anomaly, and (3) whether the orientation of the principal veins and the geometry of the vein network could be interpreted from the soil gold data.

The aim of the analysis is to determine the optimal soil grid spacing to explore for low sulphidation epithermal gold in a tropical wet and dry environment, and to provide a guide to the cut-off gold in soil value that should be considered a target for further exploration.

The aim of the analysis is to determine the optimal soil grid spacing to explore for low sulphidation epithermal gold in a tropical wet and dry environment, and to provide a guide to the cut-off gold in soil value that should be considered a target for further exploration.

8. Results

Comparison of the two simulated soil survey grids can be made within a 92 km² area covering the main mineral resource area that has been covered by both the 200 m by 200 m and the 400 m by 400 m soil survey simulations. The cost differences between the grids are considerable. Ultimately an exploration company will be considering the cost per unit area of any soil geochemistry survey and the cost is dominated by collection and analysis costs and approximately proportional to the number of samples. With 2407 samples the 200 m x 200 m simulated grid uses only 25%, and with only 662 samples the 400 m by 400 m grid has 7% as many samples as the existing 9577 close-spaced soil samples.

A summary of the gold values of the data over this area shows a similar grade distribution with 68-69% of the samples being below detection and approximately 7% of the samples over 25 ppb gold which is considered a useful detection threshold for significant gold mineralisation (Table 3).



9. Discussion

An effective soil geochemistry survey will locate all economic or potentially economic gold veins with a recognisable soil gold anomaly. The grade and extent of these gold occurrences should be indicated by the soil gold values and the size of the area of the soil anomaly. An effective soil survey will also reveal the orientation of the mineralised veins and the geometry of the vein system at a district scale, contributing valuable information to the geological interpretation of the mineralisation and guiding future exploration. The effectiveness of the 200 m by 200 m and the 400 m by 400 m soil survey simulations at fulfilling these objectives are compared and considered below.

9.1 Effectiveness at detecting known gold resources

All the current mineral resources are revealed by the current close-spaced soil survey by multiple anomalous soil values over 25 ppb gold. Applying the 25 ppb cut-off the simulated 200 m by 200 m soil grid detects all the mineral resources except for the relatively small Arizona and Espinito deposits, albeit only the larger two deposits, La India and America have multiple samples above the threshold. It is noted that both these deposits narrowly miss the cut-off and do have anomalous soil gold with soil samples of 24 and 20 ppb associated with each respectively. It is also noted that both are close to or linked to another of the larger deposits and so it is reasonable to assume the soil anomaly from the larger would have led explorers to the vicinity and that they would have been discovered.

The 400 m by 400 m soil grid has a very low discovery rate using a 25 ppb gold in soil threshold with only the two larger deposits of La India and America and two of the smaller resources, San Lucas and Agua Caliente registering. It is important to note that it is not even a reliable method to discover the larger deposits as the third largest deposit Tatiana does not make the threshold and would potentially be passed over¹ (Table 3).

9.2 Effectiveness at identifying the size of the known gold resources

The size of the deposits causing the soil anomalies can be estimated and the anomalies ranked by a combination of the size or area covered by the soil anomaly exceeding a given threshold, in this case 25 ppb gold, and by the tenure reflected by the maximum gold value.

Comparison of the 200 m by 200 m simulated soil grid with the existing close-spaced soil survey data suggests that both are equally effective at indicating the size of the deposits with La India and America providing the expected largest anomaly in both cases. San Lucas is ranked third which is higher than the resource would suggest, perhaps suggesting that this is an under-drilled target. The other resources score similarly. The only divergence from the expected order is the Tatiana deposit which appears to have a weaker than

expected soil anomaly on the 200 m by 200 m grid with only one 61 ppb gold soil sample exceeding the threshold.

The 400 m by 400 m grid only appears to detect the largest deposits and misses the smaller deposits. The 400 m by 400 m grid has effectively detected and ranked the same three deposits highest, La India, America and San Lucas, but does not detect many of the others even if the detection threshold is reduced to 10 ppb gold (Figure 7, Table 4).

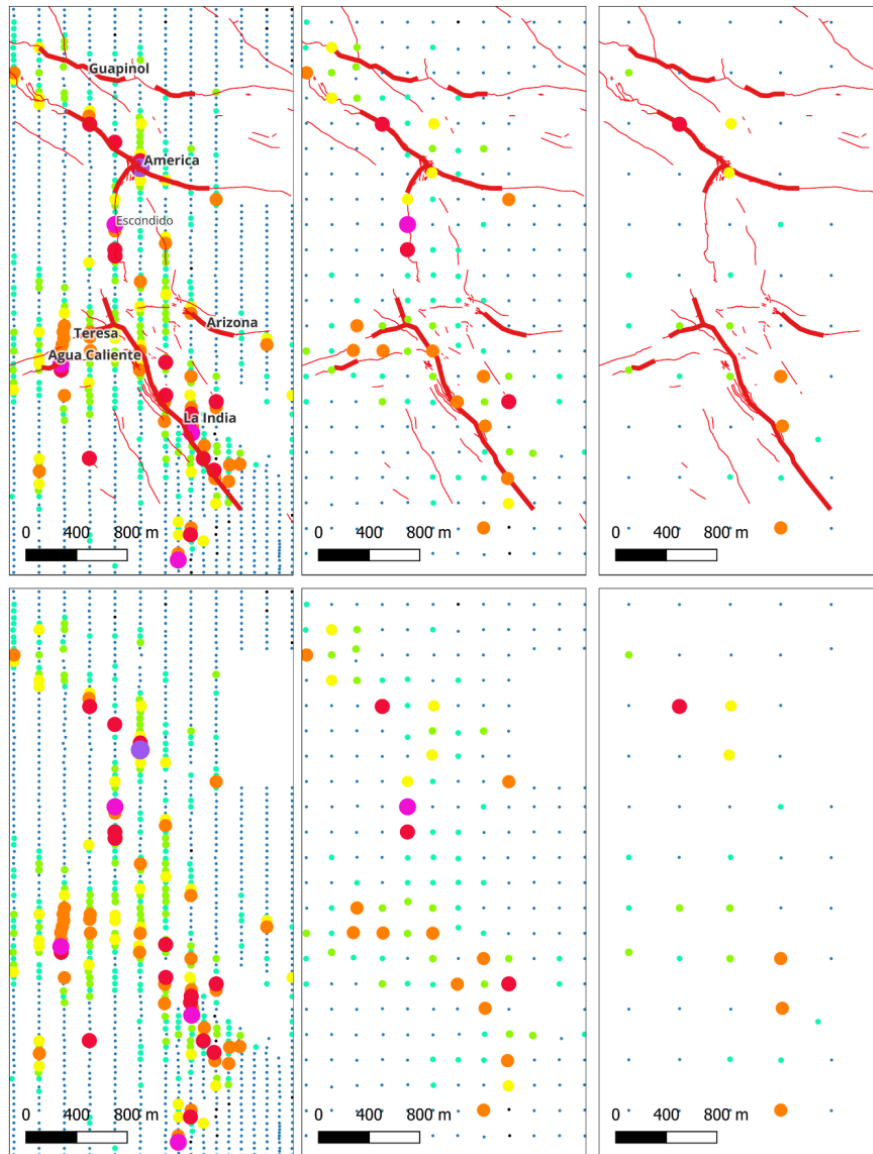


Figure 7. Map showing all the soil samples colour coded by gold content over the principal La India and America vein sets which both supported the main historic mine workings and contain the current main resource and open pit mine reserve in the La India mining district. Left: all soil data predominantly at 200 m by 50 m grid. Centre: the simulated 200 m by 200 m soil grid and (Left:) the simulated 200 m by 200 m soil grid. See Figure 6 for soil gold colour key

Table 4. Current gold endowments in the La India gold mining district with the number of associated soil samples >25 ppb gold and the maximum soil gold value for the full close spaced soil dataset and the simulated 200 m by 200 m and 400 m by 400 m soil grids

Deposit	Au (kt)	Au (g/t)	Au (koz)	200m × 50m		200m × 200m		400 × 400m	
				No. >25 ppb Au	Max Au ppb	No. >25 ppb Au	Max Au (ppb)	No. >25 ppb Au	Max Au (ppb)
La India	11,000	3.3	1,200	52	853	15	290	5	153
America	2,300	5	360	19	1778	6	329	3	329
Tatiana	1,000	5.4	180	5	2017	1	61	0	8
Cacao	1,200	2.7	100	4	86	1	55	0	15
Guapinol	500	5.9	94	2	70	2	70	0	5
Buenos Aires	310	8.2	81	5	1458	3	58	0	4
Arizona	400	4.3	56	2	108	0	24	0	1.4
San Lucas	300	5.9	56	13	1959	4	1959	2	1959
Central Breccia	920	1.9	56	incomplete		incomplete		incomplete	
Espinito	180	8.4	49	4	112	0	20	0	10
Cristalito	180	5.5	33	9	638	2	598	0	6
Teresa	90	10.6	31	6	172	3	155	0	23
Agua Caliente	43	9	13	5	575	3	223	1	41

9.3 Effectiveness at revealing gold vein orientation and network geometry

Soil sampling can be an effective mapping tool, providing quantitative information on the spacial distribution of gold mineralisation. The trends and geometry of a vein system and information on where the gold is concentrated can not only identify mineral deposits but can also reveal vectors to mineralisation that may be hidden beneath adjacent cover or at deeper levels in the bedrock (Figure 8).

When the soil gold data is viewed on a regional scale the overall network of mineralised veins and the concentration of mineralisation at La India vein can clearly be seen in both the full dataset and the 200 m by 200 m grid. The 400 m by 400 m grid has anomalies associated with most of the key resource and prospect areas but does not provide any information on orientation or relative size of the different occurrences.

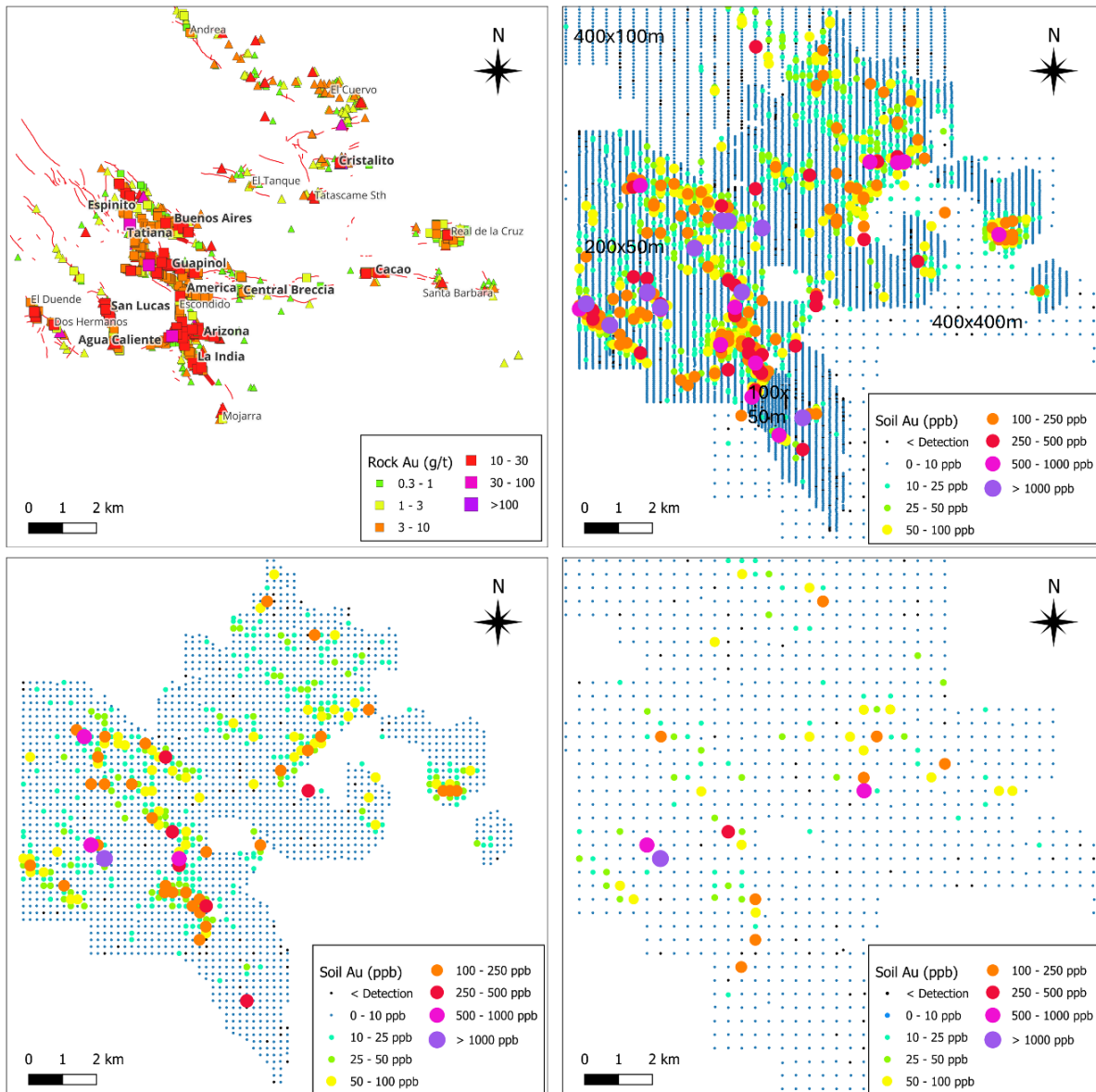


Figure 8. Top left: Mapped veins and surface rock chip and trench samples at the La India mining district, (Top right:) all soil sample data at grid spacing varying between 100 m by 50 m, 200 m by 50 m, 400 m by 100 m and 400 m by 400 m colour coded by gold content. Bottom left: Results of simulated 200 m by 200 m and (Bottom right:) 400 m by 400 m soil sample grids

10. Conclusions

The soil geochemistry data for the La India gold mining district provides a complete soil geochemistry dataset across an entire low sulphidation epithermal gold-silver district at a high resolution of 200 m by 50 m spacing. The north-south biased soil grid provides abundant data on the dominant mineralised veins which strike between east-west and northwest-southeast but does not provide good definition of a set of secondary veins that strike north-south, such as the Escondido vein which links the principal La India and



America resources. This type of biased data can lead to incomplete or incorrect interpretations of the vein geometry with the associated soil anomalies often being treated as background noise or forced into east-west interpretations.

An unbiased square grid is preferred in gold vein system such as La India where there are multiple vein directions. The existing soil dataset provides sufficient information to simulate and evaluate the effectiveness of an unbiased 200 m by 200 m and an unbiased 400 m by 400 m soil grids in a low sulphidation epithermal vein gold system in a tropical wet and dry environment. These spacings are considered reasonable for first pass regional exploration aimed at discovering low sulphidation epithermal gold vein mineralisation.

The 200 m by 200 m soil grid requires only 25% as many samples as the existing soil survey to cover the same area. A 400 m by 400 m soil grid would require approximately 9% as many samples. Both simulated grids represent significant cost savings for any exploration company.

Analysis of the simulation suggests that a 200 m by 200 m soil grid is (1) adequate to discover economic vein gold deposits in the soil type found in the tropical wet and dry zone of western Nicaragua. (2) A 200 m by 200 m soil grid will provide enough resolution to map out vein trends and the overall geometry of an epithermal vein system that is exposed at surface. (3) A 200 m by 200 m soil grid provides sufficient resolution to rank the gold anomalies by size and grade with confidence that the ranking will be broadly correlate with the size and grade of the associated gold occurrences.

A 400 m by 400 m spaced soil sampling successfully detects the larger gold deposits but will miss smaller or partially hidden deeper-seated deposits. The spacing is too wide to provide any useful information on epithermal vein orientation or network geometry. It could be considered as a first pass exploration to identify areas of interest, but there would be value in undertaking infill sampling at 200 m by 200 m, or possibly closer spacing to allow the system to be traced and targets ranked.

Soil geochemistry surveys at closer than 200 m spacing in this geology and environment will provide better information, but it is cautioned that it is unlikely to add significant information, and it may be more cost-effective to direct resources to exploration work that will locate and sample the in situ ore such as rock chip sampling, trenching or drilling.

It is important to note that this study only considers the soil gold signature. The optimal grid spacing for other pathfinder elements or to use the soil as a lithology and alteration mapping tool may be different. However, as the gold is a relatively immobile element and in vein systems is constrained to a relatively narrow geological structure then it is reasonable to expect that the effective soil signature of more mobile elements distributed in broadly distributed lithologies and alteration halos would be achieved with wider spaced grids.



11. References

1. Rogers R.D. & Mann P. 2007. Transtensional deformation of the Western Caribbean - North America Plate Boundary Zone. In: *Geologic and Tectonic development of the Caribbean plate in northern Central America*, Geological Society of America, Special Paper, 428: 37-64.
2. English, L; Galvan, VH and Pullinger, CR. 2024. Geological setting of gold-silver mineralisation in the La India mining district, Nicaragua. *Naturalis Scientias*, 1 (1): 41-55.
3. English, Luc & Cheatle Andrew. 2022. Regional exploration on the La India project, Nicaragua. *Condor Gold PLC Internal Report*.
4. SRK Consulting (UK). August 2022. A mineral resource estimate on the La India, Nicaragua. *Consultant Report for Condor Gold PLC*. (https://metalsexploration.com/wp-content/uploads/2025/02/31246_La-India-NI43-101_FS_V251022_SS.pdf)
5. Chamale, C. 2015. Geochemical orientation soil survey at La India District. *Condor Gold PLC Internal Report*. (<https://metalsexploration.com/wp-content/uploads/2025/02/Condor-Soil-Geochemistry-Review-140915-Website.pdf>)
6. Pratt, W. and Flindell, P. 2017. Final soil geochemistry report, La India, Nicaragua. Specialised Geological Mapping Ltd., *Condor Gold PLC Internal Report*. (<https://metalsexploration.com/wp-content/uploads/2025/02/La-India-Project-Soil-Geochemistry-Report-Oct-17.pdf>)
7. Hedenquist, J.W. Arribas A.R., Golzalez-Urien, E., 2000, Exploration for epithermal gold deposits in Gold in 2000, *Reviews in Economic Geology*, 13: 245-277.
8. Hawkes, H.E. and Webb, J.S. 1962. *Geochemistry in Mineral Exploration*. Harper and Row. New York, N.Y. 415 pp.
9. Lepeltier, C. 1969. A simplified statistical treatment of geochemical data by graphical representation. *Economic geology*, 64: 538-550.
10. Sinclair, A.J. 1974. Selection of threshold values in geochemical data using probability graphs. *Journal of Geochemical Exploration*, 3: 129-149.
11. Jarva, J., Tarvainen, T., Reinikainen, J. and Eklund, M., 2010 'TAPIR - Finnish national geochemical baseline database', *Science of the Total Environment*, 408: 4385-4395.
12. Pitcairn, I.K. 2011. Background concentrations of gold in different rock types. *Applied Earth Science IMM Transactions section B*, 120 (1): 31-38.

Acknowledgments

This paper is an analysis of data collected by Condor Gold PLC's team of geologists and field assistants who covered a huge area of hilly terrain methodically collecting soil samples and mapping the La India gold-silver mining district between 2015 and 2017. Their work and that of the countless prospectors, geologists and mining engineers in the decades before is gratefully acknowledged here. The paper benefitted from discussions with Condor Gold PLC's technical director Peter Flindell and company geologists Carlos Pullinger, Dr Hugo Galvan and Carlos Chamale, and would not have been possible without the support and encouragement provided by CEO Mark Child.



Author contributions

L.T.P.E. contributed to the data collection, compilation and interpretation and wrote the paper. V.H.G. and C.R.P. contributed to the data collection and interpretations.

Data availability

Data sets generated during the current study and internal company reports referenced in this paper are available from the corresponding author on reasonable request, but restrictions apply to any data used in these studies which was collected for exploration, mineral resource evaluation and mine feasibility studies under license, and so are not publicly available. The referenced internal company and consultant reports on the geology and soil geochemistry and data referring to mineral resource estimates are available on the website of the current owners of the mining concessions at www.metalsexploration.com.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Use of AI tools declaration

The author declares that he has not used Artificial Intelligence (AI) tools in the creation of this article.

