

The Mineralogical Composition of House Dust in Ontario, Canada

Michael Haile Woldemichael, B.Sc.

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Ottawa-Carleton Geoscience Centre
Department of Earth Sciences, University of Ottawa
Ottawa, ON, Canada

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Abstract

Despite increasing concern about the presence of heavy metals, pesticides and other toxins in indoor environments, very little is known about the physical and chemical composition of ordinary household dust. This study represents the first systematic investigation of the mineralogical composition of indoor dust in residential housing in Canada.

Specimens of dust were obtained from homes in six geographically separate cities in the Province of Ontario: two located on the metamorphic and igneous rocks of the Precambrian Canadian Shield (Thunder Bay and Sudbury), the other four located on Palaeozoic limestone and shale dominated bedrock (Barrie, Burlington, Cambridge, and Hamilton). Forty samples of household vacuum dust were obtained. The coarse fraction (80 – 300 μm) of this dust was subjected to flotation (using water) to separate the organic components (e.g. insect fragments, dander), natural and synthetic materials (e.g. fibres, plastics) from the mineral residue. The mineral fraction was then analyzed using quantitative point counting, polarizing light microscopy, powder X-ray diffraction and scanning electron microscopy methods.

Despite the great distances between the sampling localities and the distinct differences in bedrock geology, the mineral fraction of dust from all six cities is remarkably similar and dominated by quartz and feldspar, followed by lithic fragments, calcite, and amphibole. Some evidence of the influence of local geology can nevertheless be found. For example, a relatively higher proportion of sulphide minerals is observed in the two cities on the Canadian Shield where these minerals are clearly more abundant in the bedrock. Specimens from Sudbury, Canada's largest mining centre located atop a nickel-sulphide mineral deposit, showed the highest sulphide

contents. Quartz is the dominant mineral in all cities. All quartz grains have internal strain features and fluid inclusions that are indicative of a metamorphic-igneous provenance.

In all cities, sand is used on the streets as an abrasive for traction during the icy winter season. This sand is obtained in all cases from local glaciofluvial deposits that were ultimately derived principally from the rocks of the Canadian Shield in the last Pleistocene glaciations that affected all of Ontario. Thus, tracking in sand is the most plausible mechanism by which quartz was introduced into these homes since sampling was done, in all cases, in the winter season.

The results indicate that glacial deposits dominate the mineral composition of indoor dust in Ontario cities and that nature of the bedrock immediately underlying the sampling sites is relatively of minor importance.

Sommaire

Malgré l'inquiétude croissante pour la santé suscitée par la présence de métaux lourds, pesticides et autres toxines dans l'environnement intérieur, on connaît très peu au sujet des propriétés physiques et chimiques de la poussière domestique commune. Ce mémoire représente la première étude systématique de la composition minéralogique de la poussière domestique dans les résidences au Canada.

Des échantillons de poussière domestique furent prélevés dans des habitations de six villes géographiquement distinctes en l'Ontario : deux situées sur les roches métamorphiques et ignées précambriennes du Bouclier canadien (Thunder Bay et Sudbury), les autres situées sur les calcaires et shales du Paléozoïque (Barrie, Burlington, Cambridge et Hamilton). Quarante échantillons de poussière domestique furent prélevés et tamisés afin de retenir la fraction à gros grains (80 – 300 μm). Les composantes organiques (fragments d'insectes, squames) et matériaux synthétiques ou naturels (fibres, plastiques) furent séparés du résidu minéral par flottaison dans l'eau. La composition minéralogique de ce résidu minéral fut ensuite déterminée par comptage de points, microscopie en lumière polarisante, diffraction-X sur poudres et microscopie électronique par balayage.

Malgré les vastes distances entre les sites de prélèvement des échantillons et la nature distincte du sous-sol rocheux de ces sites, la fraction minéralogique de la poussière reste remarquablement similaire et est dominée par le quartz et le feldspath, suivi de la calcite, l'amphibole, et les fragments lithiques. On parvient tout de même à repérer une contribution du sous-sol rocheux local. Par exemple, la teneur en sulfures parmi les minéraux observés dans les échantillons des deux villes situées sur le socle

précambrien, où les roches sont enrichies en sulfures, est plus élevée. Les échantillons prélevés dans les résidences à Sudbury, la plus importante ville minière du pays située au-dessus d'un important gisement de sulfures de nickel, contiennent les teneurs les plus élevées en sulfures. Cependant, le quartz est le principal minéral dans tous les échantillons, quel que soit leur provenance. Ce quartz possède des bandes de déformation ainsi que des inclusions fluides, deux indications d'une provenance ignée ou métamorphique.

Dans toutes les villes visées par cette étude on utilise l'hiver le sable comme abrasif pour assurer une meilleure traction sur les routes et trottoirs. Dans tous les cas, ce sable provient de dépôts fluvioglaciaires locaux laissés lors de la dernière glaciation Pléistocène qui a affecté toute l'Ontario. La provenance ultime de ce sable fluvioglaciaire est principalement les roches du Bouclier canadien. Puisque que l'échantillonnage a eu lieu en hiver, il semble donc probable que ce sable se soit introduit dans les résidences par voie d'entraînement sur les chaussures des occupants.

Les résultats initiaux nous indiquent que la composition de la fraction minéralogique de la poussière domestique résidentielle dans six villes de l'Ontario est en grande partie contrôlée par la nature des dépôts glaciaux et que la nature du socle rocheux est d'importance subsidiaire.

Abstract in Amharic

ምንም እንኳን በመኖሪያ ቤት ውስጥ ስለሚገኙ አንዳንድ ጎጂ የሆኑ ንጥረ ነገሮች ለምሳሌ እንደ መርዛማነት ያላቸው ብረታ ብረቶች፣ የጥቃቅን ነፍሳት ወይም ትንሻ መግደያ መርዞች፣ እንዲሁም ለሎች አይነት በካይ ኬሚካሎች እንዳሉ አንዳንድ የውጭ ጥናቶች እያሳዩ ቢመጡም፣ ስለ ተራ የቤት ውስጥ ብናኝ (ደስት) ግን ብዙም እውቀቱ የለም። ስለዚህም ይህ ጥናት በአይነቱ የመጀመሪያ በሆነ መልኩ በቤት ውስጥ ስለሚገኙ ተፈጥሮዊ ቁስ የሆኑ ንጥረ ነገሮች (ማእድናት) በሳይንሳዊ መንገድ አጥንቶ አቅርቧል። ይህ ጥናት ቦታውን ያደረገው በካናዳ በሚገኙ መኖሪያ ቤቶች ላይ ነው። ይህም ጥናት የሚያተኩረው ምን አይነት ተፈጥሮዊ ቁስ ነገሮች (minerals) በቤታችን ብናኝ ውስጥ አሉ? የኬሚካል ጸባያቸውስ ምን ይመስላል? እንዴትስ ወደ ቤታችን ዘልቀው ይገባሉ?

ለዚህ ጥናት የሚያስፈልጉ ናሙናዎች የተወሰዱት ከስድስት የተለያዩ የካናዳ አንታሪካ ግዛት ከተማዎች ውስጥ ሲሆኑ፣ ከነዚህም ሁለቱ (ተንደር ቤይ እና ሰድቦሪ) የሚገኙት የኢግኒየስ አለቶች እና የሜታሞርፊክ አለቶች በሚበዙበት በተለምዶ የካናዳን ፕሪካምብሪያን ሺልድ በመባል በሚጠራው የሰሜን የግዛቱ ክልል ውስጥ ሲሆን፣ ሌሎቹ ደግሞ (ባሪ፣ በርሊንግተን፣ ካምብሪጅ፣ እንዲሁም ሃሚልተን) የሚገኙት በደዳባዊው የአንታሪካ ግዛት ውስጥ ላይም ስቶን እና ሼል የሚባሉት የድንጋይ አይነቶች በብዛት በሚገኙበት የሴንት ሎውረንት ሸሎቃማ ቦታ ላይ ነው። ከአርባ በላይ የቤት ውስጥ ብናኝ/ደስት ናሙናዎች ለዚህ ጥናት ተሰብስበዋል። የናሙናዎቹም መጠን፣ ክብደት እንዲሁም ይዘት ተለክቶ ከ 80 - 300 ማይክሮ ሚትር ያላቸው ብቻ ለማይስክሮስኮፒክ ጥናት በሚያስችል መልኩ ተዘጋጅተዋል።

አዘገጃጀታቸውም ፡- ተፈጥሮዊ የሆኑትን ንጥረ ነገሮች ለማስቀረት በሚል ሲሆን ህይወት ያላቸው እንዲሁም ህይወት ካላቸው የተገኙ ቁሶችን (ለምሳሌ ትንኞችን፣ ጸጉርን) ብሎም ሰው ሰራሰሽ የሆኑ ቁሶችን (ሴንቴቲክ ነገሮችን) ለማስወገድ ወሃ ውስጥ በማድረግ በማንሳፈፍ ለበለጠ ሳይንሳዊ ጥናት በላቦራቶሪ ውስጥ የማይስክሮስኮፒክ፣ የስካንደንግ ኤሌክትሮን ማይስክሮስኮፒ እንዲሁም ኤክስ-ራዲዮ-ራክሽን ምርምር ተደርጎባቸዋል።

የኛ ጥናት ለመጀመሪያ ጊዜ እንደሚያሳየው ናሙናዎቹ የተወሰዱበት ቦታዎች በጣም የተራራቁና ከክርሰ ምድራዊም አንጻር በጣም የማይገናኙ ቢሆንም እጅግ በሚገርም መልኩ እነዚህ ከስድስቱም ከተሞች የተወሰዱት የቤት ውስጥ ብናኞች ተመሳሳይ ነበሩ። ከነዚህም ተፈጥሮዊ ቁስ ነገሮች (ሚነራልስ) ኳርትዝ እና ፊልድስፓር በብዛት በሁሉም ቤቶች ውስጥ ሲገኙ ከነሱ ቀጥለው ደግሞ የተለያዩ የድንጋይ ሽርፍቶች፣ የ ካርቦኔት ሚነራልስ ውጤቶች (ካልሳይት እና ቾክ) እንዲሁም አምፊቦል የተሰኙ ሚነራሎች በቅደም ተከተል በምርመራው ተገኝተዋል። ሆኖም ግን

በአንዳንድ ወቅት እነዚህ ቤቶች ያሉበት ቦታ እና የሚገኙበት የአካባቢዊ አየር እንዲሁም የከርሰ ምድሩ አይነት እና አቀማመጥ በቤቶቹ ውስጥ ስለሚገኙት ሚኒራልስ የሚነግሩን ነገር እንዳለ ይሔው ጥናታዊ ምርምራችን ያሳያል - ለምሳሌ ያህል በቁጥር በዛ ያሉ የሰልፋይድ ሚኒራልስ ከካናዲያን ፕሪካምብሪያን ሺልድ የመጡ ናሞናዎች ላይ በብዛት ታይቷል። ይህም ሊሆን የቻለው ሰድበሪ ከተማ ኒኬል-ሰልፋይድ የሚባለውን ጨምሮ በርካታ የከርሰ ምድር ሚኒራሎችን የምታወጣ የካናዳ ከተማ በመሆኗ እንደሆነ ይሄው ጥናት ያመለክታል። በሁሉም ናሞናዎች ኳርትዝ በብዛት በመገኘት ቀዳሚነቱን ይዟል። ሁሉም የኳርትዝ ፍሬዎች በውስጣቸው ፈሳሽ ነገር የያዙ ሲሆን እንዲሁም መስመር የሚምስሉ ውስጣዊ ምልክቶች ታይቶውባቸዋል። እነዚህ ምልክቶች ደግሞ የሚስተዋሉት በ ኢግኒየስ አለቶች እና የሜታሞርፊክ አለቶች ላይ ብቻ ነው። ከላይ እንዳስቀመጥነው ደግሞ አራቱ ከተሞች የሚገኝኦት በደዳባዊው የአንታሪኦ ግዛት ውስጥ ላይም ስቶን እና ሼል የሚባሉት የድንጋይ አይነቶች በብዛት በሚገኙበት የ ሴንት ሎውረንት ሽሎቃማ ቦታ ላይ ነው - ስለዚህም እንዴት ይህ የኳርትዝ አይነት በደቡብ ክልል ተገኘ የሚል ጥያቄ ያስነሳል።

እንደሚታወቀው በነዚህ የካናዳ ከተሞች አሸዋ (በውስጡ ኳርትዝ አለው) በክረምቱ ወራት በየመንገዶቻቸው ላይ በረዶውን ለማቅለጥ ይረዳ ዘንድ የበተናል። በአንታሪኦ ግዛት ደግሞ አሸዋው የመጣው ከሰሜኑ ክፍል (ከካናዲያን ፕሪካምብሪያን ሺልድ) በመጨረሻው የበረዶ ዘመን (ፕሊዮስቶሲን ግላሺዮሽን) ጊዜ እንደሆነ ይታወቃል። ይህም ታሪካዊ ክንውን የአንታሪኦ ግዛት ከሞላ ጎደል ተመሳሳይ የአሸዋ አይነት እንዲኖራት አድርጓል። ስለዚህም ከመንገድ ላይ ወደ ቤት ውስጥ የሚገባው የአሸዋ (ኳርትዝ) አይነት መመሳሰለና በብዛትም ቅድሚያውን ሊይዝ ችሏል።

የዚህ ጥናት ውጤቶቹም እንደሚያመለክቱት በበረዶ ዘመን ጊዜ የተከማቹት የሚኒራል አይነቶች በቤቶቹ ውስጥ ባሉት ብናኞች ላይ አዎንታዊ ተጽእኖ ሲያደርሱ፡ ከከርሰ ምድሩ የተገኙት የሚኒራል አይነቶች ግን በቤት ውስጥ ብናኞች ላይ ይህን ያህል እስተዎጾ አልነበራቸውም።

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Table of Contents

Abstract	ii
Sommaire	iv
Abstract in Amharic	vi
Acknowledgments	viii
Table of Contents	ix
List of Tables	xi
List of Figures	xiii
List of Abbreviations	xix
1.0 Introduction	1
1.1 <i>Background</i>	1
1.2 <i>Purpose of study</i>	3
1.3 <i>Study scope and objectives</i>	4
1.4 <i>Novel aspects of this study</i>	5
2.0 Location, physiography and geology	6
2.1 <i>Six Ontario cities</i>	6
2.2 <i>The City of Barrie</i>	8
2.2.1 <i>Location, size and population of Barrie</i>	8
2.2.2 <i>Climate of Barrie</i>	8
2.2.3 <i>Soil, surficial and bedrock geology of Barrie</i>	9
2.3 <i>The City of Burlington</i>	9
2.3.1 <i>Location, size and population of Burlington</i>	9
2.3.2 <i>Climate of Burlington</i>	10
2.2.3 <i>Soil, surficial and bedrock geology of Burlington</i>	10
2.4 <i>The City of Cambridge</i>	11
2.4.1 <i>Location, size and population of Cambridge</i>	11
2.4.2 <i>Climate of Cambridge</i>	11
2.4.3 <i>Soil, surficial and bedrock geology of Cambridge</i>	12
2.5 <i>The City of Hamilton</i>	12
2.5.1 <i>Location, size and population of Hamilton</i>	12
2.5.2 <i>Climate of Hamilton</i>	13
2.5.3 <i>Soil, surficial and bedrock geology of Hamilton</i>	13
2.6 <i>The City of Greater Sudbury</i>	14
2.6.1 <i>Location, size and population of Sudbury</i>	14
2.6.2 <i>Climate of Sudbury</i>	14
2.6.3 <i>Soil, surficial and bedrock geology of Sudbury</i>	15
2.7 <i>The City of Thunder Bay</i>	17
2.7.1 <i>Location, size and population of Thunder Bay</i>	17
2.7.2 <i>Climate of Thunder Bay</i>	18
2.7.3 <i>Soil, surficial and bedrock geology of Thunder Bay</i>	18
3.0 Material and Methods	20
3.1 <i>Home selection and dust sampling method</i>	20
3.2 <i>Sample preparation</i>	20
3.3 <i>Description of house dust</i>	22

3.4	<i>Methods</i>	22
3.4.1	Polarized light microscopy.....	22
3.4.2	Scanning electron microscopy.....	24
3.4.3	Powder X-ray diffraction	25
3.5	<i>Mineralogical abundance by point counting</i>	26
4.0	Results	27
4.1	<i>Percent abundance mineralogy of house dust</i>	27
4.2	<i>Major mineral components</i>	29
4.2.1	Quartz	30
4.2.1.1	Quartz contents	31
4.2.2	Feldspar minerals	35
4.2.2.1	Feldspar contents	37
4.2.3	Lithic fragments.....	39
4.2.3.1	Lithic fragment contents	39
4.2.4	Carbonate minerals.....	42
4.2.4.1	Carbonate minerals contents	42
4.3	<i>Minor mineral components</i>	45
4.3.1	Amphibole minerals.....	45
4.3.2	Mica minerals	48
4.3.3	Chlorite minerals.....	49
4.3.3.1	Chlorite minerals contents	50
4.3.4	Sulphide minerals.....	50
4.4	<i>Trace mineral components</i>	53
4.4.1	Pyroxene.....	53
4.4.2	Almandine garnet	54
4.5	<i>Metallic components of house dust</i>	56
4.6	<i>Non-mineral components of house dust</i>	56
4.7	<i>Unidentified minerals</i>	57
4.8	<i>Summary of results</i>	57
5.0	Discussion	58
5.1	<i>Contribution of the local bedrock geology to the mineralogical composition of the house dust</i>	58
5.1.1	Contents of quartz in house dust and its relation to local geology.....	60
5.1.2	Contents of feldspar minerals in house dust and its relation to local geology ..	62
5.1.3	Contents of lithic fragments in house dust and its relation to local geology.....	63
5.1.4	Contents of selected minerals in house dust and their relation to local geology	65
5.1.4.1	Contents of carbonate minerals in house dust and the local geology	66
5.1.4.2	Contents of sulphide minerals in house dust and the local geology	68
5.2	<i>Provenance of mineral grains in the house dust</i>	69
6.0	Conclusions, limitations and significance	72
6.1	<i>Conclusions</i>	72
6.2	<i>Limitations</i>	73
6.3	<i>Significance</i>	74
	References	75
A.	Appendix A	83
	Mineralogy of house dust.....	83
B.	Appendix B	179

List of Tables

Table 2.1	Monthly precipitation and temperature data for Barrie.....	8
Table 2.2	Monthly precipitation and temperature data for Burlington	10
Table 2.3	Monthly precipitation and temperature data for Cambridge.....	11
Table 2.4	Monthly precipitation and temperature data for Hamilton	13
Table 2.5	Monthly precipitation and temperature data for Greater Sudbury	15
Table 2.6	Monthly precipitation and temperature data for Thunder Bay.....	18
Table 4.1	Total average content of major mineral components in house dust.....	30
Table 4.2	Summary of the statistical values of quartz contents in house dust from the six Ontario cities (ab %) included in the study area.....	34
Table 4.3.	Summary of the statistical values of feldspar content in the house dust from the six Ontario cities (ab %) included in the study area.....	38
Table 4.4	Summary of the statistical values of lithic fragment content in the house dust from the six Ontario cities (ab %) included in the study area.....	41
Table 4.5	Summary of the statistical values of carbonate minerals content in the house dust from the six Ontario cities (ab %) included in the study area.....	44
Table 4.6	Total average contents of minor minerals in house dust.....	45
Table 4.7	Summary of the statistical values of amphiboles content in the house dust from the six Ontario cities (ab %) included in the study area.....	47
Table 4.8	Summary of the statistical values of biotite content in the house dust from the six Ontario cities (ab %) included in the study area.....	49
Table 4.9	Summary of the statistical values of chlorite content in the house dust from the six Ontario cities (ab %) included in the study area.....	50
Table 4.10	Summary of the statistical values of sulphide minerals content in the house dust from the six Ontario cities (ab %) included in the study area.....	51
Table 4.11	Average contents of trace minerals in house dust.....	53
Table 5.1	Content of selected minerals in house dust from cities located on Paleozoic and Precambrian bedrock in Ontario.....	60
Table 5.2.	Content of selected minerals in house dust from homes located on Paleozoic bedrock and Precambrian Canadian Shield.....	66
Table 5.3	Potential sources of some common minerals in house dust.....	71
Table A.1	Percent abundance mineralogy of house dust specimens from 40 homes in six Ontario cities	85
Table A.2	Summary of minerals in specimen BA - 06	88
Table A.3	Summary of minerals in specimen BA - 21	89
Table A.4	Summary of minerals in specimen BA - 23	90
Table A.5	Summary of minerals in specimen BA - 36.....	95
Table A.6	Summary of minerals in specimen BA - 37.....	98
Table A.7	Summary of minerals in specimen BA - 45.....	102
Table A.8	Summary of minerals in specimen BA - 47.....	105
Table A.9	Summary of minerals in specimen BA - 54.....	109
Table A.10	Summary of minerals in specimen BU - 39.....	114
Table A.11	Summary of minerals in specimen BU - 46.....	115
Table A.12	Summary of minerals in specimen BU - 47.....	117
Table A.13	Summary of minerals in specimen BU - 54.....	118
Table A.14	Summary of minerals in specimen BU - 55.....	120

Table A.15	Summary of minerals in specimen BU - 63	122
Table A.16	Summary of minerals in specimen CA - 03	124
Table A.17	Summary of minerals in specimen CA - 12	129
Table A.18	Summary of minerals in specimen CA - 13	132
Table A.19	Summary of minerals in specimen CA - 76	135
Table A.20	Summary of minerals in specimen CA - 81	137
Table A.21	Summary of minerals in specimen HA - 03	141
Table A.22	Summary of minerals in specimen HA - 06	142
Table A.23	Summary of minerals in specimen HA - 13	145
Table A.24	Summary of minerals in specimen HA - 63	148
Table A.25	Summary of minerals in specimen HA - 104	151
Table A.26	Summary of minerals in specimen SU - 07	153
Table A.27	Summary of minerals in specimen SU - 08	155
Table A.28	Summary of minerals in specimen SU - 10	157
Table A.29	Summary of minerals in specimen SU - 25	159
Table A.30	Summary of minerals in specimen SU - 26	163
Table A.31	Summary of minerals in specimen SU - 36	165
Table A.32	Summary of minerals in specimen TB - 09	167
Table A.33	Summary of minerals in specimen TB - 18	169
Table A.34	Summary of minerals in specimen TB - 26	172
Table A.35	Summary of minerals in specimen TB - 30	173
Table A.36	Summary of minerals in specimen TB - 59	176

List of Figures

Figure 2.1. Location map of the study areas. Two of the cities are on the Canadian Shield (Thunder Bay and Sudbury, red squares) and the other four are on the St. Lawrence Lowland of southern Ontario (Barrie, Burlington, Cambridge and Hamilton, blue circle) (map from Johnson et al., 1992).	7
Figure 2.2. Regional geology of the Sudbury area (Riller et al., 1996).	16
Figure 2.3. Bedrock geology of the Sudbury area (data from OGS Earth, 1:250,000 bedrock geology, 2009).	17
Figure 2.4. Bedrock geology of the Thunder Bay area (data from Ontario Geological Survey Earth Map, OGS Earth, 1:250,000 bedrock geology, 2009).	19
Figure 3.1 Representative example of vacuumed specimen of house dust (80 - 300 μm).	21
Figure 3.2 Polished thin section of house dust (30 μm) in microscopic stage holder.	23
Figure 3.3. Examples of photomicrographs of mounted dust grains observed under plane-polarized light: A) Unspecified amphibole grain, B) Angular quartz grain, C) Iron oxide fragments, D) Aphanatic lithic fragments and fragment of insect antenna (FOV = 0.22 mm).	24
Figure 4.1. Photomicrograph of a quartz grain with myriads of fluid inclusions. The grain also shows a conchoidal fracture on the right. (PPOL, FOV = 0.55 mm).	31
Figure 4.2. Quartz content in house dust from the six Ontario cities (ab %) included in the study. Hamilton samples show the least amount of quartz whereas samples from Burlington record the highest quartz content in their house dust.	34
Figure 4.3. Photomicrograph of a turbid feldspar grain (PPOL, FOV = 0.55 mm).	36
Figure 4.4. Scanning electron photomicrograph of a perthitic feldspar grain seen in backscattered-electron imaging.	36
Figure 4.5. Feldspar contents in house dust from the six Ontario cities (ab %) included in the study. On average Cambridge samples show the highest average feldspar contents whereas Burlington samples have the lowest average feldspar contents in their house dust.	38
Figure 4.6. Photomicrograph of lithic fragments comprised of quartz, feldspar and muscovite, (PPOL, FOV = 0.55 mm).	39
Figure 4.7. Content of lithic fragments in house dust from the six Ontario cities (ab %) included in the study. The content of lithic fragments in house dust can be as low as approximately 10% and as high as 25%.	41
Figure 4.8. Content of carbonate minerals in house dust from the six Ontario cities (ab %) included in the study. Hamilton samples show the highest amount of carbonate minerals of all six cities.	44
Figure 4.9. Photomicrograph of hornblende grains (PPOL, FOV = 0.55 mm).	46
Figure 4.10. Contents of amphibole minerals in house dust from the six Ontario cities (ab %) included in the study. Dust specimens from Burlington and Hamilton have the lowest average amphibole contents. In contrast, dust from Sudbury and Thunder Bay have the highest abundances.	47
Figure 4.11. Chlorite mineral in house dust with brownish green colour and one set of cleavage (PPOL, FOV = 0.55 mm).	49

Figure 4.12. Contents of sulphide minerals in house dust from the six Ontario cities (ab %) included in the study. On average, Shield specimens have a higher abundance of sulphide minerals in their house dust than specimens from cities located on Paleozoic bedrock. This is also true in all Burlington specimens and all except one Hamilton sample, where sulphides were absent.	51
Figure 4.13. Trace minerals were relatively abundant in samples from the Shield. For example, mineral rutile was never found in Barrie specimens but it presented in all of Shield specimens.....	54
Figure 5.1. Average feldspar contents (ab %) for each of the six Ontario cities. Feldspar contents are rather uniform, regardless of the location on the Canadian Shield (red) (Fld-Precambrian mean = 21.8 %, SD = 5.9 %, n = 11) or the St Lawrence Platform (blue) (Fld-Paleozoic mean = 22.2%, SD = 4.7 %, n = 24).	63
Figure 5.2. Average contents of lithic fragments in each of the six Ontario cities. The average contents of lithic fragments in the dust from the cities on the Canadian Shield (red) (LF-Precambrian mean = 19.7%, SD = 4.7%, n = 11) and St. Lawrence Platforms (blue) (LF-Paleozoic mean = 18.8%, SD = 4 %, n = 24) are virtually identical.	64
Figure 5.3. Average carbonate minerals contents in house dust as compared in six cities. The average carbonate mineral content for the four cities located on the Paleozoic bedrock (17 ab %) is significantly higher than the average for the two cities located on the Canadian Shield (6.4 ab %).	68
Figure 5.4. Average sulphide minerals content in house dust as compared in two geologic settings. The average sulphide mineral content for the four cities located on the Paleozoic bedrock (1.2 ab %) is notably lower than the average for the two cities located on the Canadian Shield (3.3 ab %).	69
Figure A.1. Photomicrograph of biotite grains in specimen BA -23 (PPOL, FOV = 0.55 mm).	91
Figure A.2. Photomicrograph of angular quartz grain with fluid inclusions in specimen BA – 23 (PPOL, FOV = 0.55 mm).	92
Figure A.3. Photomicrograph of galena grain in incident-light polarizing microscopy (PPOL, FOV = 0.55 mm).	93
Figure A.4. Photomicrograph of lithic fragments comprised of quartz, feldspar and muscovite, (PPOL, FOV = 0.55 mm).	94
Figure A.5. Photomicrograph of lithic fragments comprised of quartz, feldspar, and muscovite (XPOL, FOV = 0.55 mm).	94
Figure A.6. Photomicrograph of perthitic feldspar grain (PPOL, FOV = 0.55 mm).	96
Figure A.7. Scanning electron photomicrograph of lamellar perthitic feldspar seen in backscattered-electron imaging.	96
Figure A.8. Carbcium carbonate powder in specimen BA – 36. Some individual grains fall within the clay size fraction (backscattered-electron image).	97
Figure A.9. Photomicrograph of hardwood cellulose in house dust of specimen BA – 37 (PPOL, FOV = 0.55 mm).	99
Figure A.10. Subhedral hornblende grain in specimen BA – 37. (PPOL, FOV= 0.55mm).	100
Figure A.11. Photomicrograph of titanium bearing magnetite mineral, under plane polarized reflected light (PPOL, FOV = 0.55 mm).	101

Figure A.12. Photomicrograph of garnet grain in specimen BA-45 (PPOL, FOV = 0.55 mm).	103
Figure A.13. Photomicrograph of angular hornblende grains in specimen BA-45 (PPOL, FOV = 0.55 mm).	104
Figure A.14. Photomicrograph of feldspar in specimen BA-45 (PPOL, FOV = 0.55 mm).	104
Figure A.15. Photomicrograph of a microcline grain in specimen BA-47 showing the characterising grid-twinning of this K-feldspar polymorph (PPOL, FOV = 0.55 mm).	106
Figure A.16. Photomicrograph of a microcline grain in specimen BA-47 showing the characterising grid-twinning of this K-feldspar polymorph (XPOL, FOV = 0.55 mm).	107
Figure A.17. Photomicrograph of a pyrite mineral in specimen BA - 47 under plane-polarized reflected light (PPOL, FOV = 0.05 mm).	107
Figure A.18. Photomicrograph of metallic welding spheres in specimen BA - 47 (PPOL, FOV = 0.55 mm).	108
Figure A.19. Photomicrograph of metal welding sphere in specimen BA – 47 under plane polarized reflected light (PPOL, FOV = 0.55 mm).	108
Figure A.20. Photomicrograph of metallic particle/copper wire in specimen BA - 54 (PPOL, FOV = 0.55 mm).	110
Figure A.21. Metallic particle/copper wire under plane polarized reflected light in specimen BA - 54 (PPOL, FOV = 0.55 mm).	110
Figure A.22. Photomicrograph of pale-green pyroxene adjacent to brownish biotite in specimen BA - 54. Note also the presence of small grains of calcite in the meltmount. Under crossed polars, these grains showed the characteristic high birefringence of all carbonate minerals. Note also the synthetic fibre (most likely rayon) to the left of the biotite and pyroxene grains (PPOL, FOV = 0.55 mm).	111
Figure A.23. Photomicrograph of greenish amphibole next to slag in specimen BA - 54 (PPOL, FOV = 0.55 mm).	112
Figure A.24. Photomicrograph of chlorite grain at centre of the plate next to a hornblende grain in specimen BA - 54 (PPOL, FOV = 0.55 mm).	112
Figure A.25. Photomicrograph of the overview of the BU 46 sample, quartz dominated specimen, (PPOL, FOV = 1.1 mm).	116
Figure A.26. Photomicrograph of the overview of the BU 46 sample, quartz dominated specimen, (XPL, FOV = 0.55 mm). Due to the inherent difficulty of preparing thin sections from house dust, thickness of resistant minerals was difficult to control and as a result the quartz grains display high birefringence due to greater than standard thickness (30 μ m).	116
Figure A.27. Photomicrograph of feldspar minerals in specimen BU - 54 (PPOL, FOV = 0.55 mm).	119
Figure A.28. Amphibole minerals showing pale green colour and dark brown colour in specimen BU - 54 (PPOL, FOV = 0.55 mm).	119
Figure A.29. Plant remains surrounded by synthetic materials like dark slag and dirt in specimen BU - 55 (PPOL, FOV = 1.1 mm).	121
Figure A.30. A photomicrograph of an overview of specimen CA-03 dominated by quartz and feldspar with few dolomite grains (PPOL, FOV = 1.1 mm).	125

Figure A.31. Unknown sulphide minerals in specimen CA -03 seen under plane polarized reflected light (PPOL, FOV = 1.1 mm).....	125
Figure A.32. Photomicrograph of a rusted iron oxide (hematite) present in specimen CA -03, under plane polarized reflected light (PPOL, FOV = 0.55 mm).....	126
Figure A.33. SEM secondary-electron image of iron oxide in specimen CA -03. SEM was used to verify the chemical composition of the mineral hematite.	126
Figure A.34. SEM secondary-electron image showing the mineralogical occurrence of ilmenite minerals in specimen CA -03.....	127
Figure A.35. Photomicrograph of dolomite minerals in specimen CA -03 (PPOL, FOV = 1.1 mm).....	127
Figure A.36. SEM secondary-electron showing fractures in dolomite in specimen CA -03.....	128
Figure A.37. Photomicrograph of plagioclase feldspar grains in specimen CA -12 (PPOL, FOV = 0.55 mm).....	130
Figure A.38. Photomicrograph of magnetite under plane polarized reflected light in specimen CA-12 (PPOL, FOV = 1.1 mm).....	130
Figure A.39. Photomicrograph of magnetite under plane polarized reflected light in specimen CA -12 (PPOL, FOV = 1.1 mm).....	131
Figure A.40. Photomicrograph of magnetite-ilmenite exsolution lamellae under plane polarized reflected light in specimen CA-12 (PPOL, FOV = 1.1 mm).....	131
Figure A.41. Photomicrograph of quartz grain with fluid inclusions in specimen CA-13 (PPOL, FOV = 1.1 mm).....	133
Figure A.42. Photomicrograph of calcite minerals in specimen CA-13 (PPOL, FOV = 0.55 mm).....	134
Figure A.43. Photomicrograph of calcite minerals at centre of the plate showing high birefringence, quartz at the right bottom corner in specimen CA-13 (XPL, FOV = 0.55 mm).....	134
Figure A.44. Photomicrograph of fluid inclusions and strain features in quartz mineral in specimen CA-76 (PPOL, FOV = 0.55 mm).....	136
Figure A.45. Photomicrograph of magnetite under plane polarized reflected light in specimen CA-76 (PPOL, FOV = 0.55 mm).....	136
Figure A.46. Photomicrograph of rounded shape quartz and plagioclase in specimen CA - 81 (PPOL, FOV = 0.55 mm).....	138
Figure A.47. Plagioclase, right side of the two grains, showing polysynthetic twinning of albite in specimen CA - 81 (PPOL, FOV = 0.55 mm). Note the quartz grain is rounded.....	138
Figure A.48. Photomicrograph of quartz with fluid inclusion at the centre of the plate, synthetic fibres on the right upper corner of the slide in specimen CA - 81 (XPL, FOV = 0.55 mm).....	139
Figure A.49. Carbcium carbonate materials, most likely cement that may be derived from a recent construction were observed in this specimen HA-06. The author does not count these materials as carbonate minerals but grouped them as lithic fragments. They are represented here because this specimen is full of this material (XPL, FOV = 0.55 mm).....	143
Figure A.50. Metallic particles dominates this specimen of HA-06 (PPOL, FOV = 0.55 mm).....	143

Figure A.51. Photomicrograph of metallic particle under plane polarized reflected light in specimen HA-06 (PPOL, FOV = 0.55 mm).....	144
Figure A.52. In this specimen HA - 06 human hairs were observed in higher numbers than all other specimens (PPOL, FOV = 0.05 mm).	144
Figure A.53. An overview of minerals in specimen HA-13. The light coloured minerals are quartz and feldspar (PPOL, FOV = 2.2 mm).....	146
Figure A.54. Photomicrograph of titanomagnetite, unusual mineral in house dust under plane polarized reflected light in specimen HA-13 (PPOL, FOV = 1.1 mm).....	147
Figure A.55. Specimen HA-13 showed unknown materials with high reflection under plane polarized reflected light (PPOL, FOV = 0.55 mm).	147
Figure A.56. Rounded shape beach sand in Hamilton specimen HA-63 (PPOL, FOV = 0.55 mm).	149
Figure A.57. Beach sand, rounded. Note, the house dust of this home (HA-63) is dominated by this type of sand (XPL, FOV = 0.55 mm).	149
Figure A.58. Photomicrograph of a brownish colour biotite grain with a perfect cleavage in specimen HA-63 (PPOL, FOV = 0.55 mm).....	149
Figure A.59. Photomicrograph of typical calcite minerals in house dust that are crushed into pieces due to calcite's low hardness (HA-63) (PPOL, FOV = 0.55 mm).	150
Figure A.60. Calcite minerals in Hamilton specimen HA-63 (XPL, FOV = 0.55 mm).	150
Figure A.61. Photomicrograph of a brownish green chlorite mineral in specimen SU-08 (PPOL, FOV = 0.55 mm).	156
Figure A.62. A brassy yellow chalcopyrite grain with a size fraction of 0.35 μm seen under plane polarized reflected light in specimen SU-10 (PPOL, FOV = 0.55 mm).	158
Figure A.63. Plagioclase feldspar grain with several inclusions of mafic silicate minerals; (Act) actinolite, (Bt) biotite, (Chl) chlorite (SEM back-scattered electron image of a feldspar grain in specimen SU-25).....	160
Figure A.64. Photomicrograph of a quartz grain with fluid inclusions in specimen SU-25 (PPOL, FOV = 0.55 mm).	161
Figure A.65. Lithic fragments with several inclusions of Fsp (Feldspar), Mag (Magnetite), Ep (Epidote) (SEM back-scattered image of rock fragment in specimen SU-25)	162
Figure A.66. Lithic fragments with several inclusions of Ttn (Titanite), Chl (Chlorite), Ab (Albite) (SEM back-scattered image of rock fragment in specimen SU-25)...	162
Figure A.67. Lithic fragment, insect antenna, and Grt (Garnet) mineral together in house dust (SU-26) (PPOL, FOV = 0.55 mm).....	164
Figure A.68. Photomicrograph of angular quartz grain with a conchoidal fracture observed under plane polarized light, in specimen SU-26.	164
Figure A.69. Photomicrograph of metallic particles in specimen TB-09 (PPOL, FOV = 0.55 mm).	168
Figure A.70. Photomicrograph of unidentified metallic particle under plane polarized reflected light in specimen TB-09 (PPOL, FOV = 0.55 mm).....	168
Figure A.71. Photomicrograph of a highly turbid and fractured feldspar grain in specimen TB-18 (PPOL, FOV = 0.55 mm).	170

Figure A.72. Photomicrograph of a rounded and greenish brown coloured lithic fragment, consisting mostly of biotite mica and amphibole group minerals in specimen TB-18 (PPOL, FOV = 0.55 mm).171

Figure A.73. This specimen TB-26 shows an unusually high number of synthetic fibres, 20 µm wide and more than 1mm long fibres (PPOL, FOV = 1.1 mm).173

List of Abbreviations

°C	degree Celsius
µm	micrometre
ab %	percent abundance mineralogy
Als	Aluminosilicate polymorphs
Amph	Amphibole
Ap	Apatite
approx.	approximately
BA	Barrie
Bt	Biotite
BU	Burlington
CA	Cambridge
Cal	Calcite, carbonate mineral
Carb	carbonate minerals
CHDS	Canadian House Dust Study
Chl	chlorite
cm	centimetre
DAs	Dissemination areas
FOV	Field of view
Fsp	feldspar
Ga	(Giga) billion years
Grt	garnet
GTA	Greater Toronto Area
HA	Hamilton
Km	kilometre
LF	lithic fragment
m	metre
masl	metre above sea level
max	maximum
min	minimum
mm	millimetre
Mt	Muscovite
N	North
n	number of specimens
Off shield	Paleozoic bedrock
OGS	Ontario Geological Survey
PLM	Polarized-light microscopy
PPOL	Plane polarized light
Px	pyroxene
Qtz	quartz
Rt	rutile
SD	standard deviation

SEM	Scanning electron microscopy
Shield	Canadian Shield or Precambrian bedrocks on the Canadian shield
SSW	South-South West
SU	The Greater Sudbury
Sul mn	Sulphide minerals
TB	Thunder Bay
U.S.EPA	The United States Environmental Protection Agency
Vol. %	Volume percentage
W	West
Wt. %	Weight percentage
XPOL	Crossed polarized light
XRD	powder X-ray diffraction

1.0 Introduction

1.1 Background

On average, Canadians spend 90% of their time indoors (Health Canada, 2009). Generally, people consider that indoor environments shield them from outdoor pollution. Mounting scientific evidence however is suggesting the contrary. For example, Spengler and Sexton (1983) illustrated that indoor environments can be more seriously polluted than outdoor environments. The United States Environmental Protection Agency (U.S.EPA) has ranked indoor pollution as a high environmental risk (Roberts & Dickey, 1995). The effects of indoor pollutants can range from simple irritation to severe debilitation (Mitchell et al., 2007). House dust in particular can act as a repository or "indoor-pollution archive", trapping and preserving contaminants (Butte & Heinzow, 2002; Liroy et al., 2002).

House dust is a heterogeneous mixture of both organic and inorganic substances such as skin cells, minerals, soil materials, plant debris, hair, textile fibres, starch grains, etc. (Fergusson & Kim, 1991; Hunt et al., 1992; Millette & Hopen, 2001; Turner et al., 2005). It is composed of particles with size fractions of less than 1 mm that are released in the house by shedding, abrasion or deterioration of materials from the indoor (e.g., indoor aerosols) or/and outdoor environments (e.g., soil particles tracked in by foot traffic) (U.S. EPA, 1997; Millette & Hopen, 2001; Turner et al., 2005; Abdul-Wahab et al., 2005). In other words, house dust or floor dust can be defined as "contents within vacuum cleaner bags" (U.S. EPA, 1997). In this thesis, the

mineralogical composition of the coarse fraction (i.e., 80 – 300 μm) of house dust was determined by common mineralogical analytical methods.

One of the earliest scientific reports on the physical characteristics and chemical composition of house dust was documented not surprisingly by the Hoover Vacuum Company in 1958 (Studer, 1958). Public policy concern of toxic components became the focus of studies on dust. Spengler and Sexton, in their 1983 study, highlighted that pollutants such as tobacco smoke, asbestos, and formaldehyde should be recognized as health concerns. From that point on, research on indoor air quality related to dust proliferated. In particular, numerous studies of elevated blood Pb levels in children from many urban residential districts drew considerable attention on the contribution of house dust on indoor air quality (Thornton et al., 1985; Duggan & Inskip, 1985; Davies et al., 1990; Health Canada, 1994; Rasmussen, 2004). Subsequent studies focused on determining baseline levels for a range of potentially toxic metals such as Pb, Cu, Zn, Cd, and Cr in household dust (e.g. Culbard et al., 1988; Kim & Fergusson, 1993; Rasmussen et al., 2001; Turner & Simmonds, 2006; Rasmussen et al., 2008). Metal speciation studies using synchrotron methods show that there are both indoor and outdoor sources of metal compounds in house dust (Beauchemin et al., 2011). Most of these studies did not include detailed mineralogical characterization of house dust.

Heavy and trace metals which are present in house dust, and which have been attributed to anthropogenic sources (e.g., leaded paints), are also ubiquitous in natural environments. Siegle (2002) has compiled the natural content of metals/metalloids that are potentially toxic to humans in selected rocks. For example, shales contain on average 20 ppm of Pb and basalt, up to 185 ppm of Cr.

In fact, in the Hoover Vacuum Company's 1958 study, the presence of soil minerals in the house dust was reported. Minerals in house dust are believed to come from soil, street dust, and bedrock. Soil, street sand, and rock fragments comprise an estimated 20% to 95% (vol. %) of house dust (Rasmussen et al., 2001). These inorganic fragments may serve as host for metals and contaminants, and may provide insight on the source of contaminants.

In 2000, Mølhavé et. al qualitatively assessed the mineralogical fraction of house dust in seven Danish office buildings. Mølhavé et. al identified 12 minerals, but highlighted that many inorganic particles could not be identified due to “the complex nature of the composition of house dust”. Only recently has the mineralogical composition of dust been considered for further detail study (Hunt et al., 1992; Millette & Hopen, 2001; Turner et al., 2005). Here, in this study, we develop knowledge base and methodology of mineral characterization in house dust.

1.2 Purpose of study

This M.Sc. thesis aims to characterize the mineralogical composition of the coarse fraction of house dust (specifically floor dust) in homes from six Ontario cities. More precisely we investigate the mineralogical composition of house dust in the six Ontario cities of Barrie (BA), Burlington (BU), Cambridge (CA), Hamilton (HA), Greater Sudbury (SU), and Thunder Bay (TB), that are included in the Canadian House Dust Study (CHDS), a nation-wide project led by Health Canada, designed to obtain baseline values of metals, contaminants and pesticides in residential environments across Canada (Rasmussen et al., 2011). While trace and heavy metal contaminants are key focuses of the CHDS, detailed mineralogical characterization helps to understand the

composition of house dust, to determine the potential sources of dust, and to elucidate how minerals are linked to contaminants.

Particulate pollutants can be adsorbed to mineral particles in the dust depending on the minerals' physicochemical properties such as size and surface texture (Rulkens, 1995; Butte & Heinzow, 2002). The metal bioavailability is also largely a function of speciation and surface reactivity, which in turn are linked to mineralogy. For instance, (Casteel et al., 2006) in their study of lead uptake measured as a function of lead mineralogy in soils, found that Pb in galena (PbS) is less bioavailable than lead in carbonate (PbCO₃) as a result of differences in mineral solubility. Therefore a comprehensive approach to the mineralogical components of house dust helps to better understand the relation of dust particles and their toxic nature.

The study was never designed with the specific objective of determining the provenance of the mineral grains found in the house dust specimen. Despite this, some conclusions can be drawn on the source of these mineral grains and particles.

1.3 Study scope and objectives

The main objective of this thesis is to characterize the mineralogical composition of house dust from six Ontario cities. As such, only Ontario cities (total of 6) of the thirteen randomly selected cities of the CHDS were included in this thesis. Thunder Bay and Sudbury are located on the Precambrian rocks of the Canadian Shield, and Barrie, Burlington, Cambridge and Hamilton, located on Paleozoic strata of the St. Lawrence platform of southern Ontario. All house dust samples were provided by Health Canada and the mineralogical characterization was conducted for the 80 µm – 300 µm size fraction.

The objectives are:

- To identify the mineralogical composition of house dust.
- To quantify the percent abundance of the mineralogical fraction of house dust.
- To compare and contrast the composition of the mineralogical fraction of house dust between cities located on the Canadian Shield vs. St. Lawrence Lowland of southern Ontario.
- To suggest the main transport vector of dust in and out of the house.
- To suggest the potential sources of minerals within the house dust.

1.4 Novel aspects of this study

The mineralogical identification and determination of house dust from Canadian homes is based on physical, chemical and microscopy techniques including polarizing-light microscopy (PLM), powder X-ray diffraction (XRD) and scanning electron microscopy (SEM). Few studies (Mølhave et. al., 2000; Millette & Hopen, 2001; Turner et al., 2005) have qualitatively investigated the mineral composition of house dust using polarizing light microscopy (PLM). Unlike these previous studies, we investigate the minerals in house dust both qualitatively (PLM, XRD, SEM) and quantitatively (quantification of percent abundance mineralogy using point-counting method coupled to PLM) (discussed further in Section 3.4 Methods).

Comparing and contrasting mineralogical components of Canadian house dust from geographically and geologically distinct areas and assessing the geological sources of house dust is a novel research topic.

2.0 Location, physiography and geology

2.1 Six Ontario cities

In this chapter physiographic and geological characterization of the six Ontario cities chosen from the CHDS study are described. House dust samples were collected from randomly selected detached homes in six Ontario cities: Thunder Bay and Sudbury are on the Precambrian rocks of the Canadian Shield, and Barrie, Burlington, Cambridge and Hamilton are on the Phanerozoic sedimentary rocks of the St. Lawrence Platform of southern Ontario. The Canadian Shield, also known as the Precambrian Shield (Fig 2.1), which consists of the oldest bedrock in Canada (i.e., 4.5 billion to 540 million years ago), is located in the central and eastern part of Canada, and is characterized by a thin cover of Quaternary sediments with numerous bedrock outcrops.

As part of the Canadian House Dust Study (CHDS), eight to ten dissemination areas (DAs) were randomly selected in each city to collect house dust in residential homes of volunteer participants (Rasmussen et al., 2011). CHDS did not sample soils. The goal of the CHDS was to obtain nationally-representative baseline house dust samples (Rasmussen et al., 2011).

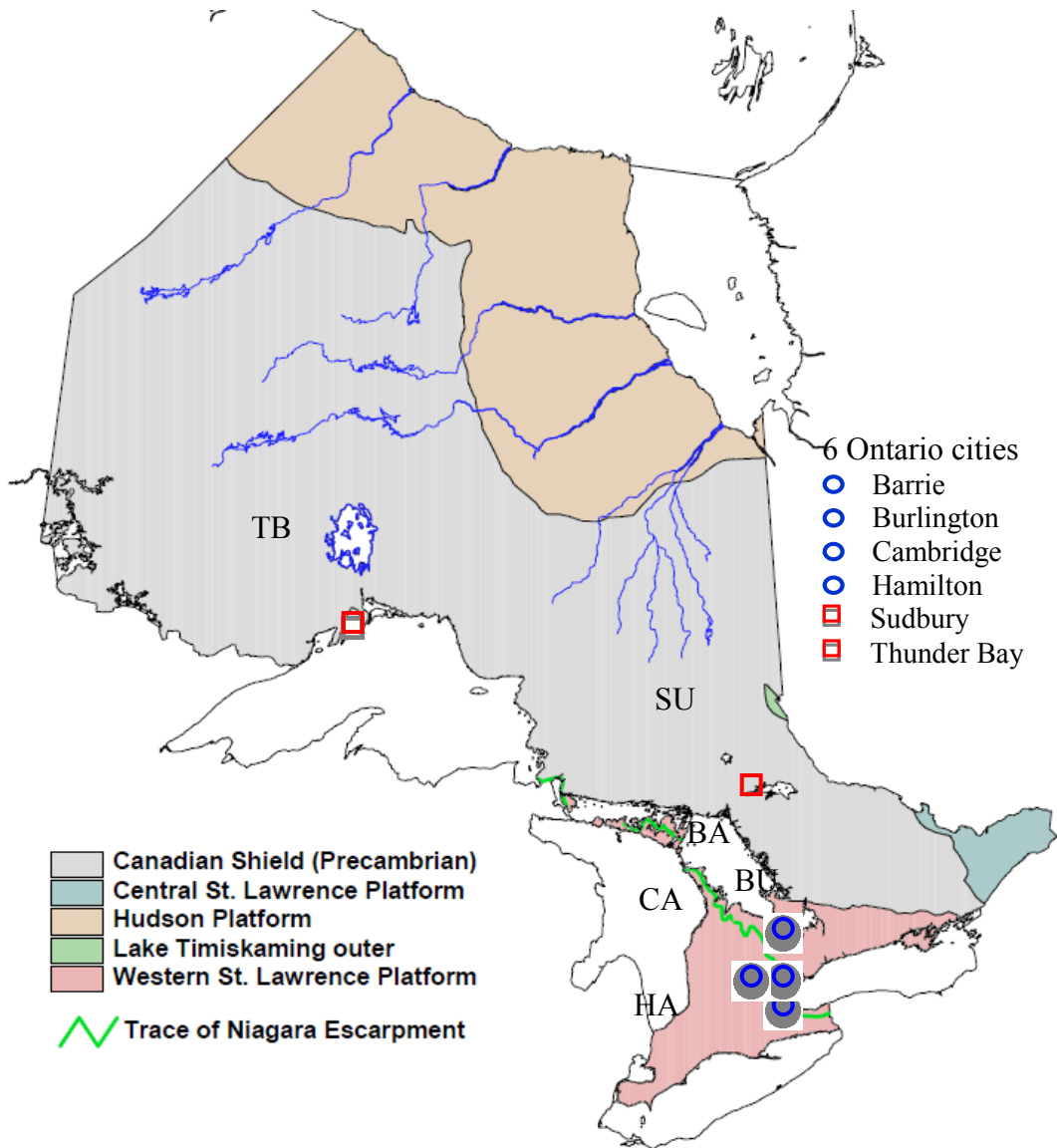


Figure 2.1. Location map of the study areas. Two of the cities are on the Canadian Shield (Thunder Bay and Sudbury, red squares) and the other four are on the St. Lawrence Lowland of southern Ontario (Barrie, Burlington, Cambridge and Hamilton, blue circle) (map from Johnson et al., 1992).

2.2 The City of Barrie

2.2.1 Location, size and population of Barrie

The City of Barrie is located in the central portion of Southern Ontario at the western end of Kempenfelt Bay, of Lake Simcoe (approx. 44°24' N and 79°40' W). The 2006 census of Statistics Canada reported a population of 128,430 residents; an increase of approximately 24,720, or around 23%, since the previous census in 2001. The city has a total land surface area of 77 km² with a population density of 1,668.14/km². Barrie is often perceived as a bedroom community since many of its inhabitants work in the Greater Toronto Area (GTA).

2.2.2 Climate of Barrie

The city is constructed on generally flat terrain with an average elevation of 221 m above sea level (masl). Lake Simcoe shares a large border with the city of Barrie. As Barrie is located in Ontario's Snowbelt, it experiences a cold and snowy winter with an annual accumulation of 238 cm of snow annually (National Climate Data and Information Archive, Environment Canada, 2009). Each winter the city provides snow removal services such as snow plowing, sanding and salting.

Table 2.1 Monthly precipitation and temperature data for Barrie

Elevation (221 m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Temp. daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Sep	Feb	Jan	Jun-Sep	Sep	Feb	Jul	Jan
	97.6	13.3	80.2	0	97.6	52.8	20.5	-8.1

2.2.3 Soil, surficial and bedrock geology of Barrie

Most of the city's area is covered by light gray, calcareous and non-calcareous sandy loam till (Hoffman et al., 1962). The Quaternary geology of Barrie consists mostly of Pleistocene tills with moderately stony to silty sand, glaciofluvial deposits of mostly fine to very coarse-grained sand and glaciolacustrine beach and bar sediments (Barnett, 1992). The thickness of Quaternary sediments in the St. Lawrence Platform can exceed 200 m (Karrow, 1989). Middle Ordovician limestone dominates the bedrock of Barrie (Liberty, 1969). The Verulam Formation underlies most of the city while the Bobcaygeon Formation occurs in a small portion in the northeastern part of the city. The Verulam Formation includes grey limestone with alternating shale and claystone whereas the Bobcaygeon Formation comprises calcarenite with fine and compacted limestone (Liberty, 1969).

2.3 The City of Burlington

2.3.1 Location, size and population of Burlington

Burlington (43° 19.8' N and 79° 49.8' W) is a city located in Southern Ontario adjacent to the city of Hamilton and on the northwestern shore of Lake Ontario. It has a total land area of 185.74 km². The population of the city is 164,415 as reported in the 2006 census. Due to its proximity to Hamilton and Toronto, Burlington is a suburb or bedroom community to these two large cities. Burlington is part of the Greater Toronto Area (GTA).

2.3.2 Climate of Burlington

Burlington is located on flat terrain with an average elevation of 99.1 masl. Burlington, with a yearly snowfall of 108.2 cm, receives the least snowfall when compared with the other cities included in this study (National Climate Data and Information Archive, Environment Canada, 2009).

Table 2.2 Monthly precipitation and temperature data for Burlington

Elevation (99.1 m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Temp. daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Sep	Jan	Jan	May- Oct	Sep	Feb	Jul	Jan
	89	32	35.2	0	89	57.1	22.3	-4.8

2.2.3 Soil, surficial and bedrock geology of Burlington

Soils in Burlington are mostly loam, ranging from clay loam to sandy loam in composition. The central part of the city is dominated by clay loam that originated from the silty clay till whereas the western part is covered mostly by sandy loam from its parent material of stony till (Gillespie et al., 1970). The surficial geology of the city is the result of the unsorted glacial till deposits laid down by the moving ice. Water-deposited sand and gravel are also associated with this till in the form of eskers (Karrow, 1963). The Halton till comprises fragments of fossilized limestone, fine-grained shales and sandstones (Karrow, 1963). In general the surficial geology of the area is dominated by glaciolacustrine deposits of the Pleistocene epoch.

Burlington lies on the Queenston Formation. The east and west end of the city are covered by Georgian Bay Formation and Lockport-Amabel Formation, respectively. The Queenston Formation, deposited in Ordovician time, consists of red

shale, arenaceous and micaceous shale. The Lockport-Amabel Formation comprises dolomite and limestone rocks and the Georgian Bay Formation consists of alternating gray shale and gray carbonates (Ontario Geological Survey, OGS Earth Map, 2009).

2.4 The City of Cambridge

2.4.1 Location, size and population of Cambridge

Cambridge (approx. 43° 19' N and 80° 19' W) is located in southwestern Ontario on the Grand River, near the adjacent cities of Guelph, Kitchener and Waterloo. Cambridge lies on a relatively flat terrain with an average elevation of 268.2 m. Cambridge has a total land surface area of 112.86 km². The population in 2006 was 120,371 residents, which yields a population density of 1,066.5/ km².

2.4.2 Climate of Cambridge

Similar to other southwestern Ontario cities, Cambridge has moderate winters with a mean January temperature of -6 degrees Celsius. The city experiences a moderate snowfall in its winter period with a yearly accumulation of 127.2 cm (National Climate Data and Information Archive, Environment Canada, 2009).

Table 2.3 Monthly precipitation and temperature data for Cambridge

Elevation (268.2m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Temp. daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Jul	Feb	Jan	May- Sep	Jul	Feb	Jul	Jan
	95.2	22.1	37.3	0	95.2	50.6	20.5	-6

2.4.3 Soil, surficial and bedrock geology of Cambridge

Cambridge's soil is mostly organic. Stony till covers the immediate surrounding area of the city. Glacial till and derived soil include fragments of dolomite bedrock (Presant & Wicklund, 1971). The surficial geology of Cambridge area is, like other regions in the southern Ontario, the result of the last Pleistocene glacial event. The transgression and regression of the ice sheets left unsorted sediments or till in this area. The bedrock geology of the Cambridge area is dominated by the Guelph Formation that formed in the Silurian period, approximately 400 million years ago (Karrow, 1987). This formation is composed of cream to brown dolomite (Presant & Wicklund, 1971).

2.5 The City of Hamilton

2.5.1 Location, size and population of Hamilton

Hamilton is located in Southern Ontario, on the western shore of Lake Ontario and at the western end of the Niagara Peninsula, at approximate geographic coordinates of 43° 10' N and 79° 55' W. The city extends over 1123.14 km². At the 2006 census, the city had a population of 504,559. It is the ninth largest city in Canada, and is the most populated city of the six cities included in this study.

Hamilton is known for its shipping port on Lake Ontario and its important manufacturing sector. It is located within Canada's most industrialized region. The city has hosted two of the major steel manufacturing companies, Stelco and Dofasco, for nearly a century (Dofasco, 2009).

2.5.2 Climate of Hamilton

Hamilton has a moderate climate when compared to most other Canadian cities. Snowfall is minimal when compared to the other six cities included in this study, except Burlington. Yearly, around 113.2 cm of snowfall accumulates in the city (National Climate Data and Information Archive, Environment Canada, 2009). Snow removal activities such as salting and sanding are done by Hamilton's public works department.

Table 2.4 Monthly precipitation and temperature data for Hamilton

Elevation (76.2m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Tem. Daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Sep	Jan	Jan	May- Oct	Sep	Jan	Jul	Jan
	88.5	26.1	32.3	0	88.5	58.4	22.5	-3.6

2.5.3 Soil, surficial and bedrock geology of Hamilton

Soils in Hamilton resulted principally from glacial processes during the last Pleistocene glaciations (Karrow, 1963). The southeastern part of Hamilton is underlain by clay till, while the western part is underlain by silt and sandy soil (Presant & Wicklund, 1971). The surficial geology of Hamilton, similar to the neighbouring city of Burlington, consists of Pleistocene deposits of the Halton till and glaciolacustrine sand (Karrow, 1963). The Halton till contains fragments of fossilized limestone, fine-grained shale and sandstones (Karrow, 1963) that are derived from the underlying Paleozoic sedimentary bedrock.

The bedrock underlying Hamilton is dominated by Paleozoic dolomite, shale, and sandstone. The Queenston Formation which is of Ordovician age is the oldest of all formations in the city. This Formation consists of red mudstone with silt intercalations. The Clinton and Cataract groups, the oldest of the Silurian age rock types, are deposits of white and gray sandstones, respectively. The Amabel and Lockport formations consist of gray dolomite. The Guelph Formation, the youngest of all, is composed of cream to buff coloured fine crystalline dolomite.

2.6 The City of Greater Sudbury

2.6.1 Location, size and population of Sudbury

The city of Greater Sudbury is located in northeastern Ontario (approx. 46° 37' N and 80° 48' W). The city received the designation of Greater Sudbury after the 2001 amalgamation of several towns and cities that comprised the former Regional Municipality of Sudbury. Greater Sudbury is the largest city by area in Ontario and it is the seventh largest municipality in Canada. It has a total land surface area of 3,200.56 km². The city has 157,857 residents, and a population density of 49.3 habitants / km².

2.6.2 Climate of Sudbury

Sudbury has a rolling topography characterized by the rocky outcrops and many lakes that are so typical of the Canadian Shield. Topography ranges from ~100 m to ~950 masl (consult the Sudbury NTS41I topographic map, Natural Resources Canada, 1997). As Sudbury is located at higher latitude than the four cities previously described, it has a relatively colder climate. Sudbury experiences heavy snowfall in the month of December with an average of 64.2 cm of snow. Sudbury gets more snowfall,

274.4 cm per year, than the rest of the studied cities (Barrie, 238.4 cm; Thunder Bay, 187.6 cm; Cambridge, 127.2 cm; Hamilton, 113.2 cm and Burlington 108.2 cm) (National Climate Data and Information Archive, Environment Canada, 2009).

The city's department of infrastructure and emergency services is responsible for snow plowing, sanding and salting. In the winter, most of the snow-packed roads in the city are sanded and plowed.

Table 2.5 Monthly precipitation and temperature data for Greater Sudbury

Elevation (347.5 m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Temp. daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Sep	Feb	Dec	Jun- Aug	Sep	Feb	Jul	Jan
	101.2	7.1	64.2	0	101.3	50.6	19	-13.6

2.6.3 Soil, surficial and bedrock geology of Sudbury

The Greater Sudbury area is located on the Precambrian Canadian Shield. The larger part of the city is situated on bedrock, which is clearly exposed at the surface as numerous outcrops. The types of soils for the city of Greater Sudbury are many and complex. Areas in the eastern part of the city are covered by calcareous silt loam lacustrine deposits, while central parts are covered by non-calcareous very fine sandy outwash or deltaic deposits (Gillespie et al., 1982). The surficial geology is mostly the result of deposited materials during the last glaciation, i.e. the Wisconsinan. Glaciolacustrine deposits include silt and clay with minor sand associated with Pleistocene and glaciofluvial outwash and deltaic gravel and sand deposits (Geological Map of the Sudbury, Ontario Geological Survey, OGS Earth, 2009).

The Precambrian bedrock can be classified into four rock types, namely the Sudbury Intrusive complex, Whitewater Group sedimentary rocks, mafic intrusive dikes and sills and the Cobalt and Elliot Lake groups of Precambrian-age sedimentary rocks (Geological Map of the Sudbury, Ontario Geological Survey, OGS Earth, 2009).

The Sudbury basin is a 1.85 Ga structure and is believed to have been created by a meteorite impact which is responsible for the concentration of numerous ore deposits. This basin is known for its high mineral concentration of nickel, copper and other metals. As a result Sudbury is known for its mining activity. Riller et al. (1996) modified the general classification of the geology of Sudbury area into Grenville Province, Southern Province and Superior Province (see Figure 2.2 below).

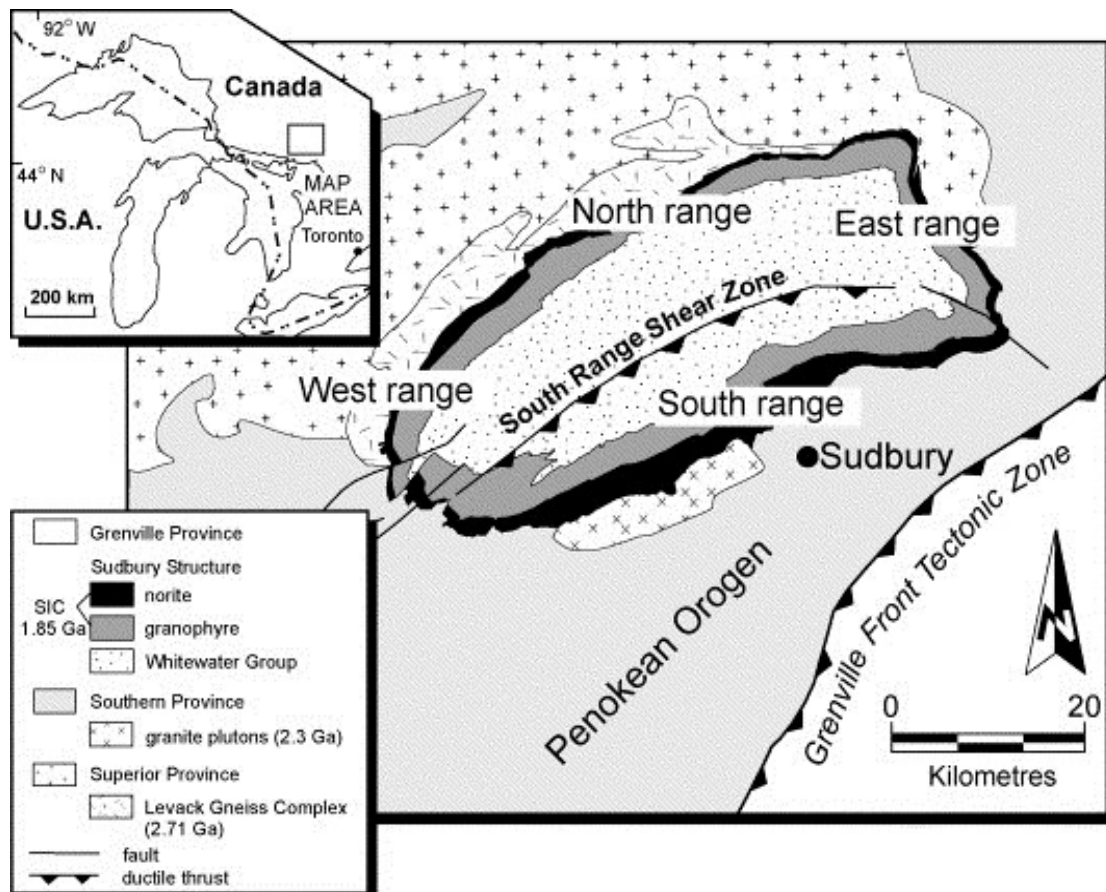


Figure 2.2. Regional geology of the Sudbury area (Riller et al., 1996).

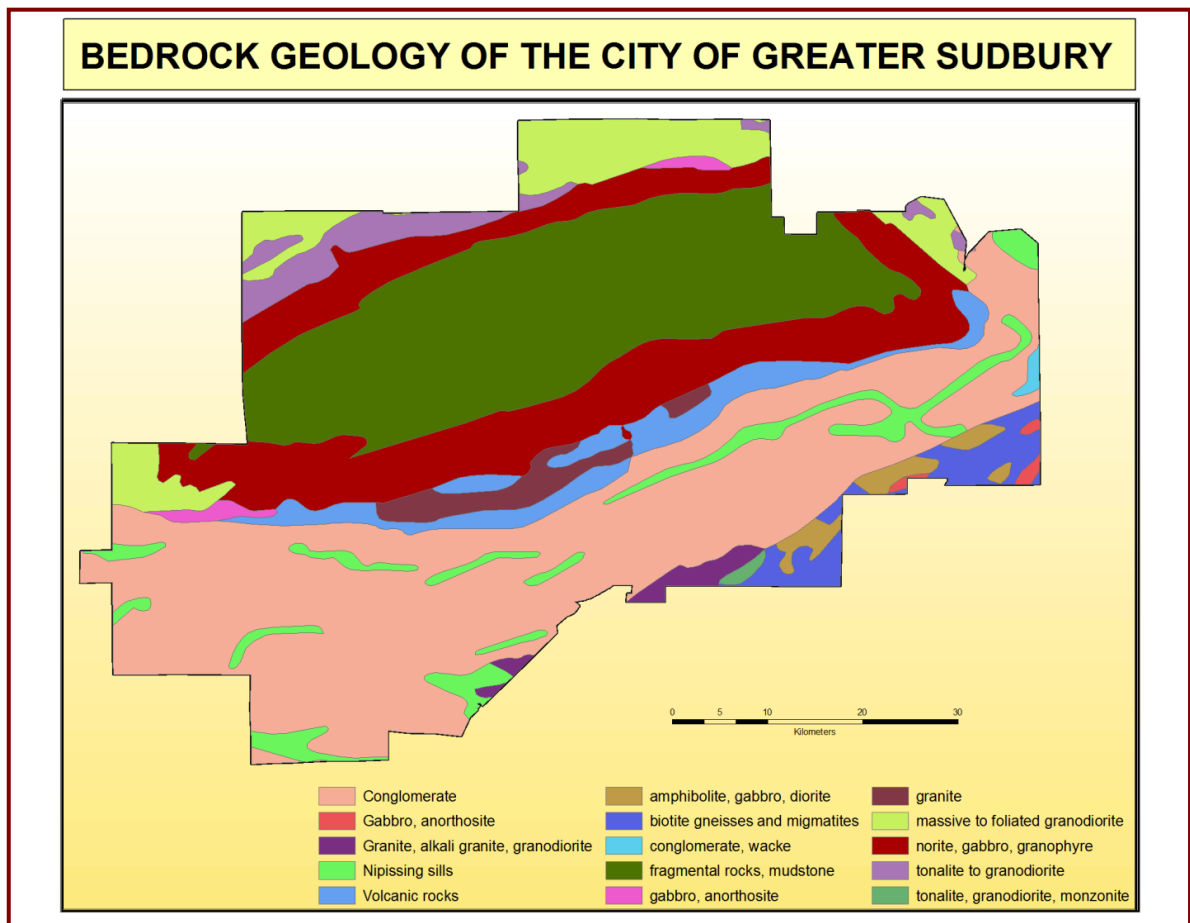


Figure 2.3. Bedrock geology of the Sudbury area (data from OGS Earth, 1:250,000 bedrock geology, 2009).

2.7 The City of Thunder Bay

2.7.1 Location, size and population of Thunder Bay

Thunder Bay (approx. 48° 22 ' N and 89° 19' W) is located in northwestern Ontario, on the northern shore of Lake Superior. It has a total land area of 328.48 km². The city's population according to the 2006 census by Statistics Canada was 109,140, with a population density of 332.3 habitants / km².

2.7.2 Climate of Thunder Bay

Topography is relatively flat in the northern part, and hilly in the southeastern part, with an average elevation of 199 masl. The amount of snow the city receives per year is 187.6 cm (National Climate Data and Information Archive, Environment Canada, 2009). The lake effect is believed to offer the city a mild summer and a relatively warm winter for its geographic latitude.

Table 2.6 Monthly precipitation and temperature data for Thunder Bay

Elevation (199 m)	Rainfall (mm)		Snowfall (cm)		Precipitation (mm)		Temp. daily average (°C)	
	Max	Min	Max	Min	Max	Min	Max	Min
Month	Jul	Jan	Dec	Jun- Aug	Jul	Feb	Jul	Jan
	89	2.5	44.1	0	89	24.9	17.6	-14.8

2.7.3 Soil, surficial and bedrock geology of Thunder Bay

More than forty soil types are documented within the city limits of Thunder Bay (Land Resource Research Institute, Agriculture Canada, 1981). The city lies on the Precambrian bedrock of the Canadian Shield with a very thin soil cover. The Precambrian rocks of the Shield are well-exposed along most of the northern perimeter of the city. Decomposed organic material, non-calcareous fine sandy loam and stony glacial till derived from black shale are some of the common soil and regolith types in Thunder Bay. The surficial geology comprises glaciofluvial deposits, tills and recent deposits. These recent deposits are composed of peat and muck. The Quaternary deposits include till with locally-deposited sand and silty sand matrix.

Volcanic-plutonic and metasedimentary rocks of the Proterozoic and Archean age dominate the bedrock geology of Thunder Bay (Geological Map of the Thunder Bay South District, Ontario Geological Survey, 2009). The black shale of Proterozoic age is common in the northern part of Thunder Bay area (Figure 2.4).

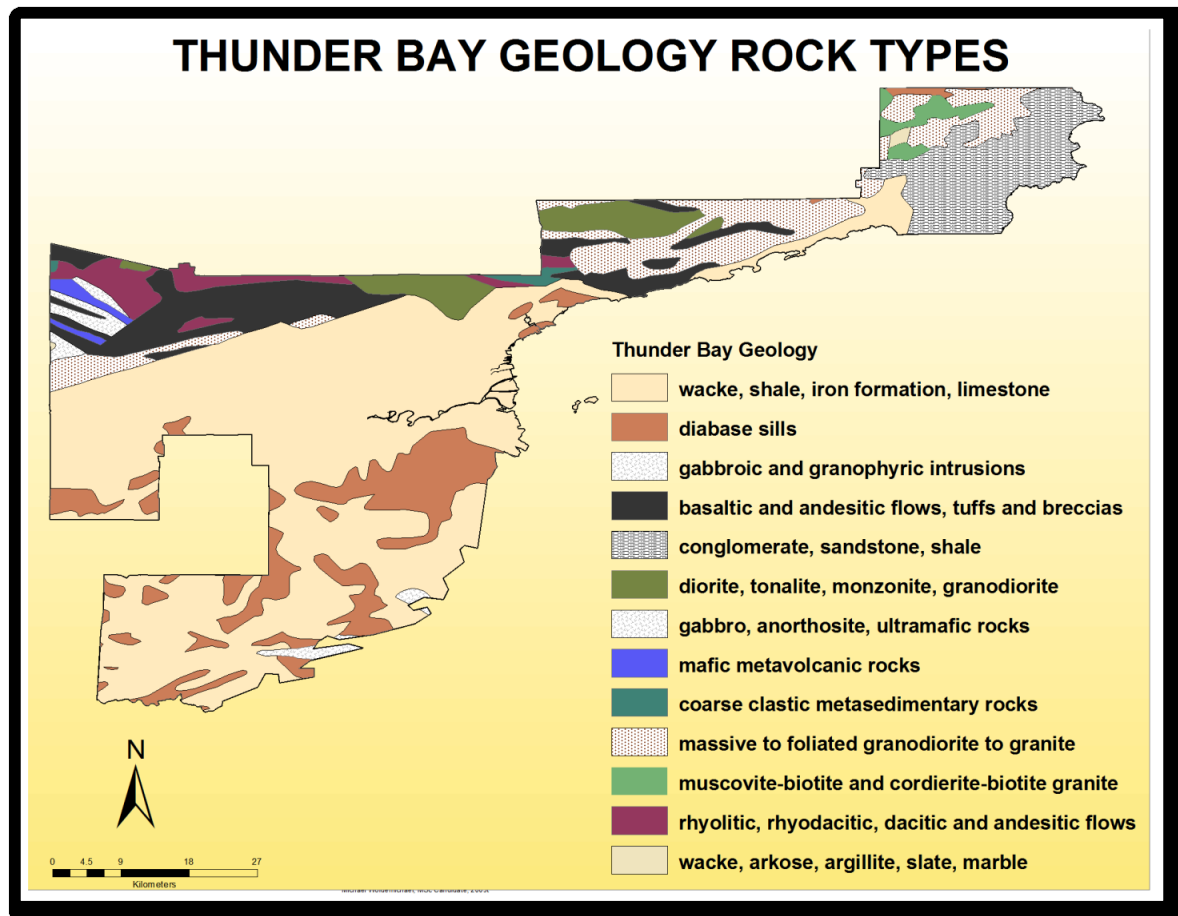


Figure 2.4. Bedrock geology of the Thunder Bay area (data from Ontario Geological Survey Earth Map, OGS Earth, 1:250,000 bedrock geology, 2009).

3.0 Material and Methods

3.1 Home selection and dust sampling method

Eight to ten dissemination areas (DAs) were randomly selected in each city to collect house dust in residential homes of volunteer participants (Rasmussen et al., 2011). The goal of the CHDS was to obtain a nationally-representative baseline sample. These selected participants homes were not known for indoor air quality problems.

The dust samples were collected according to the protocols described by the CHDS in living areas of residential homes using a High-Efficiency Particulate Air (HEPA) filter vacuum sampler (Rasmussen et al., 2011). Sampling for all six Ontarian cities occurred in the winter season.

Forty archived samples of ordinary vacuumed house dust for 40 separate homes were provided by Health Canada from the six Ontarian cities. These samples included 9 from Barrie, 9 from Burlington, 5 from Cambridge, 6 from Hamilton, 6 from Greater Sudbury and 5 from Thunder Bay. Note that 1 sample from Barrie, 3 from Burlington, and 1 from Hamilton were comprised solely of organic material, and could not be analyzed for their mineralogical content.

3.2 Sample preparation

All dust samples were air-dried and sieved into the 80-300 μm fractions at the Exposure and Biomonitoring Laboratory of Health Canada in Ottawa. The collected dust samples were all heterogeneous mixtures of a variety of organic and inorganic particles. The preliminary optical examination of bulk vacuumed dust samples (sized

80-300 μm) indicated that house dust generally includes soil minerals, lithic fragments, construction materials, skin dander, hair, synthetic fibres, insect and plant debris, and fragments of household items (Woldemichael et al., 2009).



Figure 3.1 Representative example of vacuumed specimen of house dust (80 - 300 μm).

Large organic components in the dust such as pet and human hair and large synthetic fibres were cautiously removed from the coarse fraction of the specimens by hand picking under the binocular stereoscope with powder-free gloves. Protective clothing and face masks were used to avoid potential inhalation of fine dust particulates (Rasmussen et al., 2011). Further separation of light organic components such as dander, insect fragments and synthetic fibres was accomplished by floating these materials in water, thereby producing a relatively pure mineral fraction residue

(McCrone & Hudson, 1969; Murray, 2004). This high density mineral fraction and petrographic component residues were then subjected to mineralogical characterization using the following methods described in section 3.4.

3.3 Description of house dust

The texture and colour of the 80-300 μm size fractions of the dry dust samples were first observed under the binocular stereoscope. Similar to soil colour identification (Murray, 2004), the colour of these house dust specimens was described according to the rock colour chart distributed by the Geological Society of America. For further mineralogical analysis I utilized different methods as explained in the next section.

3.4 Methods

3.4.1 Polarized light microscopy

House dust particles can be identified by polarized light microscopy (PLM) using morphological and optical properties (Studer, 1958; McCrone et al., 1997; Lioy et al., 2002; Millette, 2003). Previous studies prepared microscopic slides of dust by immersing particles in mounting media of different refractive indices. We modified the method of preparing house dust for microscopic analysis. Polished thin sections for microscopic observation were prepared for each of the 40 house dust samples by mounting mineral grains from the coarse fraction that was purified by water flotation (See above section). The grains were embedded in Petropoxy 154 (refractive index, $n_D = 1.54$) on standard 26 x 46 mm petrographic glass slides, and polished to an approximate thickness of 30 μm , as is normally done in thin sections of rock (see Figure

3.2). Due to the inherent difficulty of preparing thin sections from house dust, the thickness of resistant minerals was difficult to control.



Figure 3.2 Polished thin section of house dust (30 μm) in microscopic stage holder.

The mineralogical composition of the grains in the sections was then determined by conventional polarizing microscopy methods used in mineralogical research, e.g. colour and pleochroism, elongation, extinction, birefringence, optical sign, 2V, etc (e.g. McCrone et al., 1984). Examination of the specimen was done using both transmitted and reflected light. This allowed the distinction of opaque oxides from sulphide minerals. Abundance of the minerals were determined using a Swift Instruments point counting stage attached to a Nikon E600 research polarizing microscope. Every identified mineral and inorganic component was presented as percentile of the mineral residue. This identification and rigorous counting (1200 count per thin section) of minerals and inorganic particles in the dust yielded a quantitative determination of the mineralogical composition of the house dust specimens.

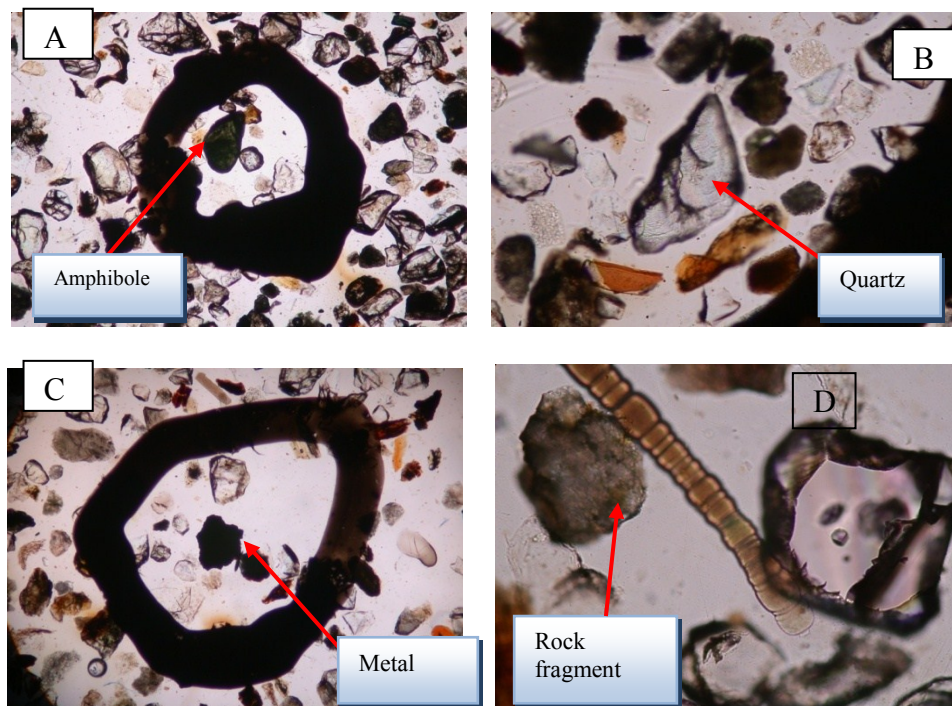


Figure 3.3. Examples of photomicrographs of mounted dust grains observed under plane-polarized light: A) Unspecified amphibole grain, B) Angular quartz grain, C) Iron oxide fragments, D) Aphanatic lithic fragments and fragment of insect antenna (FOV = 0.22 mm).

The organic content and some of the inorganic components in the thin sections was recognized by referring to the online version of the McCrone Atlas of Microscopic Particles (McCrone Atlas, 2009). Millette (2003) was able to characterize the general composition of household dust using polarized light microscopy. The authors showed that over 90% of the house dust samples were composed of common particles like skin cells, soil minerals, plant fragments, hair, cotton fibres, and starch granules.

3.4.2 Scanning electron microscopy

A total of fifteen polished grain mounts were also examined with either the JEOL JSM-6400 scanning electron microscope or the newer Tescan VEGA-II scanning

electron microscope, at the Carleton University electron microscopy facility. Detailed examinations and particle characterization were performed on selected carbon coated specimens.

Secondary electron images were used to analyse the texture and topography of the mineral grains and other components in the house dust, whereas compositional zoning or contrast among the different minerals was documented with the back-scattered electron signal. Qualitative chemical analyses of the inorganic components in the dust was acquired by energy dispersive X-ray spectroscopy for the elements Na, Mg, Al, Si, Cl, K, Ca, Fe, and S.

Other studies showed that the composition of bulk dust samples could be obtained (Møhlhave et al., 2000) with SEM to identify minerals within the house dust, including quartz, calcite, feldspar, gypsum and halite, amongst others.

3.4.3 Powder X-ray diffraction

Six select powdered dust samples were examined using the Philips X'Pert PW 3710 X-ray diffractometer at the University of Ottawa X-ray laboratory. The goal was to obtain d-spacing of minerals within the powdered dust and to compare them with already known minerals by other methods. Often X-ray diffraction methods provide a definitive identification of minerals (i.e. for crystalline substances). However, in this case of powdered dust, the results were virtually similar to our observation by PLM that showed quartz and feldspar dominating the bulk dust. As a result, Powder X-ray diffraction was not utilized in much detail for the purpose of this study, but it was used to counter check the minerals that were already identified and classified by PLM and SEM.

3.5 Mineralogical abundance by point counting

Point counting of thin sections using PLM can be utilized to determine the mineralogical composition of rock samples or individual particle size fractions of soils and sediment (Galehouse, 1971). Some previous studies (e.g. Liroy et al., 2002) estimated the relative percentage of larger particles of dust under stereomicroscopy but here I used a point counting method to better analyze the proportion of minerals in house dust semi-quantitatively. Identifying the mineralogy of the house dust also involved determining the particle size, shape, colour, porosity and textures (see Chapter 4.0 Results).

4.0 Results

4.1 Percent abundance mineralogy of house dust

In this chapter, the percent abundance of minerals and mineralogical characteristics of all house dust specimens are described. A detailed report is also found in Appendix 1A. Generally, in all the 40 house dust specimens, both organic materials and minerals were present. However, 5 samples (BA-22, BU-40, BU-44, BU-74, and HA-14) out of the 40 were composed predominantly of very light and fluffy organic and synthetic materials, with only trace amounts of minerals. In all specimens the author was able to detect, identify and analyze both the inorganic and organic components of the house dust. The results also confirm that house dust is, in addition to minerals, composed of organic materials, animal and human hairs, textile and synthetic fibres, metallic particles, salt, as well as other unidentified materials. These findings are consistent with previous studies by (Fergusson & Kim, 1991; Hunt et al., 1992; Millette & Hopen, 2001; Turner et al., 2005) who identified similar components in house dust. Since the main objective of this thesis is to identify and characterize the mineralogical components, this fraction received the author's attention. These mineral fractions of the house dust typically account for more than 60% by weight. This result is consistent with previous work by Rasmussen (2004), which indicated that the organic fraction accounts for 26 - 40 wt %. Among the mineral fraction there are some minerals and mineral groups that are more commonly present in house dust.

Of the high density residue of the house dust specimens (see Section 3.2 Sample preparation), minerals, undifferentiated members of mineral groups and petrographic components of the house dust were described as “major”, “minor” or “trace components” depending on their percent abundance (ab %) determined by point counting. In this thesis, percent abundance mineralogy (ab %) is the same as volume mineralogy (Vol %), therefore the author may use them interchangeably throughout the thesis.

$$\text{Percent abundance mineralogy (ab \%)} = \frac{\text{number of point counts of a mineral in a thin section}}{\text{total number of minerals counted in that given section}} \times 100\%$$

Components that account for 5 ab % are classified as major, 1-5 ab % minor, and < 1 ab % as trace. Major, minor and trace mineral components, plus synthetic materials are characterized meticulously alongside their volume proportions and accompanying polarizing light and electron images in Appendix 1A.

The general physical appearance (colour and texture) of the house dust specimens differ significantly among samples from different cities, or within a given city. The colour identification of the house dust vacuum samples was done according to the rock colour chart distributed by the Geological Society of America. The observed house dust colour ranges from 10 YR 6/2 colour (pale yellowish brown) to N4 colour (medium dark gray).

Eight samples from Barrie and six from Burlington showed a range of light colours from light brownish gray (5 YR 6/1) to light olive gray (5 Y 6/1), with granular and compact textures. In Cambridge, the five dust samples examined show N5

(medium gray) colour. Olive gray colour (5 Y 4/1) and medium dark gray colours (N4) were common in Hamilton (6) and Greater Sudbury (8) specimens. Five Thunder Bay samples showed 10 YR 4/2 colour (dark yellowish brown) and N4 darker gray colours. Five specimens that were composed entirely of light and fluffy organic and synthetic materials showed medium dark gray colours (N4).

The texture of the house dust for Thunder Bay is best described as silty to granular. All larger minerals in dust were coated by organic matter, clays and other finer-grained substances or materials.

For example, Sudbury and Hamilton vacuum dust samples generally showed similar olive gray and medium dark gray colours when observed under the stereoscopic microscope. Barrie and Burlington samples showed a light brownish gray colour. On the other hand, the stereoscopic examination of Thunder Bay samples revealed that this city's samples were distinctively coarser and more granular than samples from other cities in that the particles fell in the coarse end of 80 - 300 μm size range (i.e. greater than 150 μm).

4.2 Major mineral components

Of the high density residue of the house dust (see Section 3.2 Sample preparation), the four major minerals or petrographic components in the house dust specimens, notably quartz, feldspars, lithic fragments, and carbonate minerals are described below (see Table 4.1). Here, lithic (rock) fragments, strictly speaking, are not minerals but rather petrographic components of house dust. Furthermore, carbonate minerals represent minerals including calcite, dolomite, and chalk. The author is fully aware that chalk is not a mineral but it is a rock fragment composed of calcite; but for

simplicity purposes in this study in few occasions chalk is grouped under carbonate minerals.

Table 4.1 Total average content of major mineral components in house dust

Major mineral components in the house dust specimens in average ab %	
Quartz	26.5%
Feldspars	22.0%
Lithic fragments	19.1%
Carbonate minerals	14.0%

4.2.1 Quartz

Quartz in the house dust specimens occur as quartz grains, with an average size of 150 μm with diverse shapes that range from rounded to angular. Most of these transparent to translucent quartz grains show conchoidal fractures. Also it was remarkable that in almost all of the dust specimens the quartz grains showed evidence of fluid inclusions and strain features. The fluid inclusions in the quartz grains are believed to be trapped fluids during the growth of the quartz crystals. High power microscopic observation (500X) was required to resolve these fluid inclusions. Strain was demonstrated by the presence of undulatory extinction in the quartz grains when observed under crossed polars with the polarizing microscope.

The widespread presence of quartz in the house dust is no surprise. In addition to being the most abundant mineral in the Earth's crust, quartz is an essential constituent of many of the three rock types, igneous, metamorphic and sedimentary rocks. It is also resistant to abrasion and is the principal mineral in sand, which is

widely used in Canadian cities as an abrasive for traction during winter. As such, it has the ability to be tracked indoors on shoes and by pets. The most plausible source for the quartz in house dust is track-in (see Chapter 5). Identifying the mineral grains under the microscope required many hours of observation. In some instances, it was possible to distinguish inclusion-rich quartz grains from similar looking turbid feldspar grains by using the quartz's uniaxial (+) optical property. For the physical descriptions of the mineral components and volume % in all the specimens please refer to Appendix 1A.

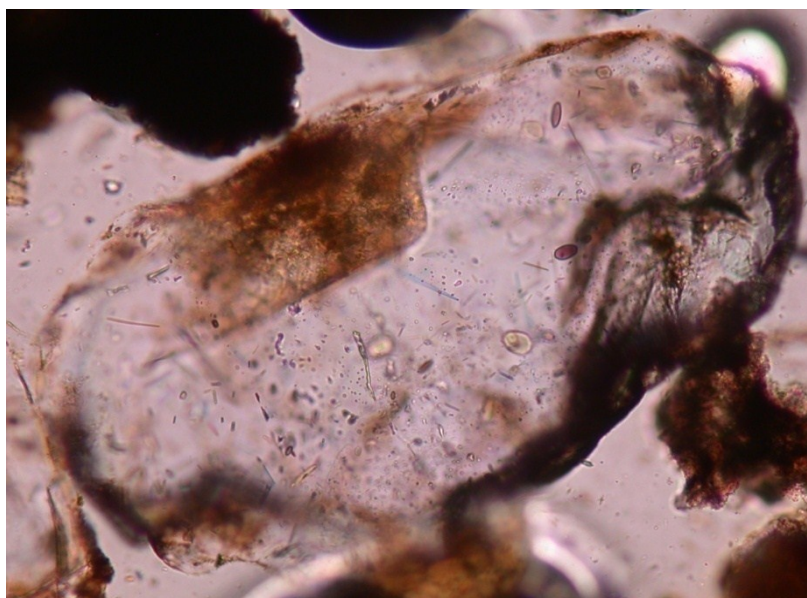


Figure 4.1. Photomicrograph of a quartz grain with myriads of fluid inclusions. The grain also shows a conchoidal fracture on the right. (PPOL, FOV = 0.55 mm).

4.2.1.1 *Quartz contents*

Quartz was found in all of the 40 house dust samples, including the 5 samples that were composed predominantly of organic particles (these 5 samples were excluded when analyzing data). On average 26.5% of the mineral fraction of the house

dust specimens was quartz. However its abundance was not uniform throughout the specimens. Quartz contents varied from one home to another within a given city and among the different cities. For example, the lowest quartz content was 14.1 % in one Hamilton specimen while the highest was 43.1% in Burlington (see Table 4.2). The lowest average quartz content was in Hamilton (Qtz-HA average 18.2 %, n = 6) and the highest average was in Burlington (Qtz-BU average 36.0 %, n = 6). Despite the similar geology and geographical location of these two neighbouring cities, their quartz content appeared to be significantly different. On the other hand, despite Sudbury's noticeably different bedrock geology from Barrie and Cambridge, these three cities have relatively similar average quartz contents (Qtz-SU average 27.7%, n = 6, Qtz-BA average 28.7%, n = 8, and Qtz-CA average 27.6%, n = 5). Thunder Bay specimens, in contrast, showed the second lowest average content of quartz (Qtz-TB average 21.1%, n = 5), next to Hamilton.

The variability of quartz contents in house dust within a given city was observed as well. Cambridge, for example, showed a relatively high range (20.7% to 33.6%, n = 5) and a higher standard variation (Qtz-CA SD = 6.2%, n = 5); Barrie specimens, on the contrary, showed low range (24% to 31%) and less variability (Qtz-BA SD = 2.9%, n = 8) (see Figure 4.2).

A comparison of quartz contents in cities located on the Paleozoic sedimentary rocks of the St. Lawrence Platform with those on the Precambrian Canadian Shield was done. Results indicated that differences between the average quartz in dust from cities located on the St. Lawrence Platform (Qtz-Paleozoic average 27.6 %, n = 24) and the Canadian Shield (Qtz-Precambrian average 24.7 %, n = 11) was not significant. The absence of a relatively significant difference between these two geologically distinct

regions might infer that local geology may not be the main factor in determining the amount of quartz grains in house dust. In general, quartz contents showed lower standard variation in specimens taken from cities on the Canadian Shield (Qtz-Precambrian range = 19.3 %, SD = 5.7 %, n = 11) than in specimens from cities in the St. Lawrence Platform (Qtz-Paleozoic range = 28.7%, SD = 7.4 %, n = 24).

In summary, quartz was found in all dust specimens from all six Ontario cities, regardless of the nature of the local bedrock geology.

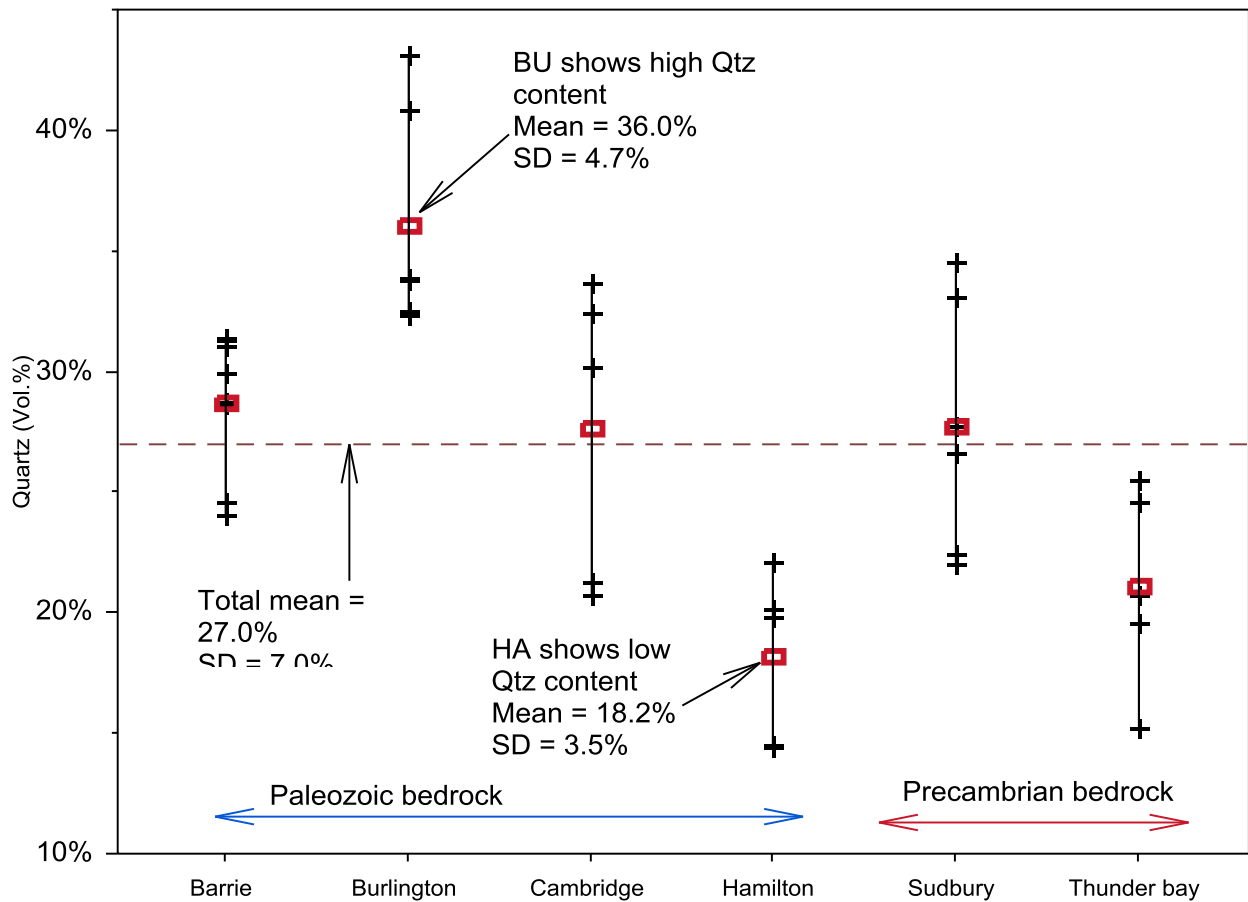


Figure 4.2. Quartz content in house dust from the six Ontario cities (ab %) included in the study. Hamilton samples show the least amount of quartz whereas samples from Burlington record the highest quartz content in their house dust.

Table 4.2 Summary of the statistical values of quartz contents in house dust from the six Ontario cities (ab %) included in the study area.

	Quartz					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	28.7	36.0	27.6	18.2	27.7	21.1
SD (%)	2.9	4.7	6.2	3.5	5.2	4.1
Min (%)	24.0	32.3	20.7	14.4	22.0	15.2
Max (%)	31.3	43.1	33.6	22.1	34.5	25.5

4.2.2 Feldspar minerals

Feldspars are the second most abundant mineral found in the house dust specimens. Feldspar minerals are ubiquitous in house dust. The size of feldspar grains varies widely within the sample fraction size (80 μm – 300 μm). Often the feldspar grains were angular. Their physical appearance, as observed under the stereoscope and microscope, varies from unfractured and transparent grains to fractured and often turbid (see Figure 4.3). The mineralogy of the feldspar minerals includes both groups of feldspar namely, plagioclase feldspars and alkali feldspars in decreasing abundance, respectively. As these specimens were not typical thin sections, but rather grain mounts, it was difficult to obtain interference figures with the polarizing microscope; nevertheless it was possible to determine the type of feldspar for some specimens using specific characteristics such as grid twinning in microcline feldspar, or albite polysynthetic twinning in plagioclase. Perthite exsolution textures were also observed (see Figure 4.4).



Figure 4.3. Photomicrograph of a turbid feldspar grain (PPOL, FOV = 0.55 mm).

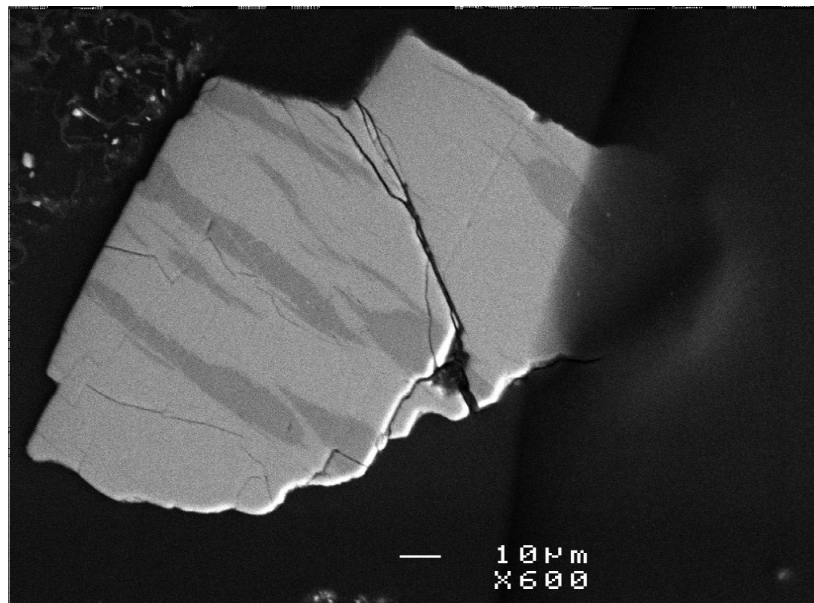


Figure 4.4. Scanning electron photomicrograph of a perthitic feldspar grain seen in backscattered-electron imaging.

4.2.2.1 *Feldspar contents*

With an average of 22.0 %, feldspars are the second most abundant mineral in house dust. Feldspars were found in all of the 35 house dust samples in all of the six cities studied. Feldspar contents per specimen ranged from 14.1% to 34.6 %. In all cities, except Burlington and Sudbury, the quantity of feldspar exceeded 30% in at least one specimen. The feldspar contents in the dust showed the highest range of values in Thunder Bay (range = 19.5 ab %, 15.1 to 34.6 %) and Hamilton specimens (range = 17.0 ab %, 14.1 to 31.1%). Burlington specimens showed the least variation (range = 9.2 ab %, 15.4 to 24.6 %). The average feldspar contents of all 6 cities were similar and lay between 18.9 % and 24.1 % (see Figure 4.5).

Thus, regardless of the location, i.e. Canadian Shield or St Lawrence Platform, the total average feldspar content appeared to be uniform.

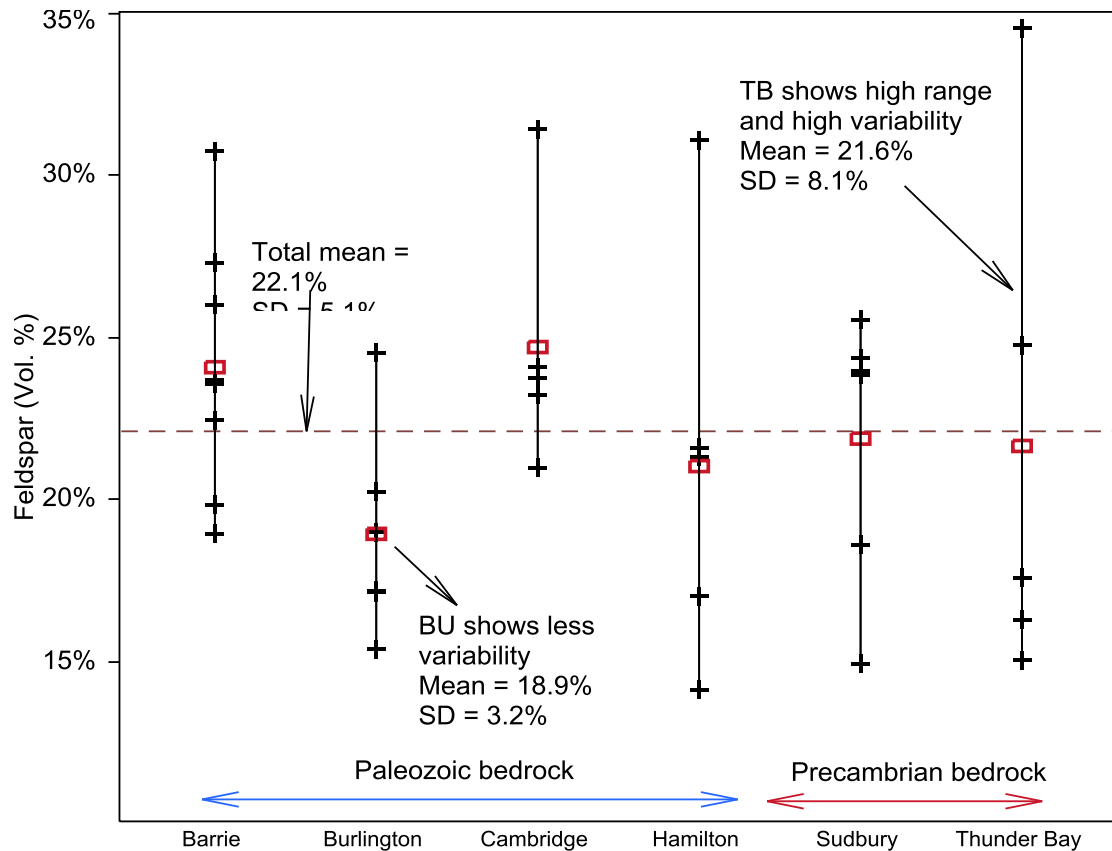


Figure 4.5. Feldspar contents in house dust from the six Ontario cities (ab %) included in the study. On average Cambridge samples show the highest average feldspar contents whereas Burlington samples have the lowest average feldspar contents in their house dust.

Table 4.3. Summary of the statistical values of feldspar contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Feldspar					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	24.1	18.9	24.7	21.0	21.9	21.7
SD (%)	3.9	3.2	3.9	6.4	4.2	8.1
Min (%)	19.0	15.4	21.0	14.1	14.9	15.1
Max (%)	30.8	24.6	31.4	31.1	25.6	34.6

4.2.3 Lithic fragments

Rock fragments were common and widespread in the house dust specimens. They were the third most abundant component. The average size of the rock fragments was 200 μm ; in a specimen size fraction of 80 – 300 μm . Of all minerals, lithic fragments showed the most irregular shapes. Their chemical composition ranged from felsic to mafic. Many of the lithic fragments in the dust specimens were identified as granitic in nature with minerals such as quartz, feldspar and muscovite.

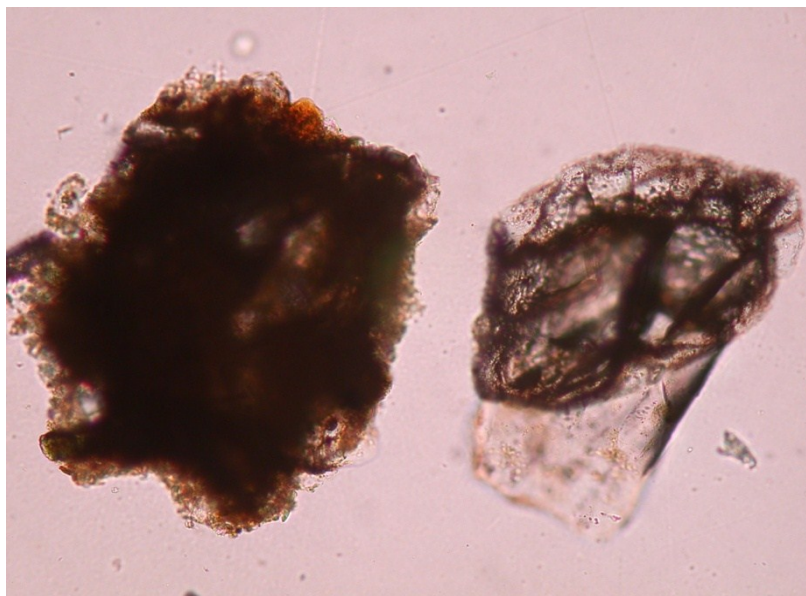


Figure 4.6. Photomicrograph of lithic fragments comprised of quartz, feldspar and muscovite, (PPOL, FOV = 0.55 mm).

4.2.3.1 Lithic fragment contents

With a total average content of 19.1 ab %, lithic fragments are the third most important component in the dust. The average abundance of lithic fragments in these specimens ranged from 16.8% to 20.7%. These averages were essentially similar across all cities. However, the proportion of lithic fragments in individual specimens from the

six cities varied. For example, we found lithic fragments as low as 9.3 % in a specimen from Thunder Bay and as high as 25.6 % in a specimen from Burlington. The range of lithic fragment contents also changed considerably from one city to another, with some cities showing a considerable range of values. Burlington and Thunder Bay specimens, for instance, showed high variability in their lithic fragments contents (LF-BU range = 14.8 ab %, SD = 6.3 %, n = 6 and LF-TB range = 16.9 ab %, SD = 6.2 %, n = 5). Cambridge samples, on other hand, recorded the least variability (LF-CA range = 5.7 ab %, SD = 2.3 %, n = 5) (see Figure 4.7). The results also indicated that proportions of lithic fragments in a specimen did not appear to be affected by the location of the house.

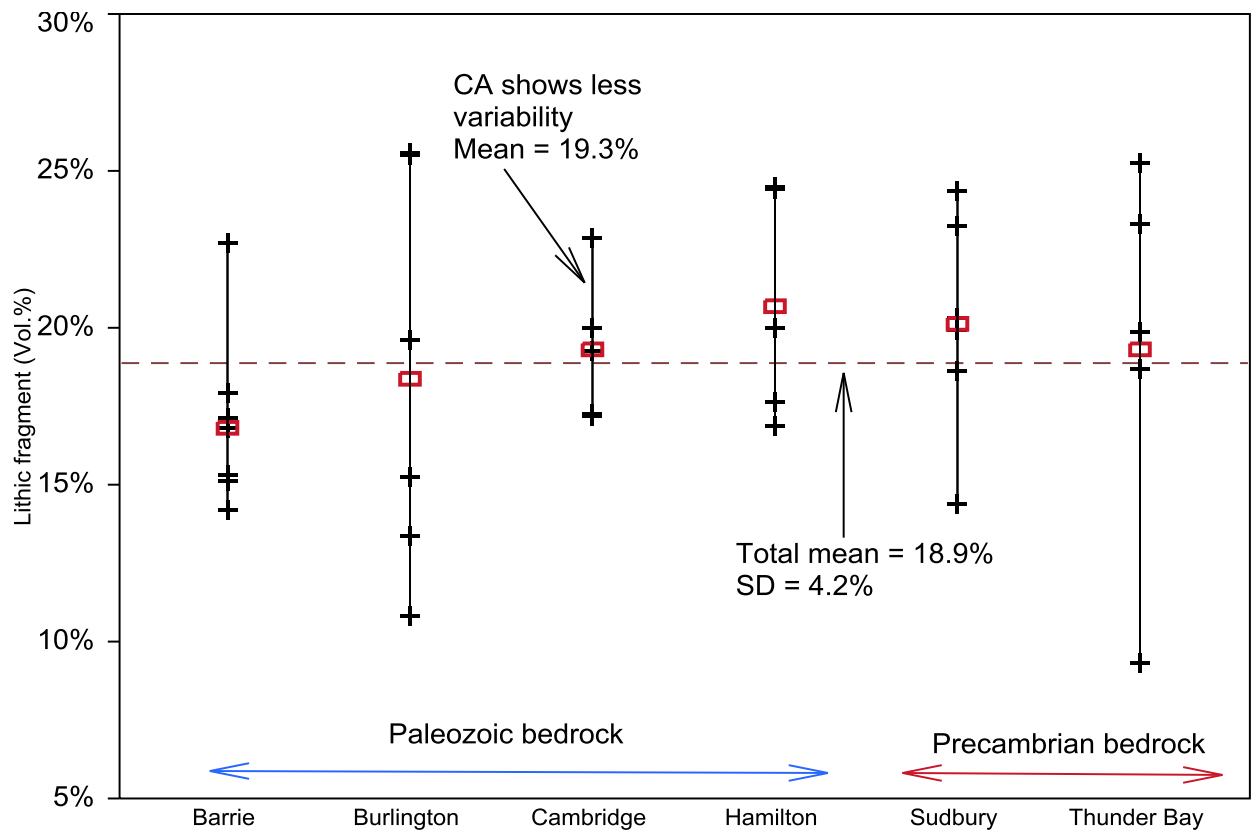


Figure 4.7. Content of lithic fragments in house dust from the six Ontario cities (ab %) included in the study. The content of lithic fragments in house dust can be as low as approximately 10% and as high as 25%.

Table 4.4 Summary of the statistical values of lithic fragment contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Lithic fragments					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	16.8	18.4	19.3	20.7	20.2	19.3
SD (%)	2.7	6.3	2.3	3.7	3.6	6.2
Min (%)	14.2	10.8	17.2	16.9	14.4	9.3
Max (%)	22.7	25.6	22.9	24.5	24.4	25.2

4.2.4 Carbonate minerals

In this study, all carbonate minerals such as calcite, dolomite, and chalk (composed of calcite) were considered as a single component. Calcite was by far the most dominant carbonate mineral in house dust. Carbonate minerals were present in all dust samples but showed considerable variation in content. Unlike the three major mineral components described above, carbonate mineral grains were fragmented and smaller in size. Carbonate grains, in the given specimens, have an average size of less than 150 μm of diameter. Often it was common to find these carbonate minerals in highly fractured or even in powder form with a size fraction of approximately 10 μm . The very small grain size and the seemingly fresh-angular morphology might be attributed to the low hardness of these minerals, 3 on the Mohs scale. Most grains are transparent under plane-polarized light and exhibit characteristic high birefringence under crossed polars.

4.2.4.1 Carbonate minerals contents

Carbonate minerals are the fourth major component of the house dust specimens, with a total average content of 14.0 ab %. Similar to quartz, feldspars and lithic fragments, carbonate minerals are ubiquitous in house dust. Carbonate minerals were found in all specimens of house dust from all six cities, despite our prior expectation not to find carbonate minerals because of their low mechanical resistance and high solubility. Carbonate mineral contents in the house dust specimens varied from a low of 2.4 ab % in one specimen from Sudbury to a high of 44 ab % in a house from Hamilton (see Table A.1). Sudbury specimens showed the lowest average content

of carbonate minerals (Carb-SU min = 3.4 ab %) while Hamilton showed the highest (Carb-HA max = 29.3 ab %).

Notable differences were observed for the average contents of carbonate minerals from the four cities located on the St. Lawrence Platform (Carb-Paleozoic) and the two on the Canadian Shield (Carb-Precambrian) (see Figure 4.8). The average carbonate mineral content observed in dust specimens from cities located on Paleozoic bedrock, at 17 ab % appears to be significantly higher than the average for the two cities located on the Canadian Shield (6.4 ab %).

Sudbury and Thunder Bay, two cities located on the Precambrian rock of the Canadian Shield, showed low average carbonate content with 3.4 % and 9.3%, respectively. Specimens from the four cities located on the Paleozoic rocks of the St. Lawrence Platform showed much higher average contents of carbonate minerals. The highest content, (29.3 %) was observed in a Hamilton sample followed by Burlington (15.2 %), Cambridge (13.5 %), and Barrie (13.2 %), respectively. This distinct variation in the average content of carbonate minerals in house dust from the six cities may be a function of the local geology.

As shown in the figure below (Figure 4.8), carbonate minerals in house dust from Sudbury and Thunder Bay are below the total average content (14.0 %), which clearly indicates a relatively significant difference in carbonate minerals content between the house dust from the St. Lawrence Platform and samples from the Canadian Shield.

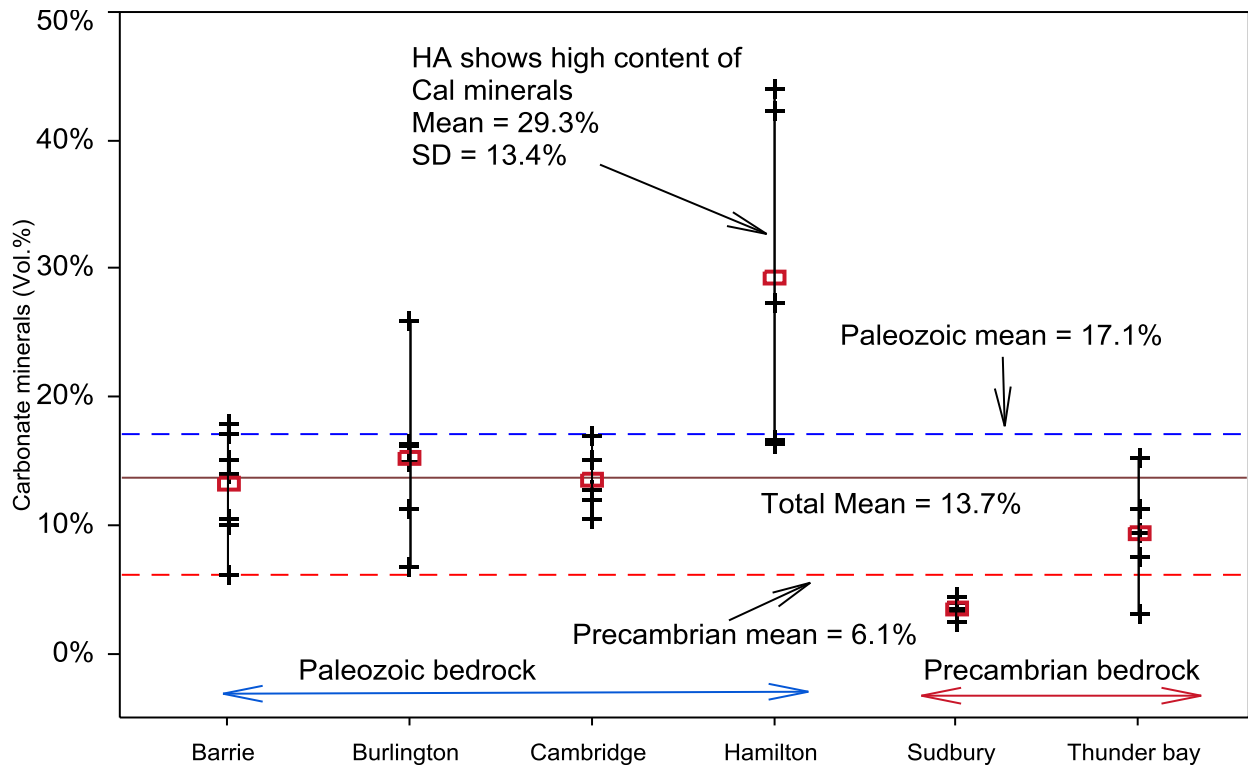


Figure 4.8. Content of carbonate minerals in house dust from the six Ontario cities (ab %) included in the study. Hamilton samples show the highest amount of carbonate minerals of all six cities.

Table 4.5 Summary of the statistical values of carbonate minerals contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Carbonate minerals					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	13.2	15.2	13.5	29.3	3.4	9.3
SD (%)	4.0	6.4	2.6	13.4	0.7	4.5
Min (%)	6.2	6.8	10.5	16.3	2.4	3.1
Max (%)	17.9	25.9	17.0	44.0	4.4	15.3

4.3 Minor mineral components

As defined in this study, minor minerals account for less than 5% of the mineralogical component of the house dust. It is worth mentioning that in some specimens they are not observed at all. In the table below (Table 4.6), the average contents of minor minerals that were identified in the dust specimens are given.

Table 4.6 Total average contents of minor minerals in house dust

Minor mineral components in the house dust specimens in average ab %	
Amphibole	4.8%
Chlorite	2.6%
Biotite	2.5%
Sulphide minerals	1.9%

4.3.1 Amphibole minerals

Amphibole minerals were minor mineral components in the dust specimens with a total average content of 4.8 ab %. The average diameter size for amphibole grains in house dust was 150 μm . In most specimens grains were anhedral. The colour of the amphibole grains, when observed under plane-polarized light, was pale green to dark green (see Figure 4.9). The amphibole mineral in the specimens was determined, from common optical properties, to be most probably hornblende. Hornblende under plane-polarizing light showed its characteristic two sets of cleavages (approximately at 60° and 120°).

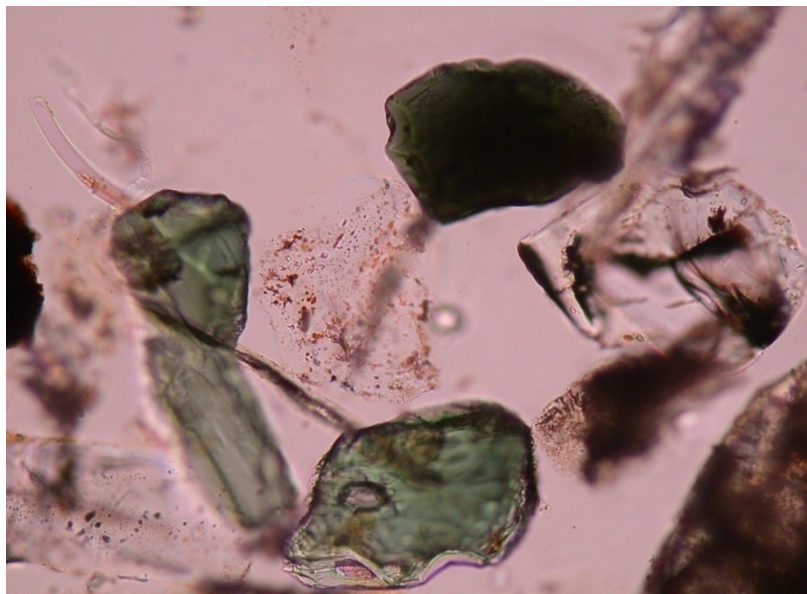


Figure 4.9. Photomicrograph of hornblende grains (PPOL, FOV = 0.55 mm).

Amphiboles, with a total average content of 4.8 ab %, are 5th in order of all mineral components present in house dust. The highest abundance of amphibole observed in a dust specimen was 9 ab %. Unlike the four previously described minerals (quartz, feldspars, lithic fragments and carbonate minerals), amphiboles were not present in all specimens; amphiboles were absent in one Hamilton specimen (HA-63). The absence of amphibole minerals in this one Hamilton specimen contributed to the high range and high variability of amphibole contents (Amph-HA range = 7.6 %, SD = 2.9%, n = 4); in contrast Cambridge specimens (see Figure 4.10) showed low range and less variability (Amph-CA range = 2.9%, SD = 1.3%, n = 5).

The average contents of amphibole minerals in specimens from cities on the Canadian Shield (Amph-Precambrian mean = 5.9%, n = 11) are higher than the average contents in cities from the St. Lawrence Platform (Amph-Paleozoic mean = 4.2%, n = 23).

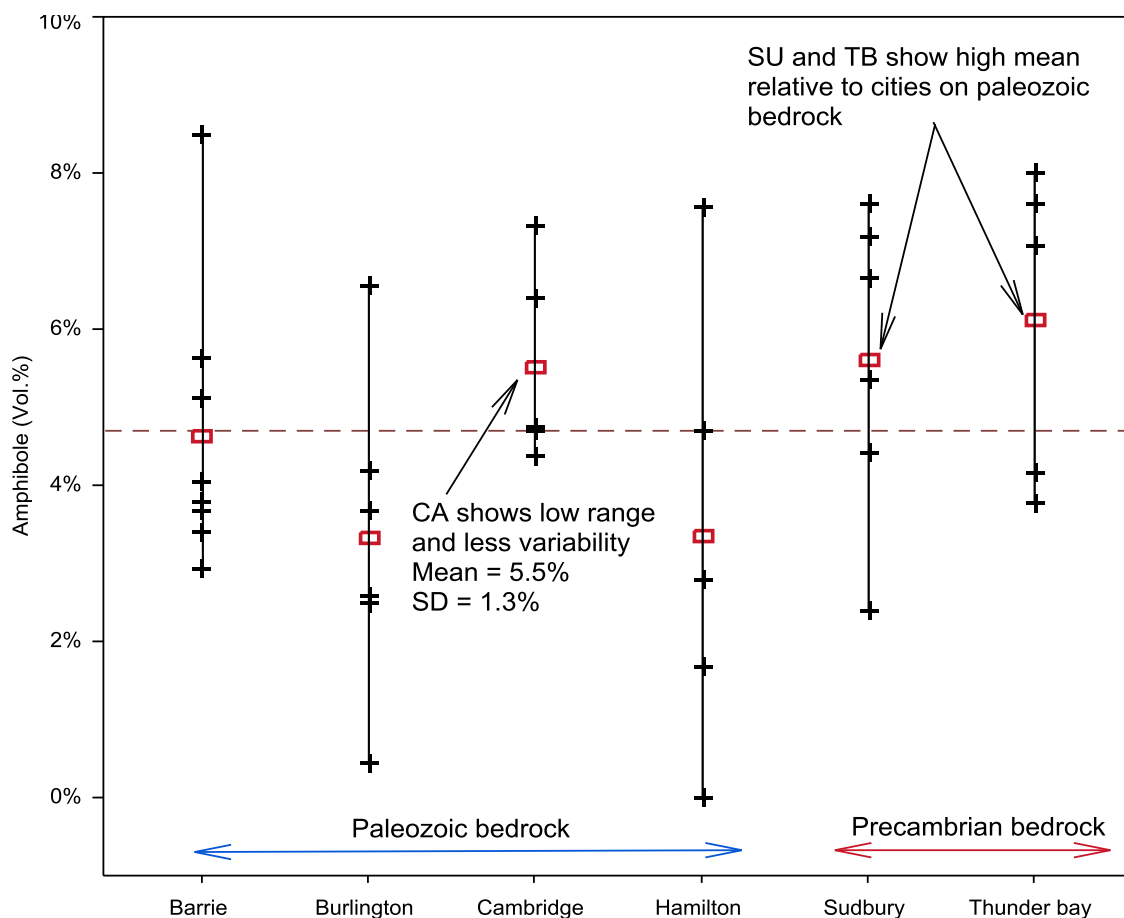


Figure 4.10. Contents of amphibole minerals in house dust from the six Ontario cities (ab %) included in the study. Dust specimens from Burlington and Hamilton have the lowest average amphibole contents. In contrast, dust from Sudbury and Thunder Bay have the highest abundances.

Table 4.7 Summary of the statistical values of amphibole contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Amphiboles					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	4.6	3.4	5.5	3.4	5.6	6.1
SD (%)	1.8	2.0	1.3	2.9	2.0	2.0
Min (%)	2.9	0.5	4.4	0.0	2.4	3.8
Max (%)	8.5	6.6	7.3	7.6	7.6	8.0

4.3.2 Mica minerals

Biotite, with total average of 2.5%, is the most common minor mineral and the 6th most abundant mineral group in the house dust specimens. Biotite, like other minor minerals, is not present in all of the 35 specimens. It is absent in one sample of dust from Burlington, Cambridge, and Hamilton (BU-46, CA-81, and HA-104, respectively) (see Table A.1). Some samples have no biotite while others have as much as 8 ab % (Bt content as in SU-36).

The total average biotite content was different for the dust samples collected from homes located on Precambrian bedrock (Bt-Precambrian mean = 4.1%, n = 11) than in homes on the Paleozoic bedrock (Bt-Paleozoic average 1.8%, n = 22).

The difference within the means of Paleozoic samples is 1.3 ab %, whereas it is 2.2 ab % for Shield samples. The high variation within the Shield samples is because Thunder Bay specimens have a higher average compared to the Sudbury specimens. Therefore, the high mean observed in the Shield samples is mainly due to the high biotite contents of the Thunder Bay specimens (Bt-TB average 5.2%, n = 5).

When the amount of biotite in house dust was compared to another type of mica, notably muscovite, the very low quantities of muscovite in many specimens came as a surprise. If muscovite was observed, it was typically present only in trace amounts i.e., less than 1% on average. As a result muscovite was grouped under trace minerals. Muscovite was absent in all Barrie samples, whereas Burlington samples averaged the highest muscovite content (Mt-BU average 1.1%, n = 5). The nature of the geology of the sampling site did not seem to be a factor as the difference in the average muscovite content in both Shield and Paleozoic samples was not significant.

Table 4.8 Summary of the statistical values of biotite contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Biotite					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	2.6	1.3	1.9	1.4	3.0	5.2
SD (%)	1.2	0.9	1.3	1.0	2.5	1.3
Min (%)	1.3	0.0	0.0	0.0	0.9	3.4
Max (%)	4.8	2.3	3.2	2.4	8.0	6.6

4.3.3 Chlorite minerals

Chlorite minerals in the house dust specimens were not as common as amphibole minerals. Chlorite in the dust can be identified by its greenish colour. Similar to micas, chlorite minerals exhibited a basal cleavage under plane-polarizing light. Chlorite minerals in the specimens showed moderate to high relief compared to the epoxy.

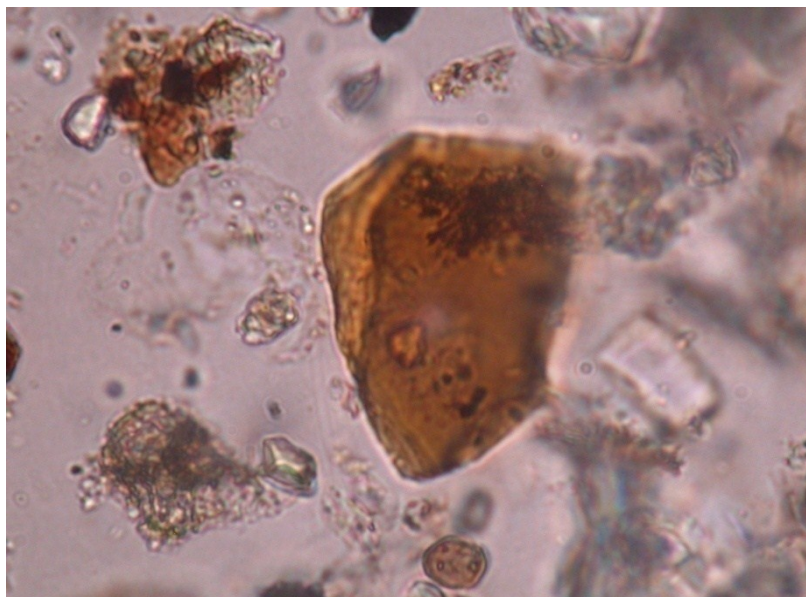


Figure 4.11. Chlorite mineral in house dust with brownish green colour and one set of cleavage (PPOL, FOV = 0.55 mm).

4.3.2.1 Chlorite minerals contents

If we were to only compare the total average of all minerals, chlorite minerals would be the 6th most important mineral. The total average of chlorite (2.6 ab %) was highly skewed by the presence of an abnormally high content of chlorite minerals in one Sudbury sample (Chl content in SU-08 was 25 ab %). The ranking of chlorite minerals was recalculated by excluding this exceptionally high sample (SU 08). Thus, chlorite minerals are not the most important minor mineral. Rather, they are second to biotite.

Table 4.9 Summary of the statistical values of chlorite contents in the house dust from the six Ontario cities (ab %) included in the study area.

	Chlorite					
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	1.9	0.5	1.0	1.9	7.7	2.7
SD (%)	1.0	0.3	0.6	1.3	9.2	0.6
Min (%)	0.4	0.2	0.0	0.0	1.6	2.1
Max (%)	2.9	1.0	1.5	3.1	25.8	3.5

4.3.4 Sulphide minerals

Sulphide minerals, with a total average of 1.9 ab %, are the third most abundant minor mineral in house dust. Like other minor minerals, sulphide minerals were not found in all house dust samples. For example, sulphide minerals were not observed in all Burlington and most of the Hamilton specimens. In contrast, they were present in all specimens from the Shield. Barrie and Cambridge, from the St. Lawrence

Platform, have similar average value to the Canadian Shield cities of Sudbury and Thunder Bay. The Canadian Shield specimens have higher sulphide minerals (mean of 3.3 ab %) than Burlington and Hamilton specimens (Fig. 4.12).

Table 4.10 Summary of the statistical values of sulphide minerals content in the house dust from the six Ontario cities (ab %) included in the study area.

Sulphide minerals						
	BA	BU	CA	HA	SU	TB
N	8	6	5	5	6	5
Mean (%)	2.3	0.0	2.0	0.4	2.6	4.0
SD (%)	1.4	0.0	1.1	0.9	1.1	1.8
Min (%)	0.9	0.0	0.4	0.0	1.6	1.2
Max (%)	4.9	0.0	3.4	2.0	4.4	5.8

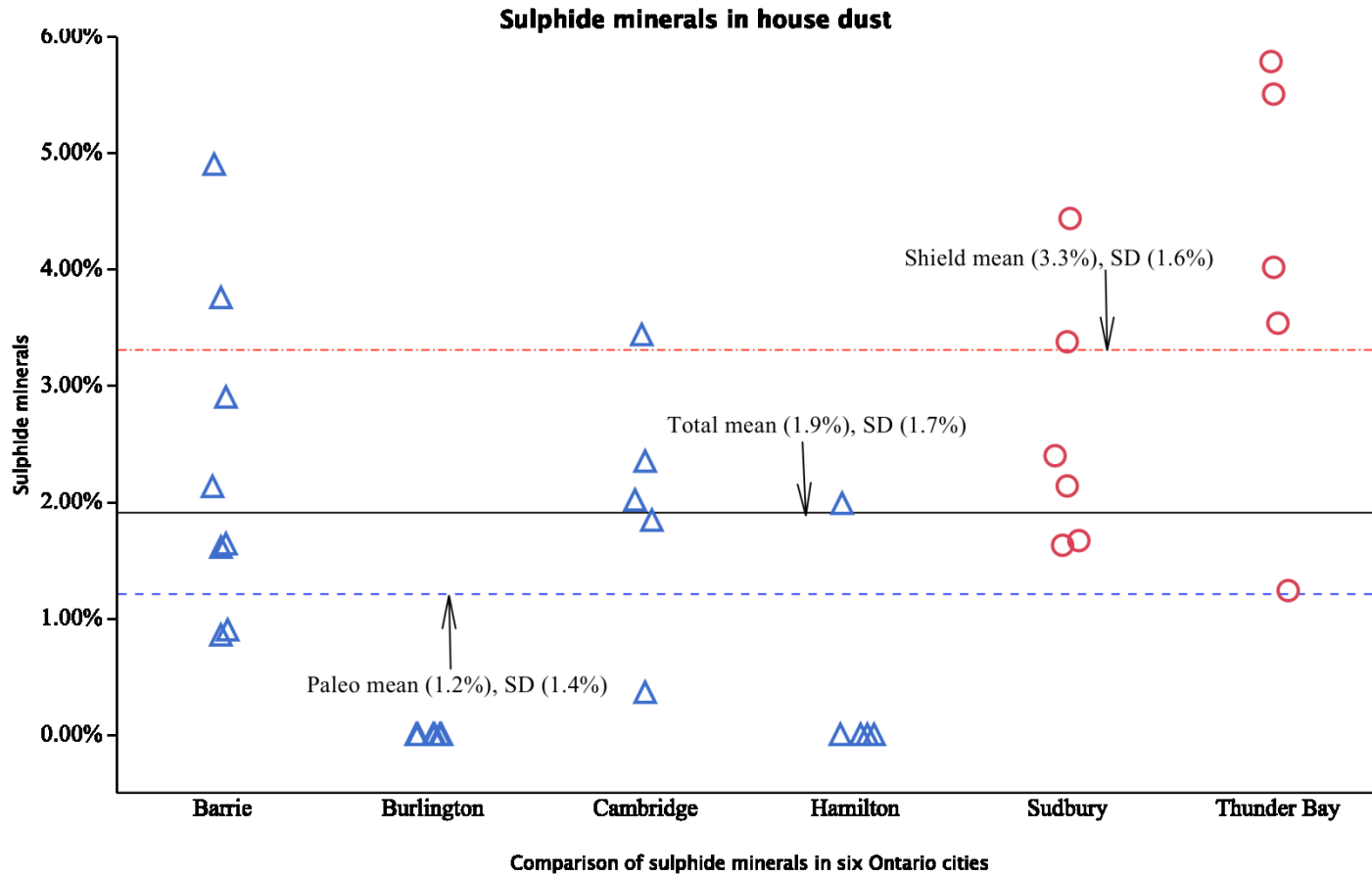


Figure 4.12. Contents of sulphide minerals in house dust from the six Ontario cities (ab %) included in the study. On average, Shield specimens have a higher contents of sulphide minerals in their house dust than Burlington and Hamilton specimens, but have similar abundance with Barrie and Cambridge.

4.4 Trace mineral components

The total average of mineral or mineral groups that are under a percentile is grouped under trace minerals. In this group, it is possible to find individual specimens with trace mineral content exceeding the 1% baseline that was defined as trace minerals across all samples and cities. For example, in one house dust specimen (SU-36) the almandine garnet content was found to be 2.7%. Trace minerals (e.g. rutile, garnet, etc...) are not discussed in detail in this thesis as their abundance in house dust do not allow to conduct a sound statistical analysis.

Table 4.11 Average contents of trace minerals in house dust

Trace mineral components in the house dust specimens in average ab %	
Pyroxenes	0.9%
Garnet	0.9%
Apatite	0.5%
Muscovite	0.4%
Aluminosilicate polymorphs	0.4%
Rutile	0.3%

4.4.1 Pyroxene

Although pyroxene group minerals are among the common rock-forming minerals, their presence in house dust was unexpectedly low. On average, 0.9% of the mineralogical components of house dust is pyroxene. As a result, pyroxene are grouped under trace minerals. The maximum pyroxene content was observed in a Sudbury

specimen (SU-36), i.e. 20 pyroxene grains were point-counted under PLM out of 376 mineral counts that resulted in this high percentage point of 5.3%.

4.4.2 Almandine garnet

Almandine garnet was the common type of garnet mineral. Almandine garnet, a hard mineral resistant to weathering, was present in a trace amount in many dust specimens. The average grain size for garnet was 250 μm . These large grains of garnet have subhedral shape when observed under plane polars. Garnet grains resemble quartz in house dust specimens but the garnet grains were often bigger, exhibit high refractive index and were isotropic. The garnet grains did not display any cleavage, but showed uneven fracture.

With a total average of 0.9%, almandine garnet is the second most abundant trace mineral in house dust. It was absent in all but one Hamilton sample and was present in all Shield samples. The abundance of almandine garnet was as high as 2.7% of the mineral fraction of house dust, as was shown in SU-36 (see Appendix A1, Table A-31).

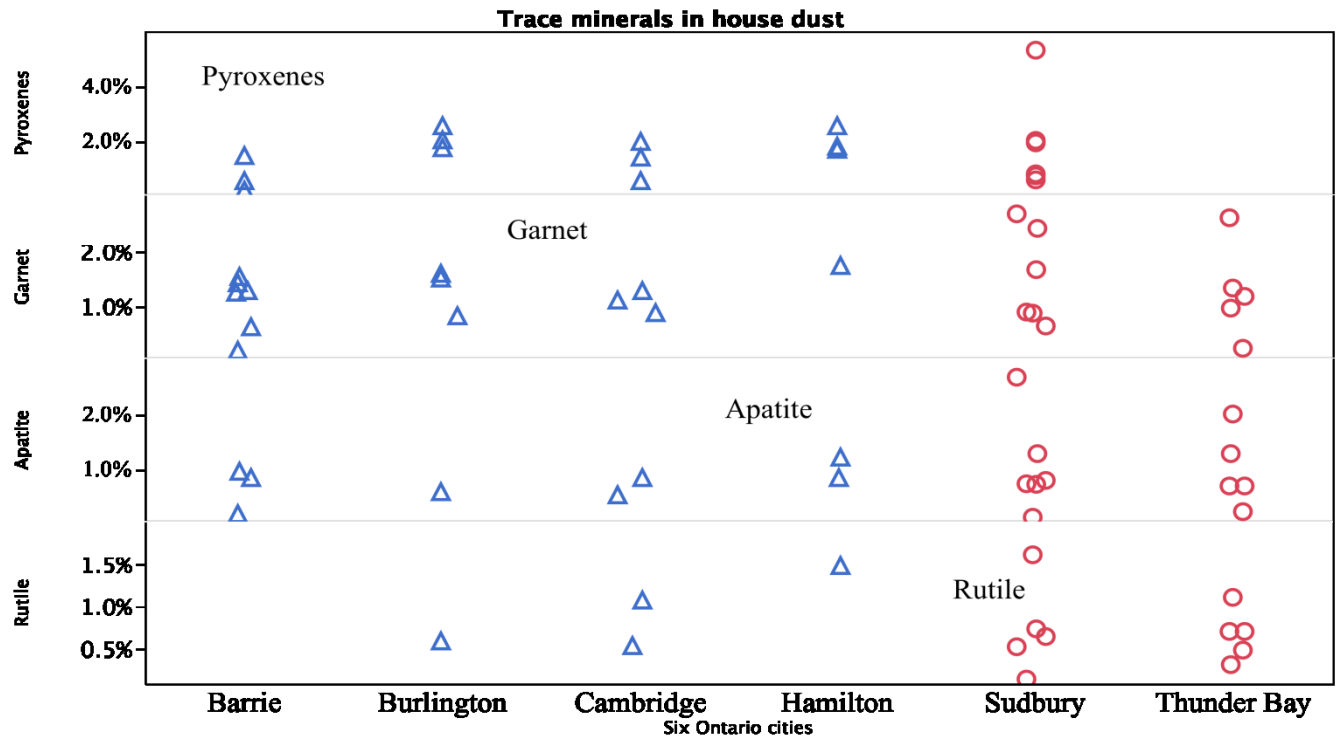


Figure 4.13. Trace minerals in house dust. These trace minerals were relatively abundant in samples from the Shield. For example, mineral rutile was never found in Barrie specimens but it was present in all of Shield specimens.

4.5 Metallic components of house dust

Metallic components of house dust were detected both under the microscope and SEM. The type of metals and the potential sources of these particles were deduced from the results of these two techniques. Some of these metals were associated with anthropogenic sources such as Cu - in copper wire; Pb – in solder, and Ni – in coins or other domestic metallic objects, to mention a few. However, there were also metallic oxide minerals identified in house dust samples. Hematite and ilmenite were among the naturally occurring metallic oxide minerals found in some of the specimens.

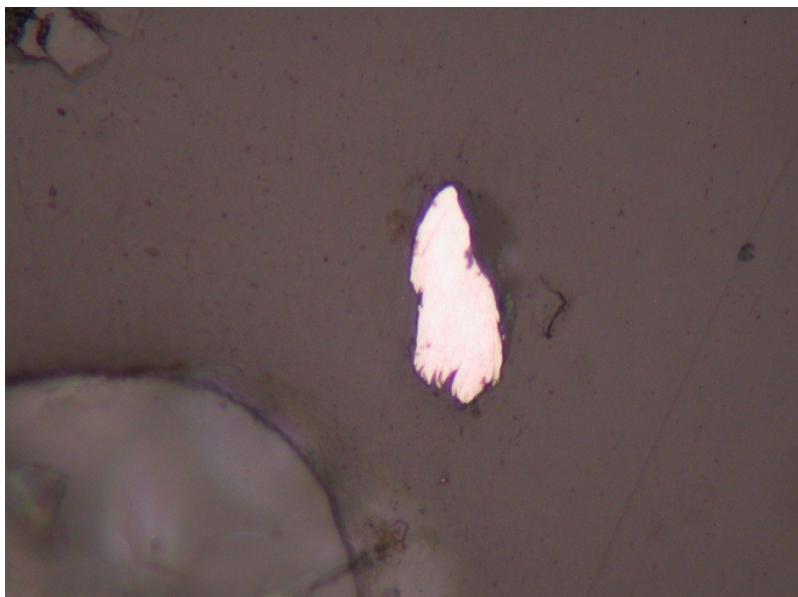


Figure 4.14. Fragments of copper wire seen under plane polarized reflected light (PPOL, FOV = 0.55 mm).

4.6 Non-mineral components of house dust

Materials such as synthetic fibres, slag and dirt are categorized under this group of Non-minerals. This group is omnipresent in all dust samples. To mention a

few, human and animal hairs, carpet fibres, and cotton fibres were very common in most of the dust samples.

4.7 Unidentified minerals

Many other minerals and components could not be identified because of the complex nature of dust. Further analyses such as XRD-Rietveld, synchrotron, and chemical analytical methods are recommended to identify these small proportions of unidentified minerals and components.

4.8 Summary of results

According to these results, the major minerals in the house dust are quartz, feldspars, lithic fragments, and carbonate minerals. Minor minerals include amphiboles, mica, chlorite, and sulphide minerals. Other minerals such as pyroxene, garnet, apatite, aluminosilicate minerals, rutile, and native elements constitute trace minerals.

5.0 Discussion

5.1 Contribution of the local bedrock geology to the mineralogical composition of the house dust

To the author's best knowledge, there have been few studies that have examined the contribution of bedrock geology to the mineralogical composition of house dust. To date, the immediate surrounding environment to the home, notably soil, is generally assumed to be the source of minerals (mineral grains, mineral groups or lithic fragments) that are found in house dust (Mølhavé et al., 2000). Some previous studies have even referred to minerals in the house dust as "soil minerals" (Hunt et al., 1992 and Mølhavé et al., 2000). The premise of this assumption is that the mineralogical composition of house dust resembles the composition of the nearest soil or the local surficial geology (a thesis often held by forensic geologists). Because the author felt that previous studies did not highlight the contribution of the local geology to the composition of minerals in house dust, this chapter qualitatively describes the extent of influence of (or the lack of) the local bedrock geology on the mineralogical composition of the house dust.

More than 40 house dust samples were collected from six Ontario cities to identify the mineral composition of house dust, as described in Chapter 3. Eleven of these were from homes located on the Precambrian Canadian Shield and 29 from the Paleozoic St. Lawrence platform.

As stated in Chapter 2, the geology of the Precambrian Canadian Shield and the Paleozoic St. Lawrence platform are distinctively different (Figure 2.1). The

Precambrian Canadian Shield, which includes most of northeastern Canada, is a vast area of subdued topography with exposed Precambrian rocks (of both Archean and Proterozoic age) that include quartzofeldspathic gneisses, granitic and other intrusive rocks, metavolcanic rocks and minor sedimentary units. The St. Lawrence platform, located in Southern Ontario, is a Paleozoic sequence of sedimentary rocks of Cambrian to Devonian age. It is generally comprised of limestone, shale, and minor sandstone (Barnett, 1992). The surficial geology of both the Precambrian Canadian Shield and the Paleozoic St. Lawrence platform was affected by many geological events (weathering, erosion, post-glacial rebound etc...) but one of considerable importance is the last Pleistocene glaciation. As the ice accumulation and extent of the Pleistocene glaciation increased, glaciers and associated glaciofluvial processes transported various types of sediments that incorporated materials from the Canadian Shield towards the SSW and deposited this clastic debris on top of the Paleozoic St. Lawrence platform (dominantly sedimentary bedrock) (Barnett, 1992). On the Canadian Shield, the glaciers were agents of erosion that resulted in low relief, polished bedrock and little soil.

Despite the contrasting nature of the bedrock geology in the Precambrian Canadian Shield and the Paleozoic St. Lawrence platform, the mineralogical composition of house dust from houses in the six Ontario cities included in this study is remarkably similar. For the most part, the content of the major minerals (i.e. ≥ 5 ab%%, defined for the purpose of this study) in house dust of homes located on the Precambrian Canadian Shield bedrock and the Paleozoic St. Lawrence platform bedrock is virtually similar. Most of the house dust samples, regardless of their location, consist of quartz, feldspar, lithic fragments, carbonate minerals and amphibole minerals. For minerals such as quartz, feldspar, and lithic fragments, the nature of the local geology

does not appear to exert a significant control on the abundance of these minerals in the house dust (see Table 5.1).

Table 5.1 Content of selected minerals in house dust from cities located on Paleozoic and Precambrian bedrock in Ontario.

	Minerals in house dust in cities on the Paleozoic bedrock (n=24)		Minerals in house dust in cities on the Precambrian Canadian Shield (n=11)	
	Mean (%)	SD	Mean (%)	SD
Quartz	27.6	7.4	24.7	5.7
Feldspars	22.3	4.7	21.8	5.9
Lithic fragments	18.8	4.0	19.7	4.7

5.1.1 Contents of quartz in house dust and its relation to local geology

Quartz is the most abundant mineral in the house dust specimens. Specimens obtained from homes located on both the Precambrian Canadian Shield bedrock and the Paleozoic St. Lawrence platform bedrock show quartz grains with myriads of fluid inclusions and internal strain features that are indicative of a metamorphic-igneous provenance (see Appendix 1A). Barnett, in 1992, documented that sediments were transported from the Canadian Shield to southern Ontario and the northern United States during the last Winsconsinian glaciation. It is also known that a Paleozoic-era quartz arenite formation, such as the Nepean sandstone in Eastern Ontario which is also derived from the Canadian Shield, is found at the base of the Paleozoic section in the study area. The quartz grains from this Paleozoic-era quartz arenite formation have a high degree of roundness as they were deposited in a transgressive marine environment, unlike the angular grains found in the house dust specimens. Considering this movement of glaciofluvial sediments and, cross-examining and

analysing the mineralogical compositions of house dust grains, the author believes the most plausible reason to explain the presence of metamorphic-igneous quartz grains in houses located on the sedimentary rocks of the Paleozoic St. Lawrence platform is that these quartz grains come from sediments that originated from the Canadian Shield. Because of this distribution of sediments from the Shield to southern Ontario by the glaciers and its associated glaciofluvial processes, the compositions and average abundance of quartz grains in the house dust specimens from these two geologically distinct areas are similar.

Some differences in the contents of quartz in house dust specimens from the same city (see Table A.1) and within cities of similar geologic settings were observed. For example, the average contents of quartz grains in the specimens from the two neighbouring cities of Hamilton and Burlington, that both share similar glaciolacustrine sand-dominated surficial geology on top of shale and limestone-dominated bedrock, appear to show a relatively significant difference. Hamilton specimens showed extremely low average quartz content (Qtz-HA average 18.2 ab %, n = 6) whereas Burlington showed high average quartz content (Qtz-Bu average 36.0 ab %, n = 6). The composition of the quartz grains, as observed under PLM and SEM, in both cities is similar; the only significant difference observed was in the average contents. Quartz from the soil sand (of a glaciofluvial deposit) that is used in the winter season to increase traction on the icy roads and sidewalks might explain the likely origin of the quartz grains observed in the dust specimens. The considerable variation of the average quartz contents between these two adjacent cities with virtually similar geology could be due to numerous non-geological factors. For instance, the amount of sand that is used on the sidewalks can be one factor, residents' habit could be another factor (usage of door mats

in winter time to prevent or reduce the amount of tracked-in mud), or the distance of the sampled homes from main roads (the farther the homes are from the main road or a dust-emitting factory, the lesser the wind transported-quartz grains are available indoors).

It is also noted that the two most abundant minerals in house dust, quartz and feldspars, together account for over 49 ab % of the mineralogical components in the house dust. The presence or absence of these two minerals, like all other minerals found in house dust, does not seem to be related to each other if not for the constant sum effect (i.e. the total of all mineral components equal 100 %, therefore if quartz is anomalously high, other components need to be low). As a result of this constant sum, Burlington results show the contents of quartz and feldspar to compensate one another. For example, quartz and feldspar data from Burlington showed that it has low average feldspar content (Fsp-BU average 18.9 ab %, n = 6) and high average quartz content (Qtz-Bu average 36.0 ab %, n = 6). Thus, on average Burlington specimens have high quartz content and low feldspar content. Overall, unlike quartz, the average feldspar mineral contents in all 6 cites showed relatively little variation, with the exception of Burlington that registered relatively low feldspar content.

5.1.2 Contents of feldspar minerals in house dust and its relation to local geology

The contents of feldspar minerals in house dust do not seem to be influenced by the local geology either. Figure 5.1 shows that contents of feldspar minerals in house dust from homes of the two geologically distinct areas (Precambrian Canadian Shield bedrock and the Paleozoic St. Lawrence platform bedrock) are similar (18 – 24 ab %) regardless of the underlying bedrock.

Feldspar minerals, like the other major minerals (quartz, lithic fragments, and carbonate minerals) were observed in all specimens. Of all cities, Burlington showed the lowest average feldspar content (Fsp-BU average 18.9%, $n = 6$) while Cambridge showed the highest (Fsp-CA average 24.7%, $n = 5$), but Thunder Bay was the one that showed the highest standard deviation among its 5 specimens (Fsp-TB SD = 8.1%, $n = 5$) (Figure 5.1).

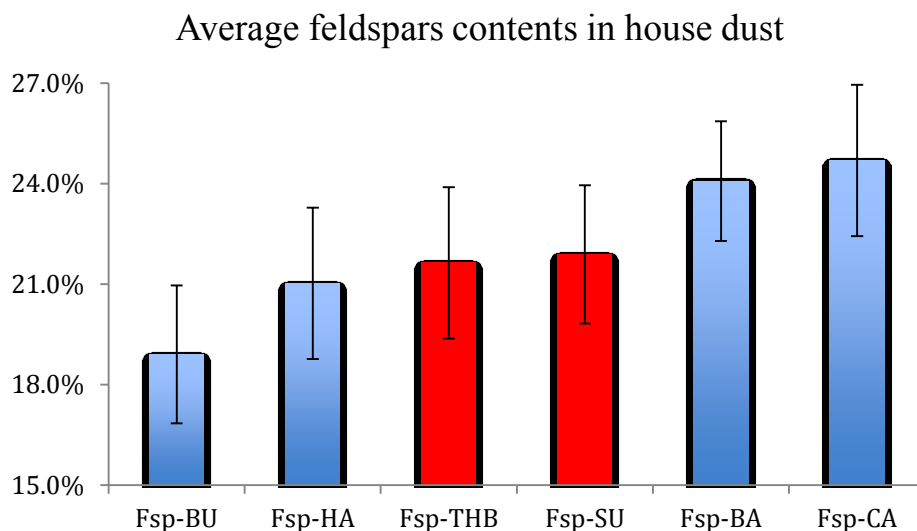


Figure 5.1. Average feldspar contents (ab %) for each of the six Ontario cities. Average feldspar contents are rather uniform (18-24%), regardless of the location on the Canadian Shield (red) (Fld-Precambrian mean = 21.8 %, SD = 5.9 %, $n = 11$) or the St Lawrence Platform (blue) (Fld-Paleozoic mean = 22.2%, SD = 4.7 %, $n = 24$).

5.1.3 Contents of lithic fragments in house dust and its relation to local geology

As with quartz and feldspar minerals, the nature of the local geology does not appear to exert much control on the content of lithic fragments in house dust. The average contents of lithic fragments for specimens from cities on the Precambrian Canadian Shield (LF-Precambrian mean = 19.7 ab %, SD = 4.7 %, $n = 11$) and the

Paleozoic St. Lawrence platform (LF-Paleozoic mean = 18.8 ab %, SD = 4.0 %, n = 24) were statistically similar (Figure 5.2). The average contents of lithic fragments do not show much difference in all cities, they range from a low of 18 ab % to a high of 22 ab %. In this study, small rock fragments (lithic fragments) in the thin sections were identified using PLM. But because of the inherent difficulty in identifying all minerals in these rock fragments and their small size, detailed differentiation and identification of all minerals that comprise the lithic fragments was not done. It is therefore hypothesized that if a detailed study on the types and composition of each mineral that comprise the lithic fragment was done, the composition of lithic fragments may vary depending on many factors including the nearby rock types (for example, mafic lithic fragments may be abundant in samples from the Canadian Shield).

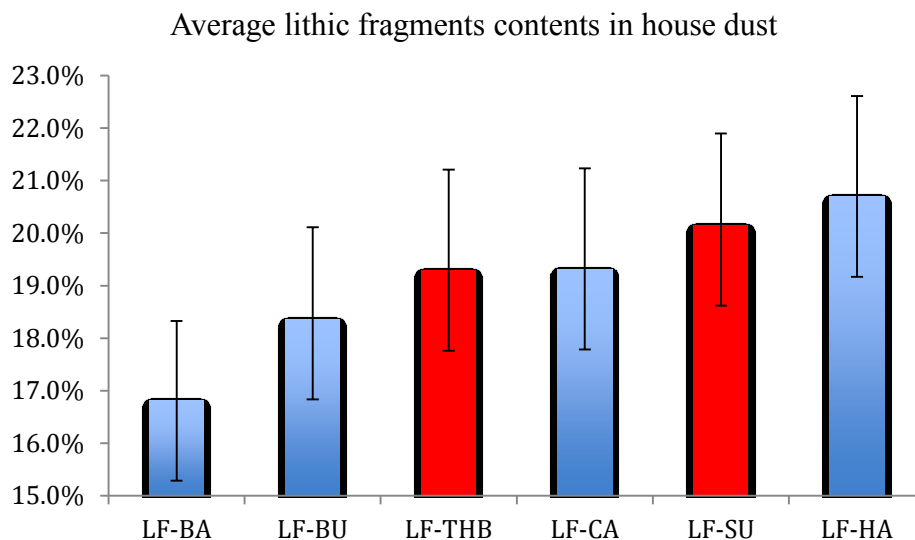


Figure 5.2. Average contents of lithic fragments in each of the six Ontario cities. The average contents of lithic fragments in the dust from the cities on the Canadian Shield (red) (LF-Precambrian mean = 19.7%, SD = 4.7%, n = 11) and St. Lawrence Platforms (blue) (LF-Paleozoic mean = 18.8%, SD = 4 %, n = 24) lie in a similar range of 17-21%.

5.1.4 Contents of selected minerals in house dust and their relation to local geology

So far, for the three major minerals quartz, feldspars and lithic fragments (not a mineral), the nature of the bedrock underlying the homes in the cities that were sampled does not appear to influence the contents of these minerals in the house dust. Regardless of the geography and the geology of bedrock, these three major minerals were present abundantly in house dust. However, there are instances where the local bedrock geology does appear to exert a limited control on the mineralogical composition and abundance of the minerals in house dust. Local geology can be attributed as a potential source for mineral content of house dust mainly in two cases: –

1. When the mineralogical composition of the mineral in house dust matches with the description of the local geology,
2. Or when a mineral is found in significantly high or low abundance in house dust in a manner that reflects the abundance (or scarcity) of the mineral in the locality.

For carbonate minerals, and some minor (i.e., 1 - 5 ab %) and trace minerals (i.e., < 1 ab %), such as amphiboles, sulphides, biotite, and garnet, local geology may influence the presence and abundance of these minerals in house dust (see Table 5.2).

Table 5.2. Contents of selected minerals in house dust from homes located on Paleozoic bedrock and Precambrian Canadian Shield.

	Minerals in house dust in cities on the Paleozoic bedrock (n=24)		Minerals in house dust in cities on the Precambrian Canadian Shield (n=11)	
	Mean (%)	SD	Mean (%)	SD
Carbonate minerals	17.8	9.3	6.4	4.2
Amphiboles	4.2	2.1	5.9	1.9
Biotite	1.8	1.2	4.1	2.3
Sulphide minerals	1.3	1.4	3.2	1.5

5.1.4.1 Contents of carbonate minerals in house dust and the local geology

A significant difference was observed in the average contents of carbonate minerals in homes located on the Precambrian Canadian Shield bedrock and the Paleozoic St. Lawrence platform bedrock (Carb-Paleozoic mean 17.8 ab %, n = 24, and Carb-Precambrian mean 6.4 ab %, n = 11). As discussed in Chapter 2 (Location, physiography and geology) the Paleozoic St. Lawrence platform bedrock is dominated by sedimentary rocks mainly limestone beds, whereas the Precambrian Canadian Shield bedrock is dominated by quartzofeldpathic igneous and metamorphic rocks. The glaciers that traveled towards SSW Ontario, as documented by Barnett in 1992, did not only erode and contain the metamorphic-igneous rocks of the Canadian Shield but also the local bedrock of the Paleozoic-era sedimentary rocks such as limestone. As the glaciers left the Canadian Shield bedrock on their southward flow, and embarked onto the Paleozoic sedimentary units of the St. Lawrence Platform, the content of limestone and other sedimentary carbonate rock clasts in the tills and associated fluvio-glacial deposits increases considerably (Cowan, 1978). The till at the Scarborough bluffs, a well-known exposure of Quaternary glacial sediments near Toronto shows a high

proportion of Paleozoic limestone clasts, in addition to the quartzofeldspathic metamorphic-plutonic rocks of Precambrian provenance (A.E. Lalonde, pers. comm.). It was not surprising to observe the average contents of carbonate minerals in homes that are located on the Precambrian Canadian Shield to be considerably less than that of the homes on the Paleozoic St. Lawrence platform as there are not apparent direct geological input of carbonate minerals into the house dust from the Shield. Furthermore, even though in both geological settings there were undoubtedly some carbonate minerals in house dust of other origins (e.g. marble etc.) than the limestone or dolostones of sedimentary origins, the specimens from the homes located on the Paleozoic St. Lawrence platform showed mainly calcite in the forms of fine grained crystals. The carbonate minerals from samples on the Paleozoic St. Lawrence platform reflected the nature of the underlying bedrock in the Paleozoic cities, which is mostly covered by limestone (see Table 5.2 and Figure 5.3). Therefore, it is possible to conclude that local geology (mainly limestone and dolostones) is likely to contribute to this significant difference in the content of carbonate minerals.

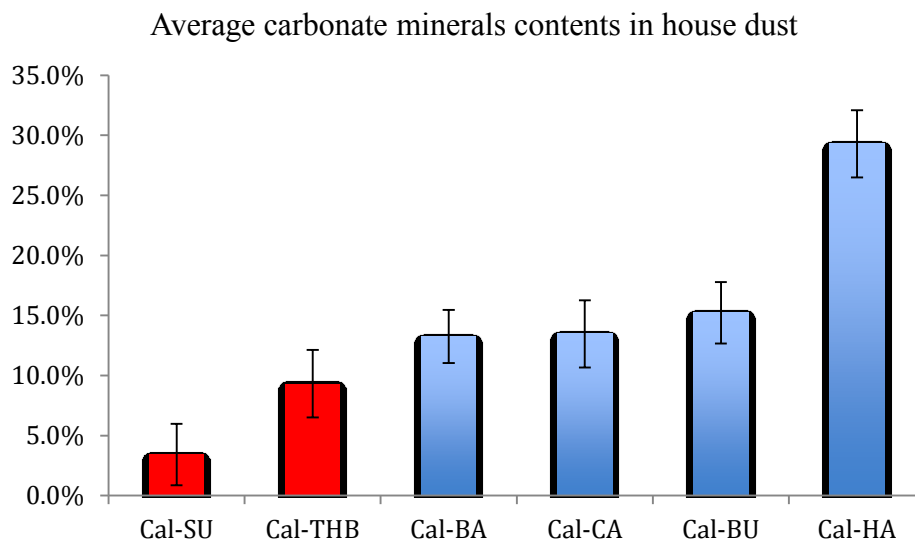


Figure 5.3. Average carbonate minerals contents in house dust as compared in six cities. Hamilton specimens showed exceptionally high carbonate mineral contents. The average carbonate mineral content for the four cities located on the Paleozoic bedrock (17 ab %) is significantly higher than the average for the two cities located on the Canadian Shield (6.4 ab %).

5.1.4.2 Contents of sulphide minerals in house dust and the local geology

The Precambrian Shield's richness in ore minerals such as sulphides might have exerted some control on the composition of the Sudbury and Thunder Bay samples that showed relatively higher sulphide mineral contents in their dust samples. Thunder Bay samples showed higher average content of sulphides coupled with high feldspar content and low content of quartz; this is probably because of the high sulphide contents in the metashales of the Thunder Bay bedrock (see section 2.7.3).

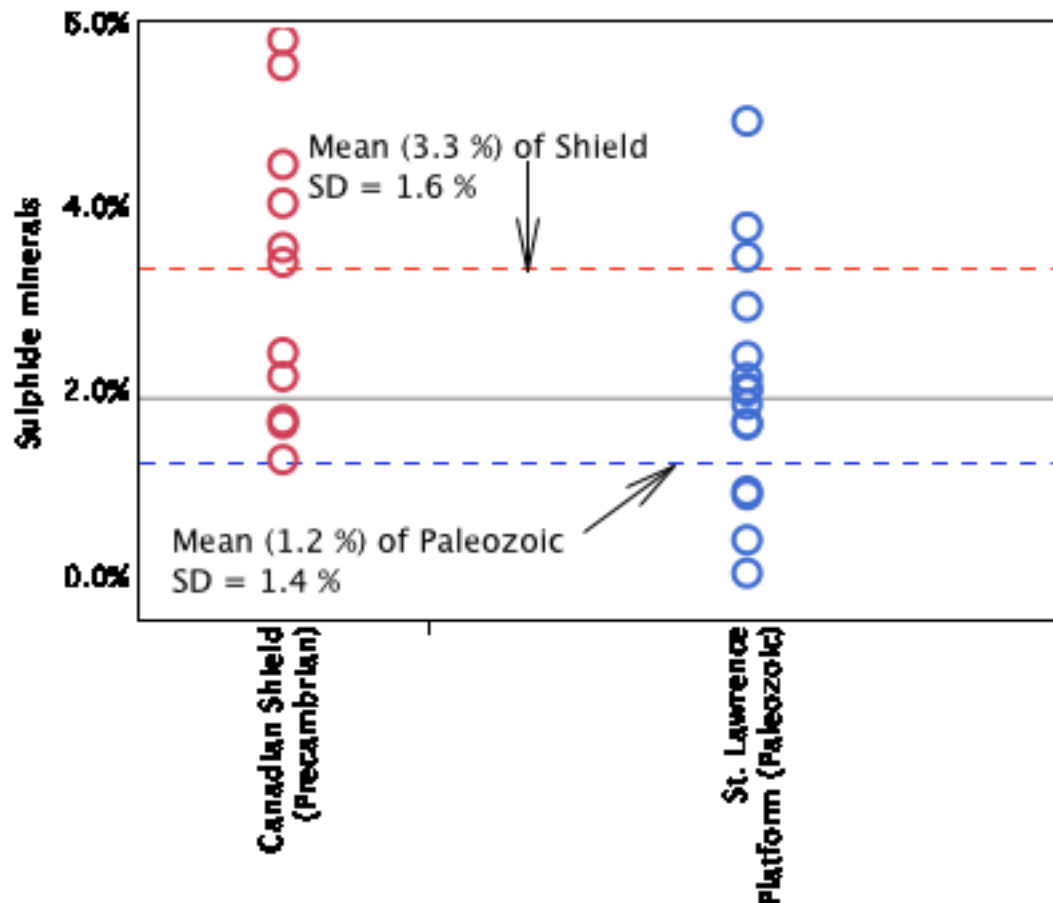


Figure 5.4 Average sulphide minerals content in house dust as compared in two geologic settings. The average sulphide mineral content for the four cities located on the Paleozoic bedrock (1.2 ab %) is notably lower than the average for the two cities located on the Canadian Shield (3.3 ab %).

5.2 Provenance of mineral grains in the house dust

Table 5.3 shows potential sources of common minerals in house dust. As all sample collection was done in winter, the amount of dirt carried into houses via shoes of occupants at the time of sampling was likely high. This dirt on the floors of the residential homes, in winter time, is often a mixture of melted ice, sand grains, salt, and other soil materials. After analysing the shape and morphology of the mineral grains we conclude that most mineral grains are tracked in to the house on the shoes of the

occupants. As indicated above in Section (5.1.1) in order for the metamorphic-igneous provenance quartz grains to be found in the house dust of the homes that are located on the Paleozoic St. Lawrence platform bedrock, they had to have travelled a considerable distance. The sub-rounded quartz grains in the specimens imply that they have travelled a long distance by glacial or fluvial transport.

In this study, the size fraction that was subjected to the analysis of mineralogical composition of house dust was 80-300 μm . The effect of wind transport mechanism of this relatively large fraction dust to a house was very minimal. Wind transportation would play a major role in particle sizes less than the 80 μm . In addition, wind transported sand grains are often common in desert climates, and the morphology of the sand grains would be well-rounded unlike what we observed in all specimens – sub-angular to sub-rounded. These sub-angular to sub-rounded quartz grains in house dust specimen exclude wind as a major transport mechanism, as their morphology would have been completely rounded.

Indoor sources are also factors in the presence of mineral fractions in house dust. For example, gypsum can be found in house dust. The potential source of gypsum in many Canadian residential homes is plaster which is used as construction material.

Table 5.3 Potential sources of some common minerals in house dust

Minerals	Potential sources
Amphibole	Metamorphic-igneous provenance
Albite	Igneous-metamorphic provenance in common rock-forming minerals
Biotite	Igneous-metamorphic provenance and outdoor soil
Calcite	Outdoor (limestone in Paleozoic bedrocks and marble in the Canadian Shield), indoor (construction materials)
Feldspars	Igneous-metamorphic provenance , soil
Garnet	Metamorphic-igneous provenance
Gypsum	Indoor (construction material e.g. plaster), evaporite deposits
Halite	Outdoor (tracked in mud from icy roads, in-situ evaporation), indoor (common salt)
Hematite	Soil, outdoor geology
Ilmenite	Igneous-metamorphic provenance
Kaolinite	Soil
Lithic fragments	Igneous-metamorphic provenance , sedimentary rocks, tills, soil
Magnetite	Soil, outdoor geology
Pyrite	Igneous-metamorphic provenance
Quartz	Igneous-metamorphic provenance , sand, tracked in, soil

6.0 Conclusions, limitations and significance

6.1 Conclusions

This thesis characterizes the mineralogy of house dust in specimens collected from 40 homes in six Ontario cities including 11 homes from the Canadian Shield and 29 from the St. Lawrence platform.

The mineralogical similarities and differences in the specimens collected from these two geologically distinct regions are summarized below. These observations provide the basis for a series of hypotheses that may be tested in the future.

1. The average contents of carbonate minerals in specimens from cities on the Canadian Shield appear to be significantly lower than that found in specimens from the St. Lawrence platform. Sudbury specimens show the minimum content of carbonate minerals in contrast to Hamilton samples, which show the maximum. These observations indicate that bedrock geology influence the carbonate content of house dust.
2. The average contents of amphibole minerals in specimens from cities located on the Shield are higher than the average contents in cities from the St. Lawrence platform, but this difference is not as significant as in the case of carbonate minerals.
3. Regardless of the home location, i.e., on the Canadian Shield or the St. Lawrence platform, the total average feldspar contents appear to be similar (19 – 25 ab % in both cases).

4. Similar to feldspar, the abundance of lithic fragments (17 – 21 ab %) in house dust does not appear to be affected by location of the home, be it on the Canadian Shield or the St. Lawrence platform.
5. The quartz mineral contents are similar (18 – 36 ab %) in both Shield and St. Lawrence platform settings. The presence of similar quartz grains in compositions in all house dust from this two geological distinct regions is important. This suggests that local bedrock geology may not be the main factor determining the amount and type of quartz grains in house dust. Instead, glacial transport and human use of glacial deposit sands for traction in the winter season appears to be the main influence.

In general, despite the great distances between the sampling localities and the distinct differences in bedrock geology of the Canadian Shield and the St. Lawrence platform, the mineralogical composition of house dust from all six cities is remarkably similar and dominated by quartz and feldspar, followed by lithic fragments, calcite, and amphibole.

6.2 Limitations

All the sampling were collected by Health Canada in winter time, that did not allow the author to compare and contrast the mineralogical composition of house dust in different seasons.

Flotation technique was used to separate denser mineralogical components from the lighter organic components of house dust. As a result, halite (i.e., salt, that is

used on roads and sidewalks to deice the snow in winter times) was dissolved during the flotation process, and thus was not observed under microscopy.

The observations presented in this thesis are considered semi-quantitative as they are based on manual point-counting (using microscopy) of selected specimens from a much larger randomized study. This is a labour-intensive but necessary step to provide background mineralogical information for future quantitative analyses using high throughput methods such as XRD-Rietveld.

6.3 Significance

This study is the first study which systematically characterizes the mineralogical composition of Canadian house dust, along with suggesting the provenance of the minerals in house dust.

Under the Chemicals Management Plan, Federal Government risk assessors used the data from this thesis for the assessment of everyday exposure of Canadians to quartz (Environment Canada and Health Canada, 2011).

This research was selected as the “best student research” at the 3rd International Medical Geology Association conference, in October 2009, in Montevideo, Uruguay. The interdisciplinary nature of this research links the Earth sciences and human health studies.

This research will be part of the “Imperfect Health” exhibit at the Canadian Centre for Architecture museum in Montreal, Canada from October 25, 2011 – March 15, 2012. This highlights the interdisciplinary relevance and the societal value of this research.

References

- Abdul-Wahab, S. A., Worthing, M. A., & Al-Maamari, S. (2005). Mineralogy of atmospheric suspended dust in three indoor and one outdoor location in Oman. *Environmental Monitoring and Assessment*, 107(1-3), 313-327.
- Barnett, P. J. (1992). Quaternary Geology of Ontario. In P. C. Thurston, H. R. Williams, R. H. Sutcliffe & G. M. Stott (Eds.), *Geology of Ontario* (Special Vol 4 Part 2 ed., pp. 1088-1042) Ministry of Northern Development and Mines.
- Beauchemin, S., MacLean, L. C., & Rasmussen, P. E. (2011). Lead speciation in indoor dust: A case study to assess old paint contribution in a Canadian urban house. *Environmental Geochemistry and Health*, 33(4), 343-352.
- Butte, W., & Heinzow, B. (2002). Pollutants in house dust as indicators of indoor contamination. *Reviews of Environmental Contamination and Toxicology*, 175, 1-46.
- Casteel, S. W., Weis, C. P., Henningsen, G. M., & Brattin, W. J. (2006). Estimation of relative bioavailability of lead in soil and soil-like materials using young swine. *Environmental Health Perspectives*, 114(8), 1162-1171.
- Cowan, W.R. (1978). Trend surface analysis of major late Wisconsinan till sheets, Brantford-Woodstock area, southern Ontario. *Canadian journal of Earth Sciences*, 15(6), 1025-1036.

- Culbard, E. B., Thornton, I., Watt, J., Wheatley, M., Moorcroft, S., & Thompson, M. (1988). Metal contamination in British urban dusts and soils. *Journal of Environmental Quality*, 17(2), 226-234.
- Davies, D. J. A., Thornton, I., Watt, J. M., Culbard, E. B., Harvey, P. G., Delves, H. T., Sherlock, J. C., Smart, G. A., Thomas, J. F. A., & Quinn, M. J. (1990). Lead intake and blood lead in two-year-old U.K. urban children. *Science of the Total Environment*, 90, 13-29.
- Dofasco. (2009). *Dofasco Hamilton Operation*. Retrieved 12/30, 2009, from http://www.dofasco.ca/bins/content_page.asp?cid=339-342&lang=1
- Duggan, M. J., & Inskip, M. J. (1985). Childhood exposure to lead in surface dust and soil: A community health problem. *Public Health Reviews*, 13(1-2), 1-54.
- Environment Canada and Health Canada, (2011). Draft screening assessment for the challenge, Quartz, chemical abstracts service registry number, 14808-60-7.
- Fergusson, J. E., & Kim, N. D. (1991). Trace elements in street and house dusts: Sources and speciation. *Science of the Total Environment*, 100, 125-150.
- Galehouse, J. S. (1971). Point counting. In R. Carver (Ed.), *Procedures in Sedimentary Petrology* (pp. 385-408). New York: Wiley Interscience.
- Gillespie, J. E., Acton, C. J., & Hoffman, D. W. (1982). General description of the soil of Sudbury (Soil map of Sudbury). *Ontario Soil Survey No. 49*. Agriculture Canada and Ontario Ministry of Agriculture and Food.

Gillespie, J. E., Wicklund, R. E., & Miller, M. H. (1970). The Soil of Halton County (Soil map of Burlington). *Ontario Soil Survey No. 43*. The research branch, Canada Department of Agriculture and the Ontario Agricultural College.

Health Canada. (1994). Update of evidence for low level effects of lead and blood lead interventions level and strategies. Ottawa, Ontario, Canada: Environmental Health Directorate.

Health Canada. (2009). *Indoor Air Quality and Health*. Retrieved 10/10, 2010, from <http://www.hc-sc.gc.ca/ewh-semt/air/in/qual/index-eng.php>

Hoffman, D. W., Wicklund, R. E., & Richards, N. R. (1962). Soil Survey of Simcoe County, Ontario (Simcoe County soil map). *Ontario Soil Survey No. 29*. The Research Branch, Canada Department of Agriculture and the Ontario Agriculture College.

Hunt, A., Johnson, D. L., Watt, J. M., & Thornton, I. (1992). Characterizing the sources of particulate lead in house dust by automated scanning electron microscopy. *Environmental Science and Technology*, 26(8), 1513-1523.

Johnson, M.D., Armstrong, D.K., Sanford, B.V., Telford, P.G. and Rutka, M.A. 1992. Paleozoic and Mesozoic Geology of Ontario; in Geology of Ontario, Ontario Geological Survey, Special Volume 4 (2), 907-1008.

Karrow, P. F. (1963). Pleistocene Geology of the Hamilton-Galt area. *Ontario Department of Mines Geological Report No. 16*.

- Karrow, P. F. (1987). Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario. *Ontario Geological Survey Report*.
- Karrow, P. F. (1989). Quaternary Geology of the Great Lakes Subregion. In *Geology of Canada* (pp. 326-350) Geological Survey of Canada.
- Kim, N., & Fergusson, J. (1993). Concentrations and sources of cadmium, copper, lead and zinc in house dust in Christchurch, New Zealand. *Science of the Total Environment*, 138(1-3), 1-21.
- Land Resource Research Institute, Research Branch, Agriculture Canada. (1981). Soils of the Thunder Bay area. *Ontario Soil Survey No. 48*. (Soil map of Thunder Bay).
- Liberty, B.A. (1969). Paleozoic geology of the Lake Simcoe area, Ontario; *Geological Survey of Canada*, Memoir 335, 201.
- Lioy, P. J., Freeman, N. C., & Millette, J. R. (2002). Dust: A metric for use in residential and building exposure assessment and source characterization. *Environmental Health Perspectives*, 110(10), 969-983.
- McCrone, W.C., Delly, J. G. (1984). Polarized light microscopy. McCrone Research Institute, Chicago, Illinois, pp. 5-60.
- McCrone, W.C., Hudson, W. (1969). The analytical use of density gradient separations. *Journal of Forensic Sciences*, 14, 370-384
- McCrone, W. C., McCrone, L. B., and Delly, J. G. (1997). Polarized light microscopy. 2nd edition. McCrone Research Institute, Chicago, Illinois, pp. 169–196.

- McCrone Atlas. (2009). The McCrone atlas of microscopic particles. McCrone Associates. Retrieved 09/10 (2010), from <http://www.mccroneatlas.com>.
- Millette, J. R. (2003). A microscopical study of the general composition of household dirt. *Microscope*, 51(4), 201-207.
- Millette, J. R., & Hopen, T. J. (2001). Characterizing household dirt: 1928-2001. *In Proceedings of Indoor Air Health, 2001*, Miami Beach, FL, 2nd International Conference on Indoor Air Health, 2001, 174-183.
- Mitchell, C. S., Zhang, J. J., Sigsgaard, T., Jantunen, M., Liroy, P. J., Samson, R., & Karol, M. H. (2007). Current state of the science: Health effects and indoor environmental quality. *Environmental Health Perspectives*, 115(6), 958-964.
- Møhlhave, L., Schneider, T., Kjærgaard, S. K., Larsen, L., Norn, S., & Jørgensen, O. (2000). House dust in seven Danish offices. *Atmospheric Environment*, 34(28), 4767-4779.
- Murray, R.C. (2004). Evidence from the Earth: Forensic geology and criminal investigation. *Mountain Press Publishing*, Missoula, MT. 227 pp 123-160.
- National Climate Data and Information Archive, Environment Canada. (2009). *Ontario, climate data*. Retrieved 10-10, 2009, from <http://www.climate.weatheroffice.gc.ca/>
- Ontario Geological Survey, Northern Development, Mines and Forestry, *OGS Earth*, Retrieved 10/10 (2009) from http://www.mndmf.gov.on.ca/mines/ogs_earth_e.asp

- Presant, E. W., & Wicklund, R. E. (1971). The Soils of Waterloo County (Soil map of Waterloo). *Ontario Soil Survey No. 44*. The Research Branch, Canada Department of Agriculture Department of Soil Science, University of Guelph and The Ontario Department of Agricultural College.
- Rasmussen, P. E. (Ed.). (2004). Elements and their Compounds in the Environment: Occurrence, Analysis and Biological Relevance, (Second Edition ed.). Germany: Wiley-VCH Verlag GmbH.
- Rasmussen, P. E., Beauchemin, S., Chénier, M., Levesque, C., MacLean, L. C. W., Marro, L., Jones Otazo, H., Petrovic, S. McDonald, L.T., & Gardner, H. D. (2011). Canadian House Dust Study: Lead bioaccessibility and speciation. *Environmental Science and Technology*, 45(11), 4959-4965.
- Rasmussen, P. E., Beauchemin, S., Nugent, M., Dugandzic, R., Lanouette, M., & Chénier, M. (2008). Influence of matrix composition on the bioaccessibility of copper, zinc, and nickel in urban residential dust and soil. *Human and Ecological Risk Assessment*, 14(2), 351-371.
- Rasmussen, P. E., Subramanian, K. S., & Jessiman, B. J. (2001). A multi-element profile of house dust in relation to exterior dust and soils in the city of Ottawa, Canada. *Science of the Total Environment*, 267(1-3), 125-140.
- Riller, U., Cruden, A. R., & Schwerdtner, W. M. (1996). Magnetic fabric and microstructural evidence for a tectono-thermal overprint of the early Proterozoic

Murray Pluton, Central Ontario, Canada. *Journal of Structural Geology*, 18 (8), 1005-1016.

Roberts, J. W., & Dickey, P. (1995). Exposure of children to pollutants in house dust and indoor air. *Reviews of Environmental Contamination and Toxicology*, 143, 59-78.

Rulkens, W. H. (1995). Methods for cleaning contaminated soils and sediments. In Willem Salomons, Ulrich Förstner, Pavel Mader (Ed.), *Heavy metals: Problems and solutions* (1st ed., pp. 169-191). Berlin: Springer.

Siegel, F. R. (2002). *Environmental geochemistry of potentially toxic metals*. Germany: Springer.

Spengler, J. D., & Sexton, K. (1983). Indoor air pollution: A public health perspective. *Science*, 221(4605), 9-17.

Studer (1958). House dust composition. *Hoover Vacuum Company*, Retrieved from Hoover Historical Centre/Walsh University.

Thornton, I., Culbard, E., & Moorcroft, S. (1985). Metals in urban dusts and soils. *Environmental Technology Letters*, 6(4), 137-144.

Turner, W. L., Millette, J. R., Boltin, W. R., & Hopen, T. J. (2005). A standard approach to the characterization of common indoor dust constituents. *Microscope*, 53(4), 169-177.

Turner, A., & Simmonds, L. (2006). Elemental concentrations and metal bioaccessibility in UK household dust. *Science of the Total Environment*, 371(1-3), 74-81.

U.S. EPA. (1997). *Exposure factors handbook (final report)*. No. EPA/600/P-95/002F). Washington DC: U.S. Environmental Protection Agency (EPA Exposure).

Woldemichael, M.H., Lalonde, A. E., Rasmussen, P. E. (2009). The Mineralogical Composition of House Dust. Health Canada Science Forum, Ottawa, Canada. Abstract 1.67.

A. Appendix A

Mineralogy of house dust

Mineral characterization of house dust

The percent abundance mineralogy and description of 40 house dust samples from six Ontario cities was done by polarizing microscopy (Chapter 3, Page 5). SEM and XRD were used to assist in the identification of individual mineral species. Proportions of minerals and organic materials were obtained by point-counting of grain-mount microscope thin sections using a Swift automated point counting stage mounted to a Nikon E600 research polarizing microscope.

The proportions thus obtained were then normalized to 100%, excluding all organic and synthetic components, e.g. synthetic fibres, skin flakes, pollen, etc.

The Summarized percent abundance mineralogy is presented below for the cities of Barrie, Burlington, Cambridge, Hamilton, Greater Sudbury, and Thunder Bay.

Table A.1 Percent abundance mineralogy (Vol. %) of house dust specimens from 40 homes in six Ontario cities

City	Specimen	Geology	Qtz	Fsp	Am	Px	Cb	LF	Bt	Ms	Chl	Ap	Grt	Rt	Als	Sul mn	Und mn
Barrie	BA 06	off Shield	24.0	27.3	5.1	0.0	15.1	15.1	2.2	0.0	0.9	0.0	0.0	0.0	0.0	0.9	9.3
Barrie	BA 21	off Shield	28.6	23.7	3.7	0.0	17.1	18.0	3.1	0.0	2.0	0.0	0.0	0.0	0.0	1.6	2.2
Barrie	BA 23	off Shield	31.3	19.0	2.9	0.0	17.9	14.2	4.8	0.0	2.5	0.0	1.3	0.0	0.0	3.8	2.5
Barrie	BA 36	off Shield	28.7	23.6	3.4	1.5	15.1	15.3	3.8	0.0	2.6	0.9	0.6	0.0	0.0	0.9	3.8
Barrie	BA 37	off Shield	24.6	30.8	5.6	0.2	14.1	15.3	2.2	0.0	0.4	0.2	1.4	0.0	0.4	1.6	3.2
Barrie	BA 45	off Shield	29.9	26.0	4.1	0.0	10.0	16.8	1.5	0.0	2.6	0.0	1.3	0.0	0.0	4.9	3.0
Barrie	BA 47	off Shield	31.3	22.4	3.8	0.0	10.4	22.7	1.3	0.0	0.9	0.0	0.2	0.0	2.0	2.9	2.0
Barrie	BA 54	off Shield	31.0	19.9	8.5	0.6	6.2	17.2	1.9	0.0	2.9	1.0	1.5	0.0	0.0	2.1	7.3
Burlington	BU 39	off Shield	33.9	20.2	0.5	0.0	25.9	15.2	0.7	0.0	0.5	0.0	0.0	0.0	0.0	0.0	3.2
Burlington	BU 46	off Shield	43.1	19.0	3.7	2.0	11.2	10.8	0.0	3.1	1.0	0.0	0.8	0.0	0.0	0.0	5.3
Burlington	BU 47	off Shield	40.8	15.4	6.6	1.8	6.8	19.7	1.3	1.5	0.5	0.0	1.5	0.0	0.0	0.0	4.3
Burlington	BU 54	off Shield	33.7	24.6	4.2	2.6	15.0	13.4	1.2	0.6	0.4	0.6	1.6	0.6	0.0	0.0	1.6
Burlington	BU 55	off Shield	32.3	17.1	2.6	0.0	16.3	25.5	2.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	3.2
Burlington	BU 63	off Shield	32.4	17.2	2.5	0.0	16.2	25.6	2.3	0.6	0.2	0.0	0.0	0.0	0.0	0.0	3.1
Cambridge	CA 3	off Shield	33.6	23.8	4.8	0.0	12.1	17.2	2.6	0.0	0.7	0.0	0.0	0.6	0.0	1.8	2.9
Cambridge	CA 12	off Shield	20.7	31.4	7.3	1.4	17.0	20.0	0.9	0.0	0.0	0.0	0.9	0.0	0.0	0.4	0.0
Cambridge	CA 13	off Shield	32.4	24.1	4.7	0.0	10.5	17.3	2.6	0.0	1.5	0.9	1.3	1.1	0.0	2.4	1.5
Cambridge	CA 76	off Shield	30.1	21.0	4.4	0.6	15.1	19.2	3.2	0.0	1.1	0.0	0.0	0.0	0.0	3.4	1.9
Cambridge	CA 81	off Shield	21.2	23.2	6.4	2.0	12.8	22.9	0.0	3.1	1.5	0.6	1.1	0.0	0.0	2.0	3.3
Hamilton	HA 3	off Shield	20.1	31.1	7.6	2.6	16.6	16.9	1.7	0.0	2.6	0.9	0.0	0.0	0.0	0.0	0.0
Hamilton	HA 6	off Shield	14.4	17.0	2.8	1.8	42.2	20.0	0.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Hamilton	HA 13	off Shield	19.8	14.1	4.7	1.7	16.3	24.5	2.2	1.0	2.7	1.2	1.7	1.5	0.7	2.0	5.7
Hamilton	HA 63	off Shield	14.5	21.6	0.0	0.0	44.0	17.6	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hamilton	HA 104	off Shield	22.1	21.3	1.7	0.0	27.3	24.5	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0
Sudbury	SU 7	Shield	27.7	23.9	7.6	0.6	3.5	23.3	0.9	1.0	1.6	0.2	0.9	1.6	0.7	3.4	3.2
Sudbury	SU 8	Shield	22.4	14.9	2.4	1.9	3.0	20.3	2.1	0.0	25.8	0.8	0.9	0.2	0.0	2.4	3.0
Sudbury	SU 10	Shield	33.0	24.0	6.6	0.7	3.3	19.9	2.2	0.0	4.1	0.7	1.7	0.7	0.0	1.7	1.3

Sudbury	SU 25	Shield	22.0	24.4	4.4	2.0	2.4	24.4	2.4	0.0	8.7	1.3	2.4	0.0	0.0	4.4	1.3
Sudbury	SU 26	Shield	34.5	25.6	5.3	0.8	4.4	18.6	2.1	0.0	3.7	0.8	0.7	0.7	0.0	1.6	1.3
Sudbury	SU 36	Shield	26.6	18.6	7.2	5.3	4.0	14.4	8.0	0.0	2.1	2.7	2.7	0.5	2.7	2.1	3.2
Thunder Bay	TB 9	Shield	20.7	15.1	7.1	0.0	15.3	23.3	6.1	0.9	3.5	0.7	1.2	0.7	1.2	3.5	0.7
Thunder Bay	TB 18	Shield	25.5	16.3	3.8	0.0	3.1	25.2	6.6	0.7	2.1	0.7	2.6	0.7	0.0	4.0	8.7
Thunder Bay	TB 26	Shield	19.6	17.6	8.0	0.0	7.6	18.7	5.3	1.3	2.2	2.0	1.3	1.1	3.8	5.8	5.8
Thunder Bay	TB 30	Shield	15.2	24.8	7.6	0.0	9.4	19.9	4.5	0.0	2.8	1.3	1.0	0.3	1.5	5.5	6.3
Thunder Bay	TB 59	Shield	24.5	34.6	4.2	0.0	11.3	9.3	3.4	0.0	2.7	0.3	0.3	0.5	0.0	1.2	7.8

City of Barrie

The city of Barrie is located in south-central Ontario on Kempenfelt Bay of Lake Simcoe. The city is located on deposits of calcareous and sandy loam soils that overlie Paleozoic limestone (see 2.2.3 Soil, surficial and bedrock geology of Barrie). Eight samples of house dust from Barrie were analysed for their mineralogical content. Although not the primary objective of this study, proportions of organic components such as skin flakes, cellulose, etc... in the dust were determined during the course of the point-counting analyses. These organic components varied from 70 to 113 counts out of a total of 1200 counts.

Table A.2 Summary of minerals in specimen BA - 06

Percent abundance mineralogy of house dust			
Barrie specimen BA - 06			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		108	24.0
Feldspars		123	27.3
Amphiboles	Ca-rich	23	5.1
Carbonate minerals	Calcite	68	15.1
Lithic fragments	Felsic	68	15.1
Micas	Biotite	10	2.2
Accessory minerals	Chlorite	4	0.9
Sulphide minerals		4	0.9
Undefined minerals		42	9.3
<hr/>			
Total minerals		450	100.0
<hr/>			
Meltmount		605	
Synthetic materials ¹	Slag, fibres, dirt	82	
Organic components ²	Pollen, spores, cellulose	63	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

Table A.3 Summary of minerals in specimen BA - 21

Percent abundance mineralogy of house dust			
Barrie specimen BA - 21			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		140	28.6
Feldspars		116	23.7
Amphiboles	Ca-rich	18	3.7
Carbonate minerals	Calcite	84	17.1
Lithic fragments	Felsic	88	18.0
Micas	Biotite	15	3.1
Accessory minerals	Chlorite	10	2.0
Sulphide minerals		8	1.6
Undefined minerals		11	2.2
<hr/>			
Total minerals		490	100.0
<hr/>			
Meltmount		525	
Synthetic materials ¹	Slag, fibres, dirt	95	
Organic components ²	Pollen, spores, cellulose	90	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

Table A.4 Summary of minerals in specimen BA - 23

Percent abundance mineralogy of house dust			
Barrie specimen BA – 23			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		150	31.3
Feldspars		91	19.0
Amphiboles		14	2.9
Carbonate minerals	Calcite	86	17.9
Lithic fragments	Felsic	68	14.2
Micas	Biotite	23	4.8
Accessory minerals	Chlorite	12	2.5
	Garnet	6	1.3
Sulphide minerals		18	3.8
Undefined minerals		12	2.5
Total minerals			
		480	100.0
Meltmount			
		459	
Synthetic materials ¹	Slag, fibres, dirt	111	
Organic components ²	Cellulose	150	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BA - 23

This specimen unlike other investigated specimens from Barrie, showed low contents of amphiboles and feldspars and higher contents of quartz. Plant leaves and cellulose were also observed. The source of this plant material was not determined.

Mineralogical observations of specimen BA - 23

Biotite

Biotite grains in this specimen averaged 175 μm in diameter. Distinguishing features are pale brown pleochroic colours.

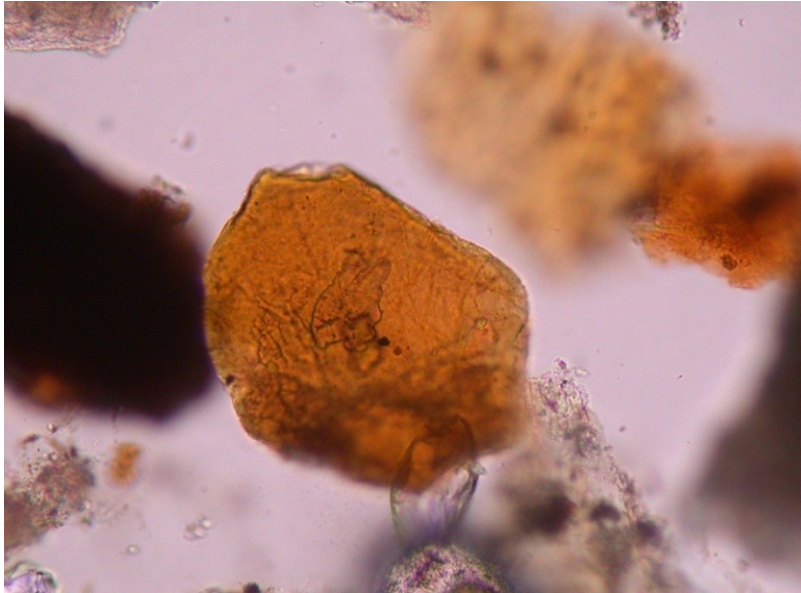


Figure A.1. Photomicrograph of biotite grains in specimen BA -23 (PPOL, FOV = 0.55 mm).

Quartz

Quartz grains in this specimen averaged 150 μm in diameter and were highly angular in shape. Fluid inclusions were identified at higher magnification (500X).

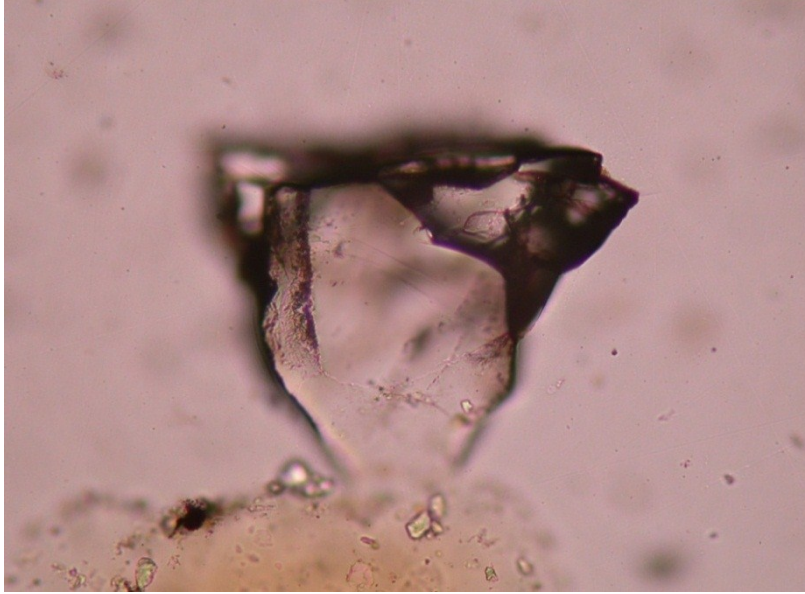


Figure A.2. Photomicrograph of angular quartz grain with fluid inclusions in specimen BA – 23 (PPOL, FOV = 0.55 mm).

Galena

Rarely identified in this study, galena was observed in this specimen.

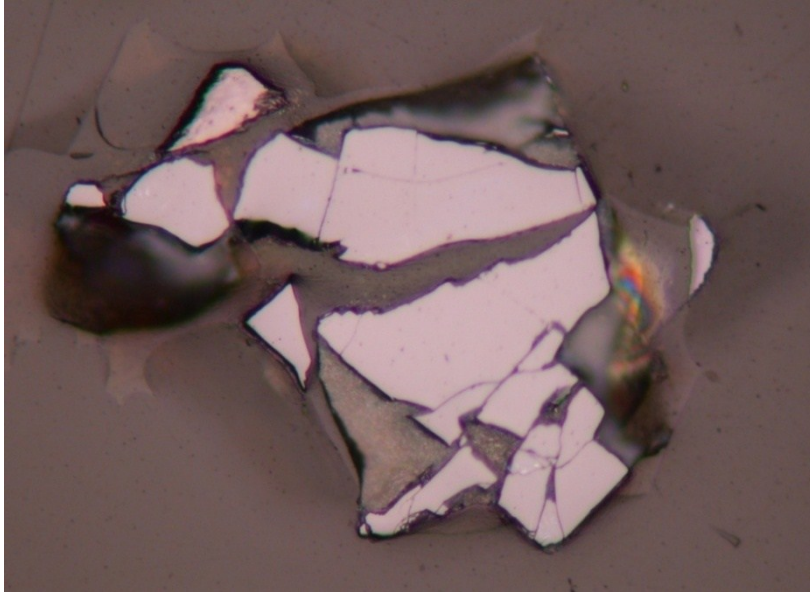


Figure A.3. Photomicrograph of galena grain in incident-light polarizing microscopy (PPOL, FOV = 0.55 mm).

Lithic fragments

Lithic fragments of granitic composition were identified. Minerals in these fragments included quartz, feldspar and muscovite.

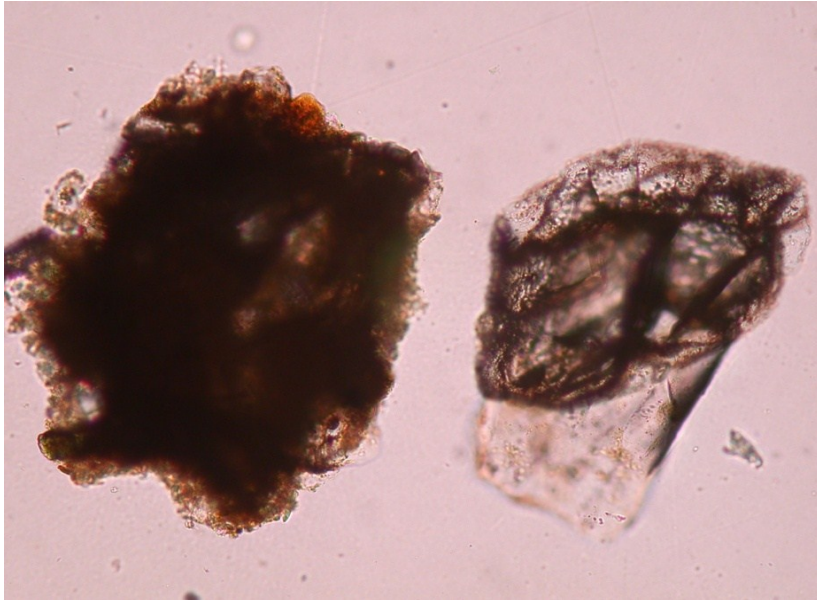


Figure A.4. Photomicrograph of lithic fragments comprised of quartz, feldspar and muscovite, (PPOL, FOV = 0.55 mm).

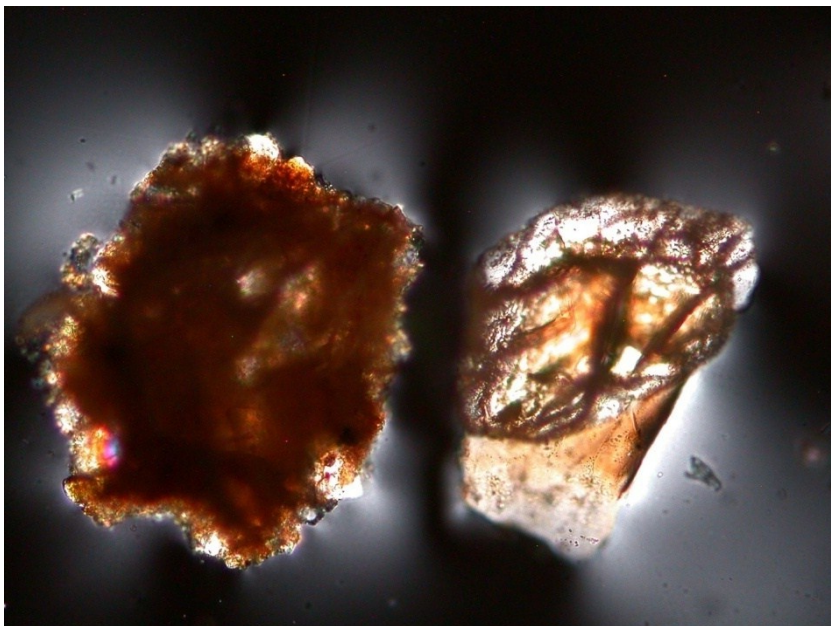


Figure A.5. Photomicrograph of lithic fragments comprised of quartz, feldspar, and muscovite (XPOL, FOV = 0.55 mm).

Table A.5 Summary of minerals in specimen BA - 36

Percent abundance mineralogy of house dust			
Barrie specimen BA - 36			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		135	28.7
Feldspars		111	23.6
Amphiboles	Ca-rich	16	3.4
Pyroxenes	Clinopyroxene	7	1.5
Carbonate minerals	Calcite	71	15.1
Lithic fragments	Felsic	72	15.3
Micas	Biotite	18	3.8
Accessory minerals	Chlorite	12	2.5
	Apatite	4	0.8
	Garnet	3	0.6
Sulphide minerals		4	0.8
Undefined minerals		18	3.8
Total minerals			
		471	100.0
Meltmount		581	
Synthetic materials ¹	Slag, fibres, dirt	76	
Organic components ²	Pollen, spores, cellulose	72	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BA - 36

Perthitic feldspar is very common in this specimen. The carbonate minerals occur in fine powder form.

Mineralogical observations of specimen BA - 36

Feldspar

Feldspars in this specimen were commonly turbid. Interference figures were difficult to obtain with the microscope.



Figure A.6. Photomicrograph of perthitic feldspar grain (PPOL, FOV = 0.55 mm).

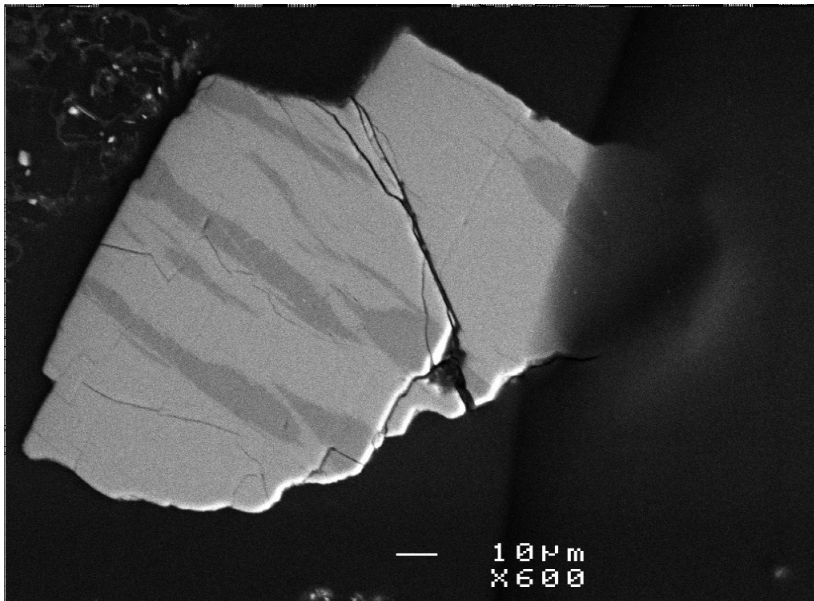


Figure A.7. Scanning electron photomicrograph of lamellar perthitic feldspar seen in backscattered-electron imaging.

Carbonate mineral - Chalk

In this specimen the carbonate minerals appeared as fine powder. These fine grains are white-coloured under plane-polarized light.

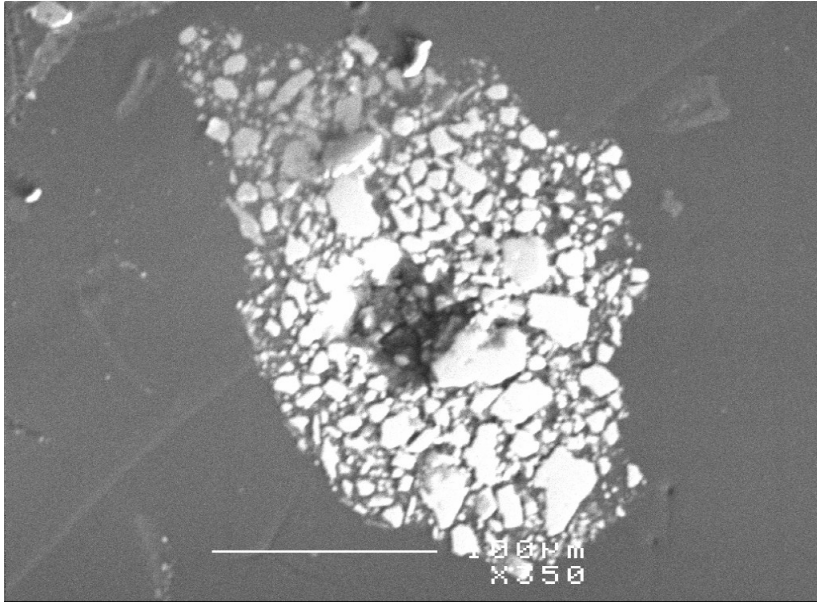


Figure A.8. Calcium carbonate powder in specimen BA – 36. Some individual grains fall within the clay size fraction (backscattered-electron image).

Table A.6 Summary of minerals in specimen BA - 37

Percent abundance mineralogy of house dust			
Barrie specimen BA - 37			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		122	24.5
Feldspars		153	30.8
Amphiboles		28	5.6
Pyroxenes		1	0.2
Carbonate minerals	Calcite	70	14.1
Lithic fragments	Ti-bearing silicate	81	16.3
Micas	Biotite	11	2.2
Accessory minerals	Chlorite	2	0.4
	Apatite	1	0.2
	Aluminosilicate ³	2	0.4
	Garnet	7	1.4
Sulphide minerals		3	0.6
Undefined minerals		16	3.2
Total minerals			
		497	100.0
Meltmount		532	
Synthetic materials ¹	Welding metals, slag	105	
Organic components ²	Skin dander, cellulose	66	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen BA - 37

Specimens BA 36 and BA 37 are similar and both are dominated by mineral grains, but hardwood cellulose was observed under plane-polarized light.



Figure A.9. Photomicrograph of hardwood cellulose in house dust of specimen BA – 37 (PPOL, FOV = 0.55 mm).

Mineralogical observations of specimen BA - 37

Amphibole

Amphibole grains were subhedral in shape, green in colour and showed the characteristic cleavages of 60° and 120° .

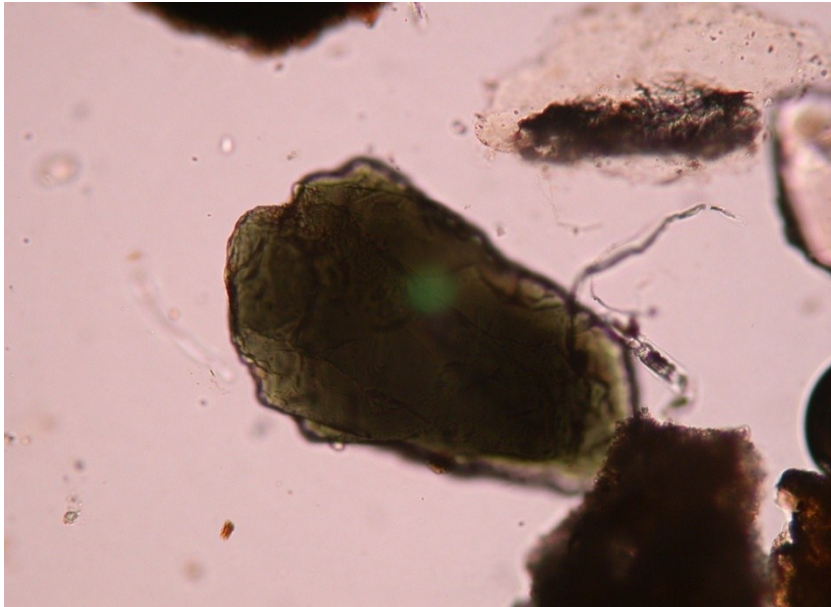


Figure A.10. Subhedral hornblende grain in specimen BA – 37. (PPOL, FOV= 0.55mm).

Titanium-bearing silicate grain

This grain is composed of quartz, plagioclase, K-feldspar, calcite and titanite. This mineral is angular and isotropic under parallel polars. This mineral shows a magnetite structure.

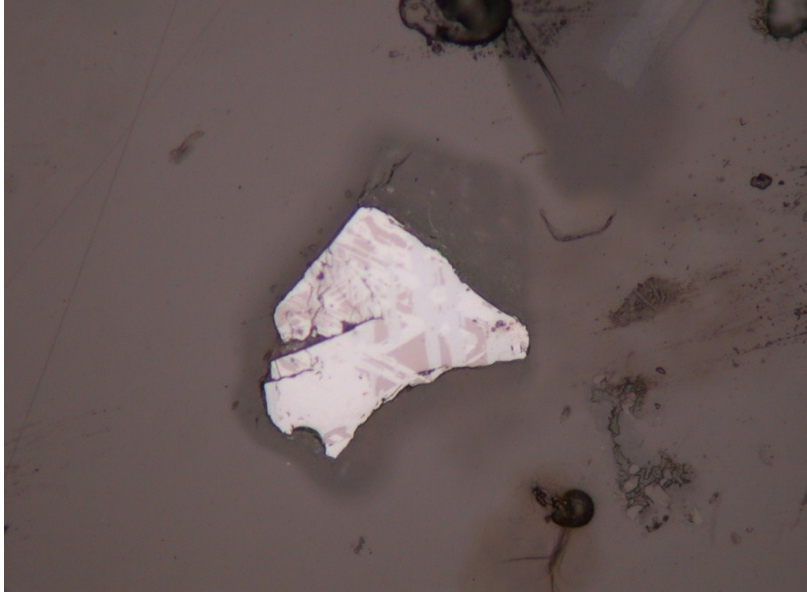


Figure A.11. Photomicrograph of titanium bearing magnetite mineral, under plane polarized reflected light (PPOL, FOV = 0.55 mm).

Table A.7 Summary of minerals in specimen BA - 45

Percent abundance mineralogy of house dust			
Barrie specimen BA - 45			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		140	29.9
Feldspars		122	26.0
Amphiboles	Hornblende	19	4.1
Carbonate minerals	Dolomite	47	10.0
Lithic fragments	Felsic	79	16.8
Micas	Biotite	7	1.5
Accessory minerals	Chlorite	12	2.6
	Garnet	6	1.3
Sulphide minerals		23	4.9
Undefined minerals		14	3.0
Total minerals		469	100.0
Meltmount		562	
Synthetic materials ¹	Slag, fibres, dirt	96	
Organic components ²	Pollen, spores, cellulose	73	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BA - 45

Unlike other specimens from Barrie, this specimen has less carbonate minerals, fibres and synthetic material. Almandine garnet is the common garnet species in this specimen. Dolomite is the dominant carbonate mineral. This specimen also has some ilmenite and iron oxide grains which showed, under the SEM, the presence of Fe, Cr, and V peaks in their X-ray energy-dispersive spectra.

Mineralogical observations of specimen BA - 45

Garnet

Large grains of garnet, in excess of 150 μm , were observed under plane polars. These grains displayed the characteristic features of very high relief and isotropic nature.



Figure A.12. Photomicrograph of garnet grain in specimen BA-45 (PPOL, FOV = 0.55 mm).

Hornblende

Amphibole occurs as green-pleochroic angular grains that are on average 150 μm across.

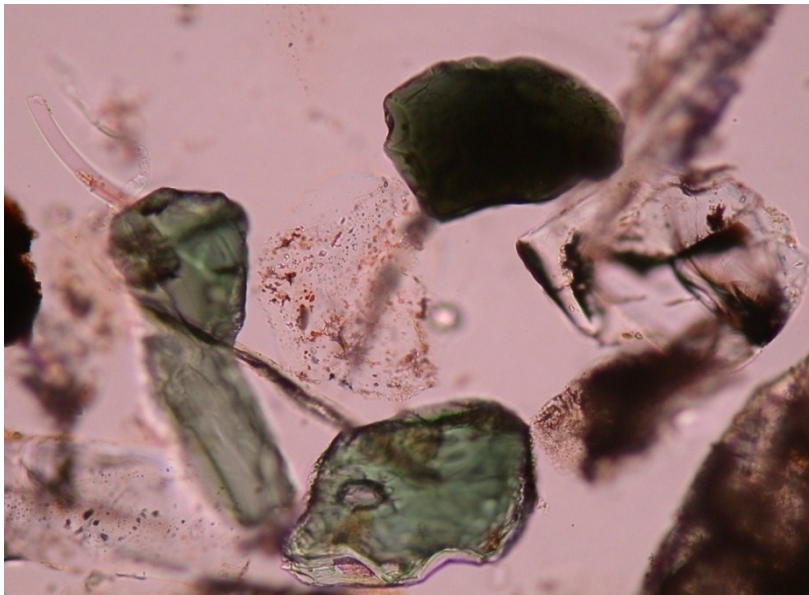


Figure A.13. Photomicrograph of angular hornblende grains in specimen BA-45 (PPOL, FOV = 0.55 mm).

Feldspar

The feldspar in this specimen is angular and slightly turbid with many fractures.

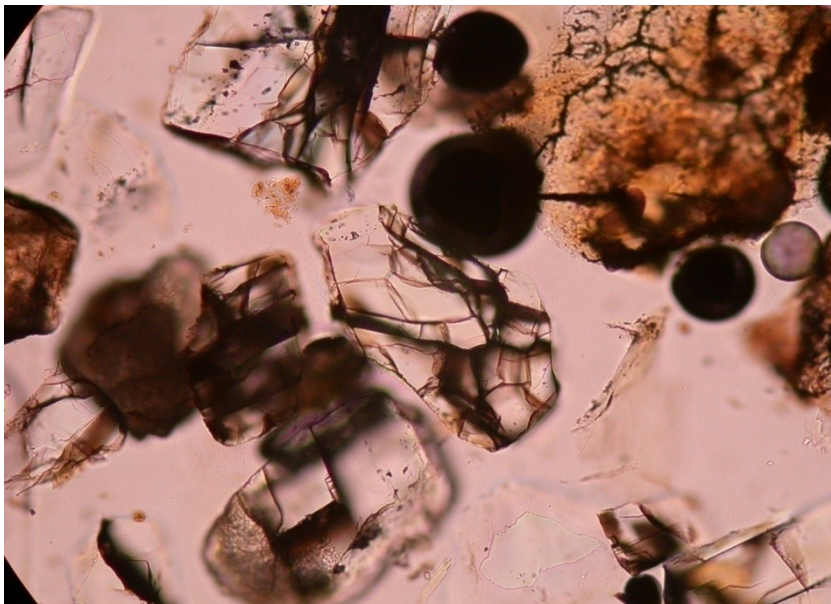


Figure A.14. Photomicrograph of feldspar in specimen BA-45 (PPOL, FOV = 0.55 mm).

Table A.8 Summary of minerals in specimen BA - 47

Percent abundance mineralogy of house dust			
Barrie specimen BA - 47			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		141	31.6
Feldspars		101	22.6
Amphiboles		17	3.8
Carbonate minerals	Calcite	47	10.5
Lithic fragments		98	22.0
Micas	Biotite	6	1.3
Accessory minerals	Chlorite	4	0.9
	Aluminosilicate ³	9	2.0
	Garnet	1	0.2
Sulphide minerals	Pyrite	13	2.9
Undefined minerals		9	2.0
Total minerals			
		446	100.0
Meltmount			
		516	
Synthetic materials ¹	Fibres, dirt	125	
Organic components ²		113	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen BA - 47

In comparison to other dust specimens from Barrie, the dust from this house is enriched in organic components such as skin flakes. The dust specimen from this house also has a higher sulphide mineral content.

Mineralogical observations of specimen BA - 47

Microcline feldspar

K-feldspar occurs as grains up to 250 μm in size that show the characteristic grid-twinning of microcline.

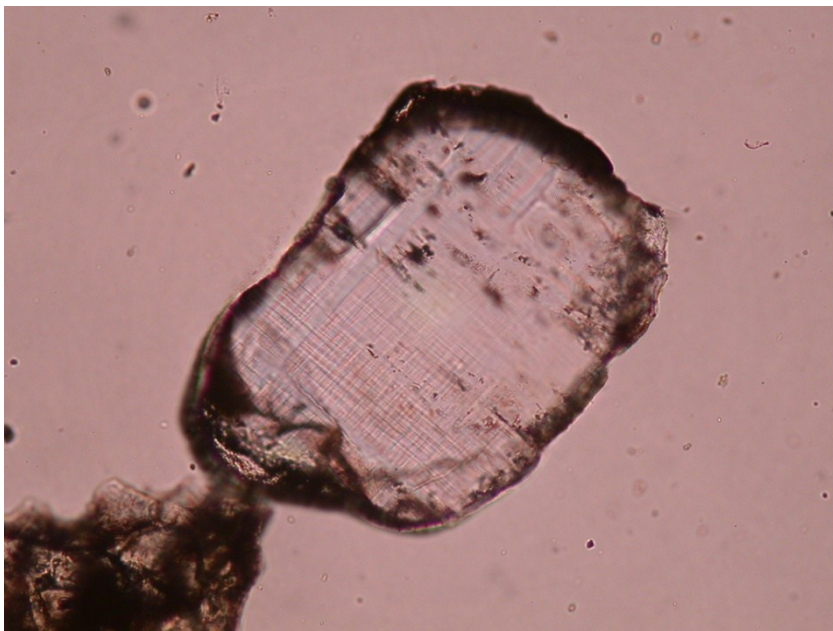


Figure A.15. Photomicrograph of a microcline grain in specimen BA-47 showing the characterising grid-twinning of this K-feldspar polymorph (PPOL, FOV = 0.55 mm).

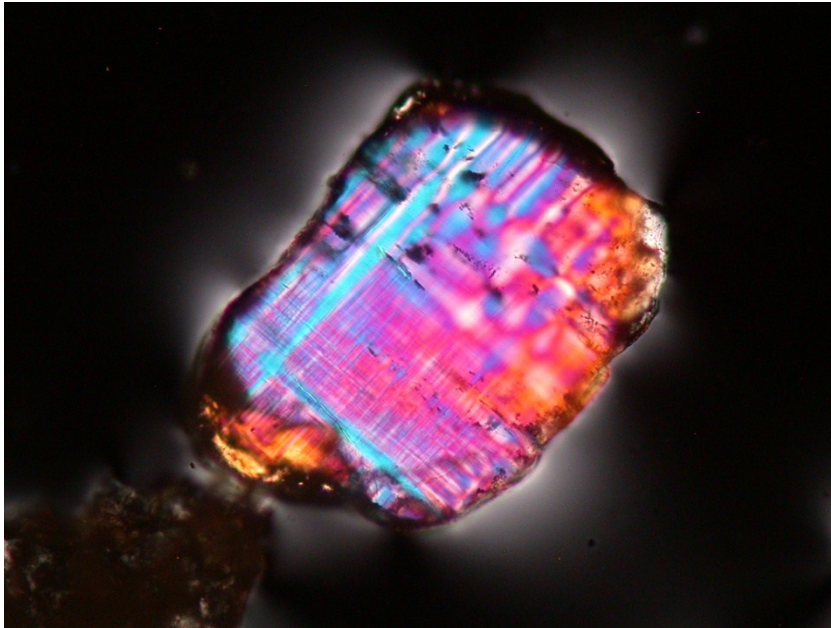


Figure A.16. Photomicrograph of a microcline grain in specimen BA-47 showing the characterising grid-twinning of this K-feldspar polymorph (XPOL, FOV = 0.55 mm).

Pyrite (an elongated pyrite grain)

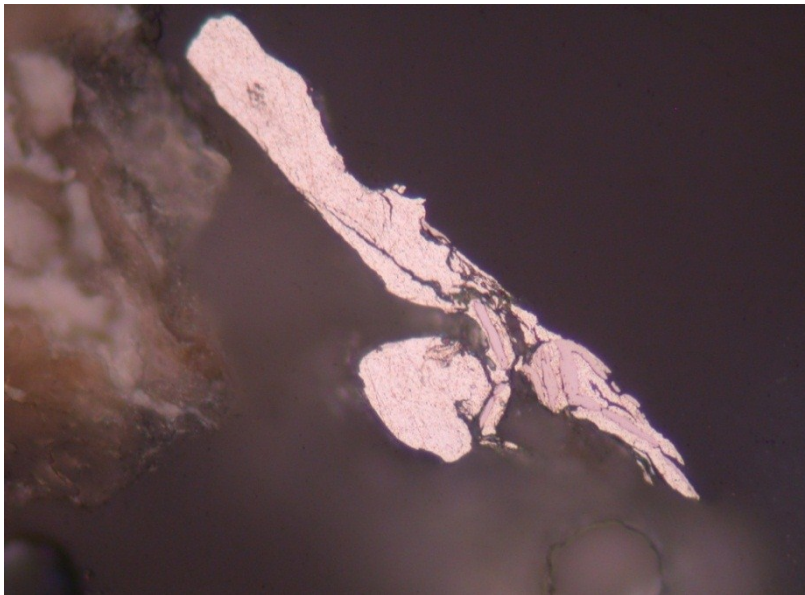


Figure A.17. Photomicrograph of a pyrite mineral in specimen BA - 47 under plane-polarized reflected light (PPOL, FOV = 0.05 mm).

Metallic welding spheres

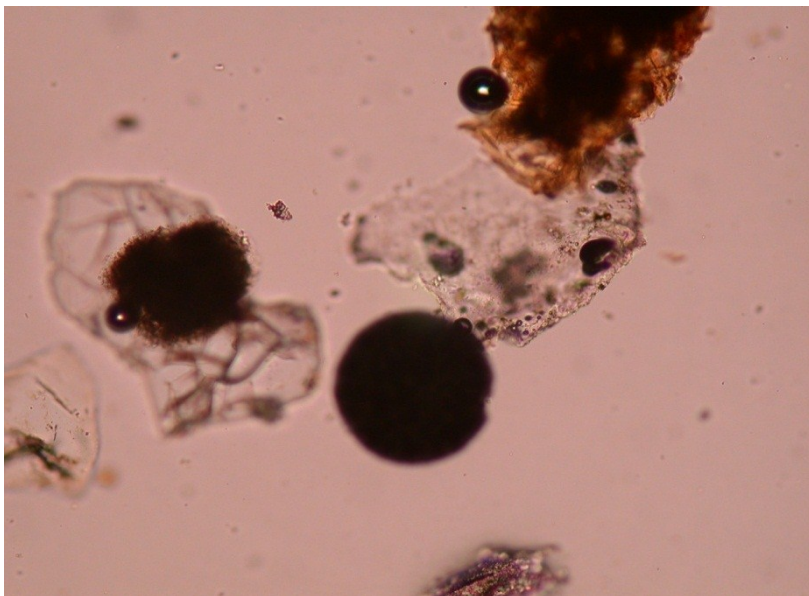


Figure A.18. Photomicrograph of metallic welding spheres in specimen BA - 47 (PPOL, FOV = 0.55 mm).

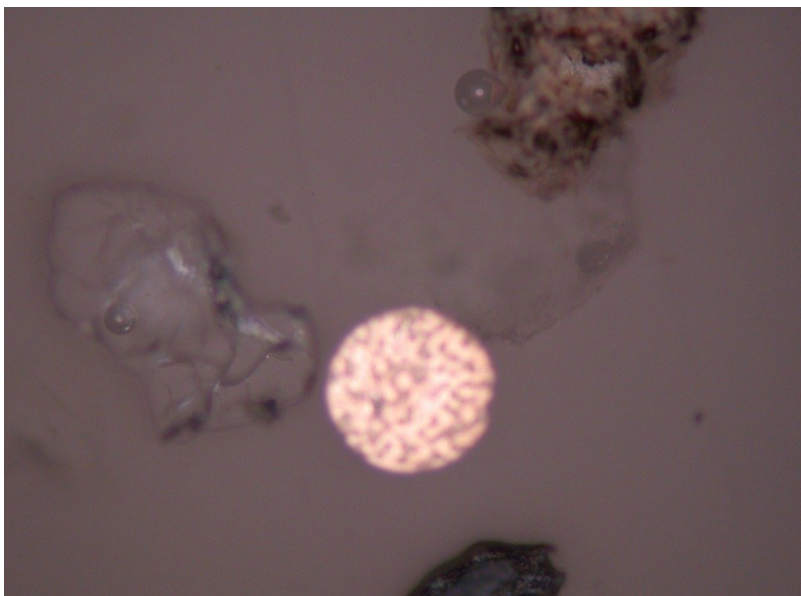


Figure A.19. Photomicrograph of metallic welding sphere in specimen BA - 47 under plane polarized reflected light (PPOL, FOV = 0.55 mm).

Table A.9 Summary of minerals in specimen BA - 54

Percent abundance mineralogy of house dust			
Barrie specimen BA - 54			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		161	31.0
Feldspars		103	19.8
Amphiboles	Ca-rich	44	8.5
Pyroxenes	Clinopyroxene	3	0.6
Carbonate minerals	Calcite	32	6.2
Lithic fragments	Felsic	89	17.1
Micas	Biotite	10	1.9
Accessory minerals	Chlorite	15	2.9
	Apatite	5	1.0
	Garnet	8	1.5
Sulphide minerals		11	2.1
Undefined minerals		38	7.3
Total minerals			
		519	100.0
Meltmount		500	
Synthetic materials ¹	Slag, fibres, dirt	81	
Organic components ²	Pollen, spores, cellulose	100	
Total			
		1200	

1 includes metallic fragments, plastic, carpet or textile fibres, etc...

2 includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BA - 54

This specimen has the highest proportion of amphibole minerals of all Barrie samples.

Similarly, it also has the highest concentration of metallic particles encountered in the entire specimen from this city.

Metallic particles

Small grains composed of clusters of fine stranded copper-coloured metallic wire are observed in this specimen. These are interpreted as fragments of electrical copper wire.

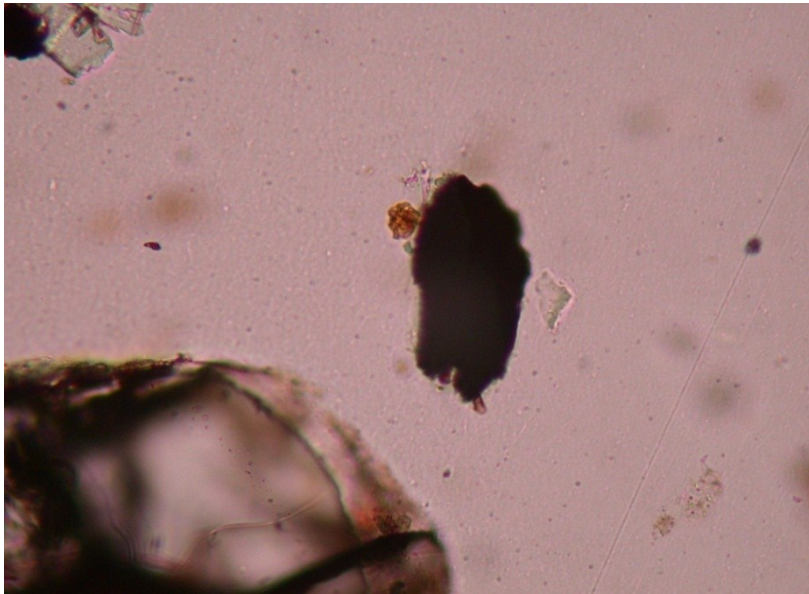


Figure A.20. Photomicrograph of metallic particle/copper wire in specimen BA - 54 (PPOL, FOV = 0.55 mm).



Figure A.21. Metallic particle/copper wire under plane polarized reflected light in specimen BA - 54 (PPOL, FOV = 0.55 mm). (The grains are opaque under plane polars).

Mineralogical observations

Pyroxene and biotite

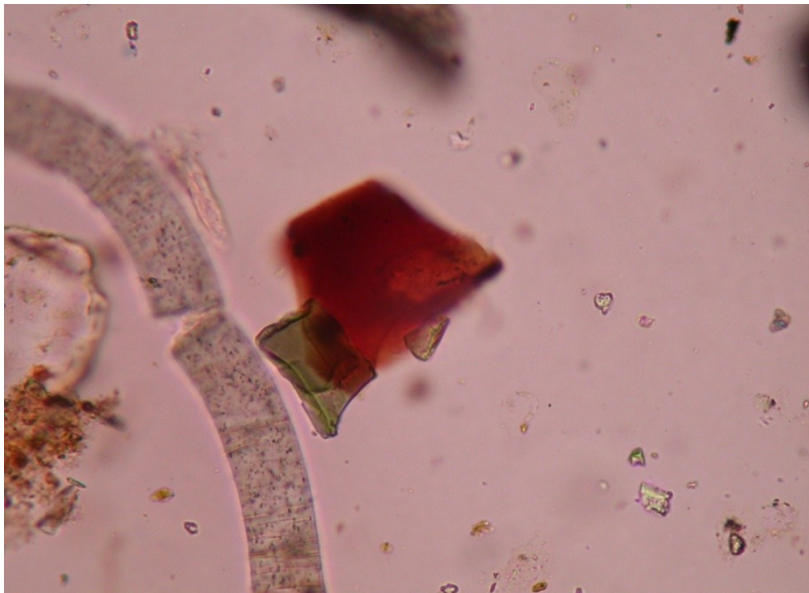


Figure A.22. Photomicrograph of pale-green pyroxene adjacent to brownish biotite in specimen BA - 54. Note also the presence of small grains of calcite in the meltmount. Under crossed polars, these grains show the characteristic high birefringence of all carbonate minerals. Note also the synthetic fibre (most likely rayon) to the left of the biotite and pyroxene grains (PPOL, FOV = 0.55 mm).

Amphiboles

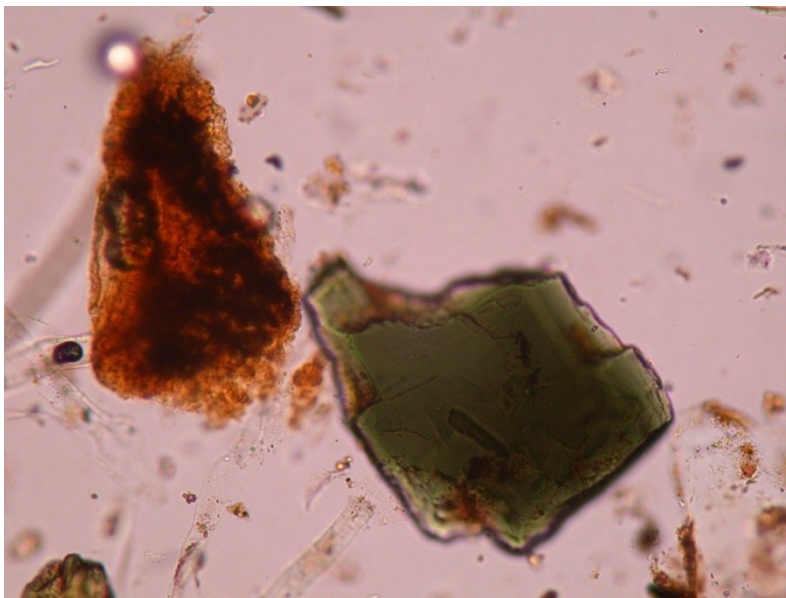


Figure A.23. Photomicrograph of greenish amphibole next to slag in specimen BA - 54 (PPOL, FOV = 0.55 mm).

Chlorite

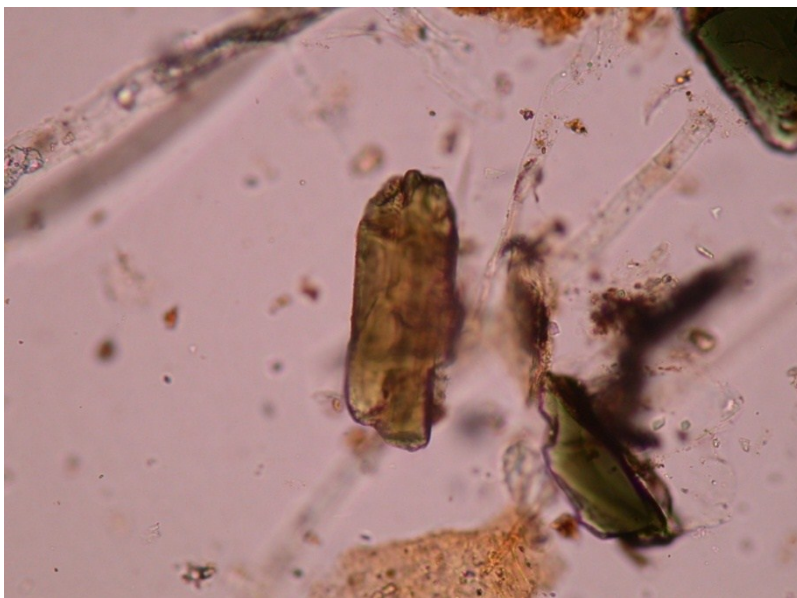


Figure A.24. Photomicrograph of chlorite grain at centre of the plate next to a hornblende grain in specimen BA - 54 (PPOL, FOV = 0.55 mm).

City of Burlington

Burlington is located on the shore of Lake Ontario, to the southwest of Toronto and northeast of Hamilton. Burlington lies on Paleozoic rocks, principally the Ordovician Queenston Formation that is composed of red arenaceous and micaceous shales, although the Georgian Bay and Lockport-Amabel formations also outcrop in the western and eastern limits of the city, respectively.

Soils in Burlington are composed mostly of loam, ranging from clay loam to sandy loam. The surficial geology of the city is the result of the unsorted glacial till deposits that were laid down by the moving sheet during the last glaciation.

Six specimens from Burlington were thoroughly investigated for their mineralogical composition.

In summary, the specimens showed an absence of sulphide and very few accessory minerals. Specimens showed mineral contents determined by point-counting on the microscope that ranged from 397 to 524 counts out of 1200. The number of counts for organic components ranged from 76 to ~240 out of the 1200.

Table A.10 Summary of minerals in specimen BU - 39

Percent abundance mineralogy of house dust			
Burlington specimen BU - 39			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		149	33.9
Feldspars		89	20.2
Amphiboles		2	0.5
Carbonate minerals	Calcite	114	25.9
Lithic fragments		67	15.2
Micas	Biotite	3	0.7
Accessory minerals	Chlorite	2	0.5
Undefined minerals		14	3.2
Total minerals			
		440	100.0
Meltmount		525	
Synthetic materials ¹	Fibres, dirt	120	
Organic components ²	Hair, cellulose	115	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

Table A.11 Summary of minerals in specimen BU - 46

Percent abundance mineralogy of house dust			
Burlington specimen BU - 46			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		211	43.1
Feldspars		93	19.0
Amphiboles		18	3.7
Pyroxenes		10	2.0
Carbonate minerals	Calcite	55	11.2
Lithic fragments		53	10.8
Micas	Muscovite	15	3.1
Accessory minerals	Chlorite	5	1.0
	Garnet	4	0.8
Undefined minerals		26	5.3
Total minerals			
		490	100.0
Meltmount		ND	
Synthetic materials ¹	Fibres, dirt	64	
Organic components ²		ND	
Total			
		554	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

ND, not determined in this specimen

General observations of specimen BU - 46

This specimen is dominated by angular quartz grains that reach up to 200 μm . Some of these grains show numerous inclusions whereas others are clear.

Mineralogical observations of specimen BU - 46

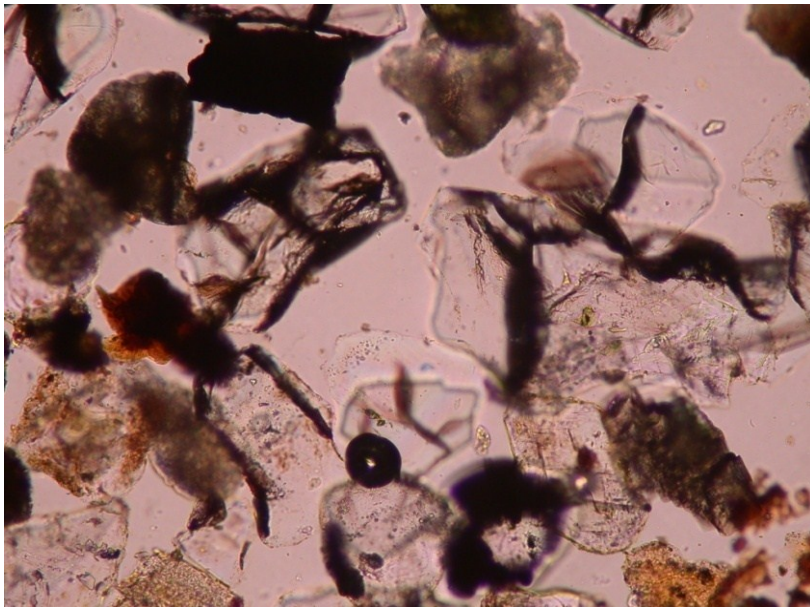


Figure A.25. Photomicrograph of the overview of the BU 46 sample, quartz dominated specimen, (PPOL, FOV = 1.1 mm).

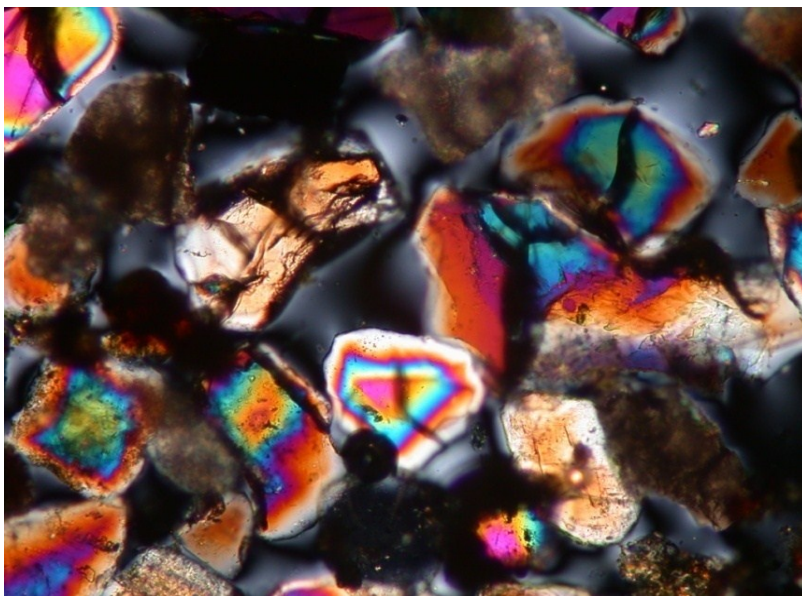


Figure A.26. Photomicrograph of the overview of the BU 46 sample, quartz dominated specimen, (XPL, FOV = 0.55 mm). Due to the inherent difficulty of preparing thin sections from house dust, thickness of resistant minerals was difficult to control and as a result the quartz grains display high birefringence due to greater than standard thickness (30 μm).

Table A.12 Summary of minerals in specimen BU - 47

Percent abundance mineralogy of house dust			
Burlington specimen BU - 47			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		162	40.8
Feldspars		61	15.4
Amphiboles		26	6.5
Pyroxenes		7	1.8
Carbonate minerals	Calcite	27	6.8
Lithic fragments		78	19.6
Micas	Biotite	5	1.3
	Muscovite	6	1.5
Accessory minerals	Chlorite	2	0.5
	Garnet	6	1.5
Undefined minerals		17	4.3
Total minerals			
		397	100.0
Meltmount		535	
Synthetic materials ¹	Fibres, dirt	148	
Organic components ²		120	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

Table A.13 Summary of minerals in specimen BU - 54

Percent abundance mineralogy of house dust			
Burlington specimen BU - 54			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		169	33.7
Feldspars		123	24.6
Amphiboles		21	4.2
Pyroxenes		13	2.6
Carbonate minerals	Calcite	75	15.0
Lithic fragments		67	13.4
Micas	Biotite	6	1.2
	Muscovite	3	0.6
Accessory minerals	Chlorite	2	0.4
	Apatite	3	0.6
	Garnet	8	1.6
	Rutile	3	0.6
Undefined minerals		8	1.6
Total minerals			
		501	100.0
Meltmount		ND	
Synthetic materials ¹	Fibres, dirt	48	
Organic components ²		ND	
Total			
		549	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

ND not determined for the organic components

General observations of specimen BU - 54

This specimen has the highest feldspar content of all Burlington. The specimen is also enriched in garnet.

Mineralogical observations of specimen BU - 54

Feldspars

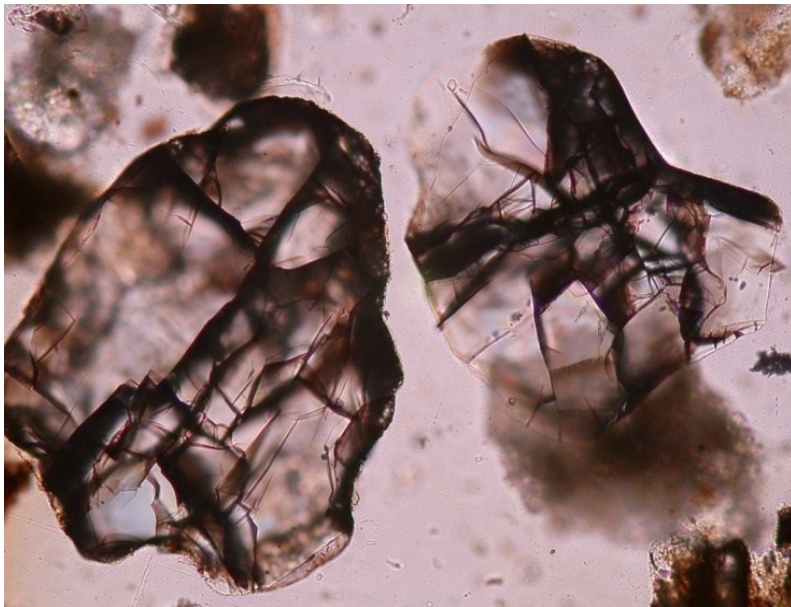


Figure A.27. Photomicrograph of feldspar minerals in specimen BU - 54 (PPOL, FOV = 0.55 mm).

Amphiboles

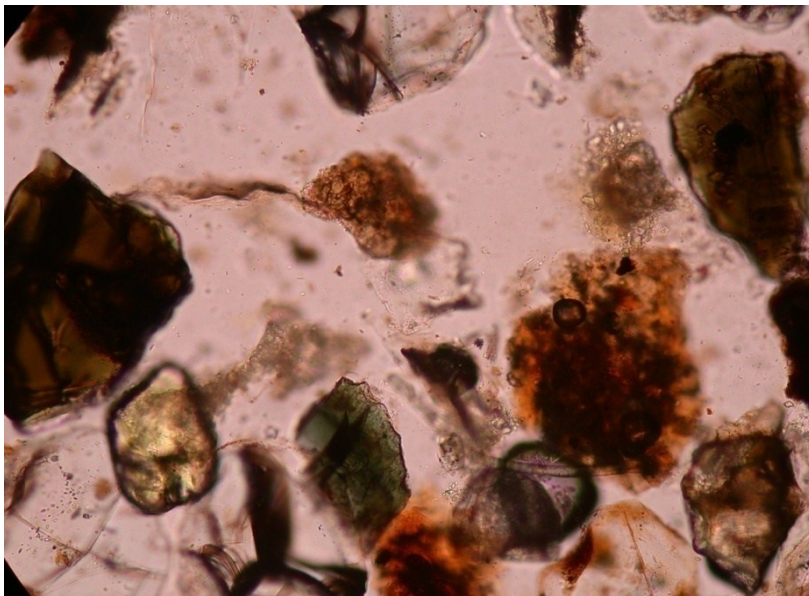


Figure A.28. Amphibole minerals showing pale green colour and dark brown colour in specimen BU - 54 (PPOL, FOV = 0.55 mm).

Table A.14 Summary of minerals in specimen BU - 55

Percent abundance mineralogy of house dust			
Burlington specimen BU - 55			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		151	32.3
Feldspars		80	17.1
Amphiboles		12	2.6
Carbonate minerals	Calcite	76	16.3
Lithic fragments		119	25.5
Micas	Biotite	10	2.1
	Muscovite	3	0.6
Accessory minerals	Chlorite	1	0.2
Undefined minerals		15	3.2
Total minerals			
		467	100.0
Meltmount		417	
Synthetic materials ¹	Fibres, soot	76	
Organic components ²	Plant remains	240	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BU – 55

This specimen of dust is dominated by cellulose in great part plant remains. Accessory minerals and metallic particles were not observed.

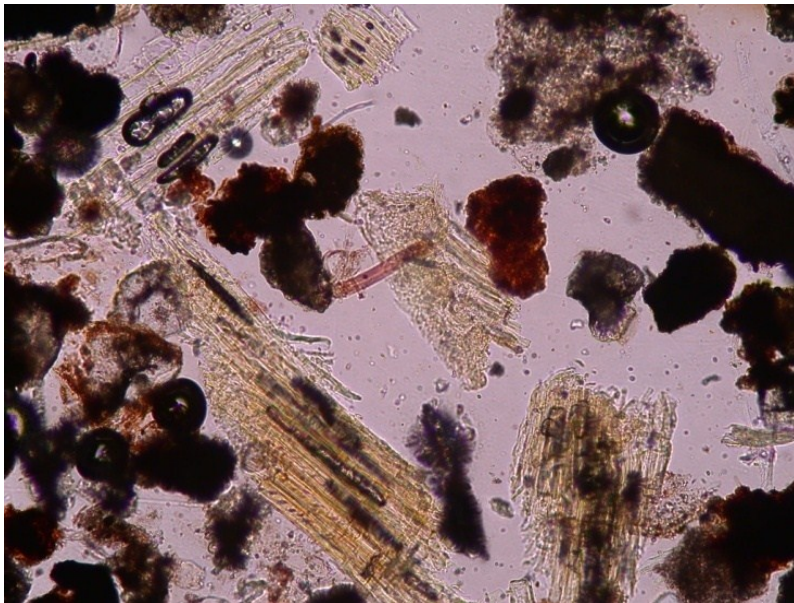


Figure A.29. Plant remains surrounded by synthetic materials like dark slag and dirt in specimen BU - 55 (PPOL, FOV = 1.1 mm).

Table A.15 Summary of minerals in specimen BU - 63

Percent abundance mineralogy of house dust			
Burlington specimen BU - 63			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		170	32.4
Feldspars		90	17.2
Amphiboles	Ca-rich	13	2.5
Carbonate minerals	Calcite	85	16.2
Lithic fragments	Felsic	134	25.6
Micas	Biotite	12	2.3
	Muscovite	3	0.6
Accessory minerals	Chlorite	1	0.2
Undefined minerals		16	3.1
Total minerals			
		524	100.0
Meltmount			
		515	
Synthetic materials ¹	Slag, fibres, dirt	85	
Organic components ²	Human hair	76	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen BU – 63

Unlike other Burlington samples this specimen showed many lithic fragments. Also its organic components were exclusively human hair.

City of Cambridge

The city of Cambridge is located in southwestern Ontario on the Grand River in the region of Waterloo.

The soil type for the city of Cambridge is mostly organic. However, stony tills cover its immediate surrounding area. The geology of Cambridge is dominated by dolomite of Guelf Formation (see 2.4.3 Soil, surficial and bedrock geology of Cambridge).

The surficial geology of Cambridge area is highly influenced by Pleistocene ice age similar to the Great Lakes region. The transgression and regression of glaciers deposited unsorted sediments or till in this area. The bedrock geology of the Cambridge area is dominated by Guelph Formation, which consists of cream to brown dolomite (see 2.4.3 Soil, surficial and bedrock geology of Cambridge).

Five specimens from the city of Cambridge were investigated thoroughly for their mineralogical content.

Table A.16 Summary of minerals in specimen CA - 03

Percent abundance mineralogy of house dust			
Cambridge specimen CA - 03			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		184	33.6
Feldspars		130	23.8
Amphiboles		26	4.8
Carbonate minerals	Calcite	66	12.1
Lithic fragments	Felsic	94	17.2
Micas	Biotite	14	2.6
Accessory minerals	Chlorite	4	0.7
	Rutile	3	0.5
Sulphide minerals		10	1.8
Undefined minerals		16	2.9
Total minerals		547	100.0
Meltmount		535	
Synthetic materials ¹	Slag, fibres, dirt	63	
Organic components ²		55	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen CA - 03

This specimen's thin section was among some samples subjected to further analyses using INCA Viga SEM machine to correlate with the data examined by PLM. Dolomite is the main carbonate mineral in this specimen.

Mineralogical observations of specimen CA - 03

An overview of specimen CA - 03 under plane polarized light microscope

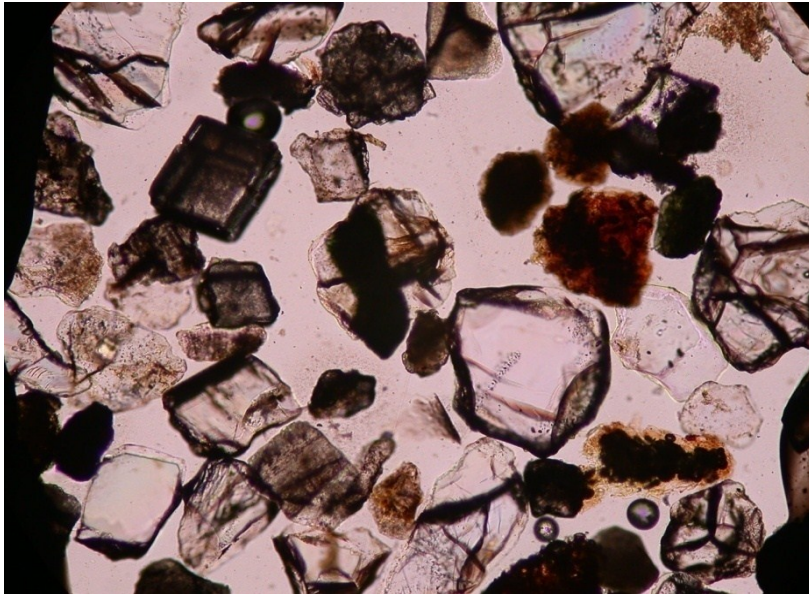


Figure A.30. A photomicrograph of an overview of specimen CA-03 dominated by quartz and feldspar with few dolomite grains (PPOL, FOV = 1.1 mm).

Unknown sulphide mineral

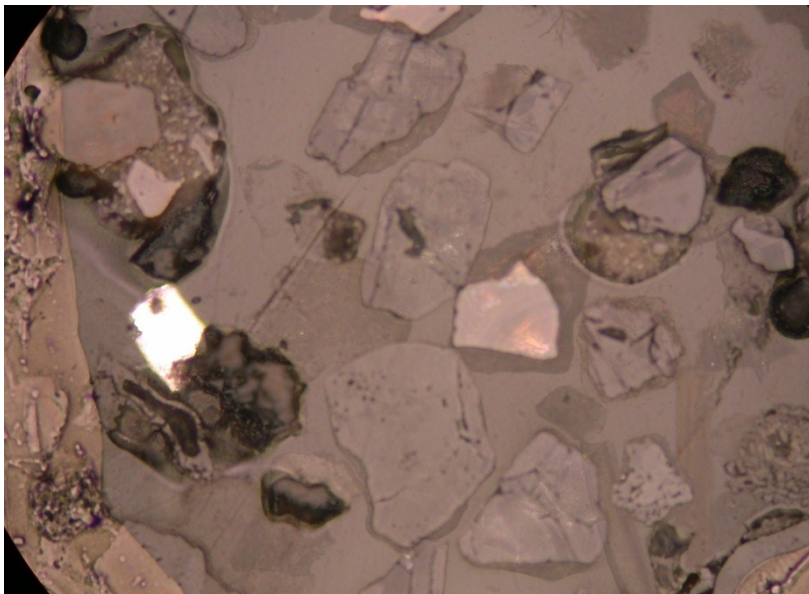


Figure A.31. Unknown sulphide minerals in specimen CA -03 seen under plane polarized reflected light (PPOL, FOV = 1.1 mm).

Hematite

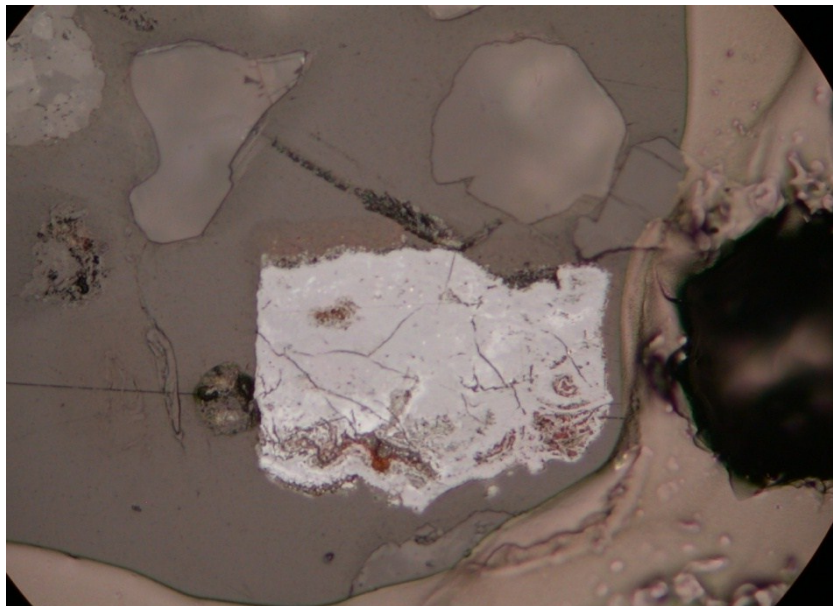
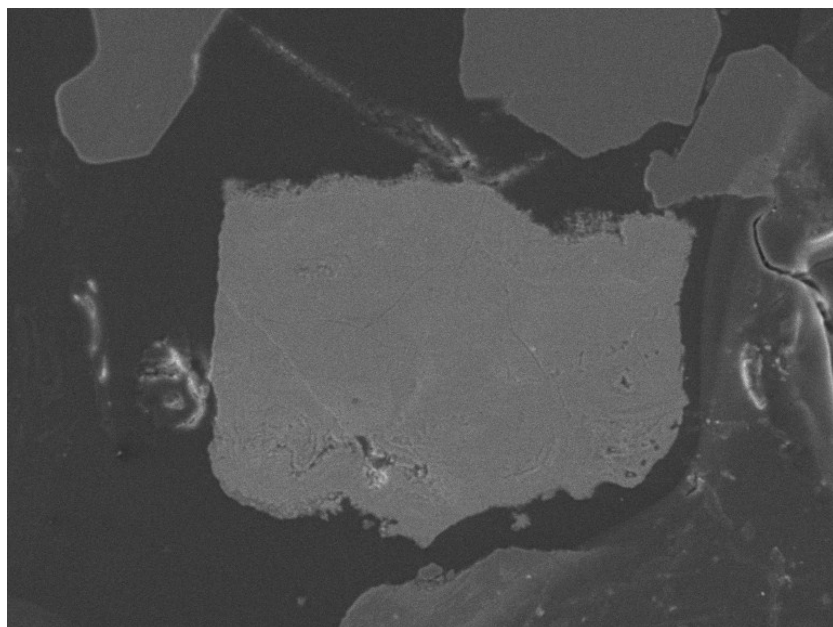


Figure A.32. Photomicrograph of a rusted iron oxide (hematite) present in specimen CA -03, under plane polarized reflected light (PPOL, FOV = 0.55 mm).



SEM MAG: 400 x View field: 562.5 μm VEGA\\ TESCAN
Det: SE Device: VEGA II XMU 100 μm Performance in nanospace

Figure A.33. SEM secondary-electron image of iron oxide in specimen CA -03. SEM was used to verify the chemical composition of the mineral hematite.

Ilmenite

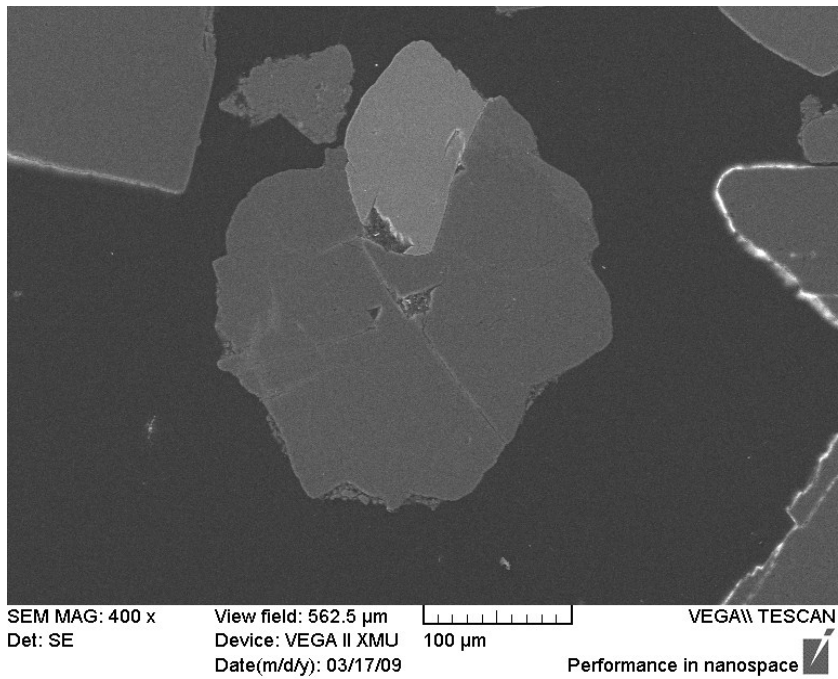


Figure A.34. SEM secondary-electron image showing the mineralogical occurrence of ilmenite minerals in specimen CA -03.

Dolomite

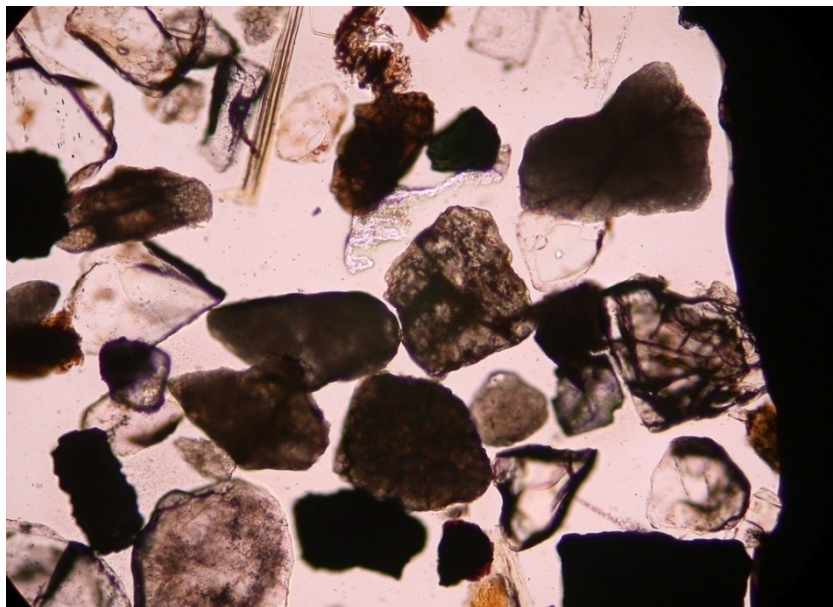


Figure A.35. Photomicrograph of dolomite minerals in specimen CA -03 (PPOL, FOV = 1.1 mm).

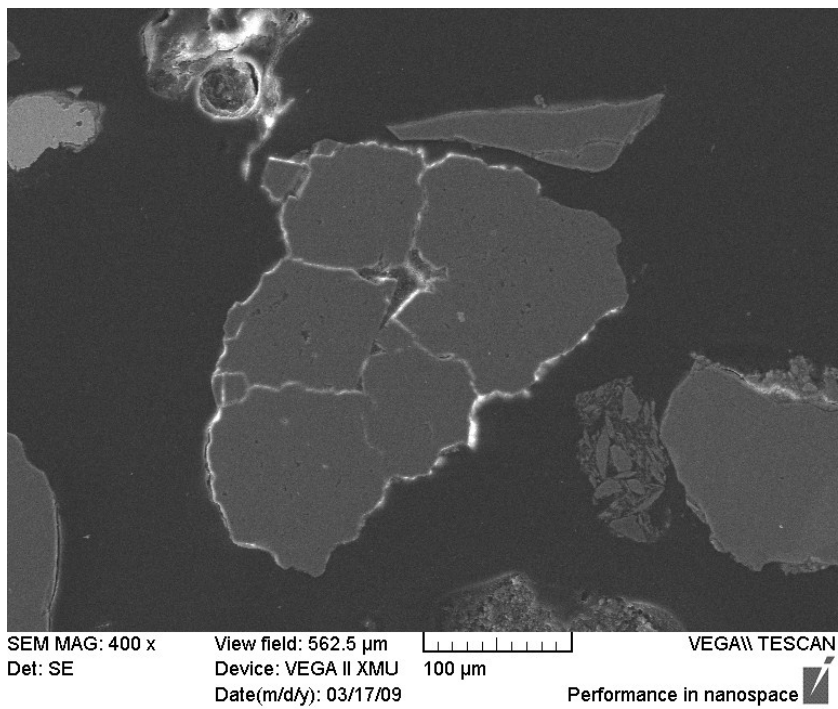


Figure A.36. SEM secondary-electron showing fractures in dolomite in specimen CA - 03.

Table A.17 Summary of minerals in specimen CA - 12

Percent abundance mineralogy of house dust			
Cambridge specimen CA - 12			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		116	20.7
Feldspars		176	31.4
Amphiboles		41	7.3
Pyroxenes	Clinopyroxene	8	1.4
Carbonate minerals		95	17.0
Lithic fragments		112	20.0
Micas	Biotite	5	0.9
Accessory minerals	Garnet	5	0.9
Sulphide minerals		2	0.4
Total minerals			
		560	100.0
Meltmount		540	
Synthetic materials ¹	Slag, fibres, dirt	51	
Organic components ²	Cellulose	49	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen CA - 12

This specimen has more feldspars, amphiboles and carbonate minerals than any of the Cambridge samples. And it has the least sulphide minerals. Of the entire specimens studied for mineralogical characterization this house dust sample has many feldspar minerals.

Mineralogical observations of specimen CA - 12

Plagioclase feldspar

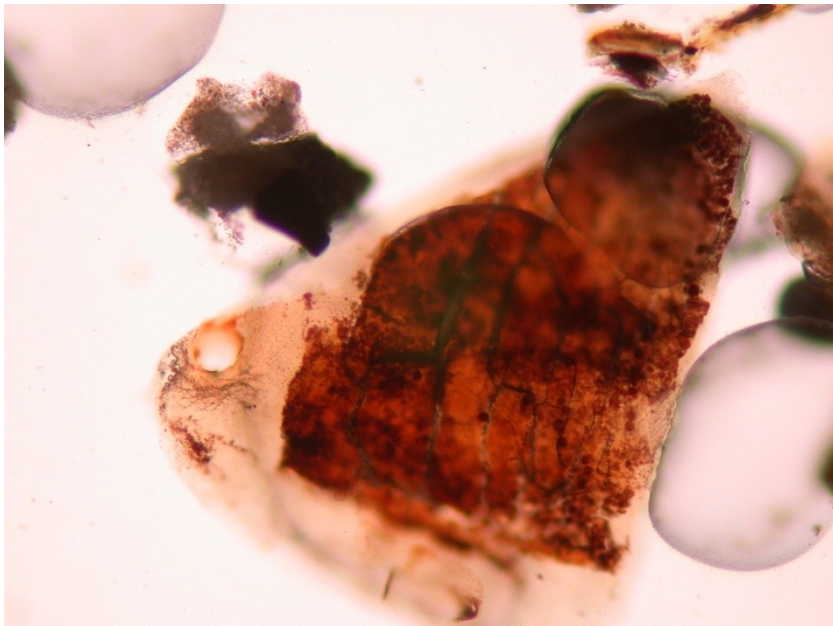


Figure A.37. Photomicrograph of plagioclase feldspar grains in specimen CA -12 (PPOL, FOV = 0.55 mm).

Magnetite

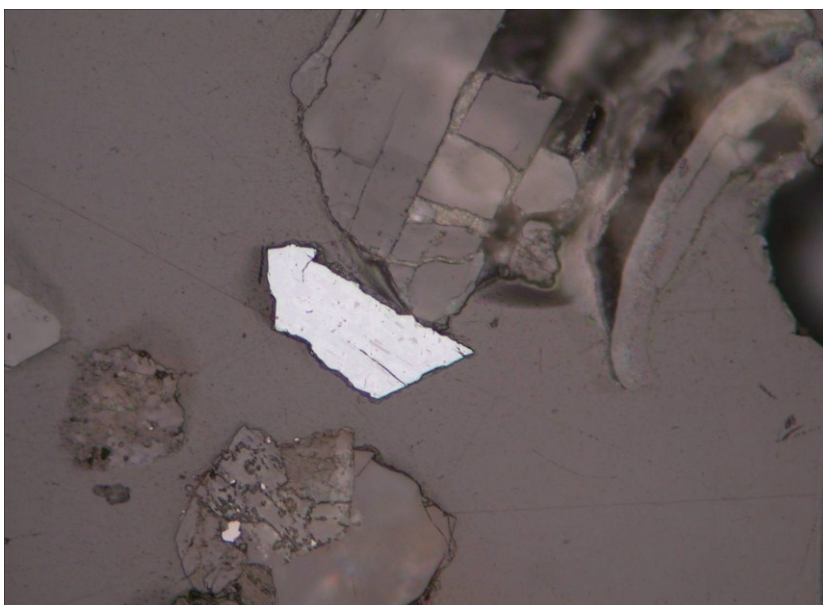


Figure A.38. Photomicrograph of magnetite under plane polarized reflected light in specimen CA-12 (PPOL, FOV = 1.1 mm).

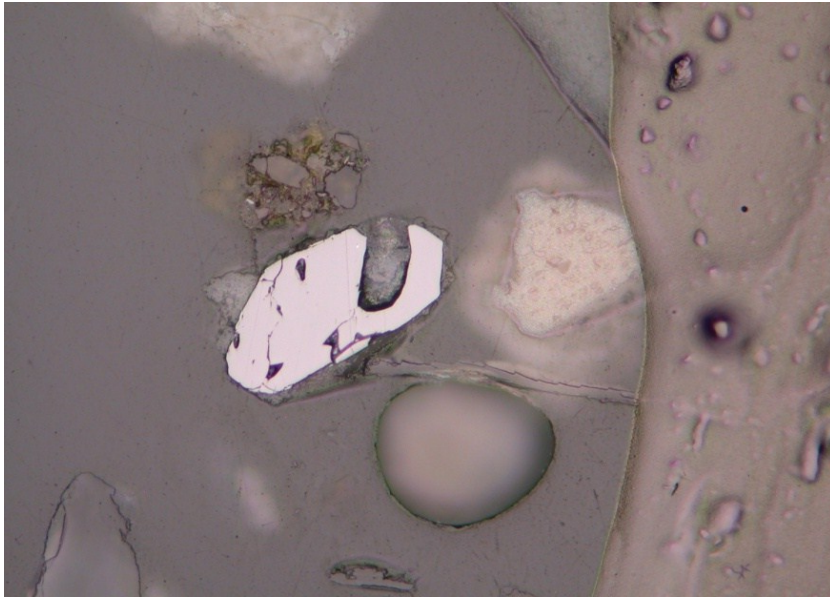


Figure A.39. Photomicrograph of magnetite under plane polarized reflected light in specimen CA -12 (PPOL, FOV = 1.1 mm).

Ilmenite

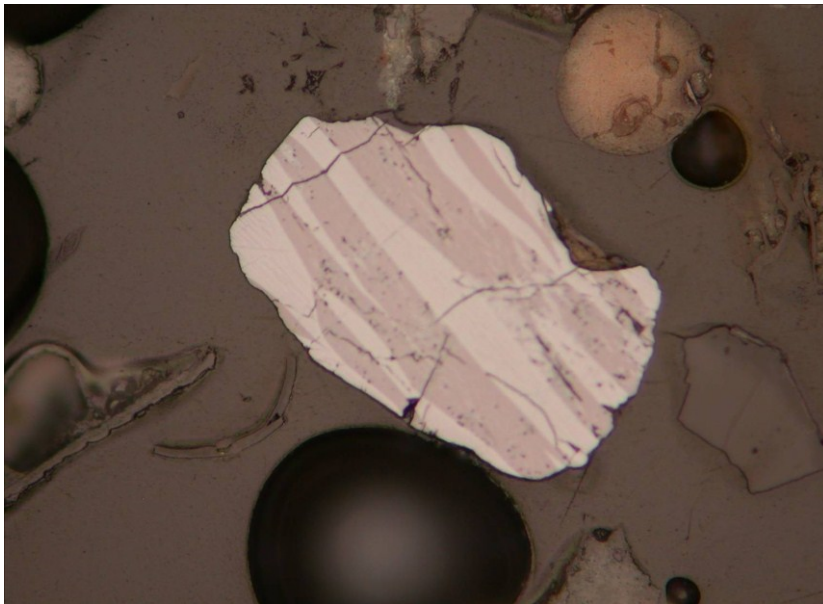


Figure A.40. Photomicrograph of magnetite-ilmenite exsolution lamellae under plane polarized reflected light in specimen CA-12 (PPOL, FOV = 1.1 mm).

Table A.18 Summary of minerals in specimen CA - 13

Percent abundance mineralogy of house dust			
Cambridge specimen CA - 13			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		152	32.4
Feldspars		113	24.1
Amphiboles	Ca-rich	22	4.7
Carbonate minerals	Calcite	49	10.4
Lithic fragments	Felsic	81	17.3
Micas	Biotite	12	2.6
Accessory minerals	Chlorite	7	1.5
	Rutile	5	1.1
	Garnet	6	1.3
	Apatite	4	0.9
Sulphide minerals		11	2.3
Undefined minerals		7	1.5
Total minerals			
		469	100.0
Meltmount		445	
Synthetic materials ¹	Slag, fibres, dirt	56	
Organic components ²	Pollen, spores, cellulose	130	
Total			
		1100	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen CA - 13

Unlike all other Cambridge samples this specimen has many accessory minerals such as chlorite, apatite, garnet, including rutile.

Mineralogical observations of specimen CA - 13

Quartz with fluid inclusions



Figure A.41. Photomicrograph of quartz grain with fluid inclusions in specimen CA-13 (PPOL, FOV = 1.1 mm).

Calcite

Calcite minerals, averaged size fraction of 10 μm , showed characteristic feature of high birefringence under XPL. Figure 43 and 44 shows this characteristic of calcite mineral in both plane polarized light and cross-polar lights.

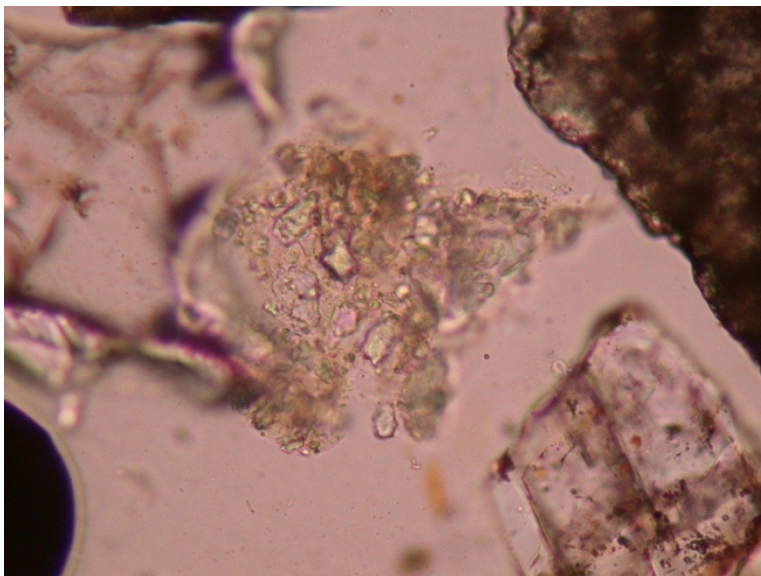


Figure A.42. Photomicrograph of calcite minerals in specimen CA-13 (PPOL, FOV = 0.55 mm).

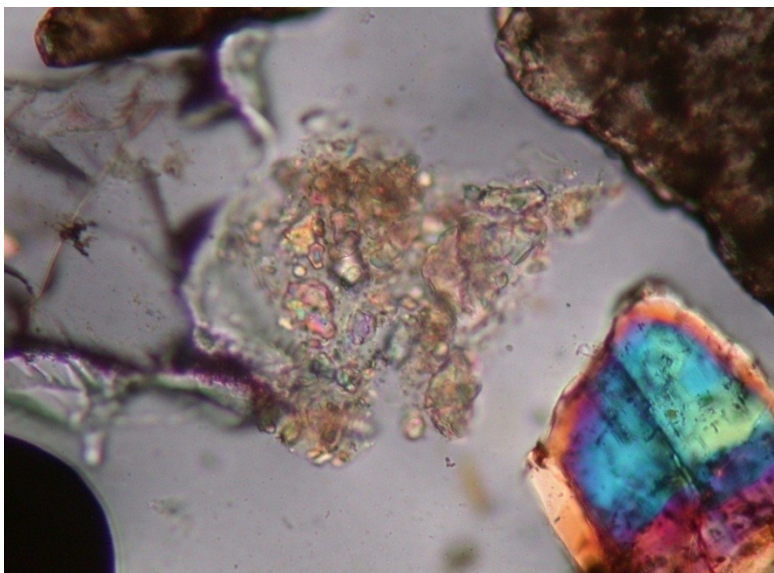


Figure A.43. Photomicrograph of calcite minerals at centre of the plate showing high birefringence, quartz at the right bottom corner in specimen CA-13 (XPL, FOV = 0.55 mm).

Table A.19 Summary of minerals in specimen CA - 76

Percent abundance mineralogy of house dust			
Cambridge specimen CA - 76			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		158	30.1
Feldspars		110	21.0
Amphiboles	Ca-rich	23	4.4
Pyroxenes	Clinopyroxene	3	0.6
Carbonate minerals	Calcite	79	15.0
Lithic fragments	Felsic	101	19.2
Micas	Biotite	17	3.2
Accessory minerals	Chlorite	6	1.1
Sulphide minerals		18	3.4
Undefined minerals		10	1.9
Total minerals			
		525	100.0
Meltmount			
Synthetic materials ¹	Slag, fibres, dirt	68	
Organic components ²		96	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen CA - 76

Similar to almost all of the 40 specimens investigated for this study, this then section showed internal strain features and fluid inclusions in the quartz grains.

Mineralogical observations of specimen CA - 76

Quartz

Quartz grains in this specimen CA - 76 similar to most of the quartz grains from this study areas show internal strain features and fluid inclusions.

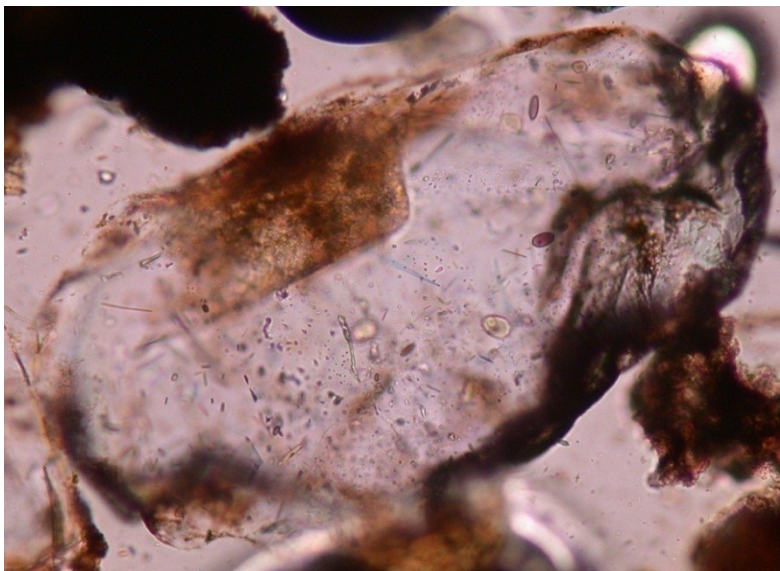


Figure A.44. Photomicrograph of fluid inclusions and strain features in quartz mineral in specimen CA-76 (PPOL, FOV = 0.55 mm).

Magnetite



Figure A.45. Photomicrograph of magnetite under plane polarized reflected light in specimen CA-76 (PPOL, FOV = 0.55 mm).

Table A.20 Summary of minerals in specimen CA - 81

Percent abundance mineralogy of house dust			
Cambridge specimen CA - 81			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		116	21.2
Feldspars		127	23.2
Amphiboles	Ca-rich	35	6.4
Pyroxenes		11	2.0
Carbonate minerals	Calcite	70	12.8
Lithic fragments	Felsic	125	22.9
Micas		17	3.1
Accessory minerals	Chlorite	8	1.5
	Garnet	6	1.1
	Apatite	3	0.5
Sulphide minerals		11	2.0
Undefined minerals		18	3.3
Total minerals			
		547	100.0
Meltmount			
		452	
Synthetic materials ¹	Slag, fibres, dirt	51	
Organic components ²	Hair and plant parts	150	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen CA - 81

This specimen CA - 81 has many pyroxene grains and lithic fragment grains as compared to other Cambridge samples. It also shows quartz grains that are

predominantly rounded in shape unlike many semi-angular quartz grains observed in other samples from similar study area.

Mineralogical observations of specimen CA - 81

Polysynthetic twinning of albite

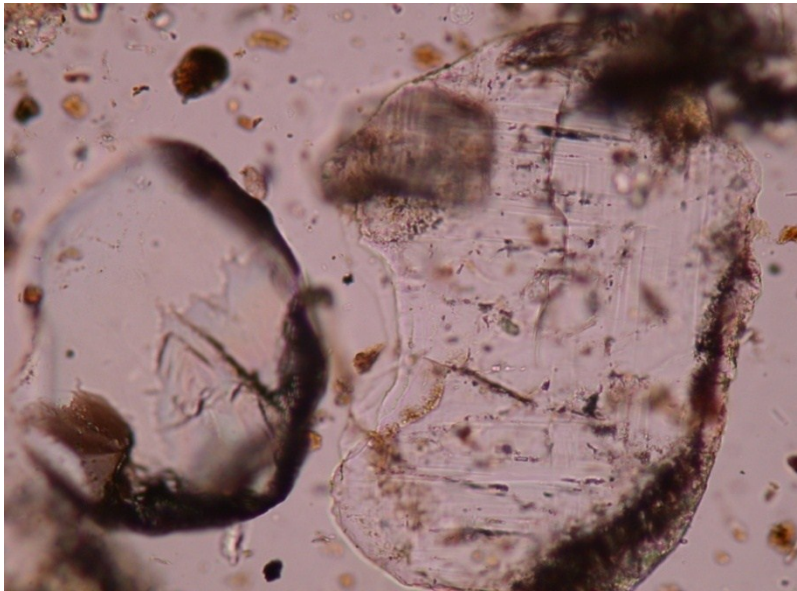


Figure A.46. Photomicrograph of rounded shape quartz and plagioclase in specimen CA - 81 (PPOL, FOV = 0.55 mm).

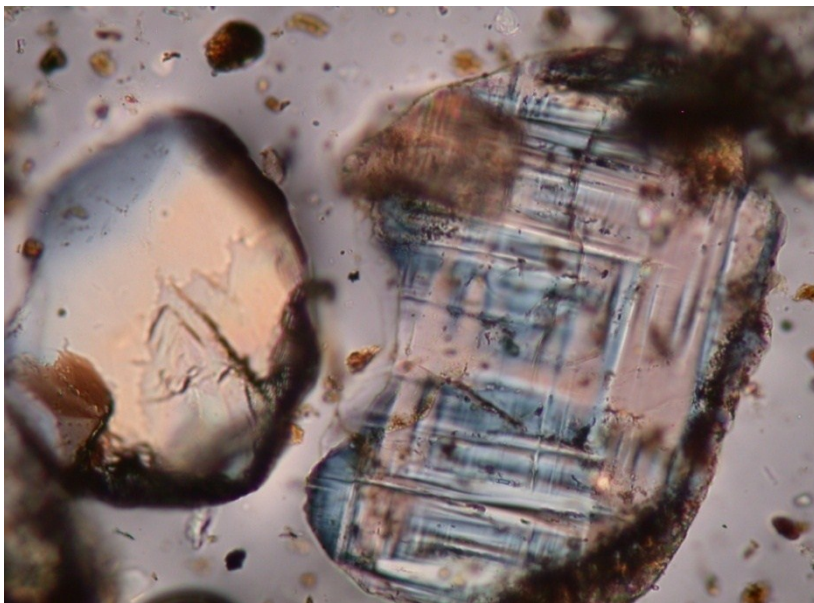


Figure A.47. Plagioclase, right side of the two grains, showing polysynthetic twinning of albite in specimen CA - 81 (PPOL, FOV = 0.55 mm). Note the quartz grain is rounded.

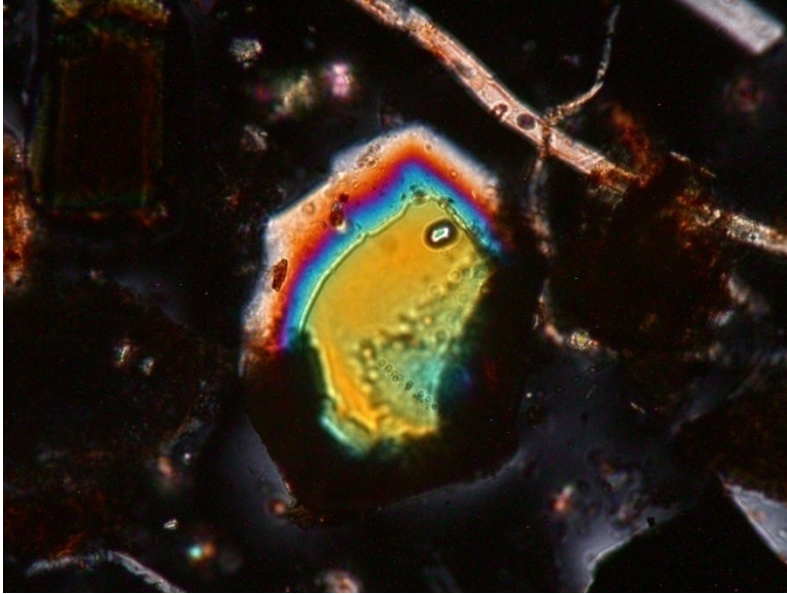
Quartz

Figure A.48. Photomicrograph of quartz with fluid inclusion at the centre of the plate, synthetic fibres on the right upper corner of the slide in specimen CA - 81 (XPL, FOV = 0.55 mm).

City of Hamilton

The city of Hamilton is located in Southern Ontario, on the western side of Lake Ontario and at the western end of the Niagara Peninsula.

The soils in the Hamilton area were deposited during the last glaciations. The southeastern part the city is covered by clay till, while the western part is covered by silt and sandy soil.

The surficial geology of the city of Hamilton consists of Pleistocene deposits of the Halton till and glaciolacustrine sand. The bedrock in Hamilton is dominated by Paleozoic dolomite, shale, and sandstone (see 2.5.3 Soil, surficial and bedrock geology of Hamilton).

Five specimens were investigated from the city of Hamilton for the mineralogical content of house dust.

Table A.21 Summary of minerals in specimen HA - 03

Percent abundance mineralogy of house dust			
Hamilton specimen HA - 03			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		93	20.1
Feldspars		144	31.1
Amphiboles	Ca-rich	35	7.6
Pyroxenes	Clinopyroxene	12	2.6
Carbonate minerals	Calcite	77	16.6
Lithic fragments	Felsic	78	16.8
Micas	Biotite	8	1.7
Accessory minerals	Chlorite	12	2.6
	Apatite	4	0.9
Total minerals		463	100.0
Meltmount		553	
Synthetic materials ¹	Slag, fibres, dirt	112	
Organic components ²		72	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen HA – 03

This specimen has high proportions of quartz, feldspars, amphiboles, and pyroxenes when compared to all Hamilton samples.

Table A.22 Summary of minerals in specimen HA - 06

Percent abundance mineralogy of house dust			
Hamilton specimen HA - 06			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		72	14.4
Feldspars		85	17.0
Amphiboles	Ca-rich	14	2.8
Pyroxenes	Clinopyroxene	9	1.8
Carbonate minerals	Calcite	211	42.2
Lithic fragments	Felsic	100	20.0
Micas	Biotite	4	0.8
Accessory minerals	Chlorite	5	1.0
Total minerals			
		500	100.0%
Meltmount			
		528	
Synthetic materials ¹	Slag, fibres, dirt	70	
Organic components ²	Plant remains	102	
Total		1200	

1 includes metallic fragments, plastic, carpet or textile fibres, etc...

2 includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen HA – 06

Calcium carbonate from construction materials were categorized under carbonate minerals group, although these are synthetic materials (See Ch5, P4, for why the author considered these materials as carbonate minerals). This house dust has many slag and organic components. Pieces of paints were observed. Plants are likely from indoor flowers. Hematite is the common iron oxide.

Carbium carbonates (most likely cement)

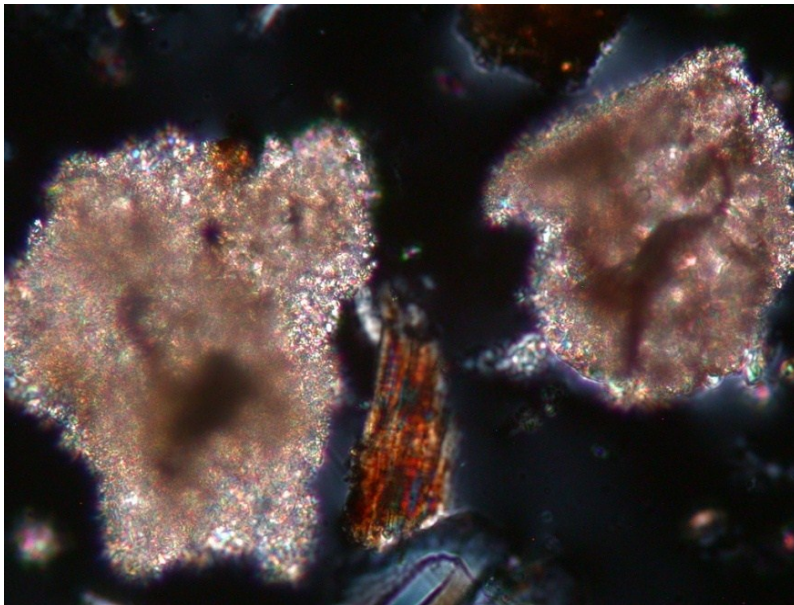


Figure A.49. Carbium carbonate materials, most likely cement that may be derived from a recent construction, were observed in this specimen HA-06. The author did not count these materials as carbonate minerals but grouped them as lithic fragments. They are represented here because this specimen is full of this material (XPL, FOV = 0.55 mm).

Metallic particles

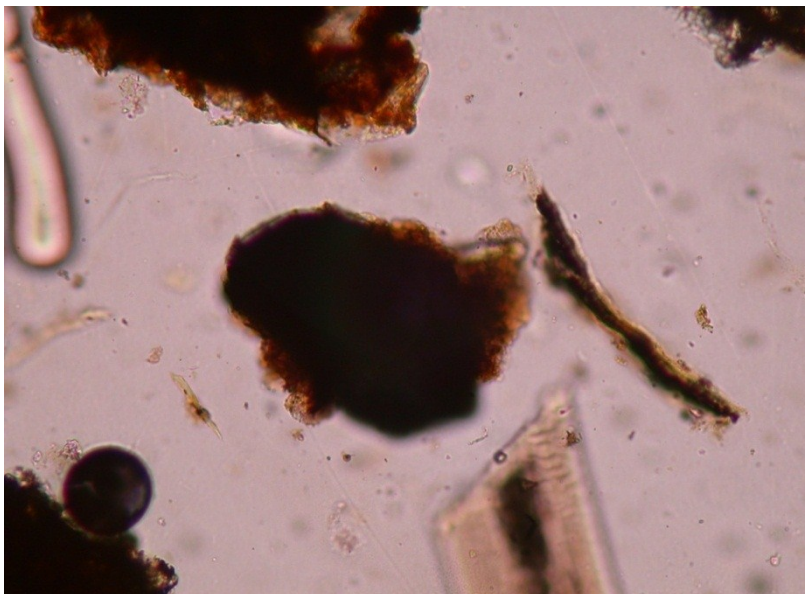


Figure A.50. Metallic particles dominate this specimen of HA-06 (PPOL, FOV = 0.55 mm).

Metallic particles

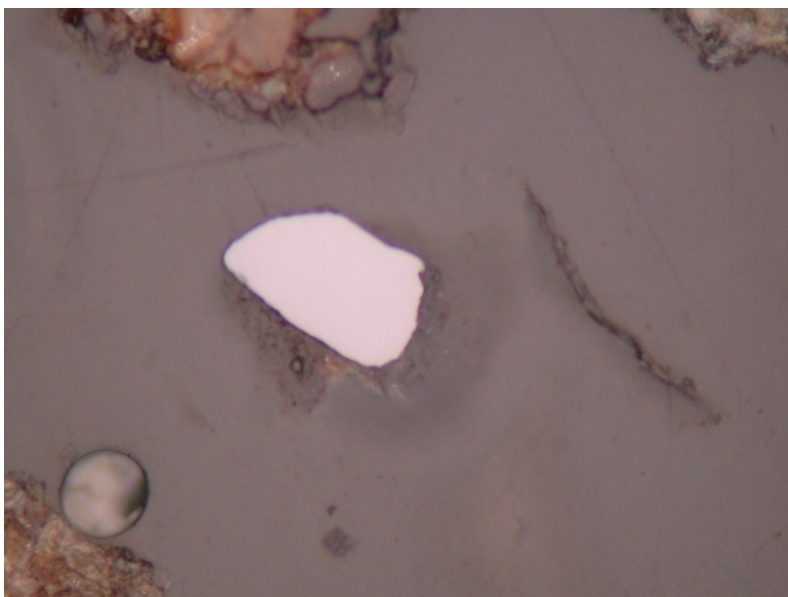


Figure A.51. Photomicrograph of metallic particle under plane polarized reflected light in specimen HA-06 (PPOL, FOV = 0.55 mm).

Hair

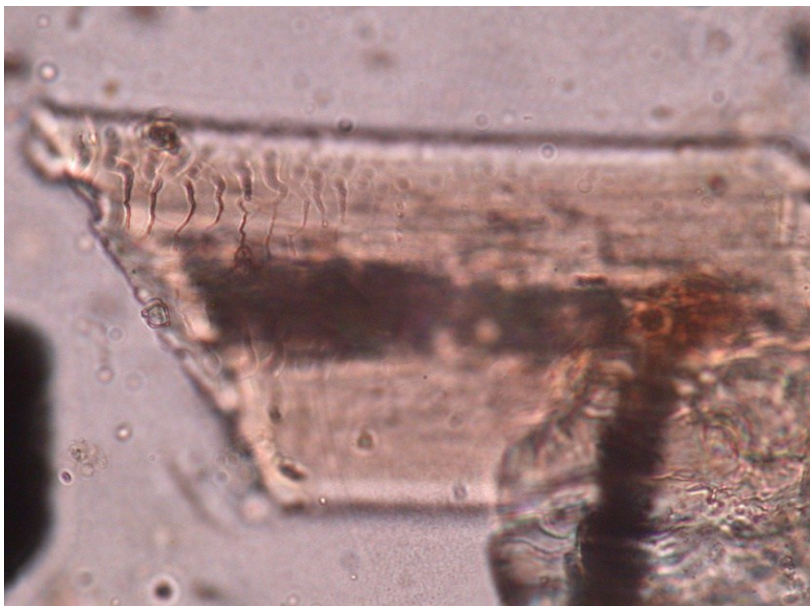


Figure A.52. In this specimen HA - 06 human hairs were observed in higher numbers than all other specimens (PPOL, FOV = 0.05 mm).

Table A.23 Summary of minerals in specimen HA - 13

Percent abundance mineralogy of house dust			
Hamilton specimen HA - 13			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		80	19.8
Feldspars		57	14.1
Amphiboles	Ca-rich	19	4.7
Pyroxenes	Clinopyroxene	7	1.7
Carbonate minerals	Dolomite	66	16.3
Lithic fragments	Felsic	99	24.5
Micas	Biotite	9	2.2
	Muscovite	4	1.0
Accessory minerals	Chlorite	11	2.7
	Apatite	5	1.2
	Rutile	6	1.5
	Aluminosilicate ³	3	0.7
	Garnet	7	1.7
Sulphide minerals		8	2.0
Undefined minerals		23	5.7
Total minerals			
		404	100.0
Meltmount		411	
Synthetic materials ¹	Slag, fibres, dirt	100	
Organic components ²	Cellulose	85	
Total		1000	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen HA - 13

Mineral grains tend to be larger than the organic components and other synthetic materials of the house dust. Very little to no fluid inclusions were observed in the

quartz grains of this particular specimen when compared to the entire samples from the six cities.

K-feldspar is the common feldspar. Carbonate minerals have the 'earthy' appearance under PLM, similar look as the hand specimen from the area - mostly dolomite. Minerals such as titanomagnetite, garnet, feldspar, and lithic fragments were also observed.

Organic components, especially cellulose were noticed.

Mineralogical observations of specimen HA - 13

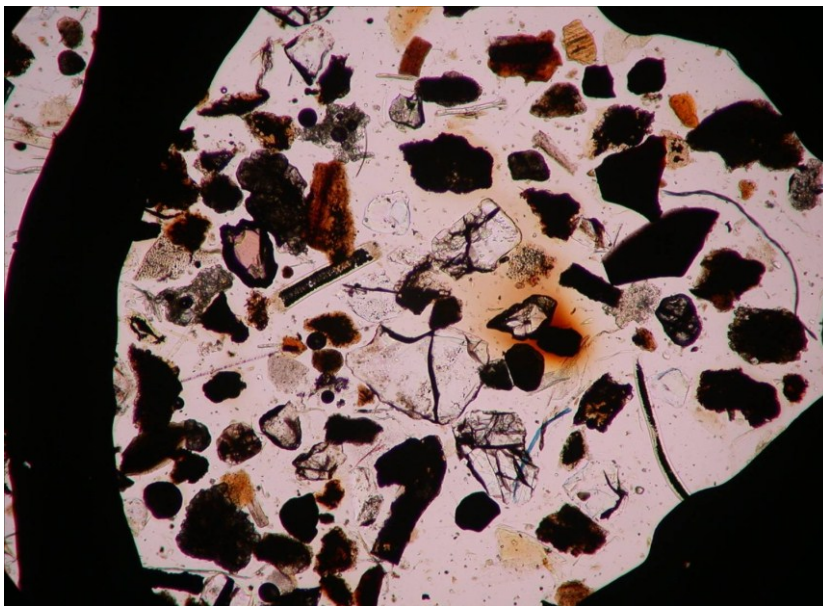


Figure A.53. An overview of minerals in specimen HA-13. The light coloured minerals are quartz and feldspar (PPOL, FOV = 2.2 mm).

Titanomagnetite

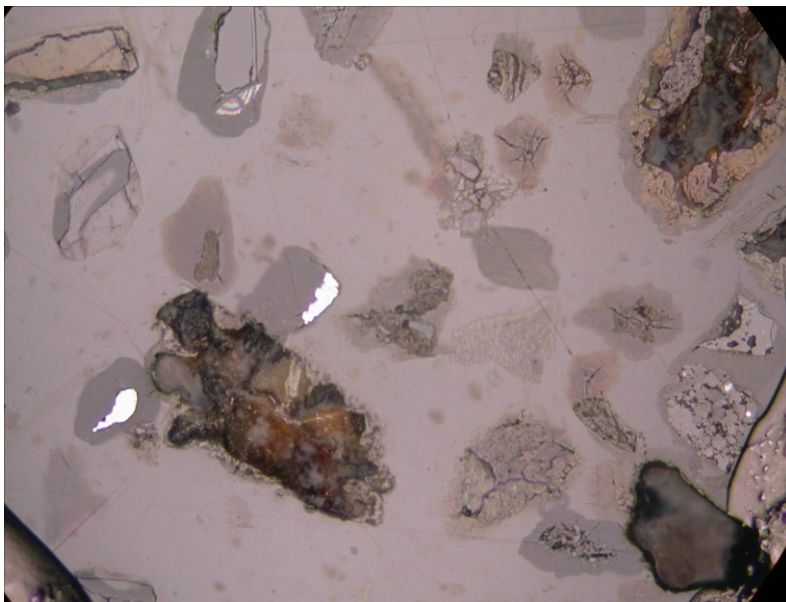


Figure A.54. Photomicrograph of titanomagnetite, unusual mineral in house dust under plane polarized reflected light in specimen HA-13 (PPOL, FOV = 1.1 mm).

Unknown particles

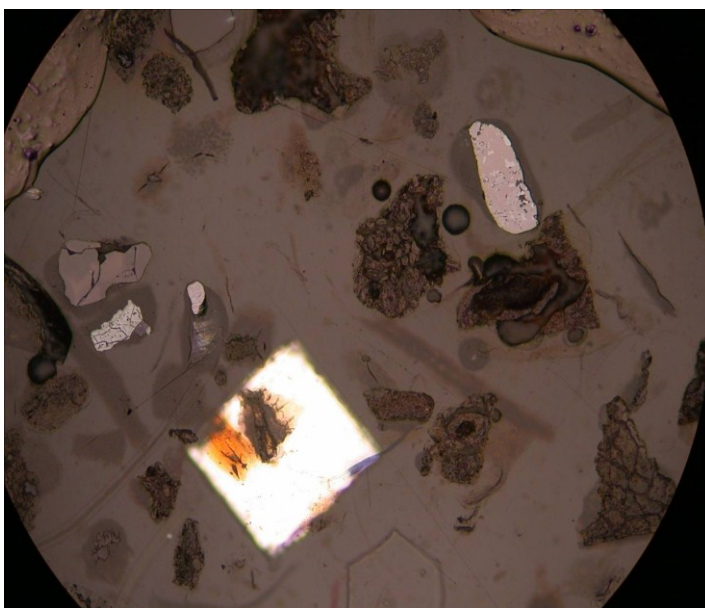


Figure A.55. Specimen HA-13 showed unknown materials with high reflection under plane polarized reflected light (PPOL, FOV = 0.55 mm).

Table A.24 Summary of minerals in specimen HA - 63

Percent abundance mineralogy of house dust			
Hamilton specimen HA - 63			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		55	14.5
Feldspars		82	21.6
Carbonate minerals ⁴	Calcite	167	43.9
Lithic fragments	Felsic	67	17.6
Micas	Biotite	9	2.4
Total minerals			
		380	100.0
Meltmount		420	
Synthetic materials ¹	Slag, fibres, dirt	180	
Organic components ²		220	
Total		1200	

1 includes metallic fragments, plastic, carpet or textile fibres, etc...

2 includes insect parts, skin dander, pollen, dust mites, etc...

4 includes calcium carbonates associated with construction materials

General observations of specimen HA - 63

Minerals like quartz, feldspars and amphiboles show less presence in this specimen than other Hamilton samples. Rusted metallic scraps were observed. Flakes of paint were also noticed. Magnetite is the common oxide mineral.

Mineralogical observations of specimen HA - 63

Biotite

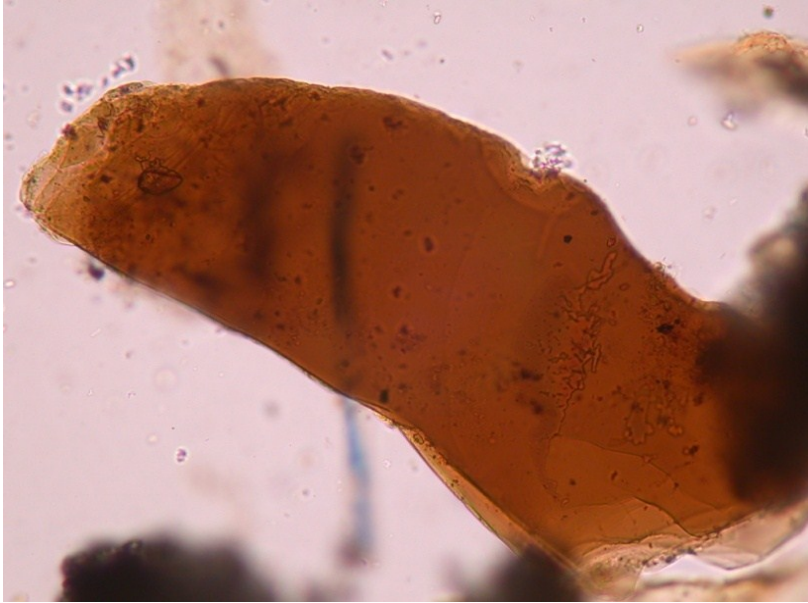


Figure A.56. Photomicrograph of a brownish colour biotite grain with a perfect cleavage in specimen HA-63 (PPOL, FOV = 0.55 mm).

Calcite minerals

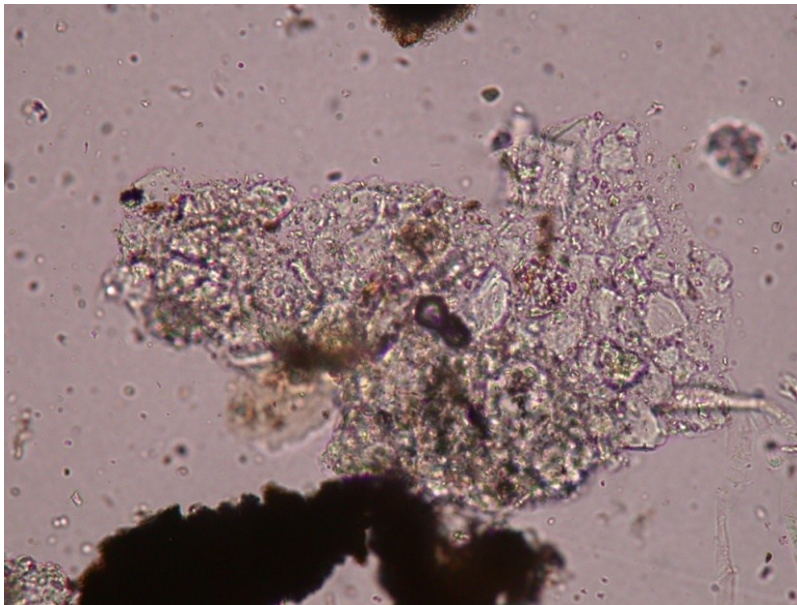


Figure A.57. Photomicrograph of typical calcite minerals in house dust that are crushed into pieces due to calcite's low hardness (HA-63) (PPOL, FOV = 0.55 mm).

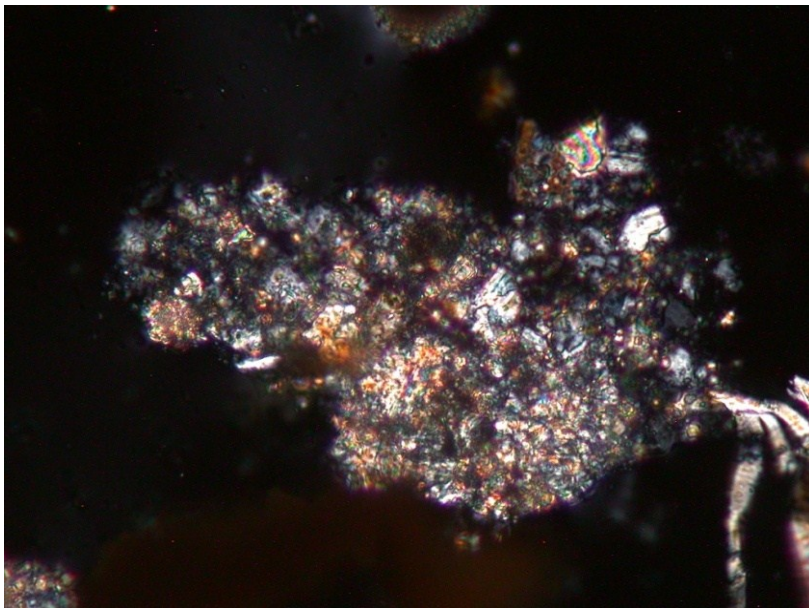


Figure A.58. Calcite minerals in Hamilton specimen HA-63 (XPL, FOV = 0.55 mm).

Table A.25 Summary of minerals in specimen HA - 104

Percent abundance mineralogy of house dust			
Hamilton specimen HA - 104			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		92	22.1
Feldspars		89	21.3
Amphiboles		7	1.7
Carbonate minerals	Calcite	114	27.3
Lithic fragments		102	24.5
Accessory minerals	Chlorite	13	3.1
Total minerals			
		417	100.0
Meltmount		496	
Synthetic materials ¹	Slag, fibres, dirt	107	
Organic components ²	Pollen, spores, cellulose	180	
Total		1200	

1 includes metallic fragments, plastic, carpet or textile fibres, etc...

2 includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen HA – 104

Soot and opaque particles were unusually high in numbers. Magnetite is the common oxide mineral in this house dust. A low number of mineral particles were observed under PLM.

City of Sudbury

The city of Greater Sudbury is located in northeastern Ontario, on the Precambrian Canadian Shield. The larger part of the city is covered by the rocky bedrock, which is exposed at the surface as outcrops.

Carbaceous silt loam lacustrine deposits cover the eastern parts of the city, and noncalcareous very fine sandy outwash or deltaic deposits cover the central parts. The surficial geology is mostly due to the result of the deposited materials during last glaciations (see 2.6.3 Soil, surficial and bedrock geology of Sudbury). The bedrock geology is mostly composed of Precambrian rocks.

Six specimens were studied from the city of Greater Sudbury to characterize the percent abundance mineralogy of house dust.

Table A.26 Summary of minerals in specimen SU - 07

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 07			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		189	27.7
Feldspars		163	23.9
Amphiboles	Ca-rich	52	7.6
Pyroxenes		4	0.6
Carbonate minerals	Calcite	24	3.5
Lithic fragments	Felsic	159	23.3
Micas	Biotite	6	0.9
	Muscovite	7	1.0
Accessory minerals	Chlorite	11	1.6
	Apatite	1	0.1
	Garnet	6	0.9
	Rutile	11	1.6
	Aluminosilicate ³	5	0.7
Sulphide minerals		23	3.4
Undefined minerals		22	3.2
Total minerals			
		683	100.0
Meltmount			
		292	
Synthetic materials ¹	Glass tube ⁴ , fibres, dirt	155	
Organic components ²	Cellulose, pollen, spores,	70	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

⁴ four grains identified as hollow glass tubes

General observations of specimen SU - 07

Minerals mostly dominate this specimen. Pyroxene exists in all investigated homes of Sudbury city.

Mineralogical observations of specimen SU - 07

Pyroxene

Clinopyroxene is the dominant type of pyroxene minerals in specimen SU - 07.

Lithic fragment

Mafic silicate minerals with feldspar grain inclusions were observed in specimen SU - 07.

Table A.27 Summary of minerals in specimen SU - 08

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 08			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		150	22.4
Feldspars		100	14.9
Amphiboles	Ca-rich	16	2.4
Pyroxenes		13	1.9
Carbonate minerals	Calcite	20	3.0
Lithic fragments	Felsic	136	20.3
Micas	Biotite and muscovite	14	2.1
Accessory minerals	Chlorite	173	25.8
	Apatite	5	0.7
	Garnet	6	0.9
	Rutile	1	0.1
Sulphide minerals		16	2.4
Undefined minerals		20	3.0
Total minerals			
		670	100.0
Meltmount			
		400	
Synthetic materials ¹	Fibres, dirt	80	
Organic components ²	Pollen, spores, cellulose	50	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen SU - 08

Unusual high amount of chlorite was observed.

Mineralogical observations of specimen SU - 08

Chlorite

Unusual amount of chlorite was observed in this specimen. Chlorite appeared subhedral, greenish brown, translucent, platy and showed pleochroism under plane polarized light.

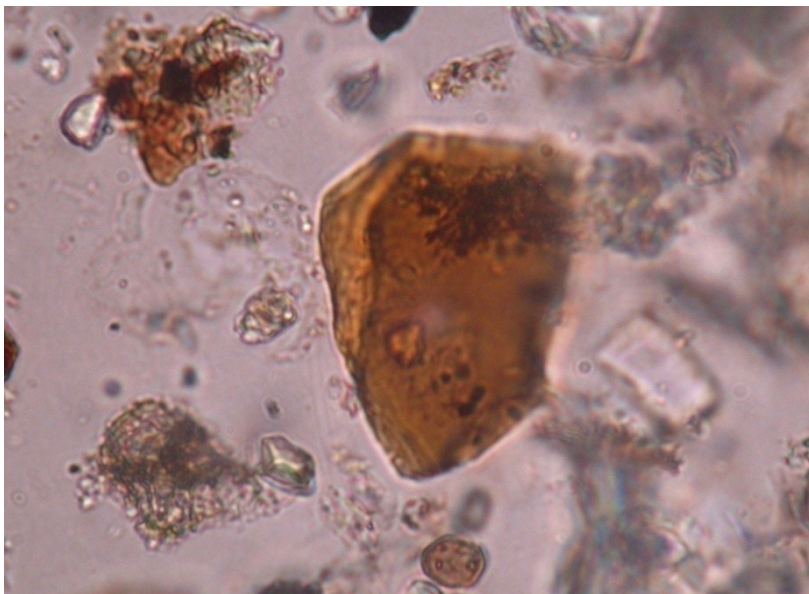


Figure A.59. Photomicrograph of a brownish green chlorite mineral in specimen SU-08 (PPOL, FOV = 0.55 mm).

Table A.28 Summary of minerals in specimen SU - 10

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 10			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		179	33.0
Feldspars		130	24.0
Amphiboles	Ca-rich	36	6.6
Pyroxenes		4	0.7
Carbonate minerals	Calcite	18	3.3
Lithic fragments	Felsic	108	19.9
Micas	Biotite	12	2.2
Accessory minerals	Chlorite	22	4.1
	Apatite	4	0.7
	Garnet	9	1.7
	Rutile	4	0.7
Sulphide minerals		9	1.7
Undefined minerals		7	1.3
Total minerals			
		542	100.0
Meltpoint			
Meltpoint		562	
Synthetic materials ¹	Fibres, dirt	56	
Organic components ²	Skin dander, exclusively	40	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen SU - 10

Chalcopyrite and other sulphide minerals were observed during mineralogical analysis.

Mineralogical observations

Chalcopyrite

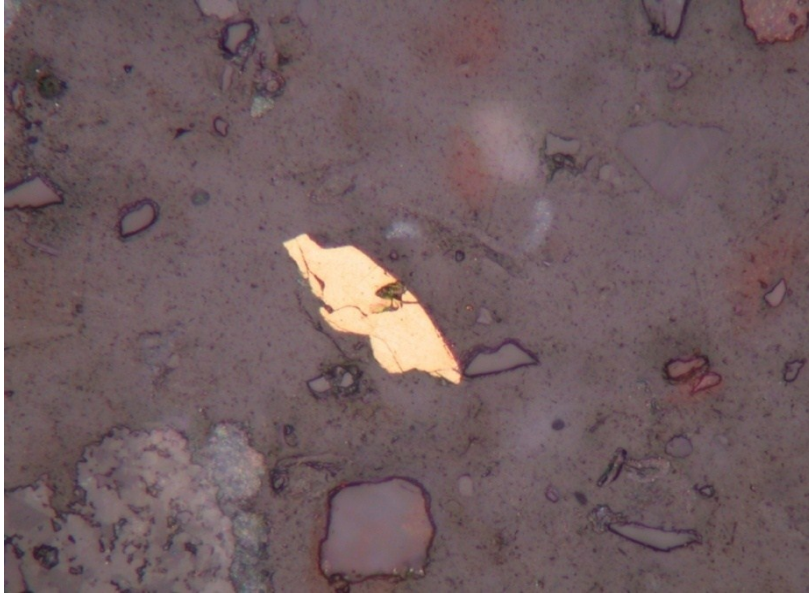


Figure A.60. A brassy yellow chalcopyrite grain with a size fraction of $0.35\ \mu\text{m}$ seen under plane polarized reflected light in specimen SU-10 (PPOL, FOV = 0.55 mm).

Table A.29 Summary of minerals in specimen SU - 25

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 25			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		119	22.0
Feldspars		132	24.4
Amphiboles	Ca-rich	24	4.4
Pyroxenes		11	2.0
Carbonate minerals	Calcite	13	2.4
Lithic fragments	Felsic	132	24.4
Micas	Biotite and muscovite	13	2.4
Accessory minerals	Chlorite	47	8.7
	Apatite	7	1.3
	Garnet	13	2.4
Sulphide minerals		24	4.4
Undefined minerals		7	1.3
Total minerals			
		542	100
Meltmount		498	
Synthetic materials ¹	Fibres, dirt	90	
Organic components ²	Pollen, spores, cellulose	70	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen SU - 25

The mineral assemblages of the lithic fragments indicate that the potential source of these fragments (rock grains) in this specimen of SU-25 is from tracking-in of igneous

rock origin. In this specimen quartz accounts for 18.33% of the minerals; this makes it the lowest quartz content in all the studied Sudbury houses. The occurrence of strain features and fluid inclusions in the quartz grains indicate a metamorphic-igneous origin.

Mineralogical observations of specimen SU - 25

Feldspars with mineral inclusions

Plagioclase feldspars are more common in this thin section. Plagioclase is associated in rock fragment matrix with minerals such as epidote, chlorite, and titanite. Albite in this thin section shows polysynthetic twinning (albite twinning).

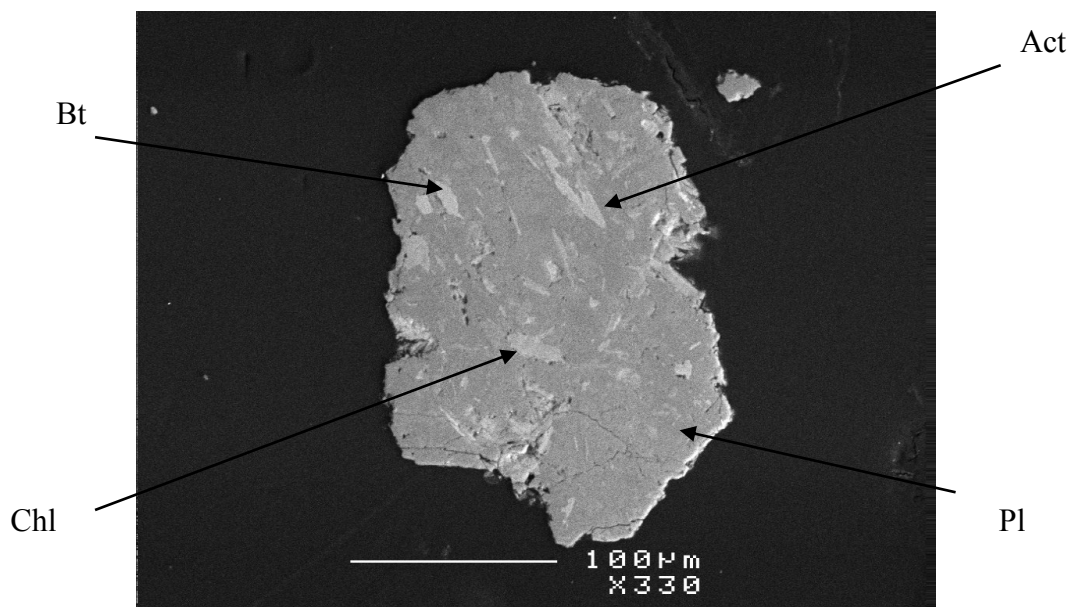


Figure A.61. Plagioclase feldspar grain with several inclusions of mafic silicate minerals: (Act) actinolite, (Bt) biotite, (Chl) chlorite (SEM back-scattered electron image of a feldspar grain in specimen SU-25).

Quartz

Colourless, sub-rounded, conchoidal fracture with fluid inclusions and strain features within the quartz grains are distinct features of quartz that originated from the metamorphic-igneous provenance.



Figure A.62. Photomicrograph of a quartz grain with fluid inclusions in specimen SU-25 (PPOL, FOV = 0.55 mm).

Lithic fragment

In this specimen there are two types of lithic fragments 1) small pieces of rocks fragments consist of quartz, feldspar, epidote, magnetite and few other mafic minerals. 2) Quartz, K-feldspar, albite, chlorite, titanite, with micro porosity as observed under SEM.

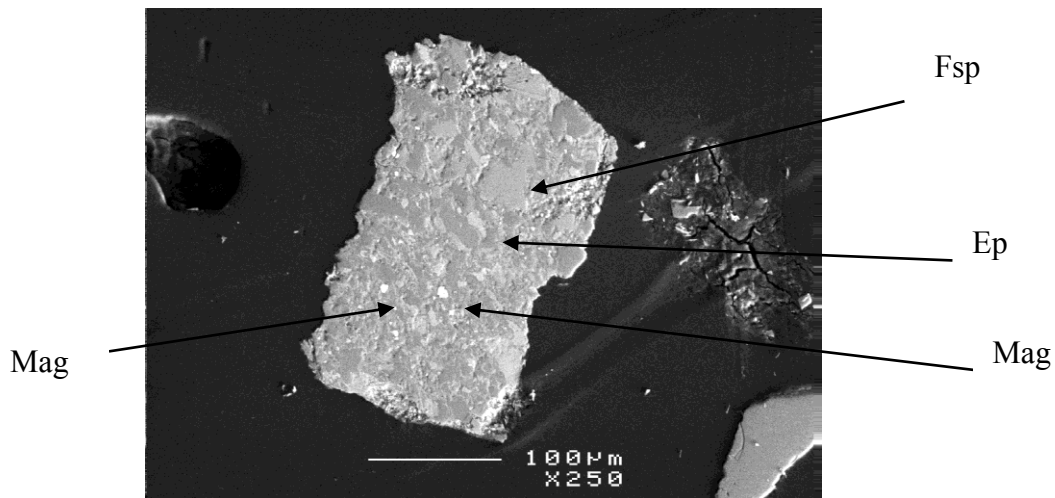


Figure A.63. Lithic fragments with several inclusions of Fsp (Feldspar), Mag (Magnetite), Ep (Epidote) (SEM back-scattered image of rock fragment in specimen SU-25)

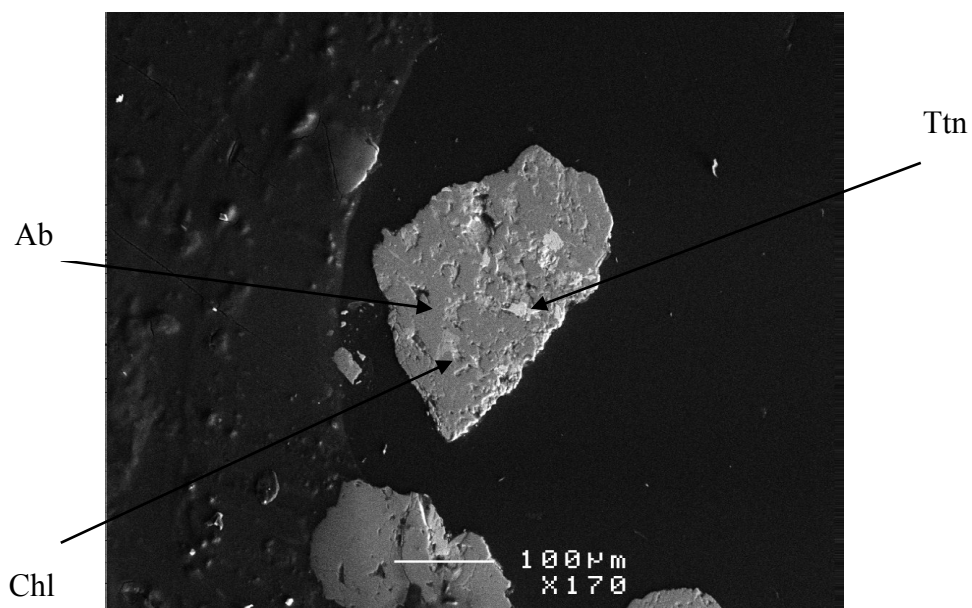


Figure A.64. Lithic fragments with several inclusions of Ttn (Titanite), Chl (Chlorite), Ab (Albite) (SEM back-scattered image of rock fragment in specimen SU-25).

Table A.30 Summary of minerals in specimen SU - 26

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 26			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		213	34.5
Feldspars		158	25.6
Amphiboles	Ca-rich	33	5.3
Pyroxenes		5	0.8
Carbonate minerals	Calcite	27	4.4
Lithic fragments		115	18.6
Micas	Biotite	13	2.1
Accessory minerals	Chlorite	23	3.7
	Apatite	5	0.8
	Garnet	4	0.6
	Rutile	4	0.6
Sulphide minerals		10	1.6
Undefined minerals		8	1.3
Total minerals			
		618	100.0
Meltmount		325	
Synthetic materials ¹		76	
Organic components ²		81	
Total			
		1100	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen SU - 26

Of all the 40 specimens studied, this specimen has the highest content of quartz.

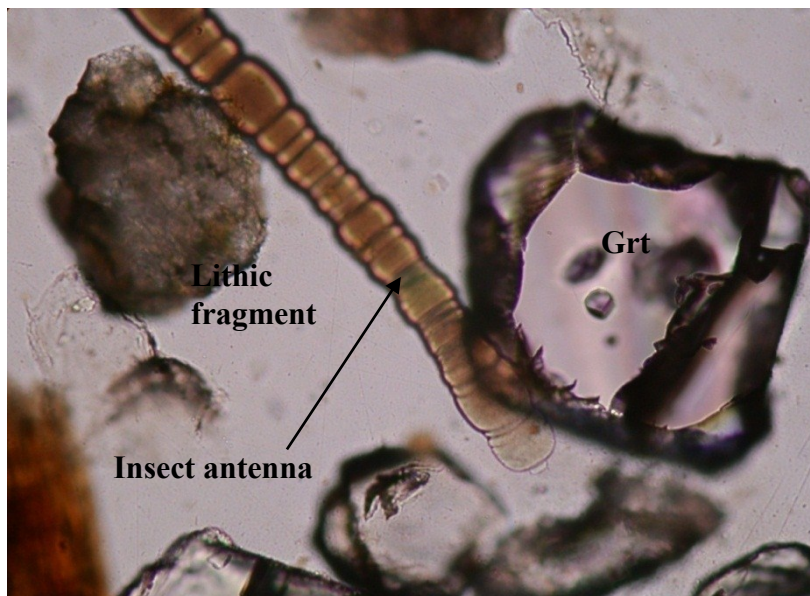


Figure A.65. Lithic fragment, insect antenna, and Grt (Garnet) mineral together in house dust (SU-26) (PPOL, FOV = 0.55 mm).

Mineralogical observations of specimen SU - 26

Quartz

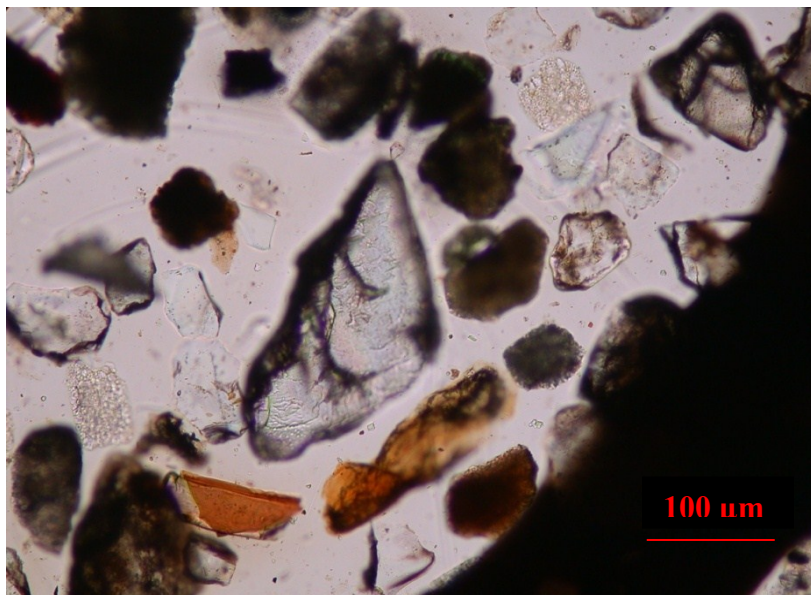


Figure A.66. Photomicrograph of angular quartz grain with a conchoidal fracture observed under plane polarized light, in specimen SU-26.

Table A.31 Summary of minerals in specimen SU - 36

Percent abundance mineralogy of house dust			
Sudbury specimen SU - 36			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		100	26.6
Feldspars		70	18.6
Amphiboles	Ca-rich	27	7.2
Pyroxenes		20	5.3
Carbonate minerals	Calcite	15	4.0
Lithic fragments		54	14.4
Micas	Biotite	30	8.0
Accessory minerals	Chlorite	8	2.1
	Apatite	10	2.7
	Garnet	10	2.7
	Rutile	2	0.5
	Aluminosilicate ³	10	2.7
Sulphide minerals		8	2.1
Undefined minerals		12	3.2
Total minerals			
		376	100.0
Meltmount		400	
Synthetic materials ¹		110	
Organic components ²		114	
Total			
		1000	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observation of specimen SU - 36

Of all the five Sudbury houses investigated this specimen has the highest amount of quartz minerals in its house dust.

City of Thunder Bay

Thunder Bay is located in Northwestern Ontario on the northern shore of Lake Superior. The city is situated on flat terrain in the northern part, and hilly terrain in the southeastern part with an average elevation of 199 meters

Thunder Bay has more than 40 soil types. It lies on the Precambrian Canadian Shield with a very thin soil layer.

The surficial geology comprises glaciofluvial deposits, tills and recent deposits. Volcanic-plutonic and metasedimentary rocks of the Proterozoic and Archean ages dominate the bedrock geology of Thunder Bay (see 2.7.3 Soil, surficial and bedrock geology of Thunder Bay).

Five house dust specimens were analyzed from the city of Thunder Bay to characterize the mineralogical content of house dust.

Table A.32 Summary of minerals in specimen TB - 09

Percent abundance mineralogy of house dust			
Thunder Bay specimen TB - 09			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		88	20.7
Feldspars		64	15.1
Amphiboles		30	7.1
Carbonate minerals	Calcite	65	15.3
Lithic fragments		99	23.3
Micas	Biotite	26	6.1
	Muscovite	4	0.9
Accessory minerals	Chlorite	15	3.5
	Apatite	3	0.7
	Garnet	5	1.2
	Rutile	3	0.7
	Aluminosilicate ³	5	1.2
Sulphide minerals		15	3.5
Undefined minerals		3	0.7
Total minerals			
		425	100.0
Meltmount		380	
Synthetic materials ¹	Fibres, dirt	90	
Organic components ²	Pollen, hair	105	
Total			
		1000	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen TB - 09

This specimen is characterized by numerous of metallic particles.

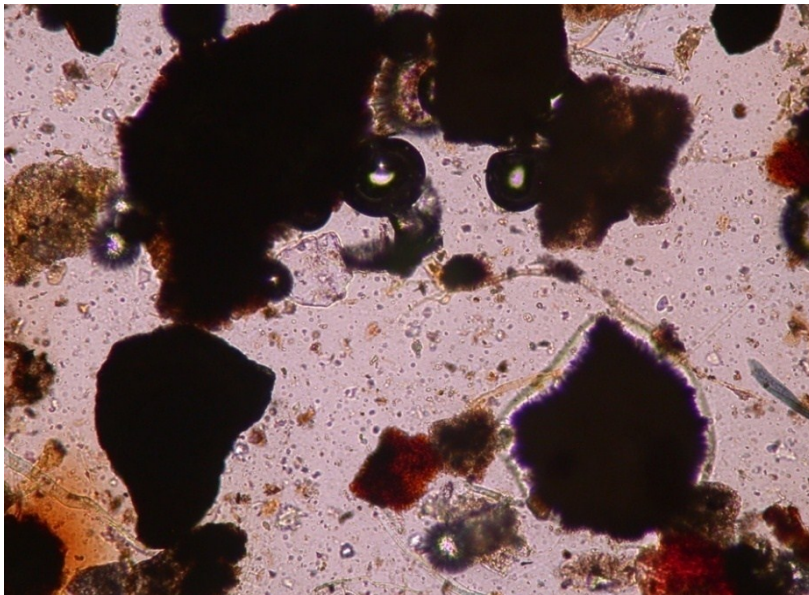
Unidentified metallic particles

Figure A.67. Photomicrograph of metallic particles in specimen TB-09 (PPOL, FOV = 0.55 mm).

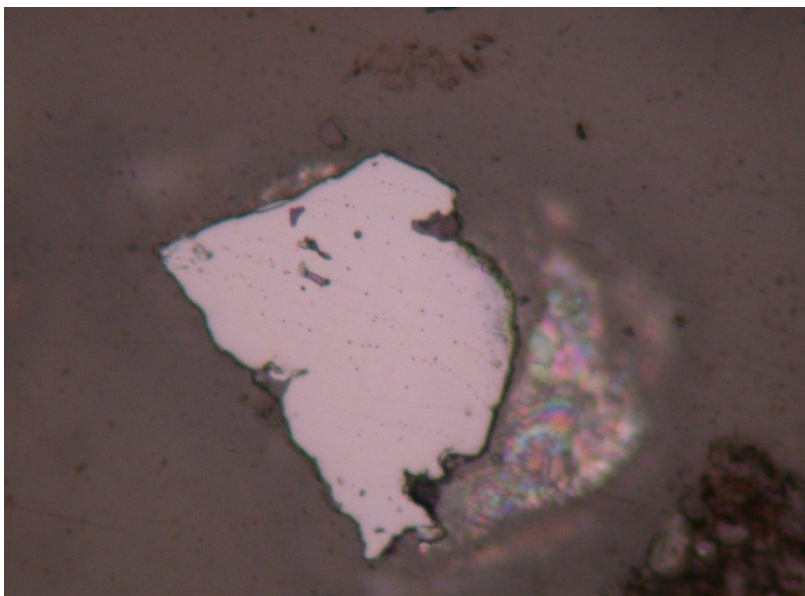
Unidentified metallic particle

Figure A.68. Photomicrograph of unidentified metallic particle under plane polarized reflected light in specimen TB-09 (PPOL, FOV = 0.55 mm).

Table A.33 Summary of minerals in specimen TB - 18

Percent abundance mineralogy of house dust			
Thunder Bay specimen TB - 18			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		108	25.5
Feldspars		69	16.3
Amphiboles		16	3.8
Carbonate minerals	Calcite	13	3.1
Lithic fragments		107	25.2
Micas	Biotite	28	6.6
	Muscovite	3	0.7
Accessory minerals	Chlorite	9	2.1
	Apatite	3	0.7
	Garnet	11	2.6
	Rutile	3	0.7
Sulphide minerals		17	4.0
Undefined minerals		37	8.7
Total minerals			
		424	100.00
Meltmount		572	
Synthetic materials ¹	Fibres, dirt	84	
Organic components ²	Cellulose	120	
Total			
		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

General observations of specimen TB - 18

This specimen is dominated by particles of synthetic materials and thus it has lower contents of feldspar grains and amphibole minerals. This specimen, TB-18, has the least carbonate mineral content of all Thunder Bay specimens.

Mineralogical observations of specimen TB - 18

Feldspar

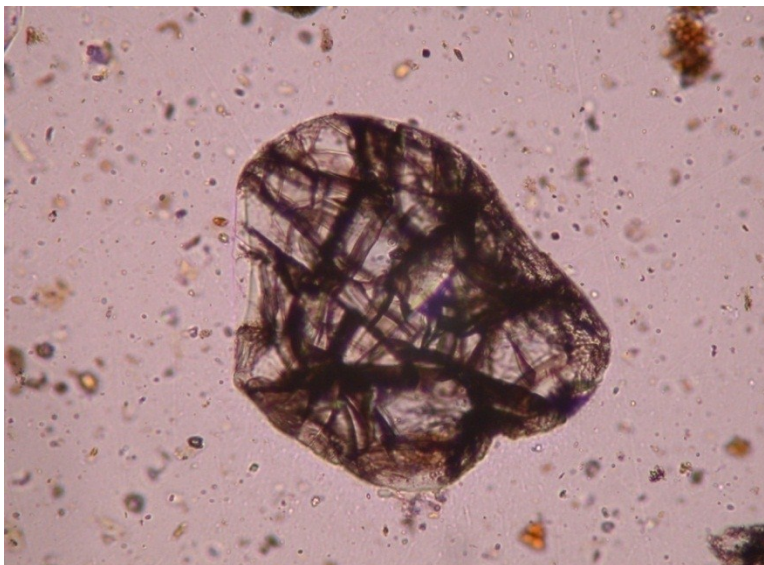


Figure A.69. Photomicrograph of a highly turbid and fractured feldspar grain in specimen TB-18 (PPOL, FOV = 0.55 mm).

Lithic fragments

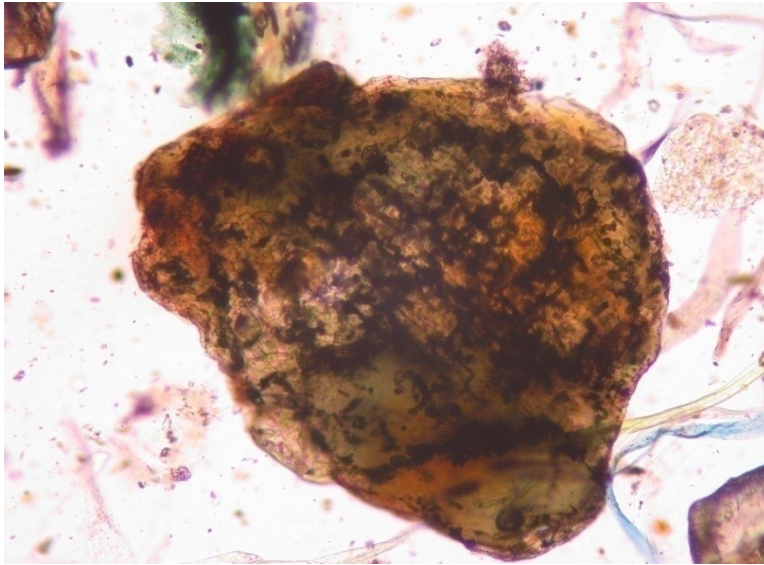


Figure A.70. Photomicrograph of a rounded and greenish brown coloured lithic fragment, consisting mostly of biotite mica and amphibole group minerals in specimen TB-18 (PPOL, FOV = 0.55 mm).

Table A.34 Summary of minerals in specimen TB - 26

Percent abundance mineralogy of house dust			
Thunder Bay specimen TB - 26			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		88	19.6
Feldspars		79	17.6
Amphiboles		36	8.0
Carbonate minerals	Calcite	34	7.6
Lithic fragments		84	18.7
Micas	Biotite	24	5.3
	Muscovite	6	1.3
Accessory minerals	Chlorite	10	2.2
	Apatite	9	2.0
	Garnet	6	1.3
	Rutile	5	1.1
	Aluminosilicate ³	17	3.8
Sulphide minerals		26	5.8
Undefined minerals		26	5.8
<hr/>			
Total minerals		450	100.0
<hr/>			
Meltmount		350	
Synthetic materials ¹	fibres, dirt	100	
Organic components ²	Pollen, hair	100	
<hr/>			
Total		1000	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen TB – 26

This specimen is dominated by non-cotton synthetic fibres. It has the least quartz of all

Thunder Bay samples but the highest aluminosilicate.

Synthetic fibres

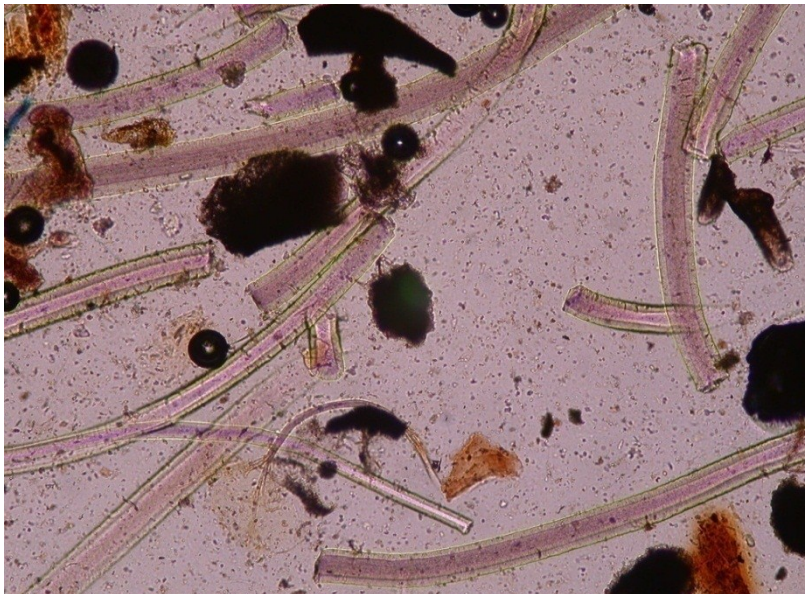


Figure A.71. This specimen TB-26 shows an unusually high number of synthetic fibres, 20 μm wide and more than 1mm long fibres (PPOL, FOV = 1.1 mm).

Table A.35 Summary of minerals in specimen TB - 30

Percent abundance mineralogy of house dust			
Thunder Bay specimen TB - 30			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		94	15.2
Feldspars		153	24.8
Amphiboles		47	7.6
Carbonate minerals	Calcite	58	9.4
Lithic fragments		123	19.9
Micas		28	4.5
Accessory minerals	Chlorite	17	2.8
	Apatite	8	1.3
	Garnet	6	1.0
	Rutile	2	0.3
	Aluminosilicate ³	9	1.5
Sulphide minerals		34	5.5
Undefined minerals		39	6.3
Total minerals		618	100.0
Meltmount		438	
Synthetic materials ¹	Fibres, dirt	44	
Organic components ²		100	
Total		1200	

¹ includes metallic fragments, plastic, carpet or textile fibres, etc...

² includes insect parts, skin dander, pollen, dust mites, etc...

³ undetermined fine-grained aluminosilicate minerals

General observations of specimen TB – 30

This specimen has higher contents of feldspar and amphibole minerals than other Thunder Bay house dust samples. Similarly, it has numerous chlorite grains and also lithic fragments, but few biotite grains.

Table A.36 Summary of minerals in specimen TB - 59

Percent abundance mineralogy of house dust			
Thunder Bay specimen TB - 59			
Mineral or group	Species or type	Point count	Percent abundance mineralogy (normalized to 100%, excluding organic components and synthetic materials)
Quartz		100	24.5
Feldspars		141	34.6
Amphiboles		17	4.2
Carbonate minerals	Calcite	46	11.3
Lithic fragments		38	9.3
Micas	Biotite	14	3.4
Accessory minerals	Chlorite	11	2.7
	Apatite	1	0.2
	Garnet	1	0.2
	Rutile	2	0.5
Sulphide minerals		5	1.2
Undefined minerals		32	7.8
Total minerals			
		408	100.0
Meltmount			
		450	
Synthetic materials ¹	Fibres, dirt	118	
Organic components ²	Cellulose	124	
Total			
		1100	

General observations of specimen TB – 59

Carbonate minerals are mostly from construction materials e.g. cement. Galena and other sulphide minerals were observed. Chlorite is the common accessory mineral in the bedrock geology. Ti/Mn/Fe bearing silicate minerals are common minor minerals in this house dust.

Below, there are five house dust specimens (HA – 14, BA – 22, BU – 40, BU – 44, and BU – 74) that showed no or extremely low amount of mineral particles in their composition of dust.

HA - 14

General observations

The unique feature of this specimen is that it is mostly organic materials. The dust from this home is dominated by human skin flakes. The dust sample may have been collected from upper the bedroom, or the amount of track-in is very small, or the occupants have cleaned the house before sampling took place. To answer why this specimen is different from the other dust samples, the author proposed hypotheses that are described in detail in the discussion section of this thesis (see 5.2 Provenance of mineral grains).

In this specimen (HA-14) there were only 3 quartz particles spotted out of the entire thin section while the average number of quartz in other dust specimens is around 90. Also, it is important to notice that animal hairs were not observed. Plant remains were not common either, as there were only ten cellulose or plant remains observed under microscope. The colour of the dust of this house (HA-14) was whitish. Generally, the dust is full of fluffs.

BA 22

General observations

There were not enough mineralogical components in the specimen to be analysed.

BU 40 and BU 44

General observations

Specimens are full of organic materials. Animal hair is the dominant organic components in BU 40. The odour of the sample for house # BU 40 was unpleasant.

BU 74

General observations

There are not sufficient mineralogical components to document. However, high amount of copper and iron was noted.

Spores and cellulose were the dominant organic materials observed.

Also, a minor amount of Ti bearing mineral was observed.

B. Appendix B

Selected Publications

1.67 The Mineralogical Composition of House Dust

M. Woldemichael, A. Lalonde, and P. Rasmussen. 2009. Health Canada science forum. Ottawa, ON November 16-17. Abstract 1. 67 and poster.

SUMMARY: Despite the increasing demand for information on the quality of our indoor environments, little is known about the physical and chemical composition of ordinary household dust. This study represents the first systematic investigation of the mineralogical composition of indoor dust in Canada.

OBJECTIVES: To identify the composition and abundance of minerals in house dust, and to compare and contrast the mineralogy of house dust from six geographically separate localities in Ontario: two located on the Canadian Shield (Thunder Bay and Sudbury), and four located on Paleozoic sedimentary bedrock (Barrie, Burlington, Cambridge, and Hamilton).

METHODS: The composition of the mineralogical fraction of dust was determined using polarizing light microscopy, X-ray diffraction and scanning electron microscopy. Fifty-four samples of the coarse fraction (80 - 300 μm) of household vacuum dust were subjected to flotation (using water) to separate the organic components (e.g. insect fragments, dander), natural and synthetic materials (e.g. fibers, plastics) from the mineral residue.

RESULTS: The mineral fraction of dust from all six cities was dominated by quartz (17-24%), feldspar (17-20%), calcite (3-11%), and amphibole (4-5%), with various rock fragments and aggregates contributing 15-28%. There was some evidence of the influence of local geology: for example, more sulphide minerals were noted in the Canadian Shield cities compared to the some other cities.

Dust samples from the six cities shared an interesting feature in common. In all localities, the quartz particles were characterized by strain features and fluid inclusions, which indicate a metamorphic-igneous bedrock source. All six cities use sand derived from glacial deposits for ice control in the winter. Thus, tracking in sand is the most plausible mechanism by which quartz was introduced into these homes since sampling was done, in all cases, in the winter season.

IMPACTS/CONCLUSIONS: Glacial deposits dominate the mineral composition of indoor dust in Ontario cities, caused by residents and their pets tracking sand into the house. This indicates that glacial sand distributed on winter roads ends up as a major constituent of house dust.

The mineralogical composition of dust in residential homes from Thunder Bay, Sudbury and Barrie, Ontario

Michael Woldemichael¹, Pat Rasmussen^{1,2}, André E. Lalonde¹

¹ Department of Earth Sciences, University of Ottawa, Ottawa, Ont., Canada K1N 6N5
² Environmental Health Sciences Bureau, Health Canada, Ottawa, Ont., Canada K1N 0K9

Introduction

Currently there is lack of quantitative and representative information on the mineralogical composition of settled dust in residential homes in Canada.

There are very few mineralogical studies of minerals in house dust that are reported in the literature (ref 1). Most published studies focus on metals, semi-volatile, non-volatile, organic components, and pesticides.

A knowledge of the provenance and nature of the minerals in house dust is fundamental to understanding the origin of toxicants, pesticides and allergens present in the dust. Recently, emphasis has been given to house dust studies in part because people in moderate climates spend up to 90% of their time in the indoor environment (ref 2).

This study addresses the lack of data on the mineralogical composition of house dust in Canada. The composition of the mineralogical fraction of dust from homes in three geographically-separate cities in Ontario is determined by optical and electron-microscopy methods.

Objectives

To identify the composition and abundance of the mineralogical fraction of house dust from three Ontario cities and;

To compare and contrast the composition of the mineralogical fraction of house dust from Thunder Bay and Sudbury, two cities located on the Canadian Shield, with Barrie, located in the Phanerozoic sedimentary lowlands.

Materials and Methods

• The house dust samples were provided by Health Canada. All samples were air dried and sieved into fine (<80µm) and coarse (80-300µm).

• Nineteen sub-samples of coarse fraction were subjected to flotation (water) to separate the organic components (e.g. insect fragments, dander), natural and synthetic materials (e.g. fibers, plastics) and mineral residue.

• Number of selected samples from Barrie, Sudbury and Thunder Bay are 8, 6 and 5 respectively

• The inorganic residue was analyzed using polarized light microscopy (PLM), powder X-ray diffraction (XRD) and scanning electron microscopy (ref 3)

• Rigorous and detailed point counting methods were implemented while using PLM technique



Fig. 1 A) Vacuumed house dust sieved into coarse fraction, 80-300µm B) Sample preparation for PLM C) separation process of mineral fraction

Mineral fraction of House Dust

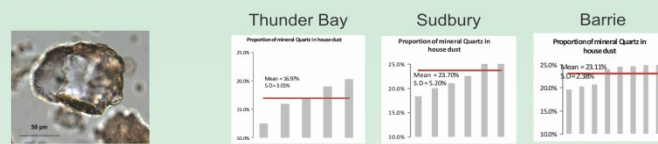


Fig. 2 Quartz in house dust - (photomicrograph with the polarizing microscope, parallel polars) Proportions of quartz in the mineral fraction of house dust. The red line represents the average of all values.

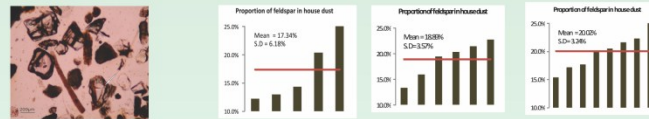


Fig. 3 Feldspar in house dust - (photomicrograph with the polarizing microscope, parallel polars) Proportions of feldspar in the mineral fraction of house dust.

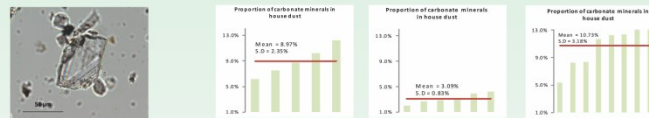


Fig. 4 Calcite in house dust - (photomicrograph with the polarizing microscope, parallel polars) Proportions of carbonate minerals in the mineral fraction of house dust.

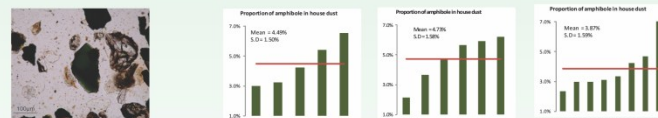


Fig. 5 Amphibole in house dust- (photomicrograph with the polarizing microscope) Proportions of amphibole in the mineral fraction of house dust.

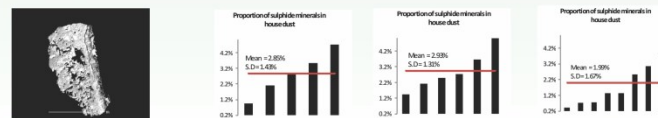


Fig. 6 Sulphide mineral in house dust- (Scanning electron image of a sulphide mineral, backscattered electron) Proportions of sulphide minerals in the mineral fraction of house dust.

Discussion

• The composition of the mineralogical fraction of house dust in the three localities studied is remarkably similar despite the great geographic distance between these localities and the variable age and nature of the bedrock geology. Major mineral components in all cities are quartz, feldspar, calcite, amphibole, and lithic fragments.

• The occurrence of strain features and fluid inclusions indicates that the quartz in dust from all three cities is ultimately of metamorphic-igneous provenance. All three cities use glacial sand derived from the Canadian Shield as an abrasive in the winter. This is the most plausible mechanism by which quartz was introduced into the homes since sampling was done, in all cases, in the winter season.

• In Thunder Bay, the relatively low quartz and low feldspar contents along with relatively high sulphide content may reflect the underlying black shale bedrock or (lacustrine clay).

• In Sudbury, the low content of carbonate minerals and the higher amphibole and sulphide contents may reflect the nature of the underlying Precambrian bedrock that is composed of mafic rocks with high abundances of sulphide-rich ore.

• In Barrie, the high proportion of carbonate minerals and the low amphibole content are consistent with the underlying Paleozoic sedimentary bedrock, which is composed primarily of limestone.

• We conclude that the nature of the surficial deposits in the sampled localities exerts a greater control on the composition of the dust than the nature of the underlying bedrock. In all cities, glacial sand derived from the metamorphic and igneous Canadian Shield appears to have been the principal source of the minerals.

References

1. Rasmussen, P. E. (2004). Can J Analytical science and spectroscopy 49 (23), pp. 166-174.
2. Health Canada, Environment and Workplace Health, <http://www.hc-sc.gc.ca/ewh-semt/air/r/poll/index-eng.php>
3. Melhave et al. (2000). Atmospheric Environment 34 (52), pp. 4767-4779

Acknowledgments

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073 The Mineralogical Composition of House Dust in Ontario, Canada

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THE MINERALOGICAL COMPOSITION OF HOUSE DUST IN ONTARIO, CANADA

Michael Woldemichael¹, André E. Lalonde¹, Pat Rasmussen^{1,2}

¹ Department of Earth Sciences, University of Ottawa, Ottawa, Ont., Canada K1N 6N5

² Environmental Health Sciences and Research Bureau, Health Canada, Ottawa, Ont., Canada K1N 0K9



Woldemichael¹, Lalonde¹, Rasmussen^{1,2}



Objectives + study area

Previous work on toxic metals in house dust by Rasmussen (2001), Molhave (1999)

Could the source of these metals be outdoor sources?

Objectives

- To determine the composition and provenance of the mineralogical fraction in the of house dust of six Ontario cities and,
- To compare and contrast the composition of the mineralogical fraction of house dust in cities located in the metamorphic-plutonic Precambrian Canadian Shield, with that of cities located in the sedimentary Paleozoic Lowlands of the Province of Ontario.



Sample preparation

- Vacuumed dust samples were provided by Health Canada
- Coarse size fraction (80-300 μ m)
- Coarse fraction was subjected to flotation
- **More than 60 wt% of the house dust is mineralogical or inorganic material**



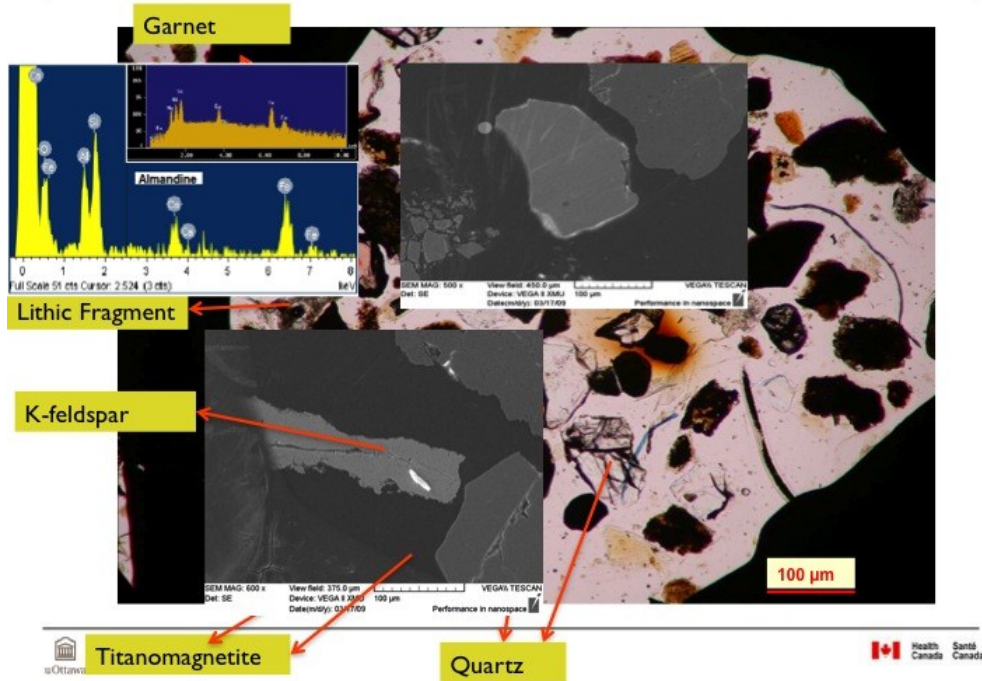
Representative example of (80 – 300 μ m) vacuumed house dust.



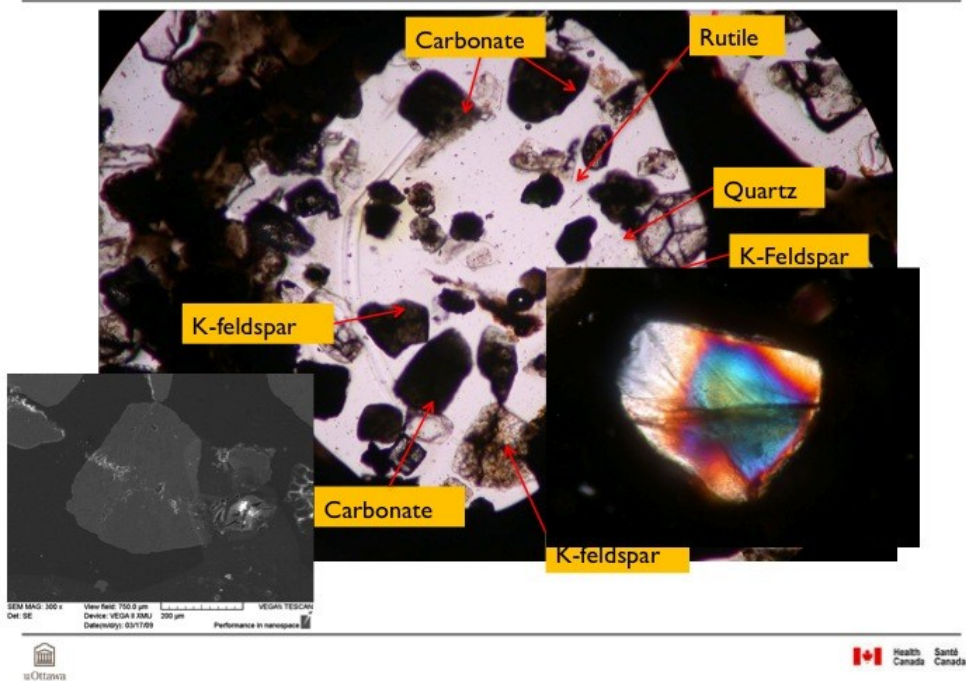
House dust specimen preparation for XRD analysis



Characterization of house dust – Sudbury (Precambrian Shield)

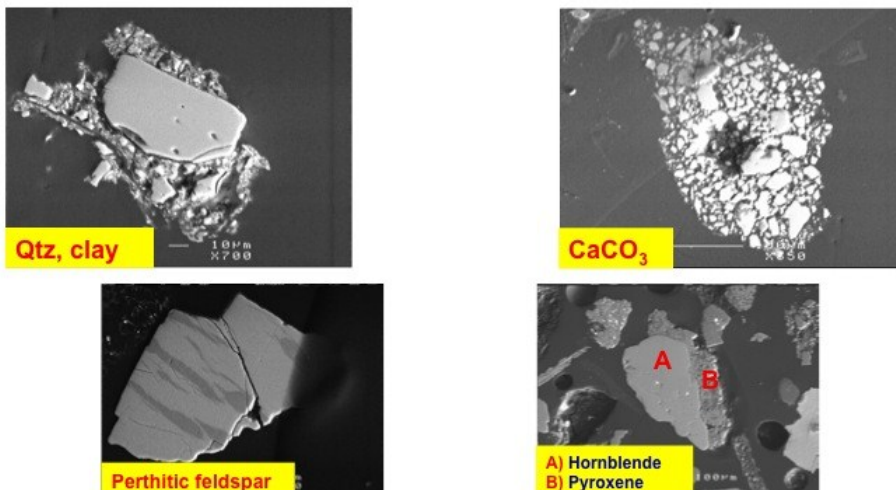


Characterization of house dust – Cambridge (Paleozoic Lowlands)



Results

Major mineralogical components in all cities, regardless of their geological location, are: quartz, feldspar, calcite, lithic fragments and amphibole



Results

The composition of the mineralogical fraction in Ontario house dust is remarkably similar despite the contrasting nature of bedrock geology

Mineral component	Sites in Precambrian Shield (n = 15)	Sites in Palaeozoic Lowlands (n = 31)
Quartz	22%	21%
Feldspar	20%	20%
Rock fragments	16%	14%
Carbonates	5%	10%
Amphibole	4%	5%

- Dust in all the sampled houses, regardless of their location, consist of quartz, feldspar and carbonate minerals.
- Synthetic and non-mineralogical fragments such as dirt, slag, plastics, paper, make up on average, 22% of the dust.

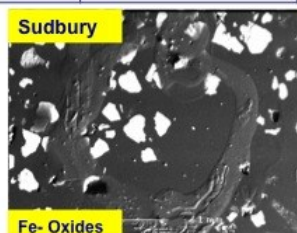
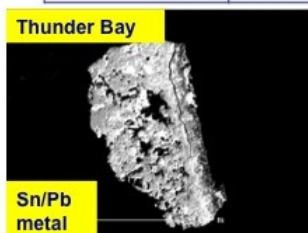


Conclusions

In general, the bedrock geology exerts limit control on the mineralogical composition of the house dust

Sulphide and carbonate mineral contents do suggest a minor bedrock contribution in Sudbury, Thunder Bay and Barrie specimens

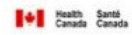
Minerals (mean)	Sudbury	Thunder Bay	Barrie
Sulphide minerals	3%	3%	1%
Carbonate minerals	3%	9%	12%



Conclusions

- The occurrence of strain features and fluid inclusions indicate that quartz in the house dust from all six cities is ultimately of metamorphic-igneous provenance.
- In all cities, glacial sand derived from the metamorphic and igneous Canadian Shield appears to have been the principal source of the minerals in the house dust.
- The nature of the surficial deposits in the cities that were studied exerts a far greater control on the composition of the dust than the nature of the underlying bedrock.

Thank you!



Thank you!

