Geo-Insights:
Geological Excerpts and Explanations from Brent Cook

Introduction

Making money in the junior mining and exploration equity markets is all about *Turning Rocks into Money™*. To do so requires an understanding of the geological characteristics of a mineral system and a reasonable sense of what it will cost to get the metal out of the rock. Because the odds of success—finding an economic ore deposit—are so heavily stacked against the explorationist it is just as imperative to know when a project is failing as when it is succeeding. Knowing more than the crowd is key.

Because we are usually dealing with early stage exploration projects at Exploration Insights we are as often as not dealing with limited data and projecting that into the third dimension—Earth. Exploration geology is not an exact science, it is an art supplemented by experience and imagination that evolves as mapping, sampling, drilling, etc., adds to the picture. Over the years we have discussed hundreds of companies and mineral properties. These discussions often involve examining and interpreting the exploration data.

Because our goal is to help subscribers better evaluate their own investments in the junior mining and exploration sector, in addition to the stocks in the EI portfolio, we have compiled this document of geo-insights. It is a compendium comprised of excerpts from Exploration Insights that we hope will be of help and value in your own research.

Good luck out there,

Brent Cook
August 31, 2012

GENERAL GEOLOGY ................................................................................................ 3
RECUMBENT SYNCLINE AS SITE FOR MINERALIZATION: SERRA PELADA ........................................... 3
GEOLOGY OF PATAGONIA; CONTINENTAL DRIFT ........................................................................... 3
LAYERED IGNEOUS COMPLEX: RING OF FIRE .................................................................................. 4
GREENSTONES BELTS ......................................................................................................................... 5
CARLIN STYLE GOLD MINERALIZATION AT LONG CANYON .......................................................... 5
GEOLOGIC HISTORY OF THE CARLIN TREND .............................................................................. 6
ALKALIC ROCKS ............................................................................................................................... 7
EPITHERMAL DEPOSITS: IN A NUTSHELL ......................................................................................... 7
EPITHERMAL SYSTEMS ..................................................................................................................... 8
Low-Sulfidation Deposits: .................................................................................................................. 8
High-sulfidation Deposits: .................................................................................................................. 9
THE GEOLOGY OF COLOMBIA ........................................................................................................ 10
GOLD PORPHYRY .............................................................................................................................. 12
VOLCANICLASTIC .............................................................................................................................. 12
GEOLOGY OF INDONESIA .................................................................................................................. 12
General Geology

Recumbent Syncline as site for mineralization: Serra Pelada

From Exploration Insights: 6/13/08

Serra Pelada, Brasil (Colossus) occurs along the hinge zone of a recumbent syncline. Take a thin phone book and squeeze it together until it folds over onto itself (go ahead, no one is looking). That is a recumbent fold. The photo below is of a small-scale recumbent fold.

![Recumbent Fold](image)

If we assume the cross section of the fold in the photo is about 100 meters high, it approximates the Serra Pelada structure. You should notice that some of the rock layers are rigid and others are soft; they seem to flow between the hard layers. The weathered-out cavities in the photo (specifically the one with the arrow) are the areas where mineralizing fluids filter through the rock sequence. This is also the place where the mineralization is deposited if the chemical, temperature and pressure conditions are favorable.

Now you have the conceptual cross-sectional shape of the Serra Pelada mineralization halo. Within this halo are numerous and complex fractures that control the location of the high-grade mineralization. At Serra Pelada this mineralized halo and its complex structural controls lie under some 200 meters of barren rock. Understanding and predicting with any certainty how much gold there is and where these high-grade structures occur is easier said than done.

Colossus is making a first pass attempt at interpreting the mineral system with drill holes spaced about 50 meters apart. On top of the need to understand the geology they must also extrapolate the assays between drill holes. In the case of Serra Pelada, there is extreme variability in grade over a short distance. The drill core from the holes gives them about five centimeters of variably broken rock with which to infer the geology, structure and grade over 50 meters of strike. It should be obvious to you by now that interpreting the geology and mineralization with certainty is much easier said than done.

Geology of Patagonia; Continental Drift

From Exploration Insights: 11/23/08

Let’s start at the beginning.

About 160 million years ago (or just after lunch on the 3rd day if you prefer), Africa began drifting away from South America. As this continental rifting progressed over the ensuing 80 million years, the earth was stretched and the crust thinned. Large fault-bounded basins formed to compensate for the extension. In what was to become Patagonia, these basins were finally stretched thin enough that magma began intruding into and pouring onto the
basin sediments. Accompanying the volcanism were numerous large areas of hydrothermal activity: hot springs much like those we see in Nevada, the Red Sea and Salton Sea Basin.

As this splitting process progressed, the Atlantic Ocean was formed and Patagonia sunk below the sea. For approximately the next 100 million years Patagonia was covered by water and later received the outwash material eroding from the early Andes Mountains. Around two million years ago (sometime just before Eve ate the apple is my best guess) Patagonia rose above sea level and erosion exposed much of the underlying volcanics and associated hydrothermal systems.

**Layered igneous complex: Ring of Fire**

*From Exploration Insights: 2/14/08*

The Ring of Fire **igneous complex** has been overturned and the magmatic layering sits on end. The geologic setting is a classic model for the formation of layered chromitite deposits, disseminated nickel-PGM mineralization and high-grade nickel-copper-PGM cumulate feeder dikes: all of which have been found. The favorable horizon extends for over 100 kilometers and has been drill tested over a very small fraction of its length. Exploration is wide open and the chances of an exciting discovery coming out of this are good. Notice I left out any reference to economics.

Geologically speaking, the **Ring of Fire** is mostly a volcanic terrain with mantle derived ultramafic intrusive complexes emplaced at the base of the volcanic pile. It may be comparable to the layered Bushveld Igneous Complex (BIC) in South Africa, albeit on a smaller scale. The BIC is a massive saucer shaped body that underlies an area of roughly 66,000 km². It outcrops as two shallow dipping, and one moderate dipping, sequences of layered igneous units that are each over 100 kilometers in length. Simply put, the layering is the result of minerals very slowly crystallizing and “raining” down through this massive magma chamber. The minerals accumulate (cumulate textures) across the floor of the chamber forming extensive and often rhythmic units or layers.

The BIC hosts nearly 90% of the world’s PGE (platinum group elements) resources, accounts for about 72% of the global platinum production, and 34% of the global palladium production. It also accounts for nearly 45% of global ferro-chrome production. Reserves are only limited by production costs and power constraints: resources are essentially limitless. You can read more here:

http://www.largeigneousprovinces.org/Downloads/BushveldLIP.pdf

The other major source of PGEs plus nickel is the world-class Norilsk deposit in Siberia. In a broad sense it is an ultramafic feeder system beneath a layered igneous complex. Some locally unique attributes are responsible for the size and high grade of its mineral deposits. Norilsk supplies the world with about 30% of its nickel, 40% of its platinum and over 60% of its palladium. In 2006, reserves stood at 5.1 million tonnes of nickel, 8.7 million tonnes of copper, 63 million ounces of palladium and 16.5 million ounces of platinum: sufficient for 50 years of production.

The ferro-chrome market is similarly supplied by a few major players and mineral districts. Approximately 45% comes from South Africa, 17% from Kazakhstan and 19% from India. According to the USGS, world resources total 12 billion tonnes of direct-shipping grade chromitite ore. Direct-shipping grade ore is greater than 38% Cr₂O₃ (chromite mineral) and a chrome to iron (Cr/Fe) ratio of greater than 1.8. The International Chromium Development Association estimated that some 19 million tonnes of marketable chromitite
ore were produced in 2006 and that the market was in oversupply. Through mid-2008 chromite demand and prices increased, however the commodities crash of late last year means demand has probably fallen nearly fifty percent. Indicative of the price and demand collapse, Xstrata’s Merafe ferro-chrome plant in South Africa is operating at 20% of capacity. London listed Ferro Metals has also reduced production while other producers work through inventories.

You begin to see the problems an emerging new nickel-chrome-PGE province will face. The new province would immediately have to compete on an economic basis with already developed mining districts hosting virtually unlimited resources. In addition to the mine development costs including roads and power, the project would have to consider the trade off costs between a new smelter in Canada vs. shipping the ore to one of the operating smelters owned by someone else. For major mining companies or investors to finance what is likely to be billions of dollars in exploration and development costs they will need to see very high returns to offset draining this swamp in the middle of nowhere.

**Greenstones Belts**
*From Exploration Insights: 4/4/09*

**Greenstones belts** are comprised of various volcanic and related rocks that, due to low-grade metamorphism (heat and pressure changed the rock mineralogy) are often green. They are also the dominant host to the major gold deposits of Eastern Canada which is why we are interested in green rocks.

**Carlin Style gold mineralization at Long Canyon**
*From Exploration Insights: 5/24/09*

*The geology and mineralization:*

The Fronteer geologic team heading up exploration at Long Canyon has done an exceptional job putting the complex pieces of this system together. We discussed this in some detail in the March 15, 2009 EI letter; there is a good presentation here (http://fronteergroup.com/sites/files/LongCanyon_technicalpresentation122008.pdf) for those interested.

Essentially, the limestone and dolomite formations hosting mineralization have been pushed and stretched apart, forming gaps or boudins along anticlines and synclines. Groundwater subsequently dissolved the carbonate rocks where the formation had been broken and formed underground caves (Fig. 2 below). North-northeast trending structures appear to control the cave development and likely somehow reflect the underlying channel ways used by the mineralizing fluids.
The mineralization is so far contained within a few north-northeasterly, roughly parallel trends. It is open to expansion to the north on all structures and to a lesser degree to the south. Given the geologic setting there is a reasonable expectation that additional mineralized parallel trends may exist to the east and/or west. Additionally and possibly most importantly, the source or feeders to the generally stratabound gold mineralization have not been located. They may occur beneath the currently known trends or lie to the east or west. Given the strength of this system these feeder structures could be very robust indeed—no guarantees though.

In short, with the increased understanding of this system we should expect drilling to rapidly add ounces, and deeper or peripheral drilling to produce additional discoveries.

**Geologic history of the Carlin trend**
*From Exploration Insights: 6/17/12*

The structural complexity at Railroad reflects, and is the result of, numerous tectonic events dating back at least 750 million years, when the paleo-continent Rodina was rifted apart, leaving the future Carlin trend at the continental margin. Beginning about 350 million years ago, continental collision and accretion to the west thrust deep ocean sediments over picturesque coral reefs along the Carlin continental margin, forming massive mountains (a tectonic relationship similar to India and the Himalayas today where you can find seashells on the mountain tops). Several pulses of magmatic activity (volcanoes) followed, as evidenced by numerous intrusive and extrusive rocks scattered across western North America. About 40 million years ago the western US began to be wrenched apart along re-activated deep-seated structures. This wrenching triggered (and tapped into) the main pulse of gold mineralization in the Carlin and Cortez trends. The Western US, in particular the Great Basin, has continued to be pulled apart, forming the current Basin and Range province. Over the past 30 million years, Reno and Salt Lake City have moved about 200 miles apart as Nevada continues to be stretched (extended). Minor periods of volcanism accompanied the extensional tectonics, with the most recent being witnessed by Indians. Pieces of the (simplified) geological evolution just described can be found at Railroad and
along the entire Carlin trend. This is exceptionally complex geology made all the more
difficult because much of it is hidden under various forms of post mineral or barren cover.
For the most part, all the major Carlin type deposits discovered over the past decade or two
have been essentially blind from surface. For those interested, this paper, “Exploration and
Geology, 1962 to 2002, at the Goldstrike Property, Carlin Trend, Nevada” by Keith Bettles is
worth a read (we have also posted it on the EI website under the Geo-Insights tab).

**Alkalic Rocks**
*From Exploration Insights: 8/30/09*

Alkalic rocks are low in silica (compared to most of the granites and volcanics you may be
accustomed to) and generally form at greater depth. They can be very important
mineralizing systems and are the driving force behind the mega-deposits of Bingham
Canyon (total resources 960Mt @ 0.7% Cu, 0.3g/t Au, 0.03% Mo) and Cripple Creek (total
production 20 million ounces and resources of 15 million ounces).

**Epithermal deposits: in a nutshell**
*From Exploration Insights: 5/27/12*

The classification of epithermal deposits (low temperature deposits) as high, low, or
intermediate sulfidation refers to the chemistry (specifically sulfur fugacity) of the
hydrothermal fluids. That chemistry is responsible for the associated minerals and alteration
that form the basis of the field classification. For our purposes, the sulfidation state reflects
the source of the fluids and contamination by ground water.

Basically, high sulfidation deposits are formed by relatively pure acidic directly tied to
magmatic fluids. Low sulfidation deposits reflect magmatic fluids that have mixed with
groundwater and are nearly neutral pH. Intermediate sulfidation is somewhere between the
two and a bit of a catchall term. All of these are capable of forming world-class precious
metal deposits, which is all we really care about.

**Epithermal Systems**
*From Exploration Insights: 6/6/08*

Epithermal systems are among the more enjoyable mineral systems to study. Briefly, they
are relatively low temperature hydrothermal systems that occur in the very upper portions
of the earth’s crust: the top few hundred meters or so. My favorite part of investigating
these systems is that the study often takes you to hot spring thermal pools on deserted
volcanic islands inhabited by scantily clad women sipping cool tropical drinks with umbrellas
in them. The graphic below depicts the overall setting of epithermal systems- you have to
supply the little umbrellas and such.
Now that you are mentally there, recognize that epithermal alteration and mineralization are the result of shallow (less than one kilometer) and relatively low temperature (about 50 to 200 degrees centigrade) hydrothermal fluids- hot water. They form in active tectonic zones associated with continental subduction and rifting like you see around the Pacific Rim of Fire. These are places where the earth is being actively pulled apart or pushed together. The majority of epithermal deposits are relatively young (35 million years or less) because they form near surface in areas of mountain building and erosion. There are, however, Australian and Argentinean examples that are over 300 million years old.

Epithermal deposits have been further subdivided into high-sulfidation and low-sulfidation types based on the distinct pH (oxidation state) of their mineralizing fluids. The pH of the hot fluids correlate reasonably well with the source of the altering and mineralizing fluids. High-sulfidation deposits are formed directly from the fluids coming out of magma. Low-sulfidation deposits are formed by the interaction and dilution of the same fluids with groundwater. The alteration and mineralization forms over hundreds of thousands of years as the fluids work their way to the surface.

**Low-Sulfidation Deposits:**

Low-sulfidation precious mineral systems are the result of alkaline to near neutral pH hot spring fluids. They typically show vertically zoned changes in rock alteration and mineralization style. This is due to the effects of decreasing pressure, salinity and temperature as the hot fluids get closer to the earth’s surface and begin to interact with groundwater. The tops of these systems are characterized by hot spring silica and carbonate deposits (sinter) that form where the water flows out across the surface. Beneath the hot springs and sinters are broad zones of low temperature veining and clay alteration of the host rock (usually volcanics). With depth, the trace mineral assemblage transitions from mercury and antimony into more gold and silver rich veins and stockworks zones. Going deeper into the system the veins tend to be more confined and further narrow into bonanza high-grade gold and silver veins. The deepest part of the low-sulfidation vein generally becomes more lead-zinc-copper rich.

The following figure borrowed from Mag Silver’s website illustrates the parts of a low-sulfidation vein. From this general model and description of low-sulfidation systems you can see that if the drill results show high lead and zinc values we could be too deep for a gold and silver deposit (usually). Alternatively, if we are standing on opaline silica sinter deposits with high mercury values we can be fairly certain that we are in the low temperature part of the system, and that the bulk of the epithermal system (usually) lies below us.
Understanding where you are in the mineral deposit model therefore directs if, where and how the property will be tested.

Active examples of low-sulfidation hydrothermal systems include Yellowstone Park, the New Zealand Taupo rift and the Geysers California. Some of the more important low-sulfidation epithermal precious metal deposits are Hishikari, Japan (8.5 million ounces gold), Kupol, Russia (6.5 million ounces gold and 80 million ounces silver) and Fresnillo, Mexico (one billion ounces silver).

**High-sulfidation Deposits:**

High-sulfidation precious metal systems, as you probably already guessed, are formed by low pH (acidic) hydrothermal fluids closely associated with magma. These strongly acidic fluids become more dilute as they move outward from a magma body. This change in fluid chemistry over distance produces a characteristic zonal change in alteration and mineralization. Once again, the interaction of hot mineralizing fluids with the environment it is moving through produces characteristic features with which we can interpret what has happened. It begins with the complete acid leaching of the rock producing a sponge-like textured rock (vuggy silica) in which nearly all the minerals, except silica, have been removed. This is typically the zone or structure where the hottest mineral fluids moved up. Moving outward from the most intense acid leached alteration, the host rock is altered to a clay-silica (quartz alunite) followed by even less intense clay alteration (kaolinite, illite, montmorillonite). Essentially, the fluids change the minerals within the host rock by adding water and/or removing elements. This alteration pattern can cover 10’s to 100’s of square kilometers.

Mineralization is mostly confined to vuggy silica and broken rock in a central zone. It is generally disseminated and consists of gold with relatively minor silver, copper, antimony, mercury, arsenic and tellurides. Often these types of deposits may be associated with porphyry copper mineralization at depth. The following figure borrowed from Almaden Minerals' website illustrates the zoning pattern in high-sulfidation systems.
Many of the strata volcanoes around the Pacific Ocean could be forming high-sulfidation deposits now. Active examples include White Island, New Zealand, Mount St. Helens, Oregon and Mount Butar, Bali. High-sulfidation gold deposits can be extremely large and include Newmont’s Yanacocha (around 40 million ounces gold), Lihir, New Guinea (43 million ounces gold) and Pascua Lama, Chile (17 million ounces gold reserves).

Accurately recognizing the type of epithermal system present on a property and then placing the outcropping mineralization and alteration within the characteristic zonal pattern is the first step to understanding a property. By doing this you can get a feel for where you are vertically and laterally within the hydrothermal system based on the geologic model. This helps determine if you are too high, too low or just right within a mineral system and directs future exploration work.

What I have tried to convey here is not only what an epithermal deposit looks like but also how and why mineral deposit models are important to exploration. There is not however any guarantee that because a property fits the model an economic accumulation of metal will be found. Nearly every uneconomic epithermal system I have looked at had many, if not all, of the characteristics the model prescribed. Likewise, some very profitable deposits lacked some important features or do not really fit any model. Mineral deposit models are conceptual tools that help direct intelligent exploration. Ore deposits are the result of unique circumstances that occur within a mineral system, or model, that produce extraordinary metal concentrations.

**The Geology of Colombia**

*From Exploration Insights: 12/20/09*

**The Rocks**

The geologic evolution and tectonic history of Colombia have been ideal for the formation of gold deposits: this is El Dorado. Colombia lies at a triple-point juncture between the Caribbean Plate, the Nazca (Pacific) Plate, and the South American plate. This dynamic setting has accreted exotic micro-plates to western Colombia and is responsible for several periods, and directions, of plate subduction and related volcanism, all of which are associated with some very deep and long-lived major transform faults. Since at least the Jurassic period (~190 million years) to the present, the geologic environment has been conducive to the formation of gold deposits.

Gold bearing hydrothermal systems ranging from high-level, low temperature epithermal types to deep, high temperature mesothermal types are all exposed due to the very rapid tectonic uplifts. Significant gold deposits in Colombia include Colosa (12.3 million ounces grading 0.86g/t Au), Gramalote (2.39 million ounces grading 1.00 g/t Au), Angostura (11.5 million ounces grading 1.09 g/t Au), and Ventana Gold’s discoveries in the California District.
The map below (Fig. 2) shows the known gold trends and ounces of both hard rock and placer gold in these belts, as of 2007. The map significantly understates the true gold endowment and extent of mineralization in the country but is the best I could come up with.

![Map showing gold belts in Colombia](image)

(Fig. 2- Gold belts from; Sillitoe 2008, SEG v. 103)

Additionally, and this is very important for you gamblers in the crowd, there are literally hundreds, maybe thousands, of gold workings, showings, and prospects scattered throughout the country. Most of these are more or less controlled by about a half dozen people or groups that have been quietly biding their time waiting for you to show up. They are wheeling and dealing these to an ever increasing number of promoters, geologists, and scumbags that are jumping into this area play called Colombia.

Here's the situation:

Most of the known gold “mines” consist of small pits or tunnels hand dug into the hillsides on narrow, erratic, yet high grade quartz veins. Almost all of these are mesothermal (higher temperature and deep) veins that offer no chance of a significant deposit but can produce some very high grades if sampled properly. I expect that in 2010 we will see many Colombia plays come out of the box with very splasasy high grades and much fanfare. Be careful: although it is geologically possible to cob enough of these Small High-grade Irregular Type (SHIT) veins into a sizeable deposit, most of the time the cobbling process only produces a random collection of SHIT veins between large areas of barren rock. A ratty sub-type of these veins, favored by many Vancouver juniors, makes for particularly disappointing gold deposits.
Gold Porphyry
From Exploration Insights: 12/20/09

The other main deposit type that occurs in Colombia is the gold porphyry. These can be quite large but low grade. Anglo Gold’s Colosa deposit (468 million tonnes grading 0.86g/t Au) discovered just a few years ago is the model for gold porphyrtes in Colombia. The issue with these, and the reason I am not jumping into some porphyrtes I know of, is that they are ultimately marginal deposits, highly sensitive to the gold price. In Colombia, the extreme topography and rapid erosion means the oxidation (good for inexpensive gold recovery) is for the most part not going to be deep or complete, hence these low grade deposits will probably require milling operations to recover the gold (assuming the ore is not refractory). Therefore, capital costs are going to run from $500 million to well over $1 billion when and if the first of the required permits is finally issued.

The second issue a junior company has to face when defining and delineating a substantial low grade resource is the cost. These are expensive programs that will require the junior company to continually raise money on the back of long, sub-one gram per tonne gold intersections. This is not a class of deposit I want to be seriously involved with until I see the major mining companies move to take out the juniors that already have defined, large low grade bulk mineable milling deposits (Detour Gold, Rainy River, International Tower Hill, Andina, Greystar etc.)

The tremendous potential I see in Colombia lies with the innovative junior explorer that has secured in-country contacts and experience, and has the ability to differentiate the good from the bad—rapidly. There are high sulfidation and low sulfidation gold deposits lurking out there that have yet to be recognized. There are also going to be shear controlled stockwork and sheeted vein systems that can be bulked up into a major deposit, and carbonate gold-base metal veins that work for small, low cost operations. The transform tectonic setting and wrench tectonics have produced ideal sites for the development of gold deposits in extensional basins and along normal faults. There are undoubtedly other settings I haven’t even considered. We have to keep an open mind yet be very discriminating in selecting companies to buy. For the time being I intend to let the dust settle and see what survives. It’s worth remembering that there are no called strikes in this game and that patience is probably the most underappreciated investment tool we have.

Volcaniclastic
From Exploration Insights: 6/05/10

Volcaniclastic is essentially erupted and broken volcanic material that has been deposited in layers after a volcanic blast or two.

Geology of Indonesia
From Exploration Insights: 12/19/11

The Indonesian Archipelago is a 4,000-mile chain comprised of over 17,000 islands straddling the equator. Nearly all of the islands are volcanic in origin and formed as a result of magmatism related to continental plate and sea floor subduction associated with the interaction of the Pacific, Eurasian, and Australian plates. [For those interested, one of the best geology papers I have ever read is Warren Hamilton’s 1998 “Tectonics of the Indonesian Region”, US Geological Survey Professional Paper 1078.]
Hydrothermal systems that result from the cooling of magma below volcanoes, hot springs, and hydrothermal systems associated with the magmatism are responsible for some very large deposits. A few of the more significant deposits in this region include Tampakan (2.4 billion tonnes @ 0.6% copper and 0.2 g/t gold); Grasberg (2.8 billion tonnes @ 1.08% copper and 0.98 g/t gold); Gosowong (4.8 million tonnes @ 16 g/t gold); Lihir (188 million tonnes @ 3.48 g/t gold); and Batu Hijau (914 million tonnes @ 0.53% copper and 0.4 g/t gold).

Without doubt, the potential for additional copper and gold discoveries in Indonesia is excellent. Nonetheless, once you have established that a project has merit, the success or failure of a company more often than not comes down to land status and politics.

**Brecciation**
*From Exploration Insights: 2/26/12*

The brecciation (broken rock) is an important part of the story, as it is the result of collapse within the rock formations due to volume loss caused by hydrothermal fluids (Fig. 2). As the hydrothermal system, comprised of hot water, silica, sulfur, and trace amounts of gold, arsenic, antimony, thallium, etc. evolves, carbonate (calcite) is dissolved from the rock. The dissolution (volume loss) forms voids within the carbonate rocks that are partially filled by rocks and sand falling into the empty spaces (a breccia). The empty spaces and cracks permit increasingly large volumes of mineralized fluids to flood the breccia and deposit gold and associated elements. The stronger and longer lived the hydrothermal system, the larger the area of alteration and, potentially, the gold deposit.

**Rhyolite volcanic rock**
*From Exploration Insights: 4/15/12*

Simplistically, rhyolite volcanic rock does not make a clean open “crack” when broken, it shatters; hence, the mineralizing fluids tend to spread out rather than focus, resulting in a zone of stockwork style quartz veining. The style of quartz veining determines the mining technique that will be employed to extract the ore.
Mineralization

“Good” and “Bad” Grades--interpreting drill results and grades

From Exploration Insights 4/05/08

We begin by addressing a subscriber question. “What constitutes high-grade gold or silver or nickel etc. and vise versa?”

This is a very common and basic question that goes to the heart of what this newsletter is all about. Essentially, at what grade is a mineral deposit economic? It would seem that the answer should be just as straightforward as the question, (e.g. “10 grams per tonne gold – good, one gram per tonne gold – bad”). However, that is not the case. The answer involves the interaction of literally dozens of data inputs, many of which are variable over time, and some of which are complete unknowns. The millions of dollars that companies spend on pre-feasibility and feasibility studies are essentially directed at determining the answer to just your question; what constitutes good grades?

Ivanhoe Mine’s Bakrychik contrasted with Goldcorp’s Marigold mine

Ivanhoe Mine’s Bakrychik gold deposit in Kazakhstan contains a measured, indicated and inferred resource of 66 million tonnes, grading 6.6 grams per tonne gold (13 million oz). Within this ore body are zones that grade in excess of 20 grams per tonne gold. One would think that a 13 million ounce deposit at this grade would be a slam-dunk moneymaker. Not true. The project has been reviewed and studied for decades and found to be only marginal to uneconomic. Only with recent high gold prices do the studies show an economic return, and this is still debatable given political and social risks.

By contrast, Goldcorp’s 66% owned Marigold gold mine in Nevada reports reserves of 55 million tonnes, grading 0.69 grams per tonne gold. On first blush, a reported drill hole intersection averaging 0.69 grams per tonne gold would most likely leave you less than enthusiastic. However, the Marigold mine produced more than 100,000 oz gold at sub-US $200 per ounce total cash cost through 2004. At the US $200 cash cost that’s about a US $700 margin on rock grading 0.69 grams per tonne gold. Not bad...

Above we have examples of two gold deposits: one is an extraordinarily profitable mine grading only 0.69 grams per tonne gold and the second, a world class gold deposit, grading nearly an order of magnitude higher that is basically marginal. What gives?

The primary issue comes down to the properties of the host rock and how the gold is tied up in the mineral crystal lattice. Specifically, the ore at Bakrychik is encapsulated within the matrix of the sulfide minerals (arsenopyrite and pyrite). The sulfide minerals are hosted in a nasty black shale, containing 4% carbon. Both the gold encapsulation and the carbon make recovery of the gold extremely difficult (double-refractory).

To process the ore at Bakrychik once is it mined the sulfides need to be separated from the carbonaceous black rock. This is done by crushing and mixing the ore with chemicals that float the sulfides into a sulfide concentrate. The double-refractory nature of the ore means that the concentration process has to keep the carbon out of the concentrate while capturing all the sulfides. This can be done, but at an added cost.
The next step, liberating the gold from the sulfide, requires breaking down the sulfide chemical bonds through an oxidation process. This basically turns the sulfide to rust. This is a naturally occurring geological process that happens over thousands of years. At Bakrychik, they will need to build a massive roaster capable of heating the ore to 700°C in order to oxidize the sulfide and liberate the gold. The oxidized rock with the gold is then passed through a series of tanks where carbon is used to re-capture the gold (carbon in leach) after which it is stripped using cyanide and finally turned into a gold bar.

The recovery gold process at Bakrychik requires the building of a complex floatation plant and roaster. These are significant up-front capital cost items. Additionally, roasting the ore is a very energy intensive process: hence, costly. Every step in the procedure necessitates additional equipment, labor and materials, thus increasing the cost to produce an ounce of gold. In summary, our apparently high-grade deposit becomes marginally economic once we add in all the costs and effort it takes to actually recover the gold.

By contrast, the Marigold ore is simply ripped out by a dozer, placed on a large heap and sprinkled with cyanide that captures the gold. The gold bearing cyanide liquid runs down on to a plastic sheet where it drains into the CIL plant and gold is recovered. That’s it- little more than an earth moving operation and large lawn sprinklers. The key to the low cost of mining Marigold ore is that it has been completely oxidized by nature and occurs in relatively soft rock.

In the comparison above, we only considered one of many possible inputs related to producing an ounce of gold. A comprehensive list would include mining method, waste to ore strip ratio, location-access-infrastructure, dilution, grade distribution, hydrology, rock hardness …..you get the point here. All of these issues come into play when determining if grades are good or bad.

**Comparing the Economics of a High Grade and Low Grade Deposit**

*From Exploration Insights 11/21/08*

The most common question I get from readers is “What are good and what are bad grades?” The answer to that question is, of course: “Well it depends”. Working out the details of “it depends” costs tens of millions of dollars and is what feasibility studies are all about. Even a very rough guesstimate of what represents good versus bad results requires some sense of the geology and metal recovery costs.

Let me offer two gold deposits that could show up as opportunities as we troll the world seeking out potential investments. The first deposit contains 1.8 million ounces grading only 0.588 grams per tonne gold. The second contains about 1.3 million ounces grading an exceptional 31 grams per tonne gold. Clearly, if grade is king then our second example is the obvious investment choice and we can move along to the bar secure in the knowledge that we know what 31 g/t Au means.

But let’s put the two deposits in a different context. The first deposit from the previous paragraph, a very low grade deposit, produces gold at a cash cost of between $340 and $405 per ounce, depending on the waste to ore strip ratio and fuel costs. Our second, high grade, deposit shows cash costs of $836 per ounce- which they project will drop to $587 per ounce once they get a new mill in place. Assuming all else remains equal going forward on these deposits, then the Newmont/Fresnillo low grade Herradura deposit obviously offers a higher profit potential than Great Basin Gold’s Hollister deposit. (We are not talking about the stocks, just the profitability of the deposits.)
Comparing Newmont/Fresnillo Herradura and Great Basin Gold’s Hollister deposit

Herradura is a large open pit, heap leach mine. It is a very simple mining operation that entails blowing the rock up, putting it in big yellow trucks, breaking it up one more time, then spreading it out in the open where a cyanide solution is sprinkled on the heap and the gold is recovered from the fluid. The Hollister deposit, by contrast, is mined by underground miners very selectively drilling, blasting, and mucking several veins that average about 0.7 meters in width. The ore is handled a few times before being trucked and milled at an offsite facility. They are currently refurbishing a mill that will decrease costs, hopefully to the $559 cash costs envisioned in the feasibility study.

How about a really low grade porphyry copper-gold deposit in British Columbia? Consider Terrane Metal’s Mount Milligan deposit, which was recently purchased by Thompson Creek for $650 million. Mount Milligan contains proven and probable reserves of 482 million tonnes grading 0.2% copper and 0.388 grams per tonne gold. Based on a feasibility study that cost in the order of $30 million to complete, the deposit is nonetheless economic. It works because power costs are very low, it is near infrastructure and a port, and the ore produces a good, high grade and clean concentrate. If this very same deposit were located on top of the Andes there is no way it could have been considered economic even under the most optimistic development and metal price scenario, because all the positive cost saving aspects of the Mount Milligan deposit are not there. No road, no water, no rail, no port, no power etc...

Despite the obvious differences between Mount Milligan and a deposit atop the Andes, it is not uncommon that a company hoping to sell us some stock will present us with comparisons of two disparate deposits. When it comes to geology and mining, it’s all about the characteristics of the mineral deposit and the cost to get that mineral out. The geology, metallurgy, mine and process costs, plus infrastructure, power, and more need to be similar or the comparison is invalid. Likewise, valuing company ABC’s deposit on a dollar per ounce or pound in the ground basis and then drawing the conclusion that it is “undervalued” because it is selling for less than company XYZ’s deposit is unsophisticated and flat-out wrong. It’s profit margin per ounce or pound that we need to consider and that really matters.

Gold Company Valuations and Economic Studies
From Exploration Insights: 5/25/10

This interesting chart shows the spot gold price in Canadian and US dollars over the past two months. The gold price in Canadian dollars has fallen about C$50 against the US dollar price. Essentially the same applies to the Australian dollar gold price, while the gold price in Mexican Pesos is down about US$70.
Costs for companies mining and producing gold in Canada, Australia, or Mexico are essentially fixed in those currencies, yet the product, gold, is fixed in US dollar terms. Therefore, and all things being equal, the cost of production for mines in these countries can be considered to have increased by approximately $50 to $70 per ounce over the past six months based on currency changes alone. For simplicity, if a mine’s net margin is $500 per ounce these mines have taken a 10% hit to the bottom line (assuming all other cost inputs remain the same and the deposits are basically the same).

But they are not.

Greystar’s (GSL/TSX) Angostrura gold deposit in Colombia contains a measured and indicated resource of 11.5 million ounces grading 1.09 grams per tonne gold. It is a large, geologically and metallurgically complex deposit that is targeting a 250,000 tonne per day mining rate at a capital cost of ~$950 million.

By contrast, Andean’s (AND.TSX) Cerro Negro deposit in Argentina contains resources of approximately 3.3 million ounces (in three high grade veins averaging ~8 grams per tonne gold plus a number of new vein discoveries). They are targeting an initial operation of 2,000 tonnes per day from an underground mine at a capital cost of roughly $225 million.

Two completely different deposits, yet investors and analysts continue to value gold deposits on a dollar per ounce-in-the-ground basis ignoring the actual costs, currency uncertainties, and quality of the resources being valued (Fig. 2 below). This simplistic valuation methodology is often propped up by citing data from various economic mining studies prepared by independent engineering firms or resource estimators. Unfortunately, all such studies are not created equal. An economic assessment is only as good as the data
going in and the people doing the study.

(Fig. 2- Market cap vs. gold resources and dollar per ounce valuations for various development projects. Note this is from May 2009; Andina (ADM) has subsequently discovered that their metallurgy is as bad as most of us already knew and you can now buy their ounces for even less.)

Case in point:

**Gammon Gold.**

In 2007, Gammon Gold (GAM.TSX) touted that they would be in full production and turning out 400,000 gold equivalent ounces (200,000 oz Au, 10 million oz Ag) at a total cash cost of around $200 per ounce. Even better, if silver production were calculated as a by-product, the cash costs would come to a negative $204 per ounce! These estimates were based on a 397 page Bankable Feasibility study authored by Kappes Cassidy. The study incorporated resource and engineering studies from a number of other independent firms that added several hundred more pages to the document. Half a dozen mining analysts from major brokerage firms subsequently issued GAM share price targets in the $25 range based on the study and Gammon’s guidance.

The reality for Gammon shareholders has been anything but what they were led to expect, however, and the share price sits at ~$7.00. For Q-1 2010, total cash costs are nearly $500 per ounce and over the life of the mine they have never met initial projections.
There are two main points to the preceding rant and commentary. First is that the belief that gold companies can be valued and compared on a market cap per ounce in the ground basis is naïve at best. It is, actually, flat out wrong.

Second, and more importantly, is that mining and economic studies need to be considered within the context of the on the ground reality of the rocks, resources, and mining. In the case of GAM, the input data (resources, mine dilution, costs, ore characteristics etc.) were wrong: garbage in garbage out. The resource model did not reflect the actual ore bodies, hence the mine was engineered for a deposit that didn’t quite exist and, finally, the company mismanaged the resources in an attempt to meet their projections.

Almost anyone can plug numbers into a spreadsheet and come up with a result. This includes engineers, analysts, investors, and me. But with mining there are so many variables, unknowns, and guesses that one has to critically look at the individual inputs to determine if they make any sense. Occasionally this is easy, but usually it is quite complex and easier said than done.

We generally avoid advanced stage mine projects in EI for just that reason. I know rocks and have been involved in a number of feasibility studies, but I have never built and run a mine; big yellow trucks don’t do if for me. Although there are some obvious “that’ll never work” mining situations (GSL and ADM come to mind) and some equally obvious “no one can screw that up” deposits (think FRG-XAU and AND), more often than not investors are in a no man’s land and have to rely on the experts. As the Gammon example and many other abandoned mines and broken dreams demonstrate, that confidence can be misplaced. Mining is as risky a business as exploration but much much more expensive.

**Alteration**

*From Exploration Insights: 8/16/09*

Alteration is one of the most important indicators of mineralization, economic or not. By properly interpreting alteration it helps us read between the lines of the geologic history. Rocks are comprised of minerals and form under specific pressure, temperature, and chemical conditions. As long as these conditions remain the same the rocks, and the minerals within, are stable and do not alter. When the pressure, chemical, or temperature
conditions change, the rock alters as it comes into equilibrium with the new environment. More often than not the alteration results from the introduction of hydrous and/or magmatic fluids into the host rock. This can occur anywhere within the earth, from the very deep high temperature/pressure environments all the way to near surface groundwater. Weathering is as much an alteration feature as is intense silicification: both force the rock into equilibrium with the current pressure, temperature, and chemical conditions. In most, although certainly not all cases it is the changes, the alteration, that introduce or concentrate the metals in which we are interested.

One example of a very common and obvious alteration is that associated with porphyry copper systems. A granitic or porphyrytic intrusive crystallizes several kilometers below the surface at relatively high temperature (~600° to 1,000°C). [There is a lot more to magma crystallization and temperatures than meets the eye. For those interested go here http://www.uwgb.edu/dutchs/petrolgy/BEUTECT.HTM] During and post the solidification of an intrusive it typically rises towards the earth’s surface while hydrothermal fluids in the 260°C range pass through the rock: the pressure, temperature, and chemical conditions have changed, hence the rock must re-equilibrate. The hydrothermal fluids are more often than not the leftover elements, minerals, and fluid that did not crystallize during the formation of the porphyry. Let’s take a look at the changes to two common minerals in our porphyry:

**Feldspar and Pyrite**

1. **Feldspar.** This is the pink to white crystal in granitic rocks which for simplicity’s sake has the formula K(AlSi3O8). Under the lower pressure and temperature conditions and with the introduction of chemically different hydrothermal fluids the feldspar turns to sericite (a white mica). Again simplistically, the formula for white mica is something like K0.5-1(Al,Fe,Mg)2(SiAl)4O10(OH)2nH2. So K(AlSi3O8) goes to K0.5-1(Al,Fe,Mg)2(SiAl)4O10(OH)2nH2.

2. **Pyrite.** This is the pale brassy to gold iron cubic mineral: fool’s gold. Under the new temperature and hydrologic conditions pyrite (FeS2) is transformed to a goethite and further to hematite (Fe2O3) releasing sulfuric acid (H2SO4). By the way, the sulfuric acid released by the oxidation of pyrite results in the acid mine drainage problem so many sulfide deposits have to deal with.

The net effect of the process described above can be visually quite impressive as shown in the photo below (Fig. 2).

(Fig. 2- Extensive sericite-goethite-hematite-quartz alteration associated with an intrusive in the San Juan Mountains, Colorado. Those were originally grey rocks that have been altered to red-yellow etc.)

There are two noteworthy points in the photo. 1.) This is only one of three mountains displaying quartz-sericite-pyrite alteration that covers several square kilometers. 2.) Despite the obvious strong and extensive alteration, most of the economic silver-lead mineralization came out of one vein located where the shaft in the lower center is. Meaning, there is no certainty that economic mineralization is always associated with alteration! More often than not alteration is not accompanied by economic mineralization. [Note we are talking economic mineralization as opposed to mineralization per se].
Now imagine covering the above scene with jungle or swamp or tens to hundreds of meters of post alteration gravel or rock. That is the situation that most exploration companies are facing today: looking for economic mineralization under cover with very little outcrop data to help. The economic portion of the alteration system, the prize, often makes up less than 1% of the entire alteration and mineral system. Is it any wonder then that most exploration companies go broke looking? Conversely, that's why the few economic discoveries are worth so very much.

**Calcrete Uranium Deposits**

From Exploration Insights: 1/2/10 and 3/28/10

Calcrete deposits are defined as such because of their association with calcium carbonate (calcrete or lime) which forms through fluctuations in the water table and evaporation. They are very near surface, aerially extensive deposits that offer a low stripping ratio (ore to waste ratio) and very low open cut mining costs. Processing generally involves an alkaline leach process, again relatively low cost, depending on mineralogy and clay content. Sulphates (gypsum and celestite) in the ore can increase process costs or complexity significantly.

The geologic term calcrete describes a near surface chemical sedimentary rock that forms in gravels and sands as a result of the precipitation of calcium carbonate from groundwater in arid environments. It is a chemically formed cement (caliche) that binds the sand and gravel together. It can be as hard as concrete or relatively soft and friable. The presence or absence of uranium mineralization in calcretes is dependent upon 1) a uranium source; 2) groundwater capable of dissolving and transporting uranium complexes; and 3) a precipitating mechanism or reductant for concentrating the uranium.

*Here’s how it basically works:*

We have a large upland area with granites and volcanics eroding away and forming stream gravels, alluvial fans, and dry lakes: essentially an outwash plain moving sediments from the mountains into a basin. Rainfall courses its way through these sediments as groundwater, dissolving and transporting uranium until the groundwater flows out into a discharge zone. Chemical changes at the outflow zone then act to precipitate the uranium out of the groundwater and form uranium deposits. The mineralization generally occurs in old streambeds and lakes.

In a bit more detail:

The upstream source terrain contains abundant rocks and sediments with elevated uranium. Normally these are light colored felsic (feldspar and silica) extrusive and intrusive rocks such as granite, rhyolite, and volcanic ash. In Patagonia, this includes ash from recent Andean volcanic eruptions and the Jurassic-aged (~160 million years ago) volcanics associated with the separation of South America and Africa. Because of uranium's large ionic radii, it is attached to crystal boundaries rather than held within the crystal lattice of the minerals that form the granites and rhyolites. It is therefore available for dissolution and mobilization by oxidizing ground waters. Once in solution, the uranium migrates down the hydrologic gradient until a chemical change forces the uranium to come out of solution.

The precipitating mechanism can vary, but usually involves a change in the oxidation state (alkaline to acid/oxidizing to reducing) and de-complexing of the uranyl carbonate-UO2(CO3). This chemical change can occur when the groundwater is discharged into a basin
or playa, runs into different stream systems (paleo-channels), comes into contact with deeper upwelling water (along a fault), hits reducing fluids or carbon (swamps, logs, and dinosaur bones) or where groundwater is constricted or ponded behind basement highs. Climatic fluctuations over 100’s of thousands of years help to re-mobilize and re-concentrate the uranium into potentially economic deposits at the same time and place as the carbonate is precipitating out as calcrete: it’s a mutual reaction. The photo below shows the Langer Heinrich carnotite uranium ore \((K_2(UO_2)_2(VO_4)_2\times3H_2O)\) in a conglomerate.

(Fig. 1- Conglomerate ore from Langer with carnotite ore [yellow] and calcrete [white]. Courtesy David Talbot, Dundee Research)

The Langer Heinrich deposit contains a measured and indicated 72 million lbs U_{3O8} grading 0.06% U_{3O8}, and an indicated 91 million lbs grading 0.06% U_{3O8} (at a 0.025% U_{3O8} cutoff). The mineralization occurs within a 15-kilometer long paleo-stream channel (Fig. 2 below). The mineralization is very near surface, is between one and 30 meters thick and 50 to 1,100 meters wide, depending on the paleo-stream channel. The carnotite is generally uniformly distributed across the entire ore deposit, however it can be quite variable over very short distances. This high local variability within the river channels is a characteristic of these deposits.

(Fig. 2- District geology and uranium mineralization [red] in paleo-channels at Langer Heinrich. Note scale)

Mantra Resources’ Nyota uranium deposit in Tanzania is somewhat different than Langer but can be considered similar in terms of the ultimate grade and mining economics. The deposit hosts an indicated 28 million lbs U_{3O8} grading 0.052% U_{3O8}, and an inferred 56 million lbs grading 0.044% U_{3O8} (at a 0.02% U_{3O8} cutoff). Mineralization occurs as stacked layers within a fluvialite sequence of river sands and clays (Fig. 3 below). It has been classified as a tabular-type uranium deposit with only minor calcrete. Carbonaceous material (mostly
plant material and pyrite) within the host sands and clays acted as the reductant for the precipitation of carnotite.

(Fig. 3- Nyota deposit cross-section illustrating stacked nature of mineralization and typical grades encountered. Link here to presentation.)

**Gold Mining: Exploration and Production Issues**

*From Exploration Insights: 5/08/10*

**The Big Gold Miners Face a Problem**

Gold is valuable because it’s durable, divisible, convenient, and consistent, and has value in and of itself. Aristotle laid that out in 350 BC; more recently, Doug Casey added a sixth reason to the list: because it is no else’s liability.

But why is the stuff so darned expensive? Why does a single ounce cost $1,200?

The answer should be painfully obvious to any geologist or speculator in gold exploration. It is extremely hard to find economic accumulations outside of jewelry stores and bank vaults. The chart below of global gold mine production during the past 30 years suggests that the major mining companies are also having a hard time finding the stuff (Fig. 1). Production shows a very simple trend: it rose until about 2000 and has fallen since then. This has happened even as the gold price increased about 400%. Those two data points tell us something fundamental: there’s a problem.

(Fig 1- Global gold mine production 1980 to 2009)

From 1980 to about 1992, production from South Africa, North America, and Australia increased dramatically. Since then it has been falling just as dramatically. Rest of World production picked up at about the same time production dropped in the established mining
districts, and has been filling the gap in production since then. The reasons for the early increase in production from South Africa, North America, and Australia, and the later increase in the rest of the world are due to factors that are not likely to be repeated. This has important implications for major gold mining companies, exploration companies, and ultimately us here at Exploration Insights.

There are three main reasons why gold production increased up to 2000 even though prices basically declined.

- The first is the advent of new mining and processing technologies that made previously uneconomic low grade deposits economic. This was mostly a result of heap leach technology and bulk mining methods. Meaning: mining companies could now scrape up large areas of low grade mineralization and sprinkle a cheap solution of cyanide on the rock to recover the gold. This primarily worked on near surface oxidized deposits in relatively dry climates.
- The second is that a huge portion of the world that had previously been closed for various reasons was opened up to exploration. These new areas include much of Latin America, Africa, and the former Soviet Union. I was part of that movement; we were able to walk onto obvious deposits with new eyes and rapidly drill out those resources. It also became markedly easier to get into these areas, so we were able to go deeper into the jungles and deserts.
- The third is that geologists had a whole slew of new exploration tools with which to scan the earth. These include satellite imagery, geophysics, and more sensitive chemical tools.

The net result was that new technologies kept old deposits going longer and made previously uneconomic ones viable, thereby ramping up production into the early 90’s. New deposits in new areas kept that production going until about 2000. All well and good, but as the image below shows (Fig. 2), the industry is not finding as many new deposits as they need to in order to maintain current production levels. And, although we can expect incremental technological improvements in processing, mining, and exploration, there is nothing revolutionary on the horizon.

(Fig. 2- Global gold discoveries by size)

This is a worrisome slide for major gold producers—they are unable to sustain themselves. For the most part they are surviving on old deposits that are running out of ore and newer deposits that are quickly headed into the "old" deposit category. Reserves from these aging deposits are not being replaced by new discoveries. Producers’ problems are further
exacerbated by the rising exploration and development costs, plus the significant time it now takes to permit and finance a new deposit.

Everything I have said up to now is good news for the junior explorers and for those of us speculating in this sector. If a company can make an economic discovery, there are ready buyers willing and able to pay a significant premium for something they want and need. Now for the bad news: it ain’t easy. Consider this next diagram.

![Diagram of geologic setting, environments, and types of deposits associated with subduction related magmatic arcs; after Corbett](image)

This very complex schematic diagram cutting the earth’s surface illustrates all of the deposit types and settings associated with subduction related magmatic mineral system: essentially the Pacific Ring of Fire and some zones running up through Central Europe. With each of these individual settings comes a characteristic mineral and alteration assemblage and zoning. On top of those factors is the structural setting and rock type, either of which can be the make or break feature for the formation of a mineral deposit.

Although nearly every intrusive will have some of the right stuff, I would estimate that 90% of these mineral systems do not contain a geologically economic deposit—they have anomalies. That “geologically economic” classification doesn’t account for the added criteria: it has to be near enough to the surface to be exploitable, have good metallurgical characteristics, and not be sitting in someplace like Venezuela or California.

Now place the same diagram under thick jungle cover or hundreds of meters of gravel and you begin to get the sense of how hard it actually is to make a real discovery. This is why maybe less than 1% of the exploration projects out there will ever turn into an economic discovery, and nearly all the exploration companies eventually go broke.

If you are an explorations company exploring somewhere in this diagram you have to know where you are, and, more importantly, where you are not. If you are an investor in said company, you had better know too.

**Mining in the Yukon**

*From Exploration Insights: 8/22/10*

There is a lot of gold in the Yukon. Although that may strike you as a rather unremarkable statement, it is important to bear in mind. The Yukon and Klondike Goldfields are littered with placer deposits, gold prospects, showings, and anomalies—so much so that anyone and
everyone can pick up a property with gold on it. This, as in our discussion of Colombia, presents a problem for investors. How do we differentiate between anomalies with the potential to produce a significant discovery and those that never will?

At this stage of the game, it is tough to differentiate solely on geologic criteria. Our understanding of the genesis and types of gold deposits in the Yukon is evolving. I suspect we will be able to break mineralization styles down into clearly intrusive-related (Fig. 1 below) and “other”. The other categories will include; deep high temperature metamorphically derived systems, sediment hosted, magmatic, and, near surface epithermal. Within those categories some will prove to be the real winners and others losers. I am not ready to make that call yet and will therefore stick to a more pragmatic approach. Big gold deposits are associated with big footprints, and investors need to first judge if the geochemical, alteration, or mineral system shows the size potential to produce a large deposit.

(Yukon deposits will have to be above average. Almost every property in the Yukon is isolated and presents special infrastructure hurdles. This means costs. What works in Nevada will not necessarily work in the Yukon. Grades will have to be higher and we need to ascertain from the start probable strip ratios (waste rock vs. ore), metallurgy, access, and environmental concerns.

**Carlin-type mineralization**

*From Exploration Insights: 11/14/10*

Sediment hosted gold mineralization is a term often used to describe Carlin-type mineralization, based on similarities in alteration, geology, and trace element geochemistry. Carlin-type mineralization is generally the result of a relatively low-temperature hydrothermal fluid flooding and replacing a carbonate (limestone) rock with silica and metal. The major (large) Carlin deposits are related to deep fault structures, and show little if any genetic relationship to an intrusive body. In my opinion, true Carlin deposits are almost entirely exclusive to the Basin and Range Province of the western US. The Timok belt may in fact contain Carlin-type gold mineralization—time will tell.
**Skarn type mineralization**

By contrast, skarn type mineralization is the result of high-temperature fluids directly associated with and usually adjacent to an intrusive body. These are common. The ore bodies are often complex, usually small to medium sized, display sharp grade variability, and contain both base and precious metals. There are occurrences of lower temperature sediment hosted gold mineralization distal to, and obviously related to, intrusive bodies.

**Geology and Mineralization: Ixtaca Epithermal Property**

*From Exploration Insights: 2/27/11*

The most striking aspect of the Ixtaca property is the extent and strength of the hydrothermal system—six by two kilometers and open. AMM geologists have located outcropping alteration and quartz veining in a creek 600 meters northeast of the nearest drill hole. A further one kilometer to the east they have identified altered volcanics associated with a strong stream sediment anomaly (grab sample results are pending). One kilometer to the north of the nearest drill hole they have discovered a small outcrop of limestone; one grab sample assayed 760 grams per tonne silver and 0.25 grams per tonne gold. Finally, 1.5-kilometers to the west of the nearest drill hole, they have found strongly altered volcanics.

Despite the drilling, we are still in the very early stages of understanding the Ixtaca mineral system. The structural controls, center(s) to mineralization, and overall context of the mineralization are yet to be determined. Given that this is a field review, we will go over the geology in some detail for those of you interested, and to provide a reference for future commentary.

The basement rock is a Jurassic aged (~170 million years old) sedimentary sequence of limestones, shales, and sands that formed in an ocean basin. About 80 million years ago the ocean basin was thrust eastward into, and under, what is now Mexico, resulting in subduction and related arc-volcanism along the entire west coast of North America (Laramide Orogeny). The sedimentary sequence was uplifted above the ocean floor as it was folded, thrust, and broken during this mountain building event. This complex basement rock is (so far) the only significant host to the precious metal mineralization at Ixtapa (see Fig. 2 below).

(Fig. 2- Limestone outcrop displaying the broken and tightly folded nature of the host rocks. This complexity helps explain the variety of vein orientations we are seeing in the core.)

Twenty-five to 50 million years ago, volcanism associated with the eastward directed subduction formed the famous Sierra Madres and reached as far east as the Ixtaca property. The Tuligtic porphyry copper prospect, about five kilometers north of Ixtaca, (and the subject of previous exploration) is related to this time period.
About 25 million years ago, a seamount (think Tahitian Islands) riding on the Farallon Plate slammed (at a few inches a year) into the west coast of Mexico, causing a rotation of the westerly directed subduction into a more northerly-directed configuration. This shift effectively ended arc related volcanism along the west coast, and formed the still active Mexican Volcanic Belt (MVB). The rotation of the arc is also responsible for extension and compression within the MVB, causing the related basins and ranges. Extensional basins accumulated volcanic ash and sediments and may also mark volcanic centers.

The Ixtaca precious metal system formed during this relatively recent MVB volcanism period. Volcanic ash was deposited on the erosional surface of the basement rocks. The ash was probably several hundred meters thick (depending on the underlying topography) and appears to have accumulated within a basin. It also appears that felsic dikes (narrow magmatic intrusions) intruded the basement rocks (AMM hasn’t documented the dikes into the overlying volcanics yet, so timing is ambiguous).

These dikes are invariably altered and associated with mineralization; however it is uncertain whether they are responsible for the mineralization or acted as a favorable conduit to the mineralization. Either way, they may represent an important “ore type” in the system.

The variable rock competency plus the geochemical and hydrologic differences between the volcanics and underlying basement rocks provide a very important lithologic control to the precious metal mineralization (volcanic tuff vs. limestone). It is clear from the alteration in the tuffs (low temperature clays, opaline silica, etc.) that they were mostly water saturated (Fig. 3 below). At the time of alteration and mineralization the entire six by two kilometer area (minimum) was a steaming and boiling zone, a setting similar to Yellowstone today. As cooler, descending groundwater circulated through the tuff and interacted (mixed) with the rising, mineral rich hot fluids in the limestone, metals precipitated in this mixing zone immediately below the lithological contact. This mixing zone has been documented by drilling to several hundred meters below the tuff-limestone contact and shows no change in mineralization or mineralogy (this is important and positive).

(Fig. 3- Steam and hydrothermally altered tuff near the basement contact as exposed in a creek 600 meters northeast of drilling. Yellow color is due to introduced iron oxide, and cracks are where hot fluids moved.)

Exploring a mineral system the size of Ixtaca takes time, especially given the dearth of surface information. Neither EI nor Almaden know what a gold/silver deposit at Ixtaca will
look like nor where it may be located. Geophysical exploration methods may be of some help; limited Induced Polarization (IP) did turn up some anomalies, and Almaden will try other geophysical tools. Surface geochemistry is useful within those windows exposing the tuffs through the recent post mineral ash; however, the volcanic tuff seems to have soaked up all the hot fluids, therefore the anomalies are probably going to be broadly dispersed. Geological reconnaissance and mapping has been, and will certainly continue to be, useful, but outcrop is limited. Ultimately, this is exploration with the drill bit. We will see both positive and negative surprises as Almaden puts the geologic picture together and comes to a better understanding of the controls to mineralization.

**Mineralization in volcanic layers**

*From Exploration Insights: 8/5/12*

An important concept to bear in mind when contemplating this mineral system is that the rocks into which the mineralization was emplaced had to be there first. A seemingly obvious statement that should guide you back in time to when dinosaurs ruled the Earth and multiple volcanic eruptions were forming layer upon layer of rock in a shallow sea behind an island arc similar to the Philippines today (sans dinosaurs). Coincident with the volcanism, hydrothermal systems deeper in the crust were pumping hot nasty ore-bearing fluids into the rocks. As each volcanic and sedimentary layer was deposited, the chemistry, temperature, and hydrology of the underlying rocks changed.
Resource Estimates

Resource Estimates Defined

From Exploration Insights: 2/20/10 and 11/6/11

Mineral resource estimates are just that—estimates. They are an estimator’s best effort to calculate the tonnes and grade of a mineral deposit from the available data. They are based on (or should be) appropriate economic parameters for the deposit, and categorized based on the level of geologic confidence the estimator has regarding the deposit’s economic viability—“reasonable prospects for economic extraction”. (Estimates are, to varying degrees, subjective and will differ between estimators.) The figure below graphically demonstrates the relationship and confidence levels between mineral resources and reserves based on the CIM definition.

The progression of resources from inferred to indicated to measured reflects an increasing confidence level on the part of the estimator that the mineral is in fact there and is potentially economic. The increasing confidence is usually a function of closer drill spacing and better geological knowledge. The amount of drilling, metallurgy, and other work is, of course, dependent on the individual deposit’s characteristics; therefore, the cost to upgrade resources and reserves is highly variable. It is important to always bear in mind that these are estimates and not certainties.

In the figure above you will note there is no “Potential” resources category. The term “potential resources” is not defined and is therefore virtually meaningless. Anyone could claim potential gold resources on any piece of ground and many unscrupulous letter writers do so with US OTC-listed junior companies. That is why few legitimate junior companies are only listed on the US Over-The-Counter dealer networks. As a rule of thumb, it is best just to avoid OTC Bulletin Board stocks.
Speculators in minerals exploration face real difficulties while attempting to interpret drill information when important pieces are missing from company press releases. Most common amongst our problems is determining what a drill interval grades when higher grade intersections are removed—essentially the residual grade. With that in mind, Corebox and Exploration Insights have jointly developed a drill hole interval calculator that provides that residual grade; we are making it available to anyone interested. This will hopefully prove popular with investors (and drive them to our respective websites).

Let’s run through a topical example that I have received queries on. Bayfield Ventures (BHV.TSX-V) recently announced results from drill hole RR10-18 on their Burns Block property adjacent to Rainy River’s gold deposit in Ontario. The headline reads: BAYFIELD CORRECTION INCREASES DRILL HOLE FROM 2.70 G/T GOLD TO 5.08 G/T GOLD OVER 81M IN RAINY RIVER, NW ONTARIO

The text of the release details the headline intersection, with narrow high grade intervals broken out of the longer 81 interval as shown below for RR10-18:

(RR10-18 drill intersections, yellow background values were used in the calculator)

As an interested speculator considering the potential economics of this interval, it is also useful to know what the rock between the high grade hits averages: the residual grade. This is important because every tonne of rock moved costs money, and therefore making money means moving as little waste as possible while optimizing the amount of ore processed. That break between ore and waste is expressed as the economic cutoff grade in grams per tonne (or whatever metal and metric you are using). Make sense?

Getting back to our example, if you follow this link to the drill hole interval calculator and plug in the yellow highlighted data from above, the result would look like this:

(The residual grade is 0.466 g/t Au over 69m. I have not included the 28m @ 13.28 or the 11m @ 2.01 because they are parts of other intervals. In the linked example you will see that I broke the 28-meter interval grading 13.28 g/t down as well.)

By pulling out the 12 meters of high grade, we are left with 69 meters grading 0.466 grams per tonne gold. Although we don't know how the gold is distributed within the 69-meter interval,
our impression of the original 81-meter interval is much changed. We are now in a better position to consider if 0.466 grams per tonne gold is likely to be above the economic cutoff or just more “highly anomalous” material. We also have a better sense of how the gold mineralization is likely distributed throughout the 69-meter interval: discretely. Consider: does it make sense to open pit mine high grade sulfide gold mineralization located at a drill depth of 488 meters? Although there are many factors that go into the answer to that question, intuitively the answer is “probably not”.

Given what we now know about the grade distribution and depth, we are in a better position to consider if an underground mining option makes sense. In an underground mining operation, continuity of high grade mineralization is critical. Our next task, then, would be to look at the gold mineralization section by section, drill hole by drill hole. Results from drill hole RR10-18 (a nearly vertical hole), which is immediately adjacent to RR10-17; suggest continuity will be a problem. My research on Rainy River’s adjacent deposit indicated that high grade continuity was also problematic.

Assays and Resource Estimates
From Exploration Insights: 7/18/10 and 2/20/11

Assays are derived from dry samples, and resource block models are based on dry tonnes. After a drill interval is collected and split, it is dried, crushed, and divided into a 30, 50, or however many gram sub-sample and then analyzed (there are a dozen things that can go wrong here). These assays are then plugged into a block model and eventually used to complete a resource estimate. The final calculation, although quite complex, can be simplified for our purposes to: resource equals tonnes times grade (R=T x G) where tonnes equals length times width times height times density (T=L x W x H x D). Density is mass per unit volume (D=m/v). But what happens to the density calculation if the rock is wet? The density goes up. Therefore so do the tonnes and metal content in the final calculation. I have seen very porous material soaked before the calculation. If the firm conducting the feasibility report doesn't catch this simple error it could lead to real problems for a marginal deposit. Minor stuff, but it all adds up.

How a drill interval is converted to an assay.

A section of drill core, call it one meter of quartz vein, is split in half, with one half going to the laboratory and the other remaining with the company for study etc. The laboratory crushes and pulverizes the half core then blends and mixes it, making a best attempt at producing a homogenous sample. From that large, mixed sample derived from half the core, a 30 to 50 gram sub-sample is collected for fire assay. The resultant assay is then assigned to the original one meter of core that originally weighed between 3 to 9 kilograms (depending on drill core size).

In a resource estimate, that one-meter assay is used to extrapolate or estimate the grade of the vein material between it and the next drill assay interval in the vein. This is accomplished through various statistical analyses and geological interpretations. The confidence an estimator has in the interpretation breaks the estimate into the measured, indicated, and inferred resource categories.

What we have done in the preceding example is taken a 30 or 50-gram assayed sample that is maybe 1% of the original core and interpolated it over a 10, 25, even 50 meter stretch of vein for which we have no data (no drill assays). We have assumed good sample and analytical quality, and then grade and structural continuity through the interpolation. The
What could possibly go wrong?

1. In a vein deposit with coarse gold erratically distributed through otherwise barren quartz, what are the odds that the drill hole will catch the gold? Generally not good, therefore the more heterogeneous the mineralization is, the more closely spaced the drill holes will have to be in order to capture a representative number of mineralized vein intersections. Drill spacing of 12.5 meters, or even less, may be required to produce a resource of sufficient confidence to move it into the reserve category--a very expensive and time consuming job you need to consider when your favorite company starts promoting highly variable results.

2. If the original, whole core sample contains a couple of small gold flakes (nuggety) what are the odds that one or both flakes end up in the half core that gets sent to the laboratory? If the geologist logging the core sees these flakes does he or she selectively pick or avoid sending these to the laboratory? We won’t even address what happens to this supposedly “representative” drill core when we experience poor core recovery, sample loss, ground water, drill and driller problems, and other acts of God.

3. At the laboratory, the final 30 or 50-gram sample may or may not contain one or both of the gold flakes. If the final sample does, then the resultant assay will be very high grade. How to limit the influence of these high grade outlier assays on the rest of the quartz vein gets us back to Rubicon’s resource estimate.

The high grade nugget problem is often addressed by applying an upper limit (assay cap) to the grade that will be used in the estimate. The capped grade (e.g. the maximum value allowed would be “30g/t Au”) is determined statistically, based on some portion of the assay database. It can be further quantified by segregating the vein assays into geologically coherent zones, structures, ore types, etc. depending on the geological detail available. The objective of capping is to restrict the influence that outlier high grade assays will have on vein material (that is almost certainly lower grade) using statistical analysis and geology.

The issue of how, when, or if to cap high grade assays is not cut and dry. Clearly, when dealing with the task of interpolating a very small assay sample into large areas with no data in narrow, nuggety vein deposits, there is room for error, both to the upside and the downside. I include below an excerpt from the Geoex report quoting Rogers’ (1982) experience at the Dome Mine, relating drill results to actual mining results:

**Bimodal Grade Populations: mineralization, faulting and eruption, grade distribution plot**

*From Exploration Insights 4/18/09*

Mineral resource estimation is the process of projecting values for one or more known points into volumes of material with unknown values: projecting the known into the unknown. When we read a company’s resource or reserve estimate we are really reading a mineral resource estimator’s projection from a compilation of single known measured points (drill-hole assays) into a volume of material in the order of one million times as large (the mineral deposit). Therefore a company’s measured, indicated, and inferred resources, as well as proven and probable reserves are only as good as the underlying data and more importantly the resource estimator. Resource estimation is very subjective and never 100% correct: it’s an estimate.
We have covered resource estimates in past EI issues. There is also the Free Report available via the website. The primary concept to keep in mind is the subjectivity and uncertainty inherent in any mineral resource estimate. The subjectivity comes down to how the geology and controls to mineralization are interpreted and, the statistical treatment of the assay data.

Here’s where the difficulty arises.

Most mineral deposits we deal with are formed in tectonically active areas (Fig. 1 below). The mineralization process is intimately associated with subduction zones, volcanoes and faults. These are dynamic geologic systems where the actual movement of faults or eruption of hot springs is responsible for the precipitation of the metal.

(Fig 1- Conceptual mineral deposit styles at subduction zone. Greg Corbett, 2002)

Examples of mineralization

The San Andreas Fault-Salton Sea area is probably a good example of an area currently experiencing mineralization. As the fault cracks and San Francisco shakes, this movement or slip causes rapid and significant changes deep within the earth along and adjacent to the fault. The important changes from a mineralization viewpoint are related to pressure and how it affects the internal fluid dynamics along the fault. Rapid changes are responsible for the precipitation of metal out of these deep metal rich fluids. Gold deposits along Canada’s Cadillac Break were formed in a similar environment.

Another good example is Yellowstone National Park. Here the feeder channels for rising mineralized fluids (surface hot springs) are eventually choked off by silica deposition. When enough pressure builds up to blow through the block, the resultant eruption causes rapid pressure/temperature changes and mineral precipitation within the feeder (a vein). The gold deposits of central Romania are the result of a massive hydrothermal system similar to Yellowstone.

Although these two processes (faulting and eruption) I described are unique to a particular location and time, they occur at many times and places all along the San Andreas Fault and in the Yellowstone area. The end result for us is that along the fault there is considerable variability between points, depending on where and how the fault moved and how the ore-bearing fluids reacted. Therefore each data point we are able to collect (drill-hole assay) along the fault intersected by a drill hole can be materially different from a point one meter, ten meters or 100 meters away. High-grade mineralization along a fault can be immediately adjacent to low-grade, due to the localized nature of each ore-forming event. The question
the resource estimator has to deal with is “how do I account for this variability with so little data?”

Often this variability shows up in grade distribution plots or histograms---stay with me here. A grade distribution plot is just what it says, drill-hole assays plotted in a chart. In a bimodal distribution there is a lower grade assay population and a higher-grade assay population.

![Schematic diagram of complete epithermal gold-silver vein system. Almaden's drilling has only penetrated to top 100 meters or so.](image)

*(Fig. 6- Schematic diagram of complete epithermal gold-silver vein system. Almaden’s drilling has only penetrated to top 100 meters or so.)*

**Capping or top cutting assays**

*From Exploration Insights: 4/25/10 and 7/11/09*

Capping or top cutting assays is a means of limiting the influence an individual assay interval has on a resource estimate for the overall deposit. You see, a drill hole only samples three- or four-inch widths of a mineral deposit. The drill core sample is cut in half, crushed, pulverized, and then reduced to a 30 to 50 gram sample for assaying (typically). That assay is assigned to the drill hole and used to reflect the grade over 25, 50, or even 100 meters of rock between it and the next drill hole.

In gold deposits, particularly high grade vein deposits, the gold tends to be erratically distributed. A drill hole may go through a very high grade section (e.g. hit a nugget) or completely miss. Although those two results are certainly part of the deposit they cannot necessarily be considered representative of the entire deposit. [For those of you watching the Stanley Cup playoffs try this if the Blackhawks are getting whooped. Throw a handful of peanuts across the table and cover them with a tablecloth. Then consider; how would you estimate the number of peanuts under the cloth using a pencil to try and “hit” the covered peanuts? To estimate this requires an understanding of the angle and velocity with which they were thrown plus enough “hits and misses” with the pencil to predict what is between the pencils stabs.] To some degree that is the issue resource estimators face. They solve this problem by getting enough drill intersections into a deposit to understand the geologic and structural controls and then statistically determine what is typical and what is an outlier in the assay population.
**Coefficient of variation for an assay**
*From Exploration Insights: 8/19/12*

For the non-geostatisticians in the audience, the coefficient of variation (CV) for this bench is over 7. The CV is a fancy way of expressing the variability of the assay (or composite) grade population used in the estimation. A CV of about 1 or less means the global variability of the data used in the estimation is at a level that, assuming all other methodologies used are appropriate, introduces little risk of the estimate being wrong. Progressively higher CVs indicate there are increasing risks of producing an unrealistic estimate due to excessive variability in the underlying data. A CV of 7, with no other mitigating constraints applied to the modeling (as is the case at Cariboo) demonstrates that the risk in the estimate is extreme and significantly outside of the geologic reality. Again a major bummer if your mine plan relies on the mineralization to be there and it isn’t.

True grade capping is a statistical treatment of assays usually used in resource calculations to constrain the effect of outlier high-grades. It requires a sufficiently large database to allow the determination of what is out of the ordinary within the overall grade population. The objective is to not let high-grade samples overly influence the estimate and produce an inaccurate and overly optimistic result.

**Grade distribution**
*From Exploration Insights: 5/13/12*

The more complex the deposit and its grade distribution, the more the likelihood of increased mine dilution. Almost invariably, mines with complex orebodies experience lower than expected head grades due to uncertainties arising during mine planning and the day-to-day issues such as grade control once in operation.

Grade is king, that’s a given, but continuity and consistency of mineralization are also very important. Deposits with grades that are relatively uniform and predictable and, even better, that display mineralization that connects well from one drill hole to the next are preferred. In such deposits, there is usually very little internal waste within the mineralized envelope.

Another good quality is when the ratio between the average grade of the deposit and the cut-off grade being applied is high, say better than 3-to-1 (e.g. average grade 0.9g/t and economic cutoff grade of 0.3g/t). Good resolution between ore and waste implies the deposit has relatively sharp boundaries and it should be easy to differentiate rock that will make money from that that won’t. Favorable continuity and consistency mean that there will likely be a much higher certainty of the tonnages and grades being produced once the deposit becomes a mine. Basically, the mine manager knows what he will be getting because the deposit is so uniform.

**Geological bias: a “feel” for rocks**
*From Exploration Insights: 7/22/12*

As an economic and exploration geologist one ends up spending considerable time in third world hellholes, rotting jungles, frigid barrens, baking deserts, and some of the most beautiful spots on Earth. Over decades of this you develop a “feel” for rocks--what works and what doesn’t-- that goes beyond pure scientific explanation. Certain mineral deposit
types and belts of rocks, or characteristics thereof, either appeal to you or don’t. This is a necessary screening mechanism, mostly acquired through failures, which helps filter the 2,000 or so properties that get pushed your way every year.

In today’s letter, 266 meters grading 1.23% copper equivalent was viewed as an extremely positive sign, whereas a 118 meter intercept grading 4.08 grams per tonne gold, and another 41 meter intercept grading 6.5% copper plus 17.5 grams per tonne gold were met with caution. This geological bias is reflected in which stock we ultimately bought with our money—the definitive test. Time will tell if our “guts” plus a bit of research was accurate or not, and it is certainly possible that the properties we passed on could turn into significant deposits---our biases are therefore both a positive and a negative of this letter.
Exploration and Mining Tools
Evaluating anomalies
From Exploration Insights: 11/13/11

At its most fundamental level, minerals exploration is really the process of identifying anomalies (geological, geophysical, or geochemical) near the earth’s surface and figuring out what they are, or aren’t. Very important point here—an anomaly is little more than some value or data point above or below a background or average value. On that score, Mother Nature has been generous to exploration geologists and the financing infrastructure that supports them—very generous. Nearly every geologic event or mineral system produces some sort of anomaly—that is what the evolution of Earth is all about: change. However, nearly every anomaly that draws the attention of investors reverts back to what it was to start with, an anomaly, but now with a bunch of holes in it. That single fact, plus the inexact nature of the science of exploration, is why the odds of success are so low. It is also why there are over 2,000 junior exploration companies—all you need to start a company is a story and geo.

As the slide below illustrates, the odds of finding an economic deposit on any given anomaly are exceptionally low. By appreciating what an anomaly really is, those odds begin to make sense.

(The odds of success for any given anomaly and the cumulative frequency distribution of approximately 5,000 gold deposits. Note that only 10% of deposits are larger than 4 million ounces. Source of chart: Stephen Enders, Society of Economic Geologists Newsletter, July 2011)
Therefore, when evaluating a junior company’s anomaly it is critical to identify if it really offers the potential for a discovery whose economic value is commensurate with the very high risk you as an investor are taking. Is the mineral system large and strong enough to produce a large rich deposit? How extensive is the alteration (anomaly) and does it fit with the geologic target being proposed? What do we have to see in the drilling to confirm that size potential? What sort of access, infrastructure, metallurgical, social, and environmental hurdles would the deposit have to overcome? Those issues cost time and capital; plus, consider how deep the proposed deposit is and what the costs and mining methods are likely to be for the proposed target. All too many deposits that are brought into production are marginal at best when factoring in the upfront risks, time and, capital and production costs.

**Radiometric Readings**
[From Exploration Insights: 07/11/08](#)

Accurate uranium analysis requires a chemical assay. Gamma-count readings, although indicative, are not legitimate for estimating grades.

**Ore body and open pit: Whittle Pit of Lydian International**
[From Exploration Insights: 5/22/11](#)

**Lydian International** released the results of a preliminary optimization study for the Amulsar Gold deposit in Armenia. The study was conducted by CSA Global and is based on 2 million ounces of gold grading 1.0 grams per tonne; it excluded 500,000 ounces of inferred gold from the nearby Erato deposit. This optimization study is in advance of a preliminary economic analysis due out in June. Its purpose was to provide a rough assessment at this point in time on the deposit’s economic assumptions, and to direct future work.

The study was based on a hypothetical open pit, built using a mining software package (Gemcom Whittle) that uses a numerical process to optimize a conceptual pit. The program provides an early look at mine economics and production sizing and helps determine investment strategy. This study assumed the resource was closed, and that any rock not in the resource estimate was waste. The figure below illustrates a generic conceptual ore body and open pit that formed the basis of the Whittle pit.
The results of the study are in line with our expectations and show a robust mine, with life of mine cash costs of $335 per ounce (I get closer to $400/oz) based on an initial three years mining 5 million tonnes, thereafter ramping up to 10 million tonnes per year. Assuming these mining rates, Amulsar will produce in the order of 150,000 ounces annually, increasing to 225,000 ounces in year four.

Whittle studies do not include capital costs. For our purposes, I have been estimating in the order of $100 million for a 5 million tonne per annum operation and now, with the proposed increase to 10 million tonnes per annum in year four, we will add another $70 million to pay for the future upgrade.

Run the numbers at your preferred gold price and, if our capex and opex estimates are close, it is clear that the potential free cash flow is not factored into Lydian’s $200 million market capitalization.

In all, Amulsar continues to be one of the best (meaning profitable) mid-sized gold deposits I know. It is still relatively unknown, is not covered by most of the analyst community, and lacks a retail buzz. The deposit’s location in Armenia also creates a perception problem that I think is unwarranted and will eventually be overcome. The government of Armenia is pro-mining and pushing LYD to get the deposit into production.

Next month we will see the results of the preliminary economic assessment based on a 2 million ounce deposit. Lydian will continue infill drilling the deposit over the summer and fall in order to increase the resource confidence, add ounces, and test other exploration areas. Assuming the gold market holds up, the current LYD price represents a discount to what I infer will be a much more valuable deposit.

**Soil Samples**

*From Exploration Insights: 9/29/09*

One excellent question that came up during one of my workshops in Toronto concerned soil samples and the reliability of such to predict mineralization. Soil samples are just another
tool in the geologist’s kit to assist in understanding a mineral system. Samples are taken on regular grid points at some depth below the surface (depending on how the soil formed), assayed for a large suite of elements, and plotted on a map. The idea is that the dirt being bagged was derived from the rock directly underneath and therefore provides a good indication of what the bedrock may contain. If the soil sampling works, the resultant maps show geochemical anomalies and trends that will direct further work such as trenching, pitting or drilling. There are numerous factors that could invalidate, negate, or somehow make the sample results erroneous and therefore the interpretations wrong.

In my poverty stricken days as a junior geologist I spent a fair bit of time dirt and rock baggin’ in a wide variety of geologic environments and weathering profiles. One has to be very careful and critically evaluate the results in the appropriate context. The results can however be very useful. This was the case with our investment in Canplats that was based on soil and pit results from their Camino Rojo discovery in Mexico in late 2007. That was a relatively simple investment decision because we knew reasonably well the geologic setting, mineral system, and likely mining scenario of that project.

**CSAMT**

*From Exploration Insights: 7/10/11*

A CSAMT (Controlled Source Audio frequency MagnetoTellurics) survey involves transmitting a controlled set of electric signals into the ground at one site and measuring the returned and natural signal, plus the magnetic field at other sites. The recorded orthogonal, horizontal electric and magnetic data is then filtered and processed through a complicated mathematical process to determine the relative resistivity of the area being investigated. The survey is a fairly easy and inexpensive geophysical tool that can be used to cover large areas and “see” up to hundreds of meters into the earth.

In the case of WKP, the resistivity anomaly relates to nearly massive silica associated with the hydrothermal system that replaced the host rock with quartz (and a bit of gold). Hence the resistivity anomaly is showing us where the center of the mineral system is.

**Stream sediment samples**

*From Exploration Insights: 7/17/11*

Stream sediment samples are a first pass reconnaissance tool that is particularly useful for rapidly evaluating and identifying geochemically anomalous stream drainages in an area with minimal other information. A small amount of sediment is collected from the stream and analyzed for a wide range of elements. The resultant data is plotted on a map, and anomalous areas are highlighted for more detailed follow-up.

Ridge and spur soil sampling is often the next stage in the exploration process. Essentially, soil samples are collected from mountain ridges and spurs that define the limits of geochemically anomalous stream drainages—i.e. walk up hill and don't come back until you find something. Again, the samples are analyzed for a wide range of elements, with the results being used to further delineate the source of the stream anomalies. Follow-up work on anomalous ridge and spur sample areas includes detailed soil sampling, trenching, mapping, geophysics, and, if warranted, drilling.
**Grab samples, chip samples**

*From Exploration Insights: 1/16/11*

A grab sample is just that—a rock is grabbed and put in a bag for assay. A chip sample consists of rock fragments broken off an outcrop, usually over a measured width. Chip samples provide a better handle on the rock and mineralization sampled because of the context provided by the width. With both chip and grab samples it is difficult to know what they actually reflect without the context provided by a detailed description and location map (none were provided by HDG).

I suspect that the grab samples presented by HDG were collected as the geologist walked over an area of limited outcrop and picked up the better looking outcrop, subcrop, or float (quartz, calcite, adularia, iron) to see what it assayed. [Outcrop is rock exposed in place, subcrop is rock that was probably derived from the immediate area, and float is rock that has been transported from elsewhere and is not necessarily representative of the underlying rock.] All are useful but have to be viewed in context.

Grab sampling can be very selective and misleading if interpreted or presented the wrong way. For instance, in the photo below you will note a very thin white quartz vein in otherwise fresh rock. Selectively sampling only the white vein could produce a very high gold assay in a sample. Ditto if you only picked up bits of quartz float. The assay results only tell you what is in the white vein and do not give a representative assay for the host rock. The host rock comprises the vast majority of the rock in the photo and throughout the area. Therefore, you may get a great assay from the grab sample but the information not provided (that everything else is barren) may well lead to ill-advised excitement and the wrong conclusion.

(Fig. 2- Thin white quartz vein carrying gold in an otherwise barren host rock)

In a mining operation there is a minimum volume of material that can be mined at a time. It could be 0.5 of a meter for a very narrow vein mine or 5 to 20 meters for a large open pit mine. Therefore assays need to ultimately be viewed in the context of the minimum mining width given the type of mining operation envisioned. This is one of the basic tenets of “Turning rocks into money™”—establishing the minimum mining width.
Life expectancy of a mine
From Exploration Insights: 6/10/12

Putting size into perspective, a mine is generally optimized to consume a deposit over an 8-12 year mine life, call it 10 years average. A one million oz deposit, assuming 80% overall recovery, would generate around 80 thousand ounces per year.

Block Caving
From Exploration Insights: 7/22/12

The Oyu Tolgoi Block Cave Project technical report describes block cave mining as “a high-tonnage underground bulk mining method generally applied to large homogeneous ore deposits. Ideally, the ore to be caved should be structurally weak, and the waste overburden should be weak enough to collapse over the ore without inducement as the ore is extracted.

“Block caving involves excavation of the natural support from beneath the ore, causing the ore to fail and collapse into the excavated void under the force of gravity and local geomechanical stresses. The broken ore is then pulled out from under the caved section through a drawpoint arrangement, subsequently removing support from ore and overburden at increasing height above the initial excavation, and eventually extending the cave upward to the surface” (16.4.1.4 Mining Method Description).

(Fig. 2: Schematic of block caving operation. A body of rock is shattered then undercut, producing a void. As the ore caves into the void it is hauled out and up a shaft to surface for processing.)

The economic and geotechnical parameters that factor into the decision to block cave are considerably different than those for an open pit mine. The most obvious aspects to bear in mind when evaluating such a deposit include:

- It is extremely expensive! The holes are deep, in this case over 2,000 meters, and could cost in excess of $300,000 each. Drilling a reasonable-sized deposit to
measured and indicated could cost $10’s of millions.

• Advancing the deposit to a feasibility level will costs $100’s of millions and could eventually require sinking a large shaft that could take the cost up to $1 billion.
• Proving a reserve will take considerable time (at least 5 years).
• Production could be more than 10 years off.
• Block cave operations “mine” all the rock. Therefore there is, effectively, no statistical cutoff grade, because all the rock collapses into the void. Grade is determined by the volume that will cave.
• Understanding rock geotechnical features; stress, fractures, faults, alteration, and orebody shape is critical to designing the mine. Once a block cave operation starts you cannot turn it off without nearly destroying the mine.
• Pre-development capital will be several $billions. The entire underground infrastructure has to be built before mining can start.
• You had better be damned sure that everything works and you will make money before developing the deposit.
Metallurgy

Oxide and Sulfide Mineralization at Camino Rojo

From Exploration Insights: 6/6/08

The resource estimate only includes oxidized rock that occurs as a near surface homogenous body. The oxidation is the result of ground water essentially turning iron sulfides (pyrite) to rust (hematite) – a process that liberates the gold. The oxide gold mineralization gradually dies out to depth where the ground water has not oxidized the sulfide bearing rock. Drill data further limits the oxide mineralization on the north and south (there is also the property boundary on the north). On the west side, oxide mineralization is terminated by a fault. We have some room for expansion to the east. Inferring mining and processing costs from similar style oxide gold deposits suggest that the Represa Zone could be quite valuable on its own. Let’s take a look at the sulfide mineralization.

At Represa, the oxide mineralization gradually transitions from a mixed oxide-sulfide horizon into an all sulfide body. The metallurgical recovery through the transition zone will depend on how effectively the gold has been liberated by groundwater. My interpretation of the core suggests that the oxidation permeates along the fractures where most of the gold occurs. This penetrative oxidation may indicate that much of the gold has been liberated from the sulfide in the transition zone. If so, this bodes reasonably well for recovering the gold through the transition zone using the same heap leach process that is used for the oxides. Canplats has not released enough drill hole information to responsibly speculate what the transition zone looks like, or where the gold resides. My resource calculation takes in some transition material, but I suspect not all of it.

Core holes are showing that gold, silver and base metal mineralization continues to depth at Represa. The sulfide mineralization is of variable but similar tenor to the oxides and is wide open below Represa.

Sulfide mineralization also occurs at depth to the west of the fault. I assume this mineralization has been down-dropped several hundred meters on the west. The apparent lack of sulfide continuity in this western block requires more drilling to establish what is going on there. It is currently too deep to offer much immediate value.

Recovering gold and/or base metals from the sulfide will take a more complex and costly process. Additionally, the mineralization will occur at the bottom of the Represa oxide pit, possibly 200 to 300 meters deep. At that depth, the likely waste to ore strip ratio could very well be prohibitive given the relatively low precious and base metal grades we have seen so far. Since this area would be mined seven to ten years from the start of mining at Represa, a risk adjusted net present value is insignificant today.

Aquiline (Navidad): Volcanogenic Sulfides and Metallurgy

From Exploration Insights: 11/23/08

Since acquiring Navidad Aquiline has spent about $45 million on the deposit (total sunk costs to date ~C$65mil). They have added to the resources by expanding the deposit and discovering new ones. Aquiline’s technical team, specifically geologist Dean Williams, has done an excellent job of coming to grips with the various styles of mineralization at Navidad. According to Dean, the deposit is the result of, and related to, an extensional basin. Lava domes formed along the margin and the basin was filled with lavas and
sediments. Lead and silver (minor copper and barite) were subsequently introduced into the sediments and formed a variety of deposit types depending on the host rock, chemistry and temperature of deposition (this becomes important to the story later on).

Resources for the entire system occur in the seven deposits illustrated in the figure below. The 2007 calculation returned a total measured and indicated resource of 127 million tonnes grading 110 grams per tonne silver and 1.06% lead (453 million ounces silver and 3 billion pounds lead).

![Project Navidad Resources 2007](image)

As is the case in many **polymetallic deposits** (especially volcanogenic massive sulfide deposits: VMS) **metallurgy** is key to economic viability. The conventional hydrometallurgical process for recovery of sulfide ores in these types of deposits is **froth floatation** (illustrated in figure below). Basically the ore is ground up, mixed with chemical reagents and made into a slurry which is then passed through a series of tubs (cells). The mixture is fluidized in the cells and the ore minerals attach themselves to the resulting froth bubbles. The bubbles and attached ore minerals are skimmed off and dried to make the concentrate that is then sold to a smelter. How well the ore minerals stick to the bubbles (recovery) depends on many variables including ore grain size and texture, ore mineral species and association, location of mineral within the crystal lattice, host rock type and alteration, trace elements and contaminants and, rock hardness. These variables are a direct function of the ore depositional environment and post-mineral changes the rock. At Navidad we have several different geologic environments responsible for ore deposition. This suggests the recovery process could be complicated.

![Typical froth floatation cell for sulfide ores](image)
**Vat and Heap Leach**
*From Exploration Insights: 8/02/09*

**Vat Leach**

In the vat leach process large tanks are used to thoroughly mix the ground ore and cyanide solution. Gold is then extracted from the cyanide (pregnant solution) and the waste (tailings) is disposed of. For a vat leach operation to work the ore has to show very good leach kinetics from relatively coarse ore, meaning: metallurgical testing should indicate that within three to four days most of the gold is recovered.

**Heap Leach**

In a heap leach, cyanide is sprinkled on the ore pile to leach the gold which is then recovered by removing the gold from the cyanide solution (see January 24, 2009 EI). Tropical high precipitation environments pose serious water balance issues: too much water coming in. Essentially the cyanide system is flooded and gold cannot be efficiently recovered, plus you have to isolate and treat all the water that enters the system.

**Metallurgy: Long Canyon, Amulsar and Miwah**
*From Exploration Insights: 5/29/11*

Metallurgy is the third primary variable (behind tonnes and grade) that speculators and mining companies need to come to grips with as quickly as possible when evaluating promising mineral properties. Metallurgical test work should be initiated when the company has a basic understanding of the possible ore types and they appear to be moving towards defining a potentially economic deposit. Poor metallurgy has been, and will continue to be, the death-nail of many projects that are currently garnering rich valuations. Therefore, solid, legitimate companies begin preliminary metallurgical work as soon as they have a feel for what the ore types and distribution within a deposit may be. Speculators had better come to grips with metallurgy as well, or face the wrong side of the value curve.

**Example: Fronteer Gold**

For instance, Fronteer Gold was performing cyanide soluble assays on core samples very early in the exploration stage in order to see if the deposit was potentially heap leachable. The results suggested it was, and this insight drove their resource definition and exploration program. If the results had shown the mineralization was refractory (not readily recovered with cyanide) Fronteer would have had to redirect their program to focus on finding higher grade material which may not have been open pitable. This requires a very different exploration mindset.

It is important to bear in mind that mineral deposits are seldom homogenous across their entire extent. The reasons are quite simple, but the processes are quite complex. Consider a gold system associated with a magma intrusion into a sequence of rocks comprised of limestone, sandstone, shale plus granite, and andesitic volcanics--basically your typical arc-related setting (refer to Fig. 1 below). As a magmatic body (pluton) evolves and cools, minerals crystallize from the melt under changing temperature, pressure, and chemical conditions. Simply stated, these crystals (quartz, feldspar, mica etc.) form granite; however, there are a lot of elements in the magma that do not get “captured” by the granite and remain as a remnant fluid near the top of the cooling granite. This remnant accumulate, scum if you will, contains silica, water, metals (gold, silver, copper, lead etc.)
and is the hydrothermal fluid responsible for making mineral deposits (if all goes well). The hydrothermal fluid also reacts and interacts with the host rock type in various ways, depending predominately on the temperature, pressure, and chemistry within the rock sequence. Therefore, we have hot fluids carrying metals reacting with the surrounding rocks as the magma body cools and crystallizes. These interactions produce geochemical anomalies, a few of which may represent economic accumulations of metal, but most of which are little more than geochemical anomalies.

(Fig. 1- By special request for my friends in Switzerland: conceptual representation of possible sites for mineralization (in red) associated with arc magmatism. More details available here. I will be thrilling the Cambridge Investment Conference with this slide during my Sunday morning presentation.)

One important point to keep in mind is that, because the host rocks, alteration, and mineralization vary across the mineral deposit, so too could the metallurgical characteristics. One part of the mineral resource may be oxidized in a silica rock that shows 90% recovery, whereas 100 meters away the resource may be hosted by a sulfidic clay-altered limestone with 45% recovery. At 1 gram per tonne gold, that’s ore vs. waste, and a resource that is only partially economic. You cannot assume that recovery is the same throughout a mineral deposit, just as you cannot assume grade is the same throughout a deposit.

The same variables that influence recovery also can affect the distribution of metals across a mineral deposit. In a typical high sulfidation gold deposit like Lydian’s Amulsar ore body, they have found high grade structures that cross-cut the low grade mineralization. The high grade structures have to be modeled (defined) separately from the low grade in order to 1.) know where it is for mining purposes, 2.) determine if it requires special metallurgical treatment, and 3.) restrict the influence of the high grade to the structures, thereby not smearing it into the low grade ore and upwardly biasing the grade.

As a mineral deposit becomes better defined through drilling and geological interpretation, the resource estimator raises the confidence level in the resource from inferred to indicated and finally measured (defined here). You will note that, despite some exceptional results (9.29 g/t Au over 21 meters, 3.29 g/t over 66 meters) from the 71 drill holes incorporated into East Asia’s inferred resource, the overall grade is just over 1 gram per tonne gold. This is presumably due to the estimators restricting the influence of the high grade to what they feel are appropriate geological controls given the drill hole spacing.

Fortunately however, for most of our purposes here at EI we are dealing with early stage results that only require a basic understanding of the geology, mineralization and metallurgy. We know that the majority of exciting exploration plays eventually die (a costly death to some); that is the nature of mining and exploration. Our goal is to get close to understanding a property as quickly as possible before the gambling herds figure out what
the fatal flaws are. Admittedly we miss a lot of exciting plays, but I don’t know how I could honestly recommend a stock without laying out the flaws.

**The 80-20 rule of metallurgy**

*From Exploration Insights: 6/10/12*

The 80-20 rule often applies to metallurgy. By this, I mean that a few tests can often tell most of the story. It’s impossible to put forth hard-and-fast rules, but in a situation where milling is needed, I think most technical people would agree that 80% or greater recovery using conventional methods is not a concern. Optimized testing usually bumps that number up a few percent. For oxidized heap leach operations recovery can be lower, because both capital and operating costs are lower—basically, weathering has done the hard work by turning the gold-bearing iron sulfides into rust, thereby liberating the gold and mitigating the need for a mill.

When initial testing indicates recoveries of significantly less that 80%, there is room for concern. Autoclaving (a process whereby gold-bearing iron sulfides are chemically oxidized in a large pressure cooker, thus freeing the gold) or other specialized treatments may be necessary. The great, 35 million ounce Donlin Creek deposit in Alaska (Barrick and Novagold) remains undeveloped, in part because the ore is refractory, meaning the gold is locked up in other minerals.