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CONTAMINATION IN OVERBURDEN SAMPLES OBTAINED BY THE ROTARY, DUAL-TUBE DRILLING TECHNIQUE

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Introduction

In winter of 1971-72 the Geological Survey of Canada carried out an overburden drilling project as a part of the Federal Winter Employment Program. The objectives of the original project were to compare various overburden drilling techniques and to seek the most efficient method of mineral tracing in areas of thick overburden. During the project approximately 6000 samples were collected, separated into various size and weight fractions, and analyzed for copper, lead, zinc, cobalt, nickel, and silver. Stratigraphic and geochemical sections were developed for all the project sub-areas and were published, along with location maps and bedrock descriptions, in G.S.C. Open File 116 (Skinner, 1972a).

The results of the project show that there are many areas of high copper and zinc concentration traceable for miles in the down-ice direction. However, during examination of selected anomalous samples to determine their mineralogy, several small metal fragments were noted and subsequently found to be a tungsten-brass mixture. After further examination of additional anomalous and non-anomalous samples revealed this contamination in varying concentrations, a detailed study of contamination was undertaken.

Contamination was eventually traced to the reaming shell used in the drill (Skinner, 1972a). During examination of the drill components, several additional sources of contamination were noted and will be discussed later.

Sample Preparation

In order to approximate the original samples as closely as possible the "250 Stored" fraction from the bucket split (Skinner, 1972a) was prepared in the same fashion. These samples were passed through a nest of sieves(10, 60, and 250 mesh). The -10, +60 split ("F" fraction) was prepared in some cases to check on the variation in mineralogy among the size fractions. The -60, +250 split was separated into heavy and light fractions using Methyline-Iodide (S.G. ≈3.3), and magnetic minerals were removed by a hand magnet from the heavy fraction. The remaining heavies were called the "E" fraction.

The "E" fraction makes up approximately 1% of the total sample weight in the Kam-Kotia area and 0.9% of the sample weight as an overall average. The magnetic minerals removed from the heavies constitute about 0.2% of the total sample weight in the Kam-Kotia area, and 0.2% of the sample weight in the larger area.

After a visual examination of general mineralogy and visible contamination, the samples were mounted in 1" Bakelite rings prehollowed to 1/16" deep and 3/4" in diameter (to prevent smaller grains from adhering to bubbles in the epoxy), polished, and examined under a microscope in reflected light.

Before mounting the samples, a representative suite of mineral grains, including contaminating fragments, were hand picked and identified by X-ray Diffraction (X.R.D.).

The analyses of the contaminating fragments were accomplished by the use of an electron microprobe with an energy-dispersive spectrometer.

Description of the Metal Fragments

Metal fragments were found in several samples in both the "E" and "F" fractions as well as in the corresponding magnetic splits. In all cases the fragments have the same general physical appearance – curved, platey, striated metal flakes with a tarnished copper colour. The fragments are very hard but do break into plates when pressed with a needle. When scratched or polished, a bright metallic silver colour is apparent, the polished sample having a yellowish tint.

The flakes are generally not magnetic although they do show up in the magnetic split. This is due to attached pieces of steel from the steel-tungsten interface in the reaming shell.

The fragments generally consist of 2 phases forming an eutectic-like mixture of tungsten and brass. Two pure brass fragments with the same composition as the brass in the tungsten-brass mixture were noted and identified by X.R.D. These fragments also are striated and curved but have a stronger copper colour, and are softer with a more ragged appearance.

One bronze flake was picked out of a sample. This flake is curved and ragged like the brass flakes but is not striated and has an even stronger copper colour.

Fragment Analysis

Semi-quantitative electron microprobe analyses were obtained for tungsten, brass, and bronze from metal fragments selected from the samples and the drill column. In addition, quantitative brass analyses were completed on four fragments. These analyses have ranges within the

analytical precision of the microprobe and the averaged values are: 49.1%-Cu, 39.0%-Zn, 10.0%-Ni, and 1.1%-Fe. Semi-quantitative microprobe scans on the tungsten phase of the eutectic-like mixture cannot distinguish metallic tungsten from tungsten-carbide. The scans detected only tungsten and the possibility of tungsten-carbide was ruled out by X.R.D.

The bronze fragment was identified by X.R.D. and compared exactly to the pattern given by a chip of the bronze collar. The bronze collar is approximately 90% copper and 10% tin as determined by microprobe analysis.

Description and Discussion of the Drilling System

In tracing the contamination, a thorough examination of the drilling system was made and several possible sources of contamination were revealed.

The drilling system used was a rotary, dual-tube, reversed-circulation drill mounted on an all-terrain vehicle. The water is pumped down the outside and the chips are returned through the bit and up the inner rods. Separation of the larger chunks is accomplished by a coarse screen placed over the collection bucket at the end of the return hose.

The drill column, starting from the bottom consists of, i) the bit (either a tungsten-carbide button bit or a steel tooth bit); ii) a reaming shell; iii) the lower adapter; iv) the drill rods (two possible types, a separate inner and outer or a combined inner and outer); v) an upper adapter; and vi) a swivel. The hoses are rubber and attach to the swivel. The water is fed to the system by a large piston-type pump.

The Drill Bit

The two types of bits are composed principally of steel. The tungsten-carbide bit has tungsten-carbide buttons inserted into the rotary head.

These buttons are pressed into the heads and held by pressure alone, no evidence of brazing was noted.

When these bits are manufactured, a copper solution is applied to the part of the bit to be threaded to dissipate the heat and prevent hardening of the shaft of the bit while the head is being heated and hardened. The copper solution acts as a heat shield and often copper derived from this process remains on the inner surface of the bit shank. This coating is about 1/32" thick and when polished or scratched the bright copper colour is readily visible; however, the coating oxidizes quickly and generally appears as a dull rusty colour. This material proved to be Cu and CuO.

The tungsten-carbide buttons are approximately 82%-W and 18%-Co, as determined by microprobe analysis. The cobalt is a binding agent for tungsten-carbide.

The Reaming Shell

This piece of the drill column screws onto the lower adapter and forms a sleeve between the column of drill rods and the drill bit. Its purpose is to enlarge the hole above the bit and prevent the rods from binding. Three rows of tungsten-carbide teeth are set into the perimeter of the shell and provide the main abrasive in the shell. The material into which these inserts are set is a tungsten-based metal which is brazed onto the steel core of the reaming shell.

The tungsten-based sleeve of material is bound together by a brass matrix forming an "eutectic-like" mixture. This mixture is brazed onto the steel portion of the reaming shell by a layer of brass (the steel is also serated for a firmer join), which appears along the edge of the join. This sleeve of material extends approximately 1½" down from the leading edge of the reaming shell and is about 3/16" thick. The

tungsten-brass sleeve has a dull grey colour that is distinct from the steel portion of the reaming shell which rusts very quickly.

Metal fragments found in the samples resemble various portions of the reaming shell. A piece of the tungsten-brass metal from the reaming shell was analyzed on the microprobe and proved to be of similar composition to the contaminants. The texture, optical properties, and colour also corroborate the suggestion that the contamination is due to the reaming shell. The pure brass flakes found in the samples are similar in all their properties to the thick layer of brass in the reaming shell, and it also can be seen that the brass from the reaming shell does erode from the shell differentially. It is probable that such erosion is increased when particularly hard or stony units, such as till, are being penetrated.

The steel portion of the reaming shell is approximately 97%-Fe, with minor Mn, as determined by microprobe analysis. This steel is highly magnetic and appears as oxidized flakes in the magnetic split.

Drill Rod Adapters

Samples of both the upper and lower drill rod adapters give X.R.D. patterns similar to an iron alloy steel, and are highly magnetic. The purpose of the adapters is to connect the various types of drill rods to the standard swivels, reaming shells and bits.

Drill Rods

Two types of drill rods were used on the drilling program. In the majority of holes the older type of separate inner and outer rods were used. Only in the "MN" project and the later "KJ" holes (Skinner, 1972a)

were the newer rods used and then only on one rig. The outer rods in both cases are an A.I.S.I. 4142 Steel (Hot Rolled Alloy) tubes. The new inner rods are a mild steel while the old inner rods are a non-magnetic stainless steel. The drill rod connectors are also a mild steel.

The Swivel

The purpose of the swivel is to provide a stationary portion of the drill column to which the hoses carrying the liquid used in the drilling (in this case water) may be attached. The upper portion of the swivel remains stationary while the lower portion rotates with the drill rods using a series of metal "O" rings and rubber-leather gaskets as bearings and seals.

There are 4 parts of this apparatus which could lead to a serious contamination problem. The upper and lower "O" rings, which rotate with the lower portion of the swivel, the large sleeve, which is stationary in the upper portion of the swivel and against which the upper "O" ring turns, and the large collar in the top portion of the swivel.

The composition of the two "O" rings has been analyzed as approximately 90%-Cu and 10%-(Sn, Fe, Ni, Zn). The large sleeve is probably the same composition but no sample was available for analysis. The upper "O" ring acts as a bearing between the upper and lower portion of the swivel. It is separated from the lower "O" ring by a series of gaskets which act as a sealing mechanism between the inside of the outer drill rod and the stationary part of the swivel.

The large collar in the top of the swivel acts as a loose bearing through which the inner drill rod passes. Sealing the top compartment from the lower portion is another series of gaskets, the top compartment

being the sample return part of the swivel. The inner surface of the collar examined had been badly scored, probably from the inner drill rods being jammed against it. The collar was analyzed as approximately 90%-Cu and 10%-Sn on the microprobe, also this material has a different X.R.D. pattern from the two "O" rings.

One fragment of bronze from an overburden drill sample has been identified by X.R.D. and it matches exactly the pattern of the material from the bronze collar.

The Water Pump

The water pump is driven by a separate power source and supplies the input water to the hole from either the reservoir (settling tank) on the vehicle or directly from some natural water source. There is little chance of contamination from the pump as it is a cylinder-piston type with a porcelain lined cylinder and a hard rubber piston.

The valves and connectors were not checked.

Tungsten Analysis

To determine how serious the contamination is in the analyzed overburden samples, the remaining portion of the original samples, the only samples that have been examined in the present study, were analyzed for tungsten. Unfortunately, in some cases there was no excess material left.

The tungsten analyses were done by a colorometric titration after a carbonate fusion extraction. This particular method is meant for geochemical samples and has an effective range from 1 to 500 ppm. For samples with greater concentrations of tungsten, an assay method that has an effective range from 100 ppm to 100% should be used. All the

tungsten analyses listed in Table 1 were done by the geochemical method.

The minimum sample weight for the geochemical method is 0.25 grams and if this is not available the reliability of the analyis is lowered. Unless indicated in the tables the minimum weight was attained.

Effects of the Metal Fragments on the Sample Analyses

In order to get an estimate of the effect of the contaminating fragments on the sample analysis, the proportion of brass in the reaming shell has to be determined. This was done by obtaining point counts on a few metal fragments and from several orientations about a plug drilled from the reaming shell. The polished sections reveal an eutectic-like pattern of tungsten and brass in fragments from all orientations. The point counting was done to overcome any effects of preferred orientation or uneven distribution of the phases caused during manufacturing of the reaming shell.

The averaged percentages of tungsten and brass, by volume, from five metal fragments and five surfaces about the reaming shell plug are 58.2%-tungsten and 41.8%-brass. This mixture has a calculated specific gravity of 14.8, which gives, when converted to weight per cent, 73.6%-W, 12.6%-Cu, 7.8%-Zn, and 5.9%-Ni in the reaming shell.

The ratios of $Cu/^{W}$, $Zn/^{W}$, and $Ni/^{W}$ are 0.171, 0.107, and 0.080 respectively. These ratios are calculated from weight per cent of the various elements in the reaming shell, and are used in determining the concentrations of copper, zinc, and nickel derived from reaming-shell fragments in the samples, based on the tungsten analyses.

Tables I and II show the tungsten analyses, the original analyses for copper, zinc, and nickel, the estimated contributions of copper, zinc, and nickel from the reaming shell fragments, and the "corrected" analyses for copper, zinc, and nickel.

As can be seen from Tables I and II, by using this simple procedure and not taking into account the unreliability of the high tungsten values, in most cases the anomalous samples are still anomalous. Assuming that there is 1% by weight of metal fragments and 1% by weight of chalcopyrite in a sample, the contribution of copper to the sample analysis from the metal fragment would be 1260 ppm and the contribution of copper by the chalcopyrite would be 3460 ppm.

In the case of Table II, which shows analyses of sample splits finer than 250-mesh ("H" fraction), the effect of the contamination is not so dramatic as in the heavy-mineral ("E") split. This is due to the reduction of the metal fragment concentration by increasing the size of the sample by approximately 95%, most of the increase being due to the addition on non-metallic silicates. However, these analyses still reflect the same trends as the heavy-mineral split.

The contamination appears in the samples after the drill has been logged passing through boulders of coarse till. Also, in areas where holes are shallow, the number of reaming shells used increases considerably, due to more frequent drilling in bedrock. This abrades the reaming shell and makes it more susceptible to wear in normal drilling procedures.

The average life span of reaming shells was approximately 606 feet with an average hole depth of 78.2 feet. In areas where there is known contamination the life of the reaming shell is as low as 189 feet at an average hole depth of 56 feet. Whenever the life of the reaming shell

drops to less than 300 feet/shell and the depth of the holes is less than the average depth, the contamination due to fragments of the reaming shell is likely to increase.

Discussion of the Effects of the Contamination on the Overburden Drilling Project

The effect of the contamination on the results of the Overburden Drilling Project is serious but does not necessarily invalidate the conclusions drawn from it. Although individual samples may be suspect and might be inaccurate, the trends of the anomalous holes are still very useful.

Generally, the reaming shell fragment provides a masking effect on the analyses, and serves to raise the concentrations of the analysed elements. Indicator trains shown by Skinner (1972), are outlined in the ice-movement direction, and can be traced to their logical sources. The Texas Gulf Sulphur mine at Kidd Creek in the "FH" and "TA" projects, the Kam-kotia mine and the Jameland mine in the "KJ" project provide three excellent examples.

In most anomalous samples examined in this study, appreciable concentrations of sulphide minerals such as chalcopyrite, sphalerite, pentlandite, and in a few cases millerite (Skinner, 1972b) have been found. In anomalous samples where the mineralogy does not support the analyses, the ratios of Cu/Zn, Cu/Ni, and Zn/Ni from the analysis approaches the corresponding ratios derived from the brass analysis. This rather simplistic model allows one to predict highly contaminated samples roughly. If a true anomalous sample is highly contaminated, the effects of the mineralogy on sample analysis would be great enough to mask the predicting effect of the ratios as in the case of KJ-48-06. Table I shows that this particular sample is highly contaminated,

but after subtracting the calculated amounts of copper and zinc due to the metal fragments, there are still appreciable quantities of copper and zinc left. Unfortunately there was not enough sample left in DU-12-11 for a tungsten analysis but there is no mineralogical evidence to support an anomaly in that sample to the extent indicated by the original analysis. Also the Cu/Zn, Cu/Ni and Zn/Ni ratios for this sample agreed in each case with the corresponding ratios from the brass in the reaming shell.

In the case of Table II ("H" fraction) values of the tungsten analyses were not so high, but this is due to the far greater amounts of non-metallic silt and clay-sized grains that make up the original sample in proportion to the worn fragments from the reaming shell. However, if the metal fragments were distributed equally between the "E" and "H" fractions a 1% concentration of fragments or sulphide minerals in the "E" fraction would be equivalent to a .05% concentration in the "H" fraction. When looked at in this light, a tungsten analysis of 600 ppm is significant. Therefore, the masking effect is still present in the "H" fraction as well. The problem becomes complex in this fraction with the inclusion of clay minerals and the possibility of ion adsorption.

Conclusions

Although some samples of the overburden drilling project are contaminated, when looked at with the trends of high samples and ice-flow directions in mind, geochemical indicator trains still appear to be useful in predicting areas of economic interest. (As an example the Kidd Creek mine would have been located by this method.)

Like any new process, there are initial problems that still have to be worked out at this writing. For any future overburden drilling of this type, all sources of contamination should be eliminated. Since this type of contamination is emphasized in heavy-mineral separates and present in the the -250-mesh and -10, +60-mesh fractions it makes little difference what sample preparation technique is used. Total examination of all apparatus should be conducted, and any possible problems eliminated. Special attention should be directed toward all wearing surfaces.

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Table 1

Heavy Mineral Fraction
(S.G. ≥3.3)

		Sample Analysis				Calculated Concentration in Contaminants			"Corrected" Analysis		
Sample number	Sample weight	W	Cu	Zn	Ni	Cu	Zn	Ni	Cu	Zn	Ni
FH-02-14	.08g	11300				1900	1200	900			
-67-29		6	85	35	35	1	1	1	84	34	34
KJ-08-14		360	160	125	46	60	39	29	100	86	17
-18-13		3200	100	160	34	550	340	260	-450	-180	-226
-26	.155g	190	120	74	22	32	20	15	88	54	7
-20-16		300	460	5960	106	50	32	24	410	5928	82
-24-04	.11g	820	252	204	57	140	88	66	112	116	-9
-23		4	80	70	37	1	1	1	79	69	38
-27-04		20	44	38	27	3	2	1	41	36	26
-28-11	.17g	47	203	151	70	8	5	4	195	146	66
-29-18		560	780	108	64	96	60	45	684	48	19
-31-06		2500	800	570	130	430	270	200	370	300	-70
-20		4000	1200	820	230	680	430	320	520	390	-90
-21		4000	1000	650	190	680	430	320	320	220	130
-22		2500	830	210	200	430	270	200	400	-60	0
32-09		800	270	170	74	140	86	64	130	84	10
-16		140	100	50	46	24	15	11	76	35	35
-33-07		2000	1300	265	480	340	210	160	960	55	320
-35-08	.17g	3700	1000	850	190	630	400	300	370	450	-110
-36-14	.22g	1500	330	200	82	260	160	120	70	40	-38
-48-06	.245g	24000	9000	8000	450	4100	2600	1900	4900	5400	-1400
MN-12-23	.09g	14	340	169	64	2	1	1	338	168	63
-13-04		20	65	25	30	3	2	2	62	23	28
NO-33-04		13	254	238	45	2	1	1	252	237	44
-09		8	152	118	38	1	1	1	151	117	37
-34-03		160	430	413	53	27	17	13	403	396	40
SS-02-02		5	51	20	27	1	1	1	50	19	26
VD-08-05		7200	4110	2090	1070	1200	770	586	2910	1320	484

Table II

-250 mesh (-64μ) fraction

	Sample Analysis				Calculated Concentration in Contaminants			"Corrected" Analyses		
Sample Number	W	Cu	Zn	Ni	Cu	Zn	Ni	Cu	Zn	Ni
02-21	120	19	20	25	21	11	10	-2	9	15
03-10	52	20	20	20	9	6	4	11	14	16
67-29	8				1	1	1			
87-08	800	362	283	95	140	87	64	122	196	31
-09	64	43	65	37	11	7	5	32	58	32
KJ-18-07	32	14	22	12	5	3	3	9	19	9
20-16	20	20	200	16	3	2	2	17	198	14
24-04	20	14	25	16	3	2	2	11	23	14
-25	12	190	200	28	2	1	1	188	199	27
31-06	40	13	24	21	7	4	3	6	20	18
-11	100	64	54	33	17	11	8	47	43	25
-20	60	20	29	23	10	6	5	10	23	18
-21	28	14	23	19	5	3	2	9	20	17
-22	12	15	22	19	3	1	1	12	21	18
23	40	24	33	26	7	4	3	17	29	23
32-08	100	27	134	27	17	11	8	10	23	19
-16	6	11	20	14	1	1	1	10	19	13
33-07	40	33	31	30	7	4	3	26	27	27
35-08	32	27	29	19	5	3	3	22	26	16
36-15	12	104	134	31	2	1	1	102	133	30
48-06	480	400	760	18	82	51	38	318	709	-20
MN-12-23	60				10	6	5			
13-19	12				2	1	1			
NO-33-04	4				1	1	1			
-09	4				1	1	1			
02-03	12	33	75	50	2	1	1	31	74	49
-08	60	79	194	181	10	6	5	69	188	176
TA-12-28	24	10	12	17	4	3	2	6	9	14
VD-08-05	120	85	51	185	20	13	10	65	38	175
DU-12-11	600	112	135	59	103	64	48	9	71	11
15	60	23	52	29	10	6	5	50	17	24