Going for Gold: Finding Lost Gold Cities in Ecuador

Abstract—In the 16th century, Spanish Conquistadors established seven "Gold Cities" in the Audiencia de Quito in the Viceroyalty of Peru in what is now Ecuador. Records in the Archives of the Indies in Sevilla, Spain and the Apostolic Library of the Vatican indicate that these cities were extremely lucrative gold producers. However, by the beginning of the 17th century, these cities had disappeared. Five of these were rediscovered by the end of the 20th century, but two of them, Sevilla del Oro and Logroño de los Caballeros, remained lost into the 21st century. In 2016, Aurania, a Canadian mining exploration company, began its search for these lost cities. On June 6, 2022, Aurania announced that Logroño, reputed to be the richest of the seven gold cities, had been found along the Rio Santiago in Ecuador in the high likelihood area of Metron's probability map for the location of Logroño. How did Metron develop this map? Answer: By applying Bayesian search theory methods to old Spanish records and maps and combining that information with modern geophysics and geochemistry.

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FINDING LOGROÑO DE LOS CABALLEROS

In 2016, Aurania acquired mineral-rights concessions in the remote Cutucu region of Southeastern Ecuador, which includes the Rio Santiago. They launched their exploration effort, which they called The Lost Cities Project (see Figure 1), on the presumption that the lost cities were located in these concession areas. At that time, there were no known gold deposits along the Rio Santiago, no concessions staked along the river, and no mining activity. However, all that changed as the price of gold surged to over $2,000/oz USD. In January of 2022, Aurania learned of a November 2021 television news report, which revealed that a sophisticated and well-funded group of "invaders" had claim-jumped legitimately held concessions along the Rio Santiago.

The invaders employed more than 50 excavators along the river and were recovering tens of thousands of dollars in gold each day. Eventually, the Ecuadorian military impounded their heavy equipment and ran off most of the illegal miners. Presuming that today's miners are extracting only the dregs of the gold that was present in the 16th century, it is likely that 450 years ago the Rio Santiago was as rich as Bonanza Creek in the Klondike when it was first discovered. The richness of the area conforms with Governor Juan de Alderete's 16th century account that in the first year of mining, almost 30,000 pesos of gold were produced at Logroño. One peso was equal to 4.6 g of "buen oro" (22.5 carat purity), making 30,000 pesos equal to approximately 4,100 troy ounces. A 1591 document contains one man's report that in one week he and six other miners extracted 350 pesos (more than 1.5 kg) of gold by hand. He said under oath, "this land was the richest in gold of all the Kingdoms of Peru".

Figure 1
Logo for the Lost Cities Project.

Aurania's subsequent sampling upstream from the excavations showed abundant fine gold in every panning sample taken. This confirmed to Dr. Barron that this section of the Rio Santiago was the location of the lost gold city of Logroño de los Caballeros. Moreover, it was situated in the high probability area of the map produced by Metron for the location of that city. The alluvial gold must have washed down from the nearby Cordillera de Cutucu, most likely from a location in one of Aurania's concession areas. Now Aurania's task is to find the source of the alluvial gold that made Logroño the richest of the Spanish gold cities.

HISTORY AND BACKGROUND

The term "gold cities" is misleading, though in conventional use at the time. These were mining camps similar to palisaded forts. The miners were laborers impressed from the indigenous people in the area. The cities typically lasted until the gold was depleted or the indigenous population died out from smallpox or other Western diseases. In the case of Logroño and Sevilla

Figure 2
Locations of Logroño and Sevilla del Oro on a map made by Diego Mendez in 1574.

del Oro, the native people repeatedly destroyed these cities until the Spanish abandoned them at the beginning of the 17th century when Spain lacked the will and resources to keep them open.

A map in the world's first published atlas (Abraham Ortelius, 1527–1598), labeled Peruviae Auriferae Regionis (Gold Regions of Peru), made by Diego Mendez in 1574 shows the location of these two cities (see Figure 2). Because of the remoteness of the area and the inability to accurately measure longitude[1] in that era, the locations shown on the map are rough estimates rather than precise locations. However, the general features of the map are accurate, which provided evidence of the existence of these cities as well as estimates of their locations.

More than four hundred years have passed since Spanish activity at Logroño ceased, and even though many of the records have been lost, what survives is a compelling narrative of gold mining in what was one of the most remote and isolated areas on Earth.

Dr. Barron first visited Ecuador in 1998 and decided to learn Spanish while staying with Professor of History, Dr. Octavio Latorre Tapia. To help Dr. Barron learn Spanish, they agreed that during the day they would speak Spanish while at night they would speak English. Dr. Latorre was lecturing at the Universidad Internacional in Quito at the time and specializing in the cartography of the age of the Spanish conquistadors in the New World.

Some years before the visit, the Ecuadorian government had engaged Dr. Latorre to perform archival research on lost gold settlements and mines. The premise being that mining in the 1600s was low-tech and inefficient so the Spanish could not have extracted all or even most of the gold from these mines. Interest in the lost Spanish gold cities was piqued after the accidental discovery of the Nambija mine complex in 1981 by two boys hunting in the forest. The mine had been abandoned after a smallpox epidemic killed the labor force around 1603. It was reactivated, and by 2000 it had officially produced some 2.7 million ounces of gold. Unfortunately, thousands of miners streamed into the city in a gold rush. This unregulated mining created an environmental disaster, as shown in Figure 3.

Later research revealed there were abundant references to Nambija in the archival literature, including a map from 1750 which gave the location. The Ecuadorian government believed that Nambija would have been rediscovered much earlier had there been a dedicated effort to search the archives for clues to its location. In addition, by regulating the rediscovery and development of lost gold cities, the Ecuadorian government hoped to avoid the environmental disaster that befell Nambija.

Even though the government stopped funding his research into lost gold cities, Dr. Latorre continued the research privately. He disclosed to Dr. Barron that this research had uncovered the existence of two lost gold settlements, "gold cities", that had still not been relocated: Logroño de los Caballeros and Sevilla del Oro. The first, named after the founder, Juan de Salinas Loyola's home in Rioja, Spain, and the second named after the Royal Seat of Seville. Both settlements were founded around 1560–1568; the last mention of them in the literature was in 1605. By 1630, they had vanished from almost all maps.

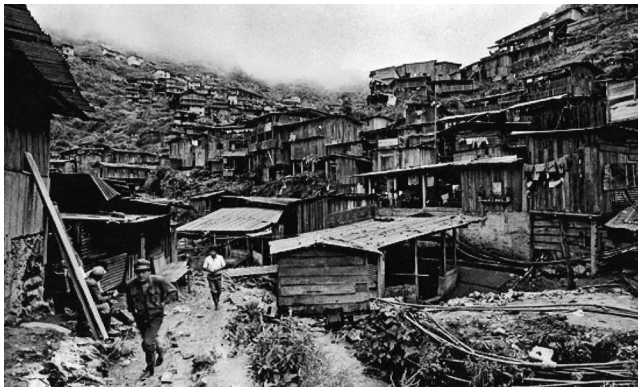

Figure 3
Nambija in 1993. Unregulated mining produced an environmental disaster.

[1] Accurate measurement of longitude requires measuring the time of the maximum height of the sun. This requires portable clocks (chronometers) that can keep accurate time over long periods. Chronometers were not generally available until the 19th century (see [1]). By contrast, the measurement of the latitude, which requires measuring only the Sun's peak altitude in degrees above the horizon, was substantially more accurate.

In 2000, Dr. Barron returned to Ecuador and discussed the possibility of forming a company with the purpose of re-locating the "Lost Cities" using both geological data and historical documentation. Dr Barron had read the book, *The Ship of Gold in the Deep Blue Sea* by Gary Kinder [2], which discussed the novel use of historical data of variable reliability in the application of Bayesian search theory. The book detailed the search for the wreck of the *SS Central America*, a side-wheel steamer that had gone down in a hurricane off the coast of South Carolina in September 1857 while carrying a shipment of gold from the United States mint in San Francisco. The Columbus-America Discovery Group engaged Dr. Stone to use their historical data search matrix to develop a probability map for the location of the wreck. This map was used to guide the search. Ultimately, the search was successful, locating the wreck in September 1988. It is considered the richest shipwreck of all time, and to date $1 billion USD in gold bars and coins have been recovered. Dr. Barron gave Dr. Latorre a copy of Kinder's book, which he quickly devoured; but the verdict was that there were insufficient historical and geographical clues to proceed in a similar way to find the two lost gold cities.

In January 2001, after receiving a tip from Ecuador's Regional Director of Mines, Dr. Barron visited the site of some gold mining in the Province of Zamora-Chinchipe, which borders on Peru. He realized that the artisanal gold miners, who were vacuum dredging in the rivers, were only 4 kilometers from the drainage divide that marked the international border with Peru. As the streams had their origins at the tops of nearby mountains in Ecuador, the source of the gold in these rivers was likely somewhere in those mountains. In April 2001, Dr. Barron began amassing exploration concessions in these mountains for Aurelian, an exploration company founded by Dr. Barron. Aurelian discovered the Fruta del Norte (FDN) gold mine in one of those concessions in March 2006 and was acquired by Kinross Gold Corp for $1.2 billion CAD in 2008.

Later in 2008, Dr. Barron again joined forces with Dr. Latorre to find the Lost Cities. By virtue of the sale of Aurelian, they now had the advantage of well-funded archival research. In addition to examining archives in Ecuador, they travelled further afield to the:

- Archivo Historico Arzobispal
- Riva Agüero Institute, Lima
- Biblioteca Nacional de España, Madrid
- Rare Book Division of the New York Public Library
- British Museum Library, London
- Archive of the Indies (Archivo General de Indias) in Seville, Spain
- Manuscript Section of the Apostolic Library of the Vatican, Rome

Over 100 historic documents relating to Logroño and Sevilla del Oro were discovered in Seville alone.

During a 2011 visit to the Vatican, Drs. Barron and Latorre found an anthology referencing the *Compendium and Description of the West Indies* written in 1628–29 by Carmelite priest Antonio Vazquez de Espinosa, which was eventually unearthed in the Manuscript Section of the Apostolic Library in the Vatican (Barb Lat. 3584). Dr. Barron was able to examine and obtain photographic reproductions of the original volume in the Vatican in May 2016. The book gives a description of how to get to Sevilla del Oro with place names that are still recognizable today and established that the Cordillera de Cutucu, a remote area in southeastern Ecuador some 100 km north of Fruta del Norte, was the site of the two lost settlements.

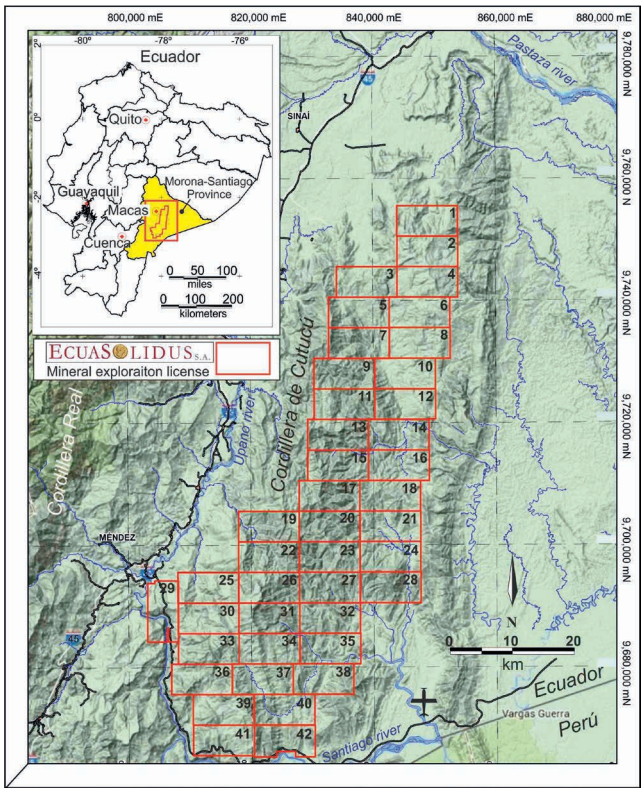

Figure 4
Cutucu project area. Red rectangles show Aurania's mineral concession areas.

By coincidence, in March 2016, Dr. Barron had applied for 208,000 hectares of concessions in the Cordillera de Cutucu area. He had been interested in this property for some time, but a long-standing moratorium on granting concessions was in effect. During the Prospectors & Developers Association of Canada Conference in Toronto, the moratorium was lifted. At 12:01 am, while others were at the Ecuadorian Ministry of Mines cocktail reception, Barron and his Vice President for Exploration were typing in the coordinates to apply for the concessions. The concessions, awarded in December 2016, are shown in Figure 4.

PROBABILITY MAPS AND LIKELIHOOD RATIO SURFACES

While Aurania was performing extensive geophysical and geochemical surveys of the Cordillera de Cutucu region to deter-

mine the locations of commercially exploitable mineral deposits, Metron was performing the tasks below.[2]

- **Probability Maps.** Using historical information such as maps and descriptions from 16th and 17th centuries indicating the location of the cities, descriptions of journeys to these cities, and present-day topological features, Metron produced probability maps for the locations of Logroño de los Caballeros and Sevilla del Oro.
- **Likelihood Ratio Surfaces.** Using geophysical survey information such as magnetic anomaly measurements and geochemical information provided by stream bed samples, Metron produced likelihood ratio surfaces indicating likely locations of gold, silver, copper, lead, and zinc deposits.

PROBABILITY MAPS FOR LOGROÑO AND SEVILLA

Metron developed the probability maps for Logroño and Sevilla using classic Bayesian search theory methods in which both objective and subjective information are incorporated into the probability distribution. Uncertainties in the information are represented by probabilities (possibly subjective). In addition, Metron considered multiple scenarios for estimating the location of each city. When information is gathered about the location of a city (or search object on the ocean bottom), it tends to coalesce into disjoint subsets of information. The information within a subset is consistent, but the information in one subset is inconsistent with that in another. As with the successful searches for the US nuclear submarine *Scorpion* lost in 1968 [3], the *SS Central America* that sank in 1857 [4], and the Air France AF 447 flight that crashed into the Atlantic in 2009 [5], Metron treated each subset as defining a scenario for the location of the city. It gave the information in each scenario a (subjective) credibility factor, produced a probability map based on each scenario, and computed a combined map that is the mixture of the scenario maps weighted by their credibility factors.

We describe the procedure for computing the Logroño map and compare the map (which was computed in 2020) to the location of Logroño discovered in 2022. The procedure for Sevilla was similar, but the location of Sevilla has not yet been discovered.

LOGROÑO PROBABILITY MAP

The Logroño probability map is based on two excellent pieces of historical information obtained by Dr Barron in his search of the archives mentioned above.[3]

- Based on the Mendez map (Figure 2), we estimated that Logroño is located at a point halfway between Zamora and Santiago de las Montañas as measured along the Zamora and Santiago rivers.
- "…the city of Logroño is within half a league of the Zamora River" [6]. As seen in Figure 5, the Zamora River becomes the Santiago River where the Upano joins it. The locations of the cities of Zamora and Santiago de las Montañas are off the map as indicated by arrows.

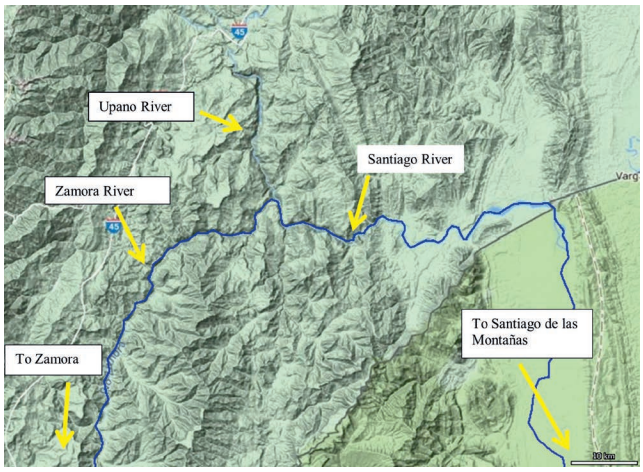

Figure 5
The Zamora River. Where the Upano joins the Zamora, the river becomes the Santiago River.

BASIC SCENARIO

Items 1 and 2 above form the basic scenario for the location of Logroño. We converted this information into a probability distribution as follows. Let d = distance between Zamora and Santiago de las Montañas as measured along the river Zamora. We estimated this distance as 423 km. Let X = the unknown distance from Zamora to Logroño as measured along the river. For the distribution of X we used a triangular distribution with density defined in (1)

$$\Pr\{X = x\} = p(x) = \begin{cases} 0 \text{ for } x < d/3 \\ \dfrac{36(x - d/3)}{d} \text{ for } d/3 \le x \le d/2 \\ 6 - \dfrac{36(x - d/2)}{d} \text{ for } d/2 < x \le 2d/3 \\ 0 \text{ for } x > 2d/3 \end{cases} \quad (1)$$

where Pr indicates probability density and d = 423 km.

We estimated that a league, as used in the historical documents, is between 4.18 km and 5.57 km (see [7]). So, half a league is roughly between 2 km and 3 km. Let H be the distance of Logroño from the Zamora River. We used the probability density in (2) to represent the uncertainty in this distance.

[2] The probability maps and likelihood ratio surfaces were computed by Joshua Hughes who is a Senior Research Scientist at Metron. Metron was aided in this effort by Drs. Camille and Richard Spencer, geochemists employed by Aurania.

[3] Dr. Barron collected a trove of information from the historical records, much of it in the original Spanish, which differs from modern Spanish much like 16th century English differs from modern English. Dr. Camille Spencer selected, curated, and translated crucial pieces of these records to provide the information used to form the Logroño probability map.

$$\Pr\{H=h\}=q(h)=\begin{cases}0 \text{ for } h<1.5\,\text{km}\\ \dfrac{1}{2\,\text{km}} \text{ for } 1.5\,\text{km}\le h\le 3.5\,\text{km}\\ 0 \text{ for } h>3.5\,\text{km}.\end{cases} \quad (2)$$

Aurania's geological experts estimated that Logroño was more likely to be located on the north side of the Zamora than the south side. We represented this by assuming:

Probability Logroño North of Zamora = p_N

Probability Logroño South of Zamora = $1-p_N$, where $p_N=0.75$.

SIMULATING THE DISTRIBUTION OF THE LOCATION OF LOGROÑO

We drew 100,000 points from the distribution defined above as follows:

- Make a draw from the distribution in (1) to obtain the distance of the sample point along the Zamora.
- Make a draw to determine if the point is North or South of the Zamora.
- Make a draw from the distribution in (2) to obtain the distance North or South for the point.

This determines a possible location of Logroño. Repeat 100,000 times. The resulting distribution is shown in Figure 6. The distribution consists of 100,000 equal probability points. The graphical representation of this distribution is obtained by imposing a grid on the area near the Santiago River and summing the probabilities of the points contained in each grid cell. The cells are colored according to the probability in them with red indicating the highest probability cells and the colors through orange, yellow, and green to blue indicating lower probability ones.

We had an additional piece of information about the location of Logroño. Specifically, "A short distance from their meeting [of the Upano and Zamora rivers] was …the famous city of Santa Ana de Logroño de los Caballeros, by another name, the city of gold", [8]. We represented this information by the likelihood function described below, which we incorporated into the distribution in Figure 6 to compute the posterior distribution shown in Figure 7. Observe that this distribution is more concentrated and closer to the junction of the Upano and Zamora rivers than the distribution in Figure 6.

LIKELIHOOD FUNCTION

We represented the information that Logroño was located a short distance from the junction of the Zamora and Upano rivers using the gamma probability density function $g_{\alpha\beta}$ given in (3) with $\alpha = 2$ and $\beta = (1/12)$km.

$$g_{\alpha\beta}(x)=\frac{x^{\alpha-1}\beta^{\alpha}e^{-\beta x}}{\Gamma(\alpha)} \text{ for x} \ge 0 \text{ where } \alpha,\ \beta>0 \quad (3)$$

where Γ is the standard gamma function with $\Gamma(n) = (n-1)!$ for n a positive integer. This density function has its maximum at 12 km from the junction as shown in Figure 8. We used this

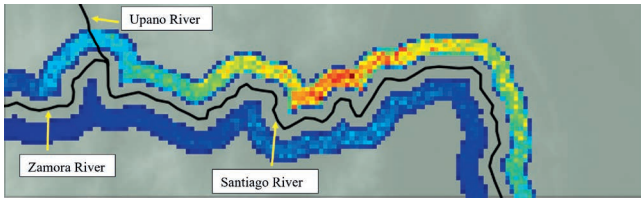

Figure 6
Probability distribution based on items (1) and (2). Red indicates high probability cells, blue low probability.

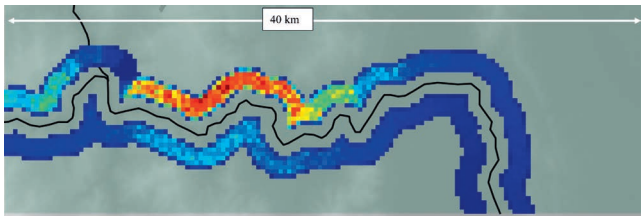

Figure 7
Logroño distribution updated with the gamma likelihood function representing the estimate of the distance of Logroño from the junction of the Zamora and Upano rivers.

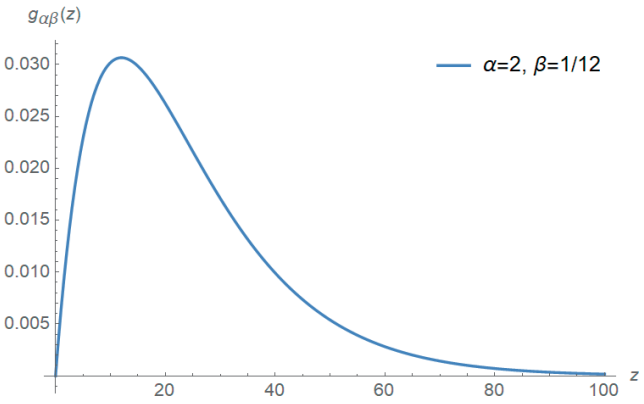

Figure 8
Likelihood function for a "small distance" from the junction of the Zamora and Upano rivers.

gamma density as a likelihood function and combined it with the prior in Figure 6 in a Bayesian fashion to compute the posterior distribution in Figure 7. Specifically, for each point in the prior distribution in Figure 6, we calculated the distance x of the point from the junction of the Zamora and Upano rivers and multiplied the point's probability by

$$\Pr\{\text{"short distance estimate"} \mid \text{Logroño at } x\} = g_{\alpha\beta}(x)$$

with $\alpha = 2$, $\beta = 1/12$.

We then renormalized the probabilities on the points to sum to 1.

LOCATION OF LOGROÑO

Figure 9 shows the location of the recent illegal mining activity along the Santiago River. Undoubtedly, Logroño was located along the banks of the Santiago River where alluvial gold was panned in great quantities from the river by the Spanish.

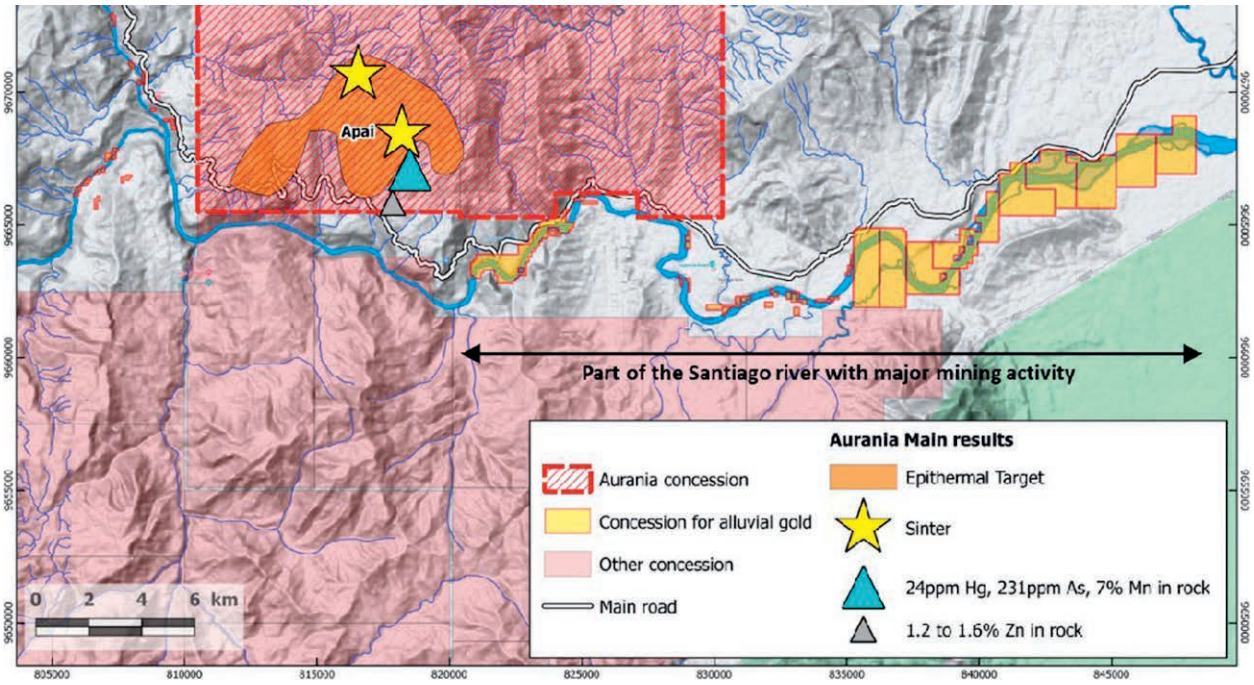

Figure 9
Areas of illegal mining activity are shown.

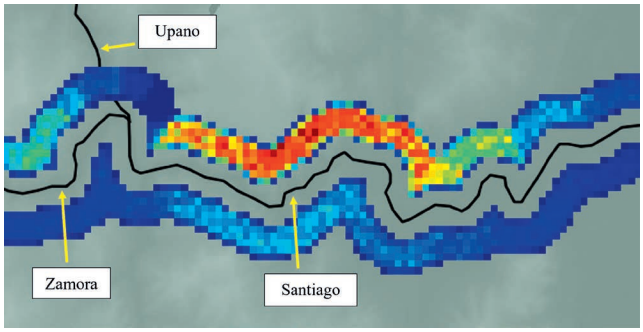

Figure 10
High probability regions for the location of Logroño.

Clearly, this gold has washed down from the mountains above the river. Figure 10 below shows an expanded version of the Logroño map in Figure *7*. The correspondence between the high probability areas on the map and the regions where illegal mining activity was taking place is striking.

Despite this preponderance of evidence, the location of ancient Logroño can never be known with absolute certainty. There will be no stone signposts, and any archeological site along the river would likely have been swept away long ago during high water or destroyed by modern mining activity.

Aurania's task now is to find the source of the gold in the alluvial deposits in the Rio Santiago. Already Aurania has found a site upstream where a landslide has revealed epithermal chalcedonic quartz veins and where gold can be panned. Epithermal deposits are likely to contain gold. There is also an epithermal deposit in the southwest corner of Aurania's concessions that is only a couple of kilometers north of the river. Aurania believes that dedicated and intensive geological mapping and prospecting will ultimately locate the source or sources of the alluvial gold in the Santiago River.

LIKELIHOOD RATIO MAPS

With help of Drs. Camille and Richard Spencer, expert geochemists employed by Aurania, Metron[4] prepared likelihood ratio maps indicating areas of high likelihood for containing gold, silver, copper, lead, and zinc. In this section, we discuss the method used to produce the likelihood ratio map indicating the presence of gold and compare it to the region near Logroño, especially the mountains above it.

For the presence of gold, we prepared likelihood ratio maps indicating the presence of epithermal deposits which are likely to contain gold and silver. We incorporated three types of evidence, lithology (types of rock found), magnetic anomalies found during magnetic surveys of the concession areas, and the minerals found in stream-bed samples in the concessions area.

We imposed a grid on a region that included the concession areas. For each piece of evidence and type of deposit, experts (Camille and Richard Spencer) estimated the following likelihood ratio at the locations x at which measurements were made:

$$\mathrm{LR}(x) = \frac{\Pr\{\text{obtain measurements at location } x \mid \text{ epithermal deposit present}\}}{\Pr\{\text{obtain measurements at location } x \mid \text{ no epithermal deposit present}\}}. \tag{4}$$

The reader may be wondering why we have chosen to encode the subjective estimates of experts in terms of likelihood

[4] The likelihood ratio maps were prepared by Joshua Hughes, Senior Research Scientist at Metron.

Table 1

Likelihood Ratios (LR) for Indicator Scores for Presence of an Epithermal Layer

	Score							
	10	6	5	4	3	2	1	0
LR	9.0	6.0	4.5	3.0	2.25	1.8	1.5	0.56

ratios. The reason is very simple and very powerful. Likelihood ratios give the proper weight to each piece of evidence in the likelihood ratio surface. We can then combine likelihood ratios from diverse types of information by simply multiplying, for each cell x, the likelihood ratios for the evidence in that cell. If there is no measurement in a cell for a given type of evidence, the likelihood ratio is set to 1 in that cell. The resulting likelihood ratio surface represents a combination of the evidence wherein each piece of evidence is given its appropriate weight as determined by expert opinion. We illustrate this process for epithermal deposits using the results of stream sediment data.

Aurania experts defined the catchment area for each stream sampled. The catchment area of a stream is the area that drains into the stream. They identified eight key chemical elements as pathfinders (indicators) of epithermal deposits of gold and silver. They are: gold, silver, tellurium, arsenic, antimony, mercury, selenium, and thallium. For each element, they set a threshold. If the stream sediment analyses corresponding to a catchment area contained the element at a level above this threshold, it received a score of 1 point for all the elements except gold which received a score of 3. The scores for a catchment area were added together to obtain a total score for the area. The maximum score that a catchment area can receive is 10. Aurania experts assigned likelihood ratios to each catchment area according to its score as shown in Table 1.

Figure 11 shows log likelihood ratio maps for the presence of an epithermal layer based on geochemical evidence from lithology, stream sediment samples, and magnetic anomalies. Figure 12 shows the combined likelihood ratio surface obtained by multiplying pointwise the likelihood values in the maps in Figure 11. Figure 13 zooms in on the section of Figure 12 near the junction of the Upano and Zamora rivers which is just upstream from the area where the illegal gold mining took place on the Santiago River. The mountains just north of the Santiago River and east of the Upano are the likely source of the alluvial gold found in the Santiago River. Observe that these mountains are marked as high likelihood regions for epithermal deposits in the map in Figure 13. Notice also that one of Aurania's concession areas is located here.

CONCLUSIONS

The accuracy of the probability map generated for the location of Logroño is another striking example of the power of Bayesian search methods. These methods allow the analyst to combine all available information, both objective and subjec-

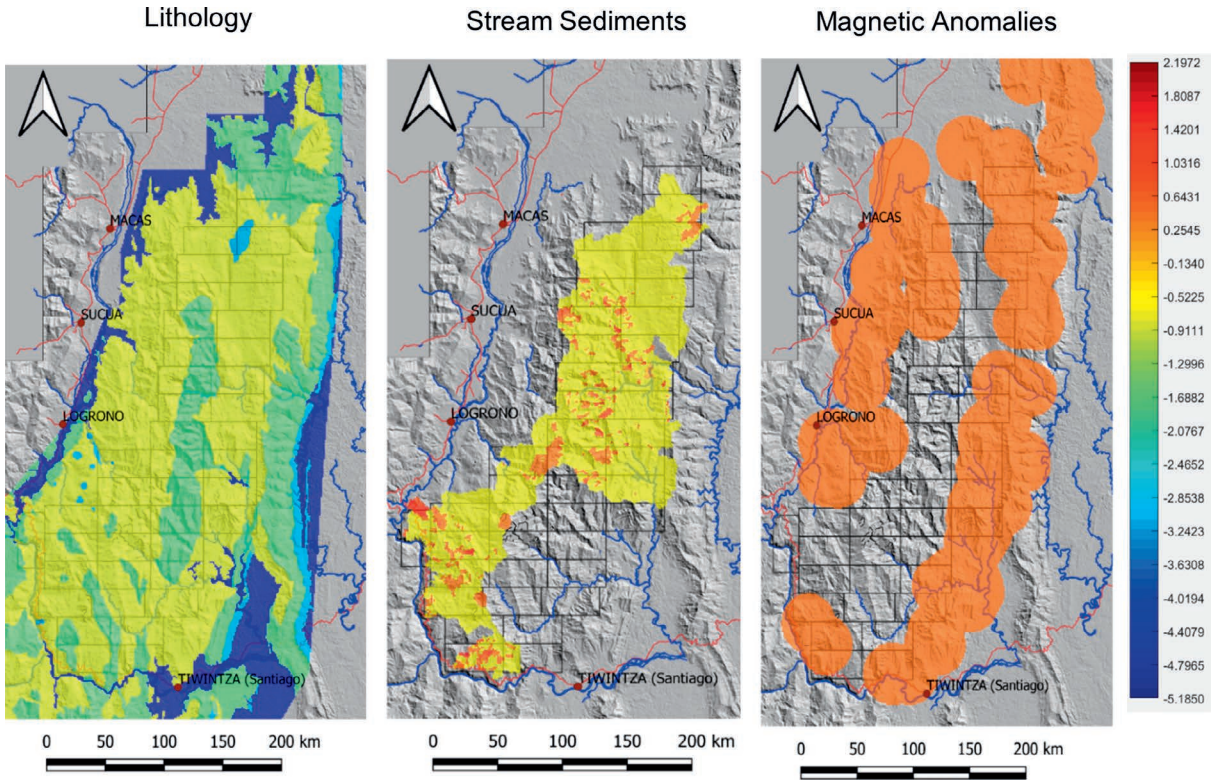

Figure 11
Log likelihood ratio maps for lithology, steam sediments, and magnetic anomalies.

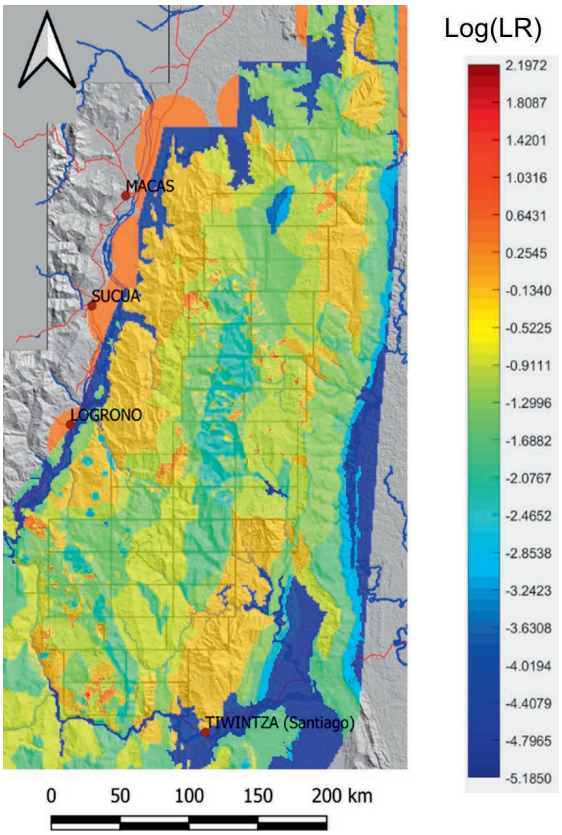

Figure 12
Combined log likelihood ratio map for epithermal deposits.

Figure 13
Log likelihood ratio map near the junction of the Upano and Zamora Rivers.

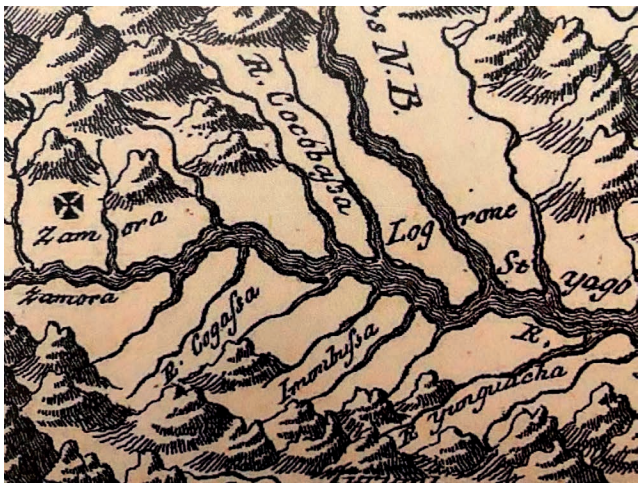

Figure 14
Maragnonii sive Amazonum Fluminis Terrarum in Orbe Maximi.

tive, in a principled Bayesian fashion, to produce a probability map for the location of the object of interest. In the Bayesian methodology, uncertainties in the information, both the objective and subjective, are represented in terms of probabilities. By constructing prior distributions using the scenario method and incorporating information using likelihood functions via Bayes rule, we can produce a probability distribution that represents the client's best understanding of the problem.

Creating a probability map for a lost or missing object is not a scientific endeavor. We do not have the luxury of repeating the experiment a thousand times to test our models and assumptions to determine which ones are correct. Instead, our goal is to produce a probability map that enables the client to search rationally and effectively. To do this, we use Bayesian methods which allow us to incorporate expert opinion and subjective judgements along with objective information. In many searches, this approach has proven to be effective and efficient. In fact, trying to take a "scientific" approach that uses only "hard" data and does not incorporate subjective information, such as expert opinion, can produce very ineffective searches.

The likelihood ratio maps produced for Aurania provide another example of the power of Bayesian methods to combine disparate types of information in a simple and effective manner. In the case of mining exploration, surveys performed by an exploration company can produce many types of evidence for the presence of economically significant mineral deposits. As in Aurania's case, that evidence can be geological, geochemical, and geophysical. Each type of information produces indications for likely location of mineral deposits. Using expert opinion to convert that information into likelihood ratios, puts the information on a common scale that reflects the strength of the evidence so that the evidence can be combined in a principled manner. We are not aware of another method that does this.

POSTSCRIPT

In August of 2022, Dr. Barron visited the Iglesia de la Compañia, in Quito, built by the Jesuit Order between 1605 and 1765. The altar, ceiling, and internal ornamentation are entirely covered with gold leaf. Over time, this church has also been called: "the Temple of Solomon of South America". Father Bernardo Recio, a traveling Jesuit, called it the "Golden Ember". On display during Dr. Barron's visit, and never examined before, was a very rare map "Maragnonii sive Amazonum Fluminis Terrarum in Orbe Maximi" (see Figure 14) published in Nuremberg in 1785 by the Jesuits, which documented the various explorations and settlements founded by them before their expulsion from the Spanish colonies in 1767. In this map, "Logrone" is placed near the beginning of the "St Yago R.", only some 20 kilometers from where Logroño was ultimately found. It is tantalizing to think that some of the gold used in the construction of this church came from the Lost Cities.

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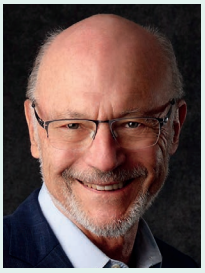

Lawrence Stone is Chief Scientist at Metron Inc. He is a member of the National Academy of Engineering and a fellow of the Institute for Operations Research and Management Science (INFORMS). He is a recipient the Jacinto Steinhardt Award from the Military Applications Section of INFORMS in recognition of his applications of Operations Research to military problems.

In 1975, the Operations Research Society of America awarded the Lanchester Prize to his text *Theory of Optimal Search*. In 1986, he produced the probability maps used to locate the *S.S. Central America* which sank in 1857, taking millions of dollars of gold coins and bars to the ocean bottom one and one-half miles below. In 2010, he led the team that produced the probability distribution that guided the French to the location of the underwater wreckage of Air France Flight AF447. Recently, he used search theory methods to help guide the Canadian exploration company, Aurania, to the location of one of the lost Spanish gold cities in Ecuador.

He coauthored the 2016 book *Optimal Search for Moving Targets*. He was one of the primary developers of the Search and Rescue Optimal Planning System (SAROPS) used by the U.S. Coast Guard since 2007 to plan searches for people missing at sea. He continues to work on a number of detection and tracking systems for the U.S. Navy. He is a coauthor of the 2014 book *Bayesian Multiple Target Tracking, Second Edition*.

Keith Barron is Chairman, President, and CEO of Ecuador gold and copper explorer, Aurania Resources Ltd. Dr. Barron has been involved as an Exploration Economic Geologist and entrepreneur for over 39 years, in more than nineteen countries. In 2001, he privately co-founded Ecuador gold explorer Aurelian Resources Inc., which was listed on the TSX-V in 2003 and made the colossal Fruta del Norte gold discovery in 2006. The company was bought by Kinross Gold in 2008 for $1.2 billion CAD. He is President and Director of Firestone Ventures (TSXV:FV) and President of Potentate Mining in Montana, USA, the world's second largest sapphire miner. He has served as a Director of several other listed companies.

At the PDAC convention in March 2008 he was awarded the Thayer Lindsley International Discovery Award for his role in the discovery of the Fruta del Norte gold deposit, and he was also jointly named the Northern Miner's Mining Man of the Year 2008. His major expertise is in gold and precious gems, although he has considerable experience in base metals, uranium and industrial minerals. His doctoral thesis documented the world's oldest epithermal gold-silver deposit at Springpole Lake in Canada. He holds a Ph.D. in Geology from the University of Western Ontario and a BSc. (Hons) in Geology from the University of Toronto.