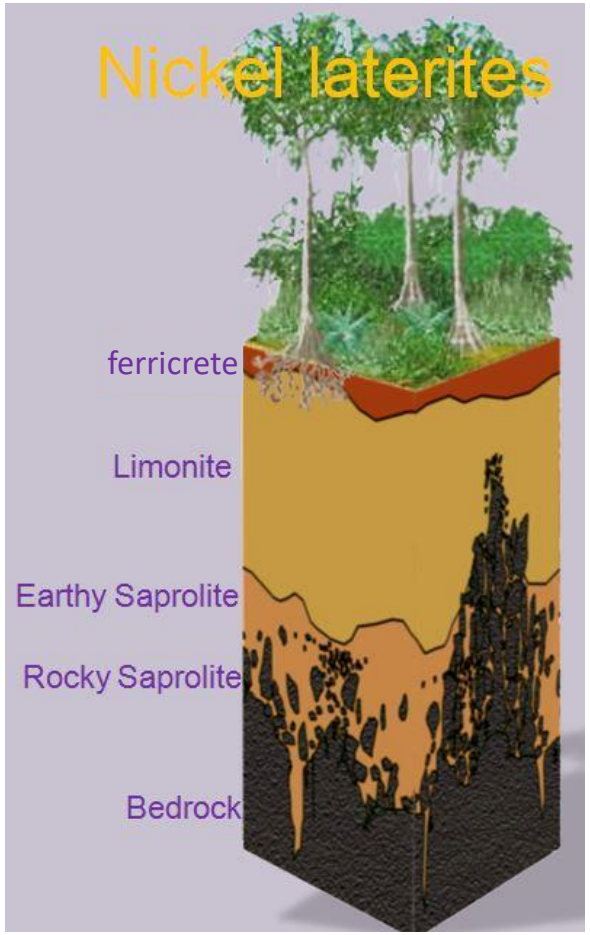
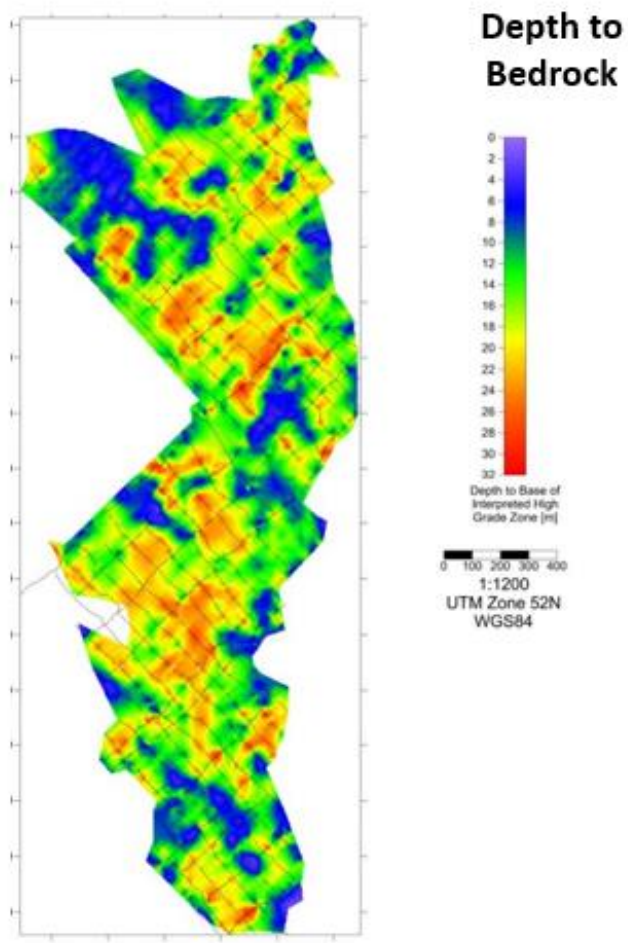
Ultra GPR for Nickel laterite exploration

groundradar

Applying Ground Penetrating Radar (UltraGPR) technologies for Nickel Laterite exploration





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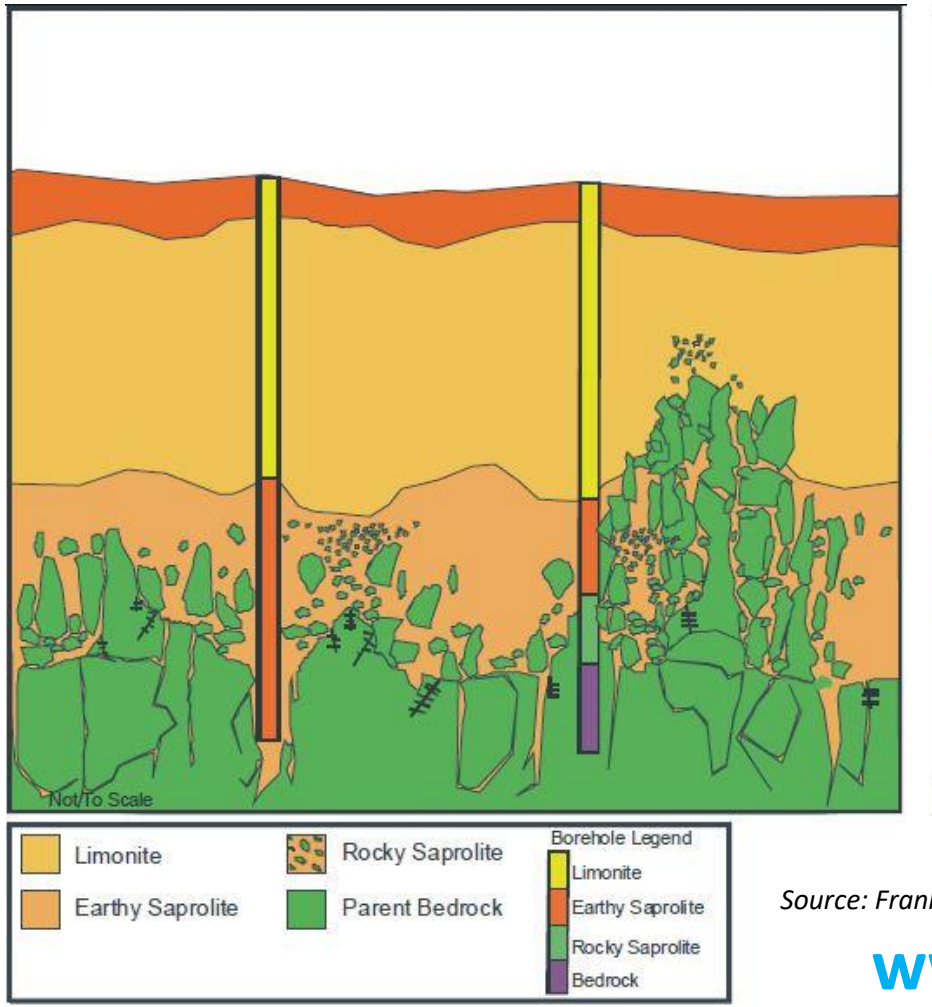
Adding value through optimizing exploration techniques

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.



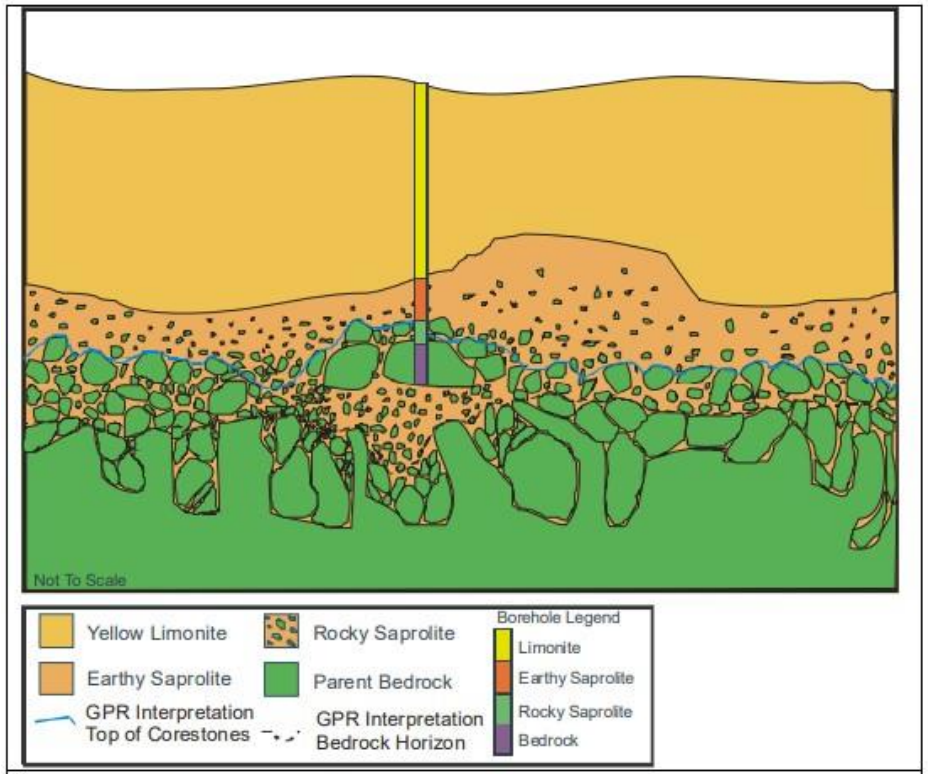


Figure 3.9 – Borehole terminated in large corestone.

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

Ultra GPR for Nickel laterite exploration

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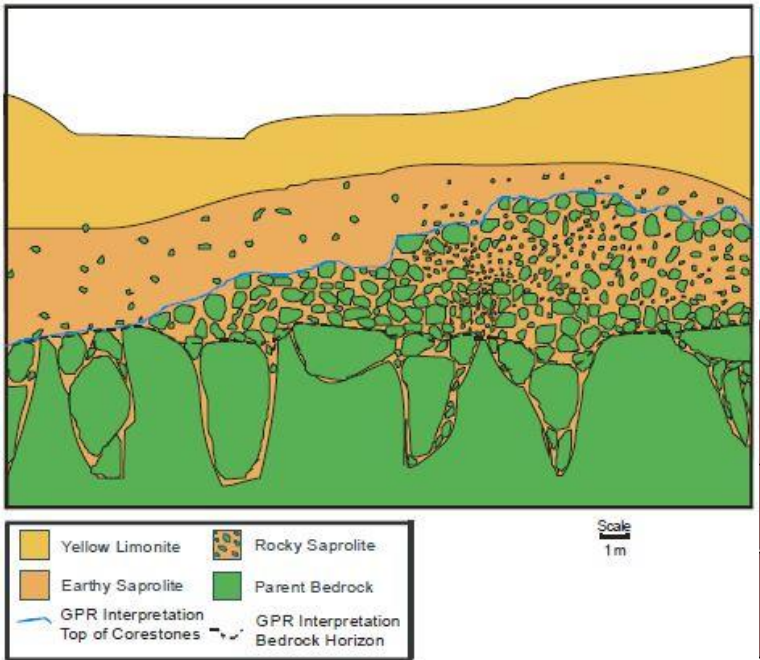
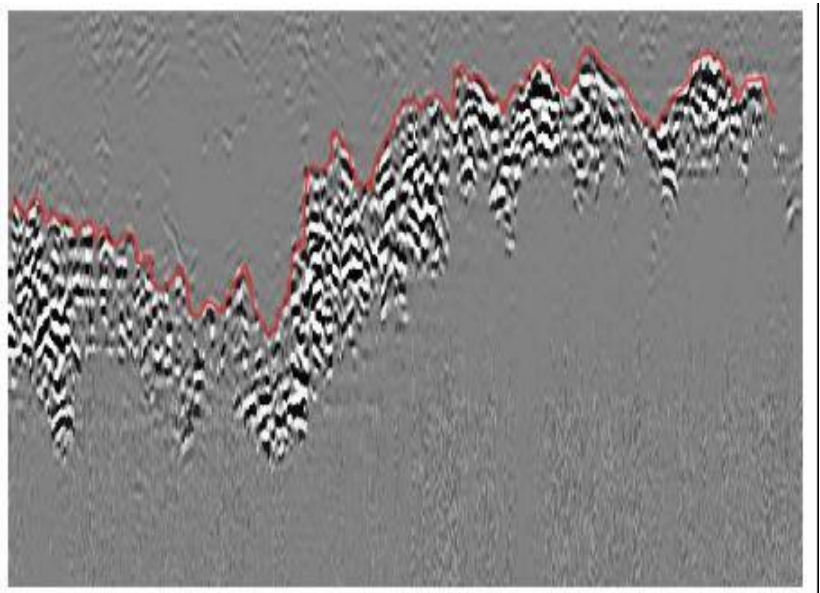
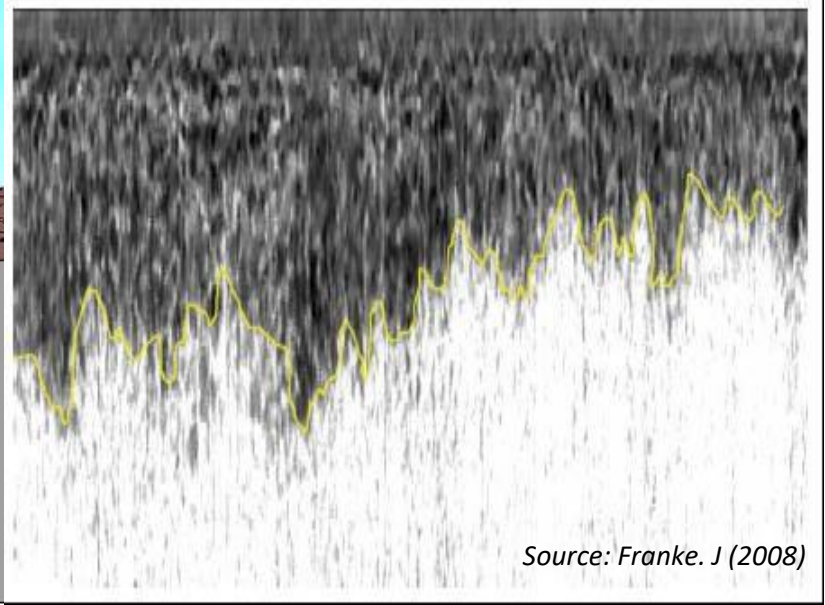
GEOPHYSICS USED FOR NICKEL EXPLORATION??

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 (Ultra GPR) is very good for Nickel 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*

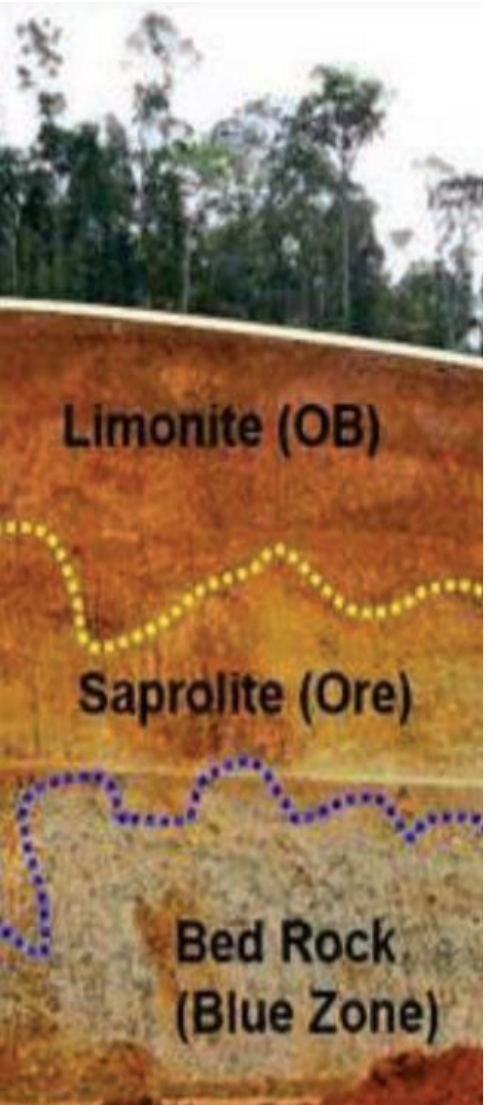






Source: Franke. J (2008)

Ultra GPR for Nickel laterite exploration



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

GPR 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)

GPR 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-Co-Fe laterite orebody dimensions and leaching distribution for more accurate resource estimates

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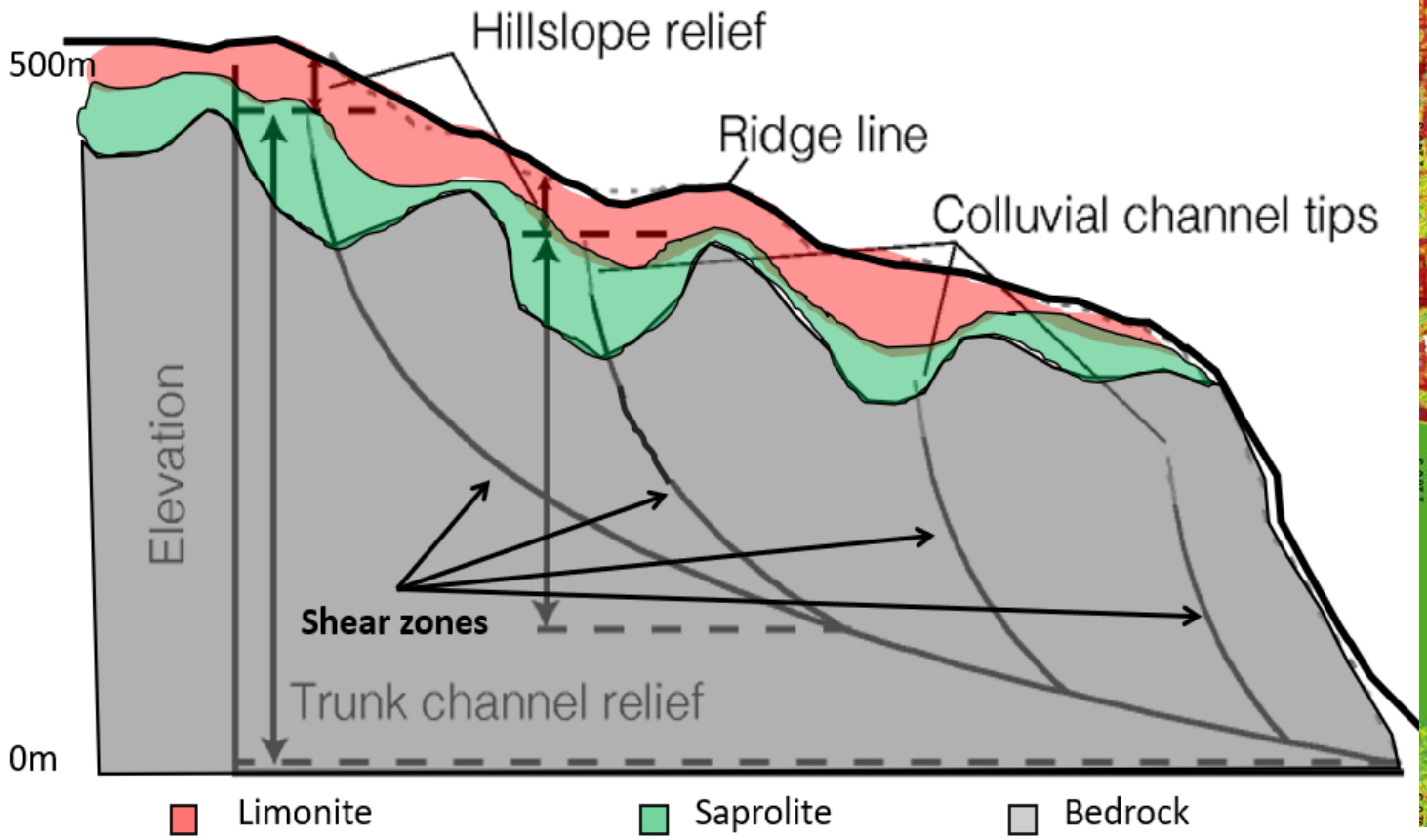
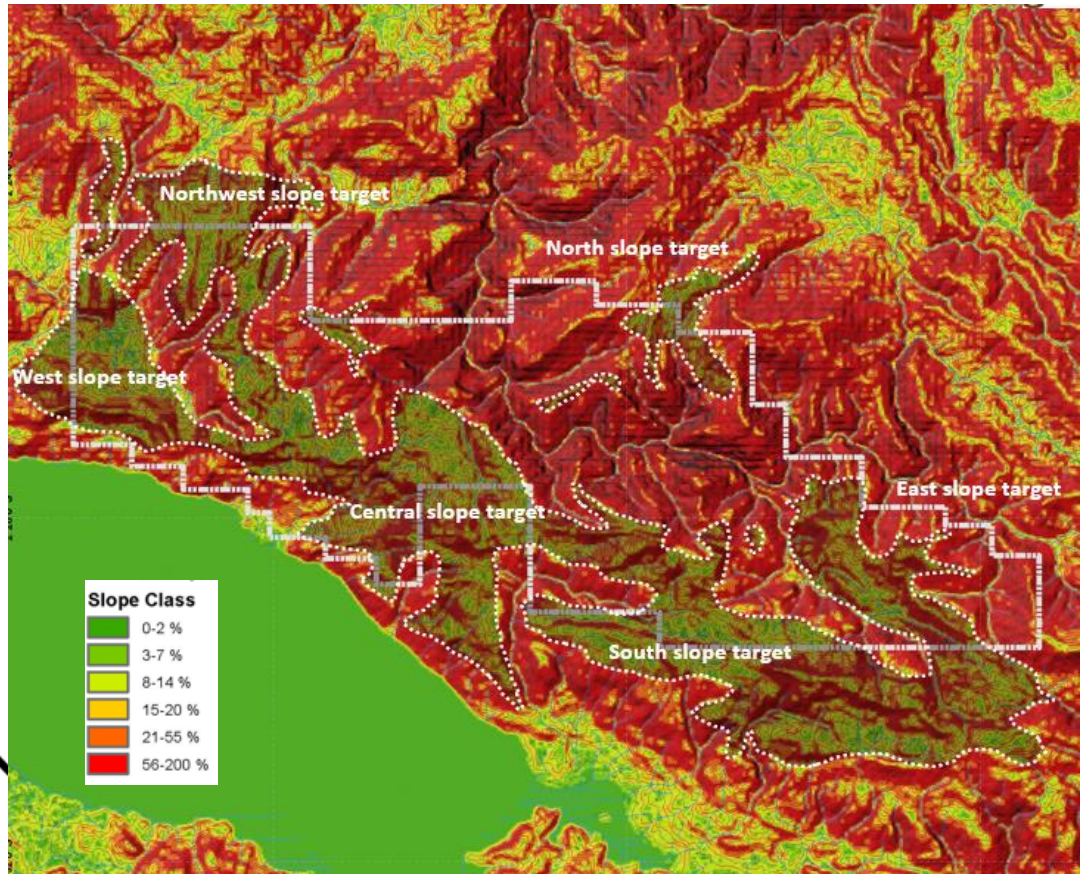
Ultra GPR for Nickel laterite exploration

Simplified Ni-Fe Laterite formation from Ophiolite rocks in Indonesia

Highly weathered laterite zones are typically structurally controlled and can influence where the increased leaching occurs, resulting in the thickest Limonite's and Saprolite's zones can be found, often these terraces can be seen from the topographic surface relief through initial slope analysis.





Ultra GPR for Nickel laterite exploration
The UltraGPR system

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

Ultra GPR for Nickel laterite exploration

Ultra GPR Benefits to support exploration of nickel laterites

- fast & effective in remote conditions, low impact on forested areas
- shows laterite thickness allowing 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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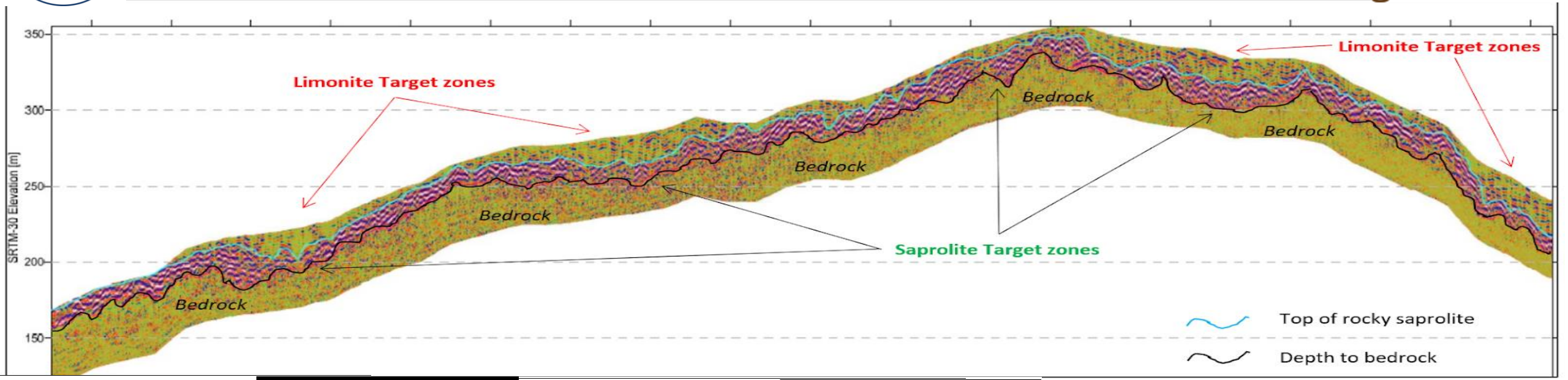
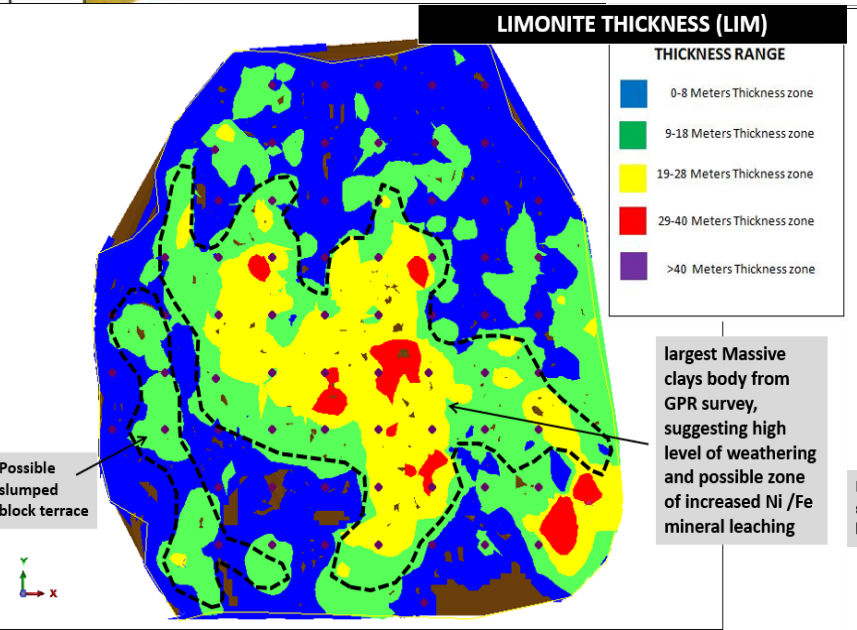
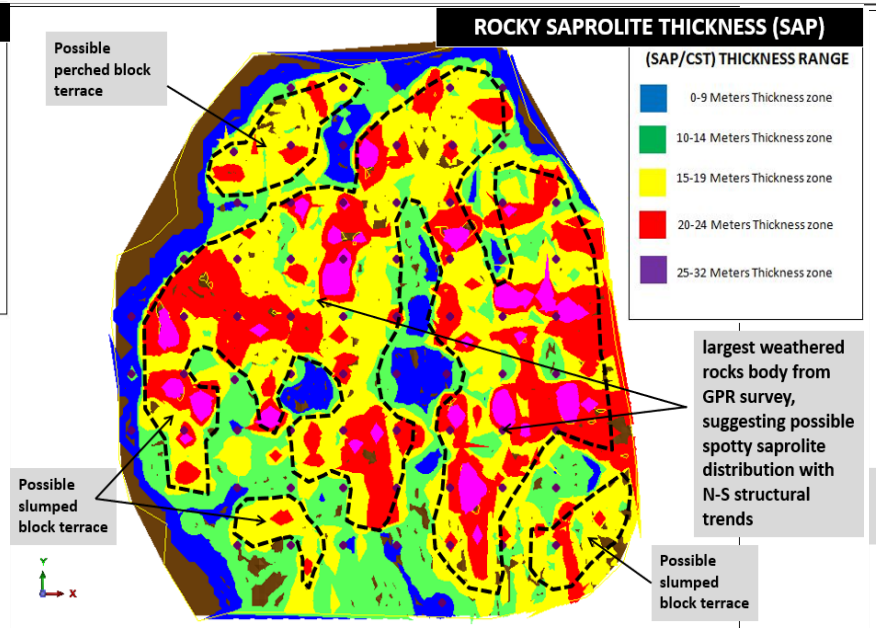
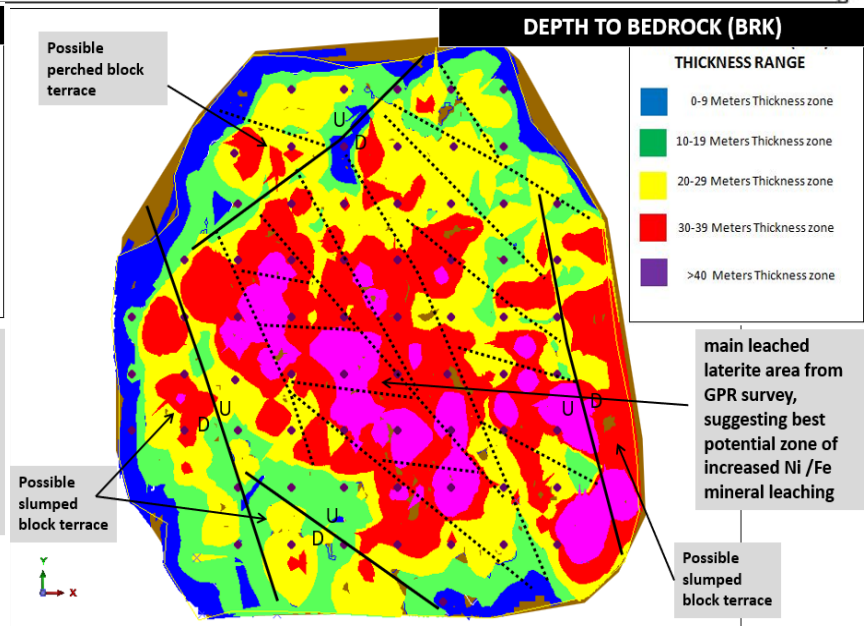
Ultra GPR for Nickel laterite exploration

UltraGPR Deliverables









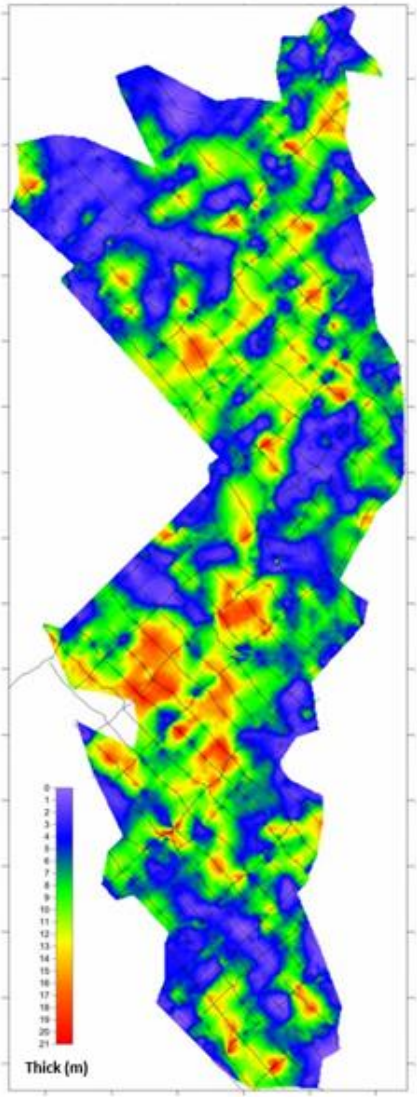
Ultra GPR for Nickel laterite exploration

UltraGPR Deliverables - Depth & zone thickness maps

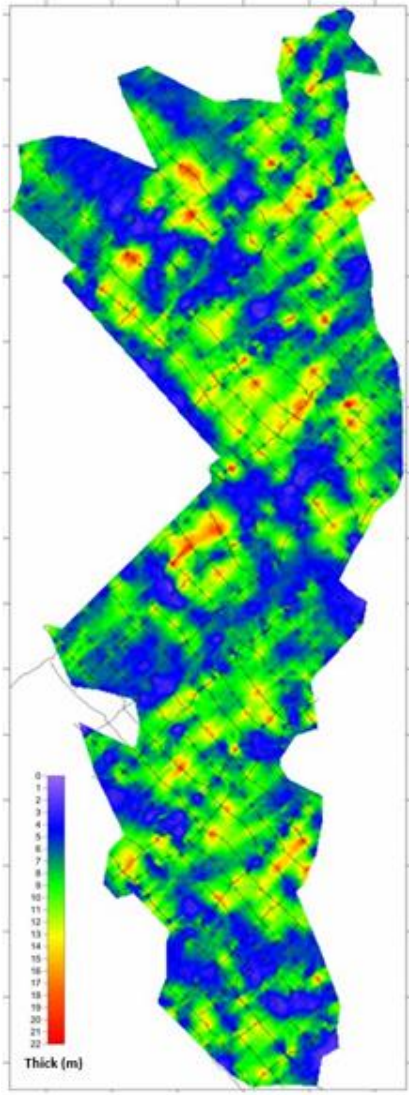
groundradar

Topography GPR lines

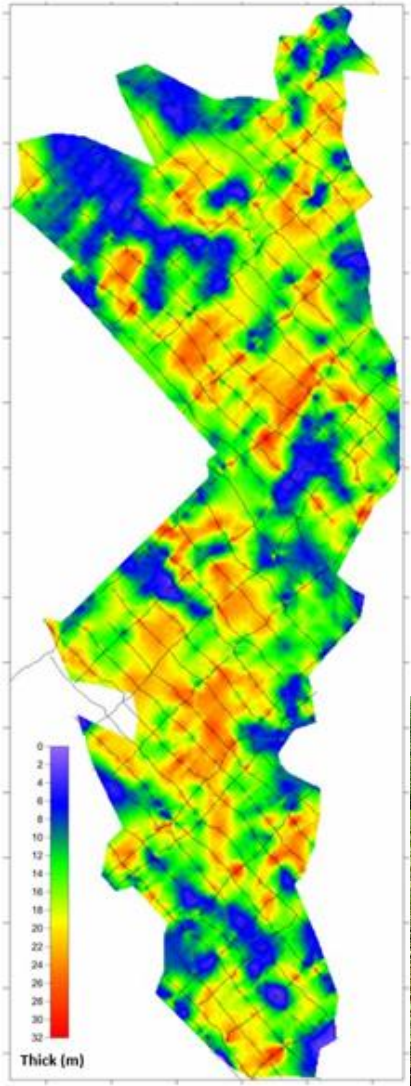
Thickness of Limonite



Thickness of Saprolite

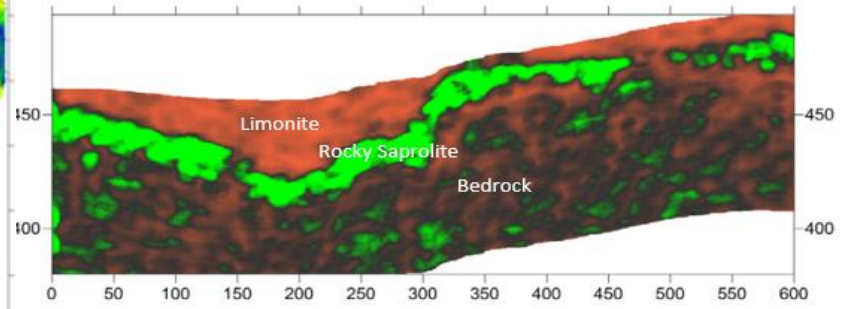


Depth to Bedrock



Global weathering profile statistics

Laterite soil transition horizon	Thickness [m]		
	Minimum	Maximum	Average
Massive Clays (Limonite)	0.44	20.52	6.22
Weathered Rocks (Rocky Saprolite)	0.38	36.27	9.81
Whole soil profile (Bedrock Depth)	1.78	38.31	16.22



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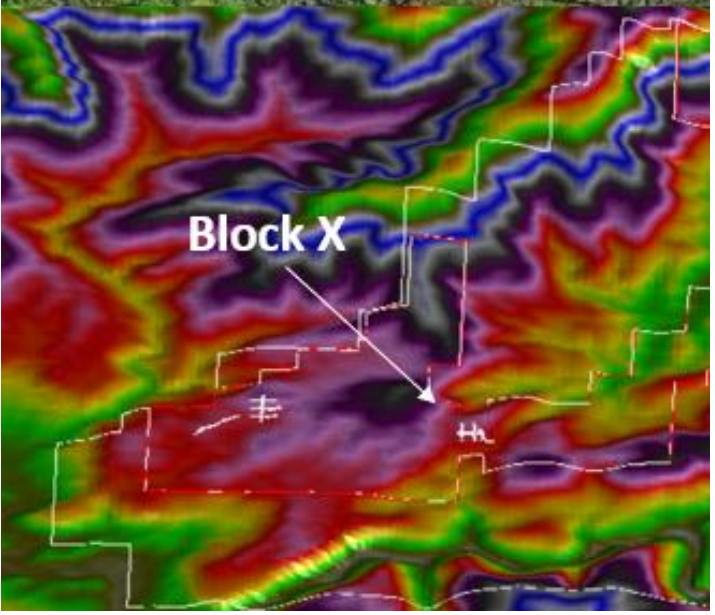
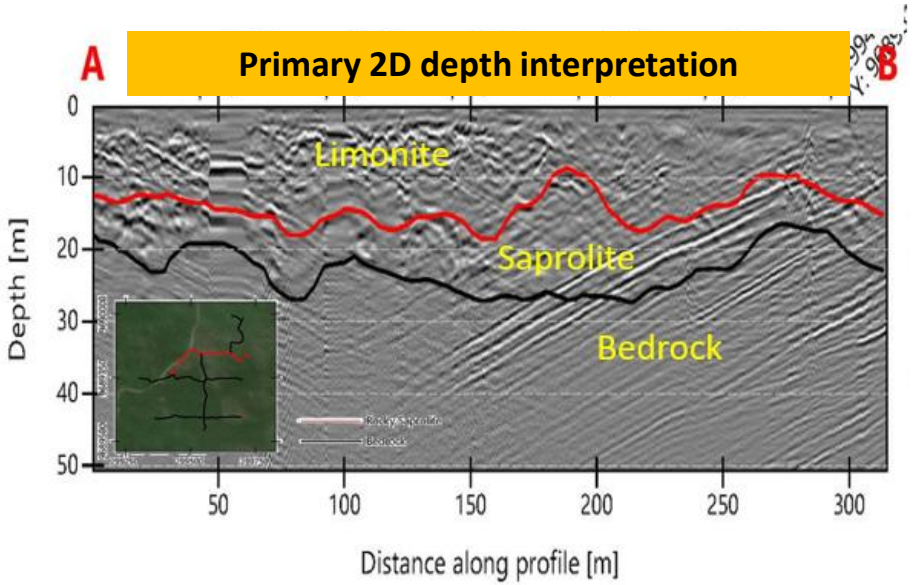
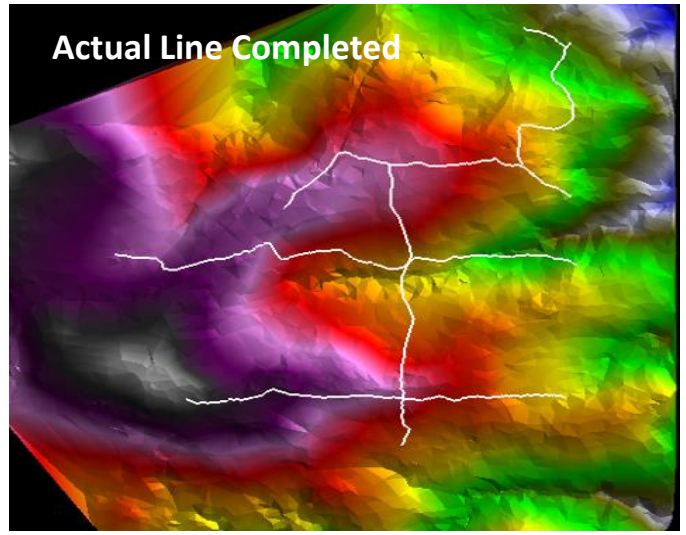
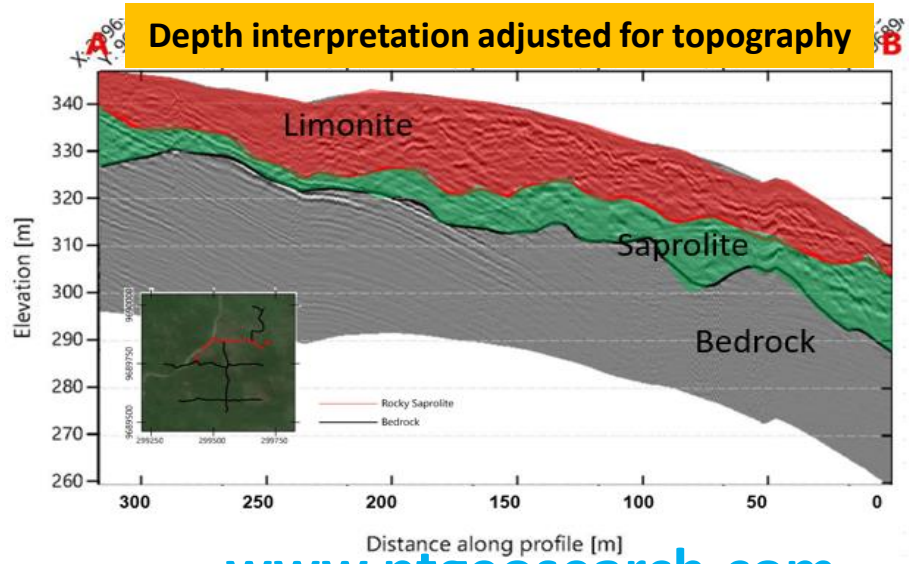
Ultra GPR for Nickel laterite exploration

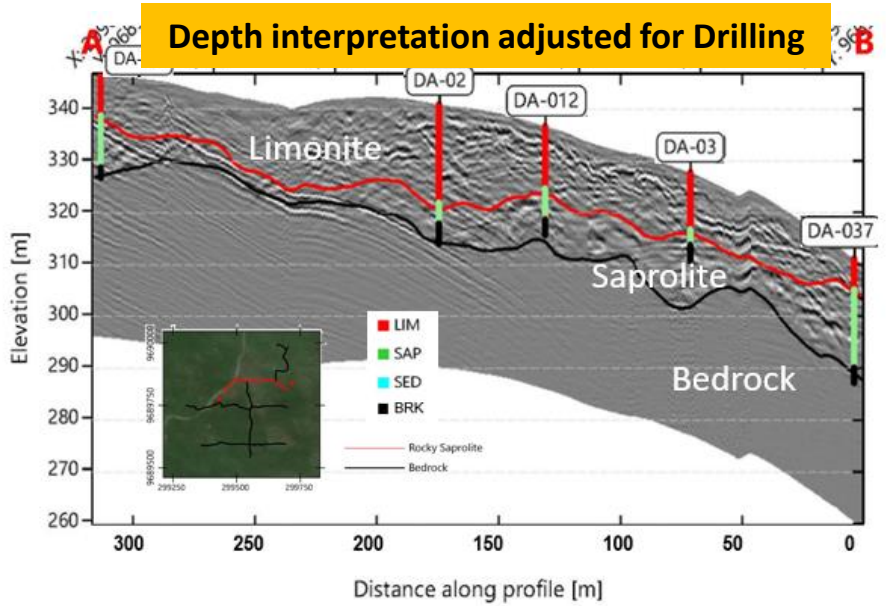
Examples - UltraGPR Survey Result











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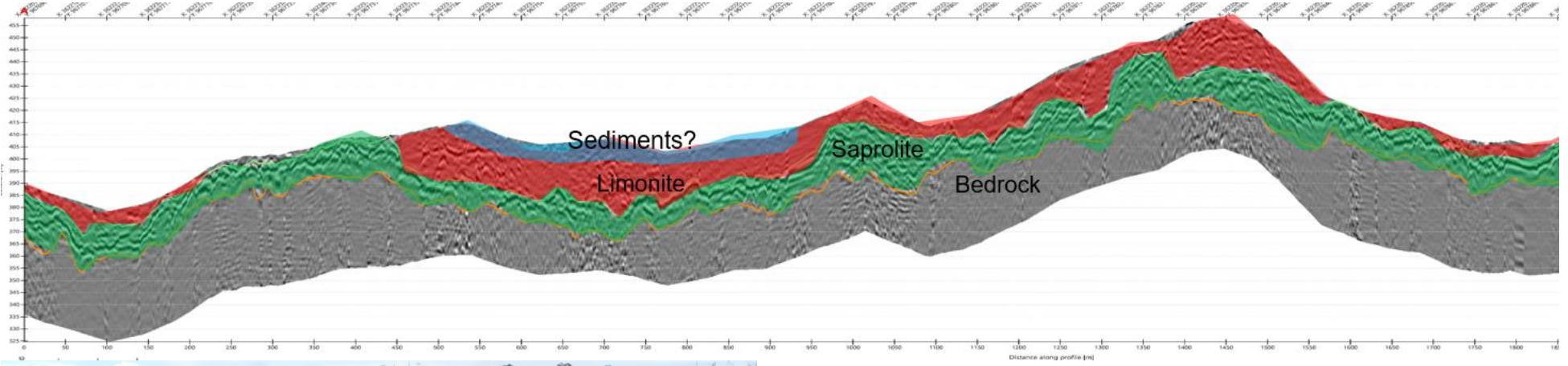
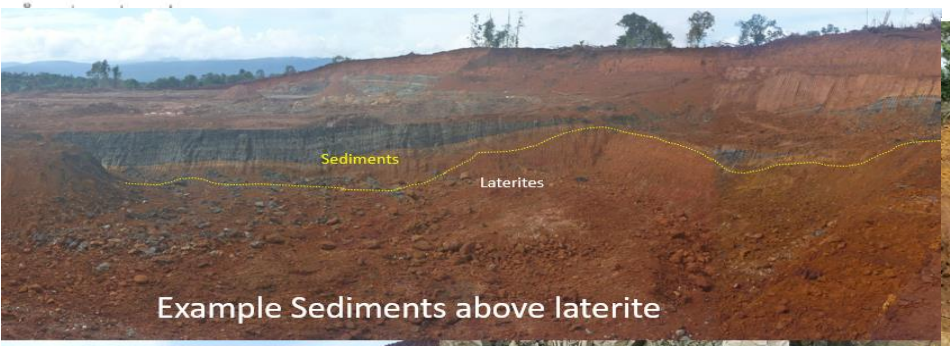
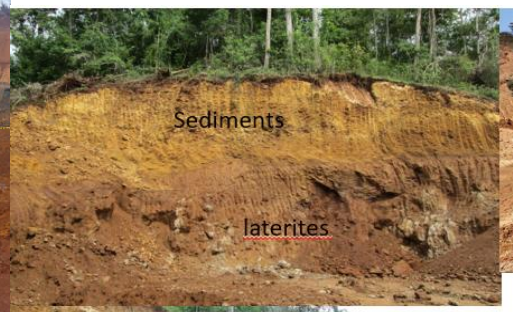
Ultra GPR for Nickel laterite exploration

Examples - UltraGPR Survey Result

local geological setting is that is not typical of most laterites in Indonesia, thick sedimentary (non- laterite) layer that lays unconformably above the laterite layers, making traditional exploration methods and identification of the laterites underneath difficult to find







Sediments

Limonite

Saprolites

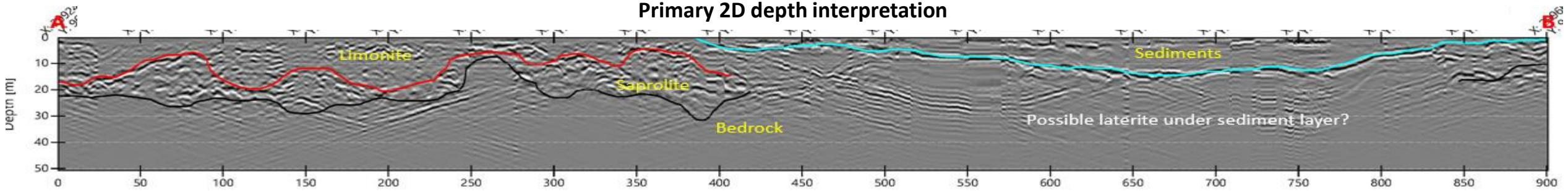
From	To	Thick (m)	Lith	Ni %	Co %	Fe %	SiO2 %	MgO %
0.00	1.00	1.00	SED	0.69	0.05	21.72	32.91	7.30
1.00	2.00	1.00	SED	0.78	0.04	22.23	33.41	7.50
2.00	3.00	1.00	SED	0.83	0.06	26.17	29.52	4.75
3.00	4.00	1.00	SED	0.80	0.05	21.44	34.19	7.81
4.00	5.00	1.00	SED	0.73	0.05	21.09	39.23	13.52
5.00	6.00	1.00	SED	0.79	0.05	20.05	36.84	12.37
6.00	7.00	1.00	SED	0.86	0.04	18.10	45.78	13.34
7.00	8.00	1.00	SED	0.74	0.04	17.71	44.67	14.16
8.00	9.00	1.00	SED	0.92	0.06	21.20	41.33	11.46
9.00	10.00	1.00	SED	0.83	0.06	23.04	44.65	11.67
10.00	11.00	1.00	SED	0.92	0.06	24.66	43.02	10.59
11.00	12.00	1.00	SED	0.82	0.06	21.67	43.82	11.41
12.00	13.00	1.00	SED	0.63	0.04	16.14	51.40	12.97
13.00	14.00	1.00	SED	0.81	0.07	23.95	41.07	9.69
14.00	15.00	1.00	SED	0.83	0.07	24.28	38.59	9.38
15.00	16.00	0.60	SED	0.38	0.02	11.12	35.72	15.96
16.00	17.00	0.40	LIM	0.87	0.06	33.18	22.11	2.67
17.00	18.00	1.00	LIM	0.85	0.06	33.87	20.71	2.68
18.00	19.00	1.00	LIM	0.83	0.07	32.23	21.85	2.79
19.00	20.00	1.00	LIM	0.89	0.05	31.36	25.58	2.97
20.00	21.00	1.00	LIM	0.94	0.06	36.27	18.59	2.09
21.00	22.00	1.00	LIM	1.01	0.07	37.95	15.03	1.65
22.00	23.00	1.00	LIM	1.04	0.07	35.78	17.56	1.52
23.00	24.00	1.00	LIM	1.16	0.08	37.36	16.51	1.83
24.00	25.00	1.00	LIM	1.37	0.09	39.16	14.54	1.22
25.00	26.00	1.00	LIM	1.23	0.08	38.01	16.16	1.11
26.00	27.00	1.00	LIM	1.27	0.08	41.26	13.32	1.93
27.00	28.00	1.00	LIM	0.99	0.06	31.44	22.55	1.74
28.00	29.00	1.00	LIM	1.47	0.09	41.96	14.53	4.84
29.00	30.00	1.00	LIM	1.29	0.09	43.38	9.63	1.86
30.00	31.00	1.00	LIM	1.17	0.08	41.09	10.75	1.20
31.00	32.00	1.00	LIM	1.20	0.08	40.66	12.00	1.64
32.00	33.00	1.00	LIM	1.16	0.07	39.67	12.99	1.41
33.00	34.00	1.00	LIM	1.26	0.08	41.69	12.25	2.05
34.00	35.00	1.00	LIM	1.29	0.08	39.81	13.04	2.47
35.00	36.00	1.00	LIM	1.33	0.07	33.32	18.37	2.96
36.00	37.00	1.00	LIM	1.33	0.06	31.73	18.93	3.08
37.00	38.00	1.00	LIM	1.32	0.06	33.89	17.85	3.56
38.00	39.00	1.00	LIM	1.49	0.06	31.40	20.70	4.31
39.00	40.00	1.00	SAP	1.75	0.06	33.03	18.78	2.09
40.00	41.00	1.00	SAP	1.87	0.06	30.63	21.66	2.96
41.00	42.00	1.00	SAP	1.92	0.06	29.61	25.21	2.60
42.00	43.00	1.00	SAP	2.01	0.05	27.73	26.94	3.31
43.00	44.00	1.00	SAP	1.78	0.04	24.77	30.43	5.15
44.00	45.00	1.00	SAP	1.78	0.05	25.35	30.51	3.80
45.00	46.00	1.00	SAP	1.54	0.04	25.00	31.93	4.71
46.00	47.00	1.00	SAP	1.67	0.06	29.05	27.07	3.66
47.00	48.00	1.00	SAP	1.64	0.05	27.21	27.38	6.01
48.00	49.00	1.00	SAP	1.74	0.04	22.24	33.45	6.50
49.00	50.00	1.00	BRK	0.43	0.01	6.60	35.34	34.19
50.00	51.00	1.00	BRK	1.16	0.04	15.90	40.09	17.21
51.00	52.00	1.00	BRK	0.37	0.01	6.82	35.29	32.69

Ultra GPR for Nickel laterite exploration

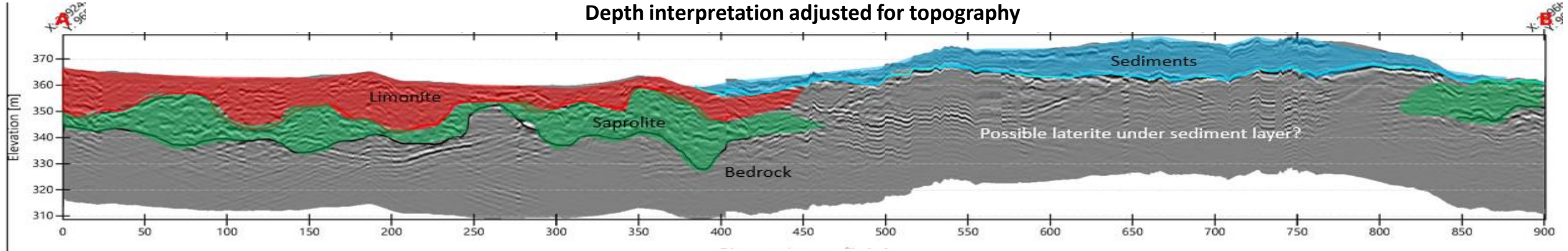
Examples - UltraGPR Survey Result

groundradar

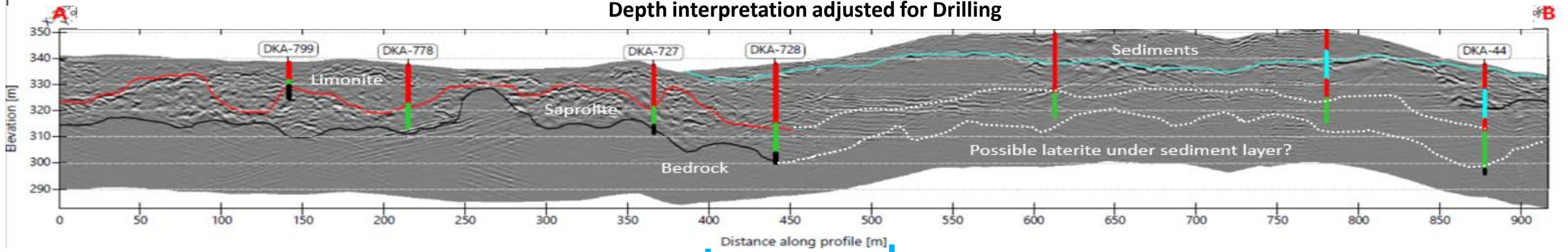
Primary 2D depth interpretation



Depth interpretation adjusted for topography

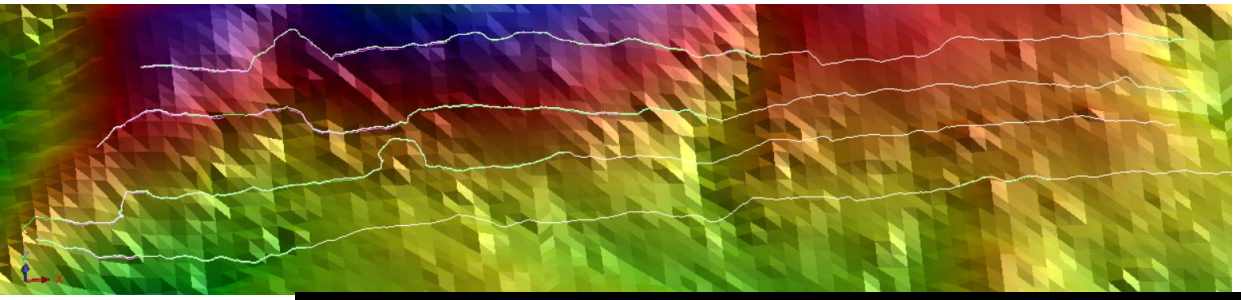


Depth interpretation adjusted for Drilling



Ultra GPR for Nickel laterite exploration

Topography Draping to Lidar

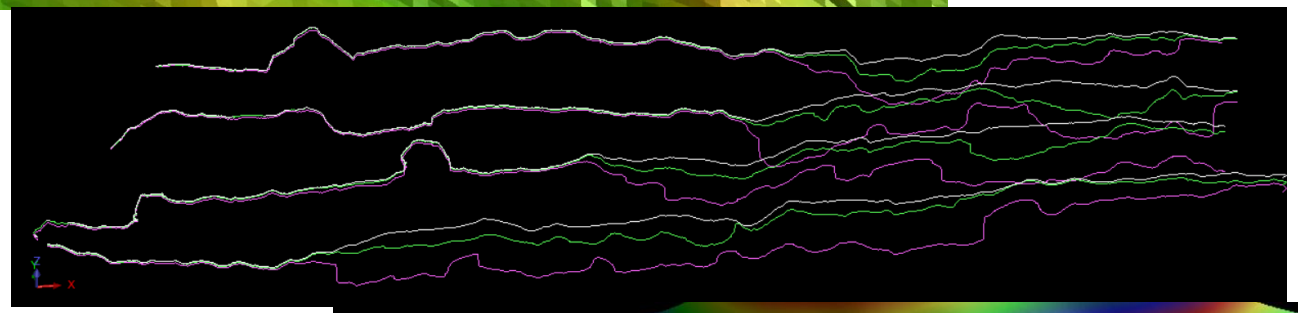


Secondary Processing – 3D modelling SURPAC

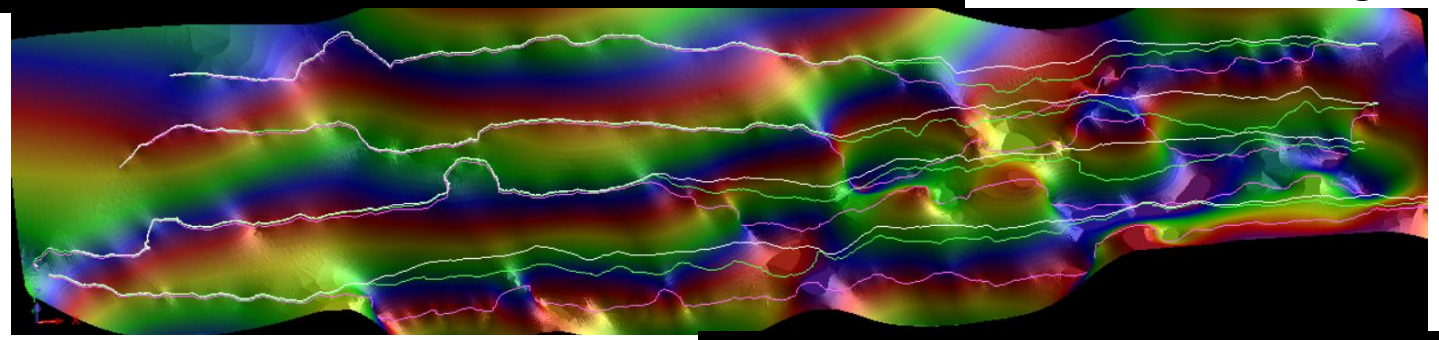
Area (Ha)	Lithology	BM Volume (m3)	Ton (Wet)
1,300	Limonite	70,000,000	125,000,000
	Saprolite	110,000,000	175,000,000
Total Volumes from UltraGPR		**180,000,000**	**300,000,000**

RD Limonite -1.8sg / Saprolite 1.6sg

3D wireframes

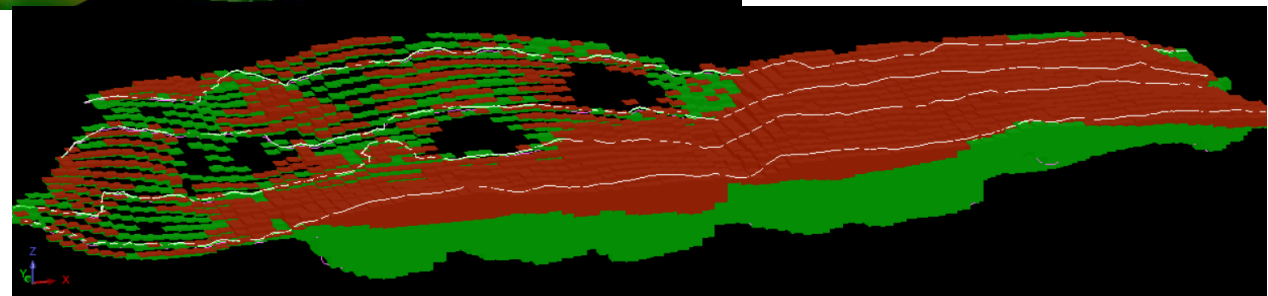


Surface contouring/Gridding



Additional step include adding the drilling assay results to improve the correlation of the GPR results and increase confidence in the models

Block Model / Volumes



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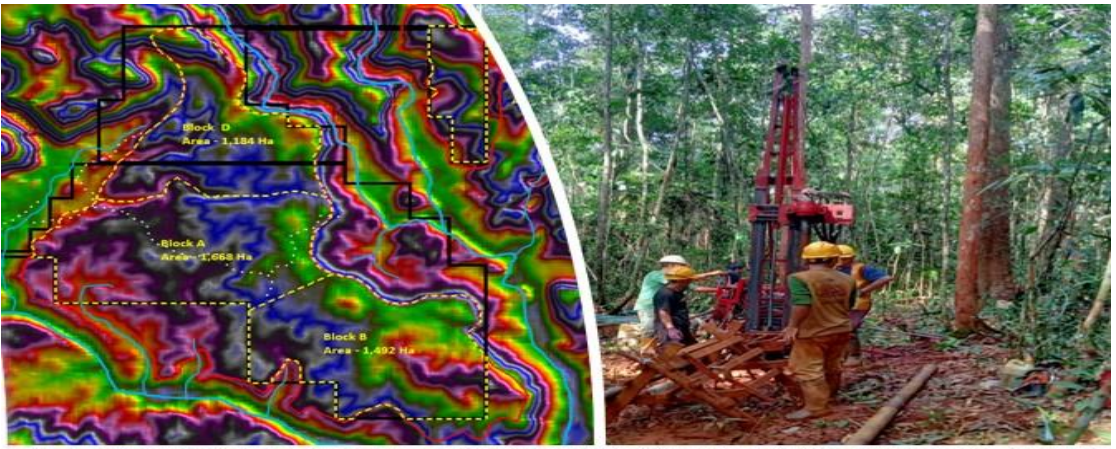
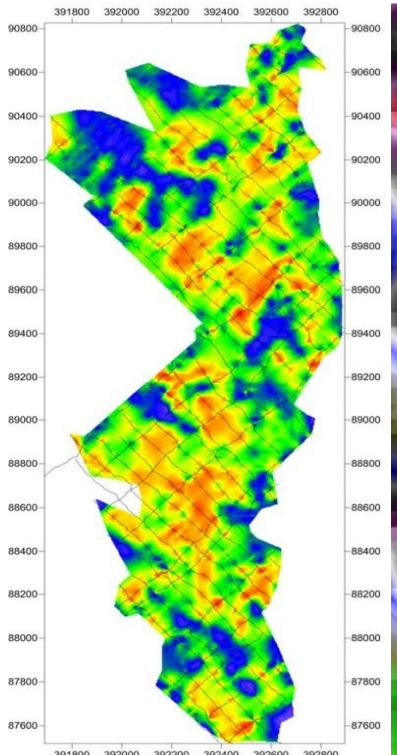
Ultra GPR for Nickel laterite exploration

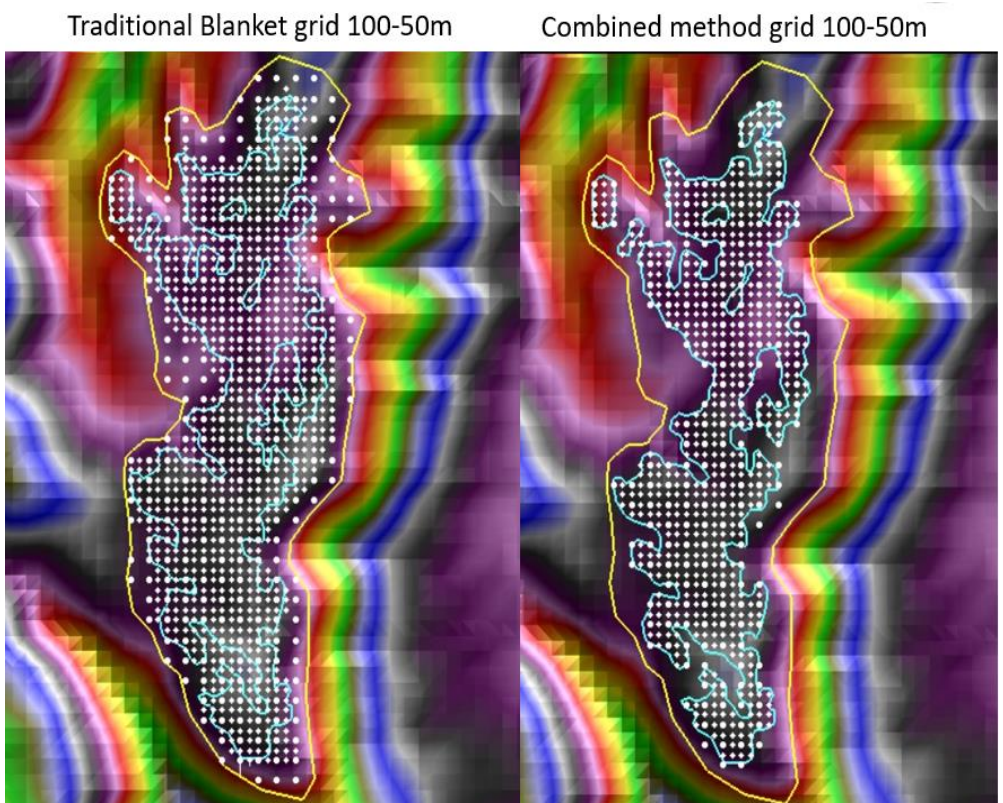
Core drilling, Sampling & Geology



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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Ultra GPR for Nickel laterite exploration

Examples - UltraGPR Survey Result

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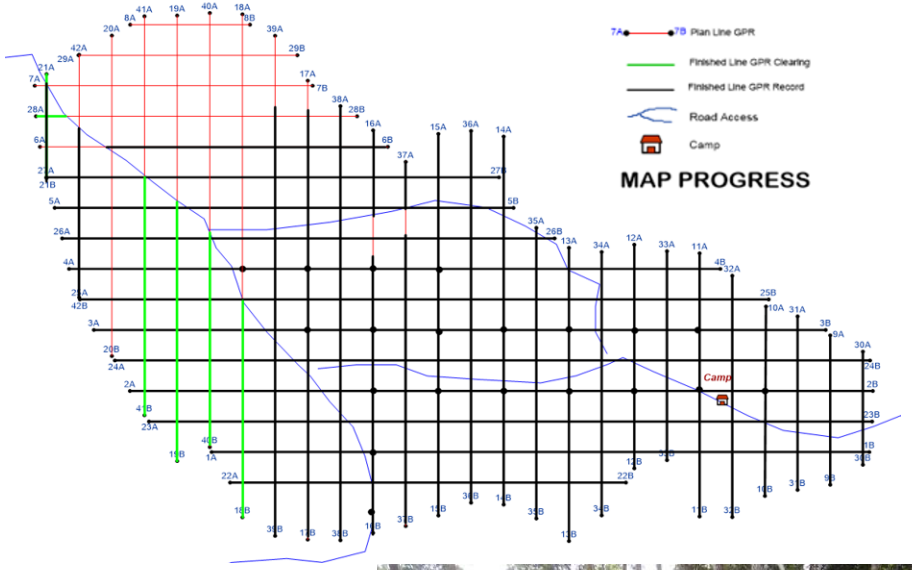
Examples - UltraGPR Survey Result

Ultra GPR for Nickel laterite exploration

UltraGPR is mostly used for exploration, usually on a 100m 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 – GPR Acquisition

- 1 GPR 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 laterite exploration

Other FAQ's

- In good conditions with lines already prepared UltraGPR acquisition team can achieve 1.5 - 3km/day on average
- Monthly targets are between 40-50km and can cover large areas up to 500-1,000ha/ 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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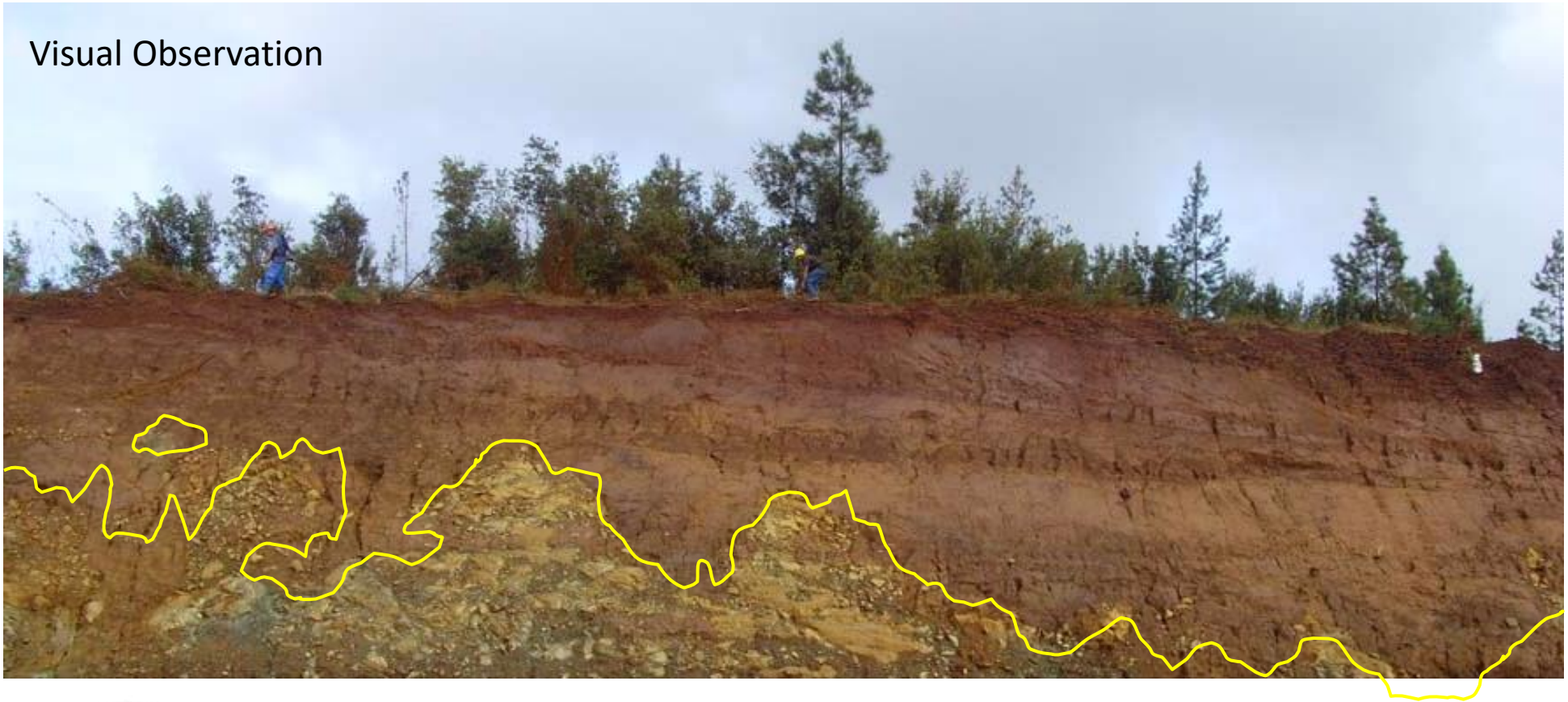
Ultra GPR for Nickel laterite exploration

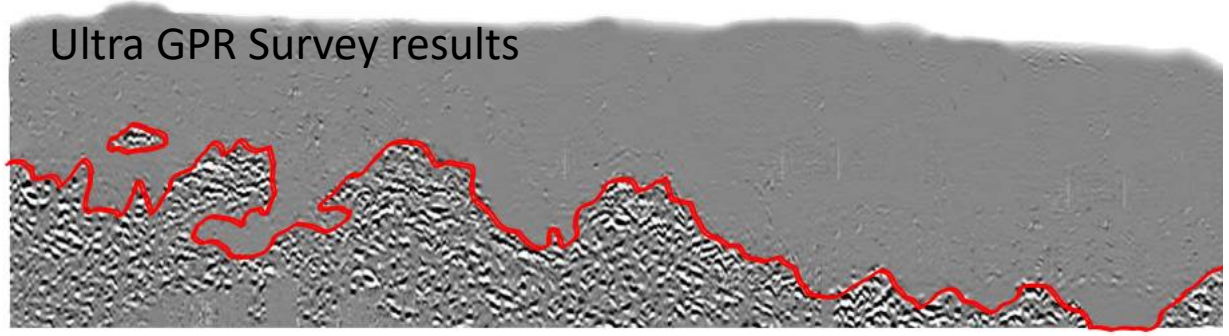
Examples of Other Geophysical Methods used in exploration

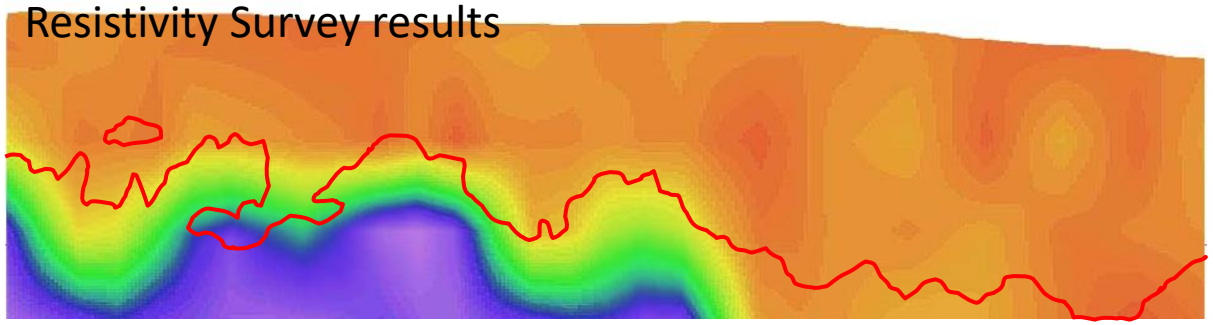
Geophysical Survey Method	Average Price Ranges, without local labor costs	Daily survey capabilities	Additional labor requiremnts	Data Processing time	Notes
RESISTIVITY (Equipment Weight 50-80 kg)	Rp 10-20 Million /km	500-1000 m/ day	8 -10 local labor helpers to assist	1 -2 months	Medium cost option with Good resolution to identify rocky saprolite and bedrock contact,
SEISMIC REFRACTION (Equipment Weight 30-60 kg)	Rp. 30 Million /km	300-400 m/day,	8 - 10 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 5 -7 kg)	Rp. 8–14 Million /km	1500 – 3000m / day, with line clearing	2 – 3 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

Ultra GPR for Nickel laterite exploration



Comparison interpretation of results between Ultra GPR and Resistivity survey





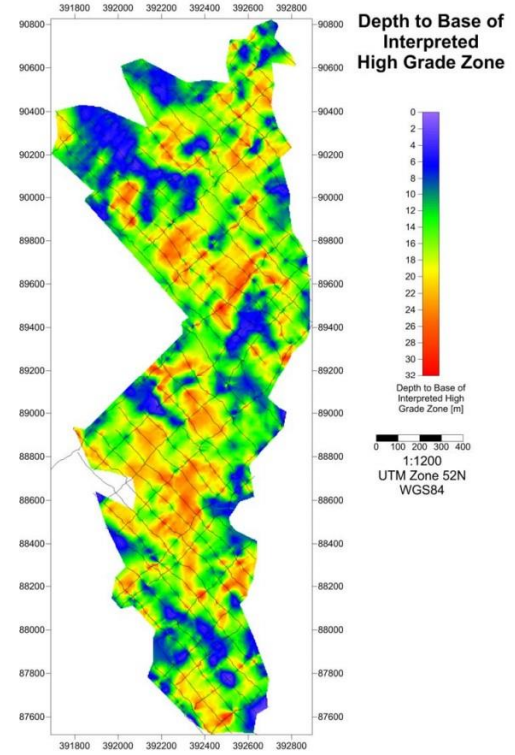
Ultra GPR for Nickel laterite exploration

UltraGPR by GroundRadar Survey equipment specifications

More detailed technology information can be found at;

www.groundradar.com

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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Ultra GPR for Nickel laterite exploration

Previous clients for UltraGPR survey, Nickel laterites (Groundradar)

Project	Client	Country
Jacare	AngloAmerican	Brazil
Barro Alto	AngloAmerican	Brazil
Onca-Puma	Canico	Brazil
Cinzeiro	Falconbridge	Brazil
Ipora	INV/TeckCominco	Brazil
Sante Fe	INV/TeckCominco	Brazil
Mirabela	Mirabela	Brazil
Lome	NiCo Exploration	Cameroon
Cerro Matoso	BHPBilliton	Colombia
San Felipe	BHPBilliton	Cuba
Camarioca	Moa Nickel SA	Cuba
Pronostico	Omicron Resources	Cuba
Cercadillo	GlobeStar Mining	Dominican Republic
Fenix	Solway Group	Guatemala
Sechol	Chesbar Resources	Guatemala
El Segundo	Jaguar Nickel	Guatemala

Ultra GPR for Nickel laterite exploration

Previous clients for UltraGPR survey, Nickel laterites (Groundradar)

Project	Client	Country
Wolo-Ponre	Ceria Nugraha Indotama	Indonesia
Sulawesi Cahaya Minerals	Merdeka Resources	Indonesia
Sarana Mineralindo Perkasa	Mercuria energy services	Indonesia
Hengjaya mineralindo (bete bete)	Nickel Industries Ltd	Indonesia
IUP 704	PT Adi Kartiko Peratama	Indonesia
Mulia	PT Bartra Putra	Indonesia
Kendari	PT Jagat Rayatama	Indonesia
Waturapa	PT PIP	Indonesia
Malili	PT Citra Lampia Mandiri	Indonesia
Wowoni, Maba East	Solway Group	Indonesia
Gag Island	BHB Billiton	Indonesia
Kolonodale, Long Ikis	PT Bildan	Indonesia
Siduarsi	PT Iriana Mutiara Mining	Indonesia
Soroako	PT Vale Indonesia TBk.	Indonesia
Santa Monica, Jira River, pinto	Weda Bay Minerals	Indonesia
Agatis, Bugis, Cendana, Damar	Halmahera sukses minerals	Indonesia
Buli	PT Aneka Tambang TBk	Indonesia
Ferronikeli	Ferronikeli Developments	Kosovo

Ultra GPR for Nickel laterite exploration

Previous clients for UltraGPR survey, Nickel laterites (Groundradar)

Project	Client	Country
Ambatovy	Sherritt	Madagascar
Valzoro	Diamond Fields Resources	Madagascar
Koniambo	Falconbridge	New Caledonia
Goro	INCO	New Caledonia
Ramu	Highlands Pacific	Papua New Guinea
Mambare	Niugini Nickel Plc	Papua New Guinea
Wowo Gap	RMI	Papua New Guinea
Bogutu	Pac-Rim Resources	Solomon Islands
Dutwa	African Eagle Resources	Tanzania
Hallmark	BHPBilliton	the Philippines
Mindoro	Crew Resources	the Philippines
Celestial	MBMI	the Philippines
Berong	Toledo Mining	the Philippines
Ipilan	Toledo Mining	the Philippines
Eskisehir	Meta Nickel	Turkey
Gordes	Meta Nickel	Turkey
Loma de Niquel	AngloAmerican	Venezuela

PT. GEO SEARCH

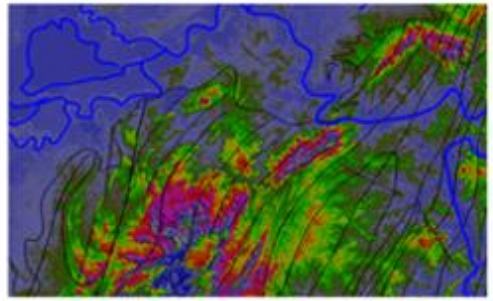
Fresh Ideas—Systematic Investigations—Optimum Results

PT Geo Search is an independent association of Australasian professional consultants providing technical services to the Asian exploration & mining industry.

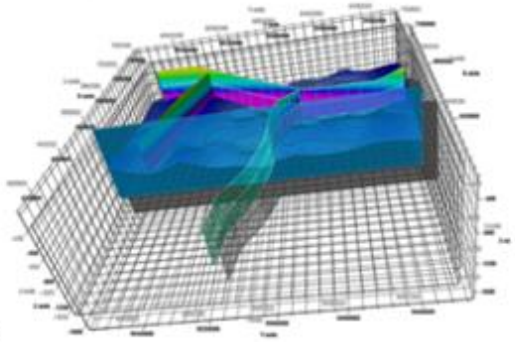
Capability Statement

Specialist services Geo Search provide:

- same day license plotting and preliminary project assessment for investors FREE OF CHARGE
- Exploration target generation and Resource evaluation
- Specialist in GIS methodology
- Application of in-house geophysical survey techniques including Seismic, Proton Magnetometer, resistivity/IP, down hole logging & Ground Penetrating Radar (GPR)
- Exploration planning and Management
- Database management
- Technical & Project Due Diligence
- Project development and management
- Resource modelling and Estimation
- General Geology & Mine planning advice for investors



GIS techniques to identify regional targets previously over looked deposits



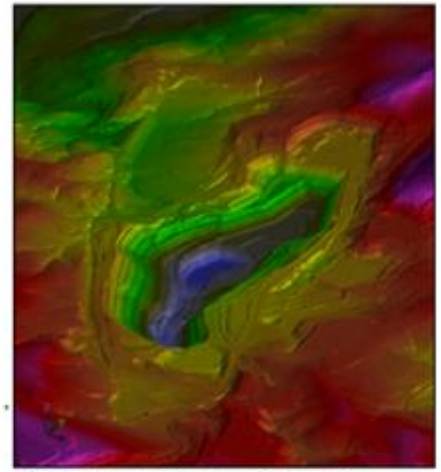
Geo Search in house geophysics capability can help identify less obvious exploration targets & provide extra confidence in existing resources development

Great mining projects always owe their success to good geology and good planning.

In addition to our well recognized expertise in the Indonesian Thermal Coal & Nickel laterite sectors, we also have significant local experience in other commodities including:

- Copper / Gold & other precious minerals
- Lead / Zinc & other base minerals
- Tungsten
- Molybdenum
- Iron ore & Mineral sands
- Industrial and Agri-minerals

Geo Search can help you at all stages of your project development from greenfield exploration to mining feasibility studies



Geo Search uses cutting edge software and techniques for geological resource modelling to increase efficiency and optimize mine returns

We perform our work according to international best practice. Including reporting to the following codes, such as JORC (2012) and KCMI (2011):

At Geo Search we use our unique blend of tried & tested systematic exploration techniques as well as cutting edge software, GIS & Geophysical technology to ensure our clients technical needs are at the forefront of the industry standards making new significant discoveries and building world class projects successfully.

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