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AN ATLAS OF ANTHROPOGENIC PARTICLES FROM LAKE ERIE SEDIMENTS

by

C.I. Dell and W.G. Booth

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INTRODUCTION

Several types of anthropogenic particles are present in the sand-size fraction of Lake Erie surface sediments. The distribution, composition, origin and environmental significance of the four most abundant types have been discussed in a paper by Dell & Booth (1977)[1].

This present report provides information on the four most abundant types plus ten additional common ones. Semi-quantitative evaluation of abundance was determined for the 0.25-2.00 mm fraction of 135 surface sediment samples using a low power stereoscopic microscope. Representative grains were picked by hand for examination with a Cambridge stereoscan scanning electron microscope fitted with an energy dispersive X-ray detector system (analysis carried out by contract to Electron Optical Laboratory, Department of Applied Physics, Ontario Research Foundation). Counts for X-ray spectra peaks are given in the following pages, although this data should be regarded as only qualitative. Moreover, surface roughness had a significant effect on counting efficiency, making any comparison of peak counts between samples of uncertain value. More detailed chemical data are given for several of the particle types. These quantitative analyses were carried out by use of an AEI SEM2A microprobe analyser (contract to Electron Optical Laboratory, Ontario Research Foundation), a Philips PW 1220 C semi-automatic X-ray fluorescence spectrometer, a Varian AA-5 atomic absorption spectrophotometer and a Leco carbon analyser. Standard samples of each of these anthropogenic types are on file at the Canada Centre for Inland Waters.

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[1] Dell, C.I. and Booth, W.G., 1977. Anthropogenic particles in the sediments of Lake Erie. Submitted for publication to Journal of Great Lakes Research.

TYPE 1 PARTICLE

Description: Black; semi-metallic lustre; vesicular structure; very irregular shape.

CHEMICAL DATA

SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Fe
1	38	211	50	-	23	44	58
2	109	481	20	-	40	43	231
3	80	304	2	-	12	36	76
4	182	621	30	-	75	19	161
5	126	356	60	-	11	41	133

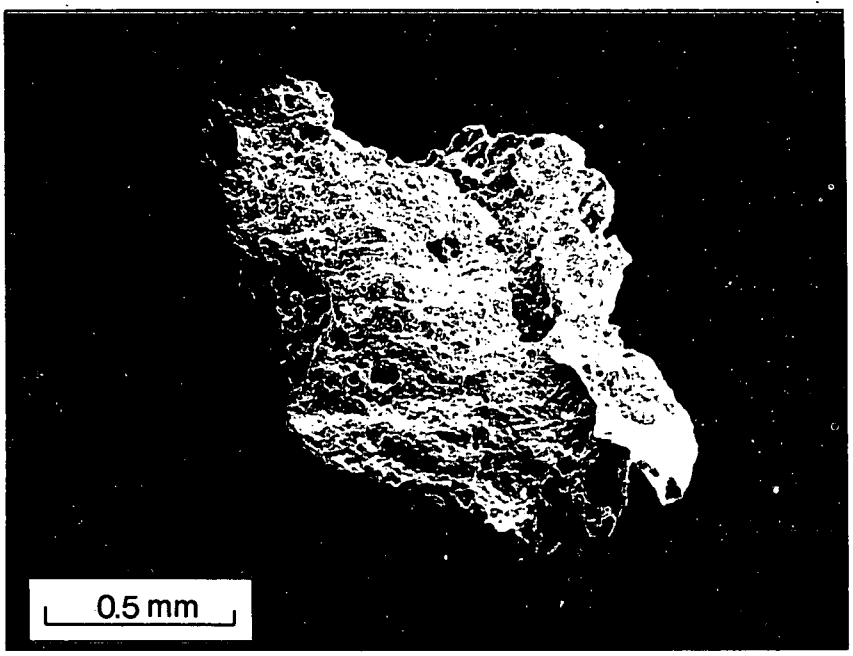
AA analysis (ppm): Cu 150, Zn 51.4, Ni 13.5, Co 4.3, Cd .44, Pb 6.8, Cr 4.3.

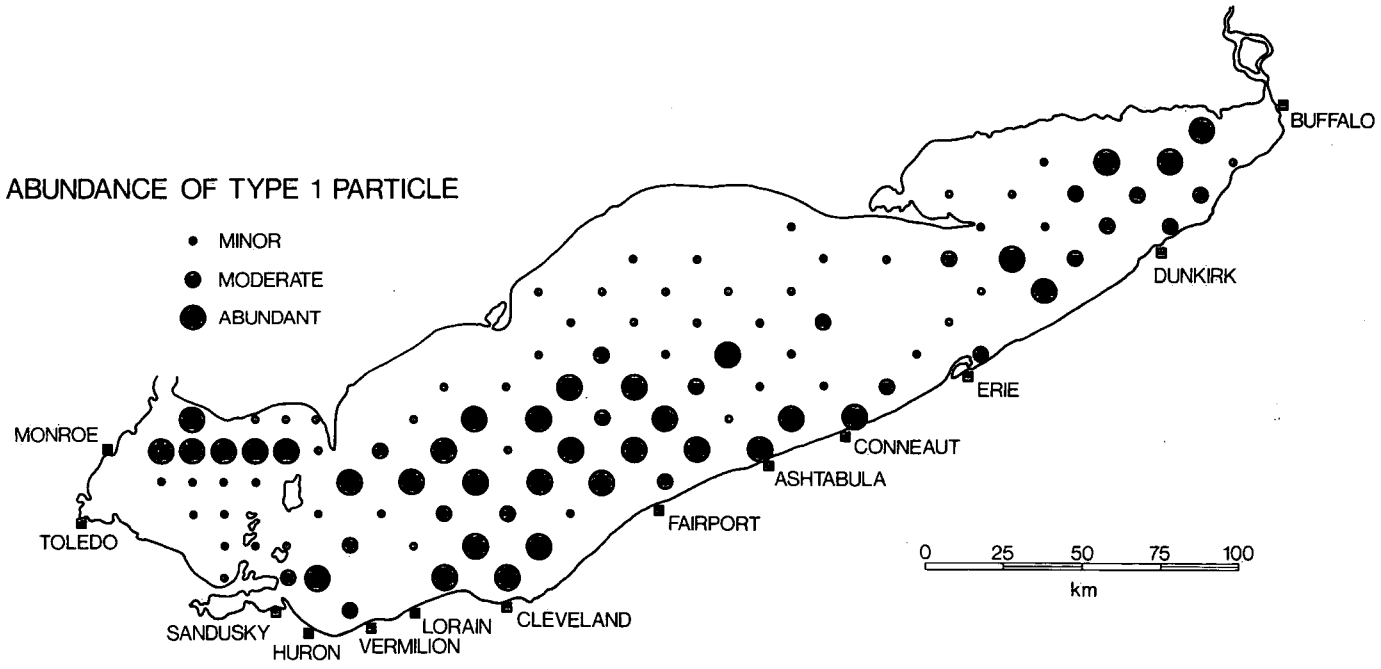
Carbon (Leco) analysis (%): Total carbon - 92.6.

Microprobe analysis (%): C 60, Si 4, Al 16, Fe 10, Ti <1, + oxygen.

Remarks: These particles are the most common type of anthropogenic particle in Lake Erie sediments, and are believed to be coked fuel derived from coal-burning ships.

SEM PHOTOGRAPH OF TYPE 1 PARTICLE





DISTRIBUTION OF TYPE 1 PARTICLES

TYPE 2 PARTICLE

Description: Black; semi-metallic lustre; columnar structure; commonly elongated in shape.

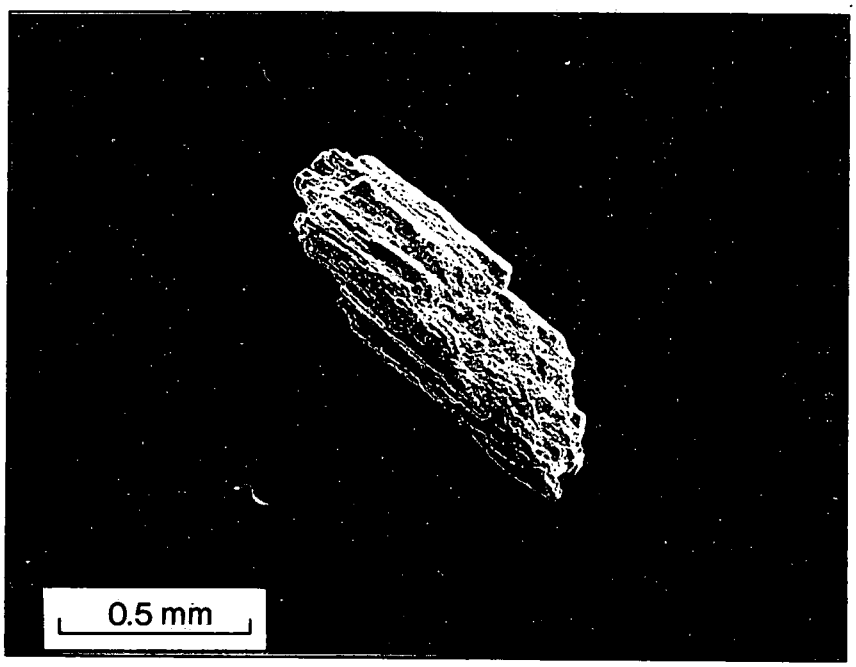
CHEMICAL DATA

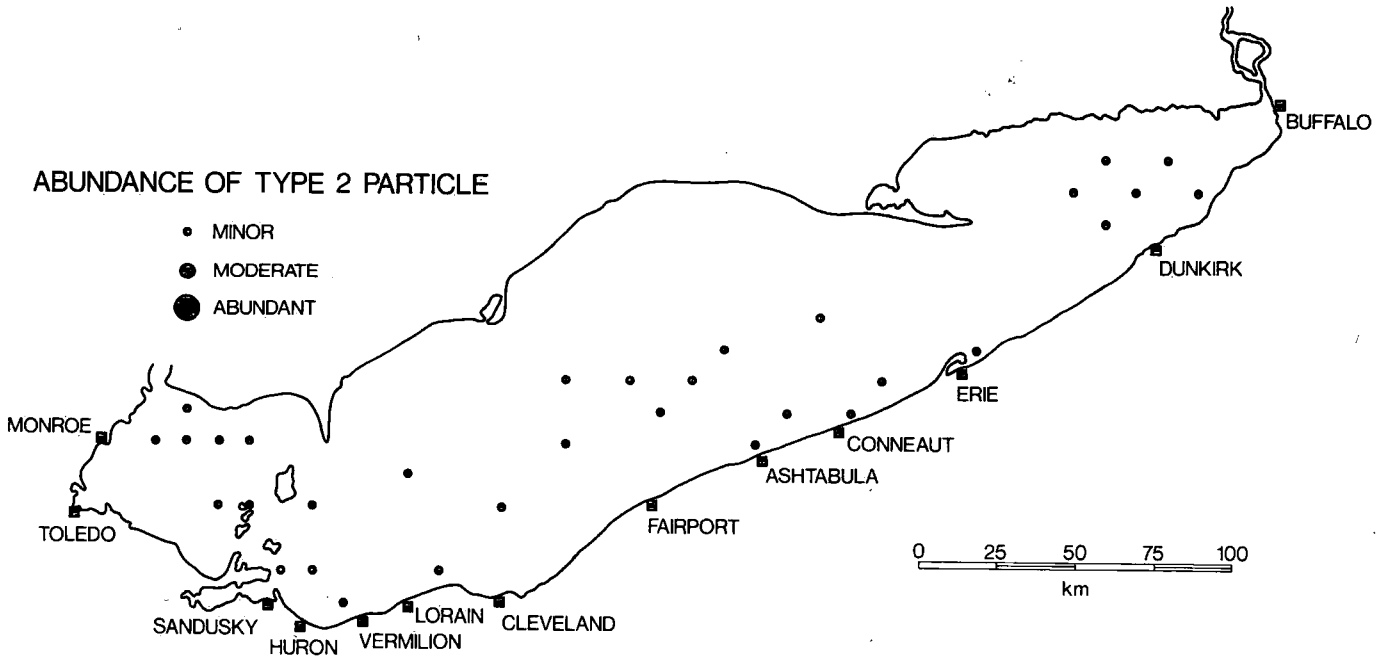
SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Fe
1	69	167	393	-	38	9	270
2	23	18	45	-	0	15	28
3	267	110	66	-	33	22	105
4	68	149	12	-	4	31	184
5	40	177	25	34	55	19	120

Remarks: Particles similar to this type, but with a pronounced cellular structure, commonly occur in Lake Erie sediments, even in samples where no other anthropogenic types occur. They are thought to be ash from burnt vegetation. Type 2 particles may be derived from coal combustion.

SEM PHOTOGRAPH OF TYPE 2 PARTICLE





DISTRIBUTION OF TYPE 2 PARTICLES

TYPE 3 PARTICLE

Description: Somewhat similar to Type 1 in appearance; but gray in colour; bright metallic lustre; very irregular shape; vesicular structure.

CHEMICAL DATA

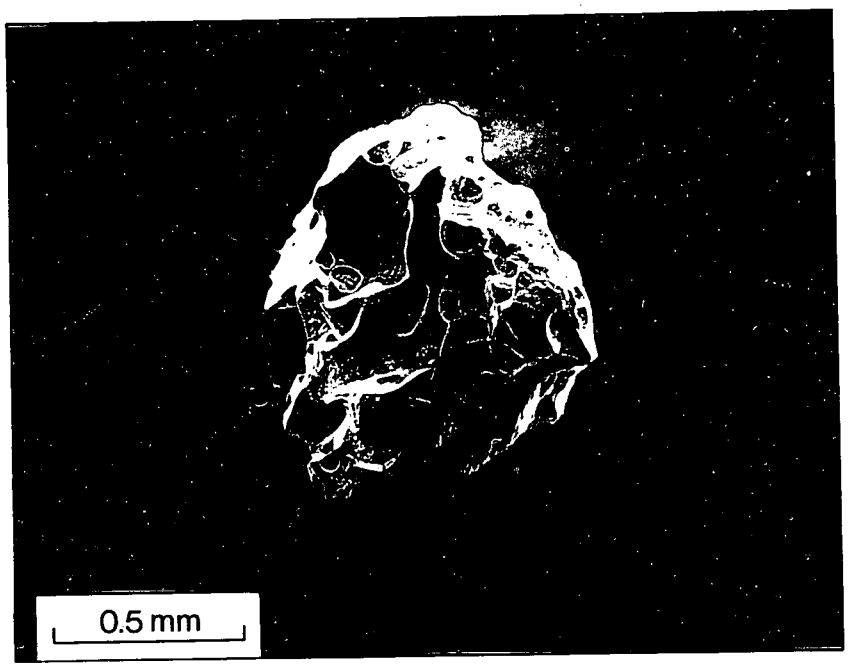
SEM/EDS counts on 5 grains

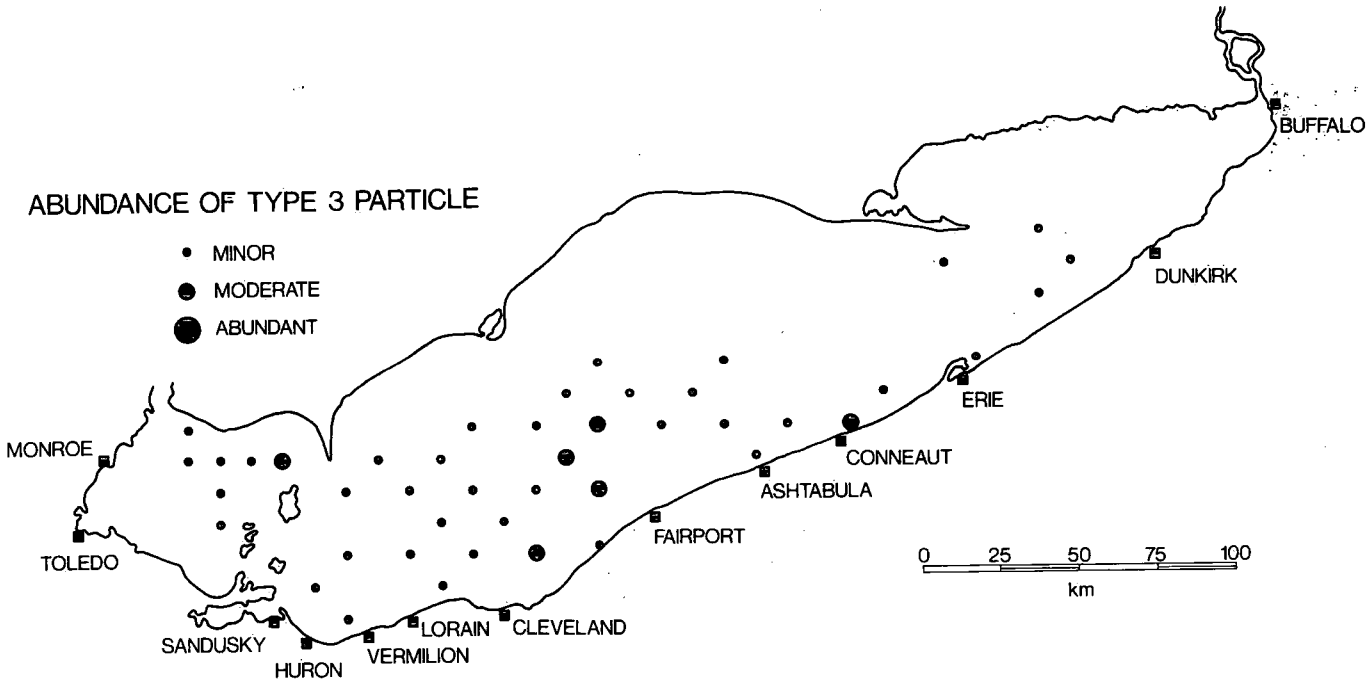
#	Al	Si	S	Cl	K	Ca	Fe
1	43	272	225	4	31	46	193
2	67	169	40	8	11	15	73
3	40	135	39	-	23	30	80
4	27	93	32	-	10	15	49
5	58	340	71	4	46	23	114

Microprobe analysis (%)

C >50, S < 2, Al, Si <1.

SEM PHOTOGRAPH OF TYPE 3 PARTICLE





DISTRIBUTION OF TYPE 3 PARTICLES

TYPE 4 PARTICLE

Description: Black, semi-metallic lustre; irregular or blocky shape; conchoidal fracture.

CHEMICAL DATA

SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Fe
1	89	215	104	4	42	56	86
2	55	93	234	9	10	43	39
3	35	1	17	-	3	8	52
4	1	9	115	1	3	35	17
5	12	36	124	3	17	65	97

AA analysis (ppm): Cu 59.9, Zn 19.2, Ni 7.7, Co 0, Cd 1.3, Pb 4.2, Cr 4.1.

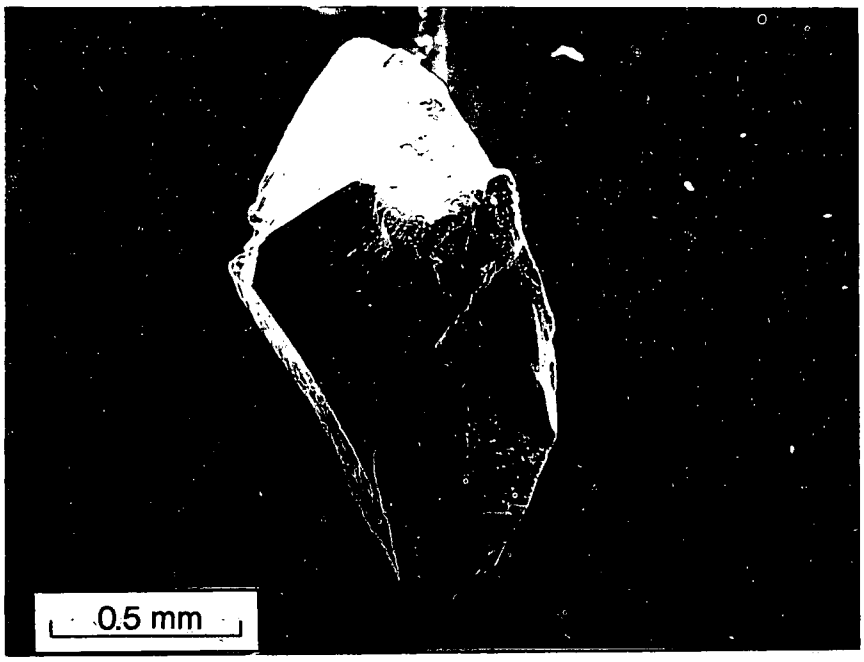
Carbon (Leco) analysis (%): Total carbon - 75.1.

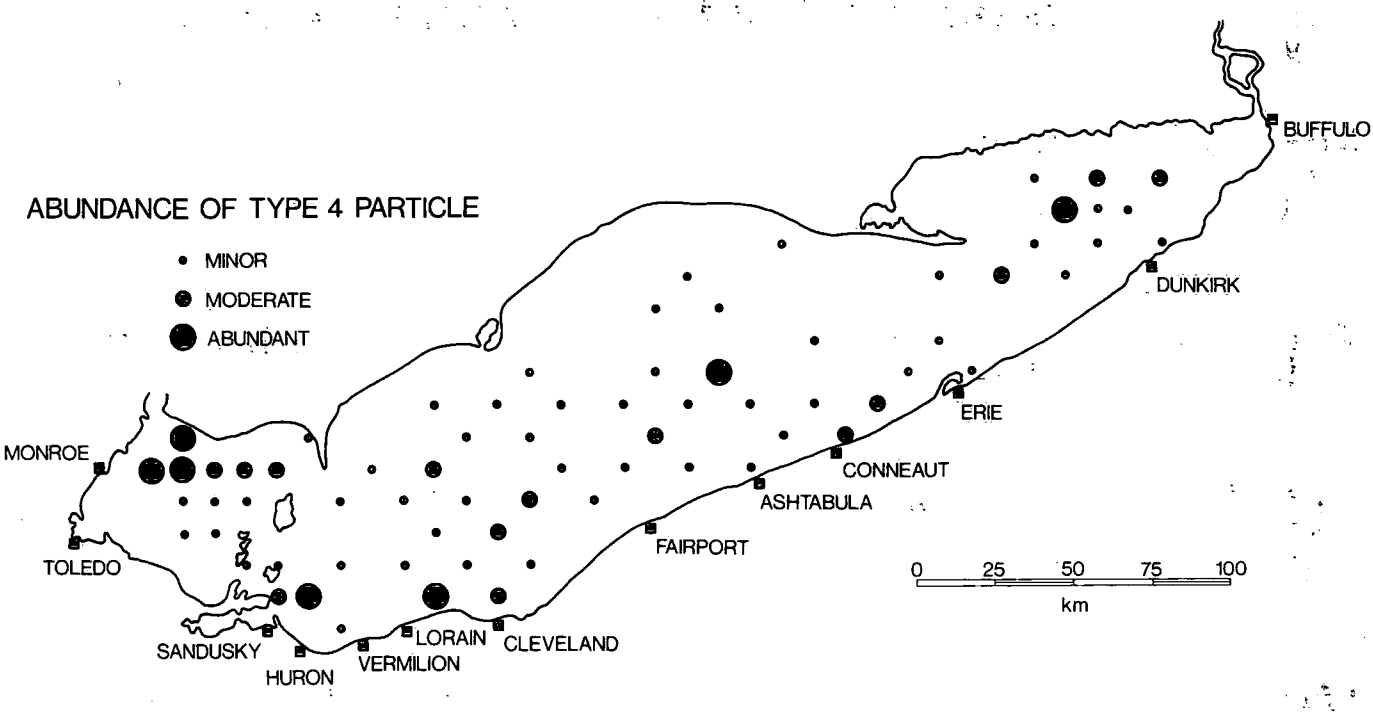
XRF analysis (%): Ti .08, Mg .22, Ca .71, K .10, Na 0, S 4.08, Fe 1.67, P .02, Mn .37, Si 0, Al 2.29.

Microprobe analysis (%): C >50%, Al, Si, Fe < 1%, oxygen present.

Remarks: These particles are very commonly found in Lake Erie sediments. Their appearance and chemical composition indicate that they are coal derived from coal-burning or coal-carrying ships.

SEM PHOTOGRAPH OF TYPE 4 PARTICLE





DISTRIBUTION OF TYPE 4 PARTICLES

TYPE 5 PARTICLE

Description: Occurs in a range of colours from white and yellowish to drak brown and black, but is most commonly reddish-brown; glassy to semi-metallic lustre; occurs in globular aggregates or single globules; commonly vesicular; very irregular shape; very dark grains may be magnetic.

CHEMICAL DATA

SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Fe
1	670	1,225	1	12	114	142	357
2	196	2,101	-	-	121	405	280
3	311	319	36	18	8	82	1,354
4	211	113	65	3	13	46	2,010
5	1,058	701	35	19	106	25	177

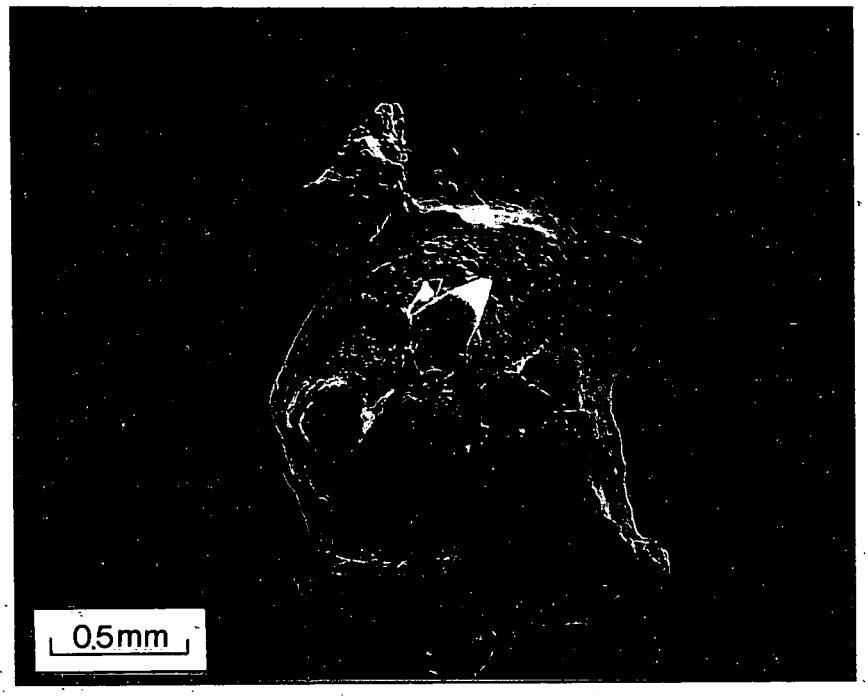
AA analysis (ppm): Cu 35.4, Zn 7.7, Ni 55.2, Co 16.3, Cd .52, Pb 2.4, Cr 7.9.

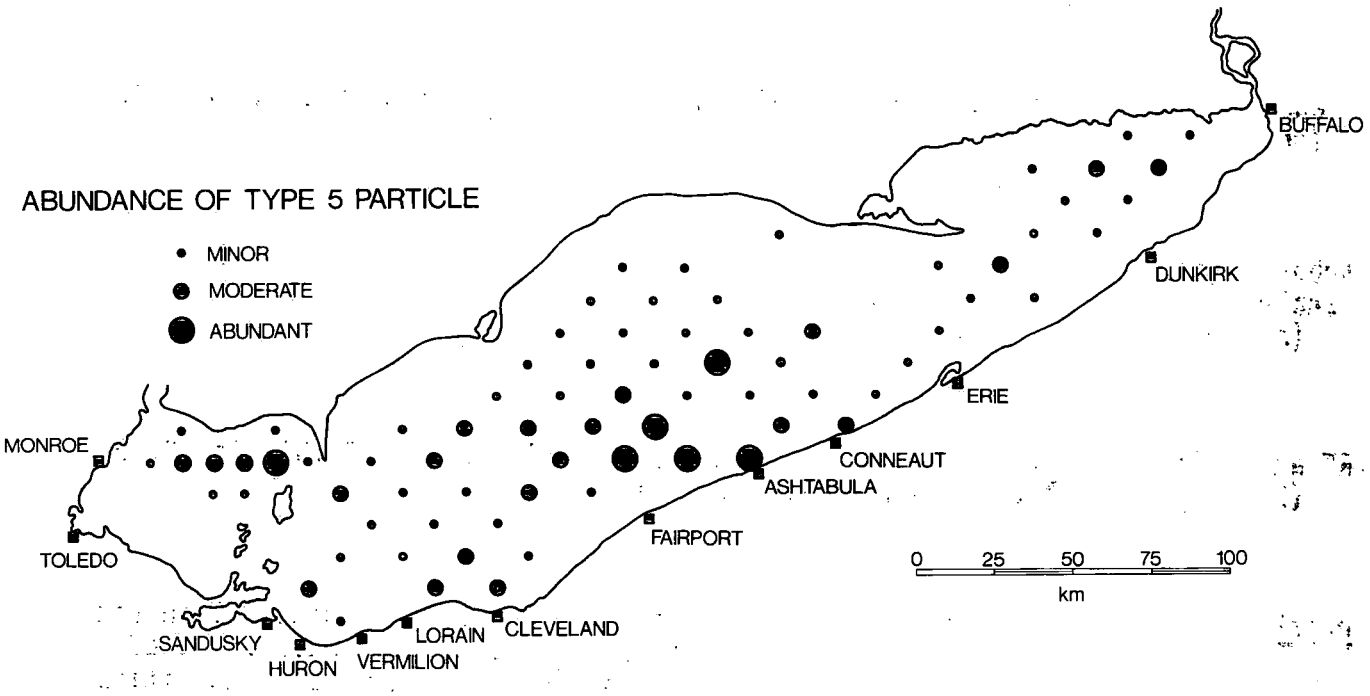
Carbon (Leco) analysis (%): Total carbon .145.

XRF analysis (%): Ti 1.23, Mg 2.53, Ca 2.23, K 1.61, Na .98, S .01, Fe 13.19, P .20, Mn .03, Si 49.47, Al 20.26.

Remarks: This is a very common type of anthropogenic material in Lake Erie sediments. It is probably fused and partially fused ash derived from coal combustion. Its chemical composition is similar to that of common crustal rocks, particularly shale, suggesting that it is derived from "inorganic" impurities in coal. The magnetic particles may be the result of the high temperature transformation of pyrite.

SEM PHOTOGRAPH OF TYPE 5 PARTICLE





DISTRIBUTION OF TYPE 5 PARTICLES

TYPE 6 PARTICLE

Description: Pale brown; glassy lustre; very vesicular; very irregular shape; somewhat massive grains may show conchoidal fracture.

CHEMICAL DATA

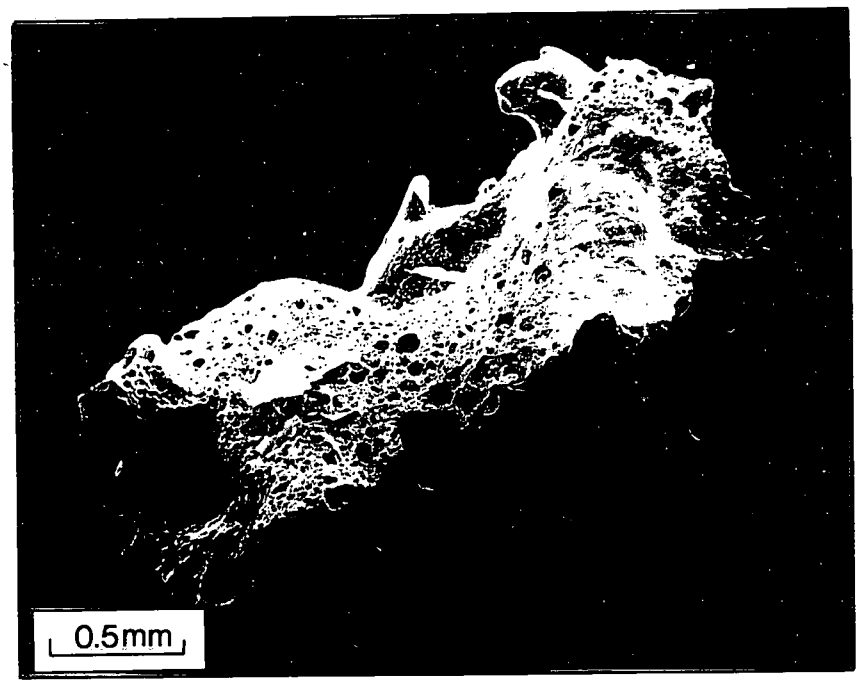
SEM/EDS counts on 4 grains

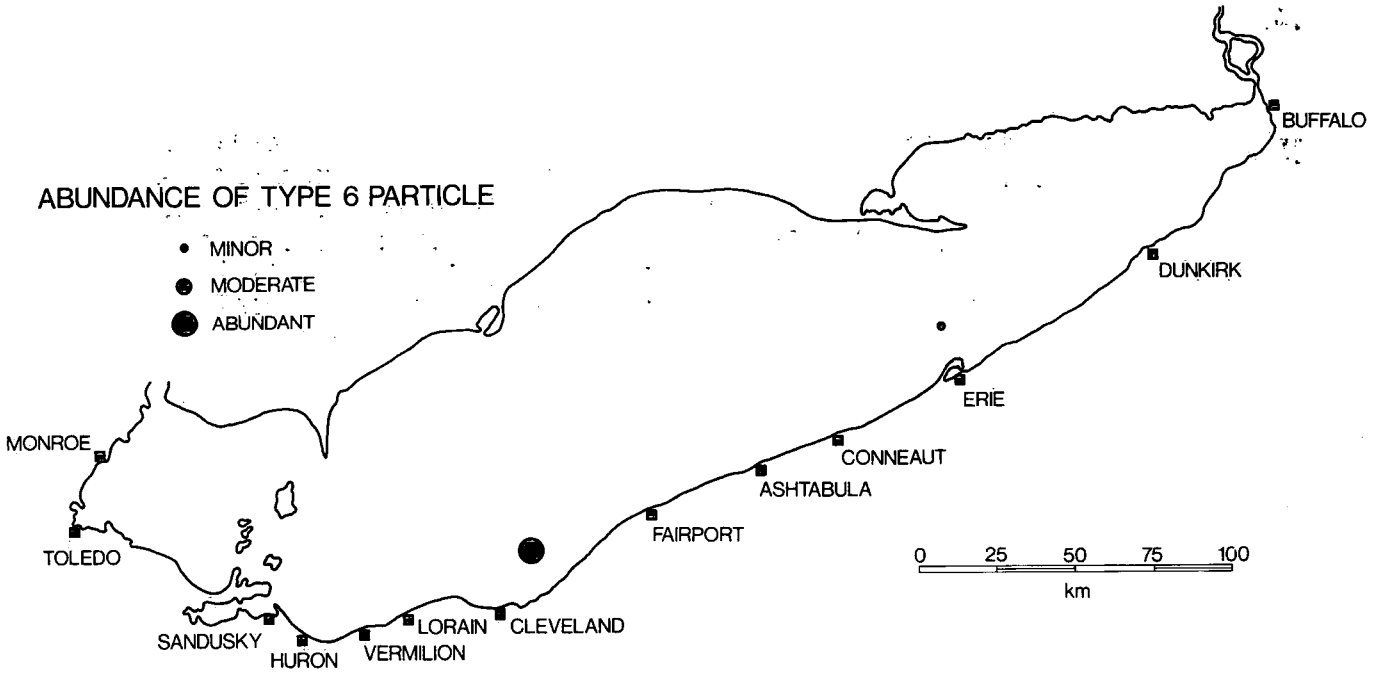
#	Al	Si	S	Cl	K	Ca	Fe
1	108	784	18	-	26	1,071	282
2	207	1,241	38	-	68	1,704	277
3	184	969	105	29	41	2,222	91
4	167	842	27	38	32	1,410	80

Microprobe analysis (%): C 5, Fe 5, Al 20, S 3, Ca 25, oxygen present.

Remarks: This particle is very abundant at one location along the south shore of Lake Erie but is absent over the remainder of the lake except for one grain found at a location much further east. The proximity of the first location to an offshore dumping ground suggests that these particles may be derived from an industrial source on shore, possibly in the Cleveland area.

SEM PHOTOGRAPH OF TYPE 6 PARTICLE





DISTRIBUTION OF TYPE 6 PARTICLES

TYPE 7 PARTICLE

Description: Very dark gray to black; semi-metallic lustre; massive or somewhat granular structure; irregular shape.

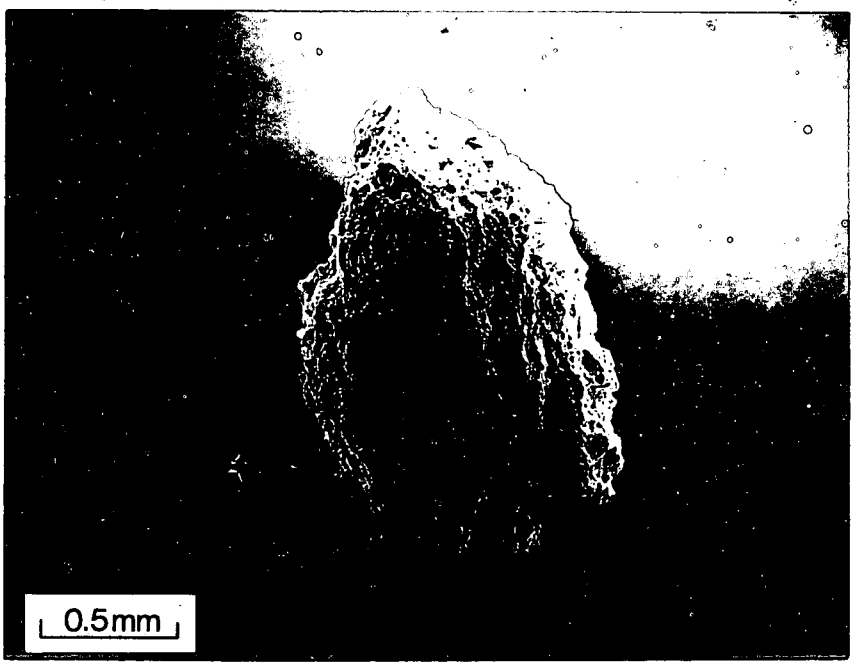
CHEMICAL DATA

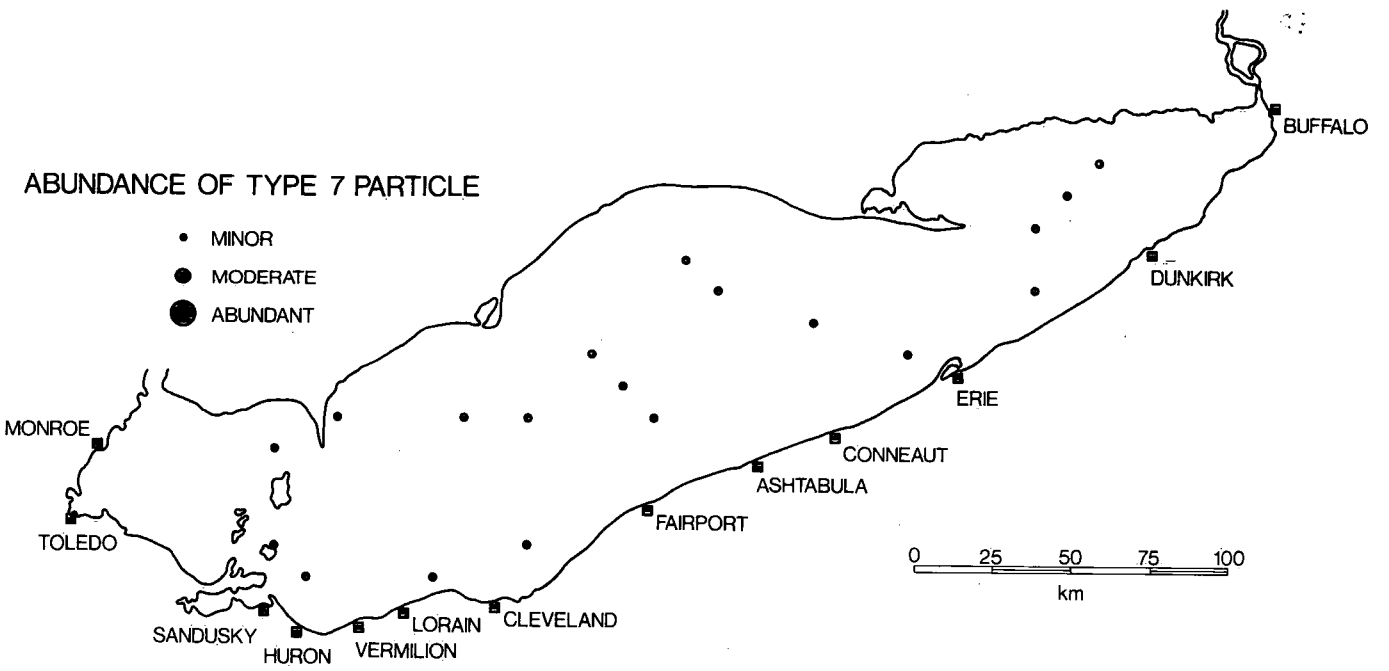
SEM/EDS counts on 4 grains

#	Al	Si	S	Cl	K	Ca	Fe
1	103	247	170	5	19	5	68
2	86	288	18	5	44	35	799
3	104	680	75	9	56	115	296
4	121	244	32	10	20	38	100
5	366	913	11	12	87	6	121

Microprobe analysis (%): C 10, Fe 6, Si 20, Al 50, oxygen present.

SEM PHOTOGRAPH OF TYPE 7 PARTICLE





DISTRIBUTION OF TYPE 7 PARTICLES

TYPE 8 PARTICLE

Description: Black; semi-metallic to irridescent lustre; globular or irregular shape; very delicate thin-walled structure; vesicular; grains generally less than 0.5 mm.

CHEMICAL DATA

SEM/EDS counts on 5 grains

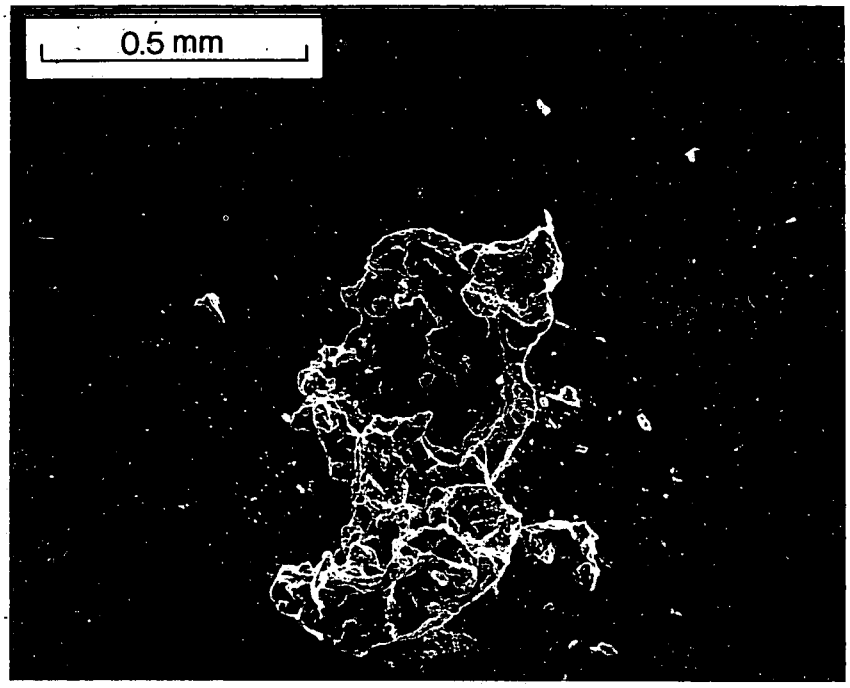
#	Al	Si	S	Cl	K	Ca	Fe
1	56	110	69	7	26	15	82
2	31	38	46	0	15	6	35
3	79	187	37	1	23	13	17
4	67	141	45	21	38	22	74
5	29	1	2	3	6	3	50

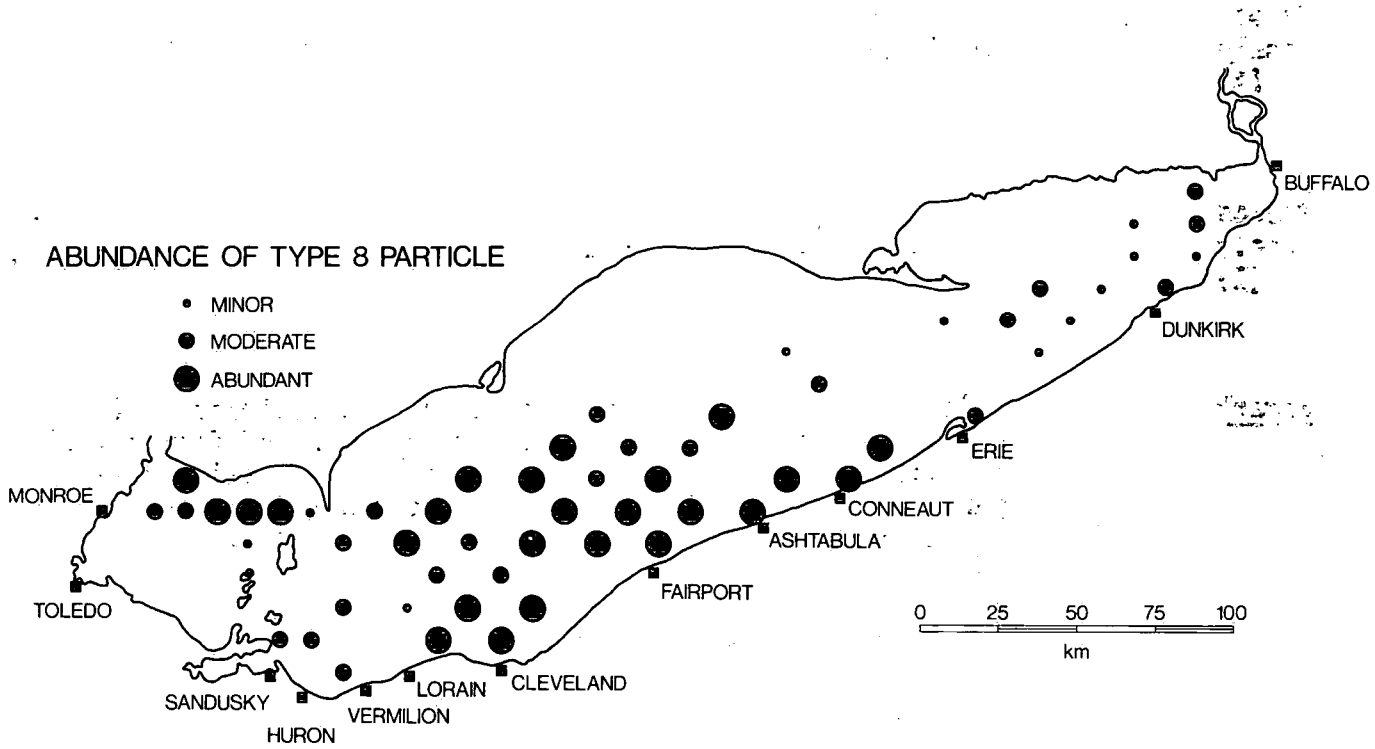
Carbon (Leco) analysis (%): Total carbon - 98.

Microprobe analysis (%): C >60, Fe < 1, i.e. organic.

Remarks: This particle is very common in Lake Erie sediments. It may be oil soot or a tarry coal exudate derived from shipping activities. However, its delicate form could allow dispersal by air or water over appreciable distances and therefore a source on shore cannot be ruled out.

SEM PHOTOGRAPH OF TYPE 8 PARTICLE





DISTRIBUTION OF TYPE 8 PARTICLES

TYPE 9 PARTICLE

Description: Black, semi-metallic lustre; massive, irregular; somewhat flake-like shape; conchoidal fracture.

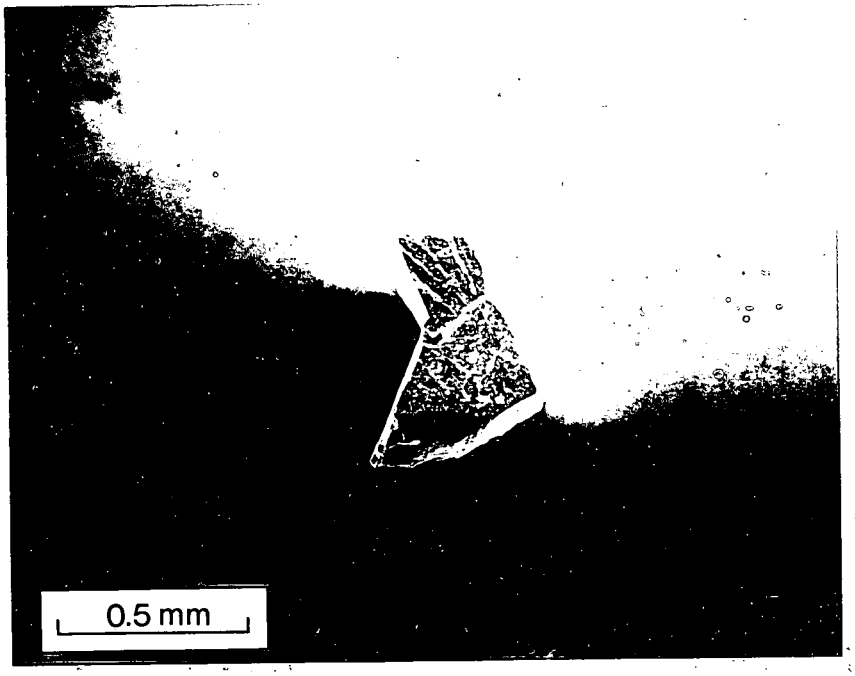
CHEMICAL DATA

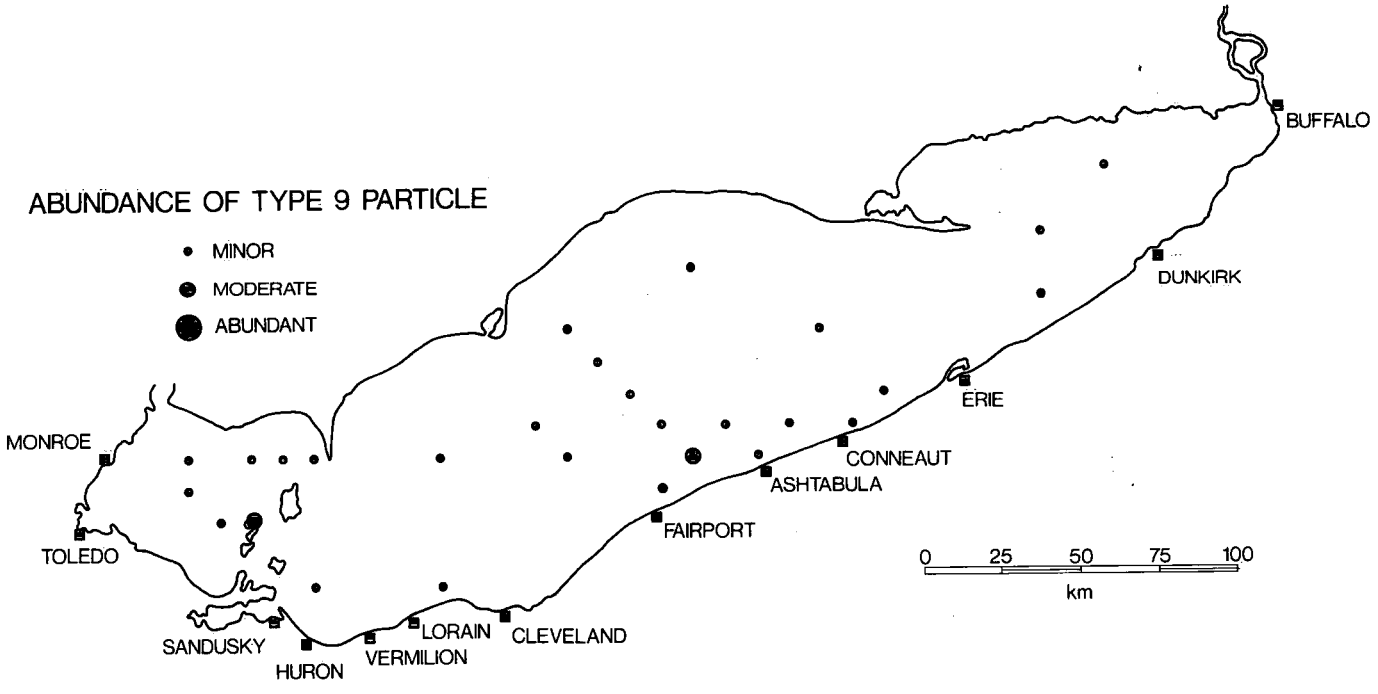
SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	43	109	99	10	18	13	-	24
2	17	61	57	61	8	15	-	29
3	220	367	96	3	35	22	-	73
4	5	922	14	26	38	429	-	435
5	18	21	90	10	3	8	-	19

Remarks: These particles are possibly thin flakes of coal.

SEM PHOTOGRAPH OF TYPE 9 PARTICLE





DISTRIBUTION OF TYPE 9 PARTICLES

TYPE 10 PARTICLE

Description: Very dark gray to black; bright semi-metallic to metallic lustre; occurs in very thin flexible flakes; very soft; makes a black mark on paper.

CHEMICAL DATA

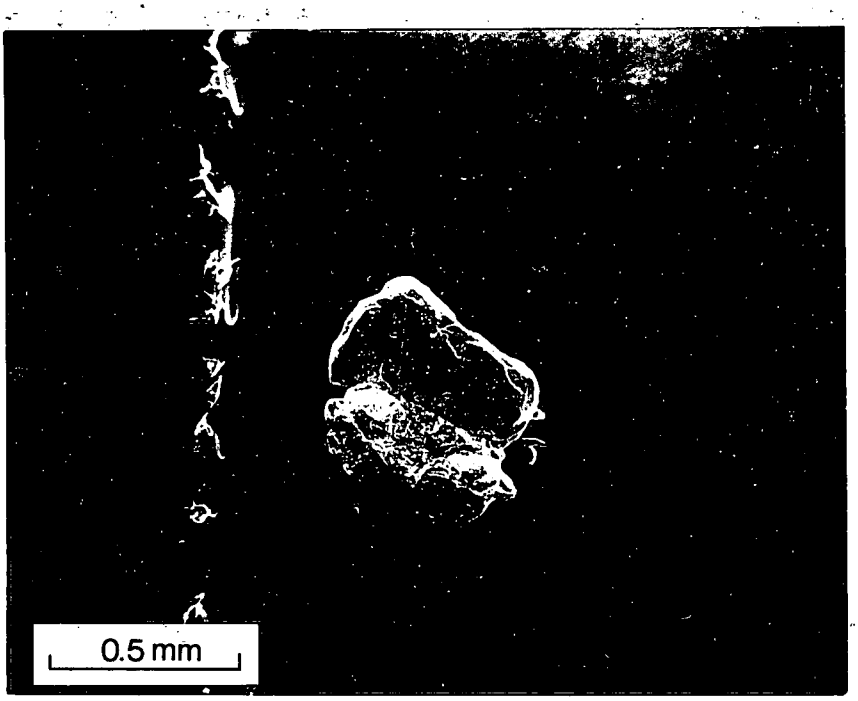
SEM/EDS counts on 5 grains

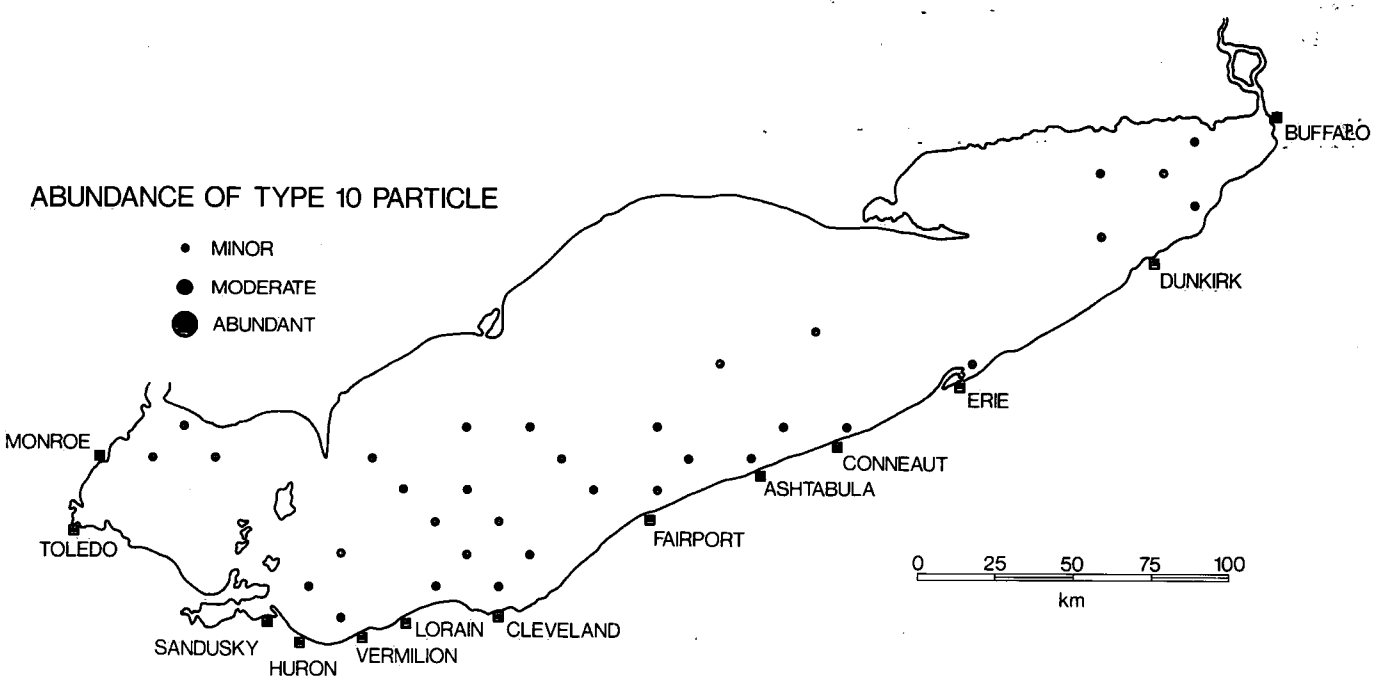
#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	7	13	15	3	18	26	-	32
2	101	988	22	5	25	669	284	216
3	42	21	1	9	5	1	-	62
4	19	125	7	13	15	16	11	106
5	53	433	12	12	38	36	10	734

Microprobe analysis (%): C >75, Fe, Si < 1.

Remarks: This particle is possibly graphite.

SEM PHOTOGRAPH OF TYPE 10 PARTICLE





DISTRIBUTION OF TYPE 10 PARTICLES

TYPE 11 PARTICLE

Description: Orange, dark brown, gray, yellowish-brown; glassy to dull lustre; vesicular; irregular shape.

CHEMICAL DATA

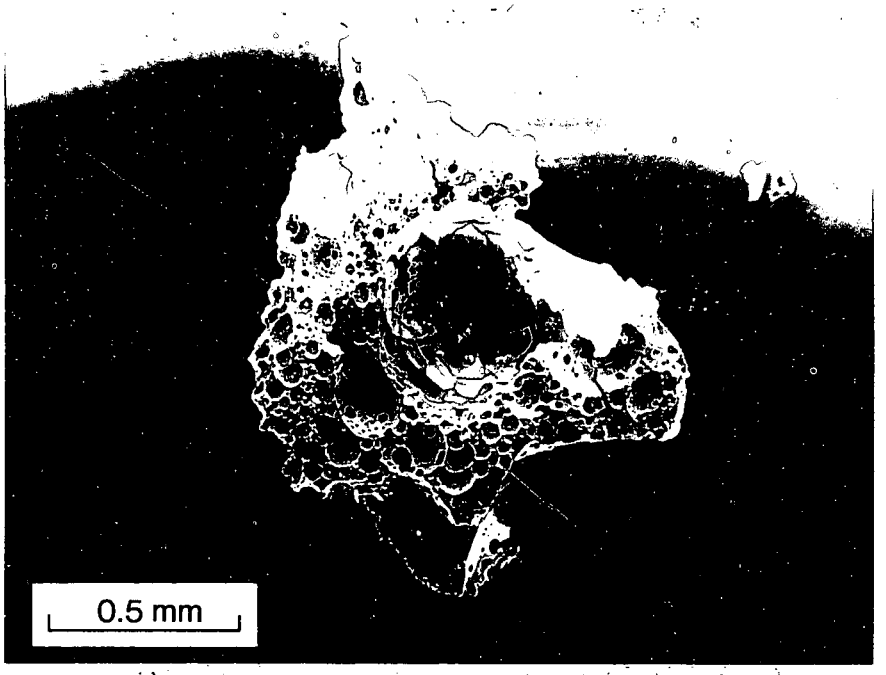
SEM/EDS counts on 4 grains

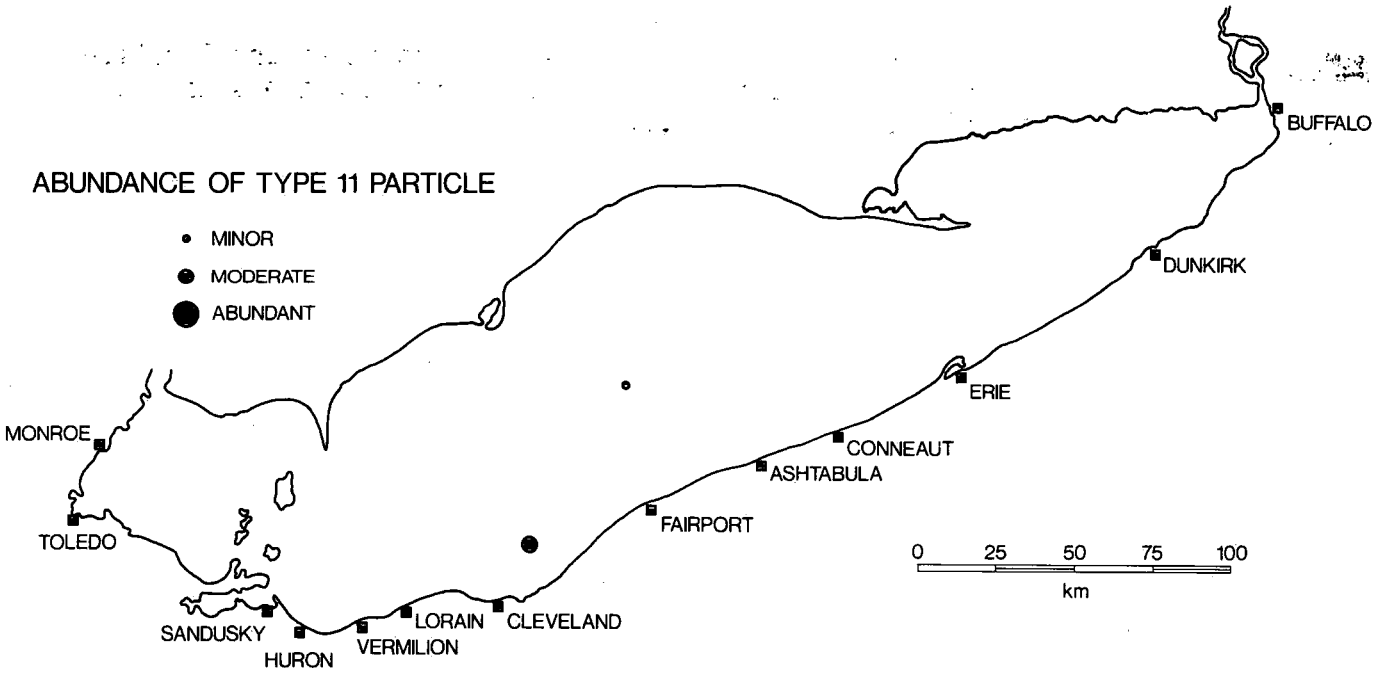
#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	53	418	11	5	30	103	19	461
2	151	1,072	11	2	20	218	36	186
3	993	2,426	9	18	270	43	121	358
4	65	263	32	18	14	247	19	40

Microprobe analysis (%): C 6, Fe 1, Si 5, Al 10, Ca 5, oxygen present.

Remarks: This particle is, like type 6, very abundant at one location in the southern part of Lake Erie. These two types may be derived from the same source.

SEM PHOTOGRAPH OF TYPE 11 PARTICLE





DISTRIBUTION OF TYPE 11 PARTICLES

TYPE 12 PARTICLE

Description: Black to dark reddish brown; semi-metallic lustre; massive or clusters of crystals with triangular faces; irregular shape.

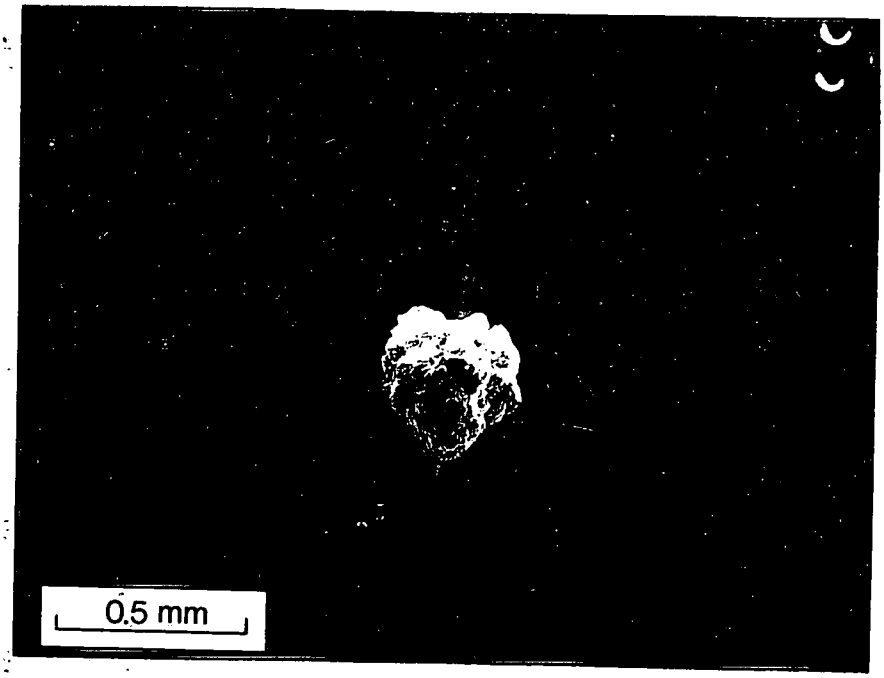
CHEMICAL DATA

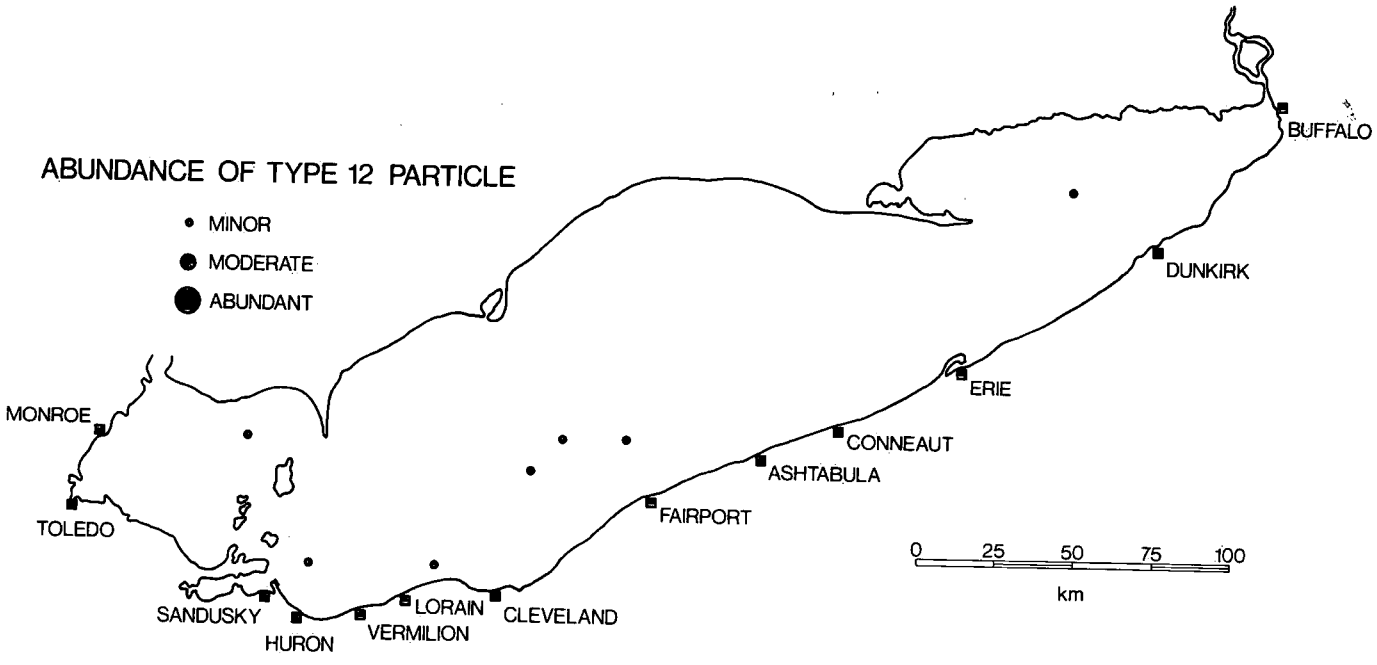
SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	59	160	2	8	7	44	26	3,158
2	45	54	15	8	1	1	33	2,837
3	34	93	16	18	4	16	20	3,228
4	198	391	8	10	3	26	8	2,286
5	63	106	2	5	25	12	23	3,554

Microprobe analysis (%): Fe 60, Al< 1, Si< 1, oxygen present.

SEM PHOTOGRAPH OF TYPE 12 PARTICLE





DISTRIBUTION OF TYPE 12 PARTICLES

TYPE 13 PARTICLE

Description: Gray with slightly bluish tint; semi-metallic lustre; very thin flakes with slightly rough surfaces; irregular or somewhat conchoidal outline.

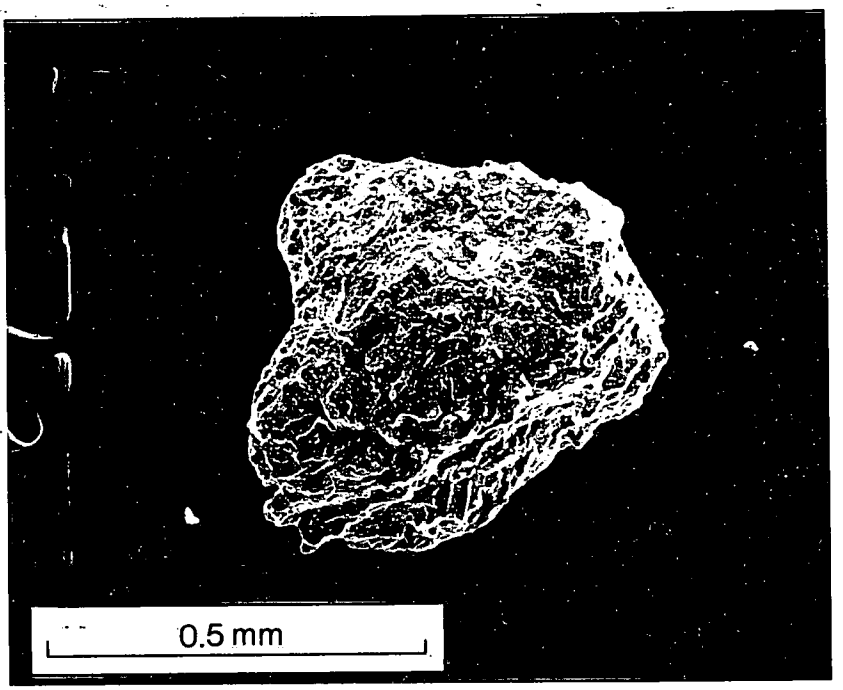
CHEMICAL DATA

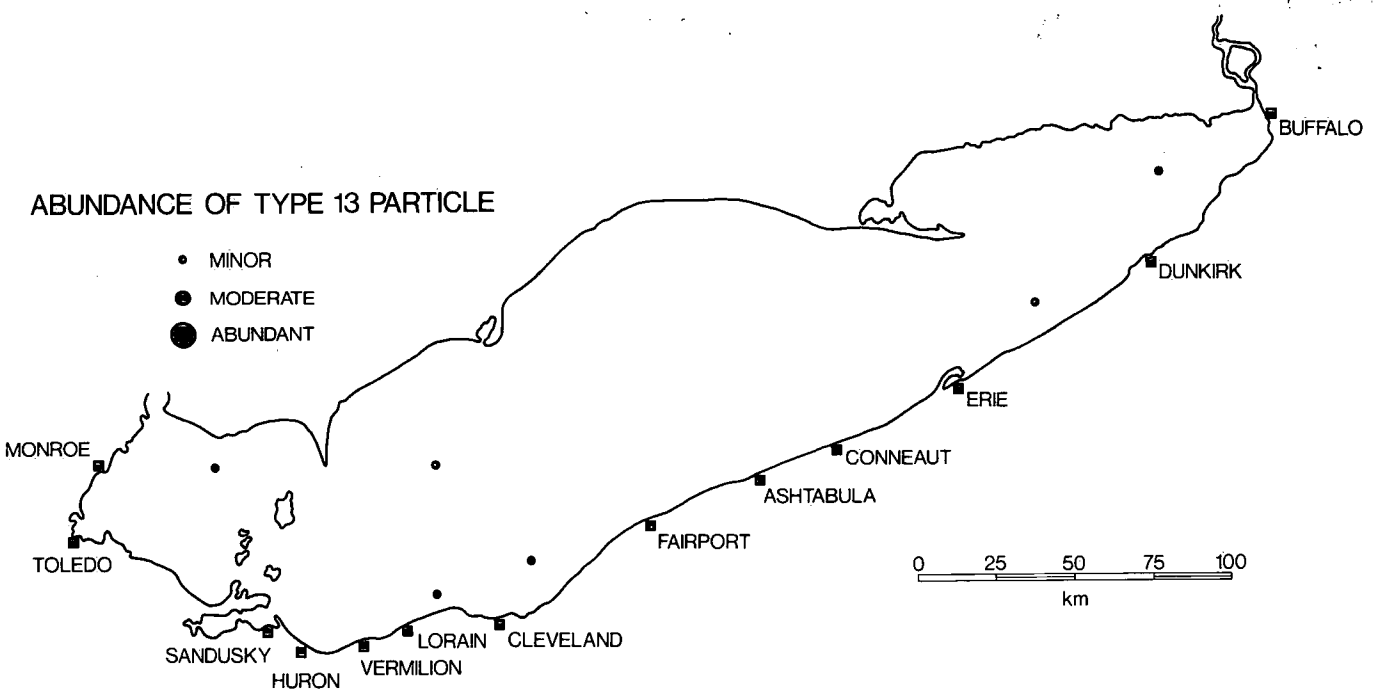
SEM/EDS counts on 5 grains

#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	36	29	32	24	26	32	2	2,652
2	31	131	-	26	36	35	9	2,382
3	17	281	3	14	13	23	19	2,516
4	15	26	4	4	21	19	0	2,447
5	531	927	7	17	248	13	25	104

Microprobe analysis (%): Fe 66, oxygen present (magnetic).

SEM PHOTOGRAPH OF TYPE 13 PARTICLE





DISTRIBUTION OF TYPE 13 PARTICLES

TYPE 14 PARTICLE

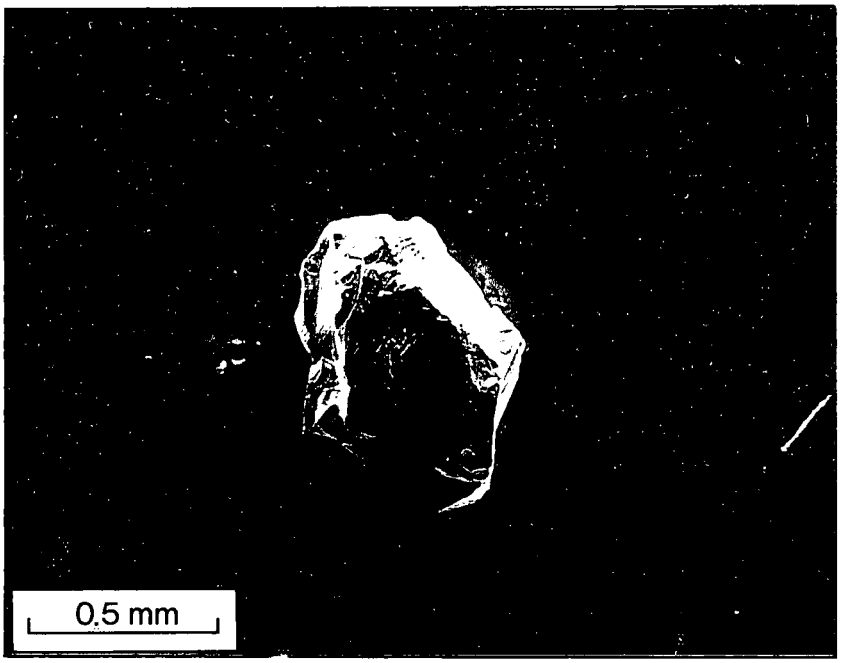
Description: Very dark gray; bright metallic lustre; massive; blacky shape with smooth surfaces or slight conchoidal fracture on edges.

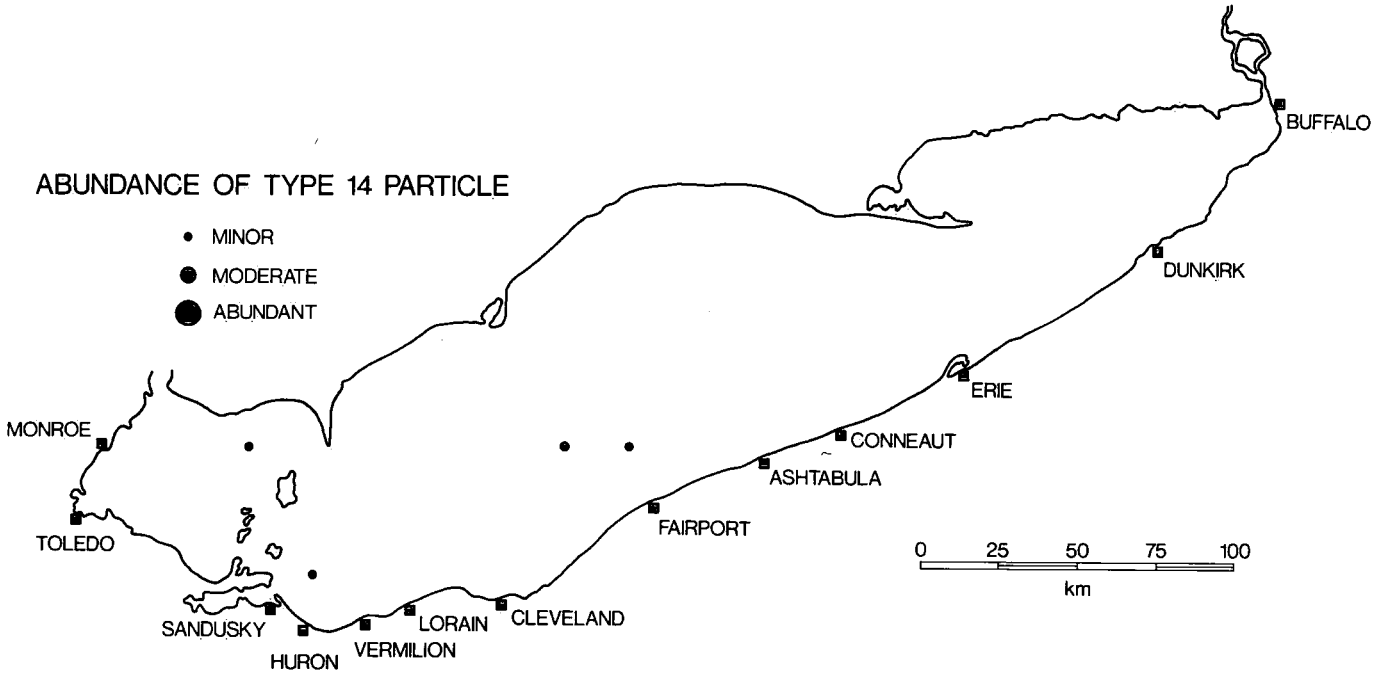
CHEMICAL DATA

SEM/EDS counts on 4 grains

#	Al	Si	S	Cl	K	Ca	Ti	Fe
1	32	15	27	10	2	8	6	2,567
2	23	9	4	3	13	10	7	870
3	16	4	14	27	14	3	19	2,314
4	40	11	20	16	17	27	34	1,976

SEM PHOTOGRAPH OF TYPE 14 PARTICLE





DISTRIBUTION OF TYPE 14 PARTICLES