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INDEPENDENT INVESTMENT RESEARCH

PolarX Limited (ASX: PXX)

Update - November 2018

INDEPENDENT
INVESTMENT RESEARCH

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PolarX Limited (ASX: PXX)

Update - November 2018

Note: This report is based on information provided by the company as at November 21, 2018.

Investment Profile - Post Merger Pro-Forma	
Share Price - 21 November 2018	A$0.07
Issued Capital:	
Ordinary Shares	298.2m
Options (Total)	5.20m
Fully Diluted	303.4m
Market Capitalisation	$20.9m
12 month L/H	A$0.065/$0.195
Cash and Liquid Investments*	A$1.05 m

*Includes ~A$0.305 m cash call prepayment held by Millrock to be applied against subsequent exploration expenditure in Alaska.

Board and Management
Mr Mark Bojanjac: Executive Chairman
Dr Frazer Tabeart: Managing Director
Dr Jason Berton: Executive Director
Mr Bob Boaz: Non-Executive Director
Mr Ian Cunningham: CFO/Company Secretary
Mitchell River Group: Technical Services
Millrock Resources: Exploration & Logistic Services

Major Shareholders	
JP Morgan (UK)	8.7%
Ruffer Gold Fund	7.2%
U.S. Global	5.3%
Top 20	65%
Board/Management/Mitchell River Group	14%

Price Chart

Senior Analyst – Mark Gordon

A VERY PRODUCTIVE YEAR

PolarX Limited ("PolarX" or "the Company") has made significant progress on the Alaska Range Project ("the Project") since our January 2018 initiation, with results of work considerably enhancing the prospectivity of the Stellar area to host major porphyry Cu-Au systems in a tectonic terrane noted for this style of mineralisation.

Much of the work during the 2018 field season involved extensional drilling of the Zackly skarn, following the March 2018 initial Inferred Mineral Resource Estimate ("MRE") of 3.4Mt @ 1.2% Cu, 2.0g/t Au and 14g/t Ag; the drilling has extended the 1,050m strike of the initial MRE by at least 850m, with the Resource open along strike and at depth. This has also increased the global MRE for the Project (including Caribou Dome) to 6.2 Mt @ 2.0% Cu and 2.0g/t Au, for 127,000 tonnes of contained copper and 217,000 oz of Au.

Importantly, the drilling intersected thick, shallowly dipping and shallow mineralisation in a separate skarn zone at the eastern end of Zackly, showing the potential for open pit mining - this included a near to true width intersection of 55m @ 0.6% Cu and 2.8g/t Au from 2.5m, 850m east of the eastern extent of the current Inferred Resource.

The reinterpretation of regional magnetics and the flying of a detailed heliborne magnetics survey has helped to further refine the geology, with this highlighting the presence of the Zackly structural trend (which hosts the skarn mineralisation) which connects two interpreted porphyry intrusive centres, Mars and Zackly SE - both of these undrilled prospects display geological, geophysical and geochemical signatures indicative of porphyry systems. This also highlights the presence of a number of major structures, which can be interpreted as controls on the location of porphyry intrusives as well as mineralising fluid pathways.

The geological reinterpretation also confirms that the Moonwalk intrusion related gold ("IRG") prospect is within the Tintina Gold Belt, immediately to the north of the Alaskan porphyry belt over which the majority of the claims are located (and which host the major Alaskan porphyries (including Pebble) - further work, with a view to drill targeting, has also been completed at Moonwalk.

KEY POINTS

Porphyry potential enhanced: The results of work to date have further enhanced the potential of the Project to host porphyry copper-gold mineralisation, which will be amongst the next drill targets for the Company - these provide considerable upside for the Project, with the potential for these styles of deposit to be very large, as exemplified by the Pebble deposit, also in Alaska, which, at a cut off grade of 0.3% Cu has close to 11Bt of MI&I Resources.

Upside and open pit potential at Zackly: The 2018 drilling has added significant size to the Zackly Cu-Au skarn mineralisation, and also highlights the potential for appreciable open cut mineralisation.

Other targets: The work over other targets, including Moonwalk has confirmed these as high quality prospects.

Attractive mining destination: Alaska is an attractive and well regarded mining destination, ranking 10th globally and 3rd in the United States in the 2017 Fraser Institute survey – the state is home to a number of metal mines, as well as coal and a large oil and gas industry, with the attractiveness of Alaska being recently highlighted by the purchase of the high grade (14.7g/t Au), 4.15Moz Pogo gold mine by ASX-listed Northern Star Minerals (ASX: NST).

Close to Infrastructure: The Project is situated close to transport infrastructure, allowing for ready vehicular access, negating the requirement for helicopter supported exploration.

Strong management and technical team: The Company has management, technical personnel and partners with extensive experience in the junior resources sector (and in the case of Millrock Resources, extensive Alaskan experience) and a proven history of technical success and delivering value to shareholders; in addition key personnel and related partners hold ~14% of the Company, thus aligning their interests with those of other shareholders.

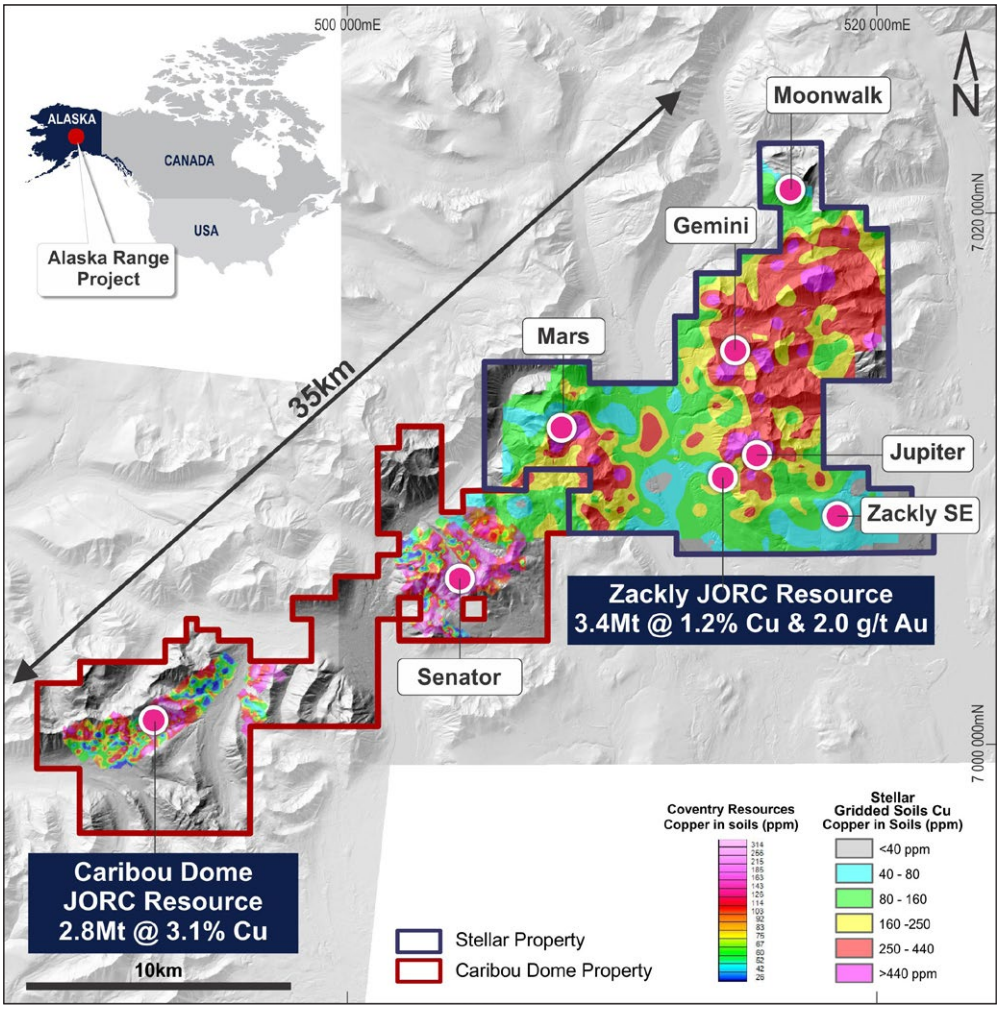
Active exploration programmes and news flow: Given the results of the 2018 work programme, we expect another concerted effort in 2019 (including expected drilling at Zackly, Zackly NE and Mars), with all indications that this will again bring very positive news; in addition nearer term news flow should include further drilling assays from Zackly and results from the Moonwalk geochemical sampling programme, as well as the Zackly MRE update in early 2019.

ACTIVITIES UPDATE

OVERVIEW

- PolarX's activities are focussed on the 242.65 km^2 Alaska Range Project, which comprises two highly prospective contiguous projects, namely Stellar and Caribou Dome, located in the Central Alaskan Ranges (Figures 1 and 2).
- Activities in 2018 have been concentrated on the Stellar area of the Project, with work completed including:
  - Addition of 34 new claims, taking the Alaska Range Project area from 203 km^2 to 242.65 km^2; the new claims cover extensions of the copper-in-soil anomalies at the Senator prospect, and extend the Zackly-Mars Cu-Au porphyry corridor.
  - Initial MRE for Zackly,
  - Reinterpretation of the regional 200m and 400m spaced magnetic data (Figure 2),
  - Detailed, 50 m line spaced airborne magnetics programme, centred over the Stellar claims (Figure 2),
  - Zackly skarn extensional and infill diamond drilling - 18 holes for 3,754.4m,
  - Detailed geological mapping, rock chip and soil sampling at the Mars porphyry Cu-Au prospect; and,
  - Detailed rock-chip sampling at the Moonwalk IRG prospect.
- This work has significantly advanced the Project, and set the scene for an exciting 2019 field season.
- The Company raised a total of A$6.4 million before costs during the year through two placements - one in the June quarter that raised A$2.517 million at A$0.105/share, and a second in the September quarter that raised A$3.883 million at A$0.11/share.

Figure 1: Project location map



Source: PolarX

INITIAL MRE - ZACKLY SKARN

- The initial Zackly MRE was delivered in March 2018, using the results of the 2017 confirmatory drilling and historic drilling - the MRE is presented in Table 1 and the combined Zackly/Caribou Dome MRE in Table 2.
- The Zackly MRE covers approximately 1,050m of strike of the skarn mineralisation, extending from surface to depths of between 250m and 500m (average 300m), and widths of between 0.6m and 12m, with an average of 3.35m - this is still open along strike and at depth.

Table 1: Zackly MRE

Zackly MRE									
Cut-off grade	Category	Million Tonnes	Cu %	Au g/t	Ag g/t	Contained Cu (t)	Contained Cu (M lb)	Contained Au (oz)	Contained Ag (Moz)
0.5% Cu	Inferred	3.4	1.2	2	14	41,200	90.9	213,000	1.5
0.8% Cu	Inferred	2.4	1.5	2.3	16.3	34,750	76.6	177,000	1.2
1.0% Cu	Inferred	1.9	1.6	2.5	17.4	30,250	66.7	152,000	1.0

Source: PolarX

Table 2: Alaska Range combined MRE, 0.5% Cu cutoff

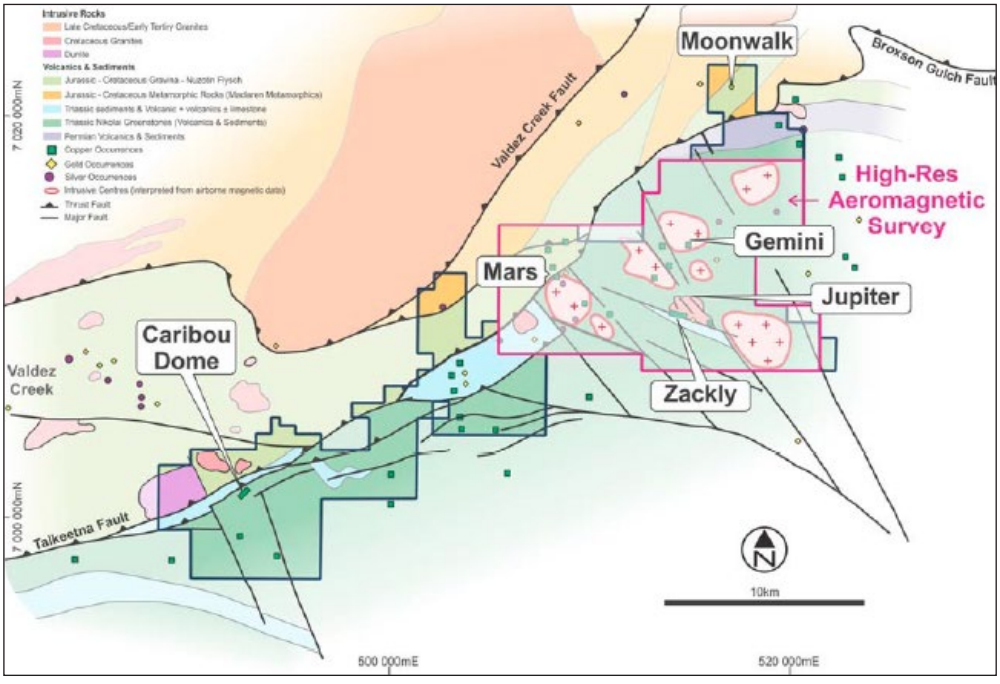
Alaska Range combined MRE, 0.5% Cu cutoff								
	Category	Million Tonnes	Cu %	Au g/t	Contained Cu (t)	Contained Cu (M lb)	Contained Au (oz)	Contained Ag (Moz)
ZACKLY	Inferred	3.4	1.2	2	41,200	90.9	213,000	1.5
CARIBOU DOME	Inferred	1.6	3.2	-	52,300	115.3	-	-
	Indicated	0.6	2.2	-	13,000	28.8	-	-
	Measured	0.6	3.6	-	20,500	45.2	-	-
TOTAL		**6.2**	**2.0**		**127,000**	**280.1**	**213,000**	**1.5**

Source: PolarX

MAGNETICS SURVEYING

- The Company undertook two key activities relating to magnetics surveying in 2018, including the reprocessing and reinterpretation of the regional dataset, and the flying of a detailed, 50m line spaced heliborne survey over the Stellar claims - Figure 2 shows the geological interpretation from the reprocessed regional data set and the area of the detailed survey.

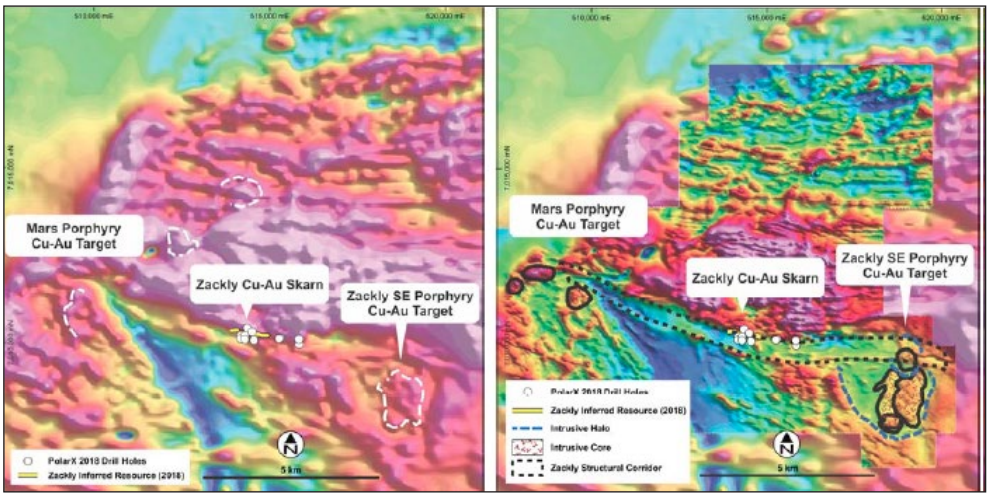
Figure 2: Geological interpretation from regional magnetics reprocessing and detailed magnetics survey area



Source: PolarX

- The geological interpretation highlights the position of most of the project immediately to the south of the thrust separating the Tintina Gold Belt to the north, and the prolific Cretaceous porphyry belt to the south (which includes the super-giant Pebble deposit); it also highlights the position of Moonwalk, an orogenic gold target, in the Tintina Gold Belt.
- The interpretation also shows the association between a number of parallel NW trending structures and the porphyry intrusions at Stellar; these could possibly reflect dilational splays off the southern WNW trending structure, and be the controlling structures for the high level intrusive placement.
- Figure 3 compares the regional and detailed datasets over the Zackly trend, and highlights the additional detail in the recent survey.
- A key outcome of this is the recognition of multiple phase intrusives at both Zackly SE and Mars, features associated with porphyry copper-gold deposits as well as the strong structural control on the Zackly trend between the two.
- This supports the porphyry prospectivity as shown by the geochemical and IP surveying over Mars.

Figure 3: Comparison between regional (left) and high resolution (right) datasets - Zackly trend



Source: PolarX

ZACKLY DRILLING

- The Company completed 18 holes for 3,754.4m at Zackly during the 2018 field season, with collars shown in Figure 4 - this adds to the 14 holes for 1,888.94m drilled in 2017.
- Results of the drilling will be used in an updated MRE, expected in early 2019 - results released to date are provided in Table 3 - some assays are awaited.

Table 3: Zackly 2018 drilling results

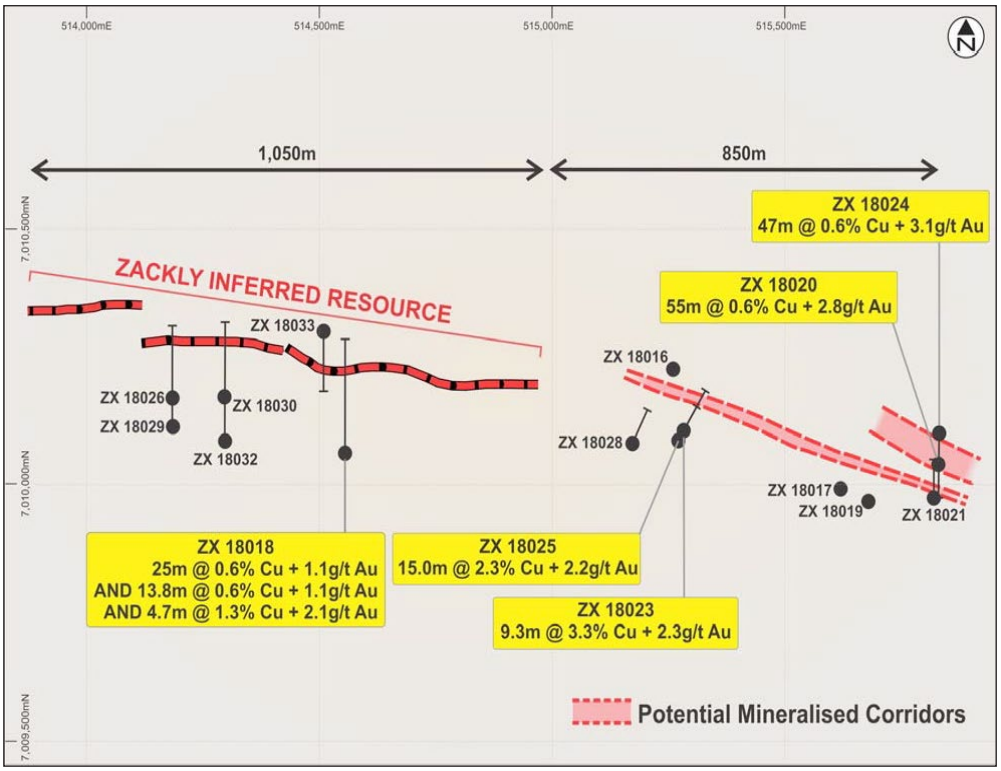
Zackly 2018 drilling results						
Hole_ID	**From (m)**	**To (m)**	**Width (m)**	**Cu %**	**Au g/t**	**Ag g/t**
ZX-18016	No significant intersection					
ZX-18017	No significant intersection					
ZX-18018	261.6	287.1	25.5	0.6	1.1	5.5
including	261.6	266.9	5.3	1.1	1.7	11.3
including	273.5	277.3	3.8	0.8	1.2	6.3
including	285.8	287.2	1.4	3.2	9.3	38.2
and	300.8	314.7	13.9	0.6	1.1	4.7
including	312.0	314.7	2.7	1.3	2.1	10.5
and	326.1	330.8	4.7	1.3	2.1	10.6
including	326.1	328.6	2.5	2.3	3.5	18.5
ZX-18019	No significant intersection					
ZX-18020	2.5	57.1	54.6	0.6	2.8	9.5
including	2.5	14.0	11.5	0.6	5.3	12.0
including	18.3	27.1	8.8	0.5	5.8	5.6
including	32.0	43.3	11.3	0.8	1.8	23.3
including	46.2	57.1	10.9	1.0	1.6	3.9

Zackly 2018 drilling results						
Hole_ID	**From (m)**	**To (m)**	**Width (m)**	**Cu %**	**Au g/t**	**Ag g/t**
ZX-18021	8.2	28.4	20.2	0.3	1.1	5.3
including	8.5	10.9	2.4	1.3	2.3	23.6
including	16.0	18.9	2.9	0.4	3.6	7.1
and	45.1	48.9	3.8	0.2	2.4	3.9
and	57.1	59.2	2.1	0.5	1.0	7.4
and	76.6	79.2	2.6	0.1	0.6	1.6
and	83.7	91.0	7.3	0.3	1.0	1.9
ZX-18023	20.8	30.1	9.3	3.3	2.3	19.7
ZX-18024	36.1	82.8	46.7	0.6	3.1	3.3
ZX-18025	84.8	99.8	15.0	2.3	2.2	11.9

Source: PolarX

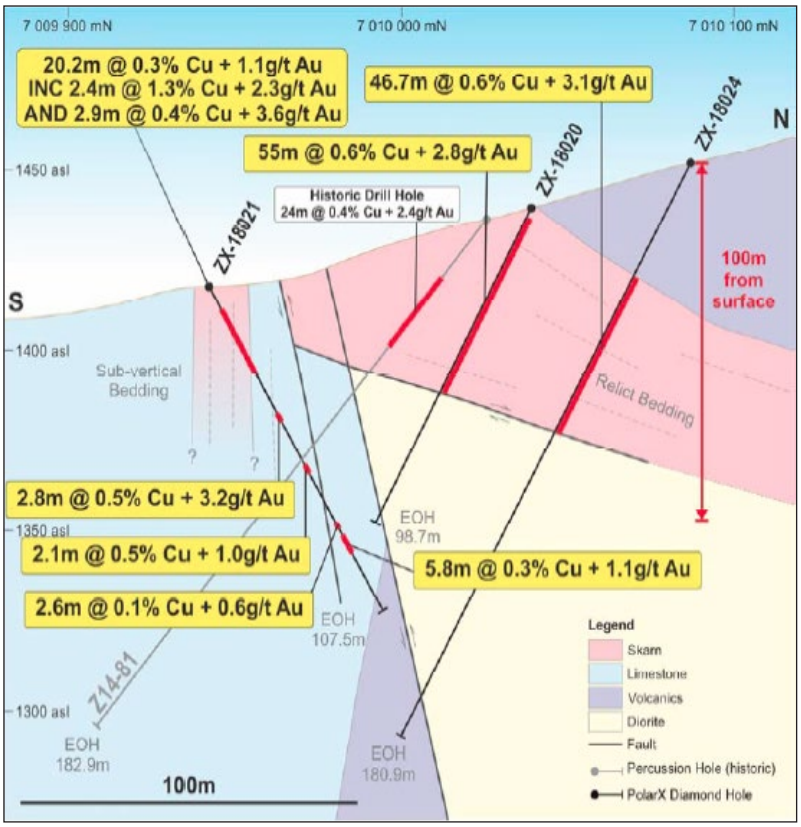
- The drilling has confirmed an extra 850m of strike length at Zackly (which is still open to the west and east), and has also intersected a thick, shallowly zone at the eastern end which is still open along strike and down dip (Figures 4, 5 and 6).
- This thick, shallow mineralisation highlights the potential for open cut mining, and also contains significant oxide mineralisation.
- As is the case for skarns, variable types have been recognised, including magnetite and garnet skarns; in addition visible gold has been noted in places, and quartz-sericite (a typical porphyry vein/alteration assemblage) veining has been recognised, providing an ESE vector to possible porphyry style mineralisation.

Figure 4: PolarX drilling - Zackly - shown significant results



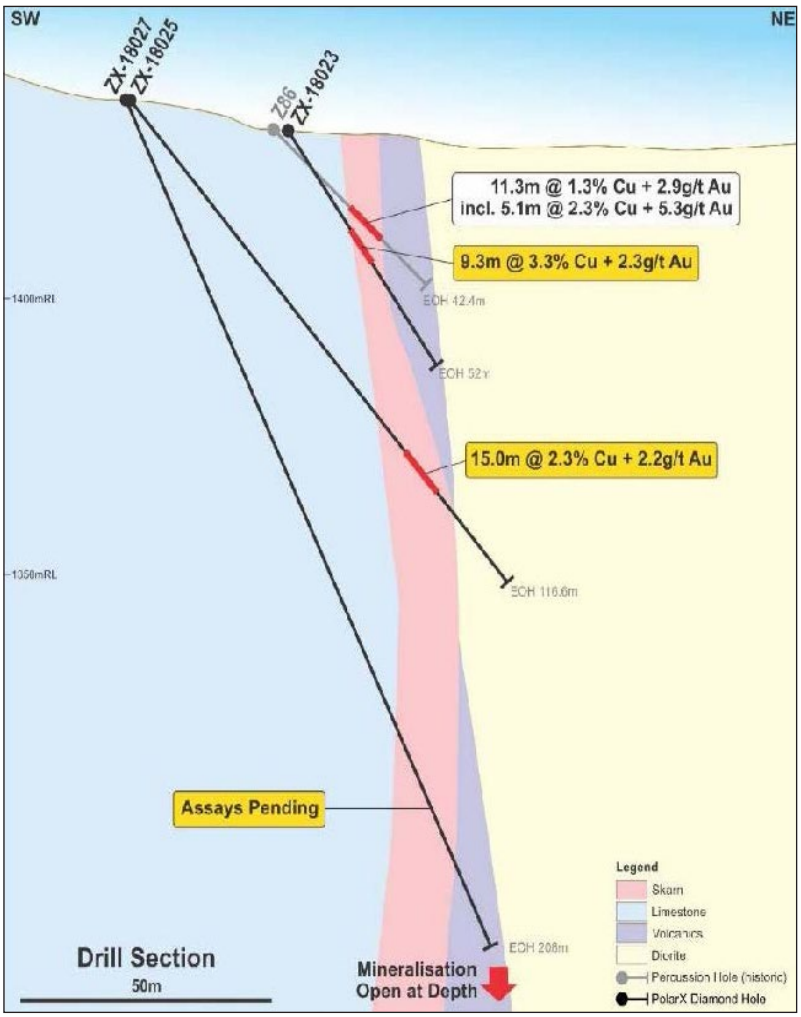
Source: PolarX

Figure 5: Zackly drill section 515,840E, showing flat-lying mineralised skarn



Source: PolarX

Figure 6: Zackly drill section 515,250E, showing vertical skarn and high grade drilling results



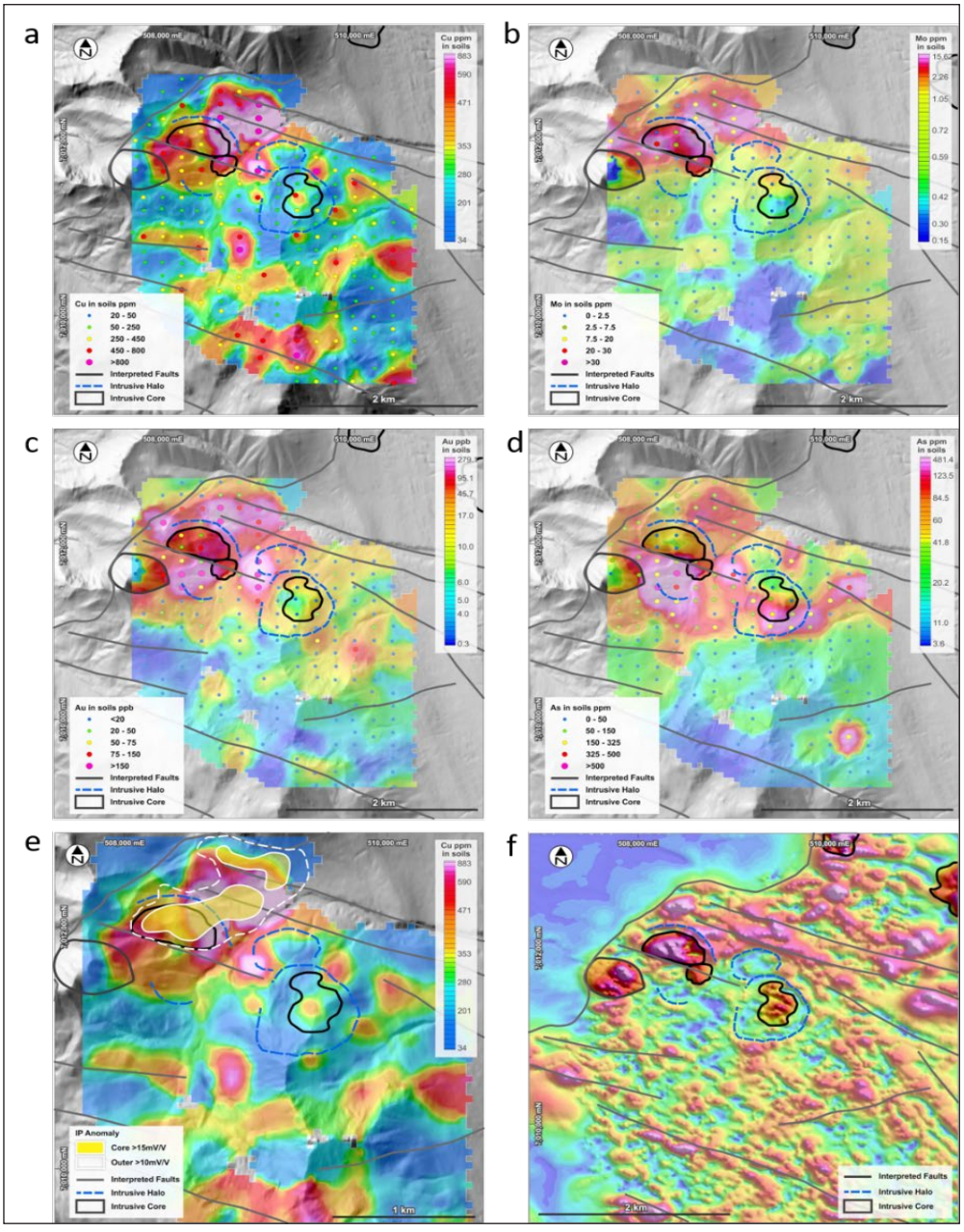
Source: PolarX

OTHER ACTIVITIES

Mars Porphyry Cu-Au Target

- The Company carried out geological mapping, and detailed soil and rock-chip sampling on a 200m x 150m grid at Mars in August, with very positive results recently being released, with these to be used to prioritise 2019 drilling targets over this very promising prospect.
- This, and earlier work, defined coincident geochemical and geophysical signatures typical of porphyry systems - these include a Cu-Au-Mo-As geochemical anomaly, coincident with an IP chargeability anomaly (with a modelled depth of 100m to 150m below surface) and a cluster of magnetic highs (Figure 7).
- In addition to the soil anomalism, (which covers an area of 2km by 1.5km) rock chip sampling returned values of up to over 50% Cu and 6.93g/t Au.

Figure 7: Gridded soil sampling results for the Mars prospect for a. copper, b. molybdenum, c. gold and d. arsenic. Also shown is e. the location of the IP anomaly which corresponds to the peak copper in soils, and f. the interpreted intrusive centres plotted on the analytical signal of the high resolution aeromagnetic data.



Source: PolarX

Moonwalk Au Target

- Activities at Moonwalk included detailed rock-chip geochemical sampling, for which assay results are still awaited.

Environmental Baseline Studies

- Groundwater and surface water baseline studies have continued at both Caribou Dome and Zackly.

PLANNED ACTIVITIES

- Key elements of the May to October 2019 field season will include drilling - although drill planning is yet to be undertaken it is expected that key targets will include Mars, Zackly SE and the Zackly skarn.
- Detailed programme planning will take place during the northern winter, with field activities commencing with camp and access preparation in April.
- Activities will incorporate aspects required for development studies for Zackly and Caribou Dome; this includes environmental monitoring/baseline programmes, which are already underway.
- Ongoing metallurgical test work is planned for the northern winter, as is an updated MRE for Zackly.

PEERS

- PolarX is one of a number of explorers and developers looking at poly-metallic resources, with these shown in Table 4, which also includes producers - this has been updated from the peer comparison table in our initiation report.

Table 4: PolarX peers

Table 6: PolarX peers

Company	Project	EV Undiluted (A$m)	Equity Resource (Kt)	CuEq Grade (%)	Deposit/ Target Style	Project stage	Metals (all resources)
Auralia Metals	Hera, Nymagee	$549.3	2,933	4.37%	Cobar	Hera - Production Nymagee - FS	Cu, Pb, Zn, Ag, Au
Terramin	Angas, Tala Hamza, BiH	$247.0	54,158	2.38%	Various	FS - Hamza C & M - Angas	Zn, Pb, Au
Heron Resources	Woodlawn	$152.1	18,100	3.78%	VMS	Development	Cu, Pb, Zn, Ag, Au
Peel Mining	Mallee Bull	$89.2	3,380	2.70%	Cobar	Drilling, Resource Expansion	Cu, Pb, Zn, Ag, Au
Red River Resources	Thalanga	$68.0	7,075	5.13%	VMS	Production	Cu, Pb, Zn, Ag, Au
Nzuri Copper	Kalongwe	$66.2	11,459	2.73%	Copperbelt	Feasibilty	Cu, Co
Orion Gold	PCM	$50.1	9,350	3.11%	VMS	Pre-Feasibility	Cu, Zn
Venturex Resources	Sulphur Springs	$41.7	25,707	2.99%	VMS	Feasibility	Cu, Pb, Zn, Ag, Au
KBL Mining	Mineral Hill	$28.0*	17,455	2.52%	Epithermal	In Liquidation	Cu, Pb, Zn, Ag, Au
Ironbark	Citronen	$20.6	70,800	2.32%	Sedex	Feasibility	Zn, Cu, Pb
PolarX	Alaska Range	$19.8	5,640	2.79%	Sedex, Skarn, Porphyry	Exploration, Drilling	Cu, Au
Hot Chili	Productora	$19.1	363,600	0.33%	Porphyry	DFS	Cu, Au, Mo
Rex Minerals	Hillside	$16.4	337,800	0.60%	IOCG	Permitting	Cu, Au, Fe
Metalicity	Admiral Bay	$10.3	170,000	2.77%	MVT	Scoping	Zn, Pb, Ag
PNX Metals	Hayes Creek	$8.7	4,076	4.39%	VMS	Feasibility	Cu, Pb, Zn, Ag, Au
White Rock	Mt Carrington Red Mountain	$7.2	16,700	3.66%	MVT	Exploration	Cu, Pb, Zn, Ag, Au
Marindi Metals	Prairie	$6.9	2,980	2.69%	Structurally-hosted	Exploration	Zn, Pb, Ag
Alta Zinc	Gorno	$6.7	3,300	2.68%	MVT	Development Studies	Pb, Zn, Ag
Renegade Exploration (ex Overland)	Yukon	$0.6	12,560	2.49%	Sedex	Feasibility	Zn, Pb

Source: IRESS, Company Reports, IIR analysis, *KBL EV as of last trade, September 2016

- This has been sorted on undiluted enterprise value, highlighting the upside potential of the Alaska Range Project and the Company.
- We have calculated the copper equivalent ("CuEq") grade using current metal prices and exchange rates - this does not take into account expected or actual metallurgical recoveries.
- We would expect uplift in value with increasing resources and exploration/drilling success - the Company has an EV at the lower end of its peers.

RISKS

- **Exploration:** This is a key risk for any explorer, however the positive results of work to date, both historical and by PolarX outside of Zackly and Caribou Dome have partly mitigated this.
- **Resource:** This is a key risk at both Zackly and Caribou Dome, where the Company is looking at a potential operation - resources will need to be able to support, given the location, a relatively expensive operation.
- **Location and climate:** Any potential operation may be comparatively high cost, given the harsh winter climate and location.
- **Funding:** This is a perennial issue for junior explorers; and PolarX will need to now go to the market to fund activities for the 2019 field season.
- **Markets:** Although reasonable at the moment, markets can turn on a dime and funding for juniors can dry up very quickly.

BACKGROUND - ALASKA

General

- Alaska, which is the largest state in the US ranks 48th in terms of population (~750,000) and last in terms of population density.
- The capital city is Juneau, with the largest city being Anchorage, with a population of ~300,000; Fairbanks (with a population of ~100,000) is Alaska's second largest city and 190km as the crow flies north of the Project.
- Alaska has a strong mining background and well-developed mining industry, and in 2016 was ranked 14th globally and 5th in the US in the Fraser Institute survey.
- This is supported by well-developed transport infrastructure including road and rail.
- Given the size of the state and population density there is no state wide power grid, however the populated areas from Fairbanks south to Anchorage are served by the interconnected "railbelt" grid, which services a large part of the Alaskan population.
- Natural gas supplies ~50% of Alaska's electricity generation, hydro ~25% and petroleum liquids and coal the majority of the rest - petroleum liquids generation is prevalent in regional communities which have no grid access.
- The nearest power station to the Alaska Range Project is a 30MW coal fired facility at Healy, some 60km north of Cantwell and located on the "railbelt" grid - this is also on the main George Parks highway and railroad, connecting Seward and Anchorage in the south to Fairbanks in the north.

Mining

- Alaska has a long history of mining, with Russian explorers mining placer gold in the early 1800's, with both placer and hard rock mining continuing and growing after the US purchase of the territory in 1867.
- Large placer discoveries and operations included Nome (discovered in 1899, and with over 5Moz produced) and Fairbanks (discovered in 1902, and with over 6Moz produced).
- Closer to the Project is the Valdez Creek Mine, with alluvial gold first being discovered in 1903 - Valdez Creek was operated by Cambior from 1984 to 1995, producing some 459,162oz of gold at up to 75,000oz annually, making it North America's largest placer operation in 1992.
- Modern hard rock gold operations include Fort Knox (7Moz Au, operated by Kinross) and Pogo (4.15Moz Au, operated by Northern Star Minerals) - these large mines are both within 200km of Alaska Range.
- Pogo was acquired by Northern Star from Sumitomo in August 2018 for US$260 million, with this soon followed by a 24% upgrade in JORC 2012-compliant Mineral Resources.
- Other major discoveries and operations include Teck's Red Dog zinc deposit, one of the largest and highest grade zinc mines in the world and located above the Arctic Circle in NW Alaska, and the Pebble Cu-Au-Mo porphyry deposit, located 320km SW of Anchorage, which is currently being permitted.
- Pebble, which is owned by Northern Dynasty Minerals, contains some 107Moz Au, 81Blbs Cu, 5.6Blbs Mo and 514Moz of Ag in a resource of 10Bt at a 0.3% CuEq cut-off.
- Another significant project is the Donlin Gold Project, 50:50 owned by Novagold Resources and Barrick Gold Corporation - with resources of over 39Moz and plans to produce over 1.1Mozpa over a 27 year mine life, this is one of the largest advanced gold projects globally, and was recently fully permitted.
- Alaska has a well-developed coal industry, with coal first being mined in the state in 1855, and has a large oil producing industry, being one of the top crude producing states in the US.

Mining Tenements

- Alaska's mining and exploration permitting regime is transparent, however rigorous - permitting and approval of work programmes can involve up to twelve federal and state agencies, depending upon the complexity of the activities, however in the case of PolarX requires approvals from one state agency only.
- Claims are based on 160 acre (and sometimes 40 acre) parcels for hard rock "lode" mineralisation, and 20 acre placer claims.

- Claims are unpatented, meaning that ownership still resides with the federal or state governments (all of the Project claims are with the state authorities, and not the federal Bureau of Land Management "BLM", thus making permitting of any operation potentially simpler than otherwise).
- As long as the annual rental and expenditure requirements are kept up claims can be held in perpetuity - rentals range from US$140 per 160 acre claim for years 1 to 5, US$280 for years 6 to 10, and US$680 thereafter.
- The minimum expenditure (referred to as "annual labour" is US$100/claim.
- As for most jurisdictions globally, approval of mining operations can include a number of federal and state agencies, an environmental impact assessment ("EIA") and stakeholder engagement; in the case of PolarX, given that the Project is on state claims, only state approvals may be necessary - the only federal input would be from the Army Corps of Engineers should the Project impact wetlands.

BACKGROUND - DEPOSIT STYLES - A BRIEF OVERVIEW

- The styles of mineralisation being explored for by PolarX are well understood, and are widespread globally, in addition they are major sources of the sought for metals.

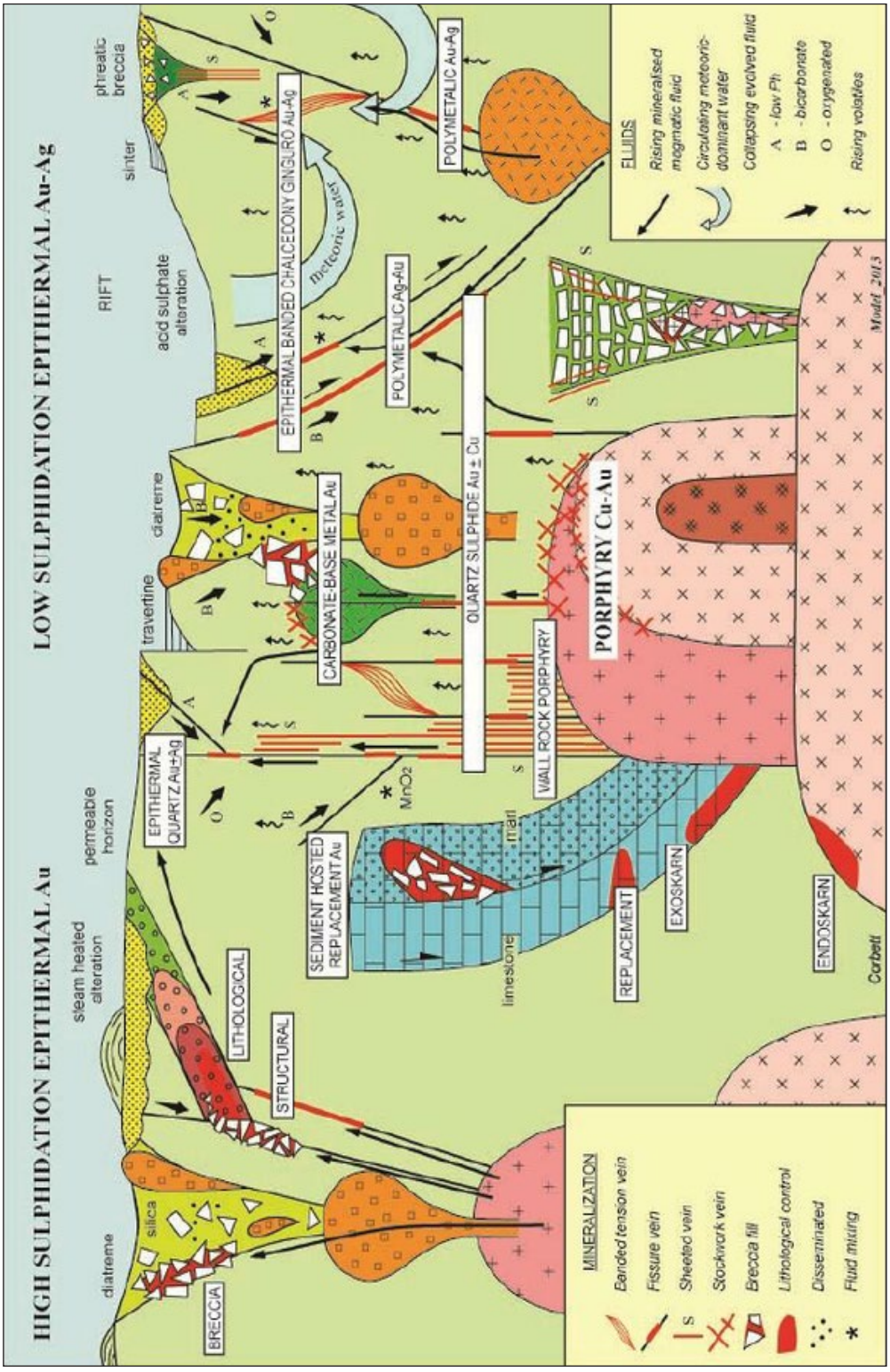
Porphyry and Porphyry-Related Cu-Au-Mo

Geology

- Porphyry copper deposits are the main source of copper globally, and are found in numerous regions, including North, Central and South America, SE Asia and Oceania and Mongolia amongst others.
- They form at convergent plate margins - these include island arc settings (e.g. the Philippines, Indonesia) and continental margins (e.g. the current South American western continental margin and the historical North American plate margin in Alaska, Figure 4).
- Copper production from the world's largest producer, Chile, is largely from porphyry copper deposits, as is that from Peru and the US, both major global copper producers.
- Molybdenum and gold are major by-products, again with Chile, the US and Peru being major producers.
- Although the primary ore is generally low grade, with a mean copper grade of ~0.5%, and gold grades ranging from 0.05g/t to ~1g/t, this is more than made up by size, with many containing 100's of millions to billions of tonnes of mineralisation.
- The key copper minerals are chalcopyrite and bornite, with mineralisation generally being disseminated and in stockwork vein zones - in the continental margin porphyries (such as those in South America) mineralisation commonly forms a shell to a barren core or a cupola over the top of the high-level, sub-volcanic porphyry intrusions.
- Notable examples include Pebble (Alaska, 10Bt), Chuquicamata (Chile) and Grasberg (Irian Jaya).
- Magmatic arc porphyry deposits are related to a number of other mineralisation styles, including gold-copper skarns, epithermal gold and mesothermal base metal carbonate vein gold - the relationship between these mineralisation styles is shown conceptually in Figure 8.
- Skarns, with an example being Zackly, are formed by the alteration of reactive rocks, such as limestone and marl with metal and volatile rich fluids emanating from an intrusive (Figure 16) - common metals include copper, gold, tungsten tin, lead, zinc and iron, with the metal types dependent on those enriched in the source intrusive.
- Skarns commonly exhibit metal zonation and numerous mineralising events - these include prograde and retrograde skarns, with the former due to alteration by the original hot fluids, and the latter due to alteration by cooling fluids during the waning of the hydrothermal system.
- As discussed earlier, the Zackly skarn is interpreted as being at least partly related to a buried porphyry intrusive, with the possibility that this is overprinting an earlier skarn related to the older, outcropping diorite.
- Major global skarn deposits include Ertsberg in Irian Jaya, paragenetically related to the nearby Grasberg porphyry copper deposit, and Ok Tedi, again with skarn mineralisation related to the adjacent porphyry mineralisation - skarn also forms within the porphyritic intrusives (endoskarn).

- These major deposits show a clear relationship between skarns and porphyries - another example includes the Cadia complex in New South Wales, Australia.

Figure 8: Conceptual model - magmatic arc related mineralisation styles



Source: Corbett and Leach, various publications

Exploration

- Porphyry copper deposits have distinctive geochemical and geophysical signatures, which are exhibited by the targets with the Alaska Range Project.
- Zoned geochemical signatures include a core of copper +- gold+- molybdenum, with this grading out to possibly lead or zinc on the peripheries.
- Other pathfinder elements commonly include tin, bismuth arsenic and antimony, with these also showing zonation.

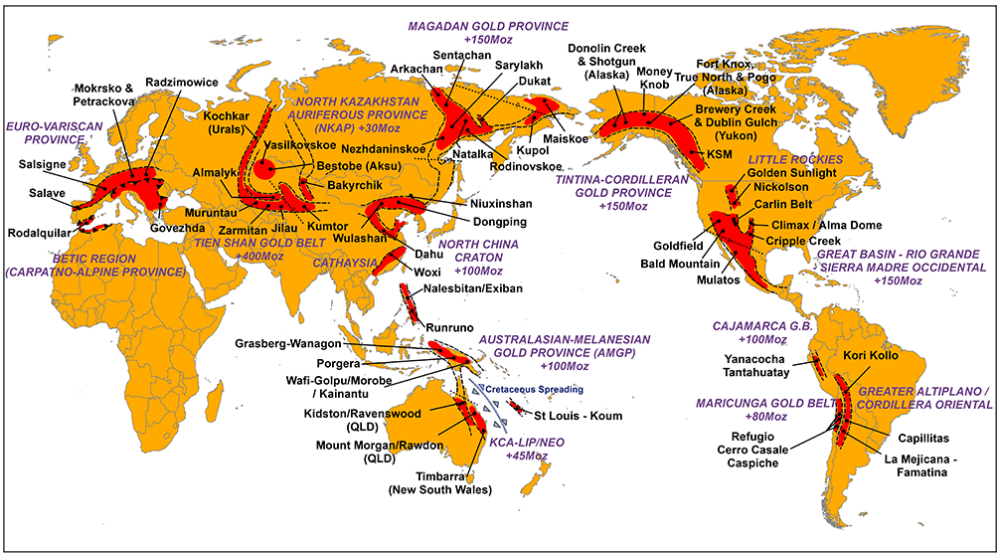
- The two major geophysical tools are magnetics and IP (chargeability) - they are often (but not always) characterized by a bulls eye magnetic anomaly, due to the presence of a core of magnetite-rich potassic alteration, surrounded by an annular low, due to the magnetite destructive propylitic and phyllic zones - this will particularly show up where the porphyry has intruded into magnetic rocks, such as basalts and andesites.
- One of the features of particularly the phyllic alteration zone is large quantities disseminated pyrite, which provides a perfect target for IP chargeability surveying.
- Geologically, porphyries are associated with distinctive alteration styles in the wallrocks, which can be recognised in outcrop.
- In skarns metal associations include proximal base metal, grading through precious metal to distal Pb-Zn-Ag veining - the metals present will depend upon the skarn style.
- Typical geophysical tools include magnetics (skarns, due to the presence of magnetite, can be highly magnetic) and EM, due to the common presence of massive sulphides.

Intrusion Related Gold Systems

Geology

- IRGS deposits span a gamut of mineralisation styles, however are all associated with post orogenic intrusives, largely situated along the continental side of a convergent plate margin, as is seen in the Tintina Belt in Alaska and British Columbia (Figures 9 and 10).
- The mineralisation style was first postulated in 1999, with steady advances in the understanding subsequent to this.

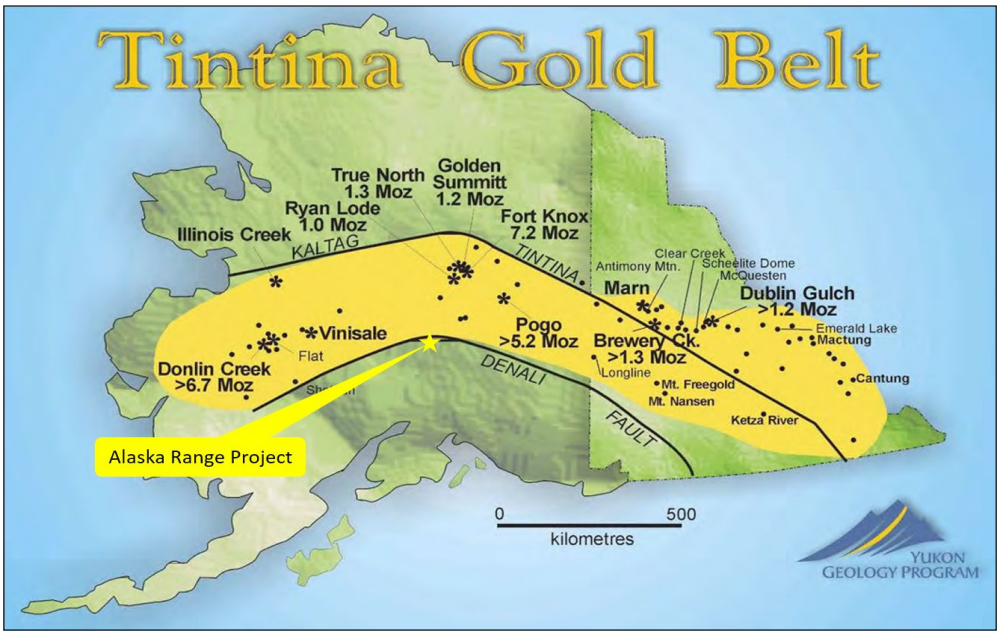
Figure 9: Global distribution of IRGS belts



Source: Adapted from Lang and Baker (2001)

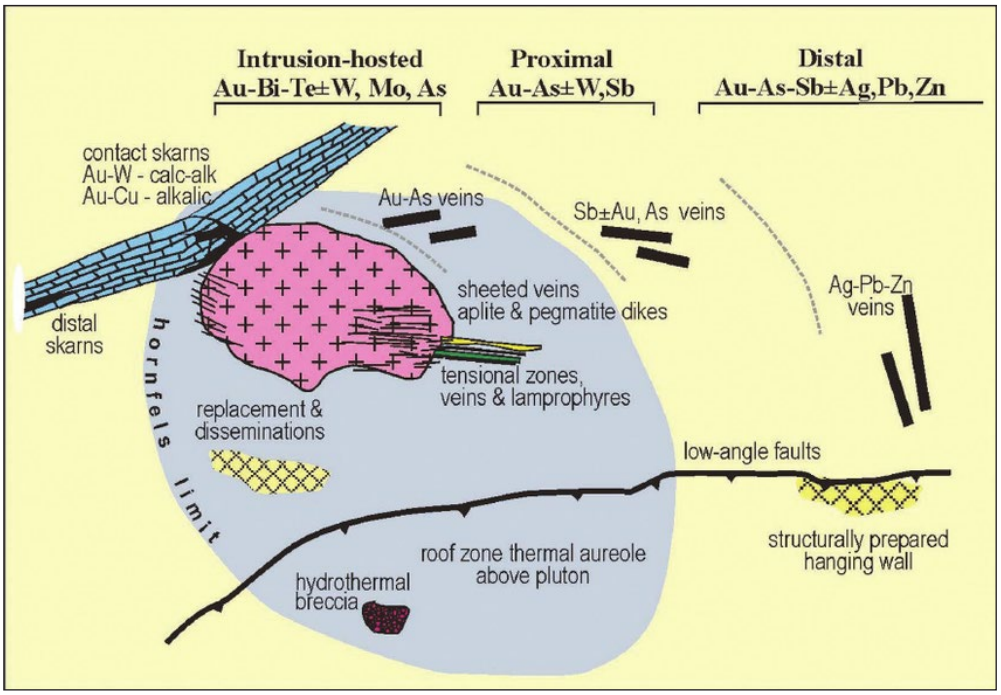
- Figure 11 shows the styles of mineralisation within the IGRS grouping - mineralisation forms over a wide depth range, from <1km to >8km, with one of the most common form sof mineralisation being low sulphide sheeted veins within the host intrusion, with the intrusive event and mineralisation largely being contemporaneous.
- These styles are also associated with other broad mineralisation groupings, including orogenic gold, with which IRGS systems are often confused.
- Differentiating features are tectonic setting (post orogenic vs orogenic), location of mineralisation within and around the cupola of the host intrusions and geochemical signatures and zonation; in addition, IRGS mineralisation is generally related to smaller intrusive bodies including stocks - they are not related to batholiths as is commonly the case with orogenic gold deposits.
- Geochemically the deposits lack significant copper, and also there is concentric mineral zoning due to a sharp geothermal gradient around the causative intrusion.

Figure 10: Tintina Gold Belt and deposits



Source: Adapted from Anchor Resources presentation

Figure 11: IRGS deposit styles



Source: Adapted from Hart (2002)

Exploration

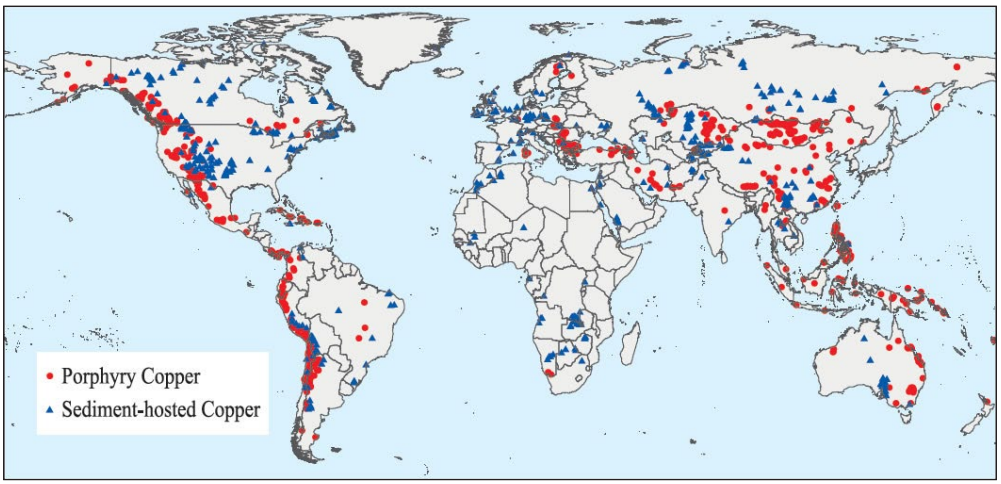
- Key exploration tools, in addition to geological mapping of the well developed alteration zones, include geochemistry and sometimes geophysics.
- Geochemical signatures are shown in Figure 11 with these similar to the Au-As-Bi-Sb-W-Zn anomalism seen at Moonwalk.
- The key geophysical tool, in areas of cover and buried intrusives, includes magnetics to recognise various intrusive phases - electrical methods are generally inconclusive given the lack of sulphides.

Sediment Hosted Copper

Geology

- Like IRGS systems, sediment hosted copper mineralisation includes a broad gamut of mineralisation styles.
- However key discriminants include the stratiform or stratabound nature of mineralisation, and as the name suggests, an association with sediments.
- Major examples include the Kupferscheifer in Western and Central Europe and the major deposits of the Central African Copperbelt, historically the world's largest producer of copper - Figure 12 shows the global distribution of both sediment hosted and porphyry copper deposits.

Figure 20: Global copper deposits



Source: Geology.com

- The majority of these formed during diagenesis, with oxidised copper bearing basinal brines being reduced by the reaction with reduced (pyritic, carbonaceous or calcareous) sediments to form the copper minerals, including primary chalcocite, bornite and chalcopyrite.
- Alaskan examples, which are also termed "Kennecott style" or "basalt copper" deposits include Kennecott, which, as mentioned previously produced ~4Mt of ore at 13% Cu.
- However, also as mentioned earlier, it has been suggested that mineralisation at Kennecott is reasonably late, with structurally controlled fluids reacting with the limestone to form the mineralisation, which includes structural and solution breccias.
- Other North American examples include the Keeneenaw and Porcupine districts of Michigan.
- One interpretation of the mineralisation at Caribou Dome, as discussed earlier, is that the mineralisation is syngenetic, being formed by the direct precipitation of copper sulphides in a euxinic environment, with the source of the copper being from the basalts of the Nikolai Greenstone.

Exploration

- Given the stratabound nature of mineralisation one of the main exploration tools is geology, and mapping out the target stratigraphy.
- This has been demonstrated at Caribou Dome/Senator, as has geophysics (IP) and geochemistry.
- Secondary and trace element geochemistry depends on the deposit, source rocks and fluid chemistry, but can include cobalt (Central African Copperbelt amongst others), precious metals, vanadium and molybdenum.

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