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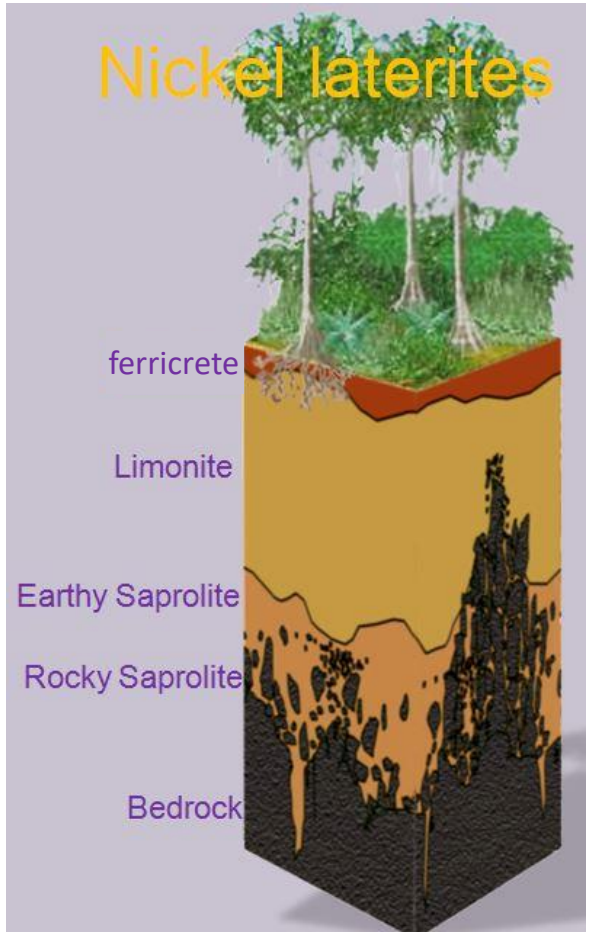
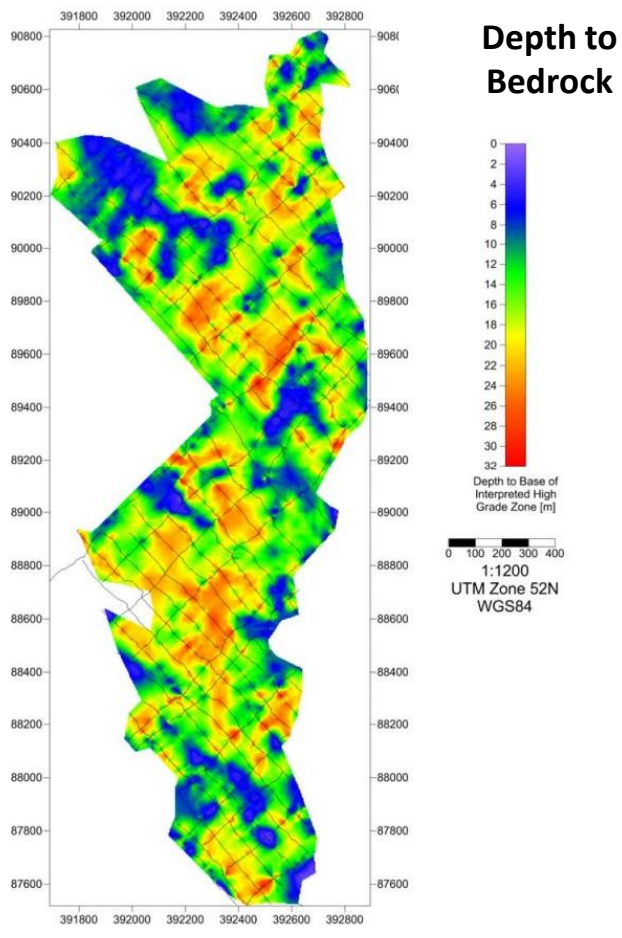
EDSA Shangri-La, Manila, Philippines

19th – 20th September 2023

UltraGPR for Nickel laterites - Adding value by optimizing exploration techniques

TOBIAS MAYA, PT Geo Search





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Nickel Global Resource Estimates

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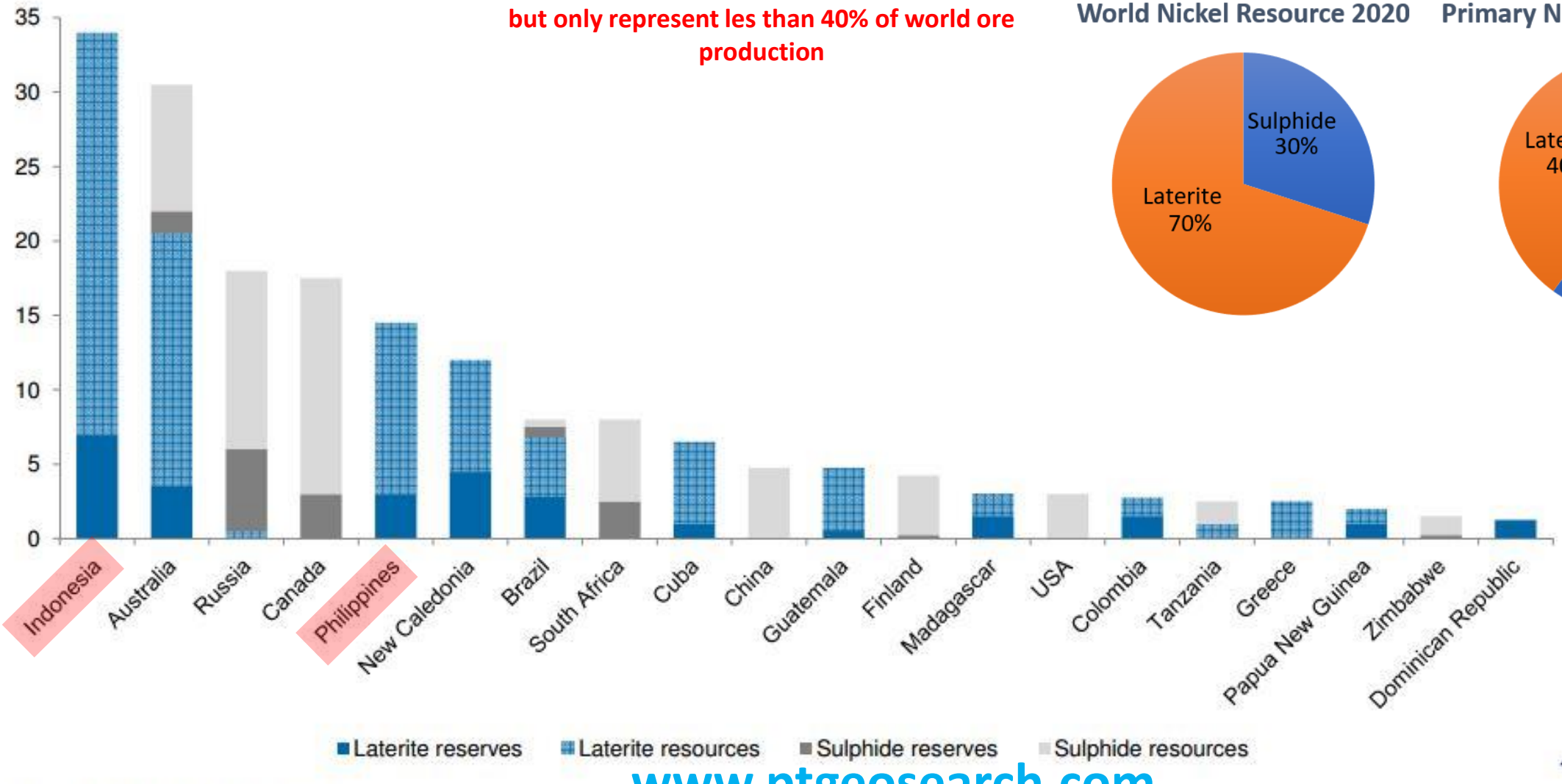
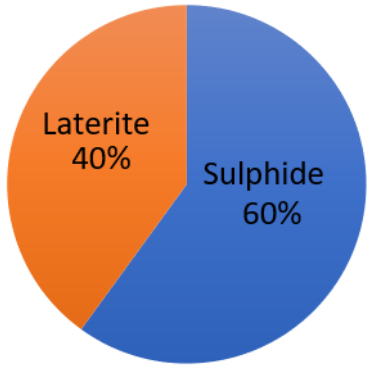
Nickel reserves and resources, Mt nickel content

70% of the global Nickel resource are laterites but only represent les than 40% of world ore production



World Nickel Resource 2020

Primary Nickel Production 2020



Source: Metalytics, USGS, Hatch

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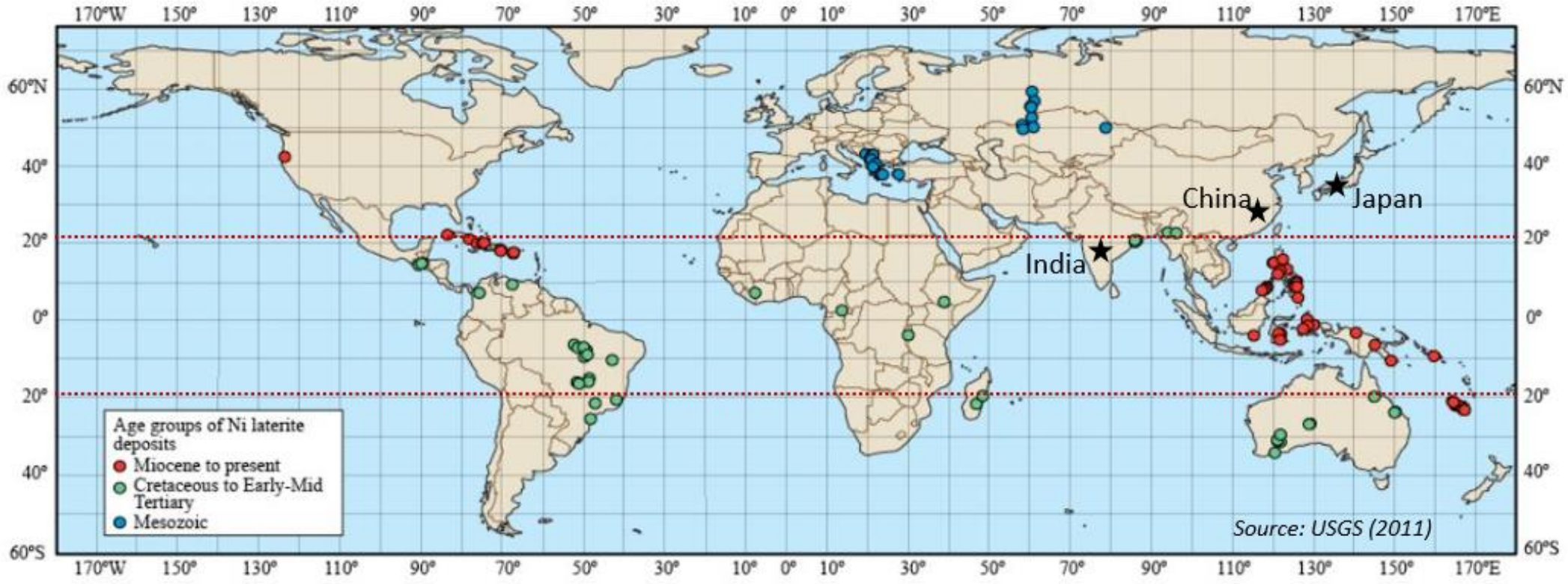
Global Nickel Laterite Resource Locations



•Much of the Nickel laterite deposit are located within the tropical zones where ophiolite rocks have been exposed to wet tropical climates for millions of years, these can develop large thick nickel laterite deposits

•Indonesia and Philippines have many known resource locations and are very well placed in proximity to the major steel industries of China, India and Japan

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Nickel Production in SE Asia – Early exploration

During the 80's & 90's large areas of Indonesia & Philippines were contracted to foreign and local mining companies to develop the mineral potential using the Contract of Work system (CoW), Until today they are the source of most of Indonesia's Known Mineral Resources & Nickel Ore production ;

- Inco (Vale), Weda Bay, Gag Nickel (BHP) & ANTAM TBk.

The CoW system resulted in a very high success rate for projects development some of the reasons for this were;

- Companies were given large areas to investigate
- Relinquishment schedules forced explorers to work quickly to identify the best areas
- Centralized control of licensing permits, providing clear and stable investment environment
- Operators were experienced technically and financially capable
- Foreign expertise was used on a transfer of technology basis
- Projects were built with long term planning and are able to endure price fluctuations

Vale (Ex-INCO) mine in Sorowako

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Nickel Production in SE Asia – Adjustment period Milestones

In 2000, Indonesian regional autonomy is granted with a proliferation of KP's (IUP) mainly owned by domestic investors were issued, although generally small from 100 - 2,000ha size

By 2003 nickel commodity prices begin to increase, Opportunistic investors abound

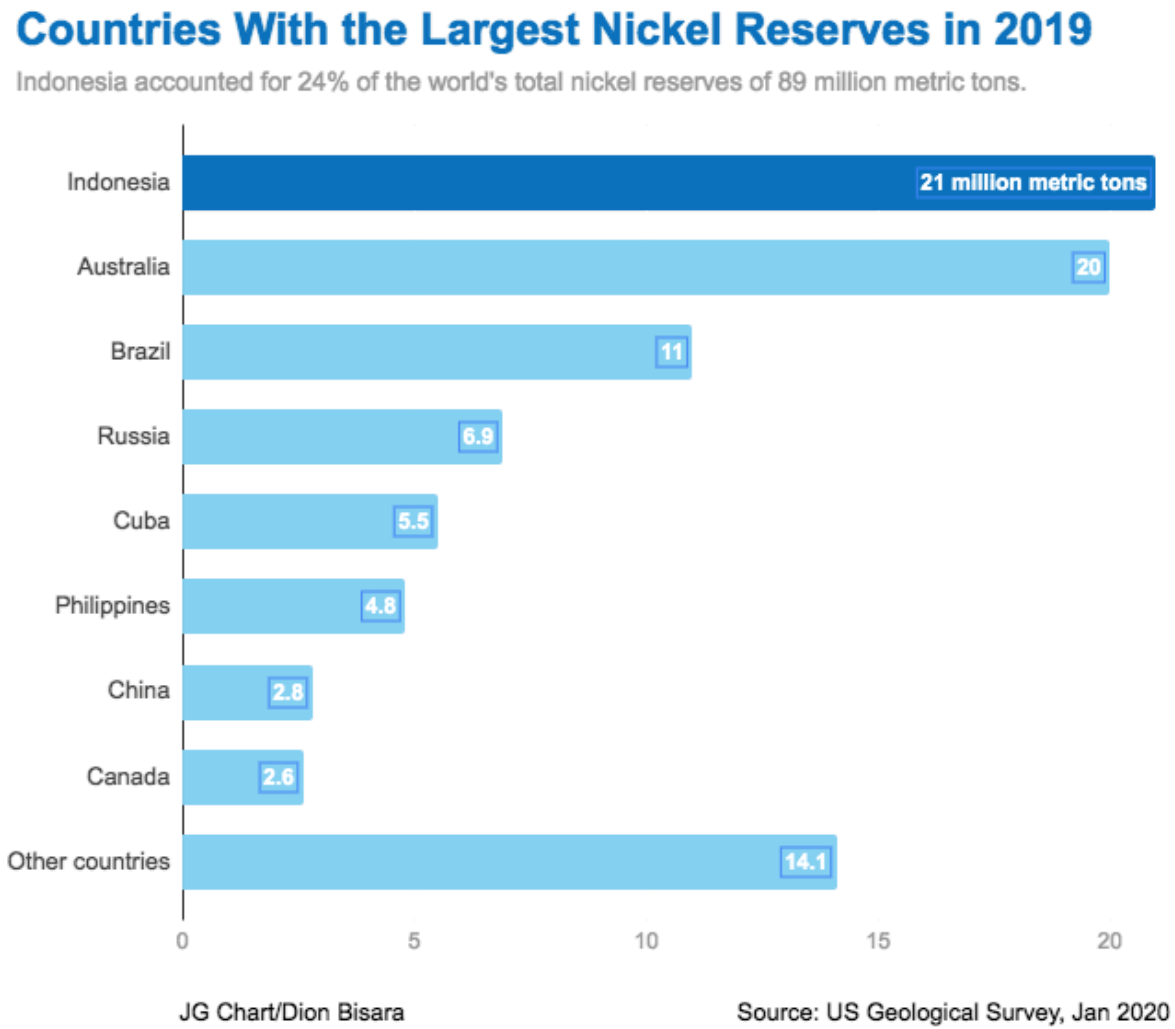
2007 investment bubble, followed by the 2008 GFC

Introduction of the new mining law in 2009, with 5 year amnesty period

Moratorium on new IUP applications from 2010, CNC clean up of non preforming leases

Enforcement of minerals export ban in 2014, planned smelter construction largely underdeveloped

Restrictions of mining operations in Philippines in 2016



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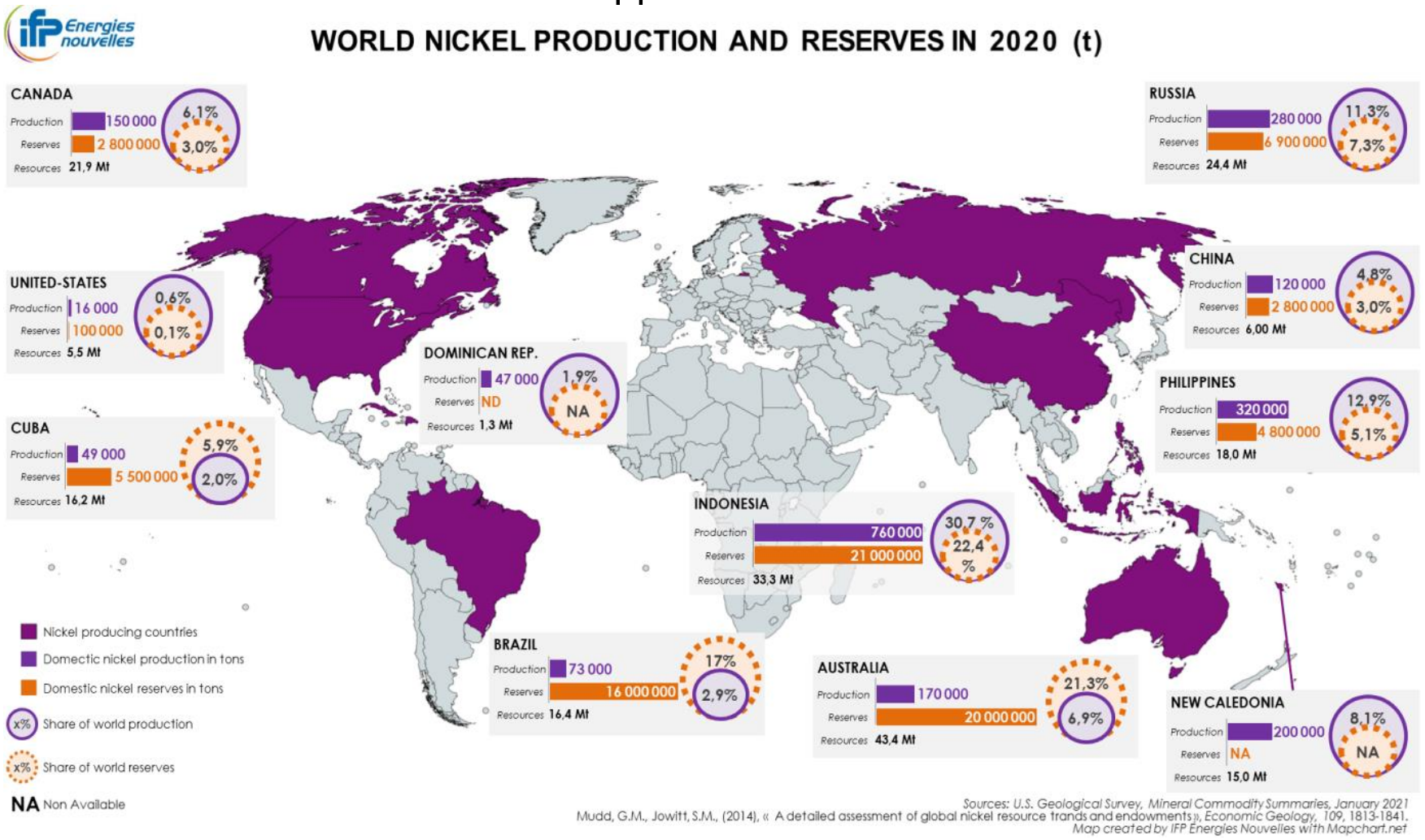
Recent positive trends for Nickel Production

Since the second half of 2016 and most of last 5 years there has been a significant increase in exploration & resource development and production activities in Indonesia and Philippines

Major contributing factors include;

- Relaxation of the export bans with introduction of the export quota system (until 2020)
- Significant investment from Chinese smelter operators to install plants in Indonesia for stainless steel production (RKEF/NPI)
- Increased demand in the domestic markets
- Strong Nickel prices
- Emerging Battery grade demand (HPAL)
- New Processing technologies



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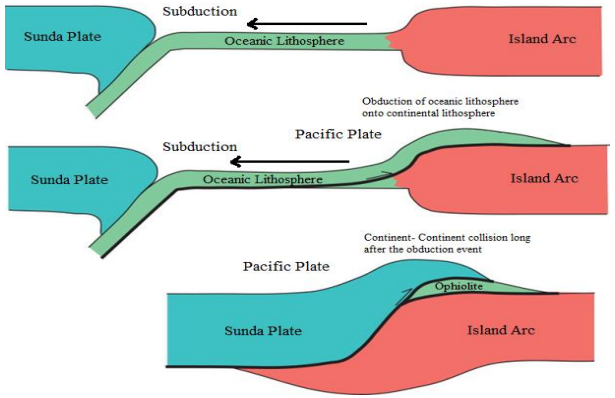
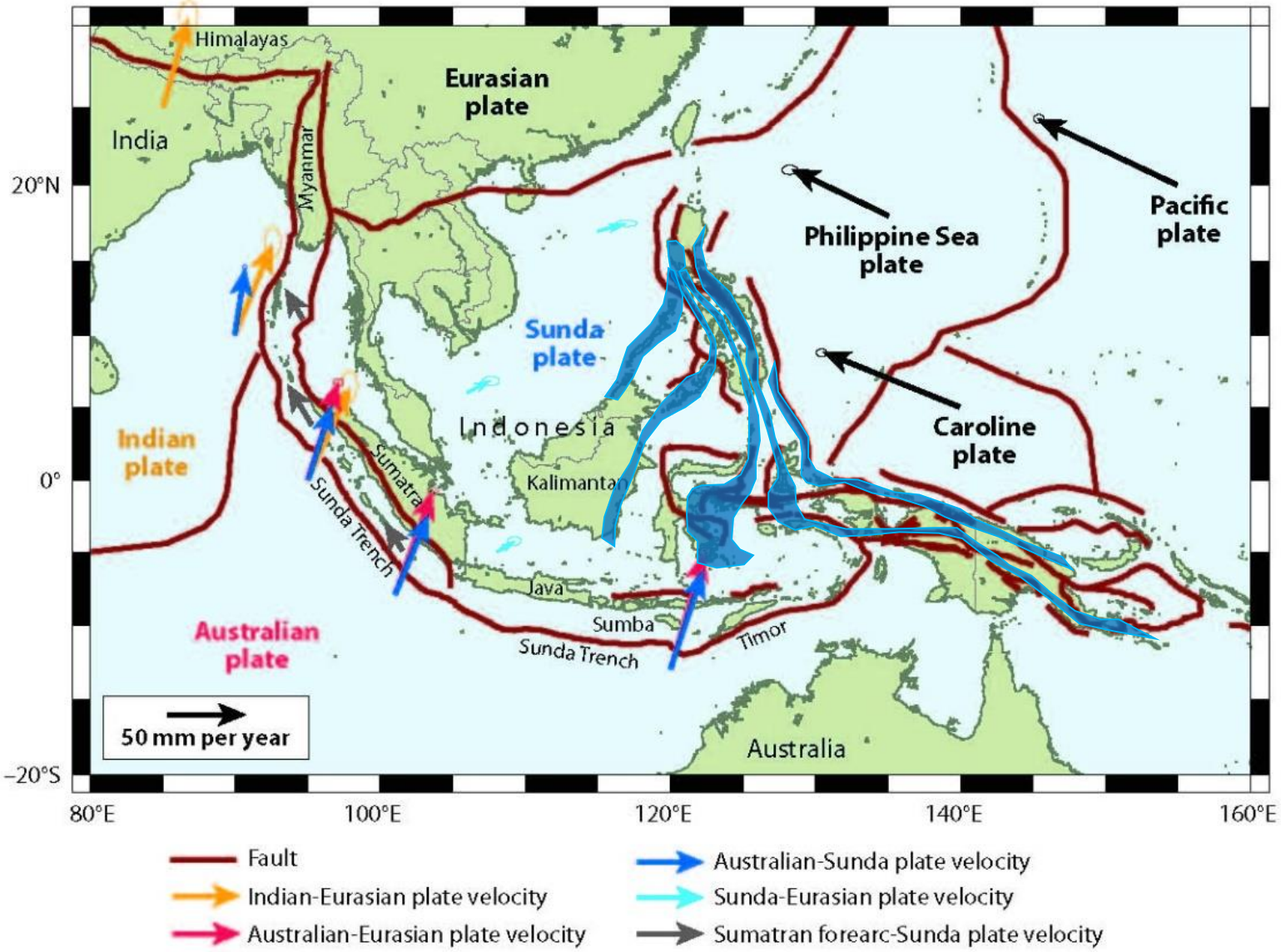
Regional tectonic setting for Southeast Asia with Ophiolite belts

Major influences from the subduction of the Australian plate (west) and Pacific Plate (east) under the Sunda plate where the Indonesia archipelago is situated

Ophiolite rocks form in a marine environment (under the ocean) and through significant tectonic events within the Obduction zone these formations are uplifted into mountain ranges around the eastern part of SE asia





Source: R.McCaffery (2009)

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Distribution of Ophiolites in SE asia

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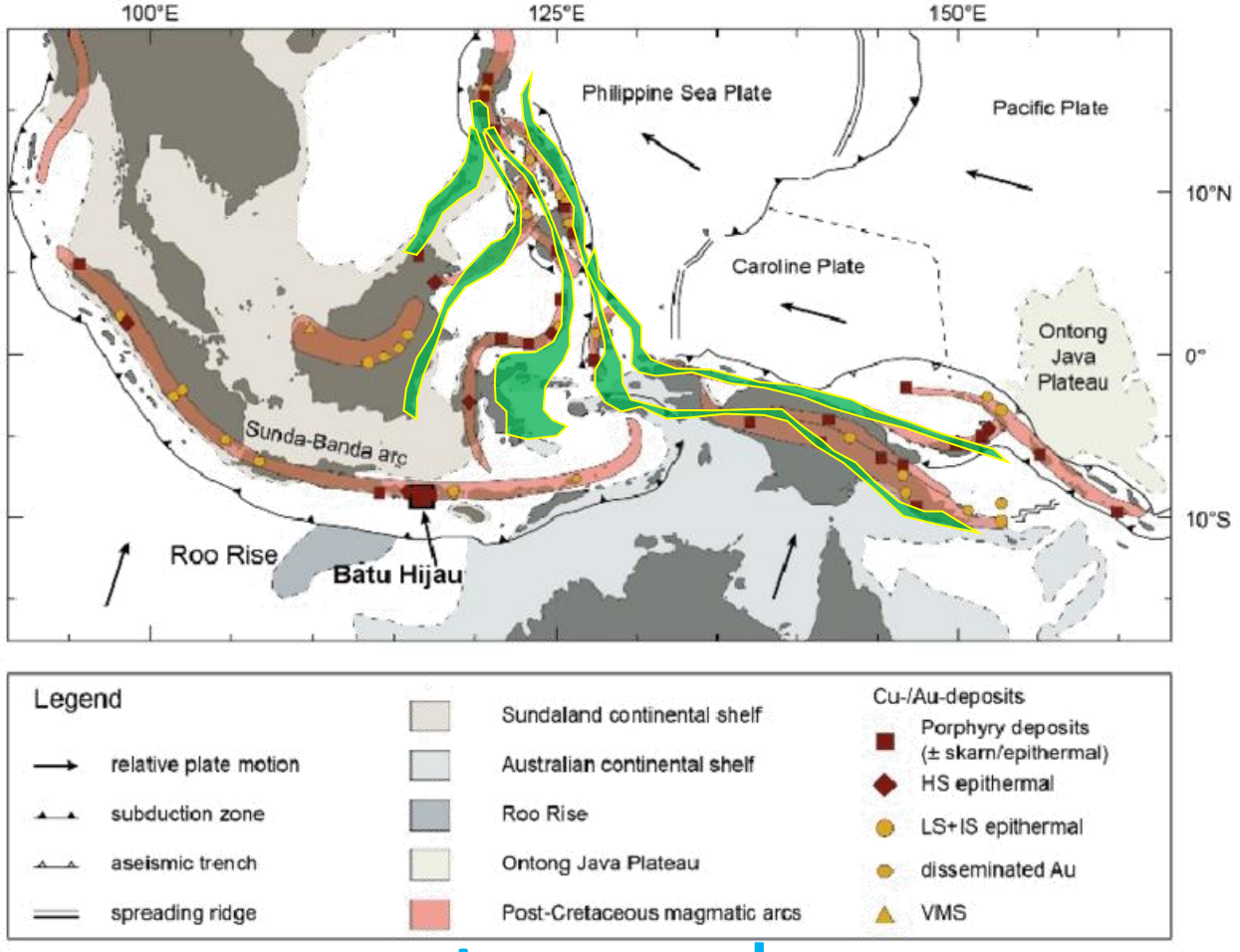
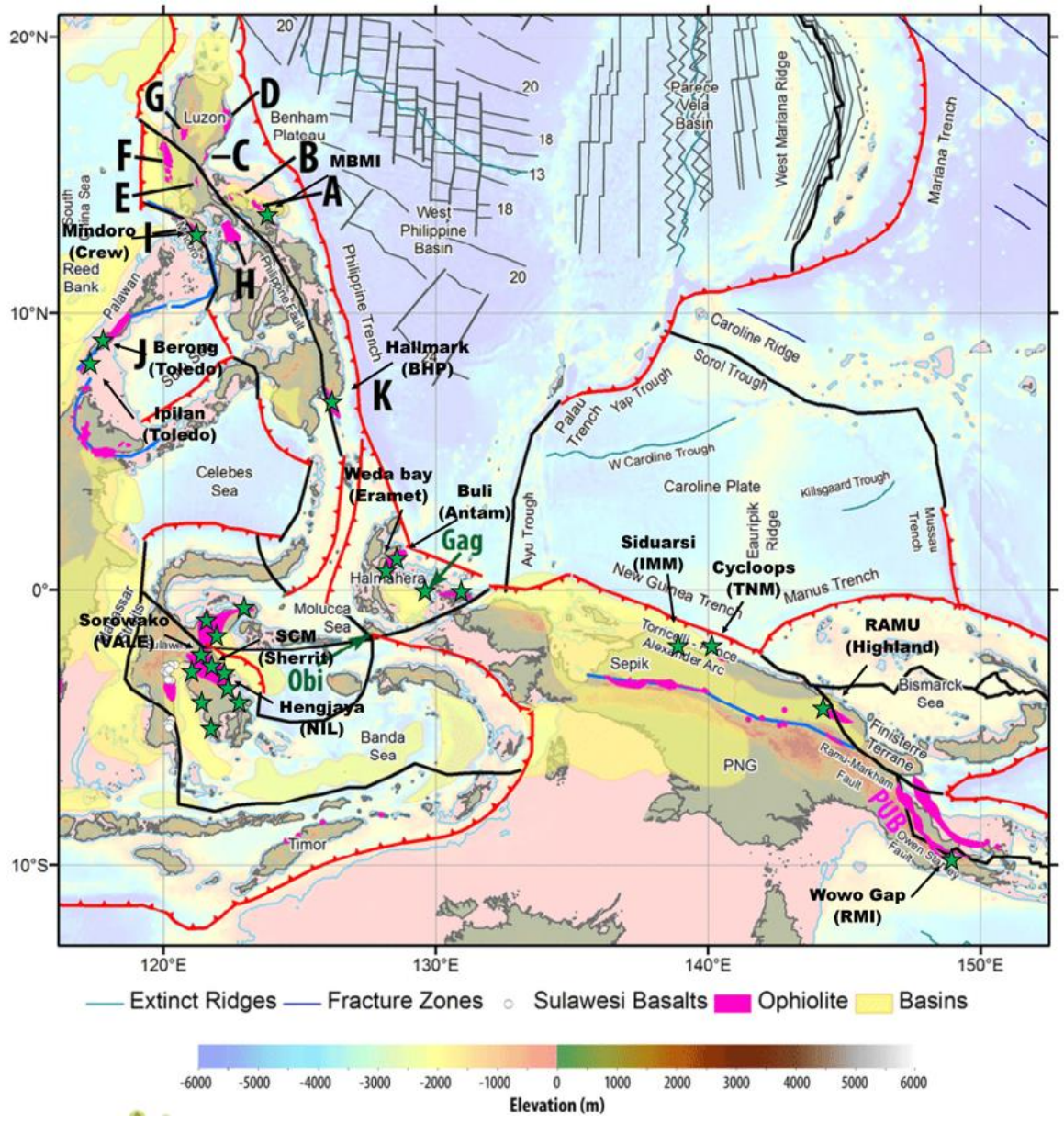
Ophiolite rocks where Ni-Fe laterites are more common, occur in the central & eastern area of Indonesia and Philippines, which host many of the critical minerals required for global demand





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Downstream Mineral Processing Investment

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Investor	$USD	RKEF	NPI	HPAL
Tsingshan (IMIP/IWIP)	$30 billion		160	4
VDNi	$20 billion		140	4
Vale	$20 billion	3		2
Huyaue HPAL	$15 billion			10
Harita Group	$15 billion	2		2
LG/Hyundai EV plant	$10 billion			2
Antam TBk.	$5 billion	3		2
Ford EV plant	$5 billion			2
BTIIG	$5 billion		60	2
Others	$15 billion	5	60	2
Total 5 year investment	$150 billion	13	420	22

Nickel Production capacity 2027	325,000	420,000	550,000
Current Nickel Annual Production 2021	740,000		
Indonesia possible increase 2022 - 2027	**555,000**	**175%**	
Total Nickel on Market	**1,295,000**		

Tesla (EV) and the Australian government (FTA & Lithium supply) are also committing future long-term investments

TAGANITO (HPAL)
NONOC (HPAL)
Aluminum
Nickel
GESIT (Aluminum)
ANTAM (Aluminum)
HARITA (Aluminum)
TIMAH (Tin)
TMM (STAL)
VDNi (NPI/HPAL)
BTIIG (RKEF/HPAL)
VALE (RKEF/HPAL)
IMIP (NPI/HPAL)
VALE (RKEF)
VALE (RKEF/HPAL)
ANTAM (RKEF)
Nickel
Indonesia
ANTAM (RKEF/HPAL)
IWIP (NPI/HPAL)
HARITA (RKEF)
HARITA (RKEF/HPAL)
(HPAL)
RAMU (HPAL)
FREEPORT (Copper)
PAPUA
Papua New Guinea
BANDA ARC
Philippine Sea
South China Sea
Celebes Sea
Sulu Sea
Java Sea
Philippines
Malaysia
Thailand
Vietnam
Cambodia
Singapore
Brunei
Gulf of Thailand
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
1500 km
Google Earth

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Future for Nickel Production in SE asia

- Indonesia will continue to grow significantly for Nickel production, global investments will support this growth into the downstream Stainless steel and EV battery markets
- Strong GDP growth for SE Asia countries with abundant critical mineral resources (Nickel, Cobalt, Copper, Gold, REE)
- Philippines can follow Indonesia investment growth, with major economic benefits (foreign Investment, Jobs, Upskilling)
- Increased nickel production over the next 5 years from Indonesia will affect DSO ore prices
- Good socialization & environmental management will be critical for future growth

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New Nickel Resource Development

•Finding Nickel laterite soils is relatively easy but identifying specific grades of limonite and saprolite requires systematic exploration methods.

•Unfortunately, a large majority of mining permits in Indonesia have poor history of using appropriate exploration techniques to comply with international standard codes such as JORC, KCMI for confident resource estimates

•This lack of geological understanding and mine planning provides a great opportunity to find new resources previously overlooked

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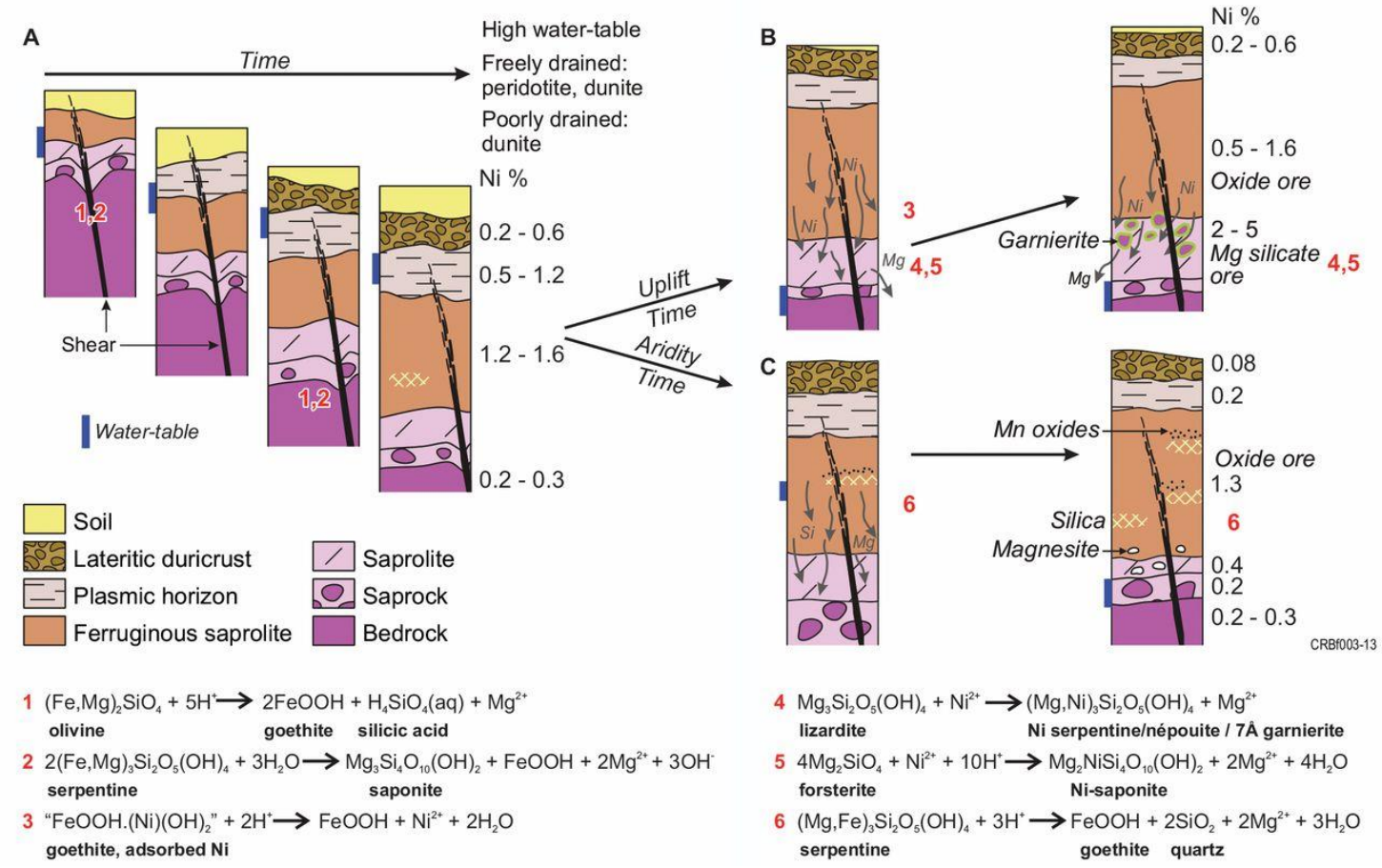
How to find the best Nickel Laterite deposits?



1 $(Fe,Mg)_2SiO_4 + 5H^+ \rightarrow 2FeOOH + H_4SiO_4(aq) + Mg^{2+}$
olivine — goethite — silicic acid

2 $2(Fe,Mg)_3Si_2O_5(OH)_4 + 3H_2O \rightarrow Mg_3Si_4O_{10}(OH)_2 + FeOOH + 2Mg^{2+} + 3OH^-$
serpentine — saponite

3 $\text{“}FeOOH.(Ni)(OH)_2\text{”} + 2H^+ \rightarrow FeOOH + Ni^{2+} + 2H_2O$
goethite, adsorbed Ni

4 $Mg_3Si_2O_5(OH)_4 + Ni^{2+} \rightarrow (Mg,Ni)_3Si_2O_5(OH)_4 + Mg^{2+}$
lizardite — Ni serpentine/népouite / 7Å garnierite

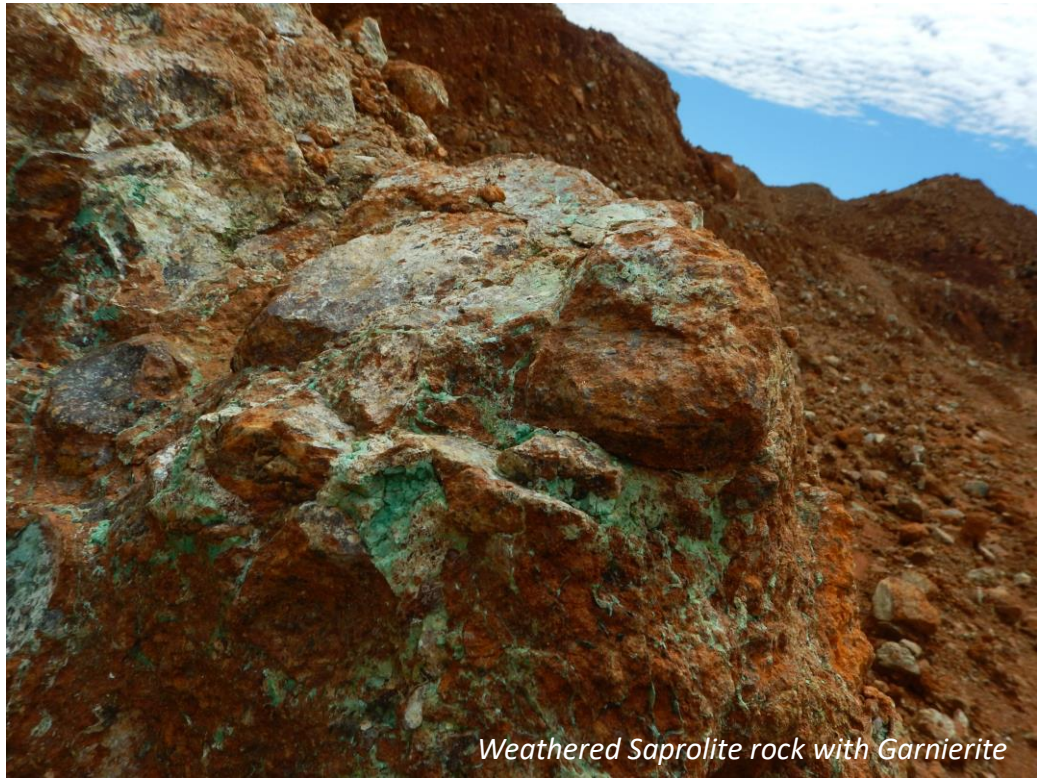
5 $4Mg_2SiO_4 + Ni^{2+} + 10H^+ \rightarrow Mg_2NiSi_4O_{10}(OH)_2 + 2Mg^{2+} + 4H_2O$
forsterite — Ni-saponite

6 $(Mg,Fe)_3Si_2O_5(OH)_4 + 3H^+ \rightarrow FeOOH + 2SiO_2 + 2Mg^{2+} + 3H_2O$
serpentine — goethite — quartz

Source: Element Geoscience world

Ni-Fe Laterite formation from Ophiolite rocks

Basically, it is formed by the process of bedrock weathering (leaching) over time, in high rainfall areas like the tropics it provides a ideal environment for laterite formation



Weathered Saprolite rock with Garnierite

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REGIONAL GEOLOGICAL / GIS STUDIES

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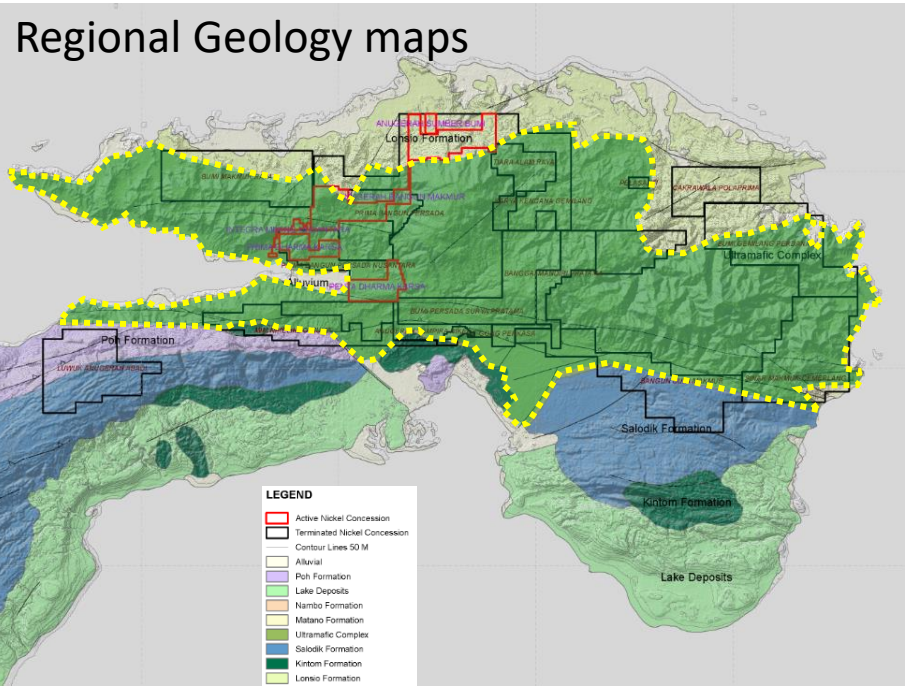
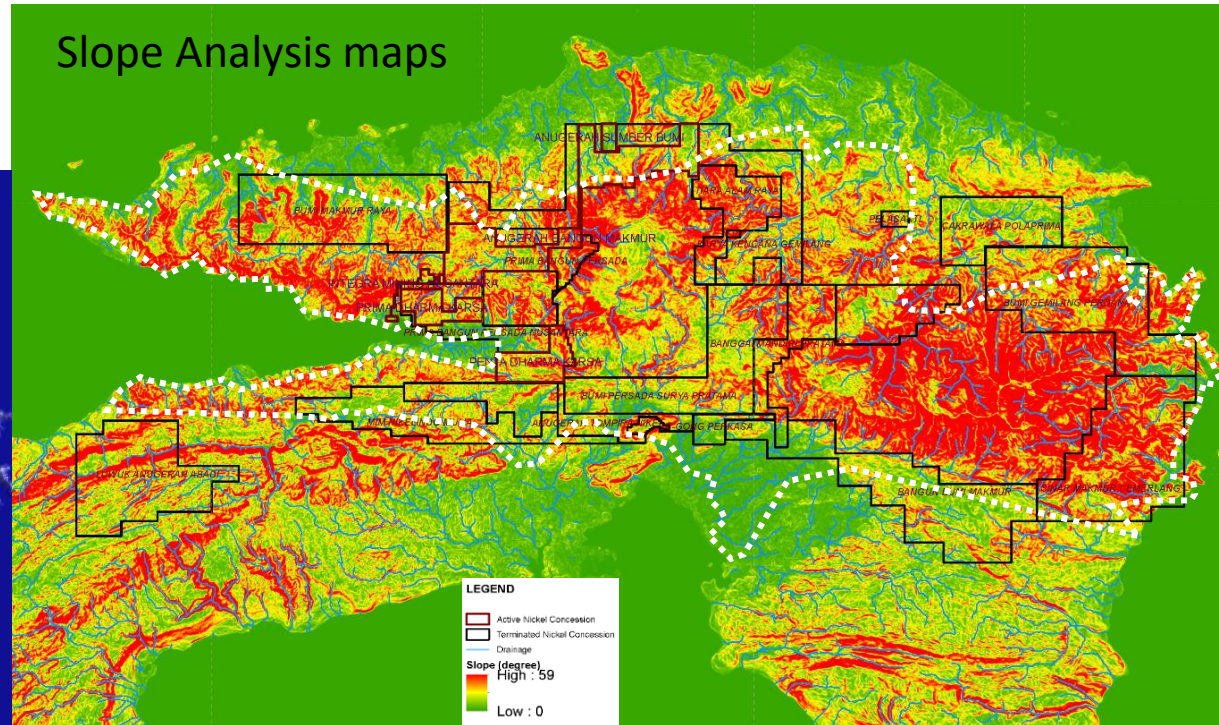
Regional Geology maps



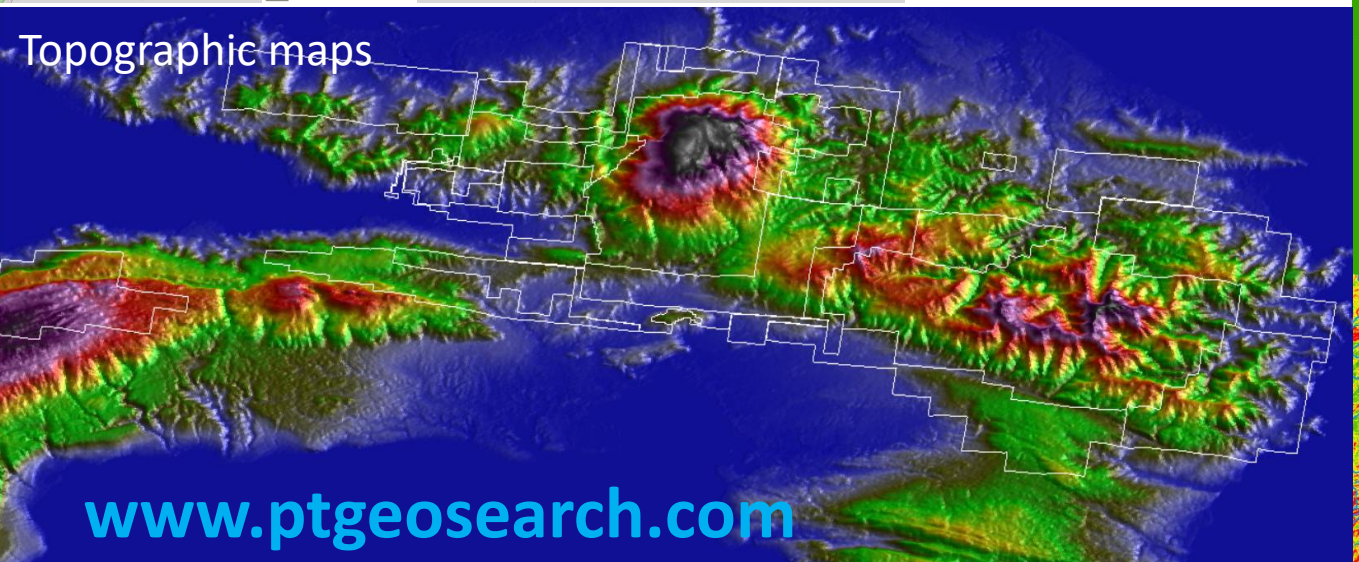
Ideally exploration for these deposits should begin with regional studies and other GIS techniques. In southeast Asia these types of laterite deposits are relatively easy to find. They can occur anywhere, where Ophiolite formations have been uplifted and weathered over time.

Based on slope analysis and general landform morphology. Flat to moderate regions with topographic slopes ranging from 0° to 18° allows laterite nickel deposit enrichment if the ultramafic rocks make up the bedrock. Moderate to steep regions on hills with slopes ranging from 18° to 35° with ultramafic bedrock generally has thinner and more erratic laterite mineralization.

Slope Analysis maps



Topographic maps



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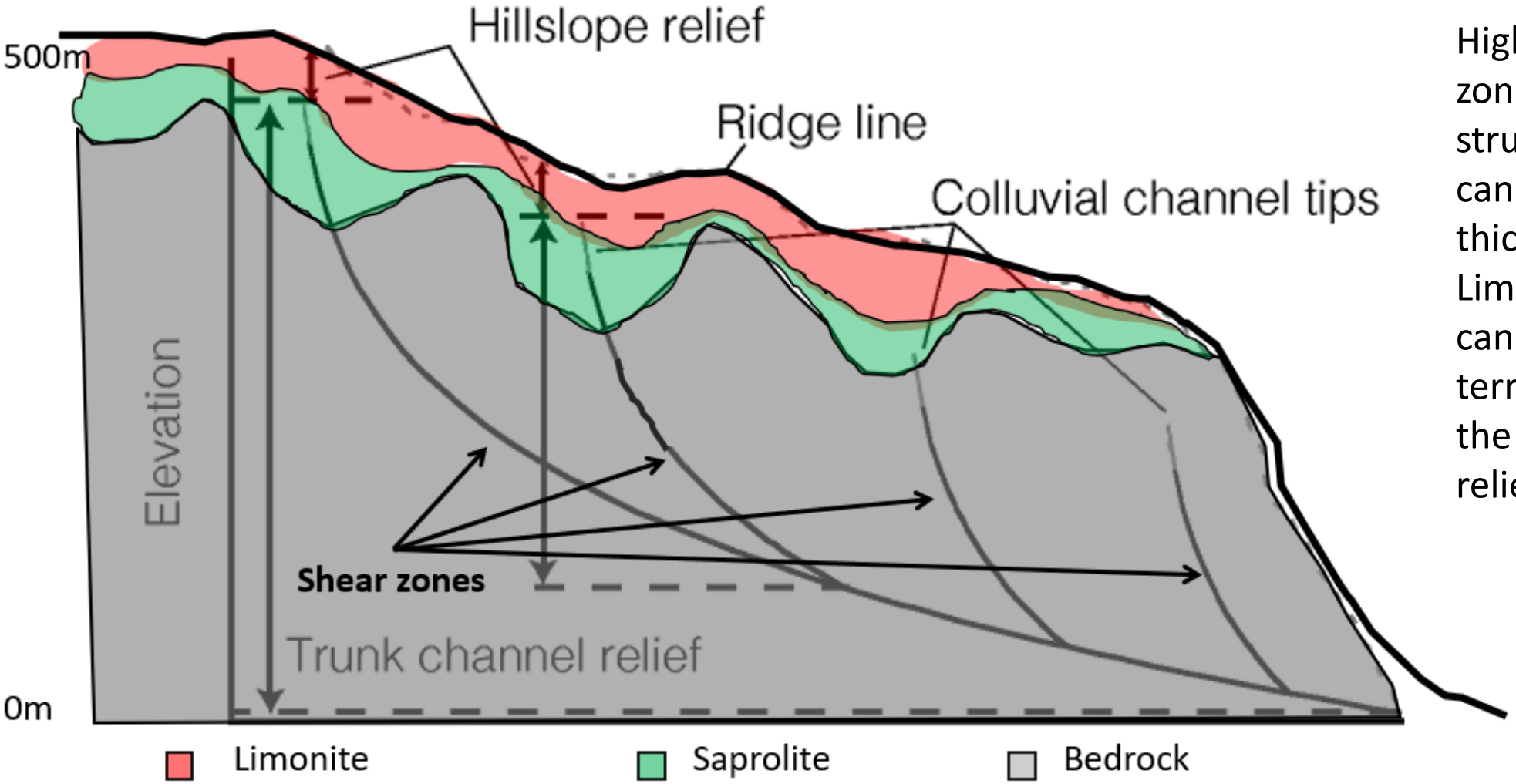
Simplified Example Ni-Fe Laterite formation from Ophiolite rocks in Indonesia



Highly weathered laterite zones are typically structurally controlled and can influence where the thickest and higher-grade Limonite's and Saprolite's can be found, often these terraces can be seen from the topographic surface relief.

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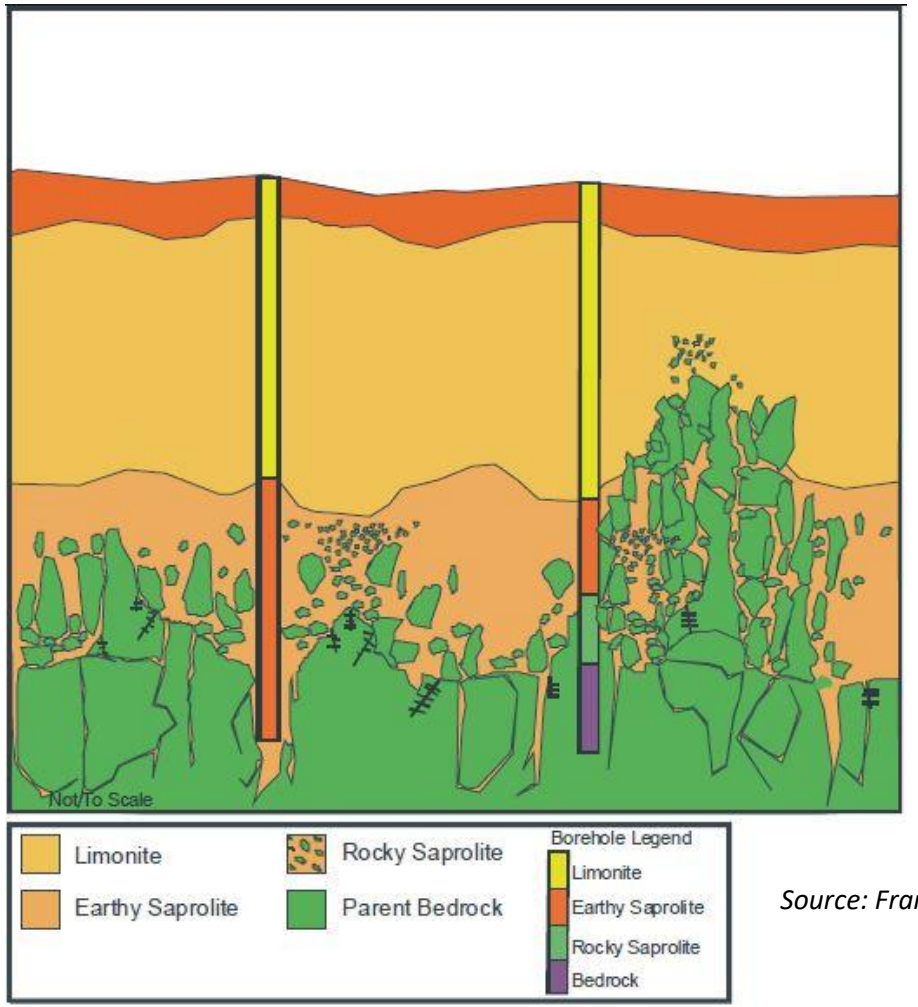
Adding value through optimizing exploration techniques

Traditionally blanket drilling on a grid over the entire deposit has been used as the industry standard for nickel laterite exploration, usually resulting in a significant cost in both core drilling and sampling.



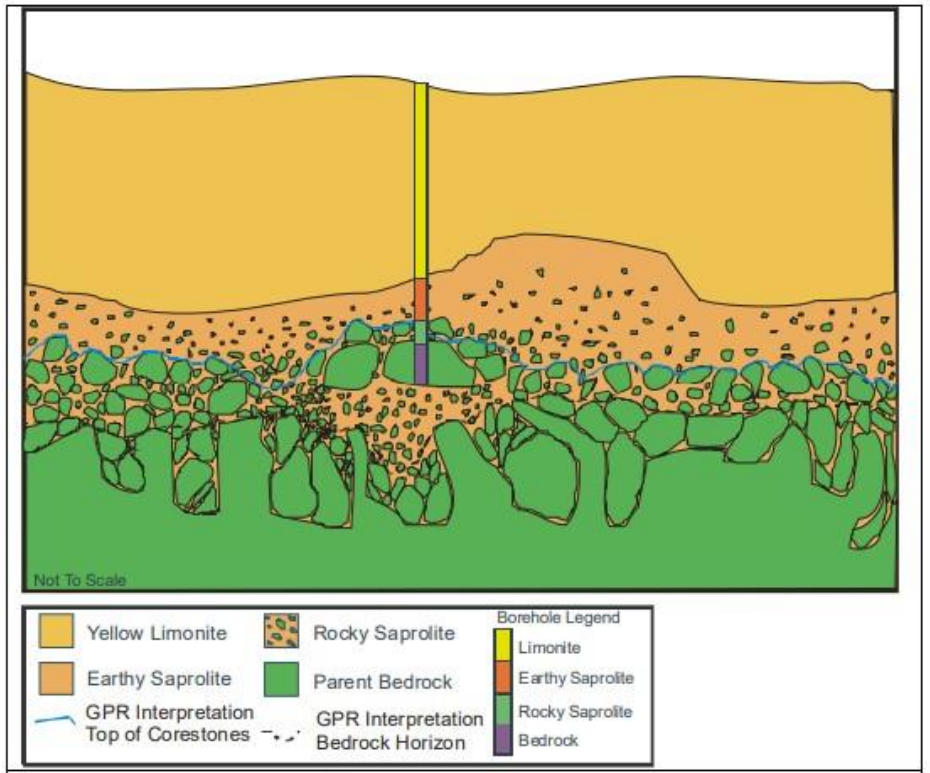


Figure 3.9 – Borehole terminated in large corestone.

Source: Franke. J (2008)

Unfortunately, a common weakness of this method is providing reliable laterite resource estimations due to extreme variability of the weathering profile and grade distribution within

Often individual drilling results can be misleading and not representative of the deposit as a whole

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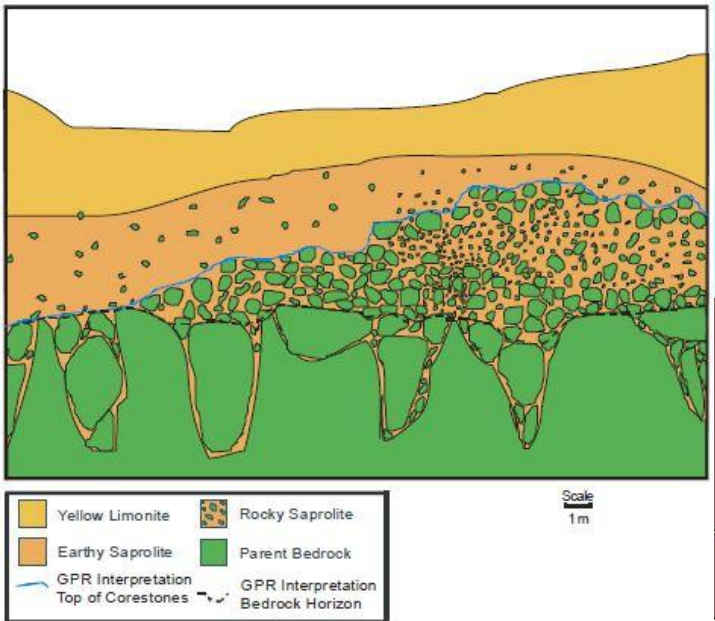
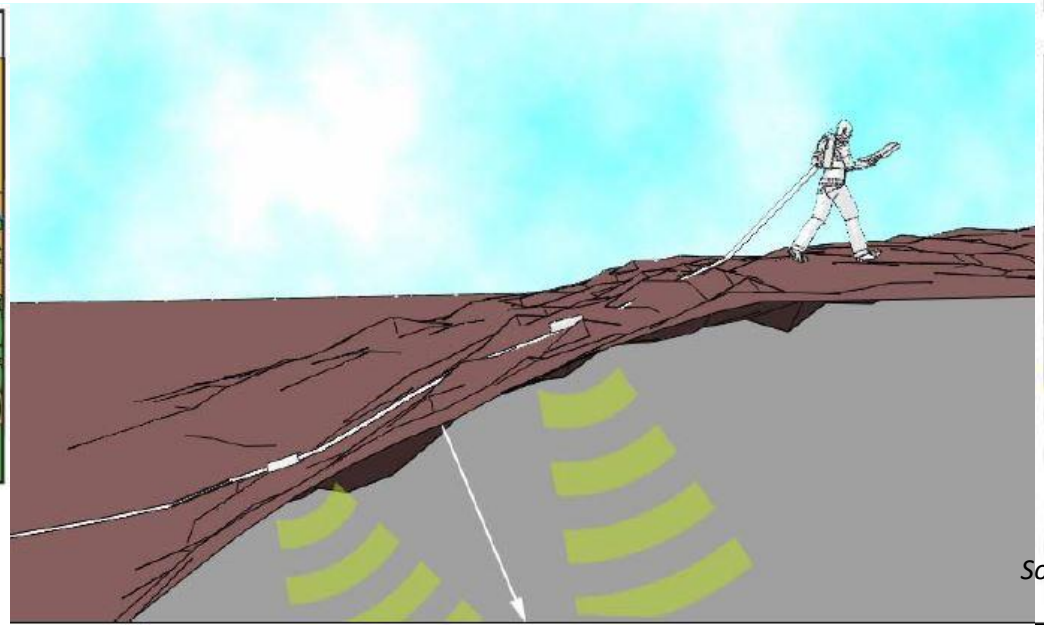
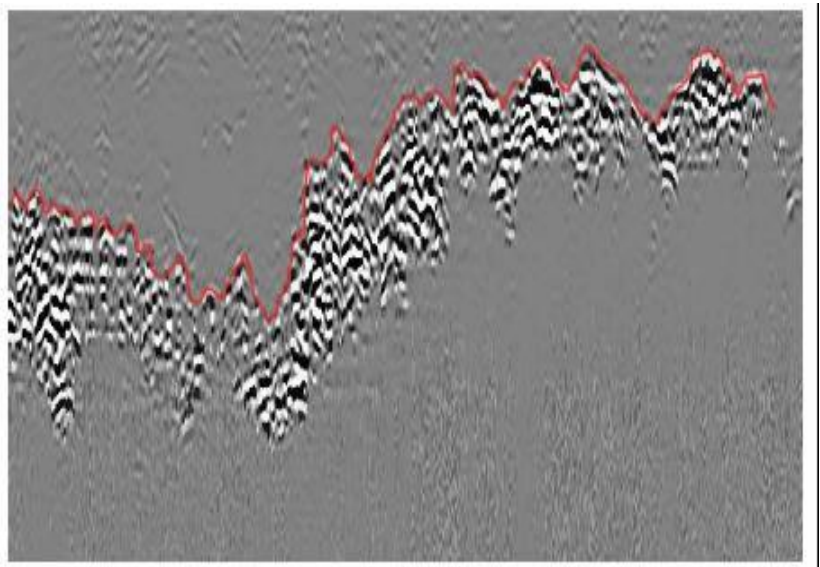
GEOPHYSICS USED FOR NICKEL EXPLORATION??

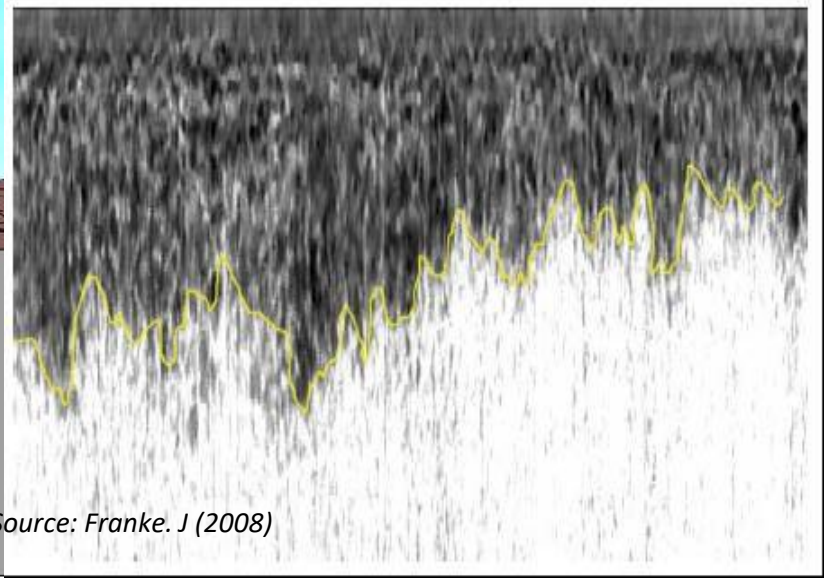
It is common to use various geophysical research methods during this stage to study the structure and composition near-surface parts of the Earth. Usually covering a larger area quicker. These methods of applied geophysics are often used to support ongoing geological investigations, in particular 2D/3D ground penetrating radar (UltraGPR) is very good for lateritic deposits

***Important Note**: the use of geophysical surveys are considered as Supportive data (Not Observations) in the JORC 2012 code guidelines. Although they can be used to increase the confidence of geological interpretation between points of observation, they should not be used for resource estimation directly*









Source: Franke. J (2008)

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TYPICAL LATERITE WEATHERING PROFILE FOR LIMONITE / SAPROLITE
With indicative mineralogy grades ranges

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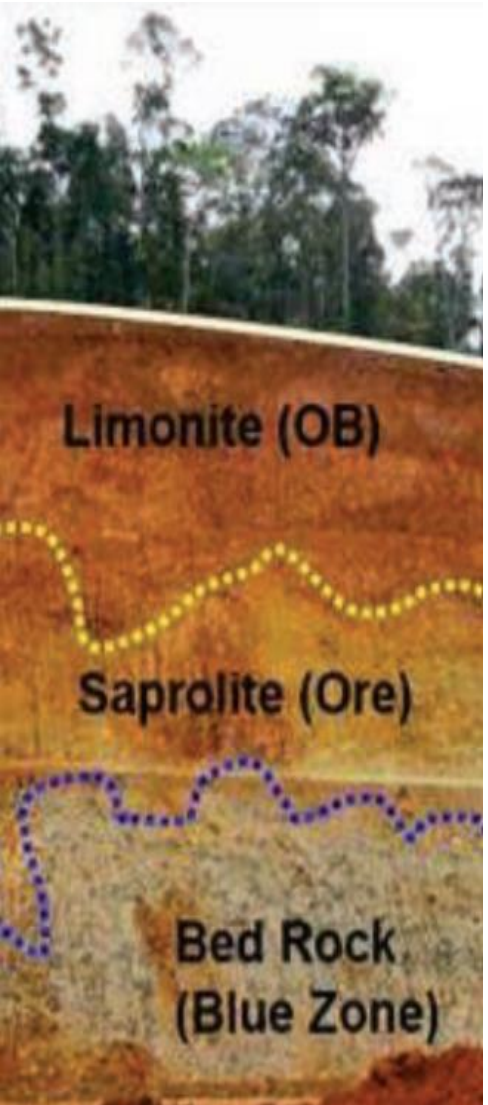

UltraGPR zones

weathering layers

MASSIVE CLAYS

WEATHERED ROCKS

FRESH ROCKS

SCHEMATIC LATERITE PROFILE	COMMON NAME	APPROXIMATE ANALYSIS (%) Ni	Co	Fe	MgO	EXTRACTION PROCESS
	RED LIMONITE	<0.8	<0.1	>50	<0.5	ACID LEACH
	YELLOW LIMONITE	0.8 to 1.5	0.1 to 0.2	40 to 50	0.5 to 5	CARON PROCESS
	TRANSITION	1.5 to 2	0.02 to 0.1	25 to 40	5 to 15	SMELTING
	SAPROLITE/ GARNIERITE/ SERPENTINE	1.8 to 3		10 to 25	15 to 35	
	FRESH ROCK	0.3	0.01	5	35 to 45	

Source: Elias.M (2013)

UltraGPR can provide a great exploration tool to identify the lithological contact between limonite's (Massive clays) and the saprolites (weathered rocks) to the bottom of the laterite weathering profile (bedrock)

Results usually providing global volumes of potential limonite and saprolite located within the survey area

Results combined with drilling data give greater confidence of Ni/Fe laterite orebody dimensions and mineralization distribution for more accurate resource estimates

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Ultra GPR for Nickel laterites

UltraGPR system

- High power transmitters and antenna (64,000 stacks) providing 3 times penetration of other commercial systems, up to 75m depth
- RTK-DGPS positioning
- Extremely rugged, light weight, waterproof and portable. ideal for remote sites with limited access
- Wireless system with no fiber optics (Bluetooth II)
- Simple to use Android phone app for data-logger

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UltraGPR Benefits to support exploration of nickel laterites

- fast & effective, Low impact on forested areas
- shows laterite profile thickness allowing quick volume estimates
- shows better definition of bedrock contact depths
- Better boundary definition of limonite and rocky saprolite zones
- allows optimization of drill programs
- Saves time & money

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UltraGPR Deliverables

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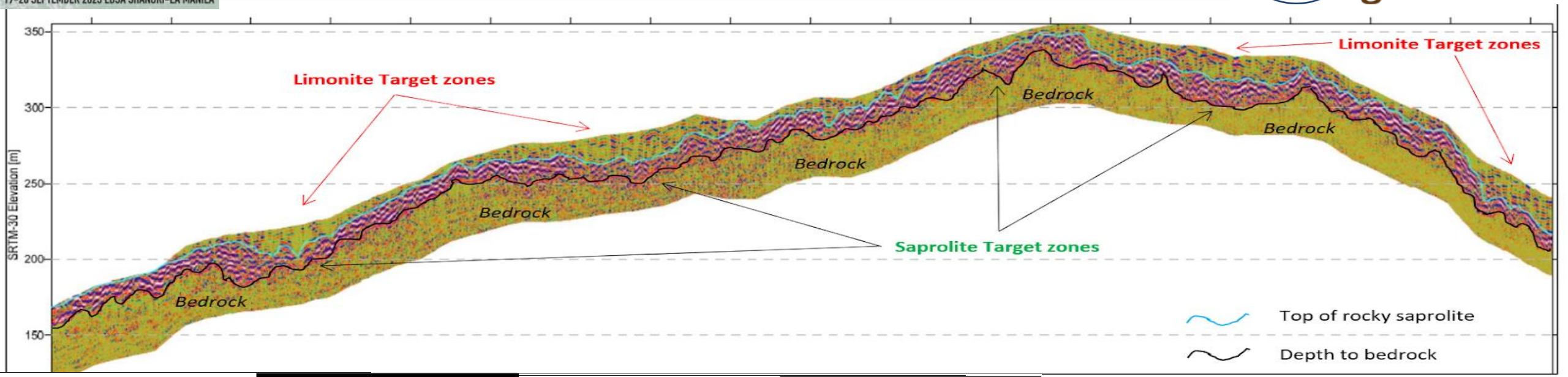
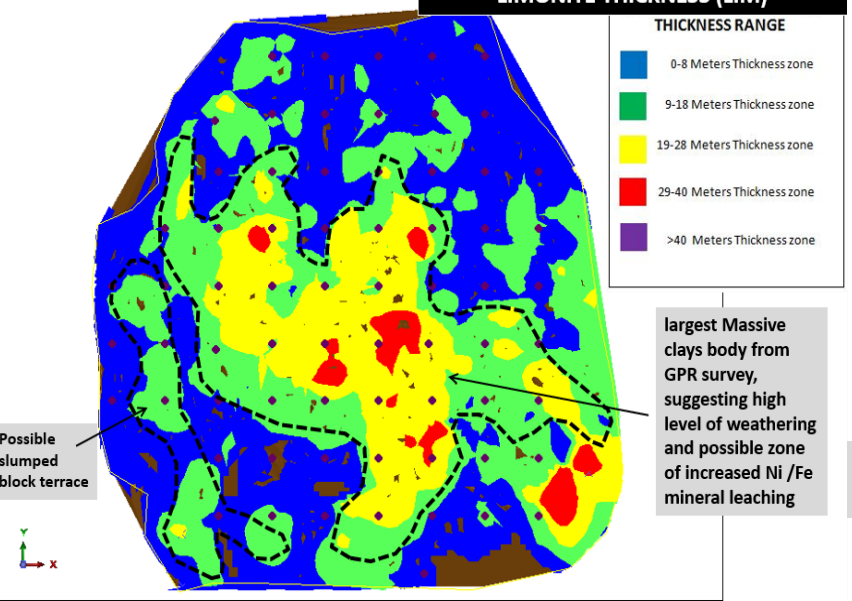
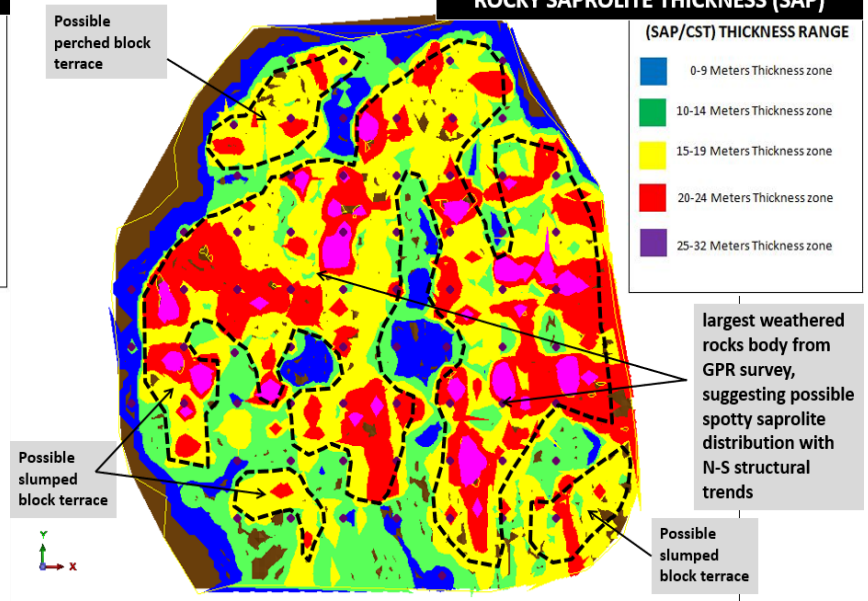


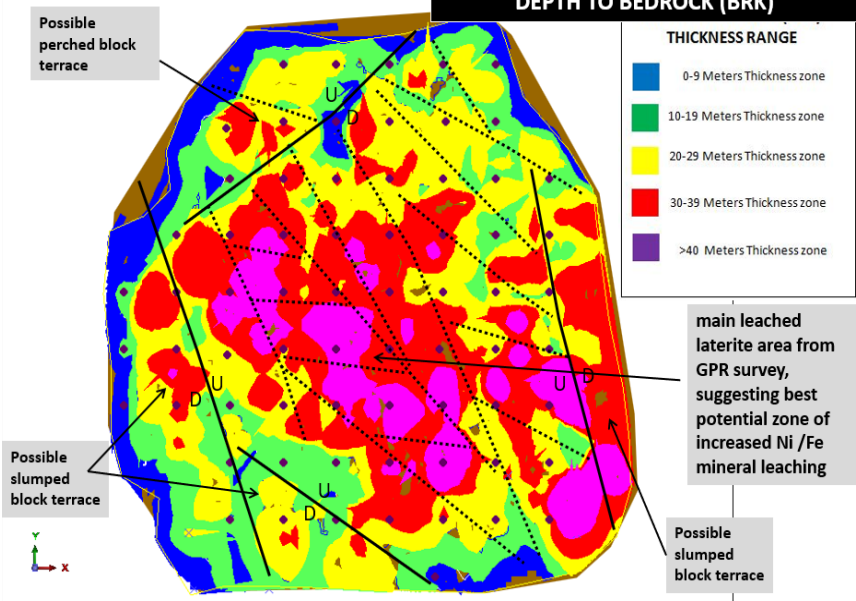
LIMONITE THICKNESS (LIM)



ROCKY SAPROLITE THICKNESS (SAP)



DEPTH TO BEDROCK (BRK)



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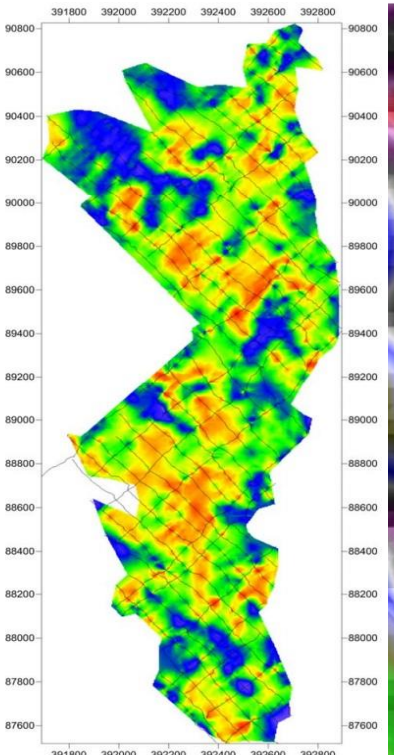
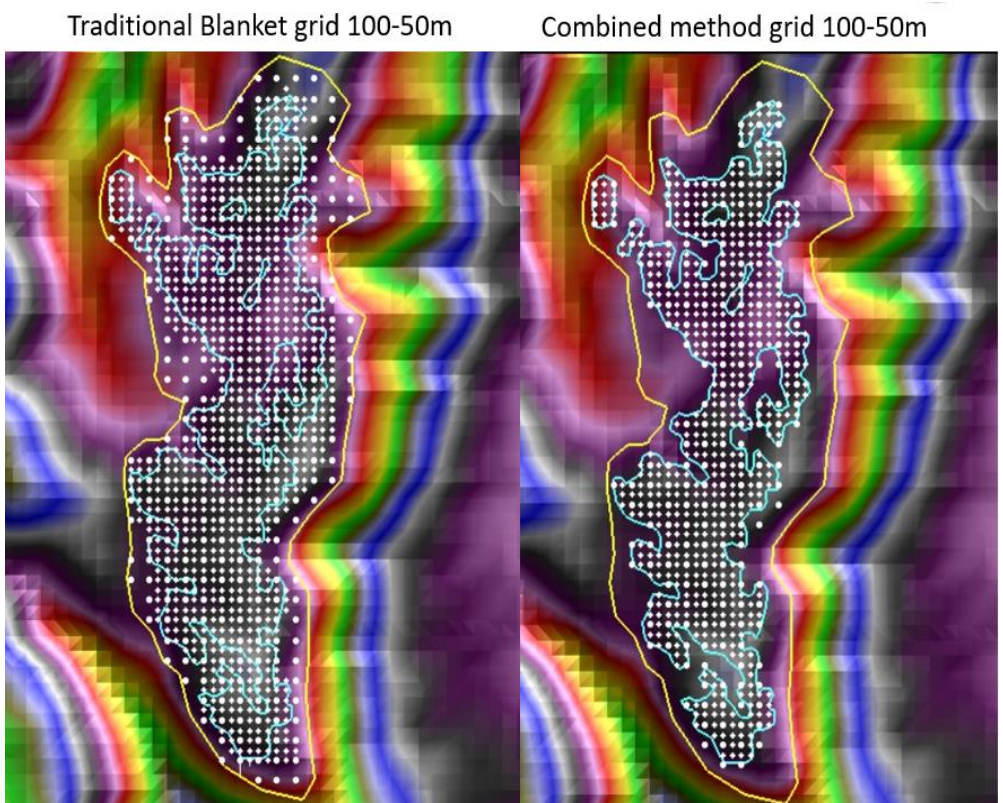
Core drilling & Sampling

Once weathered laterite zones have been identified from initial mapping and UltraGPR surveys infill drilling can be aligned to the geological structures with drilling completed in the optimal locations to target the best laterite zones

Potentially reducing expensive drilling and sampling costs by up to 40%





Additional benefits by completing the drilling phases quicker. The resulting significant completion time benefits to reach Mineral Resource Milestones faster

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19-20 SEPTEMBER 2023 EDSA SHANGRI-LA MANILA

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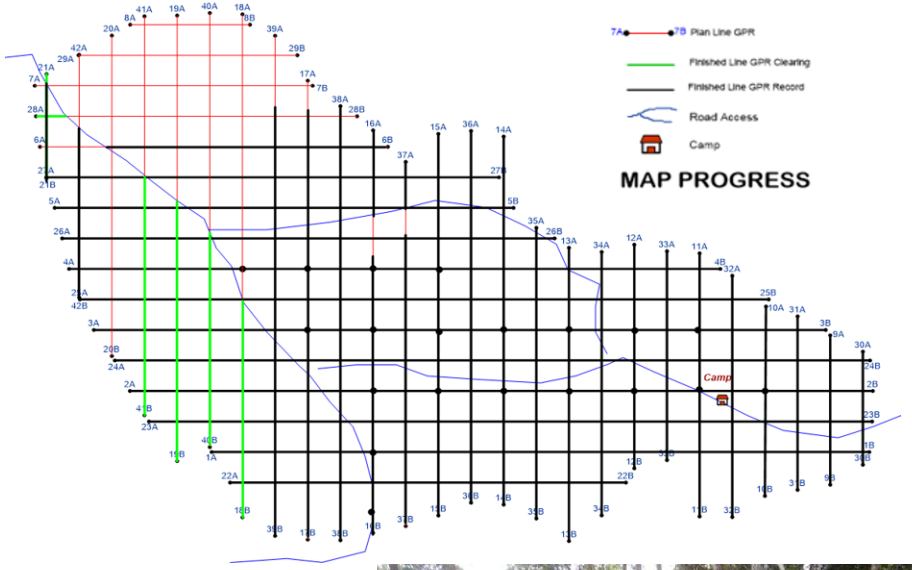
UltraGPR is mostly used for early stage exploration, usually on a 100m - 200m grid, matching the drilling coordinates, but application to grade control can also be applied is some areas to 50m or 25m grids, when required



Typical working 2 -3 team in parallel

Team 1 – UltraGPR Acquisition
- 1 UltraGPR Operator
- 3-4 field assistants

Team 2 – Line clearing
- 1 Line manager (GPS)
- 3-4 field assistants

Team 3 (optional) – Line clearing
- 1 Line manager (GPS)
- 3-4 field assistants

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Ultra GPR for Nickel laterites

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Examples of Other Geophysical Methods used in Laterites

Geophysical Survey Method	Average Price Ranges, without local labor costs	Daily survey capabilities	Additional labor requiremnts	Data Processing time	Notes
RESISTIVITY (Equipment Weight 50-80 kg)	$US 1,000-2,0000 /km	500-1000 m/ day	10 -20 local labor helpers to assist	1 -2 months	Medium cost option with Good resolution to identify rocky saprolite and bedrock contact,
SEISMIC REFRACTION (Equipment Weight 30-60 kg)	$US 2,000 /km	300-400 m/day,	10 - 20 local labor helpers to assist	1 - 2 months	High cost option with Good resolution to identify rocky saprolite and bedrock contact, but method is inefficient for large remote areas
UltraGPR - Ground Penetrating Radar **(Equipment Weight 7 -10 kg)**	**$US 500–1,000 /km**	**1500 – 3000m / day, with line clearing**	**5 – 10 local labor helpers to assist**	**3 - 5 days**	**Provides Best low cost option for excellent resolution Depth to rocky saprolite and bedrock, Quick and robust system for minerals exploration**

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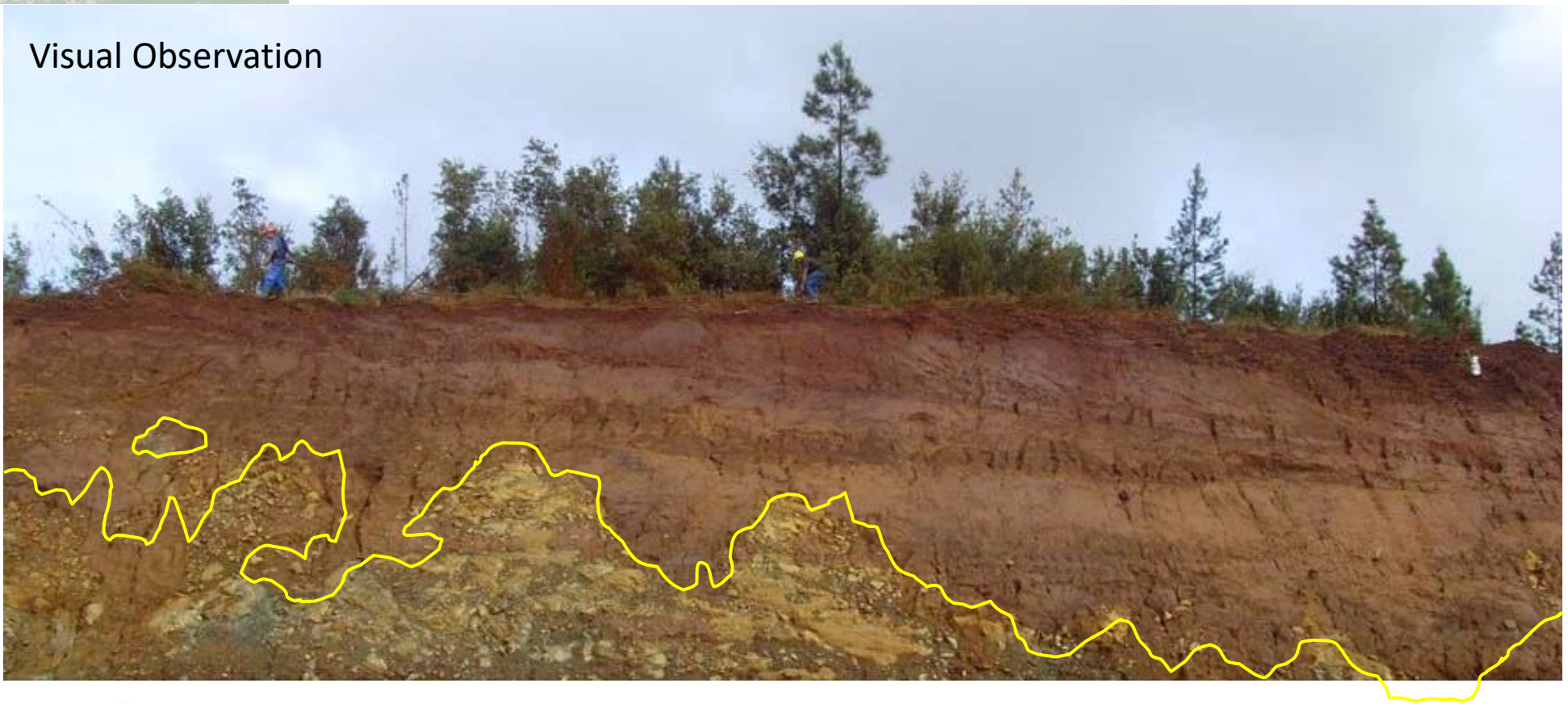
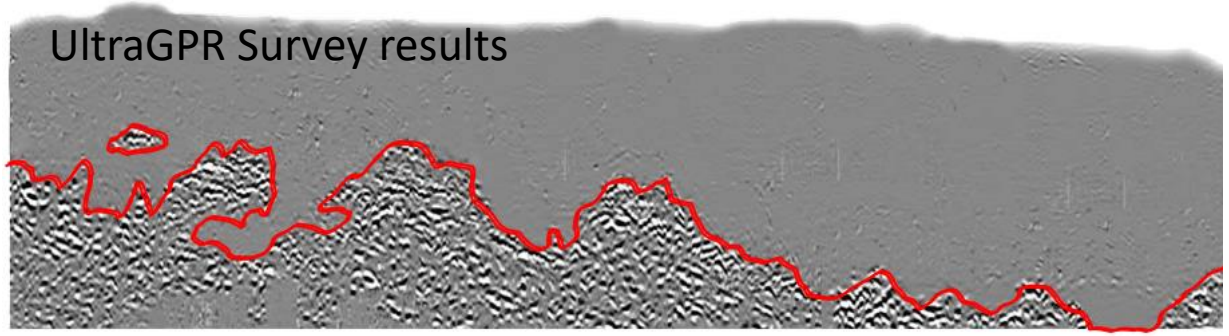
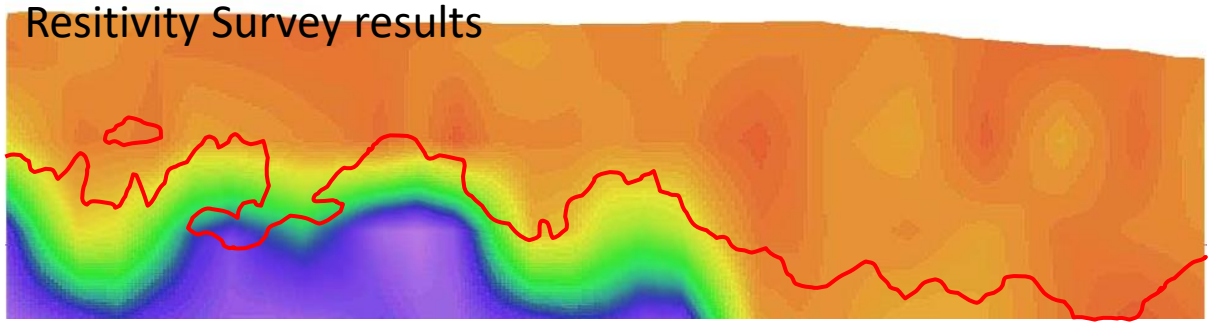


Comparison interpretation of results between UltraGPR and Resistivity survey





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UltraGPR for Nickel laterites

Other FAQ's

- In good conditions with lines already prepared UltraGPR acquisition team can achieve 2-4km/day on average
- Monthly targets are between 40-50km and can cover large areas up to 500ha/ month
- Line clearing and preparation is key to quick results
- Primary processing by Groundradar can be obtain within 24-48hrs usually, typically it is sent in batches weekly or monthly depending on the site communications
- Groundradar can also provide a viewer software for the client to edit the interpretation with new drilling and ongoing works
- Full, partial and rental packages are available to suit the clients needs and budgets

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UltraGPR by GroundRadar Survey equipment specifications

More detailed technology information can be found at;
www.groundradar.com

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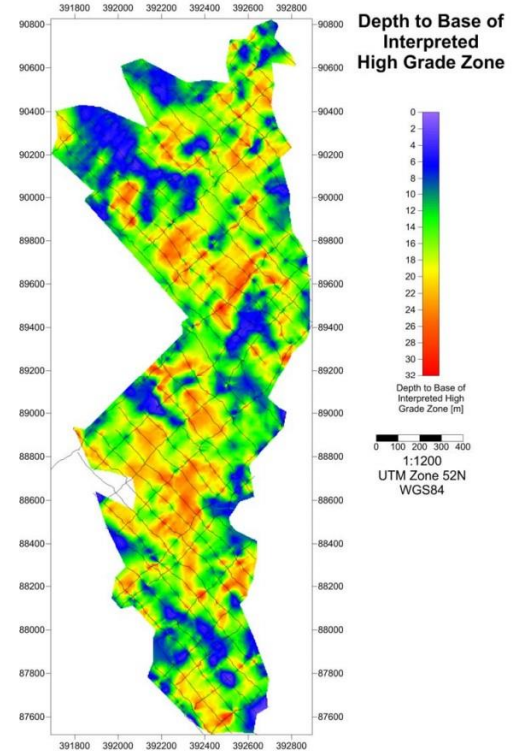
UltraGPR offers increased penetration, accuracy, ease of use, speed of surveying and reliability. Real-time sampling technology has enabled the imaging of deeper reflections than has been possible with commercially-available systems to date. Depths of up to 75 m have been achieved in lateritic weathering profiles with UltraGPR, whilst maintaining excellent profile resolution. By eliminating all wires and fiber optic cables, as well as cumbersome control units and batteries, the UltraGPR has been reduced to a single 9 m long tube. The traditional laptop computer used on commercial GPR systems has been superseded by the use of a mobile phone or PocketPC to control acquisition parameters and store data. Communication between components employs Bluetooth technology. The unit is completely waterproof and can be deployed over the most challenging of terrains.



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Future Exploration Targets???

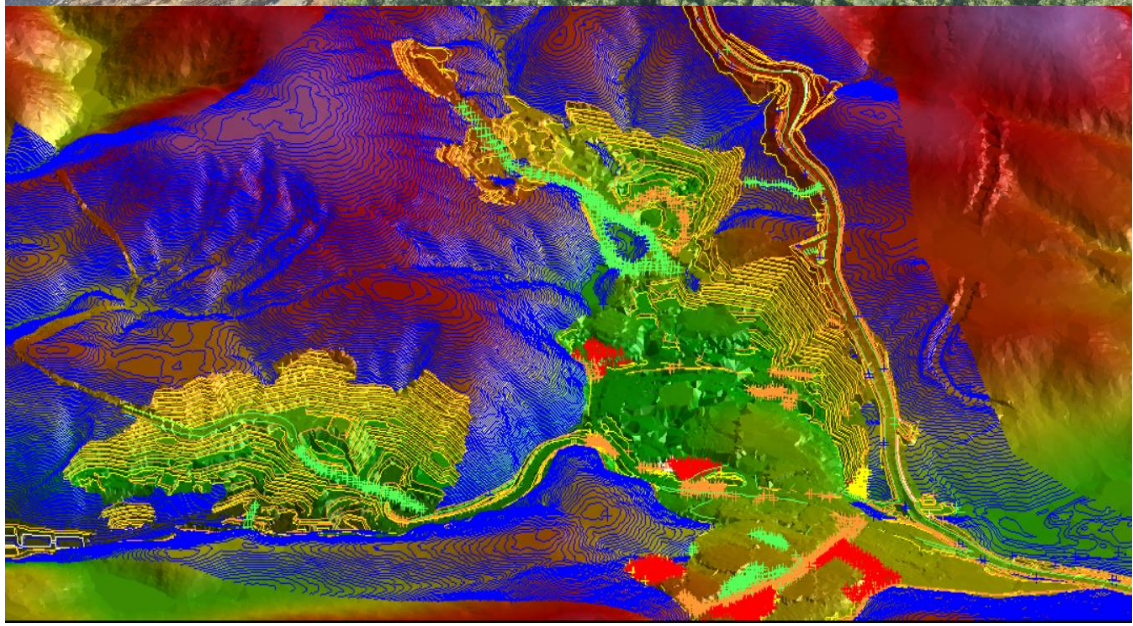
•In the future, demand for Nickel will continue to grow with Indonesia and Philippines playing a significant role both have excellent potential for the discovery of new nickel laterite resources,

•Finding Ni laterite is relatively easy, but identifying specific grades of limonite and saprolite requires systematic exploration methods.

•The next generation project discoveries will consist of deposits that are not so obvious. These new discoveries will be made by companies willing to interpret the geology and to test their ideas in the field

•Although project logistics, infrastructure and land use conflict are challenges, huge opportunities exist to expand development of the regions nickel mining industry

•Overall the exploration possibilities are wide open



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Thank You

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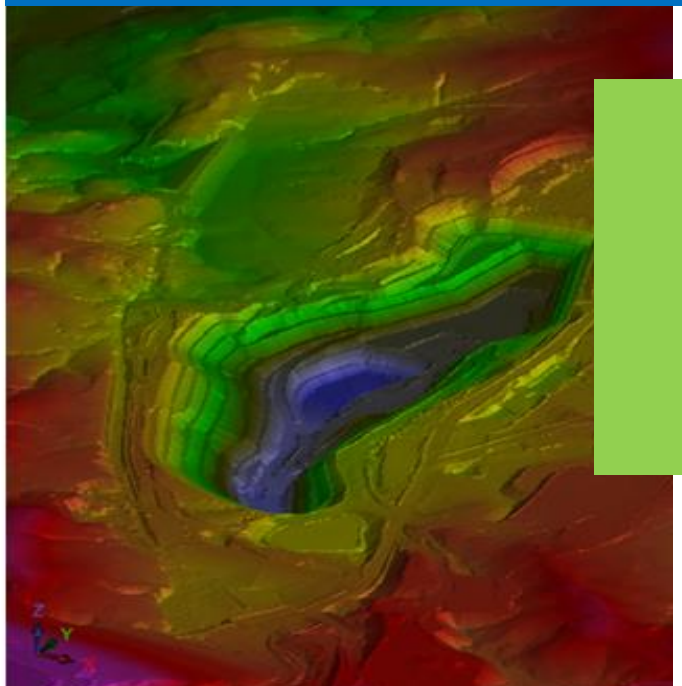

Fresh Ideas – Systematic Investigations – Optimum Results

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