HIGHLIGHTS

- **Disseminated Cu-Ni mineralization might contain economic concentrations of metals**
- **Disseminated Cu-Ni mineralization probably generated by magmatic process**
- **Massive and disseminated Cu-Ni mineralization are chemically different and appear zoned**
- **Cu:Ni ratio zonation might be useful to explore for massive/higher grade mineralization**

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Exploration for Disseminated Nickel-Copper Mineralization

Introduction

This study was initiated to determine the nature and extent of disseminated sulphide mineralization in Loveland Township drill-hole EC-16, where substantial copper-nickel-platinum group element (PGE) results were obtained from a massive sulphide sample collected at 320 feet (Table 1). If disseminated copper-nickel-PGE sulphide mineralization contains substantial amounts of metal, exploration for such deposits might 1) require a different geophysical strategy than the one used to look for massive sulphide mineralization and 2) uncover large, low-grade copper-nickel deposits.

Relevant Exploration History

Hollinger Consolidated Gold Mines Ltd. (Hollinger) explored for copper-nickel mineralization in Loveland Township using ground magnetic, very low frequency electromagnetic (VLF–EM16) and Turam geophysical surveys, as well as geological mapping. Weak coincident magnetic (100γ) and VLF–EM anomalies, but no Turam EM anomaly (Bosschart 1964), occur in the area northeast of Enid Creek between survey lines 10+00 feet and 24+00 feet (305 and 732 m) south and was drill tested by a number of drill holes, including EC-16 (MacKenzie 1964, 1966, 1967, 1968).

Diamond-drill hole EC-16 (454130E 5389330N) is a vertical hole drilled to test the northern extent of a copper-nickel mineralized zone encountered in drill-holes EC-1 to EC-15, inclusive (Vanderklift, Van Luven and Voormeij 2005). Drill-hole EC-16 intersected 3 feet (0.91 m) of massive sulphide between 320 and 323 feet that contained an average of 1.46% Ni and 0.35% Cu (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). Drilling in this hole also encountered 5 feet (1.5 m) of disseminated copper-nickel mineralization between 315 and 320 feet that contained 0.49% Ni and 0.09% Cu and 1 foot (0.3 m) of disseminated copper-nickel mineralization between 224 and 225 feet that contained 0.14% Ni and 0.09% Cu (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005).

Drill Core Geology

Diamond-drill hole EC-16 crosscut 4 different rocks units, including 1 logged as andesite and 3 logged as different types of gabbro (quartz, basic and mottled) (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). It also intersected disseminated sulphide mineralization between 225 and 325 feet (for metric equivalents *see* Tables 1 and 2) that was estimated visually to contain 0.1 to 8.0% pyrrhotite and minor chalcopyrite. Massive and disseminated mineralization was sampled between 315 and 325 feet and disseminated mineralization was sampled between 224 and 225 feet (MacKenzie 1968). The drill log lacks detail, but does indicate that the sulphide mineralization is hosted by 3 types of gabbro and there is a volcanic unit beneath (down hole) the intrusive rocks.

Sampling and Analytical Details

Telescoped diamond-drill core, consisting of samples 2 inches (5 cm) in length, was collected every 5 feet (approximately 1.5 m) from drill-hole EC-16 and was donated to the Timmins District Core Library for assessment credit. Core samples used for this study were collected from 200 to 350 feet, and submitted to the OGS Geoscience Laboratories in Sudbury to determine the concentration of the following elements by inductively coupled plasma mass spectrometry (ICP–MS, method IML-100, aqua regia leachate): silver, arsenic, gold, bismuth, cadmium, cobalt, copper, mercury, indium, iridium, molybdenum, nickel, lead, palladium, platinum, rhodium, antimony, selenium, tin, tellurium, titanium and zinc; and sulphur content using method IRC-100. The gold, iridium, palladium, platinum and rhodium content of the sample taken at 320 feet was determined using the IMP-200 (nickel sulphide fire assay) method. The IML-100 method costs 80% less than the IMP-200 method. Selected analytical results are provided in Table 1.

Results and Discussion

A massive sulphide sample collected at 320 feet (97.5 m) contained 21 290 ppm Ni, 1926 ppm Cu, 1480 ppm Co, 2.06 ppm Pd and 0.32 ppm Pt (see Table 1). Disseminated sulphide copper-nickel mineralization between 225 and 315 feet (69.6 and 96 m) contains an average of 0.19% Cu + Ni (0.108% Cu plus 0.086% Ni) (see Table 1) and 0.130 ppm Au + PGEs (Au, plus Pd, Pt and Rh) over 95 feet (29 m). Average palladium content of 0.099 ppm Pd accounts for 75% of the total Au + PGEs. Iridium content is below detection limit (0.003 ppm Ir) for all samples. The average cobalt content, 78 ppm Co, is only 3 times the crustal abundance (Wedepohl 1995).

The average Cu:Ni ratio is 1.8 from 200 to 275 feet and 0.5 from 280 to 315 feet. A massive sulphide sample collected at 320 feet has a Cu:Ni ratio of 0.09. The increase in Cu:Ni ratios from 0.09 to 0.5 and then to 1.8, upward in the drill hole, indicates that the sulphide mineralization is zoned, with nickel-rich mineralization near the base changing to copper-rich mineralization near the top. The Cu:Ni ratio zonation present in the disseminated and massive mineralization might be useful as a vector toward massive sulphides when exploring disseminated mineralization.

The Pd:Pt ratios, that range from 3.3 to 16.9 and average 11.4, were determined for 13 samples that had measurable Pd or Pt concentrations. There is no obvious zonation in Pd:Pt ratios comparable to those seen in the Cu:Ni ratios. The high Pd:Pt ratio (>5) in drill-hole EC-16, the absence of measurable iridium, as well as bismuth, selenium and tellurium contents that are 1, 13 and 44 times, respectively, greater than average crustal abundance (Wedepohl 1995) are interpreted to indicate deposition by a Bushveld Complex-like magmatic process (Godel, Barnes and Maier 2007).

The samples between 225 and 315 feet, a 100-foot (30.5 m) interval, contains an average of 0.5% S (see Table 1), consistent with the estimated pyrrhotite content. The 100-foot (30.5 m) mineralized zone has a calculated true width of 70 feet (21.3 m) because drill-hole EC-16 is vertical and the gabbro appears to dip approximately 45° east (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005).

The 2-inch (5 cm) lengths of core samples available are interpreted to represent 5-foot intervals of core. The sample at 320 feet is the only exception to this interpretation and probably represents only a 3-foot (0.91 m) long intercept of massive sulphide that was logged by MacKenzie (1968).

The 100-foot (30.5 m) intercept (Table 2: indicated by vertical line) contained metals worth a total of US$46.43 (C$60.83) per tonne on November 5, 2018. If the 60% greater specific gravity of massive pyrrhotite compared to disseminated sulphide samples (4.6 versus 2.9 g/cc) is considered, it will increase the estimate of total metal value to nearly US$60.00 per tonne. If the sample collected at 320 feet only represents a 2.5-foot zone of massive sulphides, the metal value estimate of the 100-foot (30.5 m) intercept will be only US$35.41 per tonne (not taking specific gravity into account). A mineralized zone with a true width of 70 feet (21.3 m) containing US$46.43 of metal per tonne would be comparable to an intercept containing 1.17 g/t Au. Such a deposit would have a higher grade than the 0.97 g/t Au mined at the Detour Gold Mine in 2017 (Detour Gold Corporation, news release, January 16, 2018) or the estimated grade of 1.07 g/t Au of reserves in the Goldcorp Century pit project (Goldcorp Inc.,

Investor Day 2018 presentation, January 16, 2018). Such metal values are comparable in value to the proven nickel reserve (0.32% Ni) in the geologically different Dumont deposit in Quebec (Staples et al. 2013) and could trigger a paradigm shift toward open-pit mining of disseminated copper-nickel mineralization.

The average PGE content of the 100-foot (25.9 m) intercept accounts for 18.4% of the total dollar value.

Table 1. Geochemistry of Loveland diamond-drill core EC-16.

DDH (feet)	DDH (metres)	S (%)	Cu (ppm)	Ni (ppm)	Co (ppm)	Au (ppm)	Pd (ppm)	Pt (ppm)	Rh (ppm)	Bi (ppm)	Se (ppm)	Te (ppm)	Cu+Ni (%)	Cu:Ni ratio	Pd:Pt ratio
Detection Limit:		*0.003*	*0.6*	*2*	*0.03*	*0.002*	*0.02*	*0.005*	*0.003*	*0.02*	*0.2*	*0.02*			
200	61.0	0.01	38	181	33	0.014	bdl	0.005	0.005	0.02	bdl	0.02	0.02	0.21	
205	62.5	0.12	164	181	30	0.011	bdl	bdl	0.009	0.03	0.3	0.04	0.03	0.91	
210	64.0	0.09	52	197	29	0.008	bdl	bdl	bdl	bdl	0.2	bdl	0.02	0.26	
215	65.5	0.08	27	353	43	0.002	bdl	bdl	0.004	0.02	0.4	0.02	0.04	0.08	
220	67.1	0.03	267	134	21	0.005	bdl	bdl	0.007	bdl	bdl	0.02	0.04	1.99	
225	68.6	1.04	2179	1157	113	0.010	0.05	bdl	0.003	0.05	2.5	0.25	0.33	1.88	
230	70.1	0.23	1040	236	31	0.006	bdl	0.005	0.01	0.02	0.8	0.11	0.13	4.41	
235	71.6	0.24	461	353	34	0.003	0.02	0.006	0.006	0.03	0.9	0.1	0.08	1.31	3.3
240	73.2	2.23	3671	2477	181	0.050	0.21	0.017	0.007	0.13	5.9	0.80	0.61	1.48	12.1
245	74.7	2.26	5351	2427	140	0.095	0.16	0.010	bdl	0.06	5.4	0.52	0.78	2.20	16.0
250	76.2	0.12	353	283	52	0.007	0.04	0.005	0.007	0.02	0.5	0.07	0.06	1.25	8.0
255	77.7	0.24	510	388	42	0.004	0.09	0.007	bdl	0.05	0.7	0.2	0.09	1.31	12.9
260	79.2	0.28	638	357	39	0.003	0.13	0.009	0.015	0.07	0.9	0.26	0.10	1.79	14.4
265	80.8	0.12	585	279	41	0.002	0.03	bdl	0.003	bdl	0.4	0.06	0.09	2.10	
270	82.3	0.03	140	315	42	bdl	bdl	bdl	bdl	bdl	0.2	0.02	0.05	0.44	
275	83.8	0.78	2681	1367	154	0.031	0.19	0.013	0.007	0.06	2.9	0.49	0.40	1.96	15.2
280	85.3	0.17	390	833	82	0.008	0.08	0.009	0.003	0.03	0.6	0.12	0.12	0.47	8.9
285	86.9	0.23	783	602	59	0.004	0.16	0.01	0.009	0.04	0.9	0.27	0.14	1.30	16.0
290	88.4	0.01	34	285	44	bdl	0.03	bdl	0.005	bdl	bdl	0.03	0.03	0.12	
295	89.9	0.11	167	412	55	0.003	0.03	0.006	bdl	0.04	0.6	0.12	0.06	0.41	5.0
300	91.4	0.05	217	352	50	0.002	bdl	bdl	0.01	0.02	0.2	0.03	0.06	0.62	
305	93.0	0.03	143	544	65	0.002	0.02	bdl	0.005	0.02	0.2	0.05	0.07	0.26	
310	94.5	0.12	265	884	82	0.005	0.14	0.016	0.005	0.07	0.5	0.21	0.11	0.30	8.4
315	96.0	1.25	941	2774	185	0.004	0.22	0.013	0.022	0.13	3.8	0.47	0.37	0.34	16.9
320	97.5	28.33	1926	21290	1480	0.014	2.055	0.317	0.016	1.77	33.4	7.33	2.32	0.09	6.5
325	99.1	0.03	182	45	9	0.002	bdl	bdl	0.006	bdl	bdl	0.02	0.02	4.04	
330	100.6	0.02	54	43	11	bdl	bdl	bdl	0.014	bdl	bdl	bdl	0.01	1.26	
335	102.1	0.03	34	54	21	0.002	bdl	bdl	bdl	bdl	bdl	bdl	0.01	0.63	
340	103.6	0.01	48	46	19	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.01	1.04	
345	105.2	0.01	71	51	20	bdl	bdl	bdl	0.006	bdl	bdl	bdl	0.01	1.39	
350	106.7	0.02	151	34	14	bdl	bdl	bdl	0.006	bdl	bdl	bdl	0.02	4.49	

Abbreviation: bdl = below detection limit.

Table 2. Value of metals in Loveland diamond-drill core EC-16.

		Cu	Ni	Co	Au	Pd	Pt	Rh			
	Metal Price:	2.816 (US$/lb)	5.502 (US$/lb)	27.33 (US$/lb)	39.54 (US$/g)	35.14 (US$/g)	26.52 (US$/g)	31.37 (US$/g)			
Depth (feet)	**Depth** (metres)	**Cu Value** (US$/t)	**Ni Value** (US$/t)	**Co Value** (US$/t)	**Au Value** (US$/t)	**Pd Value** (US$/t)	**Pt Value** (US$/t)	**Rh Value** (US$/t)	**Total Value** (US$/t)	**Avg. Value** (US$/t)	**Avg. Value** (US$/t)
200	61	0.24	2.2	1.99	0.55	0	0.13	0.16	5.26		
205	62.5	1.02	2.19	1.83	0.42	0	0	0.28	5.73		
210	64	0.32	2.39	1.77	0.32	0	0	0	4.8		
215	65.5	0.17	4.28	2.61	0.08	0	0	0.13	7.27		
220	67.1	1.66	1.63	1.28	0.2	0	0	0.22	4.98		
225	68.6	13.53	14.03	6.8	0.4	1.76	0	0.09	36.61		
230	70.1	6.46	2.86	1.89	0.24	0	0.13	0.31	11.89		
235	71.6	2.86	4.28	2.06	0.12	0.7	0.16	0.19	10.37		
240	73.2	22.79	30.04	10.91	1.96	7.2	0.45	0.22	73.57	**31.73**	
245	74.7	33.22	29.44	8.4	3.76	5.62	0.27	0	80.71		
250	76.2	2.19	3.43	3.1	0.28	1.41	0.13	0.22	10.76		
255	77.7	3.17	4.71	2.51	0.16	3.16	0.19	0	13.89		
260	79.2	3.96	4.33	2.34	0.12	4.57	0.24	0.47	16.03		
265	80.8	3.63	3.38	2.46	0.08	1.05	0	0.09	10.7		**46.43**
270	82.3	0.87	3.82	2.52	0	0	0	0	7.21		
275	83.8	16.64	16.58	9.28	1.23	6.68	0.33	0.22	50.96		
280	85.3	2.42	10.1	4.95	0.32	2.81	0.24	0.09	20.93	**31.31**	
285	86.9	4.86	7.3	3.55	0.16	5.62	0.27	0.28	22.04		
290	88.4	0.21	3.46	2.64	0	1.05	0	0.16	7.52		
295	89.9	1.04	5	3.34	0.12	1.05	0.16	0	10.7		
300	91.4	1.35	4.27	2.98	0.08	0	0	0.31	8.99		
305	93	0.89	6.6	3.9	0.08	0.7	0	0.16	12.33		
310	94.5	1.64	10.72	4.94	0.2	4.74	0.42	0.16	22.82	**133.95**	
315	96	5.84	33.65	11.17	0.16	7.73	0.34	0.69	59.58		
320	97.5	11.96	258.24	89.17	0.55	72.21	8.41	0.5	441.05		
325	99.1	1.13	0.55	0.54	0.08	0	0	0.19	2.49		
330	100.6	0.34	0.52	0.67	0	0	0	0.44	1.97		
335	102.1	0.21	0.66	1.28	0.08	0	0	0	2.22		
340	103.6	0.3	0.56	1.14	0	0	0	0	1.99		
345	105.2	0.44	0.62	1.2	0	0	0	0.19	2.45		
350	106.7	0.93	0.41	0.83	0	0	0	0.19	2.35		

All metal prices are bid values obtained from London Metals Exchange, Kitco and Metals Bulletin on November 5, 2018.
Abbreviation: Avg. = average.

Recommendations

Core containing disseminated copper-nickel mineralization with less than 5% sulphides should be analyzed using a multi-element ICP–MS analytical package containing both base metals and PGEs. Zonation of Cu:Ni ratios should be assessed and used to search for nearby massive copper-nickel mineralization.

Attention should be paid to weak magnetic and VLF–EM anomalies near known copper-nickel mineralization. Such anomalies might be tested using induced polarization to identify both disseminated and thin massive sulphide zones.

Conclusions

- Hollinger drill-hole EC-16 has an average Cu plus Ni content of 0.19 weight % Cu+Ni over 100-foot (30.5 m) core length or 70 feet (21.3 m) true width.
- Cu:Ni ratio zonation is present in the disseminated mineralized zone and might be useful as a vector pointing toward massive sulphide mineralization.
- The Pd:Pt ratio, absence of measurable iridium, and total bismuth, selenium and tellurium content indicate a magmatic process.
- The total metal value in the disseminated zone is estimated to be US$46.43 per tonne and would be comparable to 1.17 g/t Au (November 5, 2018 metal values).
- Average gold plus PGE content in the disseminated zone accounts for 18.4% of total metal value.

Cautionary Statement

Analytical results for the 5 cm (2-inch) length core samples collected are interpreted to represent 1.5 m (5-foot) intervals of core. This assumption is thought to be valid for most samples. The sample collected at 320 feet was obtained from 3 feet (0.91 m) of core containing massive sulphides (MacKenzie 1968; Vanderklift, Van Luven and Voormeij 2005). Given that the massive sulphide intercept is less than 5 feet (1.5 m), the value of the 100-foot (30.5 m) intercept is somewhat overestimated.

Post-Publication Addendum and Errata

In January 2023, following publication (in December 2022) of additional related analytical data, the Timmins Resident Geologist Office staff were contacted about the content of this recommendation. After a search of the Timmins Drill Core Library, staff found there existed 2 separate boxes of donated company drill core, both labelled as "box 155406". One box contained core from drill-hole L-13 and the other box contained core from drill-hole EC-16. Further investigation revealed that the drill core studied in this project was, in fact, from drill-hole EC-16, rather than from drill-hole L-13. The analytical data reported have not been affected; however, the location of the drill hole, the description of the geology and resultant interpretations required extensive modifications. This version, as of February 2023, corrects the errors.

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