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Humus sampling in the Mayville Igneous Complex, southeastern Manitoba (NTS 52L12): using the mobility of palladium in aqueous surficial environments as a guide to nickel–copper–platinum group element mineralization

By
P. Theyer

Manitoba

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E-mail:	minesinfo@gov.mb.ca
Website:	http://www.gov.mb.ca/iedm/mrd/

Cover illustration: Humus sampling in the Mayville Igneous Complex, Manitoba.

ABSTRACT

Forty humus samples, collected from the area underlain by the Mayville Igneous Complex of southeastern Manitoba, were analyzed for Pt, Pd and Au to investigate their utility as pathfinder elements in the search for Ni, Cu and platinum group element concentrations in this mafic-ultramafic intrusion. Only Pd yielded useful analytical results in this survey; both Pt and Au were persistently below analytical detection limits and will therefore not be discussed.

The solubility of Pd in water facilitates its dispersion along surface-water drainageways. The ready adsorption of Pd to organic matter, however, efficiently arrests its dispersion, resulting in anomalies with small footprints. This property makes Pd a pathfinder element capable of guiding explorationists with accuracy to the actual source of the anomaly. The method is especially useful as another viable tool in the search for sulphide-poor PGE prospects, especially in wet swamp- and glacial till–covered terrains common in the Canadian Shield.

This survey outlined three clusters and an additional isolated sample containing anomalous Pd concentrations. It is thought that these anomalous concentrations originated from Pd-bearing mineralization in contact with groundwater. Analysis of the topography and surface-water drainage patterns followed by prospecting should lead to the location of PGE-bearing source rocks.

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Introduction

The Mayville Igneous Complex (MIC), a mafic-ultramafic layered intrusion in southeastern Manitoba thought to be coeval with the Archean Bird River Sill (Figure 1; Trueman, 1980), has been explored for Ni, Cu, Cr and platinum group elements (PGE). It hosts several Ni-Cu-PGE occurrences, including the Hititrite (Wright, 1932; Theyer, 1986), the Mayville (Theyer, 1986), and a large zone of Cu-Ni-PGE–bearing sulphide mineralization recently discovered by Mustang Minerals Corporation. This mineralization is associated with an approximately 1.3 km long airborne Versatile Time-Domain ElectroMagnetic–magnetic (VTEM-mag) anomaly (Figure 2, M2 anomaly; Mustang Minerals Corporation, 2006). The discovery of the M2 zone shows that the MIC contains not only disseminated Ni-Cu-PGE–bearing sulphides in the stratigraphically higher heterolithic breccia zone (Peck et al., 2002), but also at least one disseminated to locally semimassive Cu-Ni-PGE–bearing sulphide body that is tens of metres wide, 1300 m long and currently proven to a depth of 350 m.

Exploration for Ni, Cu, Cr, and PGE in the MIC area has relied on geophysical surveys, overburden stripping and rock sampling followed by drilling. The area recently explored by Exploratus Ltd. is an area of abundant outcrop and shallow overburden forming a narrow (approximately 300 m wide) east-striking corridor whose approximate location is indicated in Figure 2 by the crosses that symbolize man-made PGE prospect pits and trenches. Since 2005, Mustang Minerals has been exploring an airborne VTEM-mag anomaly (M2 anomaly; Mustang Minerals Corporation, 2006), 1.4 km long by up to 200 m wide, that is largely covered by up to several metres of glacial till and swamps.

Parts of the MIC are comparable to a number of other, recently defined, sulphide-poor, gabbro-hosted PGE prospects that pose a severe exploration challenge. The most notable of these occurrences include the Lac des Iles (currently the only primary Pd-producing mine in Canada) and associated deposits in Ontario (Sutcliffe, 1986; Sutcliffe et al., 1989; Lavigne and Michaud, 2001), the East Bull Lake suite and the

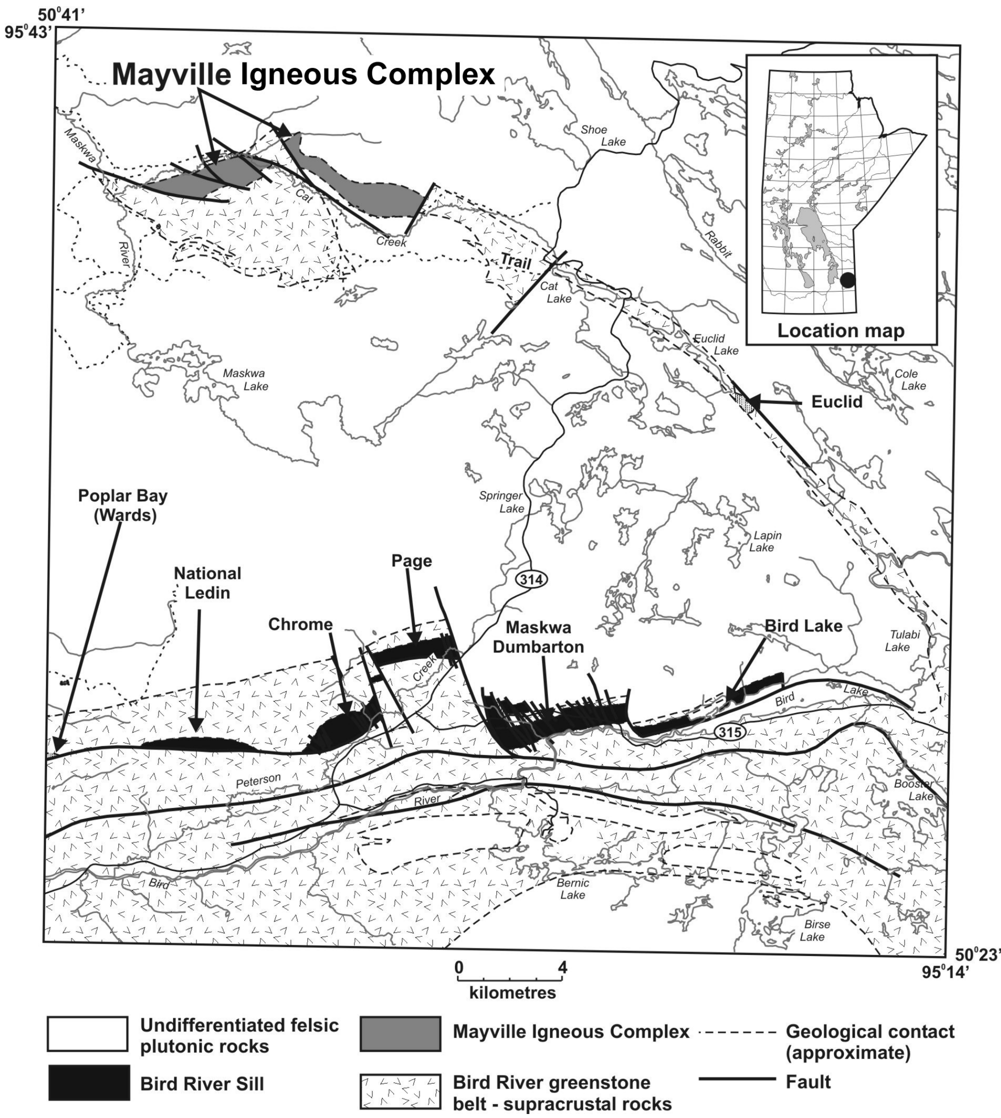

Figure 1: *Simplified geology of the Bird River greenstone belt, showing the location of the Bird River Sill and the Mayville Igneous Complex (MIC).*

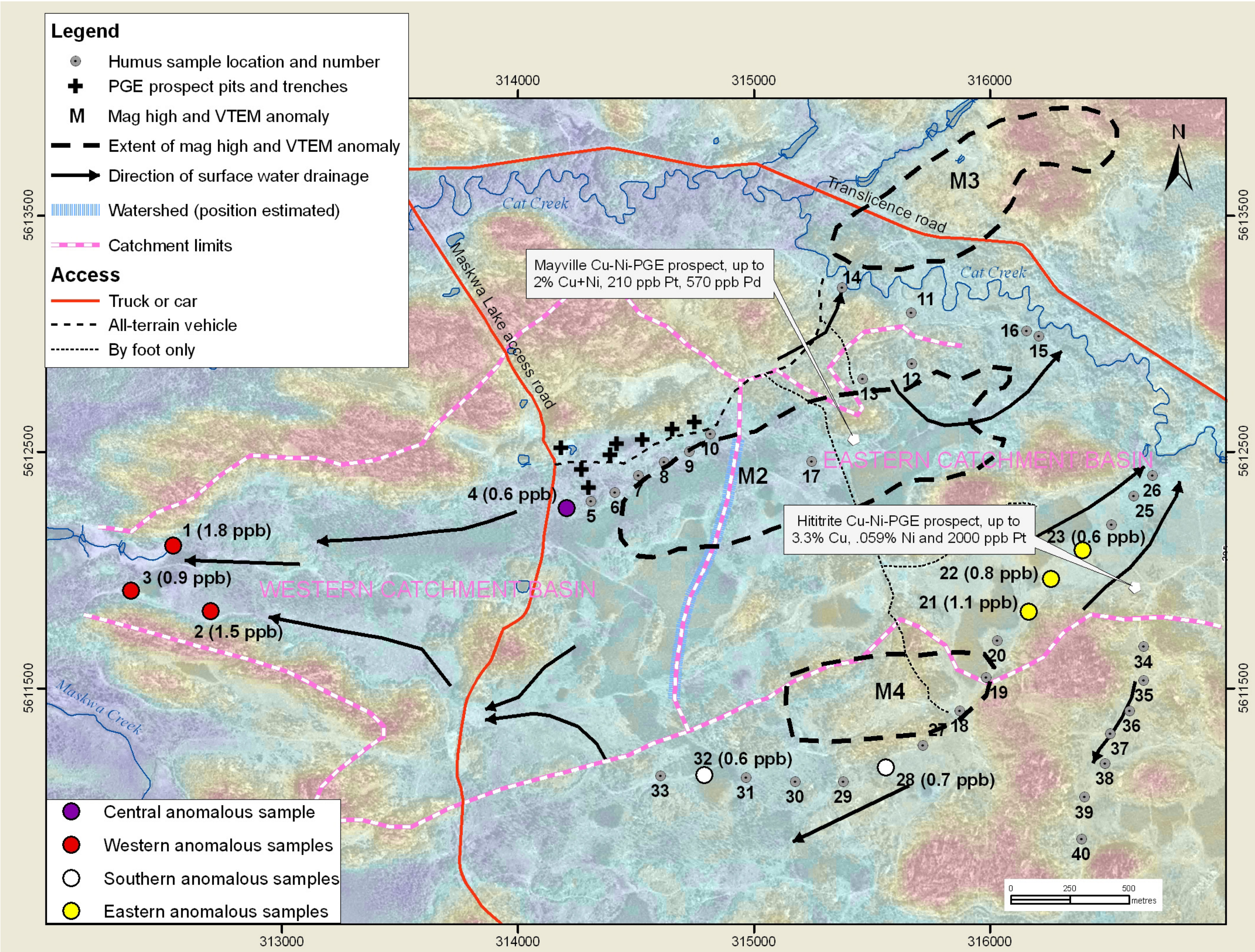

Figure 2: *Topography, surface-water drainage pattern, access, humus-sample locations and numbers, and extent and number of Versatile Time-Domain ElectroMagnetic–magnetic (VTEM-mag) anomalies in the Mayville area. VTEM-mag anomalies after Mustang Minerals Corporation (2006).*

Nipissing gabbro suite in central Ontario (Peck et al., 2001; James et al., 2002), and certain layered complexes in the Baltic Shield (Schissel et al., 2002).

Mobility of PGE in surface environments, a concept raised in the mid-1960s to 1970s, had to overcome the widespread perception by geoscientists that PGE were relatively inert. This notion was dispelled by accounts of the mobility of Pd in aqueous surface environments, such as in an analysis of the behaviour and distribution of Pd by Wood et al. (1992) and Wood (2002). Its potential use as an exploration tool was presented by Hattori and Cameron (2004) in defining the location and distribution of PGE concentrations in the Lac des Iles area, near Thunder Bay, Ontario. Fortescue et al. (1987) collected an array of humus samples, one of which carried an anomalous concentration of Pd, over what was later defined as the Roby zone of the Lac des Iles PGE deposit. Dyer and Barnett (2004) compared the geochemistry of humus, soil, water and lake-bottom sediment samples in the vicinity of several PGE-bearing targets in Ontario. They showed that the footprint of Ni and Cu anomalies was generally larger than that of Pd, making Ni and Cu anomalies easier to detect in regional geochemical surveys. The ability of vegetation to readily fix dissolved Pd near its source indicates that Pd may be used as a local vectoring tool. Cameron and Hattori (2005) presented a modern overview over worldwide geochemical exploration methods for PGE.

Geology and PGE mineralization

The MIC is a mafic-ultramafic body, at least 10 km long and 1.1 km thick, located at the contact between felsic-intermediate gneiss and wacke to the north and mafic-intermediate volcanic rocks of the Bird River greenstone belt to the south (Figure 2; Macek, 1985). The exact extent of the intrusion is unknown, since both the upper and lower contacts are poorly exposed. Peck et al. (1999) subdivided the intrusion into an upper leucogabbroic-anorthositic zone and a 200–300 m thick lower heterolithic breccia zone. The heterolithic breccia zone is characterized by blocks, up to several metres thick, of angular and embayed anorthosite surrounded and in places invaded by pyroxenite, peridotite and chromitiferous peridotite. Abundant inhomogeneously distributed pyrrhotite and subordinate chalcopyrite (varying from trace to 3%) dominate the lower part of the heterolithic breccia zone.

The most significant PGE concentrations reported in the MIC came from core in drillholes M-15 and M-16. The mineralization occurs at the base of the MIC near the sheared contact with a southern intrusion (the Copper Contact intrusion). Peck et al. (2002) described the mineralization and its tenor. Combined Pt, Pd and Au abundances of 690 ppb over 30 m in diamond-drill hole M-16 and 470 ppb over 20 m in hole M15 are highlighted by a maximum combined Au+Pt+Pd concentration of 8.5 g/t.

The Mayville mineral occurrence (Figure 2) is an approximately 35 by 60 m exposure in intensely rust-stained gabbro. Grab samples returned a maximum concentration of 520 ppb Pt and 400 ppb Pd (Theyer, 1986). The Hititrite mineral showing (Figure 2) is an historically known Pt occurrence (Wright, 1932; Theyer, 1986) in coarse-grained gabbro to melagabbro. The exposure is characterized by remobilized, very coarse grained pyrite mineralization ranging from trace to more than 15%. A table listing assay results of grab samples is contained in Theyer (1986).

Sample sites, sampling methods, sample preparation and analytical method

Hattori and Cameron, (2004) emphasized that the effectiveness of a humus sampling program in search of PGE is dependent on correctly sited sample locations, which in turn depend on a good understanding of the local topography and recognition of drainage patterns. They reported most consistent Pd concentrations in humus collected near swamps and water drainage channels. Selection of sample locations for this survey therefore favoured similar sites.

The humus layer varied considerably in composition, thickness, amount of contained water and the nature of both the humus and the substratum. Sample collection was carried out by first removing the forest litter and then hand scooping approximately 2 L of humus into cotton bags. The samples were air dried over a period of approximately 3 weeks, sieved to –80 mesh and sent to Activation Laboratories Ltd. (Actlabs) in Ancaster, Ontario for analysis (analytical code 2E). Actlabs ashed the humus and separated a 10–15 g sample that was leached using a proprietary acid extraction. The leachate was analyzed using inductively coupled plasma–mass spectrometry (ICP-MS). Detection limits with this method are 1 ppb for Au and 0.5 ppb for Pt and Pd.

Sample locations and numbers, the topography and the inferred surface-water drainage paths of the terrain underlain by the Mayville intrusion are shown in Figure 2. The area is drained by two streams: Cat Creek, which meanders in a westerly direction near the northern edge of the map, and Maskwa Creek, a north-flowing subsidiary of Cat Creek at the western edge of the map. Drainage of the large waterlogged terrain south of Cat Creek is constrained by a prominent east-striking ridge, up to 30 m high, underlain by anorthosite and leucogabbro. The ridge is breached near its eastern end by a drainage channel in which sample 14 was taken. Mineralization from the Mayville mineral occurrence and its surroundings was expected to drain into Cat Creek and therefore be detected in samples 11, 12, 15 and 16. The series of samples 4 to 10 was collected to learn about the mineralization uncovered by Exploratus Ltd. The location of sample 17 was chosen to combine the effect of the previous sample series. The series of samples 18 to 33 was collected to detect the occurrence of mineralization draining from the northwestern side of the ridge that hosts the Hititrite Cu-PGE prospect, and samples 1, 2 and 3 were collected to test for potential PGE mineralization in rocks surrounding and within the western catchment basin.

Table 1 lists sample numbers and Pd and Au concentrations (Pt was omitted, since all samples were below its detection limit of 0.5 ppb). The 'Classification' column indicates the nature of the sample site (i.e., Fen, Bog or Forest). The 'Sample site description' column contains a listing of the vegetation recognized in the vicinity of the sample site.

Discussion

The aim of this study was to test the reliability and effectiveness of humus sampling as a tool to define and delineate the extent of PGE mineralization in an area underlain by a mafic-ultramafic intrusive body. This method relies on the high solubility of Pd in aqueous surface environments facilitating its distribution and on its ready adherence to humus, resulting in Pd anomalies with a small footprint. The tight constraints on the outline of the water catchment basins and the easy identification of the drainage channels make this area an ideal test site for a method in which the recognition of surface-water flow patterns is of crucial importance.

This survey identified three humus sample clusters and an isolated sample containing anomalous Pd concentrations (Figure 2). For the purposes of this discussion, sample clusters are defined by the occurrence of at least two semicontiguous to contiguous samples containing Pd in excess of the minimum detection limit (0.5 ppb).

Western anomalous samples

The most prominent sample cluster (samples 1, 2 and 3), both in number of contiguous anomalous samples and Pd concentrations, straddles the western outflow of the western water catchment basin (Figure 2). Sample 1 was collected from the edge of a 1–2 m wide, 1 m deep channel containing water flowing slowly westward. Samples 2 and 3 were collected from a waterlogged bog assumed also to drain westward into Maskwa Creek. Palladium concentrations are significantly higher than those of most samples in this study. The origin of the anomalous Pd concentrations is unknown, although the source of the mineralization likely occurs in outcrops underlying the southern (gabbroic) and northern (anorthositic) ridges west of the watershed. In this context, it is suggested that the northern and southern ridges rimming the western catchment basin are attractive, underexplored targets for PGE mineralization.

Table 1: Description and geochemistry of humus samples, Mayville Igneous Complex.

Sample	UTM (NAD83) Easting	UTM (NAD83) Northing	Pd (ppb)	Au (ppb)	Classif-ication	Sample site description
1	312539	5612105	1.8	5	Fen	very wet; edge of creek draining swamp; tamarack, sphagnum, bulrush, reeds, sedges
2	312697	5611826	1.5	4	Bog	wet; sphagnum, birch, willow, blueberries sample collected from 10 to 30 cm depth
3	312360	5611914	0.9	3	Bog	wet; aspen, pine, labrador tea 35 cm depth
4	314206	5612264	0.6	3	Bog	wet; soggy grass, 30 cm thick waterlogged humus; stunted tama-rack, pine, willow
5	314331	5612298	-0.5	2	Forest	dry; 10 m south of pressure washed anorthosite exposure; well drained 3 cm thick humus layer
6	314412	5612329	0.6	3	Bog	wet; tamarack, pine, willows, 30 cm thick humus layer
7	314310	5612290	0.6	3	Forest	wet; spruce, willow, birch, aspen, sphagnum
8	314511	5612399	-0.5	2	Bog	wet; 30 cm thick humus layer, aspen, willows
9	314620	5612458	0.6	3	Forest	dry; aspens; 15 m W of trench; 20 cm thick humus layer
10	314727	5612501	-0.5	4	Forest	dry; 3 cm thick humus layer overlying clay; minimal leaf litter
11	314816	5612576	-0.5	3	Forest	well-drained 2 cm organics underlain by clay; bush willow, pine, aspen
12	315670	5612873	-0.5	4	Bog	wet; willow, tamarack, pine, sedges, labrador tea
13	315460	5612809	0.5	2	Bog	wet; willow, pine, sedges
14	315374	5613195	-0.5	3	Forest	dry; pine, birch, aspen, willow, 7-8 cm thick humus overlying clay
15	316209	5612991	-0.5	2	Forest	wet; birch, willow, tamarack, sedges, labrador tea
16	316157	5613013	-0.5	2	Bog	wet; sphagnum, willows, tamarack, aspen
17	315245	5612459	0.6	3	Bog	wet; aspen tamarack, willow, labrador tea, sphagnum
18	315874	5611404	0.6	2	Bog	wet; tamarack, pine, willows, sedges, labrador tea, sphagnum
19	315986	5611544	-0.5	3	Bog	wet; between escarpments 20 m south of mature spruce stand; labrador tea, sphagnum, sedges
20	316033	5611701	0.5	3	Bog	wet; willow, pine, tamarack, labrador tea, sedges
21	316163	5611823	1.1	3	Bog	wet; willow, aspen, black spruce, tamarack, labrador tea
22	316258	5611963	0.8	4	Bog	wet; dense 5-10 yrs. Growth of willow, aspen, sphagnum, sedges
23	316392	5612084	0.6	4	Bog	wet; ~ 20 years old pine, aspen, sphagnum, labrador tea, grass
24	316516	5612192	-0.5	5	Bog	wet; ~ 20 years old pine, aspen, sphagnum, labrador tea, grass
25	316612	5612313	-0.5	3	Bog	wet; recently logged (20 years) aspen and willows in clumps, labrador tea, sedges
26	316690	5612401	-0.5	4	Fen	wet; at edge of creek draining into Cat Creek; bulrushes, reeds, willows, sedges
27	315718	5611256	-0.5	6	Bog	wet; tamarack, spruce, labrador tea sphagnum
28	315558	5611164	0.7	2	Bog	wet; edge of conifer forest, labrador tea, sphagnum, sedges
29	315379	5611102	-0.5	3	Bog	wet; recently logged, aspen, sphagnum, shrubs, outcrop 10 m west
30	315176	5611102	-0.5	3	Bog	wet; tamarack, willow, labrador tea, sphagnum
31	314967	5611121	-0.5	4	Bog	wet; willow thicket; labrador tea; sphagnum
32	314789	5611133	0.6	4	Bog	wet; black spruce forest, labrador tea, sphagnum
33	314604	5611127	-0.5	15	Bog	wet; black spruce forest, labrador tea, sphagnum
34	316653	5611674	< 0.5	<1	Bog	wet; willows, aspen, tamarack, sphagnum
35	316653	5611531	< 0.5	<1	Bog	wet; willows, aspen, tamarack, sphagnum
36	316592	5611403	< 0.5	<1	Bog	wet; sphagnum, sedges
37	316510	5611307	< 0.5	<1	Bog	wet; willows, aspen, tamarack, sphagnum
38	316488	5611180	< 0.5	<1	Bog	wet; aspen, tamarack, sphagnum, sedges
39	316402	5611036	< 0.5	<1	Bog	wet; tamarack, sphagnum, sedges
40	316390	5610859	< 0.5	1	Bog	wet; sphagnum, willows, aspen

Southern anomalous samples (adjacent to VTEM anomaly M4)

Samples 28 and 32, separated by approximately 750 m, contain elevated Pd concentrations. The source of these anomalous Pd concentrations in humus is unknown, although both anomalous samples may be related to potential mineralization detected by the Mustang Minerals VTEM-mag anomaly M4 (Mustang Minerals Corporation, 2006). Sample 28 was collected from a bog located downslope of a prominent basalt ridge, in places rust-stained, that hosts the M4 VTEM-mag anomaly, and sample 32 was collected from a bog west of this ridge. Further exploration of this terrain for sulphide mineralization by surface prospecting is suggested, given the abundance of outcrops.

Southeastern anomalous samples

The source of this distinct and consistent Pd in humus anomaly, including three contiguous samples (21, 22 and 23), is interpreted to reflect the 'Hititrite' mineral exposure (Wright 1932; Theyer, 1986), a base-metals and PGE prospect exposed in two trenches underlain by gabbro (Figure 2). These anomalous humus samples were collected in a bog downslope of this mineral occurrence. It appears that this mineral occurrence is also reflected in two 'single-peak' anomalous responses located northeast of the outline of the Mustang Minerals VTEM-mag anomaly M4 (Mustang Minerals Corporation, 2006).

Central anomalous sample

An isolated anomalous sample (sample 4), collected adjacent to several rust-stained sulphide-bearing exposures, may be due to leaching of mineralization from these outcrops.

Mayville prospect and M2 anomaly

None of the humus samples collected in the northeast showed any indication of the existence of the Mayville mineral exposure (Figure 2; Theyer, 1986). This fact is exacerbated by the recent identification of a major, 1.4 km long airborne VTEM-mag geophysical anomaly (Figure 2, anomaly M2), representing the massive to disseminated sulphide mineralization that is currently being defined by Mustang Minerals. A possible reason for this is the little understood effect that the heterogeneity of the collected samples may have on metal concentrations in humus. The humus samples collected during this survey range from decayed forest litter overlying relatively well-drained sand and till beds to waterlogged bog and fen. Since the Pd in the humus samples was transported by water, it stands to reason that long-term differences in, for instance, the amount of water, the provenance of the water and possibly the rapidity of the water flow surrounding the sample may have profound effects on the Pd content of the sample.

Conclusions

Humus sampling outlined several areas containing anomalous Pd concentrations that merit follow-up. The method failed, however, to give any indication of an extensive zone of massive sulphide mineralization associated with the M2 geophysical anomaly. It is suggested that this relatively rapid, low-cost survey method has merit as an orientation tool for delineating potential exploration targets. The explorationist should strive, however, to collect samples that are as homogeneous as possible, and it should be used as a preliminary tool only, in conjunction with complementary exploration methods directed at the delineation of low-sulphide targets.

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