GEOMIN·MINEPLANNING 2023

8th International Conference on Geology and Mine Planning

Innovative Technology Solutions for Mine Planning, Risk Mitigation, and Near-mine Exploration

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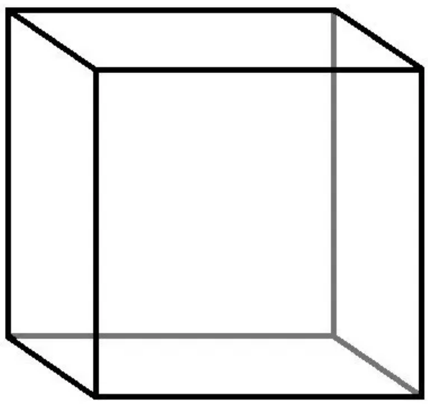
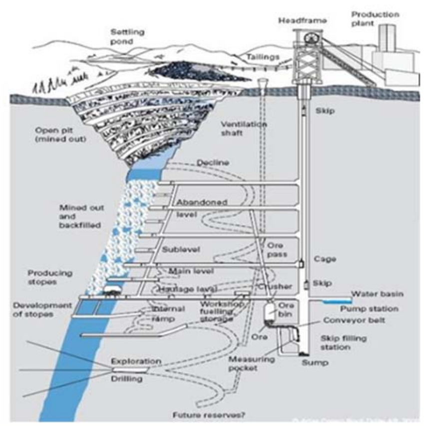
When it comes to planning…knowing is better than not knowing. Every time! Cassandra Clare





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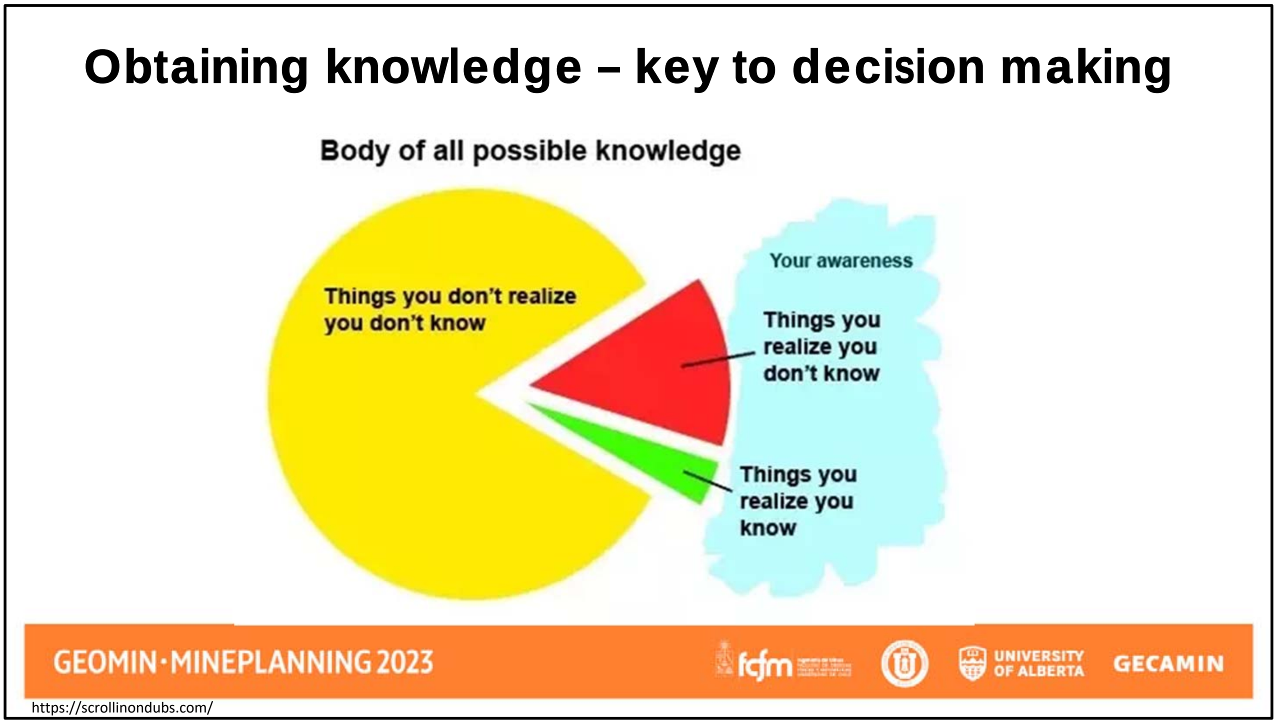
Design and Planning are the key first steps recognized as a primary line of defense for risk mitigation at mine sites.

By obtaining information early in the process and knowing about the 3D volume of space that will support your mine infrastructure for 10, 20, or 100 years ..you help to set the foundation for best practices mine planning.



This diagram has its roots in a saying from Aristotle - "The more you know, the more you realize you don't know."

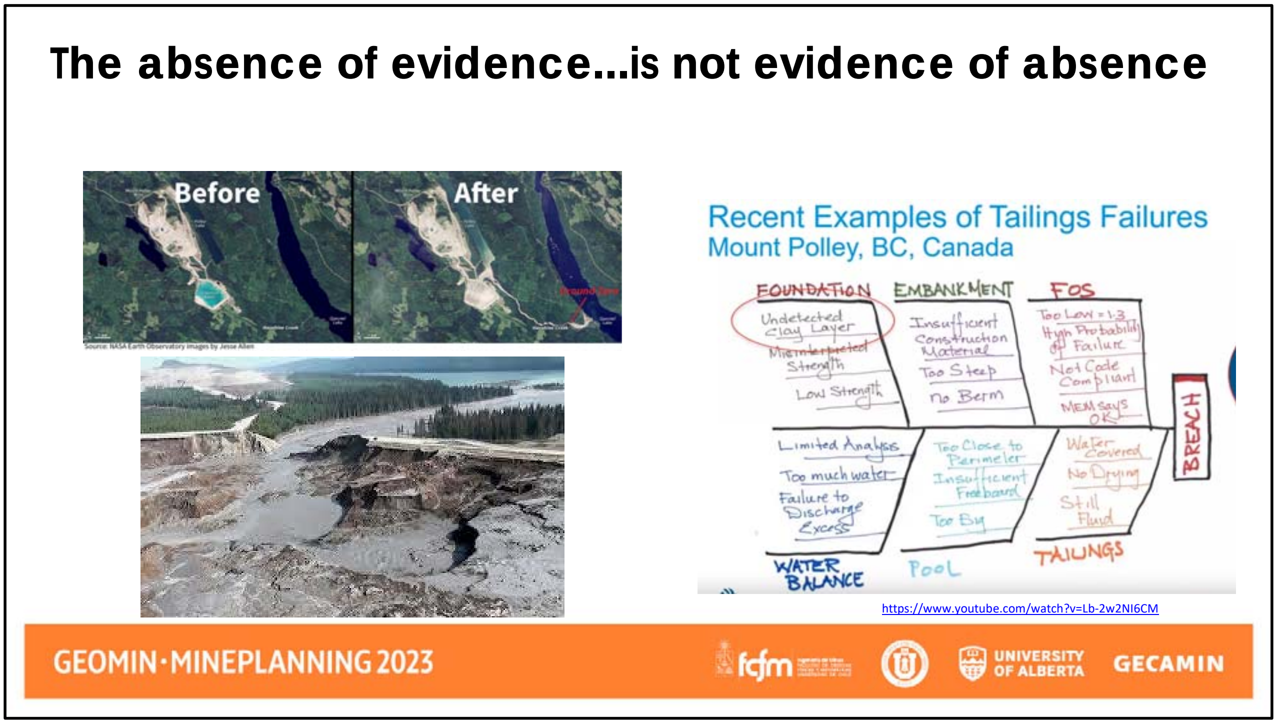
By having an understanding of the overall environment that you are working in, better decisions will be made. Consideration of all pertinent information should happen as early as possible.

This simple breakdown shows a body of knowledge about a new work environment. The green represents what you typically and readily know about a project.

The red represents things you don't know, but are going to find out – using your traditional investigative processes.

The yellow represents things that you don't realise you don't know --- in that region can lie unknown and unanticipated risks.

(famously presented by Donald Rumsfeld..
https://youtu.be/GiPe1OiKQuk)



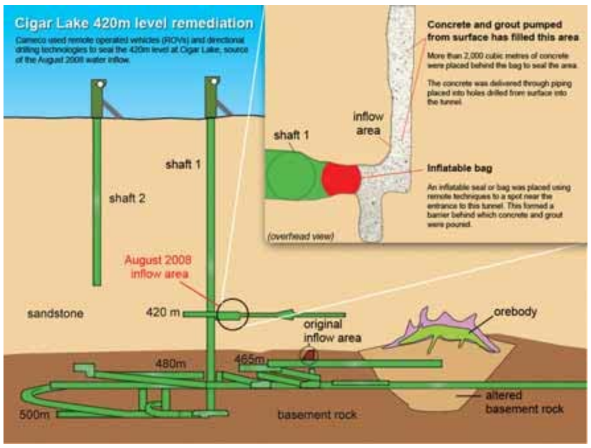
"Absence of Evidence does not mean Evidence of Absence", an old quote by Dr. Carl Sagan, means, in very simple terms, that if there is no evidence of something, one cannot conclude that the something does not exist. There might be a gap in our observation or research, which leads to the absence of evidence. Hence, just like we cannot disprove the existence of aliens, we cannot conclude a negative due to a lack of evidence. In a mine site environment one cannot conclude there are no risks in zones for which we have no information.

These images and notes come from ..
(SNC Lavelin presentation, 2018 Chad Lepoudre)

While the causes of a recent tailings dam failure in Northern BC were indicated to be multifold, one of the issues that was identified, was an unidentified clay layer in the subsurface strata.

Often traditional geophysical methods are used in site assessment work which only penetrate 10 's of metres. Below that, without other methods or extensive drilling - little knowledge can be obtained and therefore unknown risk exists.

Cameco's Cigar Lake mine flood; stock fall



420 metres

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In 2006, a catastrophic mine flood occurred at a uranium mine in Saskatchewan, Canada. It was the second such incident at the mine that year.
An undetected aquifer (water layer) contributed significantly to the disaster, starting with a rockfall and eventually completely flooding the mine and delaying the project for 6 years. Could deeper geophysics have avoided this costly situation?

(extra)
News at the time

Cameco Corp. said its Cigar Lake underground uranium project in northern Saskatchewan is expected to flood completely after a rockfall yesterday.
Cameco said the fall occurred Sunday afternoon in an underground area that had been dry and a "significant" amount of water started flowing in.
The company attempted to close two bulkhead doors Sunday evening to contain the flow and keep the rest of the area dry, but one door failed to shut completely.
Despite the flooding, the company said it is "committed to develop plans to remediate the project and preserve this valuable asset."
The mine had been on track for an early 2008 startup, but Cameco said Monday it will now have to develop new timelines for construction, cost estimates and production forecasts.
Following a trading halt for the news, investors sent Cameco shares down $4, or more than nine per

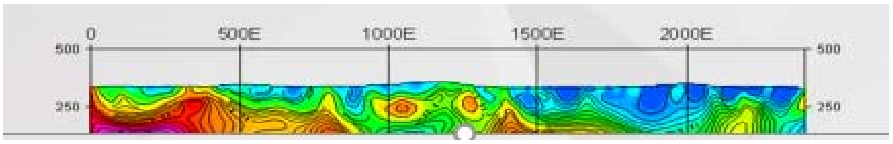
cent, to a close of $38.95 on the TSX.

Cameco Corp. announced in late October 2009 that it has resumed dewatering of underground development at the Cigar Lake uranium project in northern Saskatchewan. On August 12, 2008, an inflow on the mine’s 420-m level forced suspension of dewatering of earlier flooding that started in October 2006 at a different location in the mine. Mine development at Cigar Lake is primarily between the 465m and 500m levels. The original flooding in October 2006 occurred in a development drift on the 465m level. Mine development has been halted since that time. The 2008, 420m level source of inflow has been remediated by remotely placing an inflatable seal between the shaft and the source of the inflow and subsequently backfilling and sealing the entire development behind the seal with concrete and grout. Cameco currently anticipates that it will take six to 12 months to dewater and secure the mine, depending on what conditions are found in the shaft and the underground workings.

Cameco said it plans to dewater, re enter, and safely inspect and secure the mine. Plans were developed in consultation with Canadian Nuclear Safety Commission (CNSC) staff and the Saskatchewan ministries of Environment and Advanced Education, Employment and Labor. Cameco currently has approval from CNSC to dewater and secure the underground development and has applied to the CNSC for a license amendment to allow completion of remediation and mine construction.

Prior to the 2006 flooding, the Cigar Lake project was scheduled to begin production in 2008 and ramp up over a period of three years to design capacity of 18 million lb/y of U_3O_8. Project development was based on proven and probable reserves at that time of more than 232 million lb U_3O_8 at an average grade of 19%, making the Cigar Lake deposit the world’s largest undeveloped, high-grade uranium deposit.

What lies below the surface?



What is here ?

?

?

?

Drill Here ?

?

Drill Targeting

- Ore
- Structural information
- Hydrogeologic info

Mine site Imaging

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Typically, investigations of the subsurface involve drilling campaigns and limited scope geophysical surveys.

The industry generally follows a similar process for mine planning by collecting Geoscience information and hydrogeological information, but the limited information we collect using traditional means may not shed light on all the things… that "we do not realise…and that we do not know", and therefore can lead to risk exposure.

Many, if not most, condemnation programs are designed to check relatively shallow depths, and are only used in specific areas.

For example, a mine engineer may position a fuel holding facility on a flat piece of ground near the mine, and some condemnation will happen at the specific target area mostly to a limited depth extent.

1,000 years ago, patients survived brain surgery…

…sometimes,

and if they did, they had to live with huge holes in their heads!

Mine site Imaging

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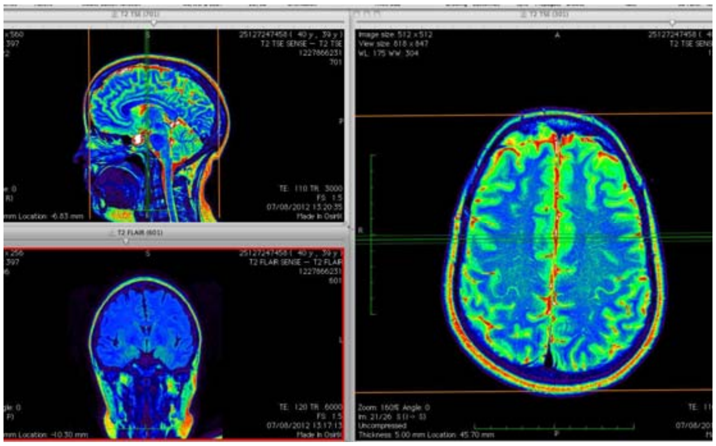
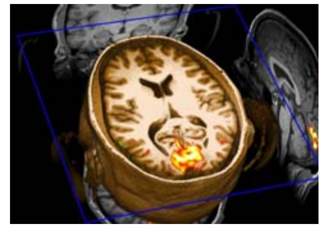
I will now provide a brief example of innovation and progress from the medical sector to illustrate my point.

They too, used drilling extensively in the distant past!!

They used this approach, because, at the time it was considered best practice.

Multi-parameter imaging is available today





Today, sophisticated imaging is a requirement prior to critical decisions.

Evolution of MRI from the 1950's - 1970's, to practical use in the 80's and 90's, and further advances in the 2000's

Mine site Imaging

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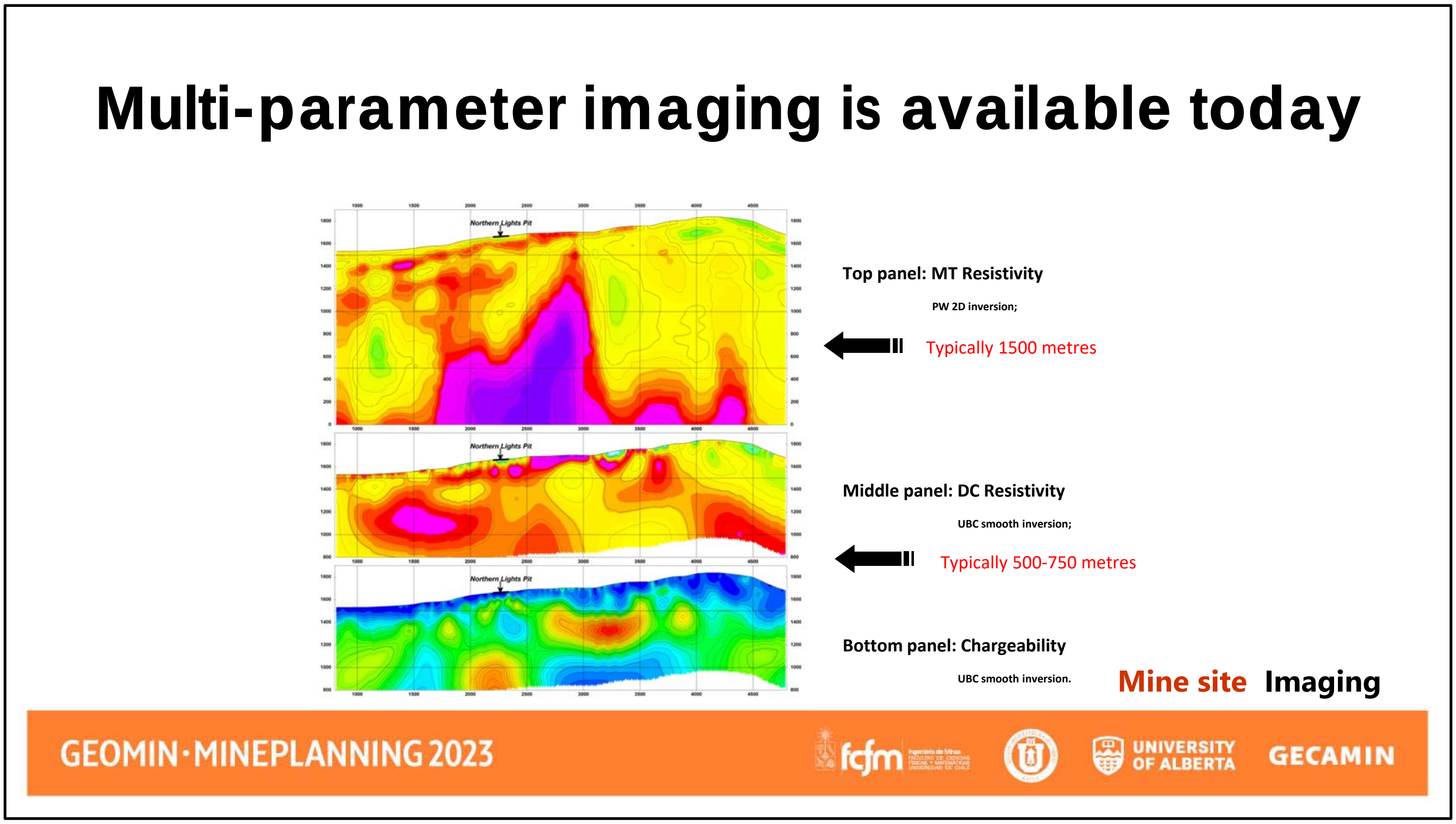
Of course today, imaging prior to surgery is a requirement. No doctor would drill into a skull without imaging.

Advances in MRI technology, which is now used routinely before cranial surgery, are very similar to the advances seen in geophysics.

Vast improvements in geophysical technology mean that there are additional tools for mine engineers to consider, such as deep sensing DCIP & MT surveys.



Geophysical imaging significantly advanced in 2000 with the commercial introduction of TITAN, a distributed multiparameter survey system. These surveys are routinely used in the mining sector, mainly for exploration.

These 2D multi-parameter surveys can provide 2 sets of deep penetrating information:

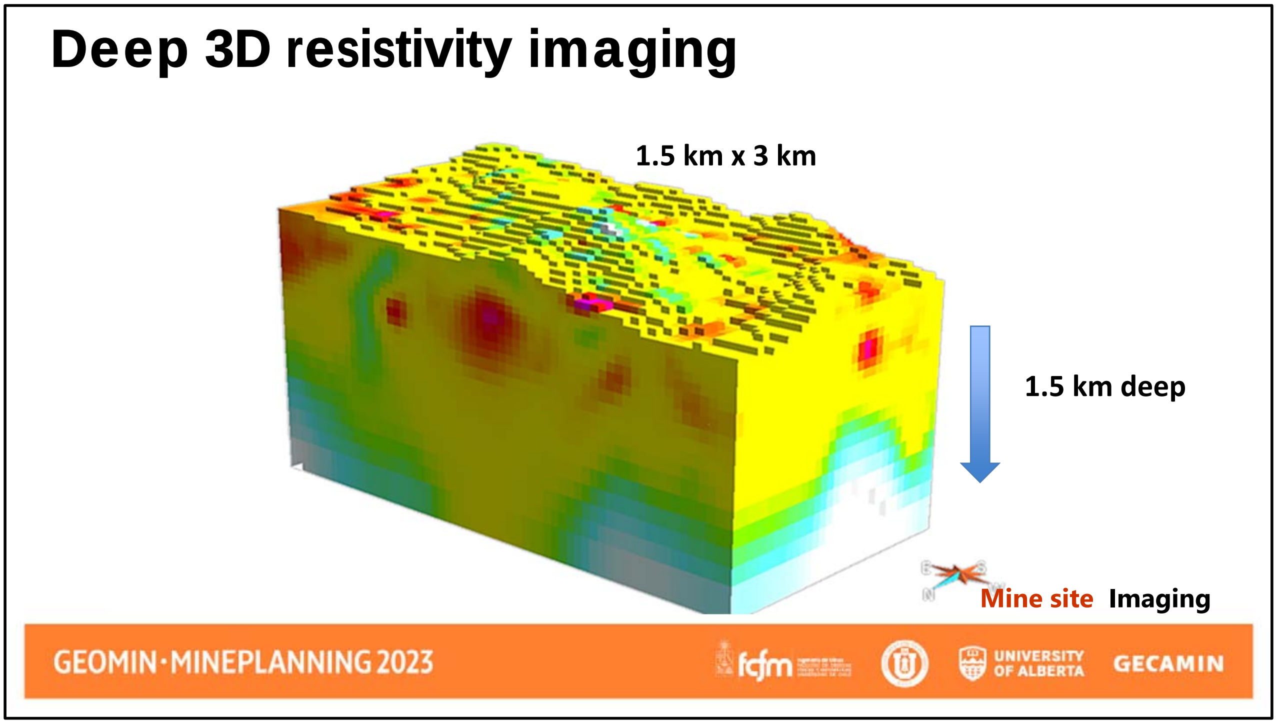
- MT resistivity data (surface to 1500m)
- DC & IP data to depths of 750m – resistivity and chargeability (a form of metal detection)

--------- extra

The advent of distributed networks of computers has helped produce more realistic representations of the earth.

- ❑Improved acquisition technology
- ❑Improved Processing
- ❑Improved Inversion 3D (data representation)

(Newmont Case study: Intrusive mapped to depth, 3 priority drill targets identified from IP, Further justification to perform additional surveys Ultimately,Newmont built their own system (with John Kingman to emulate these results)



The use of large 3D cubes of resistivity information can provide a great overview of the complete project area/volume.

Critical information for Mine planning may include:

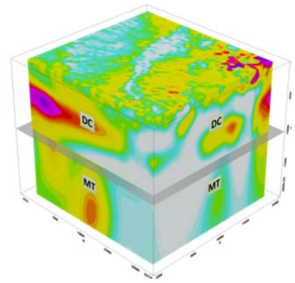
- Large deep seated fault structures and shear zones that may present risk in the form of major planes of weakness.
- A deeply buried orebody may remain undiscovered at the time of the mine development. It would be unwise to build infrastructure on top of a potential resource. This has happened in the past.
- Deep aquifers, may present flooding risk. A mine in Northern Canada, Cigar Lake was closed after a drift encountered an underground aquifer and the mine was flooded.

Deposit characterization

4 km² package imaged from surface to depth

<u>Deposit Characterization</u>

- Geology
- Geochemistry
- Drilling
- Deep Mine site imaging



E.g. 2 x 2 x 2 km

- **Structure (faults)**
- **Condemnation**
- **Tailings planning/monitoring**
- **Alteration, mineralisation (delineation)**
- **Life of mine data asset**
- **Cost $500k, time = 5 weeks**

Mine site Imaging

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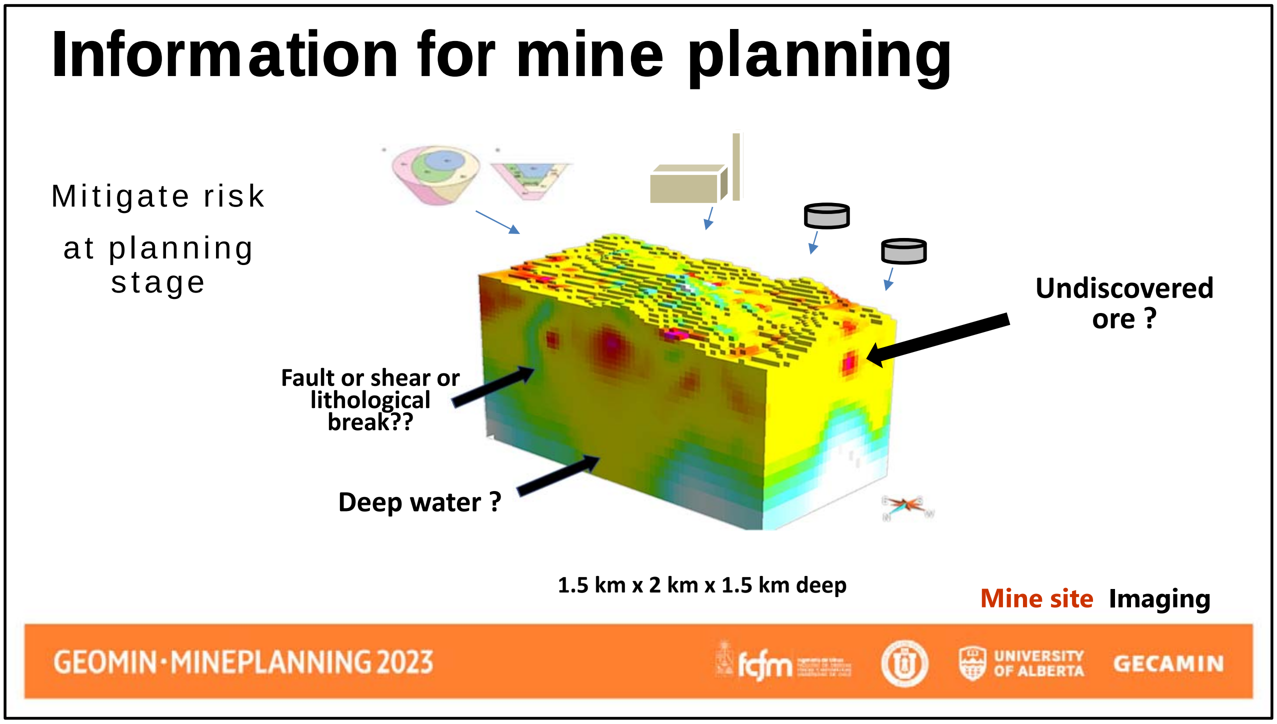
By obtaining deep 3D information about the subsurface one can increase the knowledge we have of a volume, in most cases some key information will highlight areas for further investigation, thereby focusing condemnation and risk mitigation efforts.

The overall cost of the geophysics, which is minimal, is balanced by more focused investigative drilling and avoidance of costly risks.



This represents a hypothetical example of how we can use deep imaging in such a manner.

The image highlights regions that may warrant specific investigation prior to formalizing placement of infrastructure.

Mine sites are challenging environments

Mine site Imaging

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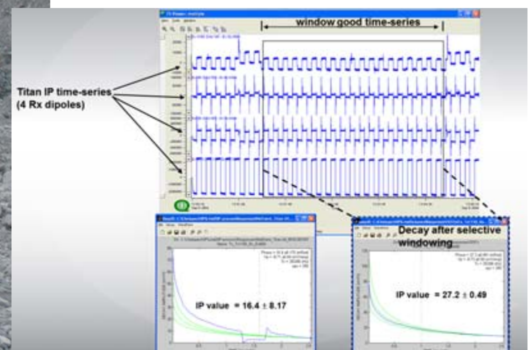
The mine does present challenges for crews working in the environment. In an ideal world, every feasibility study would involve a deep imaging program. That way many of the issues that make collecting data at the mine site would be avoided.

But the reality is that deep geophysical surveys often occur after the mine is underway, in an attempt to find more ore.

Some of the challenges are haul roads which often make scheduling a challenge. Cultural noise and power lines can make collecting good data difficult as they can interfere with signals. Active pits may present safety concerns.

It is important to have experience with mine site surveying.

Active mine deployment



Mine site Imaging

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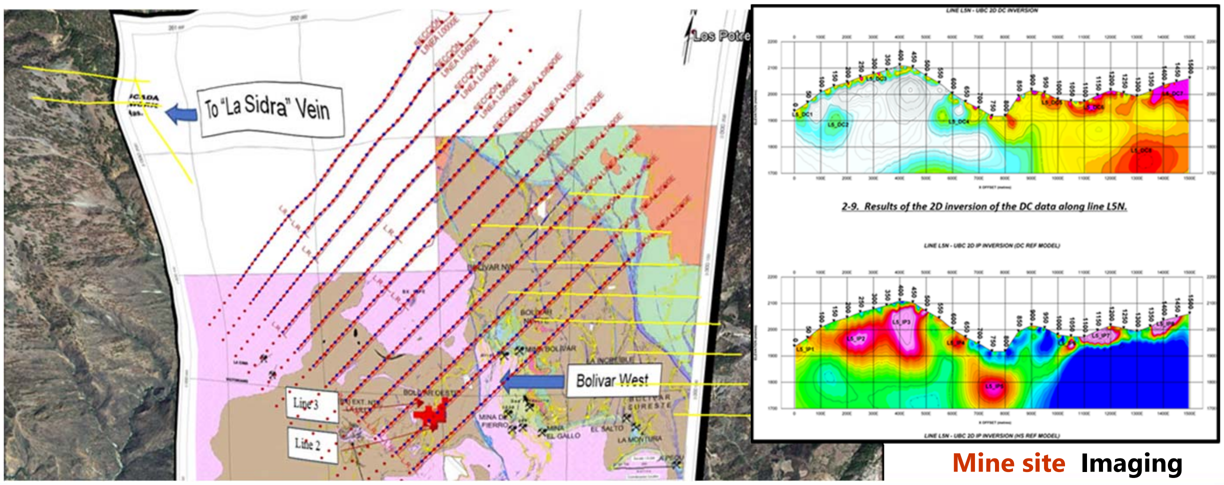
Collecting good data in active mines may be difficult. In this picture we see the temporary data receiver network – which could sit in place for 4-10 hours.

High speed data sampling provides large volumes of data which allows windowing: this is needed to minimize cultural noise to obtain accurate responses. The systems provide the needed small signal monitoring and noise rejection.

The following slides highlight the use of these deep technologies at several mines across the globe.

Case study: Bolivar Mine project, Mexico



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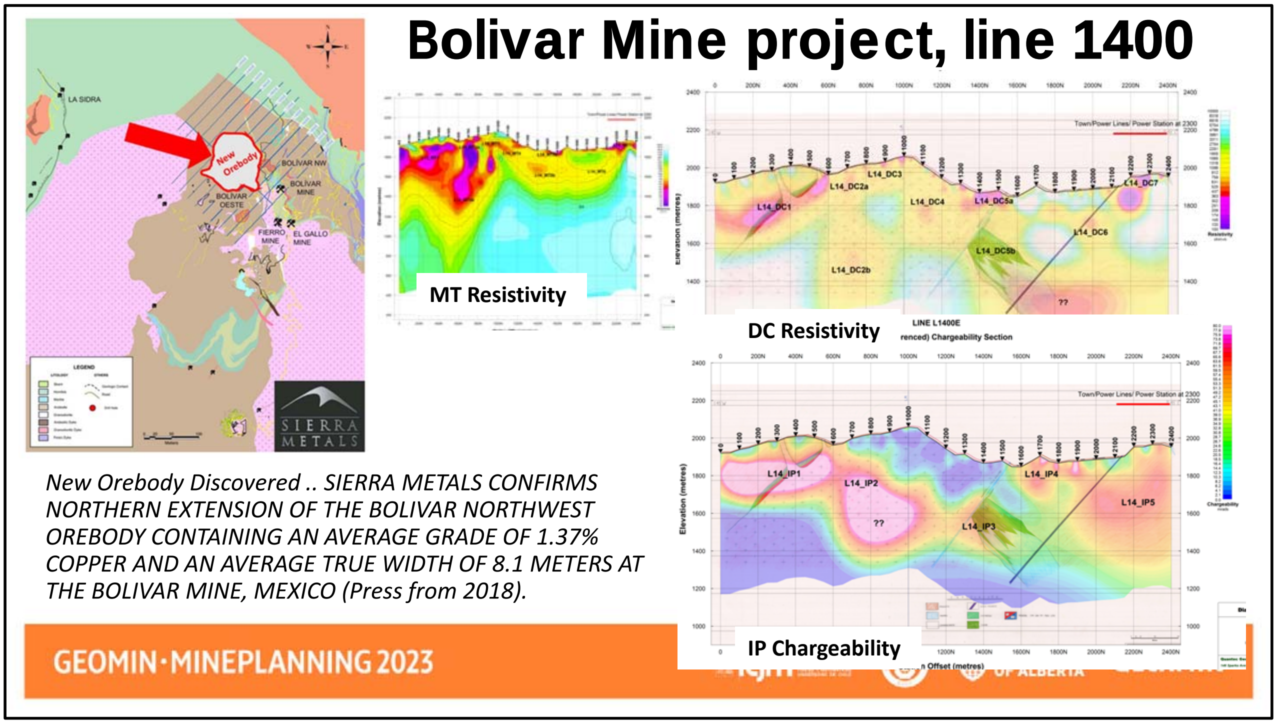
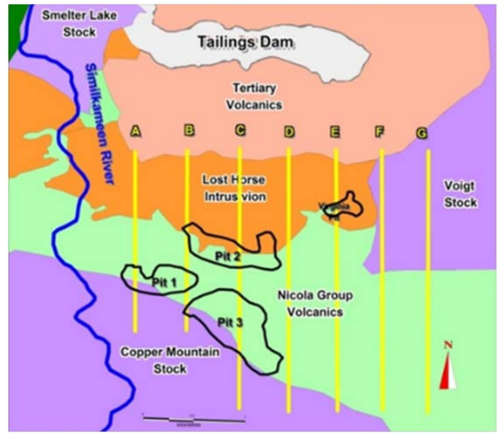
At the Bolivar mine in Mexico, imaging was used to help delineate the Bolivar deposit for drill targeting.

- Map and delineate near-surface zones associated with skarn mineralization.
- Map and delineate deep-seated alteration zones that could control or host mineralization.
- Focus drilling.
- Mine planning.



Along with helping map the subsurface, the survey results in this case lead to the discovery of another orebody.

Case study: Copper Mountain, Canada mine site investigations



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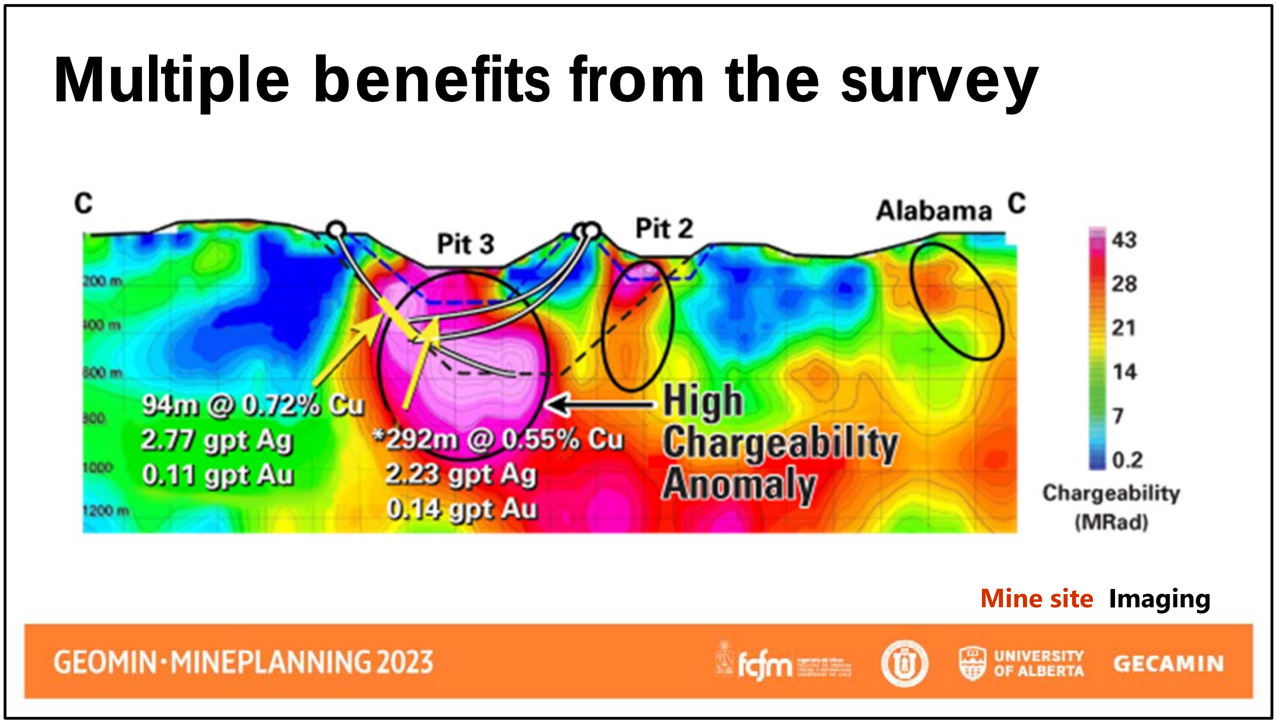
At a mine in southern BC, Canada, a study was commissioned to confirm continuity of mineralization between 2 old pits.

As part of a comprehensive mine site investigation, the study was to search for potential large, deep-seated porphyry deposits.



Survey results were spectacular with multiple significant benefits.

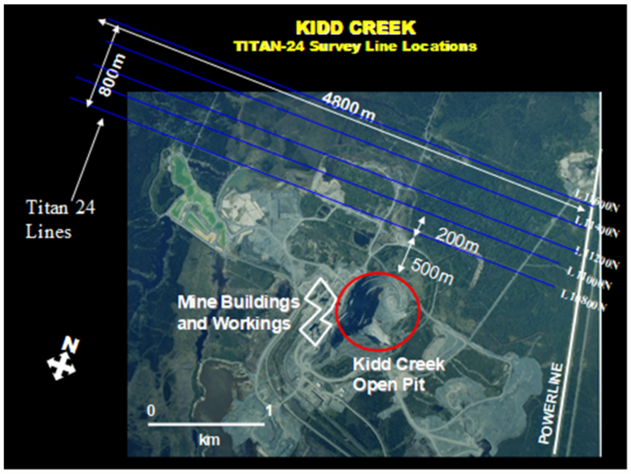
1. Savings on condemnation drilling $140k
2. Savings on **ABA** drilling $100k
3. Savings on permitting time – 2 months

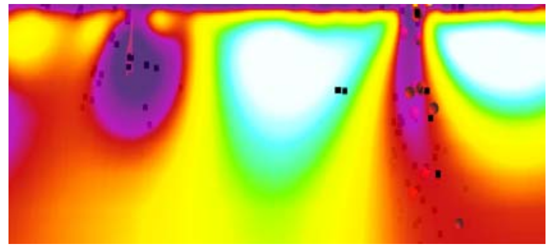
Acid-Base Accounting. In the permitting process one has to demonstrate what the rock volumes are with the various characteristics for generating or neutralizing acid drainage. The 3D geological models generated from the TITAN data meant less drilling to get samples both for ABA and condemnation drilling. (Blue area to the right indicated to the regulators that the rock unit was consistent across the region and therefore tightly spaced condemnation was not required to investigate the entire area.)

Other , more significant findings were…..

1. Discovery of new mineralization
2. Pit design changed (blue dashed line – original plans; following the survey and discovery, this was changed to the black dashed line)
3. Mine life extension – 25 years
4. The cost of the survey was only $300k

Case Study: Kidd Creek Mine, investigations





L 10800 Resistivity image shown to 800m

Mine site **Imaging**

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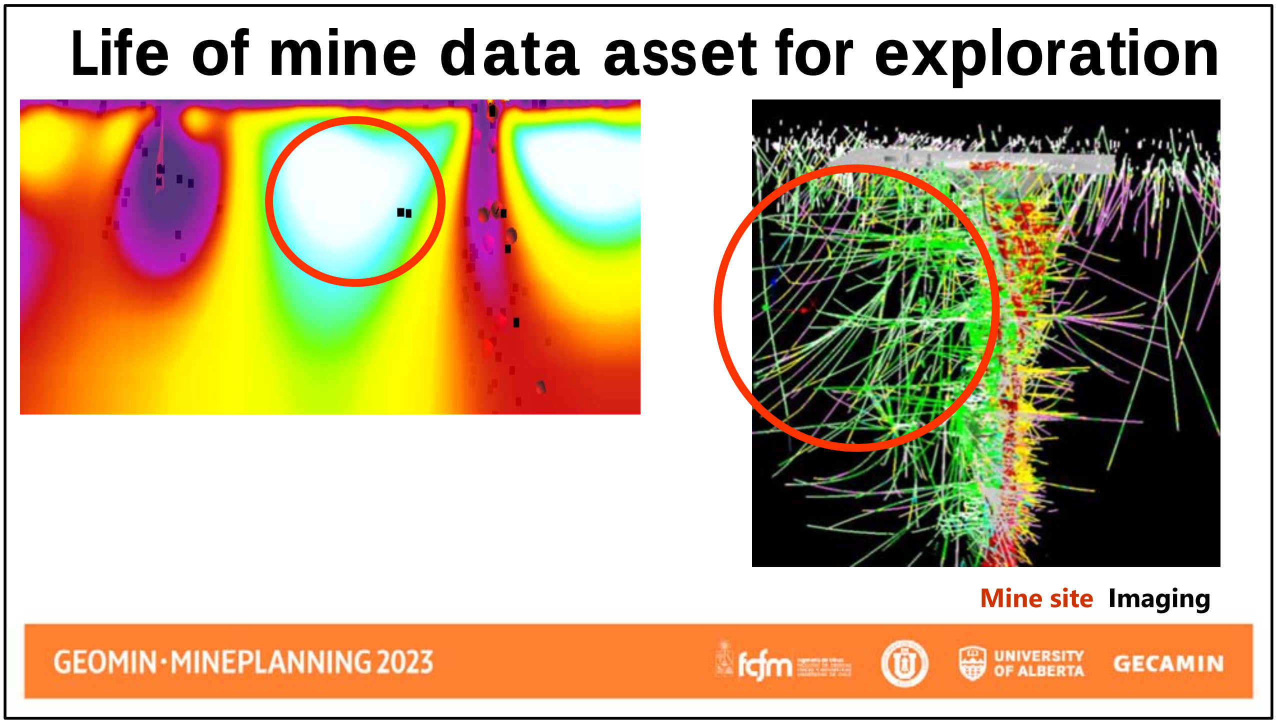
At the Kidd Creek underground mine, a TITAN deep imaging system was deployed over an area of 5 km by 1 km only 500m from the pit at the top of the mine, as an early demonstration of the technology. The approach and system successfully confirmed that TITAN was a viable and valuable exploration tool for near-mine applications. Significant savings could have been realized if the images were available over the life of mine.

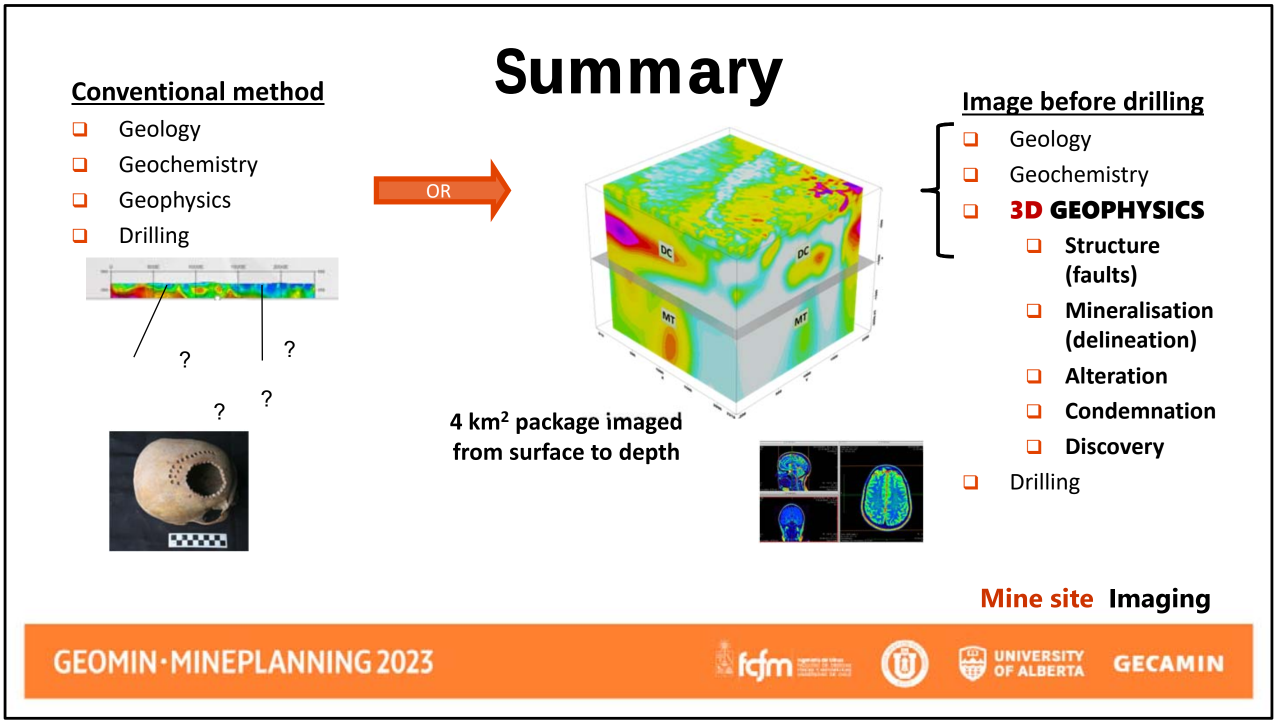
On the left we see the mine and survey lines, on the right the deep resistivity image from the DCIP survey. The reds zones indicate the conductive ore horizons, and the blue show the barren “resistive rocks”.



Resistivity image near the mine (the red circle on the left) indicates no conductive material. If this survey had been available little or no drilling would have been done in this zone (i.e. minor drill testing required in this area).

On the right we see the drilling that actually occurred in this barren zone near the mine over a 15 year period, in futile and costly efforts to find more ore.
Had the technology been used at the development stage of the mine, potential drill savings over the life of mine were estimated to be > 15 Million dollars.

Cost of the survey $400k



Today there are significant tools to help with the knowledge needed for mine planning activities. While the technology is available, it has not been utilized in this manner to the extent it could be. This is more than likely due simply to lack of awareness.

These technologies help the planners find out more about the volume that is going to host the mine.

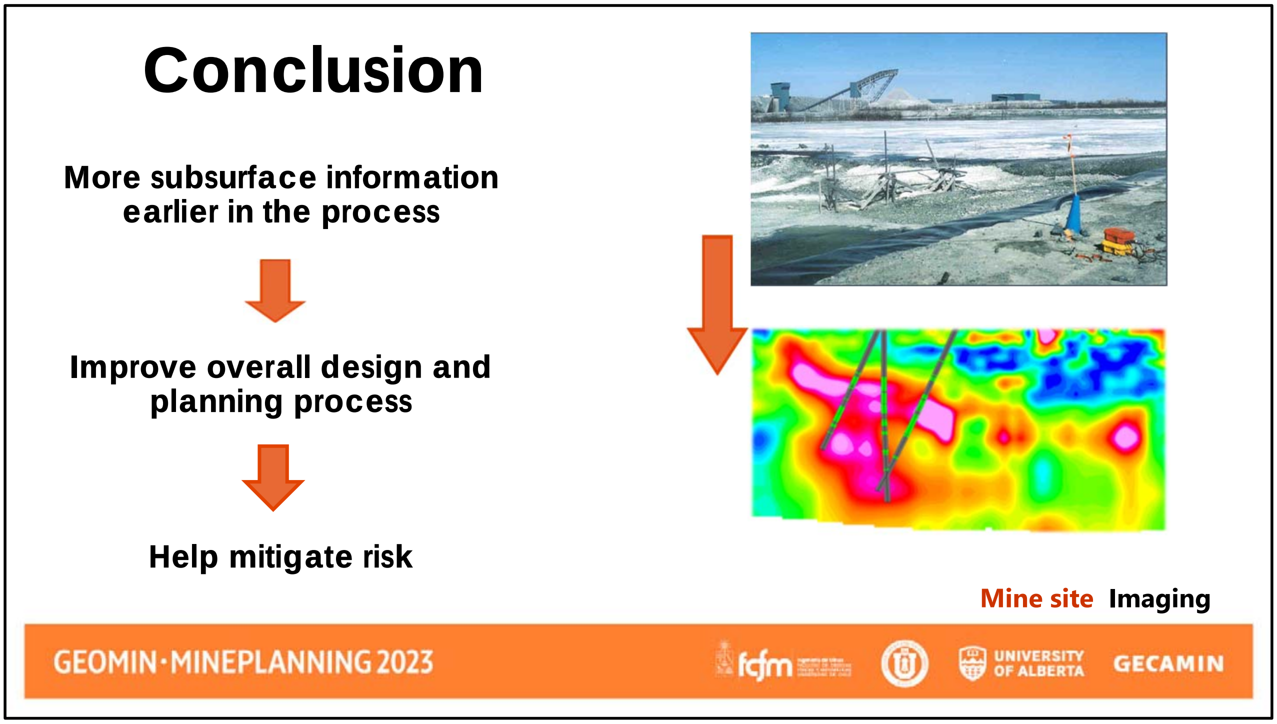
This slide demonstrates the added value of adding this sophisticated imaging into the mine planning stage of development.

APPLICATIONS OF DEEP IMAGING FOR MINE PLANNING AND EXPLORATION INCLUDE:

- Pre - tailings pond planning for risk mitigation
- Condemnation surveys for mine planning
- Additional hydrogeology information (identification of aquifers)
- Delineation surveys at the discovery stage – to focus drilling and obtain resource and subsurface information sooner – applications – before feasibility
- Near mine exploration surveys to identify new resources earlier and extend mine life
- Data asset for life of mine - monitor changes over time **(4D)**

Also could add

The alternate approach to drilling your brains out!
or
It is a “no brainer”!! … Don’t drill your brains out!!

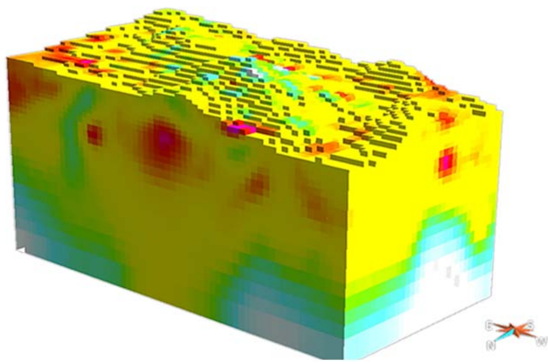


The addition of deep imaging has many benefits at the mine planning stage and over the life of the mine.

With a better picture of the subsurface you can improve drill planning for condemnation

With a site assessment utilizing deep imaging you can:

- Map deep structures and potential risks
- Map potential water sources for use/or encroachment



TRUE WISDOM IS KNOWING WHAT YOU DON'T KNOW

CONFUCIUS

Mine site Imaging

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Questions