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Geochemistry of Sediments from the North East Australian Continental Margin, including the Great Barrier Reef Slope, Queensland Plateau and Trough and the Osprey Embayment

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by D. Heggie, J. Lane and A. Herczeg

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Continental Margin Transects

GEOCHEMISTRY OF SEDIMENTS FROM THE NORTH EAST AUSTRALIAN CONTINENTAL MARGIN, including THE GREAT BARRIER REEF SLOPE, QUEENSLAND PLATEAU and TROUGH and the OSPREY EMBAYMENT.

RECORD 1993/33

AGSO Project 121.11 and 121.38

D. Heggie[1], J. Lane[1] and A. Herczeg[2]

1. Australian Geological Survey Organisation, Program in Marine Geosciences and Petroleum Geology, GPO Box 378, Canberra, 2601

2.CSIRO, Division of Water Resources, Private Bag 2, Glen Osmond, South Australia 5064

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EXECUTIVE SUMMARY

Several gravity cores were collected, as part of the Continental Margins Program, from the Queensland Plateau, the Queensland Trough, the Great Barrier Reef Slope and the Osprey Embayment off the northeast Australian continental margin during Rig Seismic Survey 51, September-October, 1985. These cores were collected from water depths of between 30 and 2949 m.

This Record presents the geochemical results conducted on several cores from that survey. These data form part of a geochemical data-base which is being systematically assembled from various parts of the Australian continental margin. The purpose of these geochemical data-bases is to systematically develop an understanding of the controls on the geochemical compositions of sediments from around Australia and hence contribute to an assessment of potential environmental change (both man-made and natural) and anthropogenic contributions to the continental shelves and slopes. The data also have implications for identifying processes controlling the formation of some seafloor minerals e.g.marine phosphorites and manganese crusts and nodules.

The data and some preliminary analysis of that includes - major and minor elemental compositions, total organic carbon and calcium carbonate contents of sediments, radiochemical contents of sediments (and the determination of Pleistocene sedimentation rates), pore water analyses of metabolites (nitrate, ammonia, silicate and manganese), and radiocarbon contents of the surface sediments.

The radiocarbon ages determined for the surface (0-3 cm) samples from eight cores varied between, 1240±130 BP and 7110±100 BP. Sedimentation rates, determined by radiochemical methods from three gravity cores in water depths between about 1100 and 3000 m from the Queensland Plateau and Osprey Embayment were found to be 0.45, 0.51 and 0.7 cm kyr^{-1} respectively. These represent average sedimentation rates for Late Pleistocene sediments from this area.

The concentrations of organic carbon in the core-tops (0-3 cm), off Northeast Australia varied between 0.13 and 0.78 %, and concentrations generally decreased down-core indicating significant oxidation of organic matter. The pore water metabolites measured in several cores varied in a systematic way also indicating organic matter degradation processes by major oxidants oxygen and sulphate, and secondary oxidants (nitrate, manganese and iron oxyhydroxides). The data from the Queensland Plateau suggest relatively low inputs of organic matter to the sediments, while data from the Great Barrier Reef slope indicated sulphate reduction processes occurring at shallow

depth in the cores, and suggest significantly higher inputs of organic matter to slope sediments than Plateau sediments.

A data-base of major and minor trace element abundances has been assembled. Preliminary analysis of part of that data suggest that several trace elements (arsenic, cerium, cobalt, chromium, lanthanum, neodymium, nickel, lead, rubidium and scandium) covary with Al_2O_3 and Fe_2O_3, indicating a control on their concentrations and distributions by clay contents and iron oxyhydroxides. Similarly, barium, cobalt, copper, nickel and lead appear to covary with MnO_2, which suggests a control on their compositions by manganese oxyhydroxide scavenging processes.

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INTRODUCTION

During the Continental Margins Program many cores have been collected as part of the surface geochemistry program. Several of these cores have been analysed for light hydrocarbon concentrations and compositions as part of an evaluation of surface geochemistry techniques in support of offshore hydrocarbon exploration. These data are being summarised into a light hydrocarbon data-base and AGSO Record (Heggie and Tindall in preparation).

A complementary exercise to this effort has been to extend seafloor sampling from the continental shelf onto the continental slope. Most of these cores have not been analysed for light hydrocarbons, because of the unlikely possibility of hydrocarbon migration to the slope, or into sediments of the relatively deep parts of the slope. However, in an effort to systematically understand the controls on the chemical compositions of the sediments of the Australian continental margin, several cores have been analysed for a variety of chemical components. These analyses include major and minor element compositions by XRF (X -Ray Fluorescence) calcium carbonate and total organic carbon content, radiochemical contents - to determine sedimentation rates - and several cores have had analyses conducted on the chemical compositions of the pore fluids separated from sediments. These analyses have applications to diagenetic reactions occurring in the near-surface (<10 m) sediments and hence are important in understanding processes of some seafloor mineral formations e.g., marine phosphorites and manganese nodules and crusts. These data also provide a fundamental framework to understand controls on the chemical compositions of sediments, including the relative importance of continental runoff and local oceanography (as reflected in the presence/absence of upwelling and associated high organic matter productivity). In many instances these data also document 'baseline' environmental conditions and can be used to assess environmental impact including potential anthropogenic inputs, and natural (climatic) environmental change.

This Record documents analyses conducted on several cores collected from northeast Australia during 1985 on Rig Seismic survey 51. The locations of the cores collected are shown in Figure 1 and summarised in Table 1. The different analyses carried out on these sediments include ^{14}C age determinations, organic carbon contents , radiochemistry, pore water and solid phase major and trace elements (Table 2).

The purpose of this Record is to assemble data for the study area, such that it can be utilised for additional analysis. This Record is therefore primarily a data compilation, although the radiochemical data are discussed to determine sedimentation rates. A number of plots have been produced to assist with a general overview of the geochemical properties of these sediments. These plots include down core profiles of the pore water metabolites, nitrate, manganese, ammonia and silicate. These data should be viewed in the context of a systematic distribution of sedimentary metabolites described by Froelich and others (1979). The data from Froelich and others (1979) were collected from the deep-water parts of the Atlantic Ocean in areas of moderate to high organic matter productivity which are appropriate for continental margin sediments. These down-core trends in the pore water profiles can be used as a guide for interpreting the down-core profiles of sediments from the northeast Australian continental margin.

A variety of cross-plots have been produced to provide a preliminary perspective on controls on the chemical composition of sediments from northeast Australia and to allow easy comparison of the chemical composition of these sediments with others. Because alumino-silicate phases, iron and manganese oxyhydroxides are major phases for the transport of trace elements in the sea, these plots include Al_2O_3 versus all other elements analysed for, Fe_2O_3 versus all elements analysed for and MnO_2 versus all elements analysed for.

The radiochemical properties of the sediments have been analysed to determine sedimentation rates, and these data are included and discussed in some detail. The radiochemical data were contributed by A. Herzceg while at the Australian National University, who was a co-investigator on the geochemistry of northeast Australian sediments.

This Record complements a large suite of sedimentological and other data assembled as part of this survey (Davies and Symonds and others, unpublished)

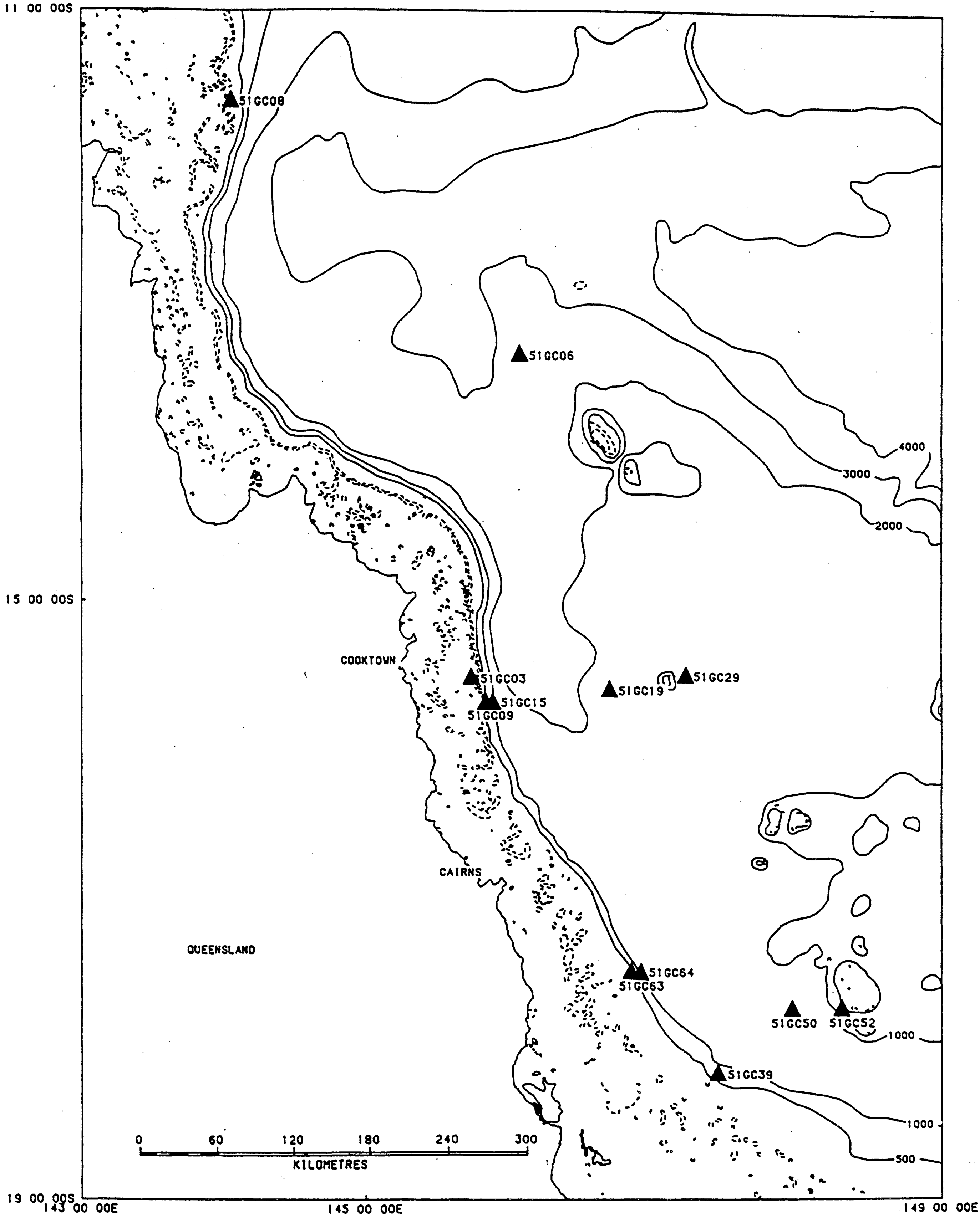
Objectives

The primary objective of the continental margin transects geochemical profiles is to understand the major controls on the chemical compositions of continental margin sediments. This Record collates all the available geochemical data from the Northeast Australia region. The purposes of collecting and collating these data include:

1. To determine the early diagenetic processes occurring in the sediments of Northeast Australia, including the deep water parts of the Queensland Trough, the Great Barrier Reef slope, the Queensland Plateau and the Osprey Embayment

2. To determine the ages of sediment samples and hence sedimentation rates from the continental margin, including offshore Queensland Plateau, the Osprey Embayment and the Queensland Trough.

3. To determine the major and minor element contents of the sediments and the processes controlling their chemical compositions.



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PREPARED BY: JENNIFER L LANE
DATE: 15 OCTOBER 1993

Figure 1. Location of cores off the northeast Australian continental margin

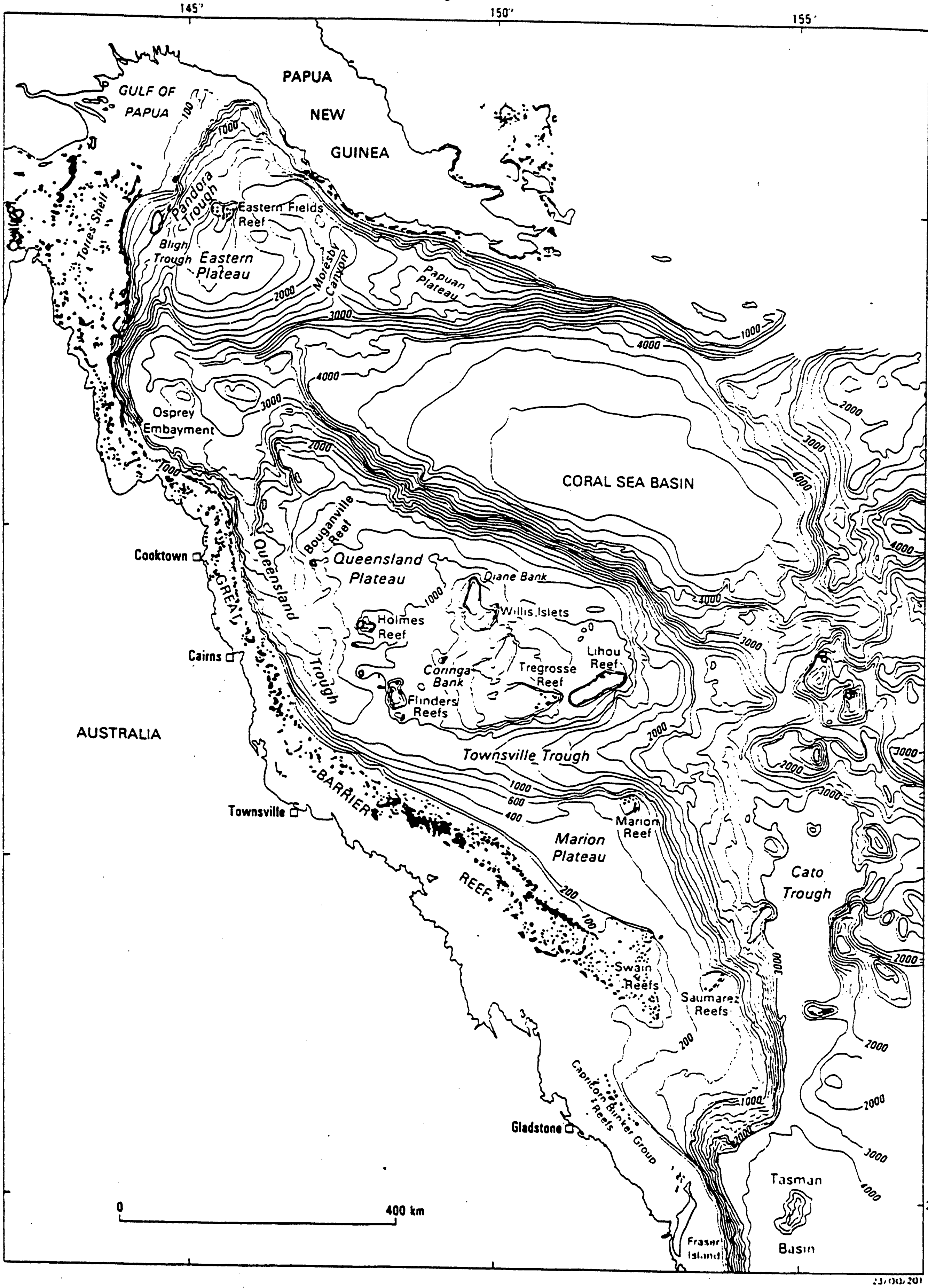


Figure 1b. Detailed bathymetric map of study area offshore northeast Australia

Table 1 Location of Northeast Australia cores

Core	Longitude (deg, min)	Latitude (deg, min)	Water Depth (m)	Location
51GC03	15 31.39'S	145 44.03'E	30	Halimeda Bank
51GC06	13 21.223	146 03.885	2949	Osprey Embayment, adjacent to slope
51GC08	11 37.643	144 04.069	416	Raine Island entrance, slope sediment
51GC09	15 41.495	145 49.673	400	mound feature in front of main reef edge
51GC15	15 40.934	145 52.452	1005	Queensland Trough northern transect
51GC19	15 36.514	146 40.964	1871	Queensland Trough, northern transect
51GC29	15 30.775	147 12.990	1175	Eastern Queensland Plateau
51GC39	18 10.391	147 26.105	556	outer edge of upper slope terrace
51GC50	17 44.687	147 56.728	1165	Queensland Trough, southern transect
51GC52	17 44.984	148 18.569	1044	Queensland Trough, southern transect
51GC63	17 30.331	146 52.652	748	Continental slope, Geranium Passage
51GC64	17 29.729	146 54.412	933	Continental slope at Geranium Passage

Table 2 Summary of Cores Analysed

North East Australia Survey 51

Core	Total samples Analysed	Analyses Performed C14	Organic Carbon	Pore Water	Solid Phase Majors	Solid Phase Trace	Radio-Chemistry	CaCO3 (wt%)
51GC03	19	-	-	19	-	-	-	-
51GC06	31	✓	19	31	19	19	7	-
51GC08	8	-	-	8	-	-	-	-
51GC09	11	✓	11	11	9	9	-	9
51GC15	15	✓	-	15	15	15	-	-
51GC19	19	-	-	11	2	2	-	19
51GC29	14	-	12	14	13	13	5	13
51GC39	10	✓	10	10	10	10	-	10
51GC50	17	✓	17	14	15	15	8	-
51GC52	10	-	-	10	-	-	-	-
51GC63	14	✓	12	13	-	-	-	12
51GC64	14	✓	14	13	-	-	-	14

METHODS

Radiocarbon Age Determination

Radiocarbon age dating determinations were completed on eight cores from North-east Australia. The ^{14}C age determinations were completed at the Australian National University, Research School of Pacific Studies (RSPS), Radiocarbon Dating Research centre. Eight samples were analysed for the ^{14}C content on the inorganic carbon component and two samples were analysed for the ^{14}C content of organic carbon.

Organic Carbon

The determinations of organic carbon in the sediments from northeast Australia were analysed at the Australian Institute Marine Science, using milligram quantities of dried sediments and methods modified from those described in Sandstrom and others (1986). Organic carbon contents were determined on seven cores, with several analyses being conducted to construct down-core profiles.

Pore Water

The methods used to analyse the pore water compositions were similar to those described in Heggie and others (1987); Heggie and others (1990). The pore water samples were analysed for nitrate, ammonia, manganese, total carbon dioxide and silicate. Sediment cores were split and one-half of the core was sampled for pore water metabolites. Sections of approximately 3 cm of sediment were loaded into centrifuge tubes as soon as the core was split in the laboratory on the ship. Samples were collected at about 10 cm intervals in the top section of core, but at 20 cm intervals in the deeper sections of cores. Pore waters were separated from the sediments by centrifuging at 15, 000 rpm for about 10 minutes. Pore waters were siphoned off and filtered through precleaned 0.45 Nuclepore filters and analysed for ammonia and manganese at sea using colorimetric methods. Nitrate and silicate were analysed at the Australian Institute of Marine Science using standard Technicon Autoanalyzer methods. Total carbon dioxide was analysed at the Australian Geological Survey Organisation (AGSO) laboratories using a OIC (Oceanography International Corporation) carbon analyser. Approximately 1 ml of pore water was acidified with phosphoric acid and the liberated carbon dioxide measured with an infra red detector. Because of the limited volumes of pore water available, these analyses were only conducted on select cores.

Major and Minor Element Compositions

Major and trace element analyses were measured by x-ray fluorescence at the Australian Geological Survey Organisation with methods modified from those originally presented in Norrish and Hutton (1969).

Radiochemistry

Select sediments were analysed for their radiochemical properties in order to determine sediment accumulation rates. These methods are discussed in detail in the section dealing with sedimentation rates of cores collected from the Queensland Plateau and Osprey Embayment.

RESULTS AND DISCUSSION

Radiocarbon Age Determinations

A summary of the radiocarbon age determinations for eight cores are presented in Table 3 below. The individual results for each sample, as presented by RSPS, are included in Appendix 1. The radiocarbon ages have been determined on the 0-3 cm samples from each core. The calcium carbonate contents of these samples varied between 56 and 82%. The radiocarbon ages on these samples varied between 1240 ± 130 and 7110 ± 100 years BP.

Table 3. Radiocarbon Age Determination for eight cores from northeast Australia

RADIOCARBON AGE DETERMINATION North East Australia			
Sample	**Carbon fraction**	**Age (years)**	**%CaCO3**
GC006	inorganic	3940±150 BP	56
GC009	inorganic	1240±130 BP	64
	organic	104.8±3.0 %Modern	
GC015	inorganic	1530±170 BP	60
GC029	inorganic	5300±200 BP	82
GC039	inorganic	7110±100 BP	76
GC050	inorganic	2130±160 BP	80
GC063	inorganic	2500±150 BP	72
GC064	inorganic	2060±160 BP	72
	organic	102.4±3.9 %Modern	

Organic Carbon contents of Sediments

The percent weights of organic carbon in cores 51GC06, 51GC09, 51GC29, 51GC39, 51GC50, 51GC63 and 51GC64 are presented in Tables 4 through 10, below. In general, the highest concentrations of organic carbon were measured in the top interval (0-3cm) of cores and concentrations generally decreased with increasing depth in the sediment, although some cores showed near constant organic carbon contents to depths greater than 1 metre. Core-top concentrations of organic carbon varied between 0.78 and 0.13%. The accuracy of the analyses are ±0.03%. Analyses were conducted in duplicate. An average percent coefficient of variation for duplicate analyses was found to be ±3.00% for the analyses shown below (104 samples analysed).

Table 4. Organic carbon contents for core 51GC06

Core	Depth(cm)	C wt%
51 GC06	0 - 1.5	0.30
51 GC06	1 - 1.5	0.26
51 GC06	3 - 4.5	0.23
51 GC06	6 - 7.5	0.21
51 GC06	9 - 10.5	0.20
51 GC06	14 - 15.5	0.19
51 GC06	17.5 - 19	0.21
51 GC06	21 - 22.5	0.21
51 GC06	24.5 - 26	0.18
51 GC06	28 - 29.5	0.18
51 GC06	40 - 41.5	0.19
51 GC06	46.5 - 48	0.18
51 GC06	53 - 54.5	0.17
51 GC06	62.5 - 64.5	0.19
51 GC06	72.5 - 74.5	0.20
51 GC06	82 - 83.5	0.20
51 GC06	101 - 102.5	0.21
51 GC06	110.5 - 112	0.25
51 GC06	120 - 121.5	0.22

Table 5. Organic carbon contents for core 51GC09

Core	Depth(cm)	C wt%
51 GC09	0 - 3	0.78
51 GC09	10. - 13	0.68
51 GC09	10. - 13	0.71
51 GC09	30 - 33	0.64
51 GC09	30 - 33	0.62
51 GC09	50 - 53	0.65
51 GC09	70 - 73	0.66
51 GC09	90 - 93	0.59
51 GC09	110 - 113	0.59
51 GC09	130 - 133	0.53
51 GC09	150 - 153	0.49

Table 6. Organic carbon contents for core 51GC29

Core	Depth(cm)	C wt%
51 GC29	0 - 3	0.13
51 GC29	6. - 9	0.10
51 GC29	14 - 17	0.09
51 GC29	29 - 23	0.10
51 GC29	30 - 33	0.09
51 GC29	40 - 43	0.09
51 GC29	50 - 53	0.09
51 GC29	70 - 73	0.09
51 GC29	90 - 93	0.08
51 GC29	130 - 133	0.08
51 GC29	150 - 153	0.06
51 GC29	170 - 173	0.08

Table 7. Organic carbon contents for core 51GC39

Core	Depth(cm)	C wt%
51 GC39	0 - 3	0.35
51 GC39	6. - 9	0.34
51 GC39	12. - 15	0.32
51 GC39	20 - 23	0.33
51 GC39	30 - 33	0.33
51 GC39	50 - 53	0.30
51 GC39	70 - 73	0.31
51 GC39	90 - 93	0.30
51 GC39	110 - 113	0.30
51 GC39	139 - 133	0.31

Table 8. Organic carbon contents for core 51GC50

Core	Depth(cm)	C wt%
51GC50	0 - 3	0.30
51GC50	6. - 9	0.21
51GC50	6. - 9	0.20
51GC50	12. - 15	0.21
51GC50	20 - 23	0.29
51GC50	20 - 23	0.28
51GC50	30 - 33	0.30
51GC50	40 - 43	0.24
51GC50	50 - 53	0.09
51GC50	60 - 63	0.20
51GC50	70 - 73	0.17
51GC50	80 - 83	0.16
51GC50	100 - 103	0.20
51GC50	125 - 128	0.16
51GC50	145 - 148	0.20
51GC50	165 - 168	0.23
51GC50	109 - 193	0.26

Table 9. Organic carbon contents for core 51GC63

Core	Depth(cm)	C wt%
51 GC63	0 - 3	0.54
51 GC63	6.-9	0.53
51 GC63	12. - 15	0.48
51 GC63	18 - 21	0.46
51 GC63	24 - 28	0.58
51 GC63	40 - 43	0.44
51 GC63	50 - 53	0.48
51 GC63	60 - 63	0.46
51 GC63	70 - 73	0.44
51 GC63	80 - 83	0.44
51 GC63	100 - 103	0.48
51 GC63	120 - 123	0.45

Table 10. Organic carbon contents for core 51GC64

Core	Depth(cm)	C wt%
51 GC64	0 - 3	0.53
51 GC64	6 - 7	0.52
51 GC64	12 - 15	0.55
51 GC64	18 - 21	0.51
51 GC64	30 - 33	0.57
51 GC64	40 - 43	0.53
51 GC64	50 - 53	0.49
51 GC64	70 - 73	0.46
51 GC64	90 - 93	0.51
51 GC64	110 - 113	0.56
51 GC64	130 - 133	0.51
51 GC64	150 - 153	0.48
51 GC64	170 - 173	0.54
51 GC64	190 - 193	0.62

Pore Water Geochemistry

The pore water data for twelve cores from northeast Australia are summarised in Tables 11 through 22. The down core profiles for nitrate, ammonia, carbon dioxide, manganese (pore water) and manganese (solid phase) are presented in Figures 3 - 14. The plots have not been interpreted in detail, but a systematic approach to assist in the interpretation of these plots is shown in the equations, and the predicted down-core metabolite profiles below (Froelich and others, 1979) and in Figure 2. Pore water profiles of ammonia concentrations have been modelled according to Bender and Heggie (1983) to calculate the organic matter oxidised during sulphate reduction processes in the sediments. These results are summarised at the end of the Tables and Figures below.

Organic Matter destruction in Sediments (modified from Froelich and others, 1979)

(1) Oxygen reduction

$106(CH_2O)16(NH_3)+(H_3PO_4)+138O_2 \rightarrow 106CO_2+16(NH_3)+H_3PO_4+122H_2O$

(2) Nitrate Reduction

$106(CH_2O)16(NH_3)+(H_3PO_4)+94HNO3 \rightarrow 106CO_2+55.2N_2+H_3PO_4+177H_2O$

(3) Manganese Reduction

$106(CH_2O)16(NH_3)+(H_3PO_4)+236MnO_2+472H^+ \rightarrow 236Mn^{2+}+106CO_2+$
$8N_2H_3PO_4+366H_2O$

(4) Ferric iron reduction

$106(CH_2O)16(NH_3)(H_3PO_4)+424FeOOH+848H^+ \rightarrow 424Fe_{2+}+106CO_2+16(NH_3)+$
$H_3PO_4+742H_2O$

(5) Sulphate reduction

$106(CH_2O)16(NH_3)+(H_3PO_4)+53SO_4^{2-} \rightarrow 53S^2+106CO_2+16(NH_3)+$
$H_3PO_4+106H_2O$

(6) Methanogenesis

$106(CH_2O)16(NH_3)+(H_3PO_4) \rightarrow 53CO_2+53CH_4+16(NH_3)+H_3PO_4$

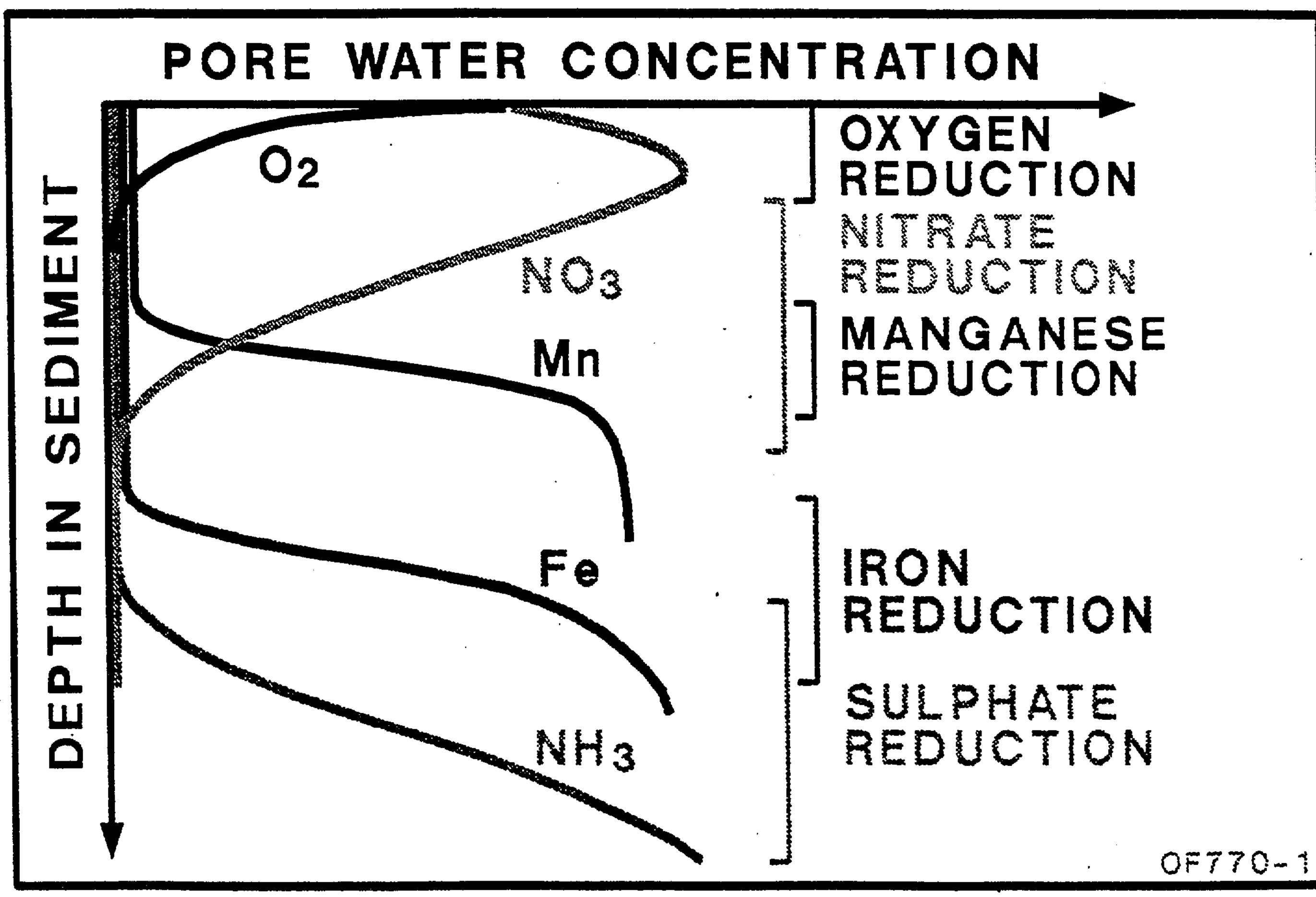


Figure 2. Schematic representation of trends in pore water profiles (After Froelich, 1979).

Table 11 Pore Water results for core 51GC003

Survey	Core	Depth (cm)	NH3 (umol/l)	Mn (umol/l)
51	GC003	10-14	7	<0.4
		34-38		<0.4
		38-62	49	<0.4
		82-86	77	<0.4
		103-121	89	<0.4
		151-179		<0.4
		175-179		<0.4
		199-203		<0.4
		223-227		<0.4
		247-251	40	<0.4
		271-275	130	<0.4
		295-299		<0.4
		319-323		<0.4
		343-347		<0.4
		367-371		<0.4
		391-395	136	<0.4
		415-419		<0.4
		439-443		<0.4
		463-467		<0.4

Table 12 Pore Water results for core 51GC006

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)	SiO2 (umol/l)
51	GC006	0.75				1.878	234
		0 - 1.5	36.0	1.4	<0.4		
		1.5 - 3.0	35.0	4.8		2.288	209
		3.0 - 4.5	35.0	2.6			263
		4.5 - 6.0	37.0	6.5	<0.4	2.231	274
		6.0 - 7.5	31.0	9.5	<0.4	2.519	250
		7.5 - 9.0	30.0	2.4	<0.4	2.277	280
		9.0 - 10.5	30.0	11.8	<0.4	2.230	245
		10.5 - 12.0	28.0	14.8	<0.4	2.359	262
		14.0 - 15.5	27.0	3.4	<0.4		290
		17.5 - 19.0	25.0	2.8	<0.4	2.269	251
		21 - 22.5	23.0	2.6	<0.4	2.091	261
		24.5 - 26.0	21.0	2.1	<0.4	2.185	267
		28 - 29.5	19.0	4.2	<0.4	2.311	267
		35 - 36.5	18.0	0.9	0.9	2.397	268
		40 - 41.5	11.3	2.6	9.7		262
		46.5 - 48	8.0	7.6	19.3		288
		53 - 54.5	0.5	2.7	26.2	2.408	278
		63.5				2.290	
		63 - 64.5	2.8	6.9	31.9		251
		73.5				2.550	
		73 - 74.5		0.9	38.8		
		82.75				2.374	212
		83 - 84.5	<0.1	6.3	45.4		
		91.75				2.397	
		93 - 94.5		9.1	48.1		
		101.75				2.478	216
		103 - 104.5	<0.1	10.5	44.8		
		111				2.408	
		113 - 114.5		11.8	52.4		
		120 - 121.5		15.5	52.5	2.057	

Table 13 Pore Water results for core 51GC008

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)
51	GC008	0 - 7	<0.1	17.4	2.2	97
		20 - 27	0.5	19.6	2.5	133
		40 - 45	0.5	24.9	1.0	141
		60 - 65	0.5	27.2	1.3	141
		80 - 84	0.5	23.9	1.9	128
		100 - 104	0.3	28.9	1.1	129
		120 - 124	0.5	23.9	1.1	131
		140 - 144	0.5	39.7	0.8	130

Table 14 Pore Water results for core 51GC009

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 (mmol/l)
51	GC009	0 - 3	<0.1	45	5.6	119	2.105
		10 - 13	<0.1	98	3.1	157	2.360
		30 - 33	<0.1	307	1.9	202	3.192
		50 - 53	<0.1	321	2.0	254	3.853
		51.5001					3.824
		70 - 73	<0.1	565	1.7	246	4.645
		90 - 93	<0.1	677	1.5	284	5.222
		111.5				292	6.051
		111.5001					6.018
		130 - 133	<0.1	754	1.6	310	
		150 - 153	<0.1	1159	2.0	306	8.072

Table 15 Pore Water results for core 51GC015

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 mmol/l
51	GC015	0 - 3	0.5	24	13.5	186	2.470
		10 - 13	1.8	70	11.6	240	2.703
		30 - 33	1.8	87	8.9	268	3.185
		50 - 53	1.9	145	8.9	278	3.493
		70 - 73	1.7	141	9.6	286	3.629
		90 - 93	1.1	113	8.9	304	3.716
		110 - 113	0.8	300	12.0	258	4.130
		130 - 133	0.8	311	17.0	297	6.999
		150 - 153	0.8	314	13.3	266	4.792
		170 - 173		483	16.9		
		190 - 193		342			
		215 - 218		481			
		240 - 253		404			
		265 - 268		554	24.0		
		290 - 293		705			

Table 16 Pore Water results for core 51GC019

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 (mmol/l)
51	GC019	0 - 3	45.0	1.4	<0.4	174	2.167
		6 - 9	35.0	1.9	0.6	198	2.204
		12 - 15	25.0	1.5	<0.4	186	2.204
		18 - 21	19.0	2.1	1.0	195	2.365
		30 - 33	9.1	3.7	13.3	235	2.310
		40 - 43	1.0	4.1	10.8	152	1.862
		60 - 63	3.4	15.1	14.5	158	1.879
		70 - 73		10.4	12.6		
		80 - 83	1.8	13.8	12.6	132	2.101
		110 - 113	1.0	20.5	16.8	173	1.832
		130 - 133	0.3	28.2	21.4	166	2.015
		150 - 153		30.6	21.1		2.064
		170 - 173	0.5	38.4	23.8	178	2.084
		190 - 193		42.0	16.5		
		210- 213		78.2	24.6		2.232
		240 - 243		70.2	25.6		2.340
		250 - 253		61.5	30.2		1.967
		270 - 273		53.0	31.5		2.236

Table 17 Pore Water results for core 51GC029

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 (mmol/l)
51	GC029	0 - 3	40.0	2.0	1.1	149	2.635
		6 - 9	38.0	2.8	<0.4	148	
		14 - 17	34.0	4.2	<0.4	160	
		20 - 23	37.0	4.0	<0.4	158	
		30 - 33	34.0	4.6	<0.4	157	
		40 - 43	33.0	2.4	<0.4	157	2.635
		50 - 53	29.0	3.1	<0.4	156	2.391
		70 - 73	29.0	1.7	<0.4	167	2.329
		90 - 93	26.0	2.9	<0.4	157	2.403
		110 - 113	22.0	2.6	0.5	159	2.254
		130 - 133	18.0	2.8	1.8	149	1.185
		150 - 153	17.0	2.8		149	1.050
		170 - 173		2.5	2.7		2.352
		190 - 193		3.3	2.8		

Table 18 Pore Water results for core 51GC039

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)
51	GC039	0 - 3	0.5	36.4	2.8	85
		7 - 9	<0.1	108.0	5.0	130
		12 - 15	0.3	131.2	2.9	155
		20 - 23		160.4	2.2	
		30 - 33	<0.1	196.0	3.3	186
		50 - 53	<0.1	237.6	4.5	156
		70 - 73	<0.1	314.8	3.5	234
		90 - 93		370.0	3.0	228
		110 - 113	<0.1	384.4	3.0	235
		130 - 133	<0.1	422.8	3.5	219

Table 19 Pore Water results for core 51GC050

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 (mmol/l)
51	GC050	0 - 3	53.0	18.4	0.8	109	2.188
		6 - 9	32.0	512.0	1.0	121	
		12 - 15	25.0	<0.1	0.3	132	2.305
		20 - 23	15.1	2.8	0.3	142	2.401
		30 - 33	6.5	1.6	0.7	142	2.346
		40 - 43	1.0	2.0	1.0	137	2.322
		50 - 53	<0.1	7.2	2.3	125	2.241
		60 - 63	0.7	26.8	5.8	111	
		70 - 73	0.6	33.2	6.8	136	2.229
		80 - 83	0.4	29.2	7.6	132	
		105 - 108	0.5	34.4	9.7	129	2.133
		125 - 128	0.4	34.8	8.3	123	2.102
		145 - 148		43.6	9.0	129	2.159
		165 - 168		55.6	8.2		2.159

Table 20 Pore Water results for core 51GC052

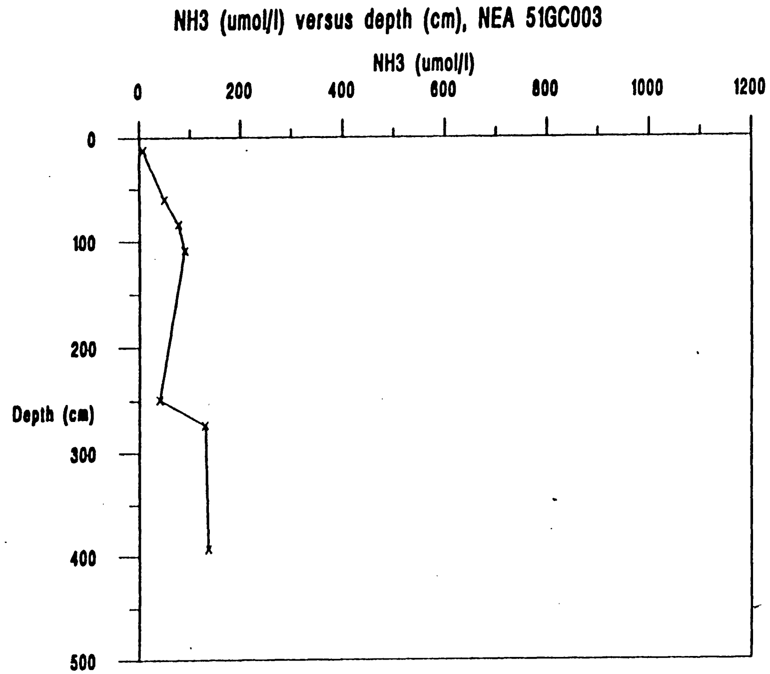
Survey	Core	Depth (cm)	CO2 (mmol/l)	SiO2 (umol/l)
51	GC052	0 - 3	2.285	58
		6 - 9	2.455	182
		12 - 15		191
		20 - 23	2.365	202
		30 - 33		206
		40 - 43	2.217	216
		50 - 53	2.160	207
		60 - 63	2.373	219
		80 - 83	2.327	213
		100 - 103	2.215	

Table 21 Pore Water results for core 51GC063

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	SiO2 (umol/l)	CO2 (mmol/l)
51	GC063	0 - 3	6.1	19	97.1	128	2.093
		6 - 9	<0.1	48	9.0	175	2.294
		12 - 15	0.3	93	9.1	204	2.48
		18 - 21	0.5	111	9.6	228	2.654
		24 - 28	2.0	142	8.5	260	2.878
		40 - 43	<0.1	185	8.3	286	3.357
		50 - 53	1.6	247	6.9	238	3.474
		60 - 63	7.3	328	7.0	240	3.694
		70 - 73	0.2	346	6.4	296	4.155
		80 - 83	<0.1	358	7.4	285	4.696
		100 - 103	<0.1	488	6.0	294	5.131
		120 - 123	1.0	539	6.1	282	5.498
		130 - 133				308	4.279

Table 22 Pore Water results for core 51GC064

Survey	Core	Depth (cm)	NO3 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 mmol/l	SiO2 (umol/l)
51	GC064	0 - 3	2.0	10	7.7	2.208	179
		6 - 9	0.4	51	9.8	2.263	20.8
		12 - 15	0.9	75	9.2	2.449	225
		18 - 21	1.9	101	11.1	2.504	246
		30 - 33	1.9	116	9.3	2.454	237
		40 - 43	2.2	147	9.8	2.881	272
		50 - 53	1.5	164	9.3	2.810	268
		70 - 73	0.8	209	10.4	3.264	306
		90 - 93	1.1	289	7.2	3.708	268
		110 - 113	1.0	239	8.0	4.091	268
		130 - 133	0.9	330	10.8		278
		150 - 153	0.5	324	8.5	4.654	281
		170 - 173	0.5	436	11.5	5.203	290



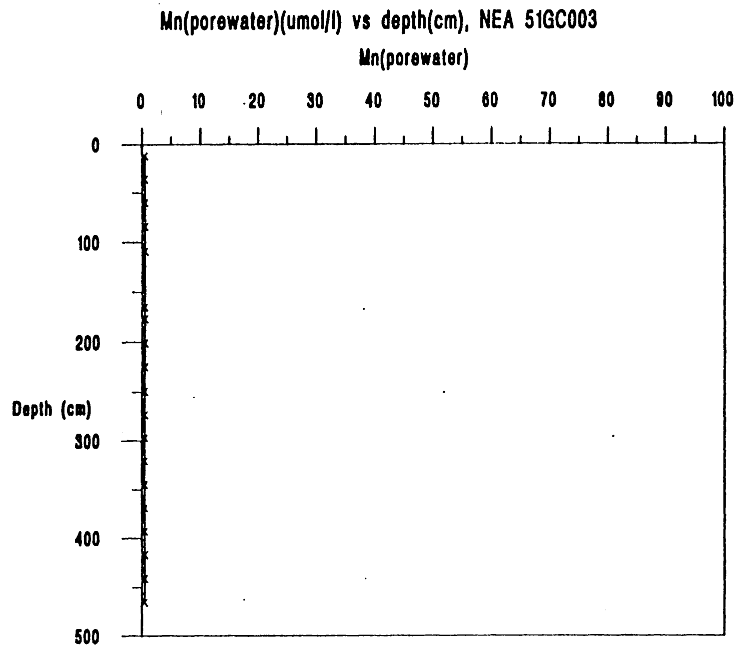
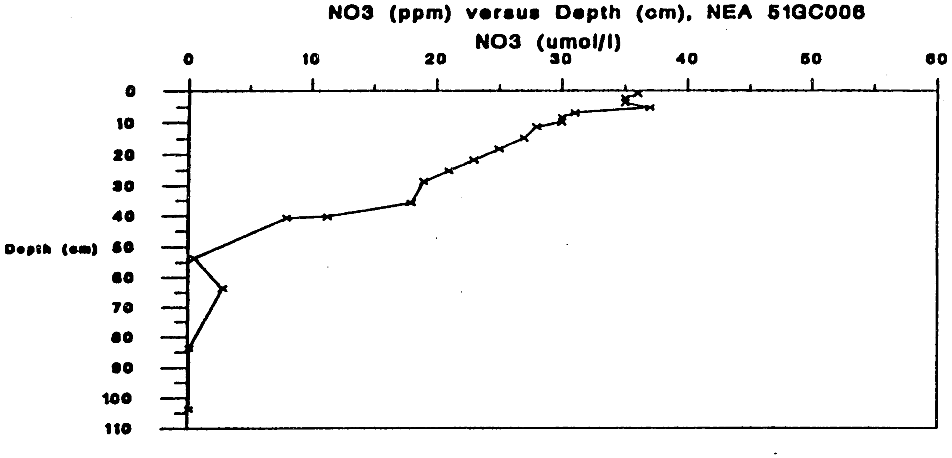
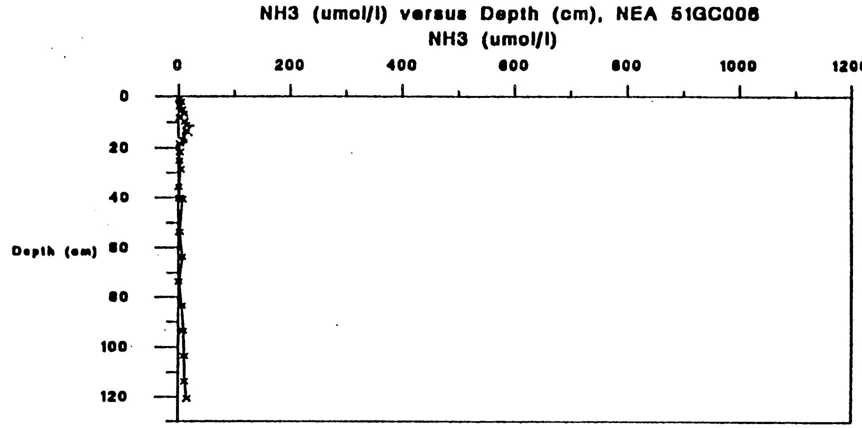


Figure 3. Down core profiles of NO_3 (μmol/l) and pore water Mn (μmol/l) from core 51GC003.





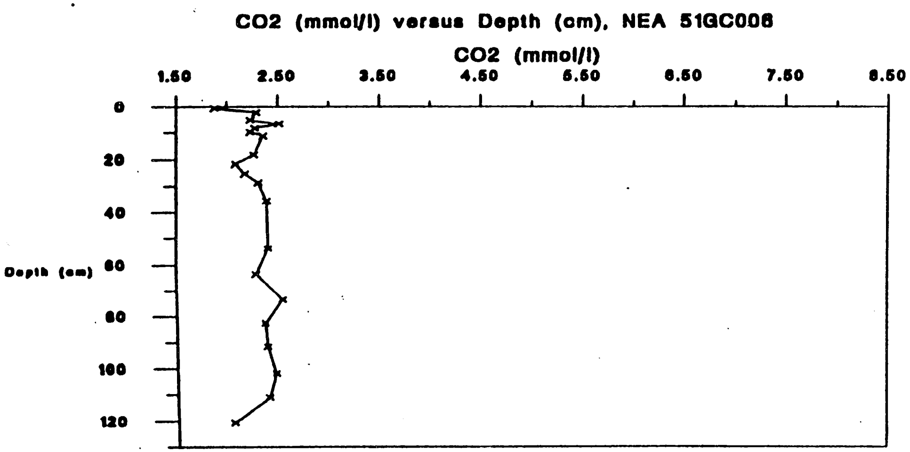
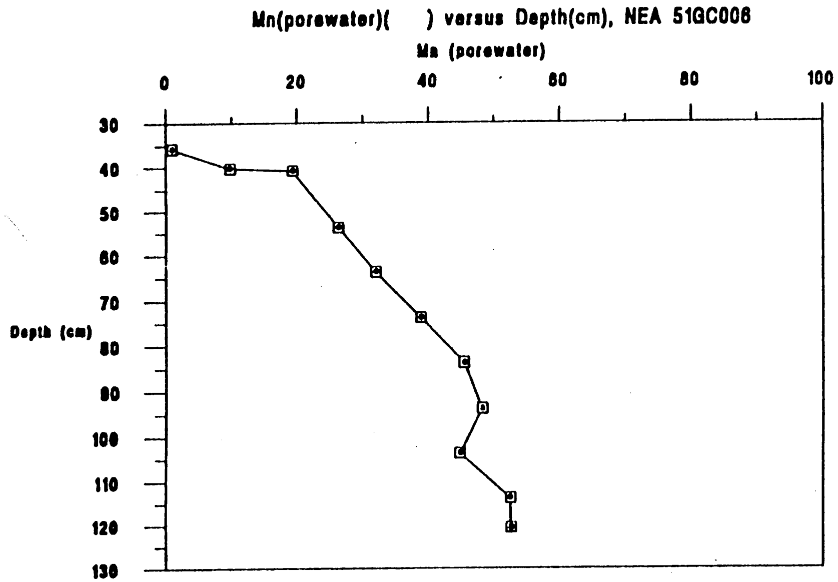


Figure 4a. Down core profiles of NO_3 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) from core 51GC006



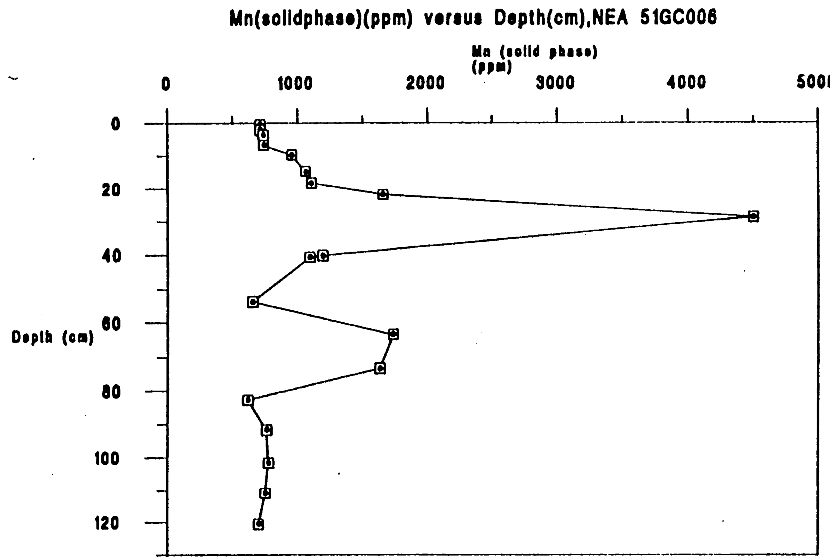
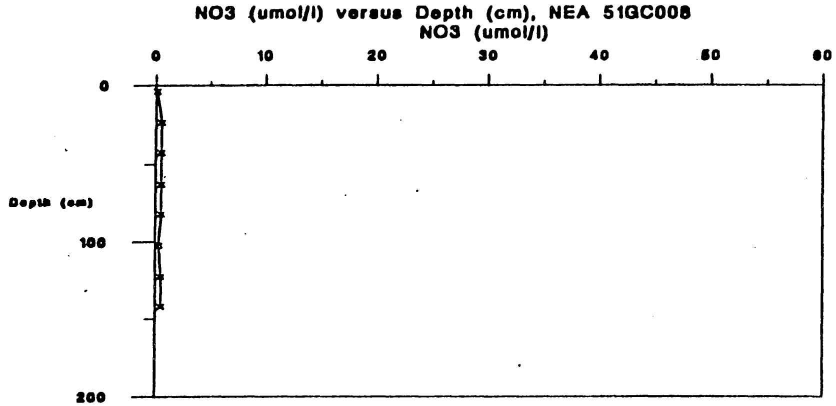
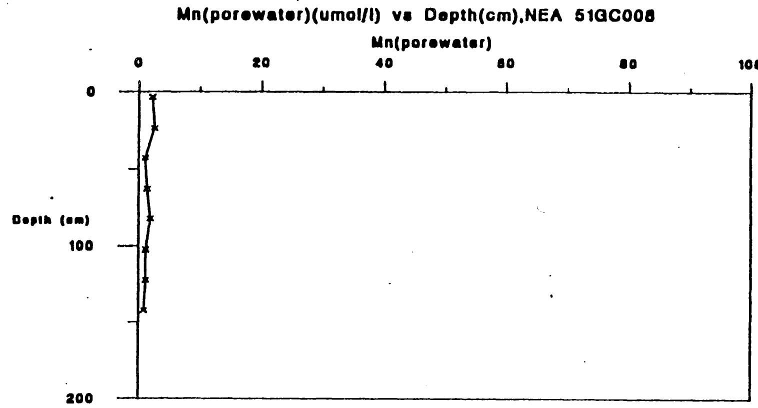


Figure 4b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC006.





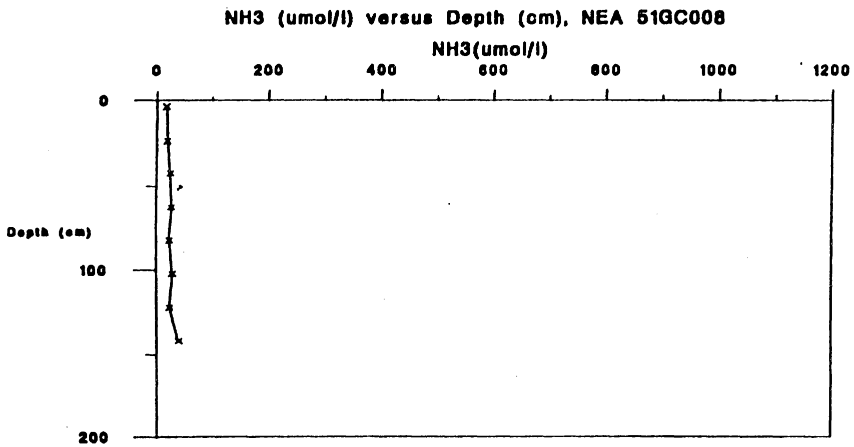
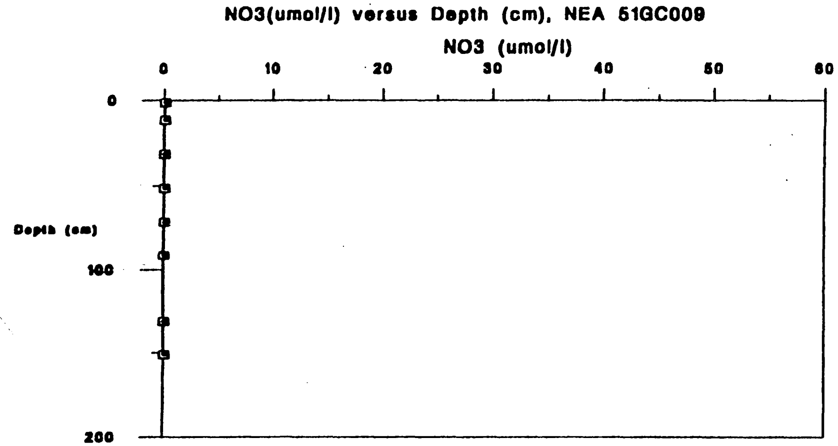
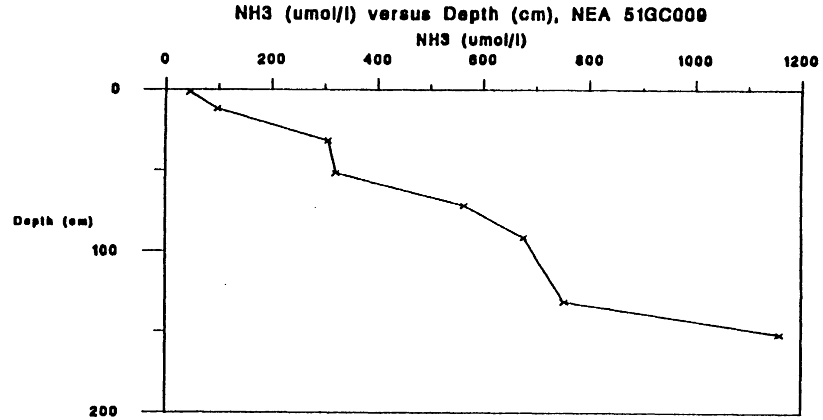


Figure 5. Down core profiles of NO_3 (μmol/l), NH_3 (μmol/l) and Mn (pore water) (μmol/l) from core 51GC008.





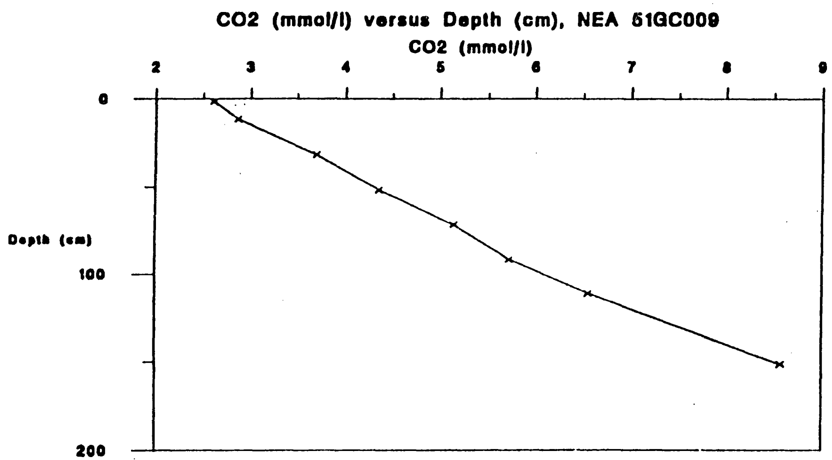
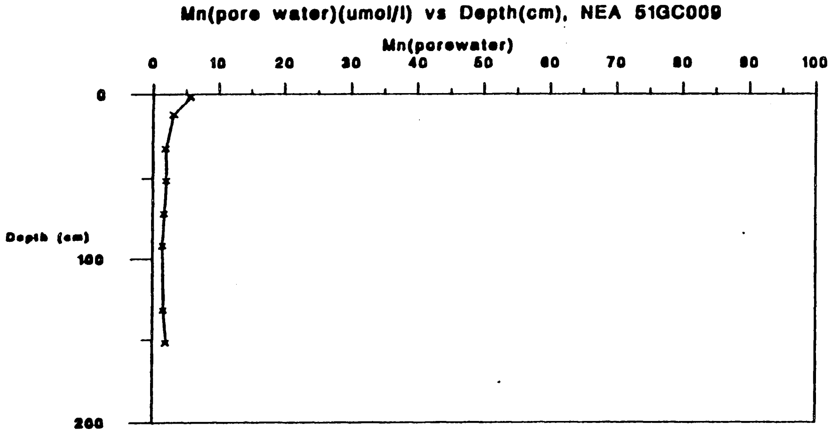


Figure 6a. Down core profiles of NO_3 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) from core 51GC009.



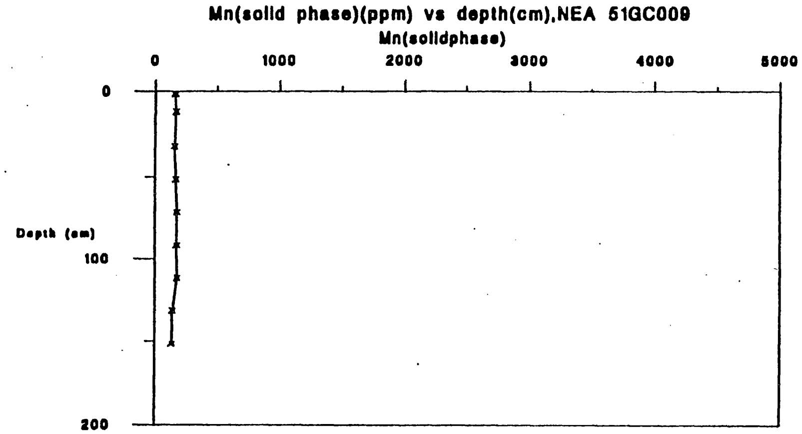
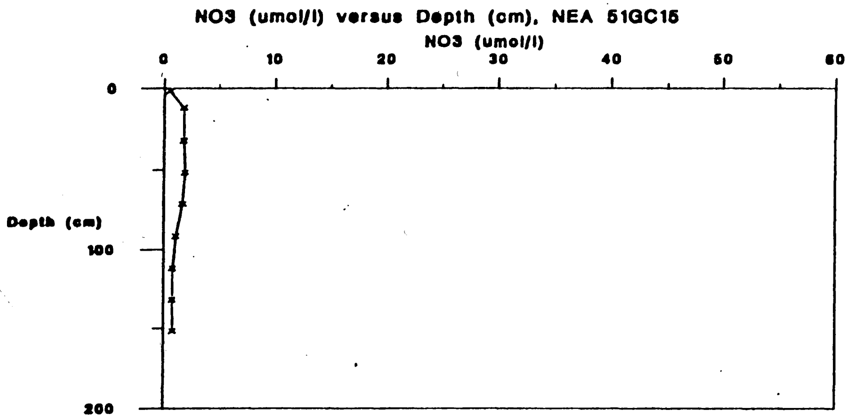
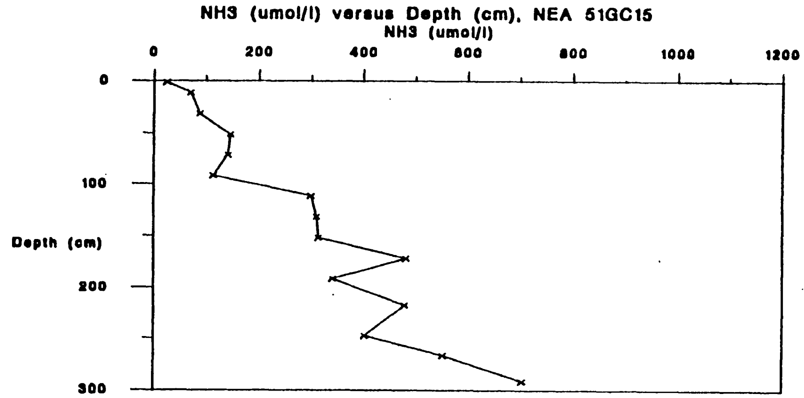


Figure 6b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC009.





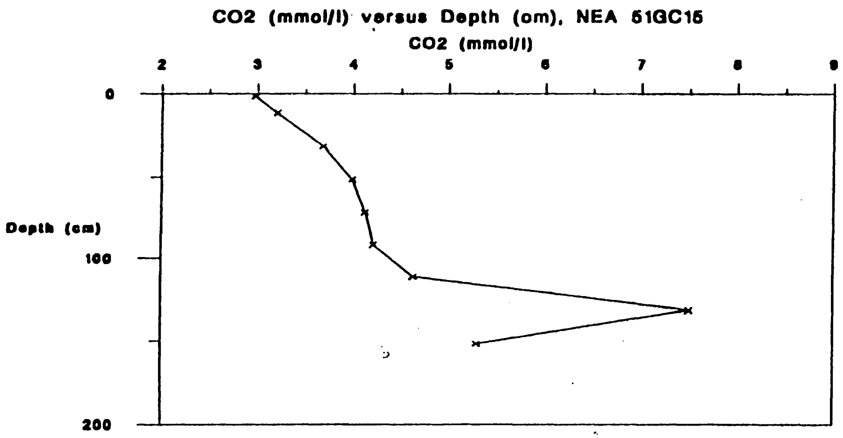
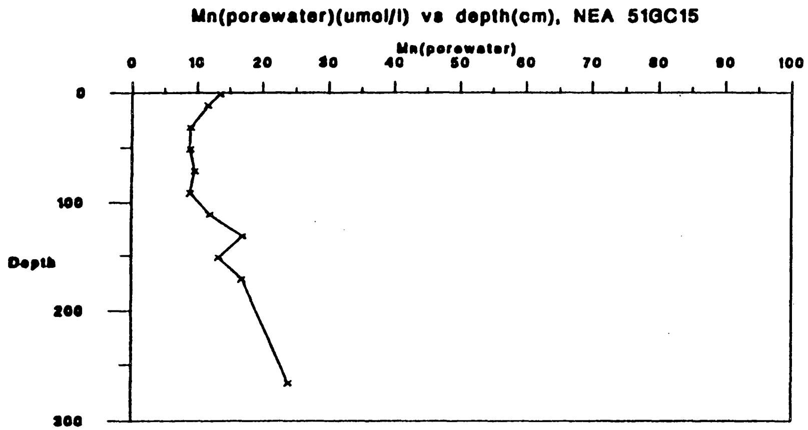


Figure 7a. Down core profiles of NO_3 (μmol/l), NH_3 (μmol/l) and CO_2 (mmol/l) from core 51GC15.



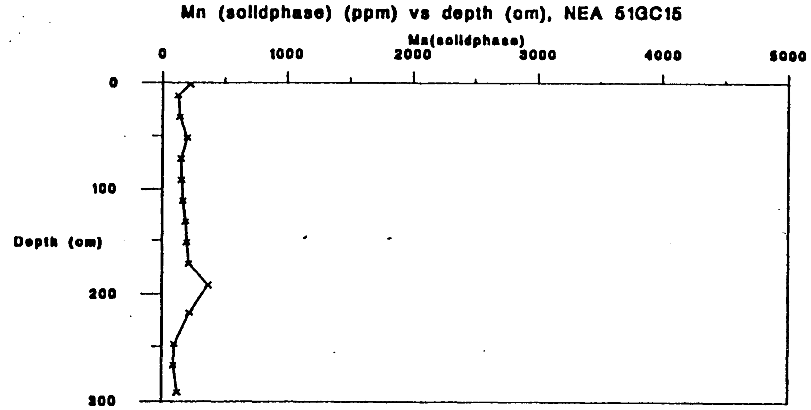


Figure 7b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC15.

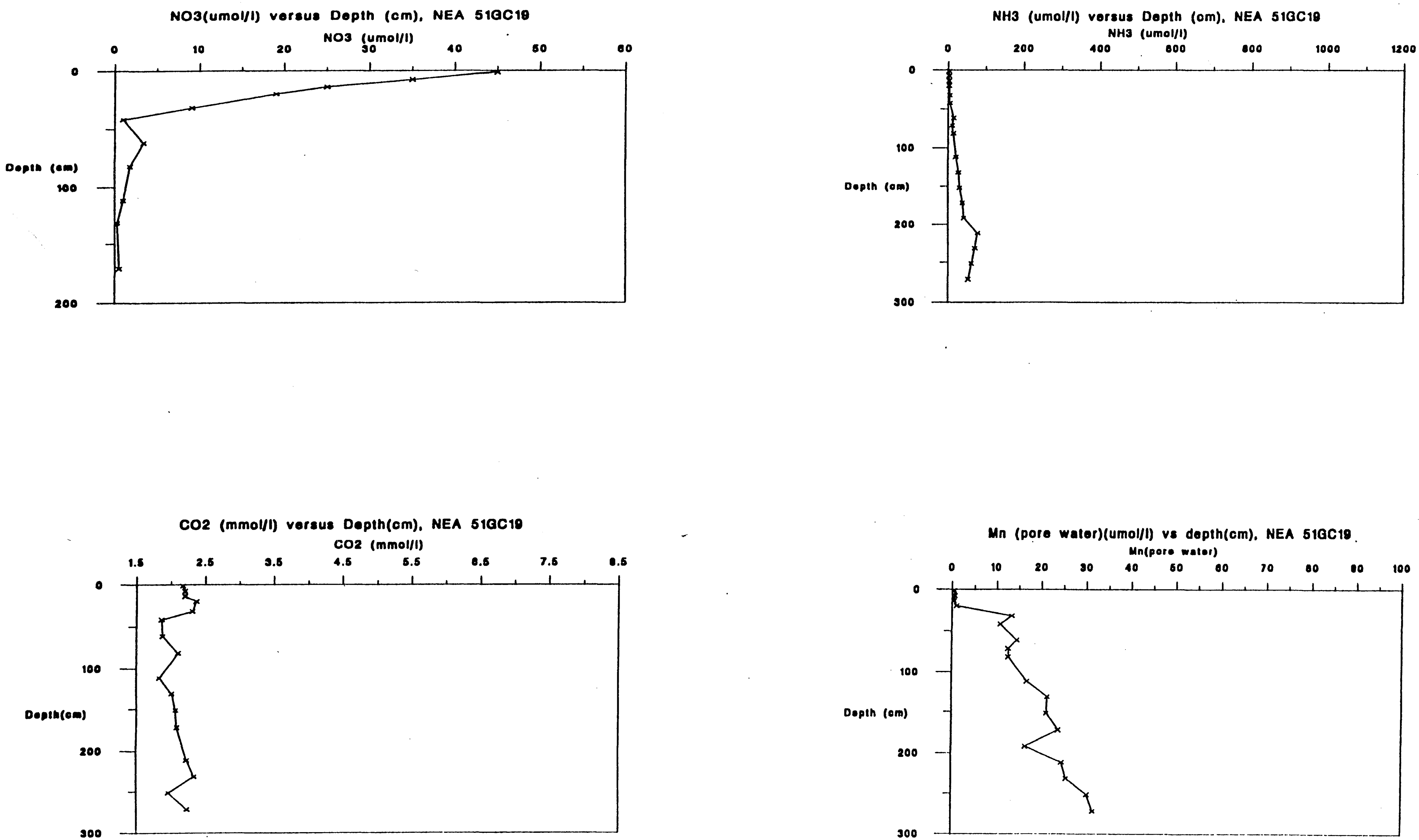
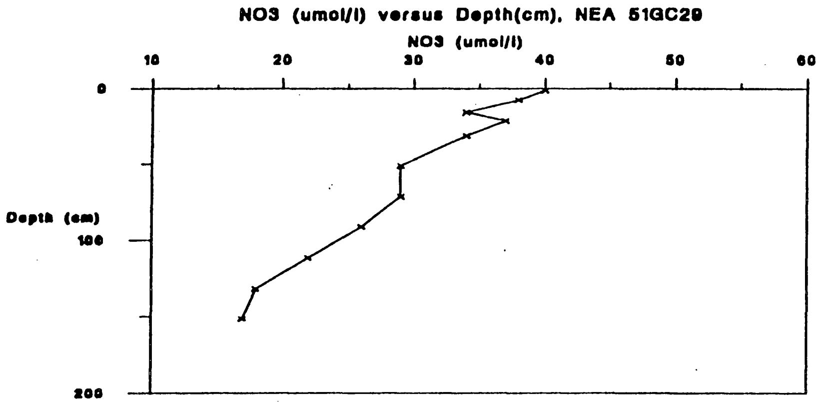
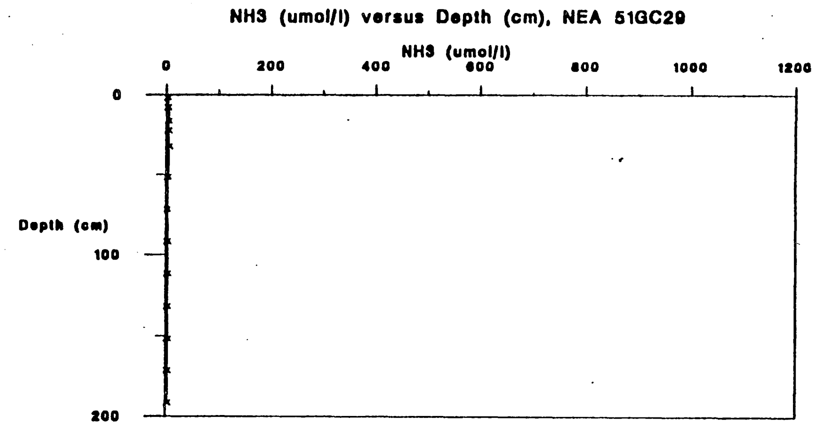


Figure 8. Down core profiles of NO_3 (µmol/l), NH_3 (µmol/l), CO_2 (mmol/l) and Mn (pore water) (µmol/l) from core 51GC19.





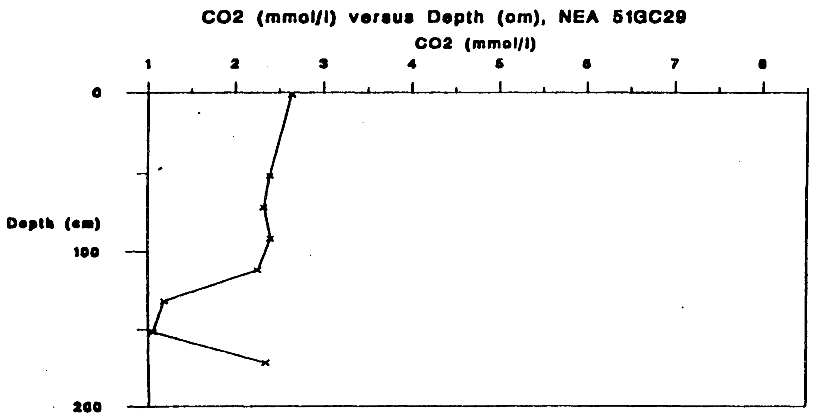


Figure 9a. Down core profiles of NO_3 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) from core 51GC29.

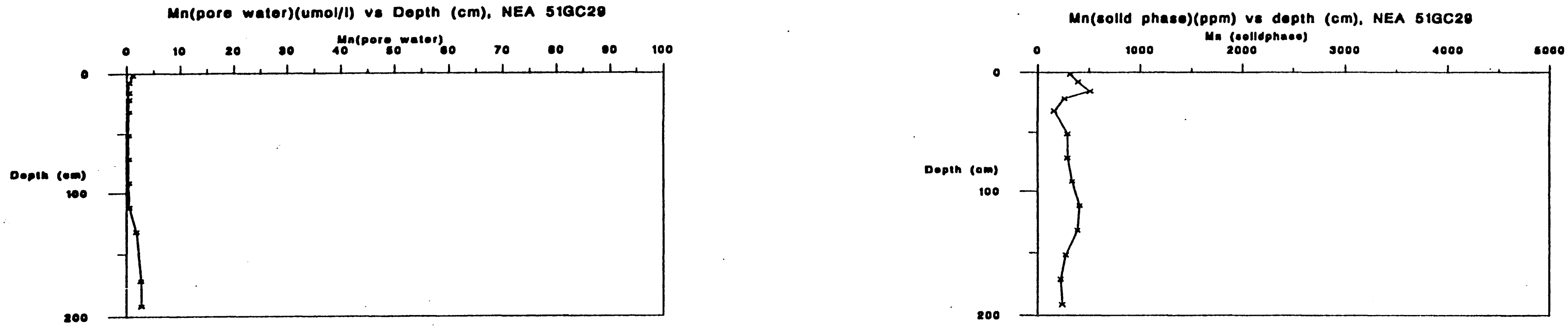
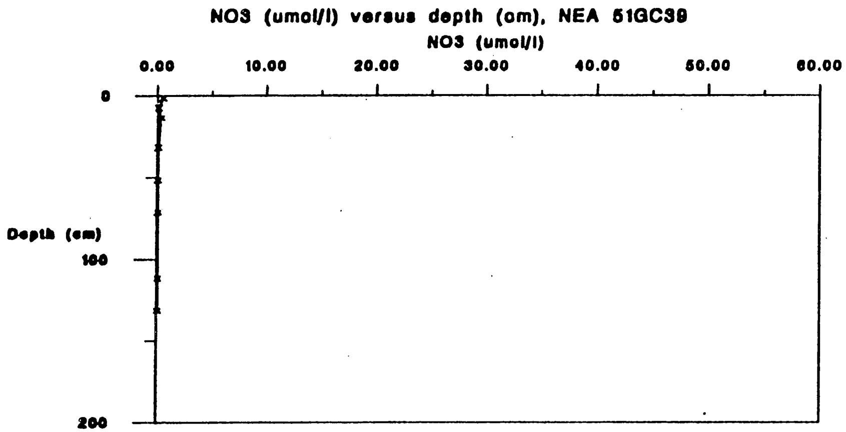


Figure 9b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC29.



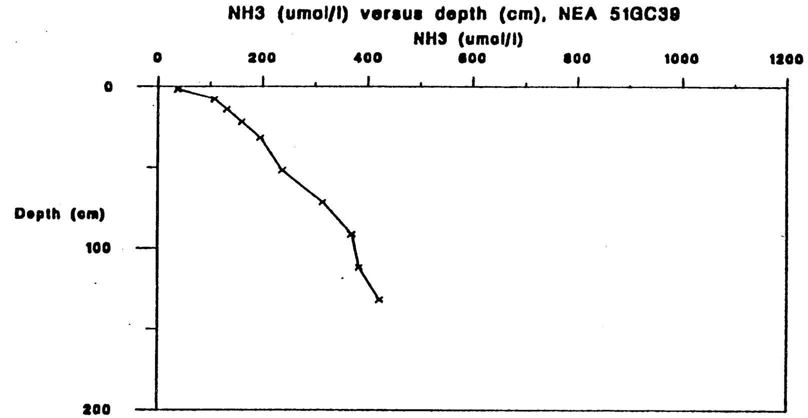
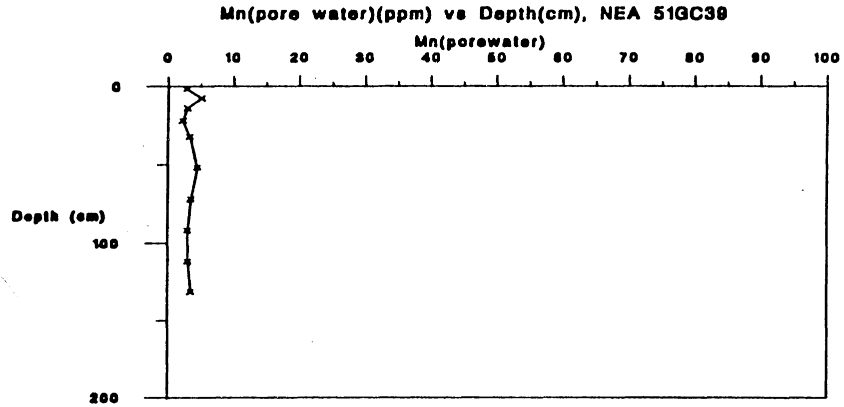


Figure 10a. Down core profiles of NO_3 (µmol/l) and NH_3 (µmol/l) from core 51GC39.



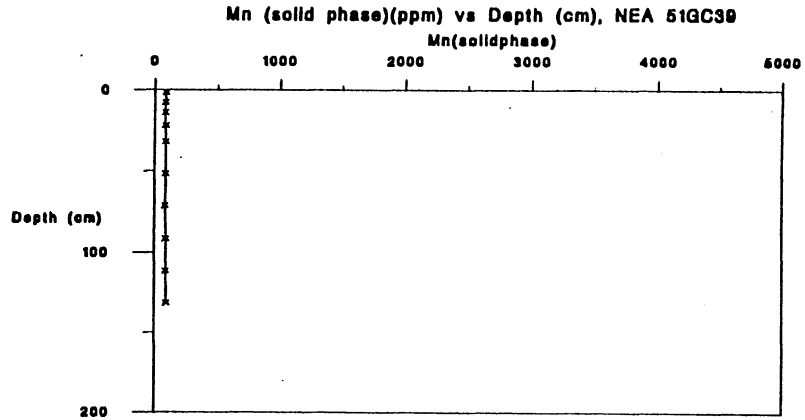
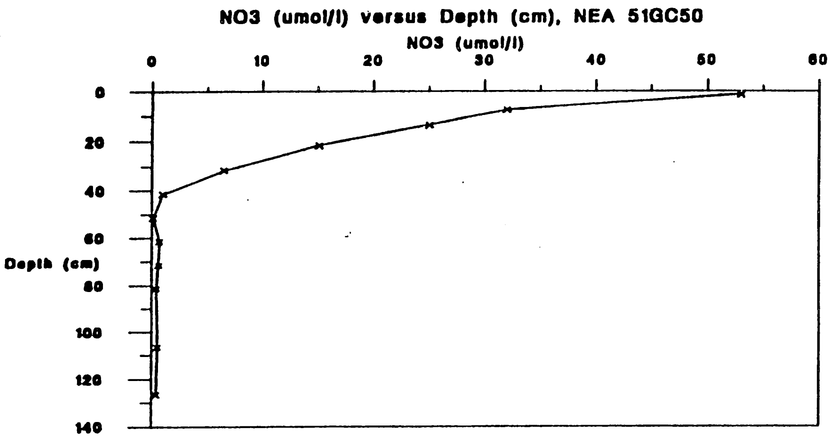


Figure 10b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC39.



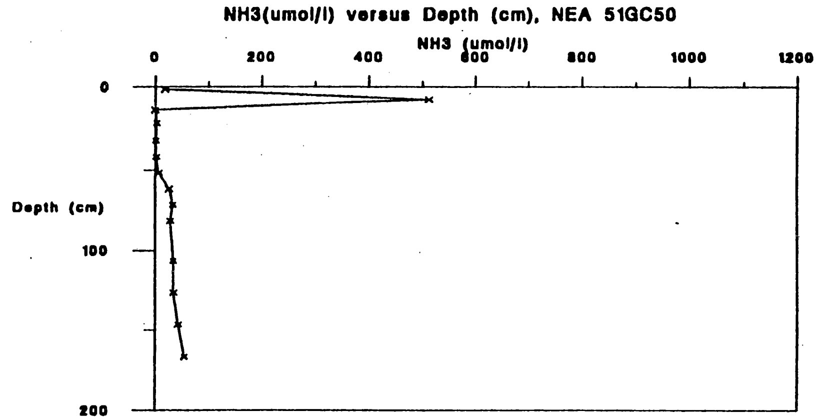


Figure 11a. Down core profiles of NO_3 (µmol/l) and NH_3 (µmol/l) from core 51GC50.

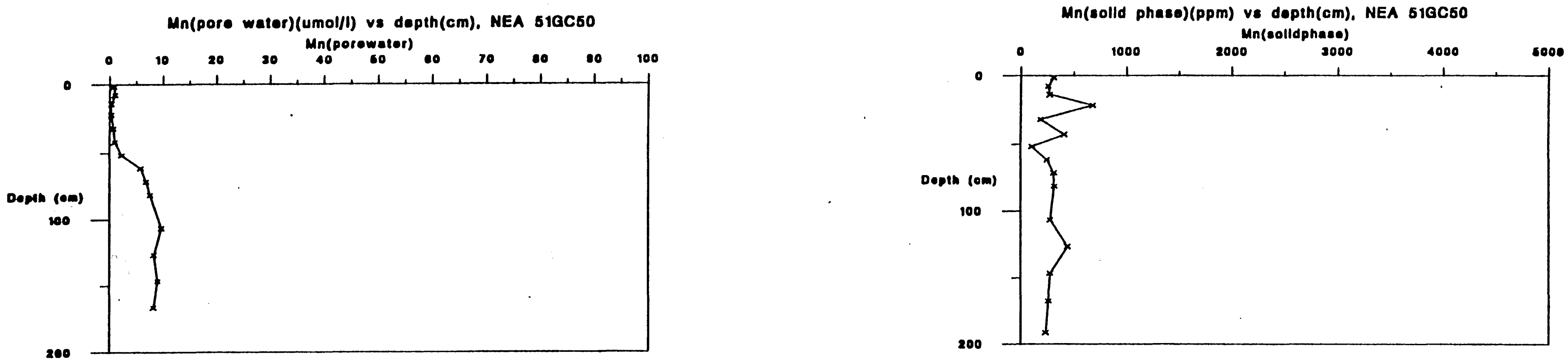


Figure 11b. Down core profiles of Mn (pore water) (μmol/l) and Mn (solid phase) (ppm) from core 51GC50.

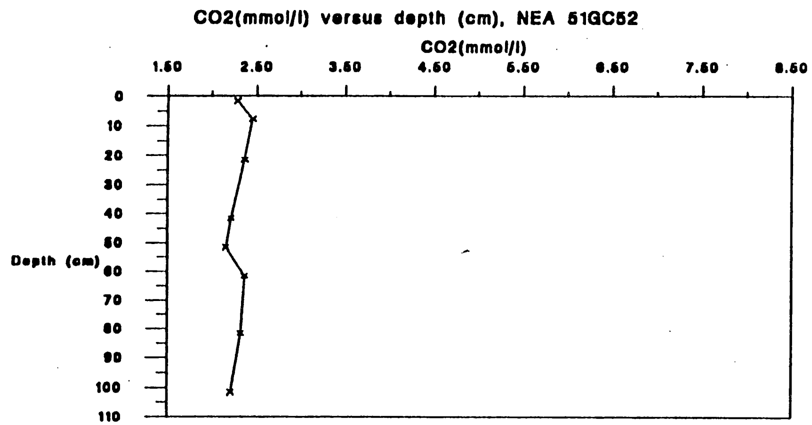


Figure 12. Down core profiles of CO_2 (mmol/l) from core 51GC52.

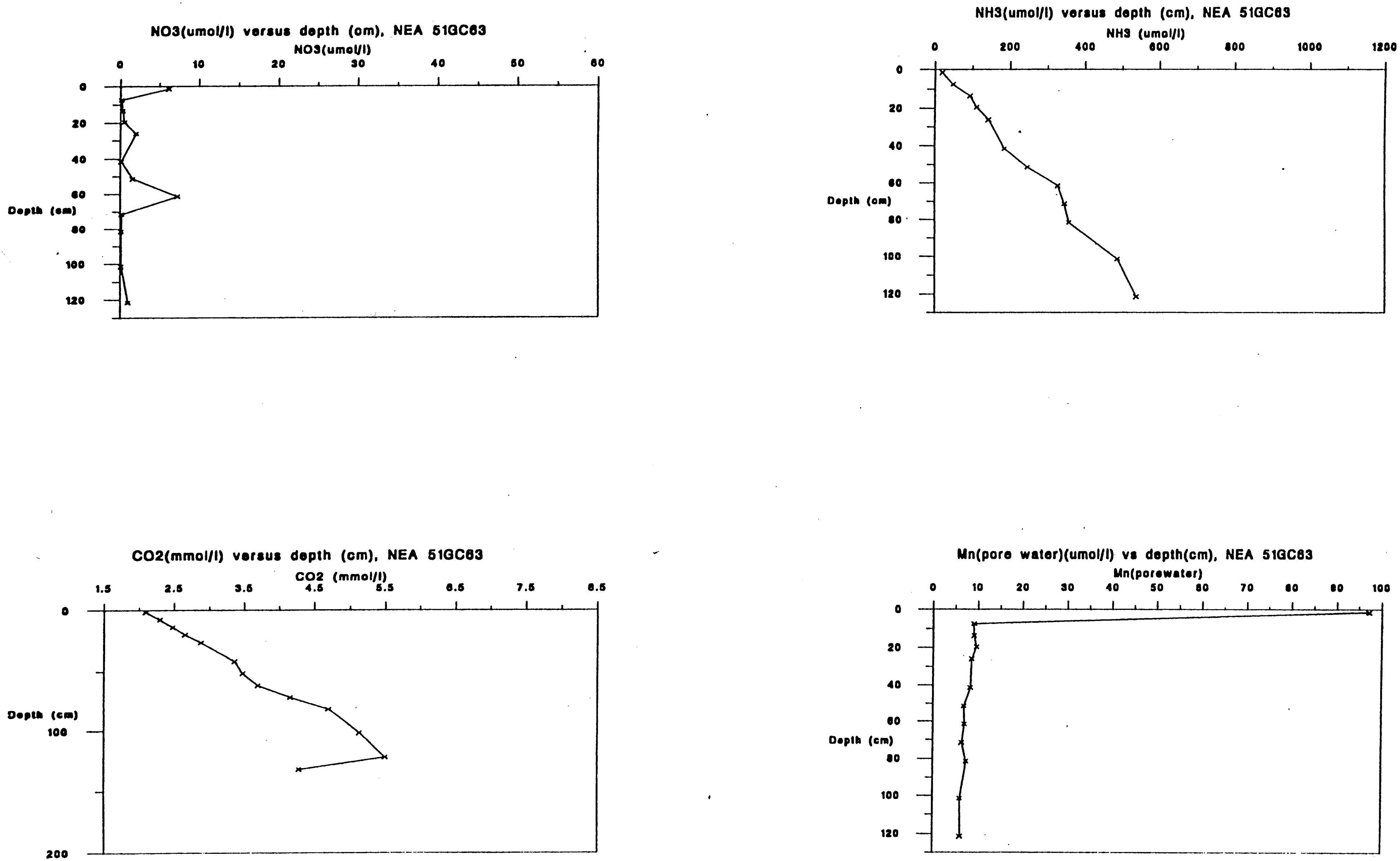


Figure 13. Down core profiles of NO_3 (μmol/l), NH_3 (μmol/l), CO_2 (mmol/l) and Mn (pore water) (μmol/l) from core 51GC63.

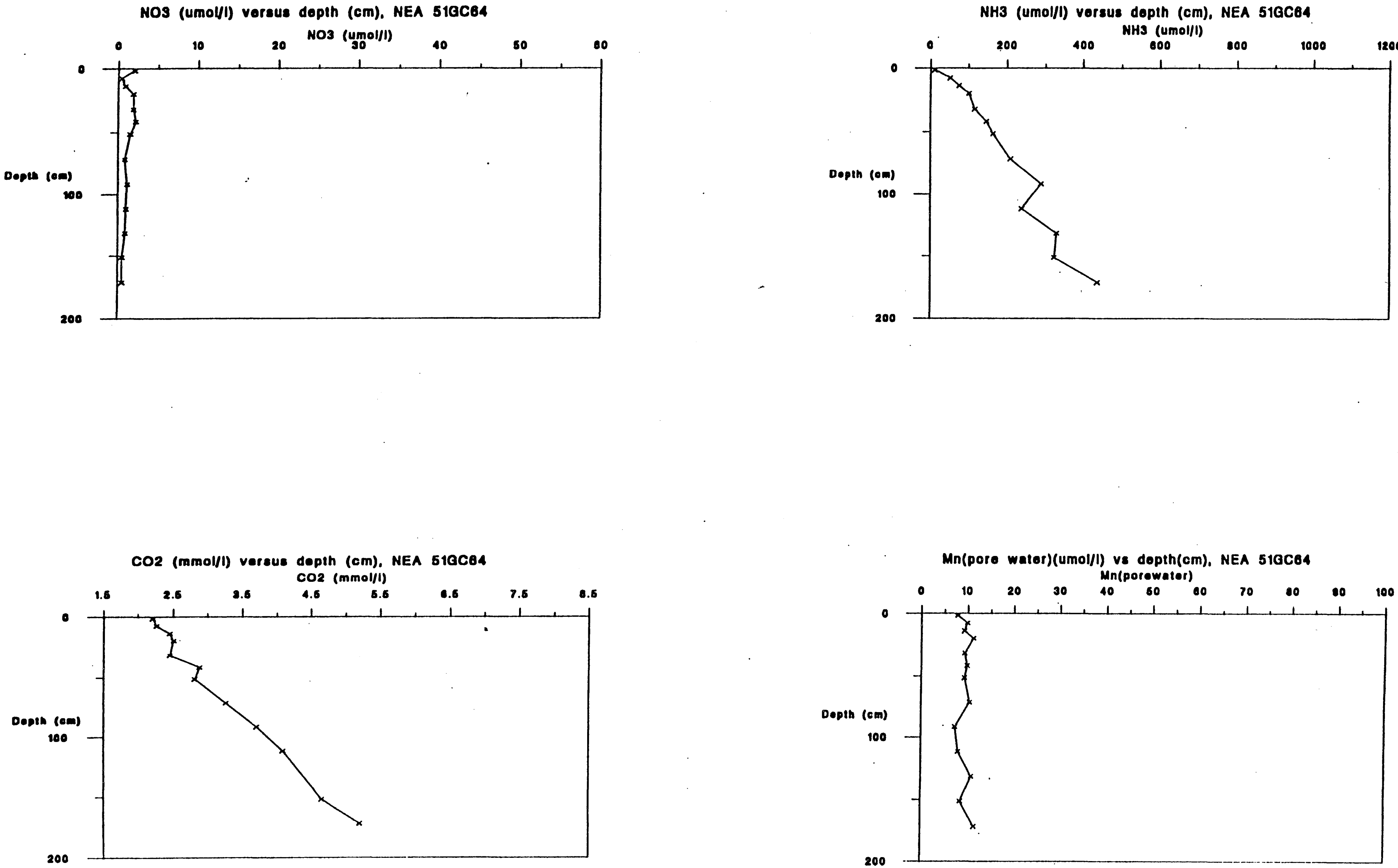


Figure 14. Down core profiles of NO_3 (µmol/l), NH_3 (µmol/l), CO_2 (mmol/l) and Mn (pore water) (µmol/l) from core 51GC64.

Sulphate reduction rates in sediments.

Ammonia concentrations in the sediments were found to increase markedly above background concentrations at relatively shallow depths in the sediments. The appearance of ammonia is indicative of sulphate reduction as indicated by equation (5) from Froelich and others (1979) shown above. The ammonia profiles have been modelled according to the rationale presented by Bender and Heggie (1984) using the rate equation shown below. The ammonia flux is estimated first, and converted to an equivalent sulphate reduction flux by the stoichiometric ratio between ammonia and sulphate ($\Delta NH_3/\Delta SO_4 = 16/53$). From this an equivalent amount of organic matter oxidised is calculated from equation 5 and the stoichiometry of $\Delta CH_2O/\Delta SO_4 = 106/53$. The results are summarised in Table 23 and the accompanying Figure 15

Rate Equations

$$-dD^2C/Dz^2 = J$$

$$J = J_o e^{-\alpha z}$$

$$C = C_o + (C_m - C_o)(1 - e^{-\alpha z})$$

At z = 0, $$dC/dz = (C_m - C_o)\alpha$$

$$F_{NH_3} = D_{NH_3}\ (Cm - Co)\alpha$$

$$F_{SO_4} = 53/16\ D_{NH_3}(Cm - Co)\alpha$$

$$C_{org} = 106/16\ F_{NH_3}$$

Table 23 Ammonia and sulphate fluxes in pore water and the calculated flux of organic carbon oxidised during sulphate reduction.

Core	$\Delta C/\Delta Z$	F_{NH_3} (μmolecm^{-2}yr^{-1})	F_{SO_4} (μmolecm^{-2}yr^{-1})	$F_{C_{org}}$ (μmolecm^{-2}yr^{-1})
51GC003	1.29e-3	0.179	0.594	3.93
51GC008	6.8e-3 1.7e-3	0.945	3.13	20.74
51GC009	2.26e-4 8.07e-3	0.031	0.104	0.689
51GC015	2.32e-3 4.51e-3	0.323	1.07	2.14
51GC019	6.2e-3 1.4e-5	0.0009 0.002	0.003 0.006	0.019 0.043
51GC039	6.74e-3 8.04e-3	0.936 1.117	3.10 3.70	20.55 24.52
51GC063	4.63e-3	0.642	2.13	14.10
51GC064	3.15e-3 4.26e-3	0.438 0.592	1.45 1.962	9.61 13.00

D_{NH_3} = 139cm^{2}yr^{-1} = pore water diffusion coefficient of ammonia

$\Delta C/\Delta Z$ is the gradient in the pore water ammonia concentration at Z = 0 (the depth where NH_3 begins to rise above background).

F_{NH_3} is the pore water ammonia flux (μmolecm^{-2}yr^{-1})

F_{SO_4} is the pore water sulphate flux (μmolecm^{-2}yr^{-1})

F_{corg} is the calculated flux of organic carbon oxidised during sulphate reduction.

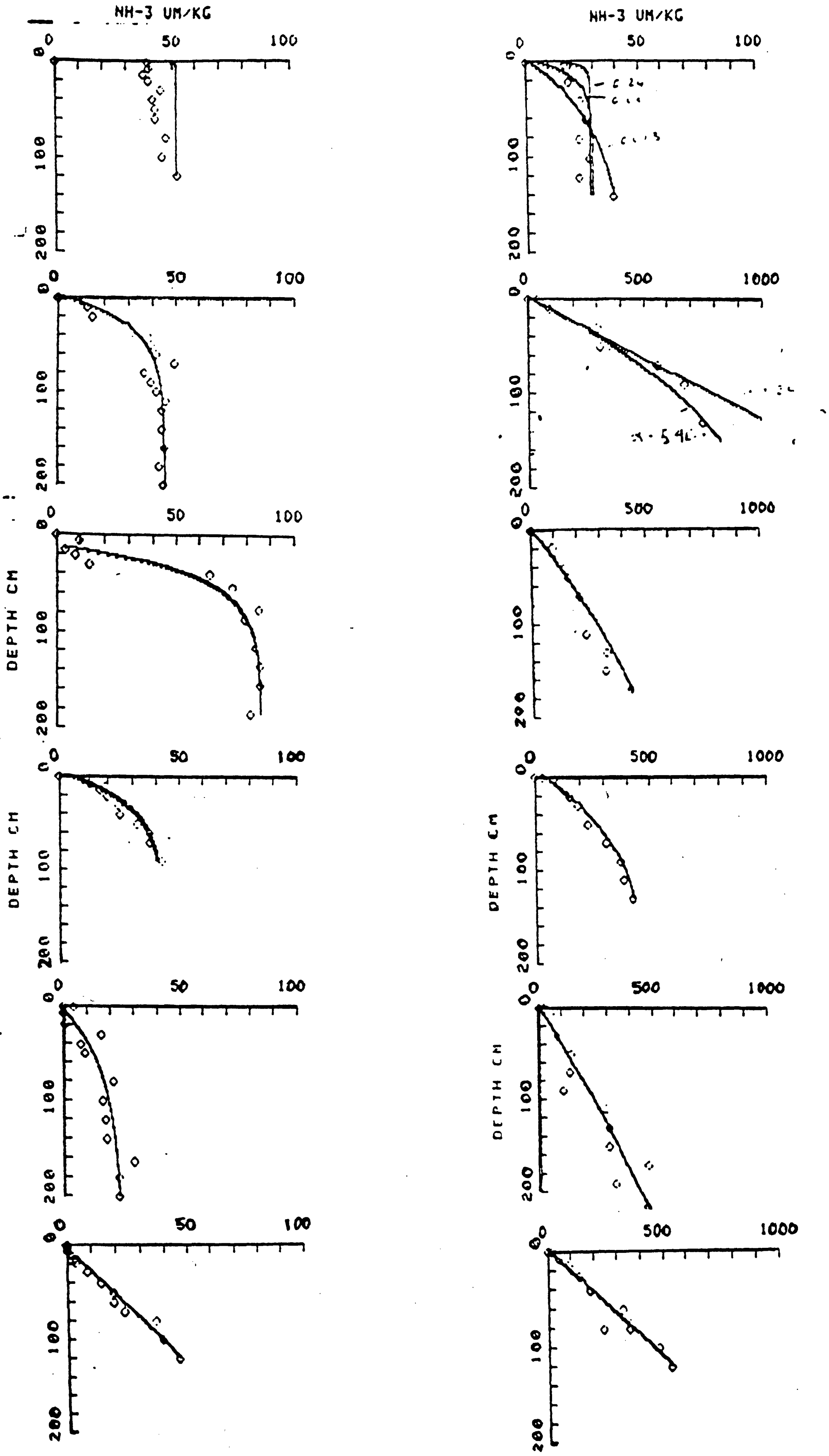


Figure 15. Ammonia profiles modelled according to Bender and Heggie (1984).

Solid Phase Major and trace element abundances

The major element and trace element analyses performed on seven cores from northeast Australia are presented in Tables 25-31. The analytical methods used in determining the major and minor elemental compositions of sediments are discussed in Cruikshank and Pyke (1993). The accuracy and precision of these analyses are also outlined.

A number of plots have been produced from these data to provide an easy and preliminary perusal of the ranges of concentrations of most elements measured. Plots have been constructed this way to provide an easy comparison of concentrations between the different geographical areas and sedimentary regimes from northeast Australia Survey 51, and from other parts of the Australian margin. These plots include Al_2O_3 versus all elements (Appendix 2). Because Fe_2O_3 and manganese oxyhydroxides (MnO_2) are major controls on trace element compositions in marine sediments, several plots (Appendix 3) show Fe_2O_3 with select major and trace elements and (Appendix 4) plot manganese (MnO_2) versus other select major and trace elements. The data tables and plots shown do not include all data. However, the results of all analyses conducted are included in the data-base.

Based on the plots, the ranges of concentrations for those elements shown are summarised in Table 32. Several of the trace elements measured (arsenic, cerium, cobalt, chromium, lanthanum, neodymium, nickel, lead, rubidium and scandium) show a co variance (although we have not statistically quantified the co-variance) with Al_2O_3, and Fe_2O_3, indicating controls on their compositions probably by clay contents and iron oxyhydroxides.

Similarly, several trace components (barium, cobalt, copper, nickel, lead) of the sediments showed a co variance (although this has not been quantified statistically) with MnO_2, indicating a control on their concentrations and distributions probably by manganese oxyhydroxide scavenging processes.

The abundances of some trace elements that are indicative of oceanographic and sedimentary processes have been normalised to aluminium abundances and these results are summarised in Appendix 5. From these data the core-top element/aluminium ratios have been assembled and these data are summarised in Table 33. The core-top element/aluminium ratios plotted as a function of water depth are shown in Figures 16 through 26. From these plots several elements (zinc, nickel, manganese, copper, barium and phosphorus) show similar features, including higher element/aluminium ratios in those mid-slope sediments (nominally defined as those between water depths of 1000-1500 m) than those found in upper-slope sediments (water depths <1000 m) and lower-slope sediments (water depths>1500 m). The two cores which have the highest element/aluminium ratios are 57GC29 and 57GC50, both of which are found in the trough or on the flank of the Queensland Plateau (Fig. 1). In these cores the pore water data indicate oxic to sub-oxic near-surface sediments and evidence of manganese reduction and remobilisation at depths below about 50 cm. The core-top enrichments of these elements may (in part) be related to scavenging of these elements from the water column and preservation in oxic surface sediments, with little diagenetic remobilisation from the core-tops. In contrast, the lowest element /aluminium ratios were measured on the upper-slope sediments (<500 m), and here the pore water data show no nitrate and high ammonia concentrations in the near surface sediments, and these data are indicative of anoxic sediments. The relative depletion of these elements in sediments suggests reductive remobilisation and loss from the sediments to the overlying bottom waters in these upper-slope cores.

The relative abundances of these elements (normalised to aluminium) in sediments from north-east Australia are compared with those from the southern margins of South Australia, Victoria and West Tasmania in the table below.

Table 24. Comparison of element abundances in surface sediments between north east and south east Australia (the water depth ranges reported are for the highest ratios).

ELEMENT	SOUTH EAST AUSTRALIA		NORTH EAST AUSTRALIA	
	Range	WD range	Range	WD range
Phosphorus	<0.1	<1000	<0.03	1000-2000
Silicon	2.0-6.0	<1500	2.0-5.0	<1000
Strontium	200-5000	<1000	500-3500	<1500
Chromium	10-45	<1500	2-18	500-1000
Vanadium	15-50	<500	10-16	<1500
Barium	0-600	>1500	25-350	1000-2000
Copper	2-25	>1500	3-35	1000-2000
Manganese	25-300	>2000	50-600	1000-2000
Zinc	10-20	<1000	5-40	1000-2000
Nickel	6-18	<1000	2-35	1000-2000
Titanium	<0.1	>3000	<0.1	<1000

Table 25 Major and trace element analyses for core 51GC006

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I.
51	GC006	0-1.5	16.16	0.29	6.02	2.23	0.21	0.09	36.09	1.11	1.58	0.64	0.08	0.10	35.44
	GC006	1.5-3.0	15.70	0.29	5.86	2.22	0.16	0.09	37.06	1.07	1.37	0.57	0.05	0.08	35.39
	GC006	3.0-4.5	16.21	0.30	6.11	2.29	0.18	0.09	36.76	1.05	1.42	0.63	0.08	0.09	34.80
	GC006	6.0-7.5	17.58	0.32	6.62	2.46	0.17	0.10	35.92	1.03	1.39	0.68	0.08	0.09	33.89
	GC006	9.0-10.5	20.66	0.37	7.94	2.96	0.18	0.13	32.18	1.14	1.59	0.81	0.09	0.09	31.99
	GC006	14.0-15.5	20.31	0.36	7.65	2.93	0.16	0.14	33.19	1.07	1.58	0.81	0.09	0.09	31.98
	GC006	17.5-19.0	22.03	0.39	8.25	3.14	0.17	0.14	30.77	1.11	1.56	0.86	0.06	0.08	31.81
	GC006	21.0-22.5	20.89	0.37	7.71	3.17	0.11	0.21	32.01	1.12	1.65	0.82	0.09	0.09	31.69
	GC006	28.0-29.5	19.02	0.35	7.12	3.19	<0.01	0.60	33.59	1.13	1.51	0.75	0.09	0.09	32.63
	GC006	40.0-41.5	17.74	0.32	6.63	2.57	0.27	0.15	35.42	1.02	1.45	0.72	0.09	0.09	33.34
	GC006	46.5-48.0	17.10	0.30	6.44	2.47	0.25	0.13	33.42	1.01	2.47	0.80	0.06	0.08	35.83
	GC006	53.0-54.5	17.23	0.31	6.42	2.37	0.39	0.08	36.12	0.99	1.56	0.70	0.08	0.09	34.05
	GC006	62.5-64.5	16.80	0.31	6.32	2.55	0.18	0.22	36.04	0.98	1.45	0.69	0.09	0.09	34.19
	GC006	72.5-74.5	24.81	0.44	9.09	3.66	0.28	0.21	27.49	1.35	1.69	0.99	0.10	0.08	29.97
	GC006	82.0-83.5	26.87	0.40	7.57	2.60	0.42	0.08	28.84	1.18	1.51	0.95	0.08	0.09	29.54
	GC006	91.0-92.5	21.06	0.38	7.61	2.59	0.46	0.10	31.88	1.17	1.60	0.87	0.08	0.09	32.31
	GC006	101.0-102.5	23.38	0.41	8.54	2.87	0.48	0.11	30.84	1.24	1.54	0.94	0.09	0.09	28.83
	GC006	110.5-112.0	22.91	0.41	8.39	2.59	0.67	0.10	30.01	1.17	1.54	0.94	0.09	0.09	31.38
	GC006	120.0-121.5	27.07	0.46	9.05	3.01	0.50	0.09	27.03	1.29	1.62	1.08	0.08	0.09	28.73

Table 25 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC006	0-1.5					11			53			710				27		
	GC006	1.5-3.0	3.5	312	1	15	10	29	<3	51	6	5	710	3	5	8	27	9	4
	GC006	3.0-4.5	2.5	330		18	11	33	5	55		11	737	9		10	27	7	
	GC006	6.0-7.5	3.5	374		21	12	38	4	56		12	740	5		11	31	9	
	GC006	9.0-10.5	6.5	477		28	13	49	7	60		16	954	8		15	33	10	
	GC006	14.0-15.5	4.5	526		26	13	44	3	58		17	1059	8		15	36	11	
	GC006	17.5-19.0	4.0	469	2	19	12	39	3	55	7	12	1105	7	5	13	41	13	<3
	GC006	21.0-22.5	5.0	671		25	15	45	4	57		17	1656	11		17	43	10	
	GC006	28.0-29.5	5.0	644		22	18	42	5	62		18	4500	13		16	36	10	
	GC006	40.0-41.5	3.5	472		20	14	35	4	53		13	1191	8		12	30	12	
	GC006	46.5-48.0	4.0	455	1	19	13	32	<3	49	7	11	1090	7	4	12	32	10	<3
	GC006	53.0-54.5	4.0	510		19	10	36	5	47		13	649	6		11	25	9	
	GC006	62.5-64.5	4.0	445		18	16	32	3	51		14	1735	8		11	38	10	
	GC006	72.5-74.5	7.5	627		31	20	54	8	77		20	1633	6		20	46	11	
	GC006	82.0-83.5	4.0	441		27	12	51	6	29		17	616	6		15	28	10	
	GC006	91.0-92.5	4.5	356		22	13	44	7	29		12	761	5		12	30	9	
	GC006	101.0-102.5	7.0	407		28	13	48	4	42		18	774	4		14	31	9	
	GC006	110.0-112.5	9.5	470		34	16	59	4	36		17	751	5		15	38	14	
	GC006	120.0-121.5	5.0	325		25	14	49	6	29		15	699	4		13	29	10	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC006	0-1.5									47	
	GC006	1.5-3.0	27	24	<2	1053	2	<0.5	41	16	44	64
	GC006	3.0-4.5	26	23		1050	3		46		46	62
	GC006	6.0-7.5	31	24		1068	3		53		47	66
	GC006	9.0-10.5	40	27		1051	4		74		55	76
	GC006	14.0-15.5	38	26		1029	4		74		54	73
	GC006	17.5-19.0	42	23	<2	948	4	1.5	59	26	56	80
	GC006	21.0-22.5	37	27		967	4		80		57	76
	GC006	28.0-29.5	33	27		1008	2		78		54	69
	GC006	40.0-41.5	30	24		1036	3		67		51	64
	GC006	46.5-48.0	30	26	<2	998	4	0.5	54	21	51	64
	GC006	53.0-54.5	28	24		1054	4		64		49	61
	GC006	62.5-64.5	27	22		1052	2		57		49	67
	GC006	72.5-74.5	42	31		858	5		97		65	96
	GC006	82.0-83.5	41	28		962	3		72		55	117
	GC006	91.0-92.5	37	24		952	3		59		57	76
	GC006	101.0-102.5	41	26		874	3		66		59	83
	GC006	110.0-112.5	48	30		776	4		102		69	94
	GC006	120.0-121.5	47	24		1042	5		63		57	104

Table 26 Major and trace element analyses for core 51GC009

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I
51	GC009	0-3	16.27	0.27	5.30	1.45	0.29	0.02	35.85	2.44	1.35	0.63	0.07	0.17	35.88
	GC009	10-13	16.89	0.27	5.54	1.63	0.28	0.01	35.03	2.47	1.22	0.66	0.06	0.23	35.28
	GC009	30-33	15.83	0.26	5.30	1.49	0.28	0.01	35.76	2.46	1.27	0.69	0.05	0.27	35.69
	GC009	50-53	16.69	0.28	5.52	1.66	0.23	0.02	35.64	2.77	1.15	0.65	0.06	0.30	35.12
	GC009	70-73	18.37	0.30	6.38	1.91	0.24	0.02	33.28	2.57	1.23	0.72	0.07	0.31	33.94
	GC009	90-93	18.18	0.31	6.34	1.91	0.20	0.01	33.74	2.52	1.24	0.71	0.06	0.30	34.06
	GC009	110-113	17.74	0.30	5.94	1.83	0.23	0.02	34.40	2.53	1.17	0.67	0.07	0.33	34.24
	GC009	130-133	19.30	0.31	6.21	1.86	0.30	0.02	33.49	2.47	1.32	0.77	0.10	0.38	32.81
	GC009	150-153	19.94	0.32		1.76	0.30	0.02	33.63	2.43	1.18	0.72	0.09	0.37	32.59

Table 26 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Co (ppm)	Ce (ppm)	Cu (ppm)	Cr (ppm)	Cs (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC009	0-3	1.5	72	1	6	25	9	40	<3	6	9	157	6	4	10	16	12	<3
	GC009	10-13	2.5	78	<1	6	25	10	44	<3	6	8	164	3	4	12	16	7	<3
	GC009	30-33	1.5	82	2	6	19	10	42	7	6	11	155	6	3	10	15	8	<3
	GC009	50-53	2.0	72	1	6	23	10	39	<3	5	11	164	7	4	9	17	6	<3
	GC009	70-73	2.0	80	1	7	25	10	44	6	6	11	176	8	5	11	18	7	<3
	GC009	90-93	2.0	77	2	7	22	10	42	4	7	12	172	3	5	11	20	7	<3
	GC009	110-113	2.0	76	2	7	21	10	41	3	7	10	176	5	5	11	17	7	<3
	GC009	130-133	3.0	90		8	27	11	47	5		14	139	4		14	17	6	
	GC009	150-153	2.0	86		8	31	11	47	4		16	132	6		14	17	8	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC009	0-3	30	24	<2	2747	4	2.5	30	13	28	65
	GC009	10-13	33	25	<2	2707	4	2.5	31	13	34	70
	GC009	30-33	31	26	<2	2730	3	2	26	12	29	63
	GC009	50-53	32	25	2	2671	4	3	29	12	30	65
	GC009	70-73	37	26	<2	2513	5	3	34	14	34	70
	GC009	90-93	37	25	2	2512	4	3.5	30	13	33	69
	GC009	110-113	34	24	<2	2529	4	3.5	29	13	31	69
	GC009	130-133	37	24		2455	5		37		32	73
	GC009	150-153	37	23		2499	4		36		29	84

Table 27 Major and trace element analyses for core 51GC015

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
51	GC015	0-3	18.54	0.29	5.75	1.69	0.28	0.02	34.51	2.05	1.15	0.67	0.07	0.14	34.45
	GC015	9-12	18.82	0.31	6.17	1.81	0.30	0.02	34.49	2.05	1.30	0.73	0.09	0.16	33.29
	GC015	30-33	19.07	0.33	6.44	1.82	0.34	0.02	34.35	2.13	0.97	0.76	0.10	0.16	33.68
	GC015	50-53	20.61	0.33	6.64	2.01	0.23	0.02	32.42	2.06	1.28	0.76	0.07	0.17	33.00
	GC015	70-73	20.82	0.35	6.77	2.05	0.29	0.02	33.11	2.05	1.15	0.80	0.10	0.19	32.45
	GC015	90-93	22.62	0.37	7.04	2.05	0.33	0.03	31.98	2.05	1.11	0.88	0.10	0.21	31.21
	GC015	110-113	21.79	0.36	6.84	2.00	0.31	0.03	31.93	2.09	1.32	0.79	0.10	0.22	32.22
	GC015	130-133	23.34	0.39	7.62	2.29	0.29	0.03	29.54	2.07	1.50	0.86	0.10	0.23	31.69
	GC015	150-153	26.22	0.44	8.41	2.47	0.33	0.03	27.53	2.03	1.33	0.96	0.10	0.25	29.74
	GC015	170-173	31.34	0.52	9.57	2.79	0.36	0.03	23.35	1.90	1.65	0.13	0.09	0.28	27.03
	GC015	190-193	36.95	0.67	13.40	3.94	0.41	0.05	15.29	1.82	1.56	0.38	0.10	0.44	23.50
	GC015	215-218	28.44	0.51	9.76	2.84	0.52	0.03	23.87	0.79	1.32	0.10	0.12	0.36	28.82
	GC015	240-243	17.74	0.27	5.26	1.32	0.25	0.01	37.06	0.61	1.16	0.68	0.08	0.14	34.85
	GC015	265-268	23.35	0.31	6.34	1.68	0.26	0.01	33.47	0.11	1.00	0.86	0.08	0.14	31.38
	GC015	290-293	20.53	0.34	6.26	1.87	0.33	0.02	32.83	2.06	1.32	0.78	0.09	0.40	32.69

Table 27 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC015	0-3	2.0	119	2	22	6	42	<3	13	6	9	220	3	4	10	16	60	3
	GC015	10-13	1.0	122		26	8	44	6	14		13	123	6		11	16	12	
	GC015	30-33	1.5	138		29	8	49	5	14		15	139	8		13	17	6	
	GC015	50-53	1.5	115	<1	22	7	42	<3	14	7	12	196	5	5	9	18	8	<3
	GC015	70-73	2.0	135		30	8	51	5	14		14	150	3		15	18	8	
	GC015	90-93	1.5	136		33	9	52	4	13		16	152	4		15	20	9	
	GC015	110-113	1.5	123		27	8	47	5	13		14	166	5		13	18	7	
	GC015	130-133	1.0	123		27	9	48	3	14		15	187	4		15	20	9	
	GC015	150-153	3.0	135		35	10	55	4	14		17	197	4		16	21	9	
	GC015	170-173	3.5	136		39	10	58	4	13		19	211	5		17	22	10	
	GC015	190-193	12.0	146		56	12	84	5	15		27	368	5		23	30	15	
	GC015	215-218	12.0	133		48	9	73	4	14		23	217	4		21	25	11	
	GC015	240-243	5.0	168		31	8	44	6	16		17	97	10		14	16	10	
	GC015	265-268	1.0	131		23	7	45	6	13		13	93	6		10	15	7	
	GC015	290-293	3.0	108		24	8	50	3	11		13	121	4		12	18	6	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC015	0-3	34	26	<2	2586	4	3	32	14	34	128
	GC015	10-13	36	22		2499	5		38		36	90
	GC015	30-33	39	25		2531	5		42		35	83
	GC015	50-53	39	26	2	2333	5	3	35	15	38	128
	GC015	70-73	42	25		2376	4		42		37	93
	GC015	90-93	43	25		2251	5		44		37	106
	GC015	110-113	41	23		2254	4		39		35	96
	GC015	130-133	44	26		2078	5		40		39	108
	GC015	150-153	50	25		1946	6		50		40	119
	GC015	170-173	57	23		1646	7		50		42	155
	GC015	190-193	84	24		1098	10		74		51	184
	GC015	215-218	61	25		1772	8		65		42	144
	GC015	240-243	47	22		1746	6		51		33	129
	GC015	265-268	33	22		2236	3		44		34	89
	GC015	290-293	37	24		2252	4		40		38	100

Table 28 Major and trace element analyses for core 51GC019

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I.
51	GC019	0-3	17.57	0.26	4.64	1.51	0.17	0.06	38.39	0.92	1.07	0.55	0.05	0.09	34.65
	GC019	30-33	14.77	0.26	5.47	2.04	0.05	0.34	38.19	0.81	1.40	0.56	0.05	0.09	36.16

Trace element analyses

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC019	0-3	2.0	316	2	17	8	29	5	27	4	9	473	8	4	10	22	20	<3
	GC019	30-33	5.0	498	1	17	18	26	3	40	6	11	2828	10	4	12	40	9	3

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC019	0-3	27	23	<2	2157	2	2	27	16	36	123
	GC019	30-33	30	19	<2	1323	3	1.5	34	23	44	60

Table 29 Major and trace element analyses for core 51GC029

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I.
51	GC029	0-3	3.10	0.06	1.10	0.55	<0.01	0.04	50.00	0.70	1.19	0.13	0.03	0.11	43.30
	GC029	6.-12	2.64	0.06	1.09	0.52	<0.01	0.05	50.50	0.65	1.15	0.13	0.03	0.09	43.25
	GC029	14-17	2.46	0.05	0.93	0.50	<0.01	0.06	50.94	0.60	0.97	0.12	0.04	0.09	43.52
	GC029	20-23	2.36	0.05	0.84	0.47	<0.01	0.03	51.13	0.56	1.00	0.11	0.04	0.09	43.44
	GC029	30-33	2.55	0.06	0.87	0.47	<0.01	0.02	51.04	0.47	1.13	0.11	0.05	0.09	43.37
	GC029	40-43	2.95	0.07	1.03	0.52	<0.01	0.04	50.75	0.53	1.03	0.13	0.04	0.08	43.02
	GC029	50-53	3.25	0.07	1.20	0.54	<0.01	0.03	50.24	0.54	1.00	1.13	0.05	0.08	42.95
	GC029	70-73	4.06	0.09	1.49	0.68	<0.01	0.04	49.93	0.59	0.99	0.16	0.08	0.08	42.02
	GC029	90-93	2.57	0.06	0.92	0.46	<0.01	0.06	51.52	0.56	0.95	0.10	0.05	0.07	42.87
	GC029	130-133	3.07	0.06	1.12	0.43	0.12	0.05	50.44	0.48	1.10	0.20	0.09	0.09	42.75
	GC029	150-153	3.28	0.07	1.19	0.45	0.11	0.04	50.02	0.45	1.27	0.17	0.08	0.09	42.72
	GC029	170-173	2.77	0.06	1.97	0.38	0.11	0.03	50.50	0.45	1.23	0.14	0.07	0.09	43.08
	GC029	190-193	2.81	0.06	1.00	0.39	0.11	0.03	50.17	0.43	1.14	0.15	0.07	0.09	43.36

Table 29 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC029	0-3	2.0	182	<1	<3	9	6	3	18	1	5	312	10	<2	2	18	5	<3
	GC029	6-12	0.5	165	<1	4	5	5	<3	17	1	4	389	3	<2	3	19	4	<3
	GC029	14-17	0.5	202	1	7	6	6	<3	18	1	5	505	13	<2	7	48	4	<3
	GC029	20-23	1.0	169	<1	8	4	4	<3	14	1	3	254	10	<2	6	13	4	<3
	GC029	30-33	0.5	190	1	<3	3	6	5	14	1	4	159	8	<2	<2	9	5	<3
	GC029	40-43	<0.5	176	<1	4	7	7	<3	15	1	5	290	7	<2	4	15	5	<3
	GC029	50-53	0.5	162	<1	6	7	6	<3	16	<1	2	290	9	<2	4	14	4	<3
	GC029	70-73	1.5	198	<1	11	6	7	3	18	2	7	331	3	<2	8	14	5	<3
	GC029	90-93	1.0	213	<1	10	6	5	6	15	1	5	406	9	<2	7	15	6	<3
	GC029	130-133	1.5	191		6	9	8	<3	16		6	384	9		5	17	5	
	GC029	150-153	1.0	151		6	9	40	3	15		5	269	7		7	17	5	
	GC029	170-173	1.0	205		4	7	7	4	14		6	224	9		6	15	4	
	GC029	190-193	1.0	179		5	8	9	5	13		4	237	3		6	14	3	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC029	0-3	2	22	<2	1902	1	1	9	12	22	14
	GC029	6-12	<1	18	<2	1431	<1	0.5	10	14	19	13
	GC029	14-17	<1	25	<2	1412	<1	<0.5	10	16	19	12
	GC029	20-23	<1	24	<2	1342	<1	0.5	8	15	17	12
	GC029	30-33	<1	24	<2	1312	<1	<0.5	9	14	18	13
	GC029	40-43	1	20	<2	1260	<1	<0.5	8	15	19	16
	GC029	50-53	2	22	<2	1251	<1	1	6	12	19	16
	GC029	70-73	4	26	<2	1159	<1	<0.5	14	15	21	19
	GC029	90-93	2	27	<2	1142	<1	0.5	14	14	18	13
	GC029	130-133	2	13		1168	1		14		20	15
	GC029	150-153	2	13		1304	<1		13		19	12
	GC029	170-173	<1	10		1315	<1		13		18	13
	GC029	190-193	1	8		1263	<1		12		17	17

Table 30 Major and trace element analyses for core 51GC039

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I.
51	GC039	0-3	8.71	0.10	1.60	0.51	0.11	0.01	44.31	2.20	1.09	0.24	0.03	0.18	40.42
	GC039	6.-12	8.06	0.09	1.69	0.44	0.13	<0.01	44.56	2.22	1.38	0.33	0.08	0.20	40.66
	GC039	12.-15	7.70	0.09	1.63	0.40	0.15	0.01	15.36	2.30	1.35	0.34	0.08	0.20	40.80
	GC039	20-23	7.74	0.09	1.61	0.41	0.14	0.01	45.00	2.29	1.46	0.33	0.07	0.21	40.94
	GC039	30-33	8.09	0.11	1.76	0.49	0.13	0.01	44.84	2.34	1.13	0.26	0.05	0.20	40.76
	GC039	50-53	9.15	0.11	2.00	0.51	0.18	0.01	44.12	2.23	1.23	0.31	0.08	0.20	39.96
	GC039	70-73	9.42	0.12	2.09	0.54	0.17	0.01	44.22	2.22	1.09	0.30	0.08	0.20	39.56
	GC039	90-93	10.22	0.12	2.20	0.59	0.16	0.01	43.57	2.21	1.24	0.32	0.08	0.20	39.19
	GC039	110-113	10.22	0.12	2.14	0.55	0.18	0.01	43.37	2.16	1.42	0.34	0.08	0.21	39.22
	GC039	130-133	10.19	0.13	2.29	0.62	0.19	0.01	43.13	2.25	1.25	0.33	0.08	0.23	39.27

Table 30 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC039	0-3	1.5	40	2	14	2	15	<3	6	1	6	88	7	2	5	6	8	<3
	GC039	6-12	0.5	47		10	3	18	<3	6		5	80	7		6	7	4	
	GC039	12-15	1.5	43		13	3	18	<3	6		5	80	7		8	7	3	
	GC039	20-23	1.5	45		12	3	18	<3	7		5	83	6		6	8	2	
	GC039	30-33	1.0	38	1	3	2	17	<3	6	1	2	85	5	<2	3	7	4	<3
	GC039	50-53	1.0	51		10	4	21	<3	7		4	87	6		6	7	4	
	GC039	70-73	1.0	54		13	3	21	6	6		7	80	5		9	7	4	
	GC039	90-93	1.5	52		14	4	21	<3	7		7	89	7		6	8	4	
	GC039	110-113	1.0	49		12	4	20	5	6		7	87	7		7	8	5	
	GC039	130-133	0.5	51		16	4	23	<3	7		7	92	8		8	8	4	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC039	0-3	7	22	<2	2858	<1	1.5	13	6	13	66
	GC039	6-12	8	14		2985	<1		12		11	61
	GC039	12-15	8	11		3007	1		14		11	53
	GC039	20-23	8	14		2839	1		11		11	52
	GC039	30-33	8	21	<2	2842	<1	1.5	9	7	14	52
	GC039	50-53	10	12		2815	2		14		14	48
	GC039	70-73	12	12		2889	1		15		13	56
	GC039	90-93	12	14		2755	2		16		14	60
	GC039	110-113	11	15		2679	1		17		14	61
	GC039	130-133	12	13		2695	2		16		15	57

Table 31 Major and trace element analyses for core 51GC050

Survey	Core	Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	CaO (wt%)	MgO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	L.O.I.
51	GC050	0-3	5.03	0.10	1.77	0.72	<0.01	0.04	47.72	1.06	1.23	0.20	0.05	0.13	35.93
	GC050	6-9	6.15	0.11	2.25	0.74	0.11	0.03	46.87	1.04	1.46	0.26	0.09	0.14	41.08
	GC050	12-15	8.50	0.17	3.11	1.03	0.12	0.04	44.77	1.03	1.43	0.33	0.08	0.03	39.68
	GC050	20-23	14.72	0.28	5.70	1.97	0.09	0.09	38.61	1.10	0.12	0.57	0.06	0.11	35.93
	GC050	31-33	11.36	0.22	4.53	1.47	0.12	0.02	41.56	1.09	1.43	0.48	0.09	0.13	37.72
	GC050	40-45	13.81	0.20	4.20	2.01	0.12	0.06	40.12	1.01	1.29	0.50	0.10	0.12	36.57
	GC050	50-53	17.64	0.12	2.22	0.67	0.15	0.01	40.75	0.68	1.41	0.41	0.05	0.11	35.80
	GC050	60-63	6.17	0.11	2.40	0.69	0.14	0.03	46.53	0.78	1.27	0.32	0.09	0.12	41.34
	GC050	70-73	4.58	0.09	1.71	0.50	0.13	0.04	47.86	0.74	1.04	0.22	0.07	0.11	42.99
	GC050	80-83	6.53	0.12	2.59	0.79	0.14	0.03	46.39	0.79	1.30	0.33	0.10	0.12	41.07
	GC050	105-108	11.14	0.20	4.26	1.39	0.17	0.04	42.08	0.83	1.22	0.55	0.09	0.10	38.18
	GC050	125-128	5.51	0.11	2.04	0.66	0.14	0.06	47.82	0.81	1.23	0.30	0.10	0.12	41.17
	GC050	145-148	12.43	0.23	4.67	1.47	0.20	0.04	41.05	0.89	1.24	0.61	0.09	0.11	36.96
	GC050	165-168	6.68	0.12	2.41	0.79	0.17	0.03	45.34	0.78	3.09	0.40	0.09	0.13	39.75
	GC050	190-193	9.02	0.17	3.33	0.91	0.21	0.03	43.52	0.96	1.64	0.43	0.10	0.15	39.75

Table.31 (cont)

Survey	Core	Depth (cm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	La (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)
51	GC050	0-3	1.5	184	2	6	3	10	<3	18	2	2	307	10	2	5	13	10	<3
	GC050	6-12	0.5	257		10	6	17	5	18		6	257	6		8	15	6	
	GC050	12-15	1.5	243		12	6	20	3	20		8	271	9		8	16	8	
	GC050	20-23	4.0	158	2	14	6	23	<3	23	6	8	682	7	5	8	39	7	<3
	GC050	30-33	4.0	244		19	8	25	4	23		10	185	6		12	16	6	
	GC050	40-43	18.0	247		19	10	26	6	20		14	410	8		13	16	7	
	GC050	50-53	1.5	98		11	6	14	4	8		7	105	7		6	9	6	
	GC050	60-63	0.5	313		10	5	13	7	12		12	246	7		11	13	6	
	GC050	70-73	<0.5	198	1	5	3	6	<3	11	1	5	312	8	2	8	12	5	<3
	GC050	80-83	1.5	248		8	6	11	8	13		7	316	7		8	13	5	
	GC050	105-108	1.0	252		13	6	22	4	16		9	276	5		9	15	7	
	GC050	125-128	0.5	303		9	6	12	<3	14		6	441	7		8	13	5	
	GC050	145-148	1.5	315		21	8	28	6	28		13	276	8		13	23	8	
	GC050	165-168	0.5	202		12	6	16	4	15		6	260	8		9	16	4	
	GC050	190-193	1.0	187		12	7	22	5	19		7	236	7		7	17	4	

Survey	Core	Depth (cm)	Rb (ppm)	Sc (ppm)	Sn (ppm)	Sr (ppm)	Th (ppm)	U (ppm)	V (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
51	GC050	0-3	6	25	<2	2721	<1	1	9	19	21	26
	GC050	6-12	10	17		2660	<1		16		23	25
	GC050	12-15	15	20		2508	<1		21		27	34
	GC050	20-23	32	19	<2	2301	3	1	21	15	38	56
	GC050	30-33	24	22		1883	2		25		33	42
	GC050	40-43	24	21		1822	3		30		30	60
	GC050	50-53	14	20		1500	<1		14		16	338
	GC050	60-63	11	15		1723	1		17		24	34
	GC050	70-73	7	20	<2	1632	<1	1	10	13	21	30
	GC050	80-83	12	17		1647	<1		14		26	35
	GC050	105-108	25	21		1516	4		24		29	45
	GC050	125-128	9	16		1681	<1		17		22	29
	GC050	145-148	26	20		1814	2		36		35	54
	GC050	165-168	11	18		2128	<1		19		24	32
	GC050	190-193	16	18		2104	<1		25		31	37

Table 32 Range in concentration of major and minor elements present in the sediments, off the northeast Australian continental margin

Element	Minimum	Maximum
Al2O3 (wt%)	0	14
SiO2 (wt%)	0	40
Fe2O3 (wt%)	0	4
TiO2 (wt%)	0	0.7
FeO (wt%)	0	0.7
MnO(wt%)	0	60
MgO (wt%)	0	3
Na2O(wt%)	0	3.1
K2O (wt%)	0	1.5
P2O5 (wt%)	0	0.15
Sulphur (ppm)	0	0.5
CaO (wt%)	0	60
Arsenic (ppm)	0	20
Barium (ppm)	0	700
Bismuth (ppm)	0	3
Cerium (ppm)	0	60
Cobalt (ppm)	0	20
Chromium (ppm)	0	90
Cesium (ppm)	0	9
Gallium (ppm)	0	10
Copper (ppm)	0	80
Lanthanum (ppm)	0	30
Molybdenum (ppm)	0	14
Manganese (ppm)	0	5000
Niobium (ppm)	0	6
Neodymium (ppm)	0	30
Nickel (ppm)	0	50
Lead (ppm)	0	60
Praseodymium (ppm)	0	5
Rubidium (ppm)	0	90
Scandium (ppm)	0	35
Tin (ppm)	0	3
Strontium (ppm)	700	3010
Thorium (ppm)	0	11
Uranium (ppm)	0	4
Vanadium (ppm)	0	105
Yttrium (ppm)	5	25
Zinc (ppm)	10	70
Zirconium (ppm)	10	130

Table 33 Core-top elemental ratios and water depths for cores from the northeast Australian continental margin

Survey	Core	Depth (cm)	Water Depth (m)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)
51	GC009	0-3	400	0.011	2.71	0.058	25.67	3.21	14.26
51	GC039	0-3	556	0.015	4.81	0.071	47.24	17.71	7.09
51	GC015	0-3	1005	0.010	2.85	0.057	39.10	13.80	4.27
51	GC050	0-3	1165	0.023	2.51	0.064	196.42	10.68	19.22
51	GC029	0-3	1175	0.022	2.49	0.062	312.63	10.31	30.92
51	GC019	0-3	1871	0.009	3.34	0.063	128.68	11.81	10.99
51	GC006	0-4.5	2949	0.007	2.37	0.056	100.60	9.35	16.44

Survey	Core	Depth (cm)	Water Depth (m)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)	Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
51	GC009	0-3	400	55.97	5.70	10.70	979	10.70	9.98
51	GC039	0-3	556	103.92	7.09	8.27	3375	15.35	15.35
51	GC015	0-3	1005	72.29	5.26	11.17	850	10.52	11.17
51	GC050	0-3	1165	327.73	13.88	6.41	2905	9.61	22.42
51	GC029	0-3	1175	535.93	30.92	3.44	3267	15.46	37.79
51	GC019	0-3	1871	192.61	8.96	10.99	878	10.99	14.66
51	GC006	0-4.5	2949	228.93	8.71	8.71	340	13.22	14.19

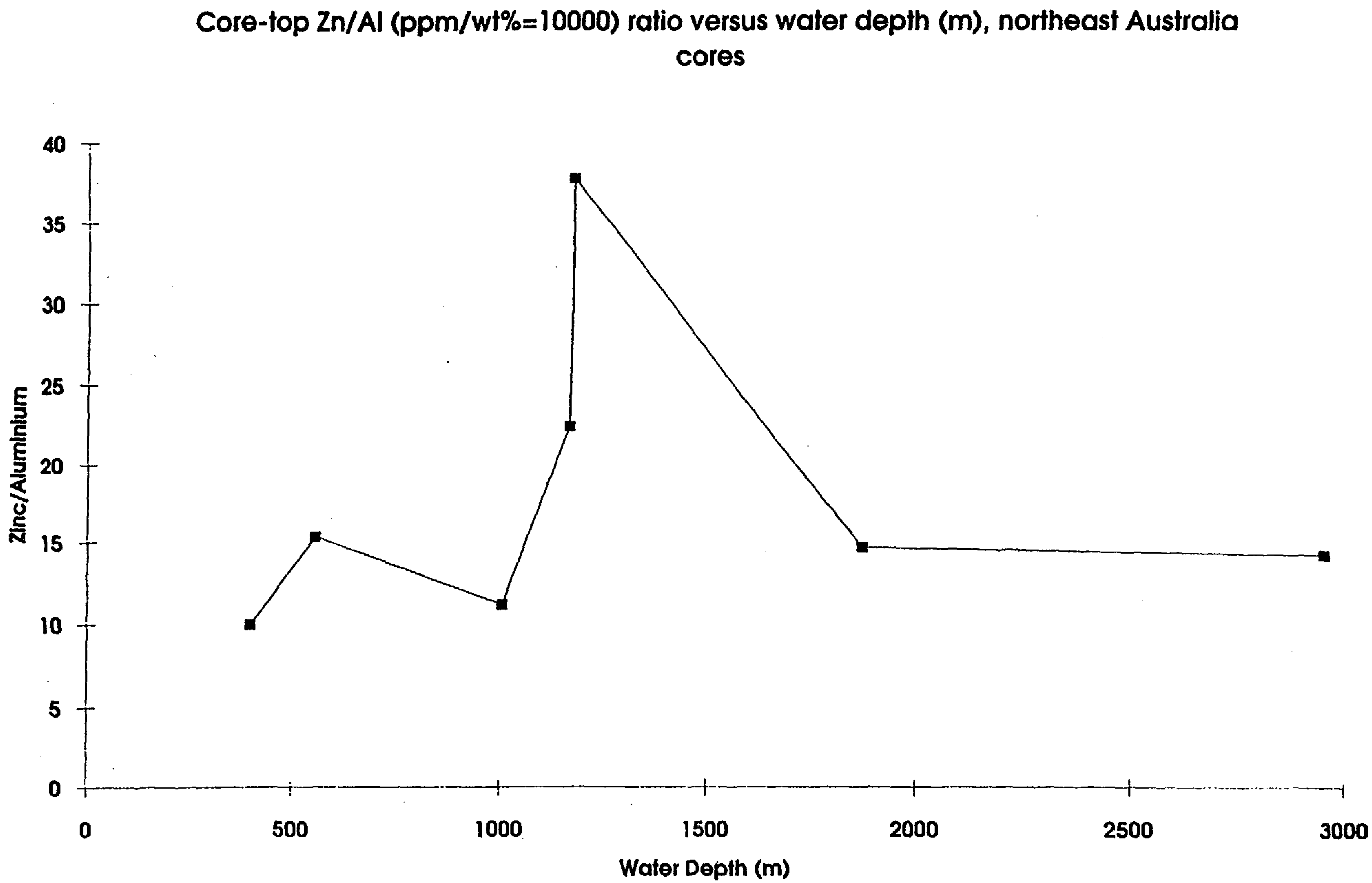


Figure 16. Core-top Zinc/Aluminium ratio plotted as a function of water depth

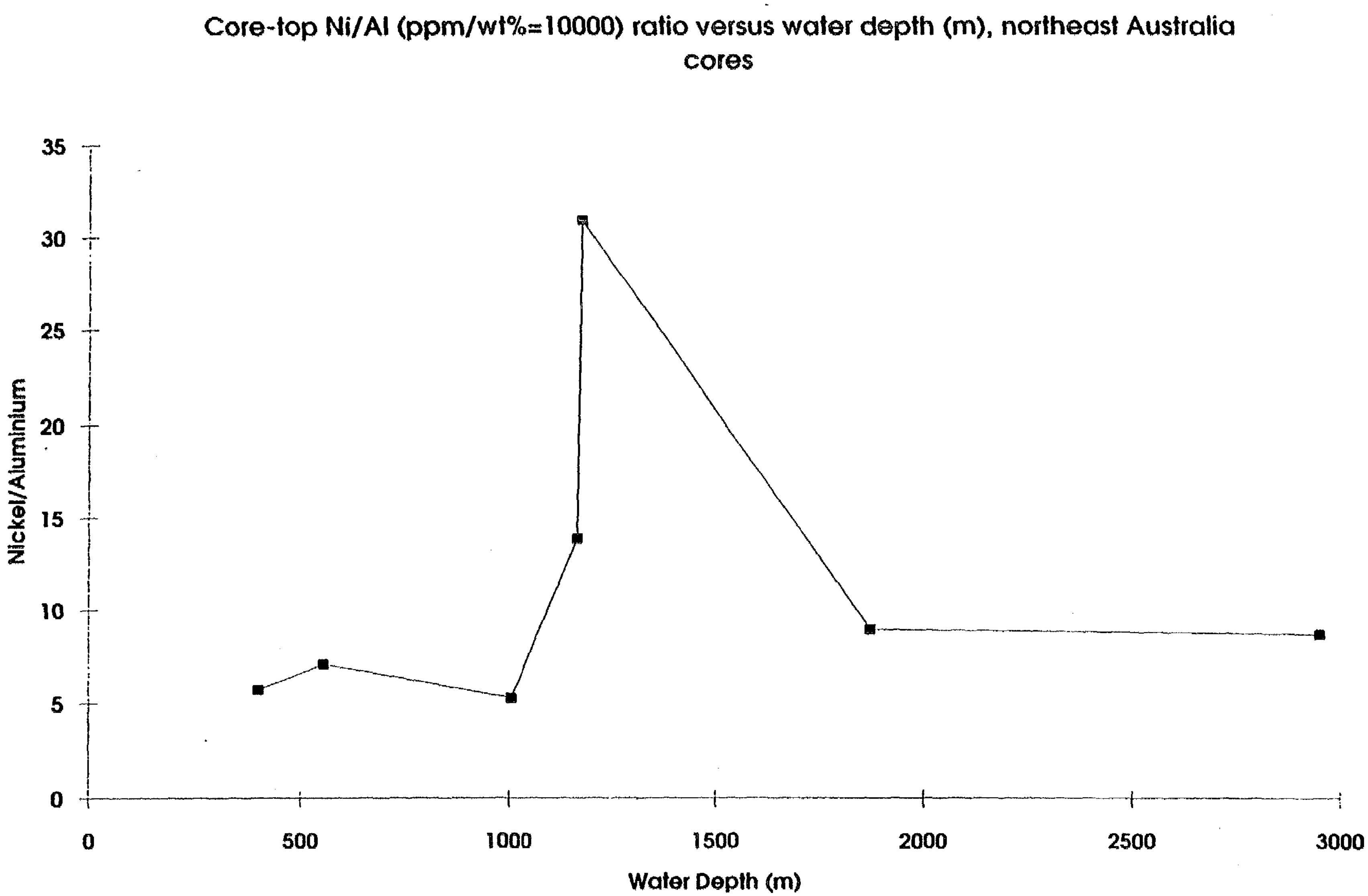


Figure 17. Core-top Nickel/Aluminium ratio plotted as a function of water depth

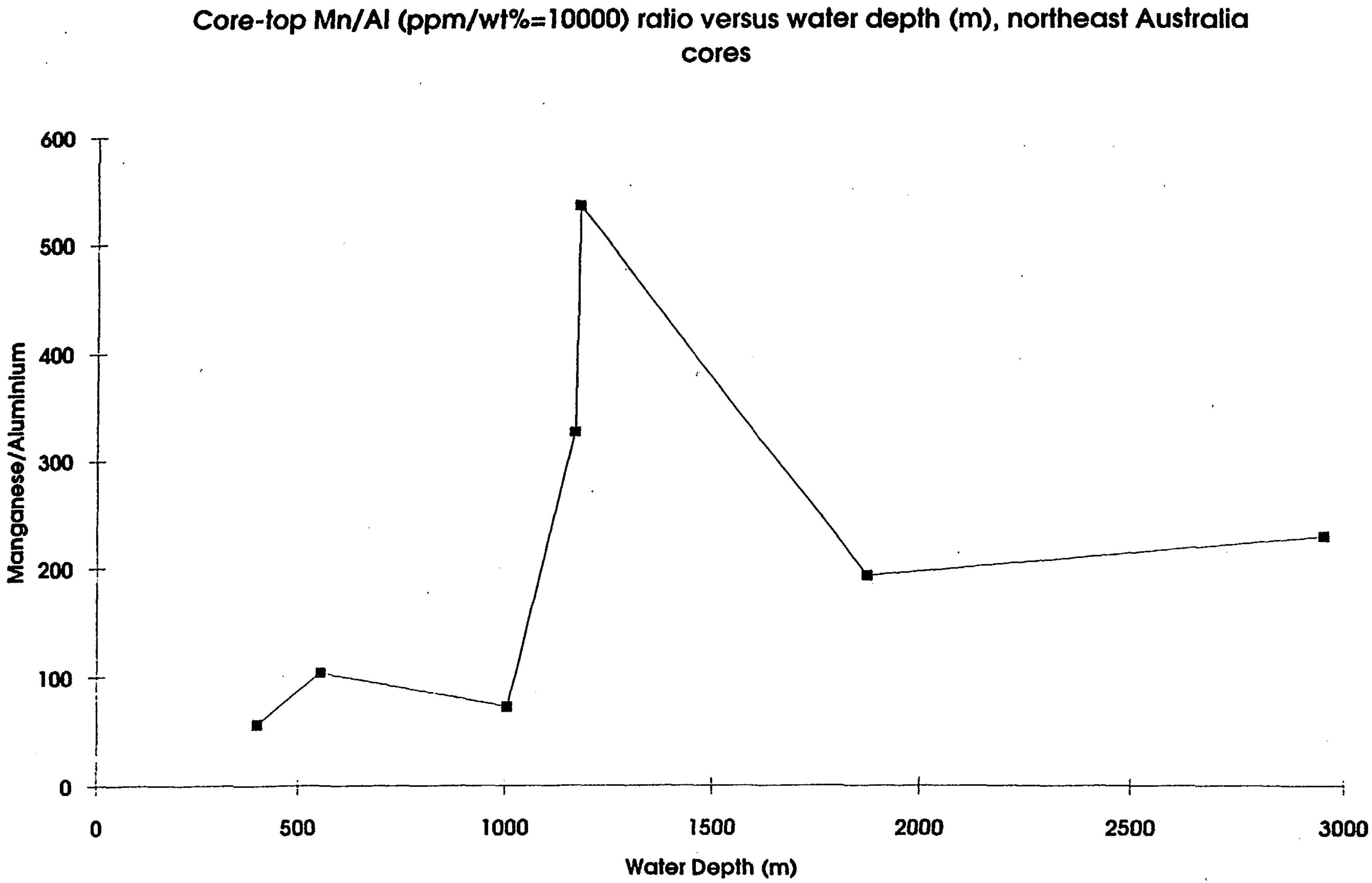


Figure 18. Core-top Manganese/Aluminium ratio plotted as a function of water depth

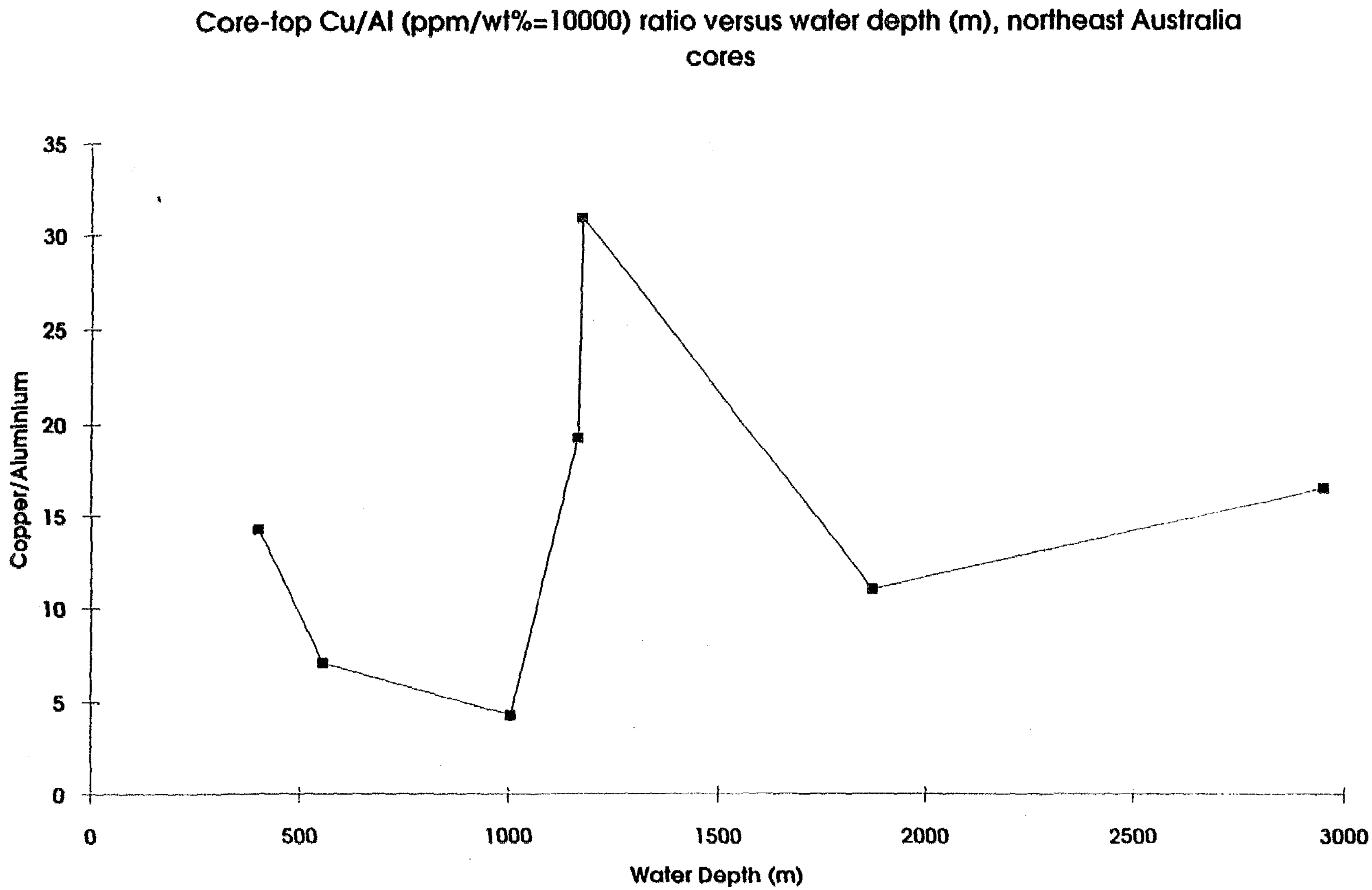


Figure 19. Core-top Copper/Aluminium ratio plotted as a function of water depth

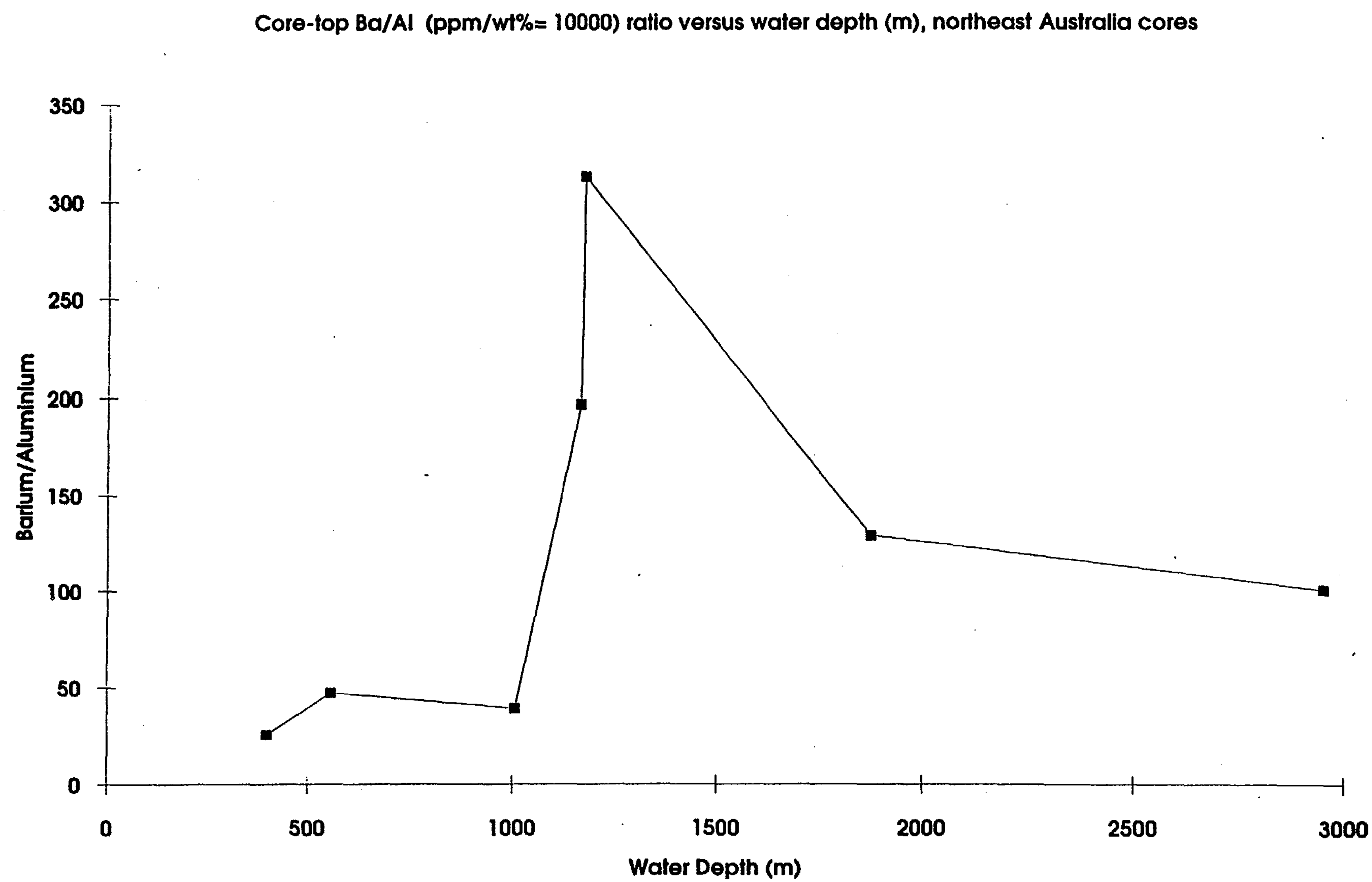


Figure 20. Core-top Barium/Aluminium ratio plotted as a function of water depth

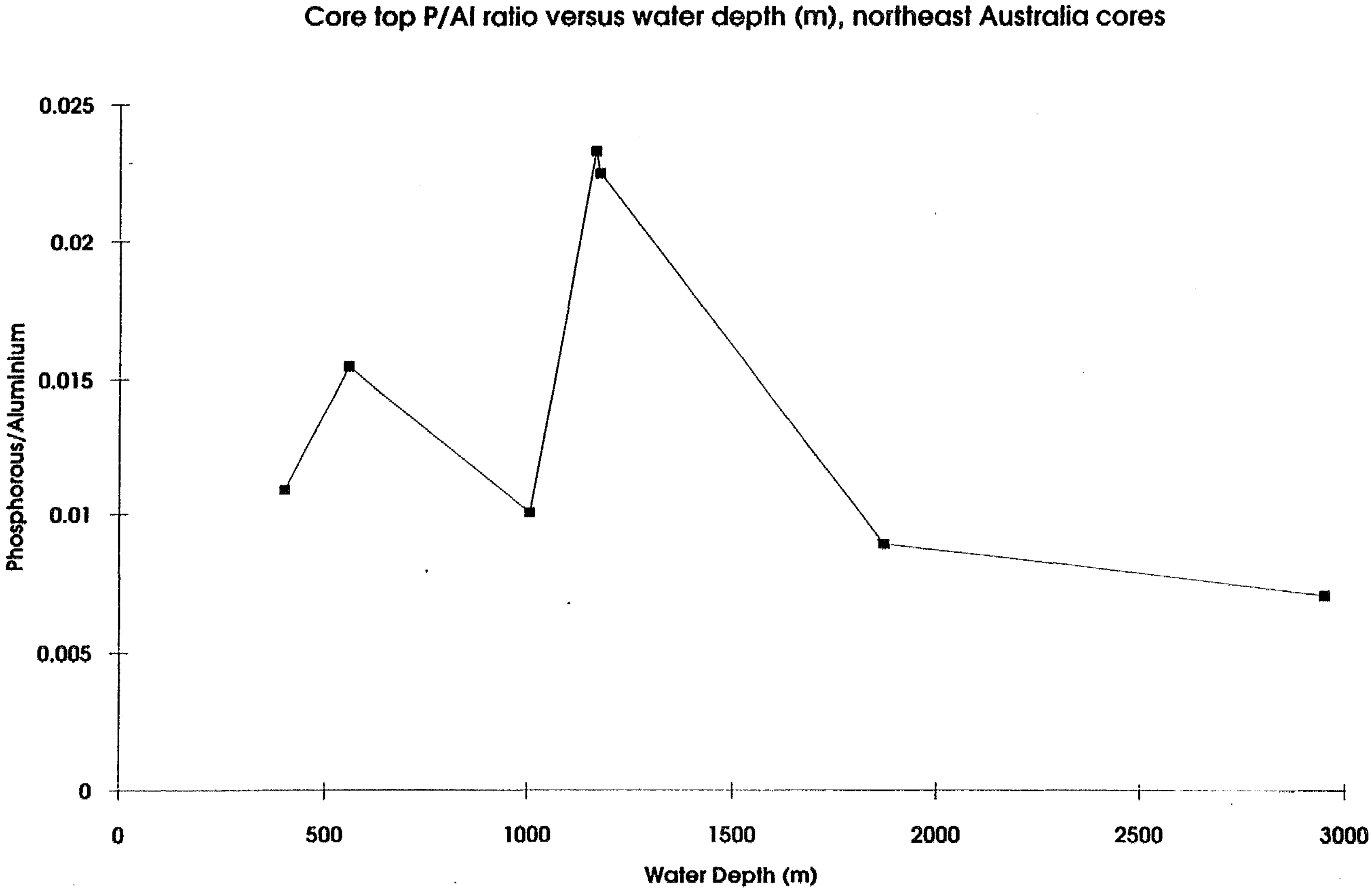


Figure 21. Core-top Phosphorous/Aluminium ratio plotted as a function of water depth

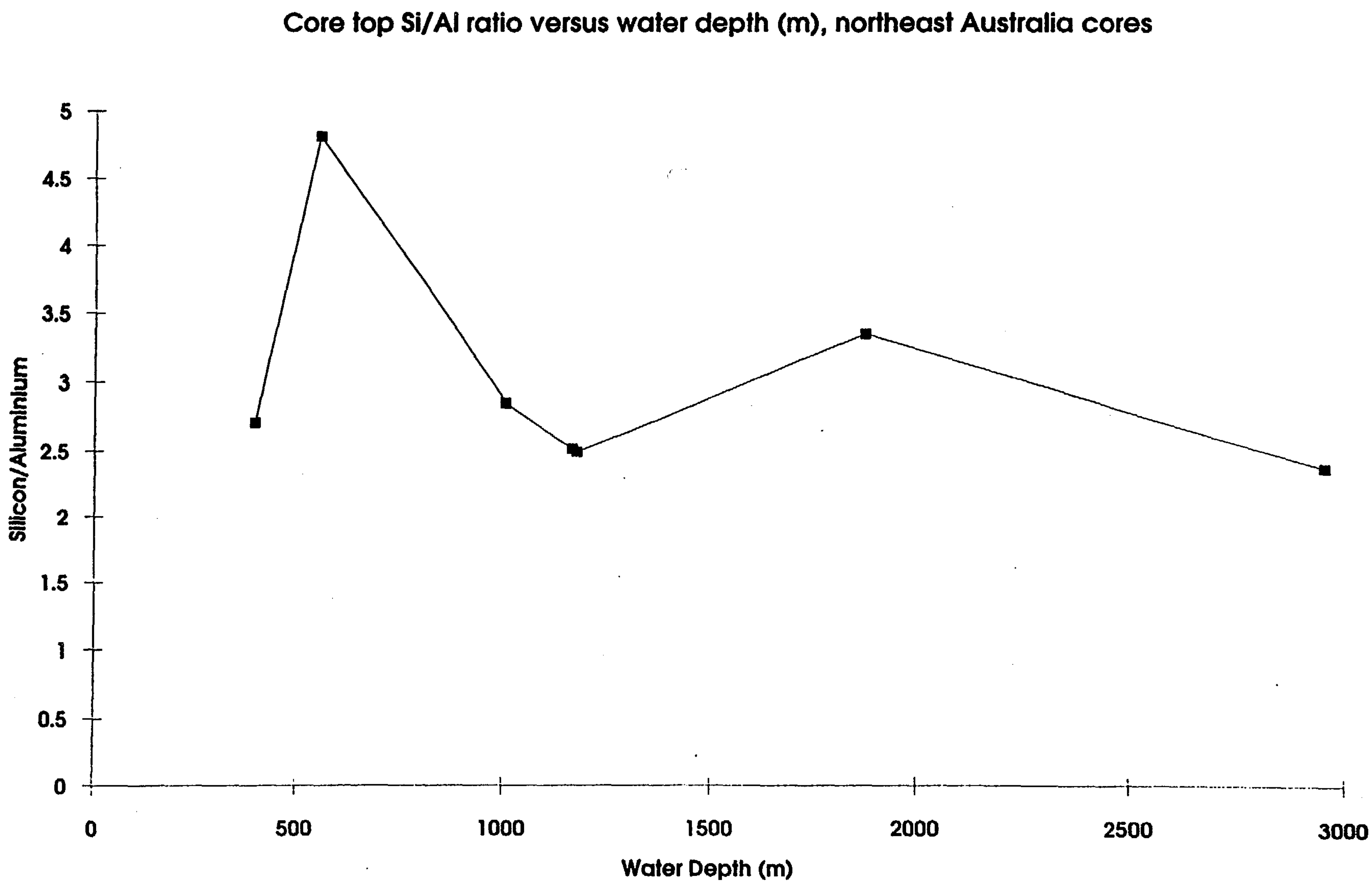


Figure 22. Core-top Silicon/Aluminium ratio plotted as a function of water depth

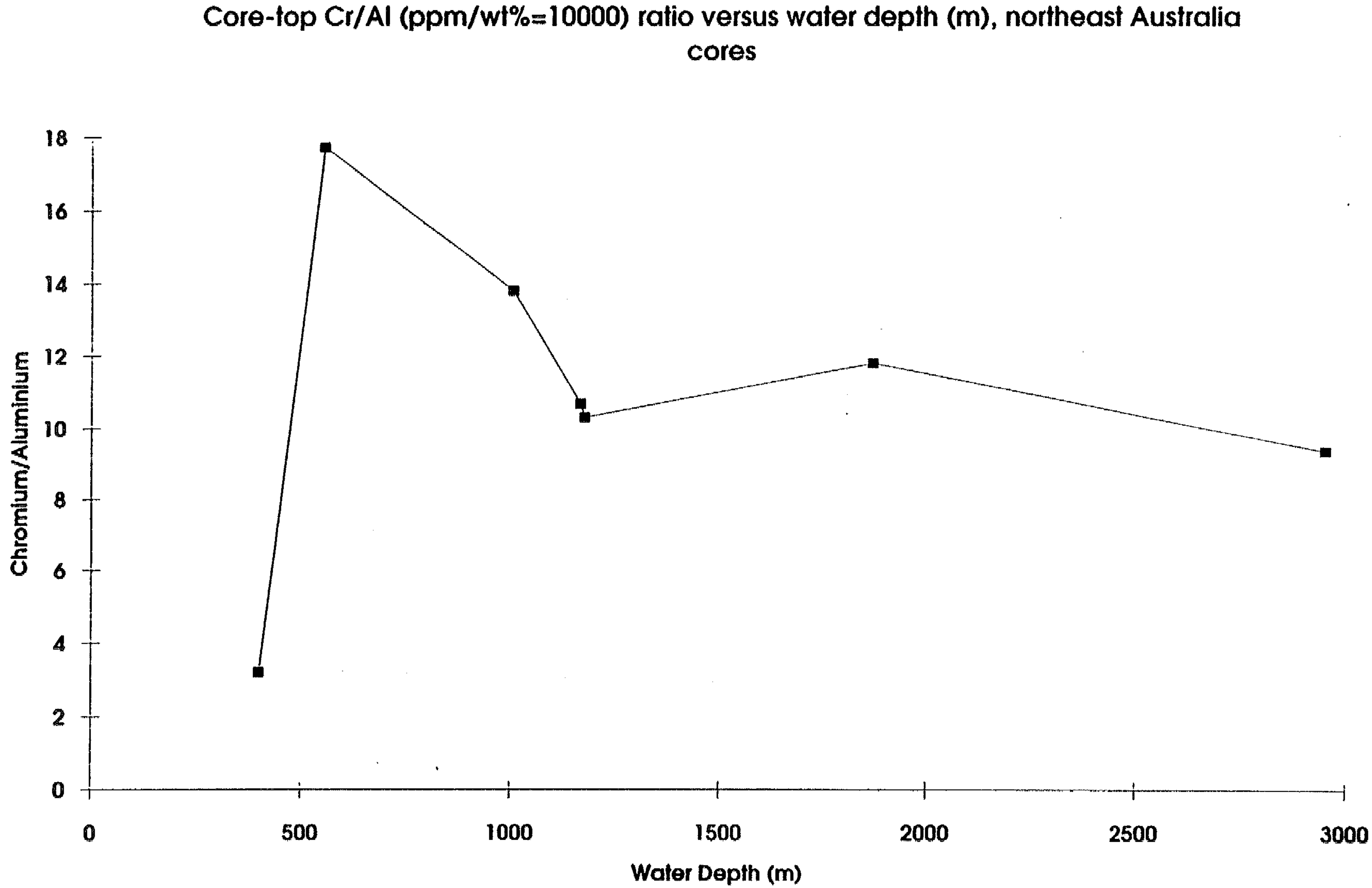


Figure 23. Core-top Chromium/Alùminium ratio plotted as a function of water depth

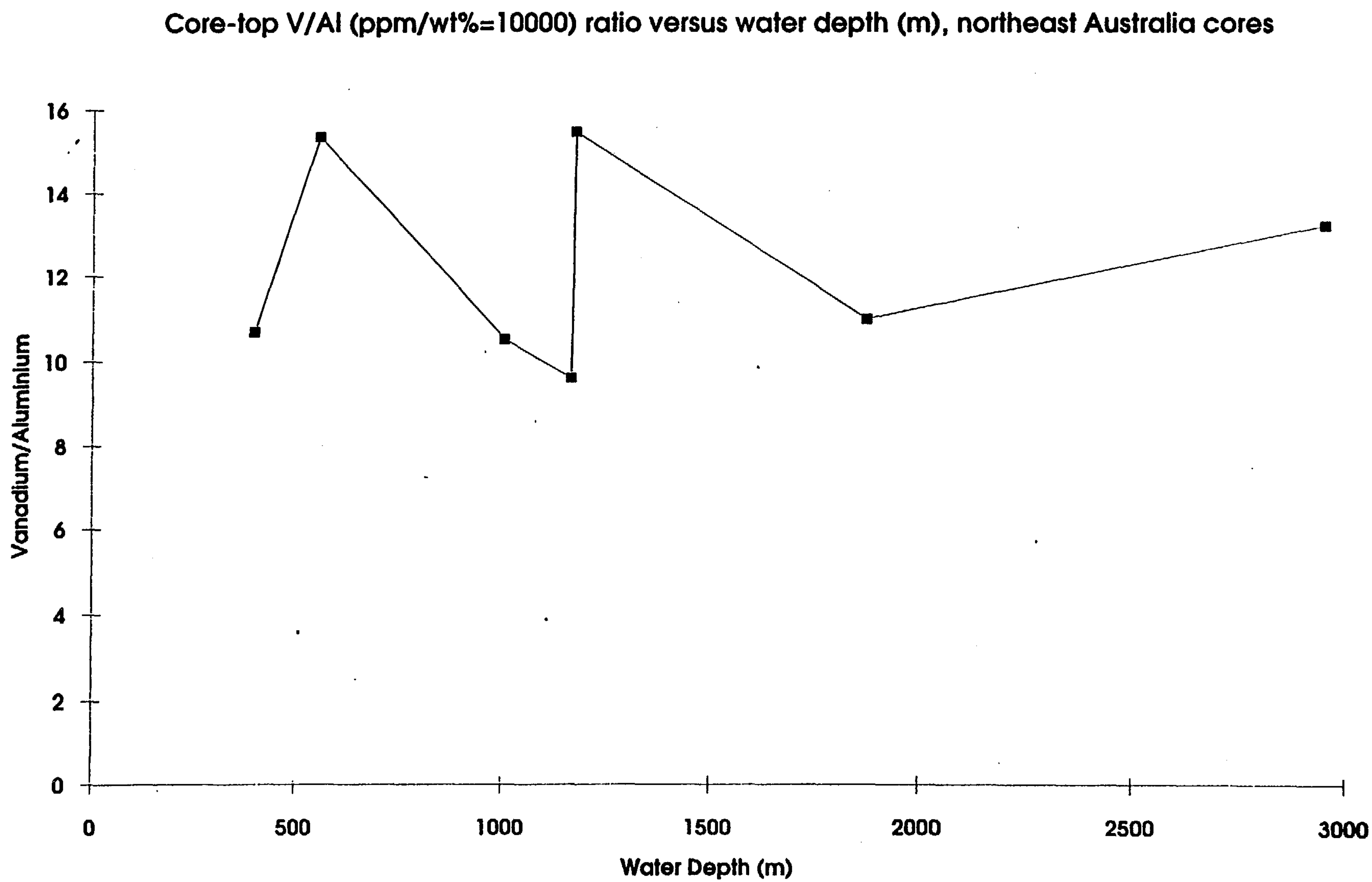


Figure 24. Core-top Vanadium/Aluminium ratio plotted as a function of water depth

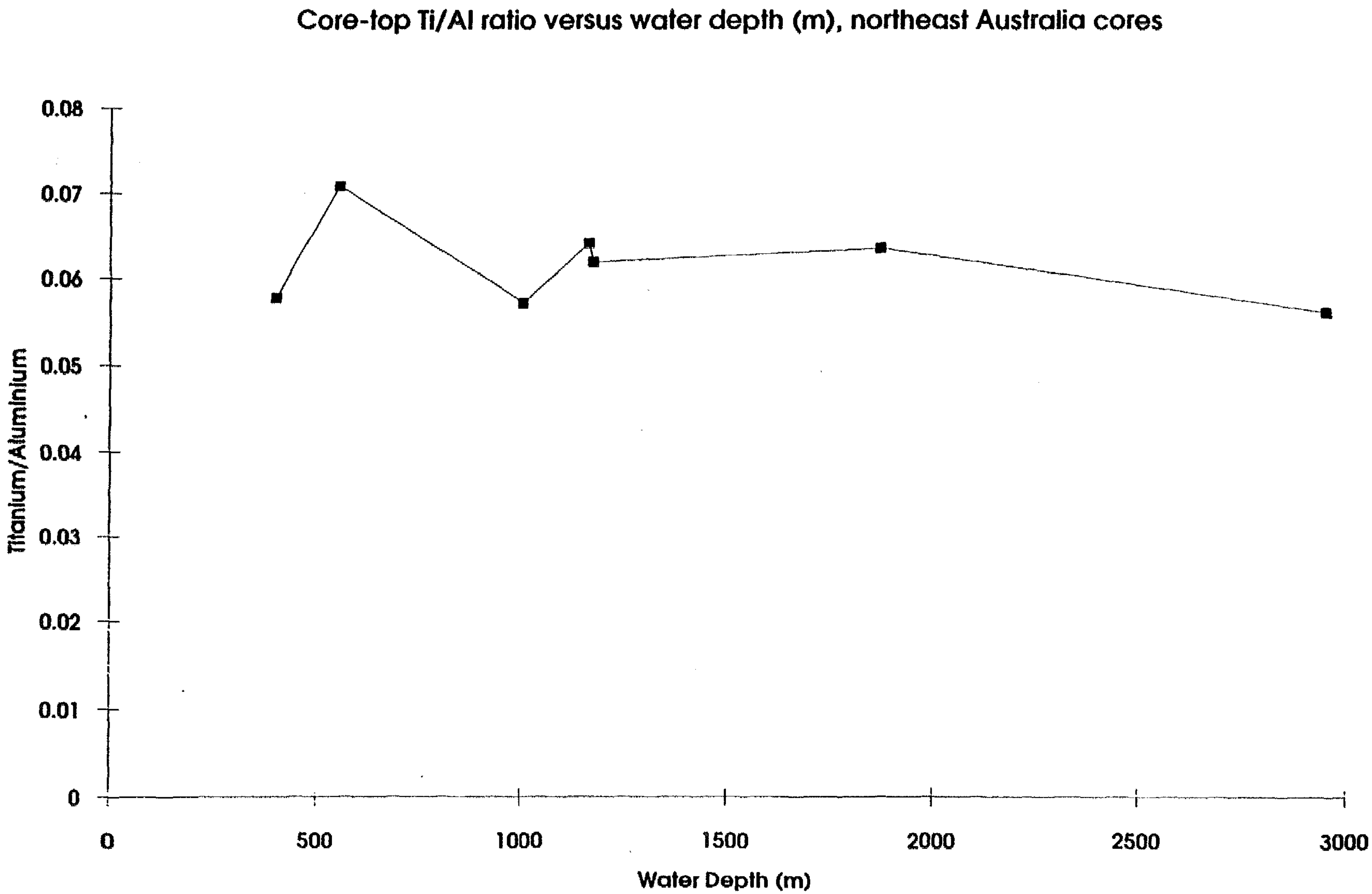


Figure 25. Core-top Titanium/Aluminium ratio plotted as a function of water depth

Uranium and Thorium Geochemistry and Sedimentation Rates on the Queensland Plateau and Osprey Embayment.

Several cores were selected from the Queensland Plateau and the Osprey Embayment to determine sedimentation rates by radiochemical methods. Cores from the Great Barrier Reef slope were not analysed because of an anticipated low abundance of excess Thorium 230. Cores from the Queensland Trough were not analysed because of evidence of sediment slumps and turbidity flows from the adjacent upper continental slope. These analyses were conducted at the Research School of Earth Sciences , Australian National University.

Methods and Data Analyses

Gravity core samples were obtained soon after return of the samples to shore. The cores were split longitudinally and sub samples taken at various depths. Sediment samples were oven dried (~60°C), ground in a mortar and pestle, and about 3 g taken for analysis of U and Th isotopes. Our method follows that of Anderson and Fleer (1982) with some minor modification. Samples were dissolved in concentrated nitric, perchloric and hydrofluoric acid and ^{232}U and ^{228}Th yield tracers added. Samples were taken to 9M HCl and passed through an anion ion-exchange column to separate U and Th. The separate fractions were further purified by solvent extraction and ion exchange. The pure U and Th fractions were extracted into TTA (thinly triflouroacetone)/benzene and evaporated onto stainless steel planchets. Alpha counting was done on Ortec Si surface barrier detectors (FWHM-25-35KeV) coupled to a Tracor-Northern multichannel analyser. The errors quoted in Table 34 account for 1σ counting errors, 1% spike uncertainty and 1% uncertainty in counting efficiency. Reagent blanks run during the course of sample analysis were undistinguished from the counter background.

Uranium is very soluble in sea water due to formation of strong CO_3^{2-} ion complexes (Gascoyne, 1982). Typical open ocean concentrations are about 3 μg L^{-1} (Ku and others, 1977) and it is removed very slowly (Residence time ~5 x 10^5 yr) from the water column. $^{234}U/^{238}U$ ratios are about 1.14±0.03 in sea water (Thurber, 1962; Ku and others, 1977) due to preferential mobilisation of ^{234}U.

Thorium is very particle reactive in the ocean with concentrations less than 0.08 μg m^{-3} (Cochran, 1982). ^{232}Th enters the ocean primarily attached to detrital particles. ^{230}Th is produced in situ via decay of ^{234}U but is rapidly scavenged by particles and is transported to the sediments. The sea water $^{230}Th/^{234}U$ activity ratio is less than 6 x 10^{-4} indicating that ^{230}Th is removed faster than its half-life of 75,000 yr (Cochran, 1982).

The sequestering of Th isotopes by particulates in the oceans produces an excess of ^{230}Th activity over that of its immediate parent ^{234}U in bottom sediment. The excess Th (xs^{230}Th) will approach equilibrium with respect to its parent at a rate determined by its half life of 75,000 years. The sedimentation rate can be calculated from the equation:

$$\ln (\mathrm{xsTh\text{-}230})_z = \ln (\mathrm{xsTh\text{-}230})_{z=0} - (\lambda_{230}/s)\, z \qquad (1)$$

where $(\mathrm{xsTh\text{-}230})_z$ is the activity of excess ^{230}Th (xs $^{230}Th = \Sigma^{230}Th - {}^{234}U$) at some depth z in the sediment, $(\mathrm{xsTh - 230})_{z=0}$ is the xs^{230}Th activity at the core top, λ_{230} is the decay constant of ^{230}Th (75,000 yr), and s is the sedimentation rate in cm yr^{-1}. From a plot of ln xs^{230}Th versus depth in the core, one obtains a slope and the sedimentation rate calculated from the expression:

$$s = \lambda/\mathrm{slope}.$$

To calculate sedimentation rates, we have corrected the data to account for variable $CaCO_3$ content which may bias the results because $CaCO_3$ is essentially a diluent for xsTh - 230. Using Th-232 as an index (Th-232 being attached primarily to the clay fraction of the sediment) may alleviate some of the problems associated with variable $CaCO_3$ flux, but is unsatisfactory because its source is not the same as that for ^{230}Th and therefore may in itself vary independently. The sedimentation rates derived here are therefore mean values for the carbonate-free portion. It does not imply that sedimentation was constant throughout the entire interval of the dated portion of the core, however it is assumed that the flux of xs^{230}Th to the sea bottom and that the accumulation rate of the ^{230}Th carrier portion of the sediment is constant.

U and Th behaviour in sediments

Activities, concentrations and activity ratios of U and Th nuclides analysed in three cores collected from the Queensland Plateau are given in Table 34. U concentrations (on a $CaCO_3$-free basis) are in the range 1.2 - 10.1 dpm g^{-1} and Th (as Th-232) concentrations are in the range 3.9 - 32.1 ppm with a general decrease in concentration down core. Cores GC050 and GC029 display substantial enrichment of Th-232 in the core tops indicating either increased detrital input during the most recent phase of sediment. U-238 concentrations vary in concert with Th-232 and in cores GC029 and GC050 have considerably higher uranium concentrations in the upper portions than that expected in clay particles alone. Uranium in these sediments is most likely controlled by sequestering of U (and Th) possibly by Fe-Mn oxyhydroxides. $^{234}U/^{238}U$ activity ratios are generally within the analytical uncertainty of the range 1.0 - 1.15 which is the range expected for a mixture of detrital material with an AR of 1 and a carbonate plus organic fraction having an AR of 1.15. Those samples which have AR's significantly less than 1 may be derived from younger (i.e. Pleistocene) weathered material in which ^{234}U has been preferentially mobilised resulting in a residual solid material having an AR less than secular equilibrium.

Sedimentation Rates

Sediment accumulation rates for three gravity cores (GC06, 3050m; GC029, 1200m; GC050, 1150m) were determined from the slope of a plot of xs^{230}Th versus depth (Fig. 26). The calculated rates are 0.45, 0.51 and 0.7 cm kyr^{-1} respectively although the latter determination is problematic due to a wide scatter in the data points (R=0.6). For GC06 and GC029 the apparent accumulation rates provide a chronology of Late Pleistocene sedimentation for this region. We can thus use it as an absolute framework in which to interpret variations in carbonate and organic carbon content and changes in sedimentation patterns related to sea-level change during the Late Pleistocene.

Table 34 Radiochemistry and percent calcium carbonate results for cores 51GC006, 51GC029 and 51GC050

Survey	Core	Water Depth (m)	Depth in Core (cm)	U-238	U (ppm)	U-234	Th-232	Th (ppm)	Th-230	U-234/U-238	xsTh-230	Th/U
51	GC06	3050	0.75	1.01	1.35	1.11	2.56	10.41	19.43	1.099	18.32	7.7
		3050	2.25	1.07	1.43	0.93	1.5	6.1	12.41	0.869	11.48	4.3
		3050	3.75	0.85	1.14	0.93	2.2	8.9	16.9	1.094	15.97	7.9
		3050	63.5	0.84	1.13	0.88	1.57	6.38	5.72	1.048	4.84	5.7
		3050	120.75	0.64	0.86	0.62	1.4	5.69	1.8	0.969	1.18	6.6
		3050	35.75	0.43	0.58	0.45	0.5	2	3.6	1.047	3.15	3.5
		3050	91.75	0.471	0.63	0.46	0.5	2	1.75	0.977	1.29	3.2

Survey	Core	Water Depth (m)	Depth in Core (cm)	U-238	U-238 Error	U (ppm)	U-234	U-234 Error	Th-232	Th-232 Error	Th (ppm)	Th-230
51	GC029	1200	1.5	1.86	0.13	2.5	1.64	0.12	1.28	0.16	5.2	25.4
		1200	7.5	0.26	0.01	0.35	0.28	0.01	0.11	0.01	0.46	1.7
		1200	31.5	0.22	0.01	0.3	0.21	0.01	0.12	0.01	0.49	1.58
		1200	51.5	0.19	0.01	0.26	0.22	0.01	0.112	0.01	0.46	0.93
		1200	91.5	0.233	0.01	0.31	0.254	0.01	0.121	0.01	0.49	0.7

Survey	Core	Water Depth (m)	Depth in Core (cm)	U-238	U-238 Error	U (ppm)	U-234	U-234 Error	Th-232	Th-232 Error	Th (ppm)	Th-230
51	GC050	1150	1.5	1.2	0.1	1.61	1.15	0.01	1.66	0.08	6.75	16.3
		1150	7.5	0.8	0.02	1.07	0.84	0.02	0.16	0.01	0.65	1.51
		1150	31.5	0.97	0.03	1.3	0.86	0.02	0.46	0.02	1.87	1.84
		1150	61.5	0.85	0.02	1.14	0.94	0.2	0.35	0.02	1.42	2.51
		1150	105	0.93	0.03	1.25	1	0.03	0.46	0.02	1.87	1.3
		1150	51.5	0.55	0.03	0.74	0.6	0.04	0.38	0.03	1.55	0.63
		1150	81.5	0.64	0.03	0.86	0.7	0.03	0.44	0.02	1.8	0.78
		1150	13.5						0.29	0.03	1.2	1.98

Survey	Core	Water Depth (m)	Depth In Core (cm)	Th-230/Th-232	%CaCO3 frac	CaCO3 free	xsTh-230 (CO3)	LnxsTh-230
51	GC06	3050	0.75	7.59	59.	2.44	44.701	3.8
		3050	2.25	8.273	63	2.7	30.996	3.434
		3050	3.75	7.682	61.5	2.6	41.522	3.726
		3050	63.5	3.643	60	2.5	12.1	2.493
		3050	120.75	1.286	48	1.92	2.266	0.818
		3050	35.75	7.2	64.8	2.84	8.946	2.191
		3050	91.75	3.5	60.4	2.53	3.264	1.183

Survey	Core	Water Depth (m)	Depth In Core (cm)	Th-230 Error	U-234/U-238	xsTh-230	Th/U	%CaCO3 frac	CaCO3 free	xsTh-230 (CO3)	LnxsTh-230
51	GC029	1200	1.5	1.2	0.882	23.76	2.1	81	5.26	124.978	4.828
		1200	7.5	0.05	1.077	1.42	1.3	93.4	15.15	21.513	3.069
		1200	31.5	0.04	0.955	1.37	1.7	92.3	12.99	17.796	2.879
		1200	51.5	0.04	1.158	0.71	1.8	92.3	12.99	9.223	2.222
		1200	91.5	0.03	1.09	0.446	1.6	92.3	12.99	5.794	1.757

Survey	Core	Water Depth (m)	Depth In Core (cm)	Th-230 Error	xsTh-230	Th/U	%CaCO3 frac	CaCO3 free	xsTh-230 (CO3)	LnxsTh-230
51	GC050	1150	1.5	0.44	15.15	4.2	79	4.76	72.114	4.278
		1150	7.5	0.05	0.67	0.6	83.5	6.06	4.06	1.401
		1150	31.5	0.07	0.98	1.4	68.7	3.19	3.126	1.14
		1150	61.5	0.07	1.57	1.25	79.6	4.9	7.693	2.04
		1150	105	0.05	0.3	1.5	73.6	3.79	1.137	0.128
		1150	51.5	0.04	0.03	2.1	75	4	0.12	-2.12
		1150	81.5	0.03	0.08	2.1	75	4	0.32	-1.139
		1150	13.5	0.12			75	4		

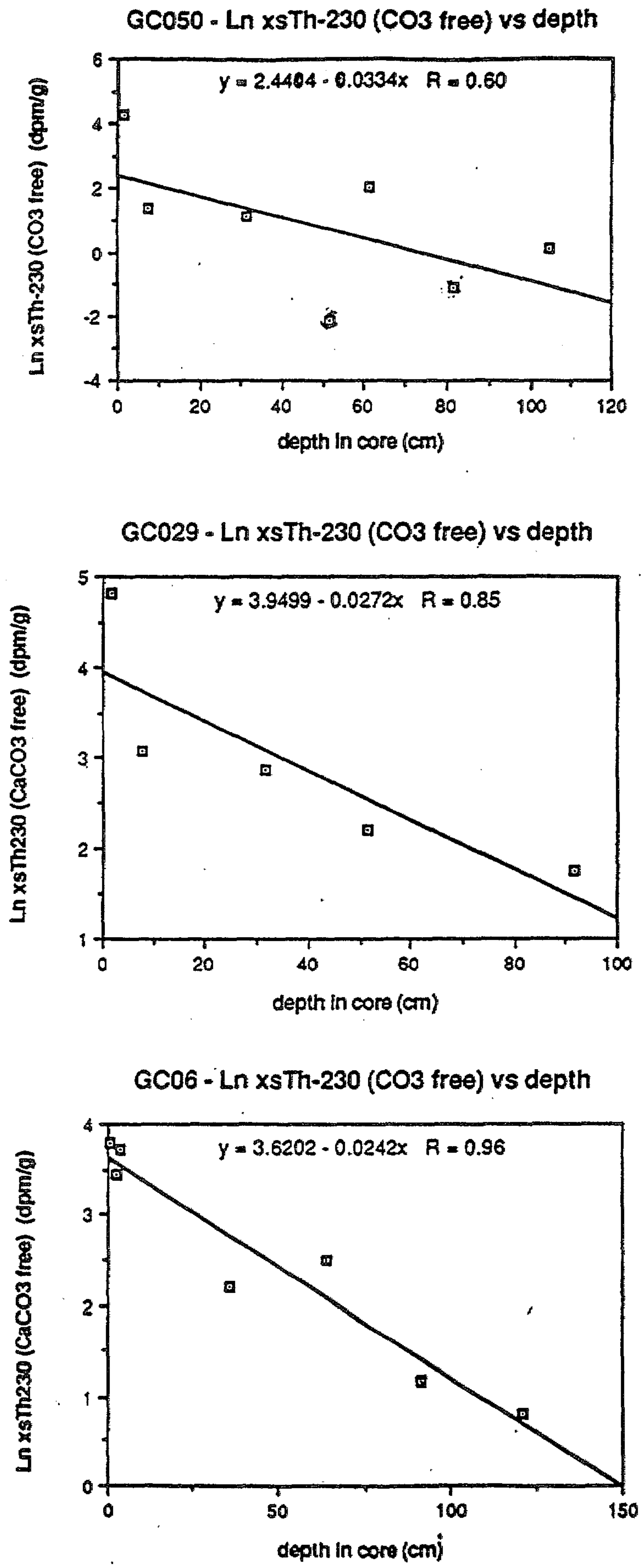


Figure 26. Determination of sediment accumulation rates for three cores, (GC006, GC009 and GC050) from the slope of a plot of xs230Th versus depth in core.

SUMMARY

As part of 'Rig Seismic' Survey 51 off northeast Australia, a number of gravity cores have been analysed for a variety of geochemical properties and parameters. The twelve cores utilised for geochemical analyses were collected from water depths of between 30 and 2950 m. These cores were collected from a variety of locations including; the Queensland Plateau, Queensland Trough, Osprey Embayment and the Great Barrier Reef slope.

The analyses included major and minor element compositions by XRF, calcium carbonate and total organic carbon content, radiochemical contents - to determine sedimentation rates - and several cores have had analyses conducted on the pore fluids separated from sediments. These latter analyses were conducted to develop an understanding of organic matter degradation and storage processes in sediments, and have implications for environmental change and the formation of some seafloor minerals.

(1) The radiocarbon ages determined for the surface (0-3 cm) samples from eight cores varied between, 1240±130 BP and 7110±100 BP. These ages were determined from the ^{14}C content of the inorganic carbon component.

(2) The uranium and thorium concentrations of three cores collected from the Queensland Plateau and Osprey Embayment were analysed to determine sediment accumulation rates. Uranium concentrations (on a carbonate-free basis) are in the range 1.2 - 10.1 dpmg^{-1} and Thorium concentrations (as Th-232), are in the range 3.9 - 32.1 ppm with a general decrease in concentration down core.

The calculated sediment accumulation rates for the three cores (GC06, 2949 m; GC029, 1175 m and GC050 1165 m) were determined from the slopes of plots of excess Th-230 versus depth, and were found to be 0.45, 0.51 and 0.7 cm kyr^{-1} respectively. These represent average sedimentation rates from these cores for Late Pleistocene sediments from this area.

(3) The concentrations of organic carbon in the sediments off northeast Australia was generally highest in the top interval (0 - 3 cm) of the core, with concentrations generally decreasing down-core. The range in organic carbon content in the top 3 cm

of each core varied between 0.13 and 0.78 %.

(4) The pore water metabolites measured in several cores varied in a systematic way indicating organic matter degradation processes by major oxidants (oxygen and sulphate) and secondary oxidants (nitrate, manganese and iron oxyhydroxides). The data from the Queensland Plateau suggest relatively low inputs of organic matter to the sediments, while those data from the Great Barrier Reef slope indicate sulphate reduction processes occurring at shallow depth in the cores, and suggest significantly higher organic inputs to slope sediments than plateau sediments. Rates of sulphate reduction were calculated from pore water ammonia profiles. These data when combined with organic carbon burial and preservation rates will allow an assessment of the organic matter mass balances between slope and plateau sediments.

(5) A data-base of major and minor trace element abundances has been assembled from which controls on the chemical compositions of sediments can be determined. The data base provides a geochemical framework which could be used to assess the potential anthropogenic contributions to these sediments. Preliminary analysis of part of that data suggest that several trace elements (arsenic, cerium, cobalt, chromium, lanthanum, neodymium, nickel, lead, rubidium and scandium) covary with Al_2O_3 and Fe_2O_3, indicating a control on their concentrations and distributions by clay contents and iron oxyhydroxides. Similarly, barium, cobalt, copper, nickel and lead appear to covary with MnO_2, which indicates a control on their compositions by manganese oxyhydroxide scavenging processes.

ACKNOWLEDGEMENTS

We thank the Master and crew of RV Rig Seismic for assistance during collection of these cores, and AGSO technical and scientific staff for assistance in processing the cores. The organic carbon analyses were conducted by Frank Tirendi at the Australian Institute of Marine Sciences (AIMS). Some pore water analyses were also conducted at AIMS with the co-operation of Miles Furnas and Alan Mitchell. Radiocarbon contents were determined by John Head at the Australian National University Research School of Pacific Studies. XRF analyses were conducted by John Pike at AGSO. We thank P. A. Symonds for a review of this document.

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Appendix A: Radiocarbon data for cores collected off northeast Australia

The Australian National University

Research School of Pacific Studies

Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5755

Submitter	A Herczeg
Submitter's Code	GC 06
Site & Location	Offshore - Qld plateau, N. Qld Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-355.7 ± 11.0 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-387.9 ± 10.8 ‰
AGE	3940 ± 150 BP

COMMENTS

John Head
for
Henry Polach
18/2/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

Telex : AA 62693 reses Fax : 61 62 474639 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
E-mail, ACSnet : SAR410@CSC1.ANU.OZ, from O/seas through BITnet via @MUNNARI.OZ

The Australian National University

Research School of Pacific Studies

Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5752

Submitter	A Herczeg
Submitter's Code	GC 009
Site & Location	Barrier Reef QLD
	Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-97.9 ± 13.8 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	143.0 ± 13.6 ‰
AGE	1240 ± 130 BP

COMMENTS

John Head
for
Henry Polach
18/2/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
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Telex : AA 62693 reses Fax : 61 62 474639 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
E-mail, ACSnet : SAR410@CSC1.ANU.OZ, from 0/seas through BITnet via @MUNNARI.OZ

The Australian National University
Research School of Pacific Studies

Radiocarbon Dating Research
ANU, GPO Box 4
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU- 5756

Submitter	A.L. Herczeg
Submitter's Code	GC 015
Site & Location	Barrier Reef, Queensland, Australia
Sample Material	Marine Carbonate from core sample
Physical Pretreatment	None.
Chemical Pretreatment	Residue of carbonate after acid evolution with 6N HCl, filtered rinsed & dried.

$d^{14}C$	585.6 ± 56.5	‰	
$\delta^{13}C$	-24.0 ± 2.0	‰	estimated
$D^{14}C$	582.4 ± 56.7	‰	
AGE	158.2 ± 5.7	%M	

Comments

cf. 1530 ± 170 BP for SU5756K-1
^{14}C activity value may be higher than the true value because of the small sample size. Even so, it is highly probable that "bomb" ^{14}C is present, and the organic material is post 1950 in age.
John Head

for
Henry Polach
13/9/89

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is -450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error <2.0 indicates that the value was measured.

Telex : AA 62693 reses Fax : 61 62 490738 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
E-mail, ACSnet : SAR409@CSC1.ANU.OZ, from Overseas through BITnet via @MUNNARI.OZ

The Australian National University
Research School of Pacific Studies

Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5756

Submitter	A Herczeg
Submitter's Code	GC 015
Site & Location	Barrier Reef QLD
	Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-130.0 ± 17.6 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-173.5 ± 17.1 ‰
AGE	1530 ± 170 BP

COMMENTS

John Head
for
Henry Polach
18/2/88

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- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

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The Australian National University

Research School of Pacific Studies

14C ANU

Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5757

Submitter	A Herczeg
Submitter's Code	GC 029
Site & Location	Offshore Qld plateau N.Qld Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-455.7 ± 13.0 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-482.9 ± 12.6 ‰
AGE	5300 ± 200 BP

COMMENTS

John Head
for
Henry Polach
18/2/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

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Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5759

Submitter	A Herczeg
Submitter's Code	GC 039
Site & Location	Offshore Qld plateau N.Qld Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-565.6 ± 5.1 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-587.3 ± 5.1 ‰
AGE	**7110 ± 100 BP**

COMMENTS

John Head
for
Henry Polach
9/3/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

Telex : AA 62693 reses Fax : 61 62 474639 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
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Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

14C ANU

Report on Radiocarbon Age Determination for ANU-5758

	A Herczeg
Code	GC 050
tion	Offshore Qld plateau N.Qld
	Australia
rial	Marine Carbonate from core sample
atment	None.
eatment	None.

$d^{14}C$	-192.1 ± 15.1 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-232.5 ± 14.7 ‰
AGE	2130 ± 160 BP

Head

:h

John Head
for
Henry Polach
18/2/88

ige BP ± error

blications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* *rn ± error* if given.

oon 19, 353-

eported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-

79, in Berger
ust quote
.

ded oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.

vas measured.

$\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

: 81 2592 (h)
I.OZ

2693 reses Fax : 61 62 474639 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
il, ACSnet : SAR410@CSC1.ANU.OZ, from O/seas through BITnet via @MUNNARI.OZ

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ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5753

Submitter	A Herczeg
Submitter's Code	GC 063
Site & Location	Barrier Reef QLD
	Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-229.1 ± 10.2 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-267.7 ± 10.1 ‰
AGE	**2500 ± 120 BP**

COMMENTS

John Head
for
Henry Polach
18/2/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

Telex : AA 62693 reses Fax : 61 62 474639 Tel : 61 62 49 3122 (w); 61 62 81 2592 (h)
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Research School of Pacific Studies

Radiocarbon Dating Research
ANU, GPO Box 4,
CANBERRA 2601, Australia

Henry A Polach

Report on Radiocarbon Age Determination for ANU-5754

Submitter	A Herczeg
Submitter's Code	GC 064
Site & Location	Barrier Reef QLD
	Australia
Sample Material	Marine Carbonate from core sample
Physical Treatment	None.
Chemical Treatment	None.

$d^{14}C$	-185.6 ± 10.7 ‰
$\delta^{13}C$	0.0 ± 2.0 ‰
$D^{14}C$	-226.3 ± 10.7 ‰
AGE	**2060 ± 110 BP**

COMMENTS

John Head
for
Henry Polach
18/2/88

- In your publications you must always quote Laboratory code, Sample Number and *Conventional age BP ± error* or *% Modern ± error* if given.
- Ages are reported as *Conventional years BP* or *% Modern* (Stuiver and Polach, 1977, Radiocarbon 19, 353-363).
- Recommended oceanic reservoir correction for Australia is - 450 ± 35 (Gillespie and Polach, 1979, in Berger and Suess (eds), Radiocarbon Dating, UCLA Press, 404-421). If a correction is applicable you must quote Laboratory Code, Number and both the *Conventional age BP* and the *Reservoir Corrected age BP**.
- Estimated $\delta^{13}C$ values are assigned an error of 2.0 permil. Error < 2.0 indicates that the value was measured.

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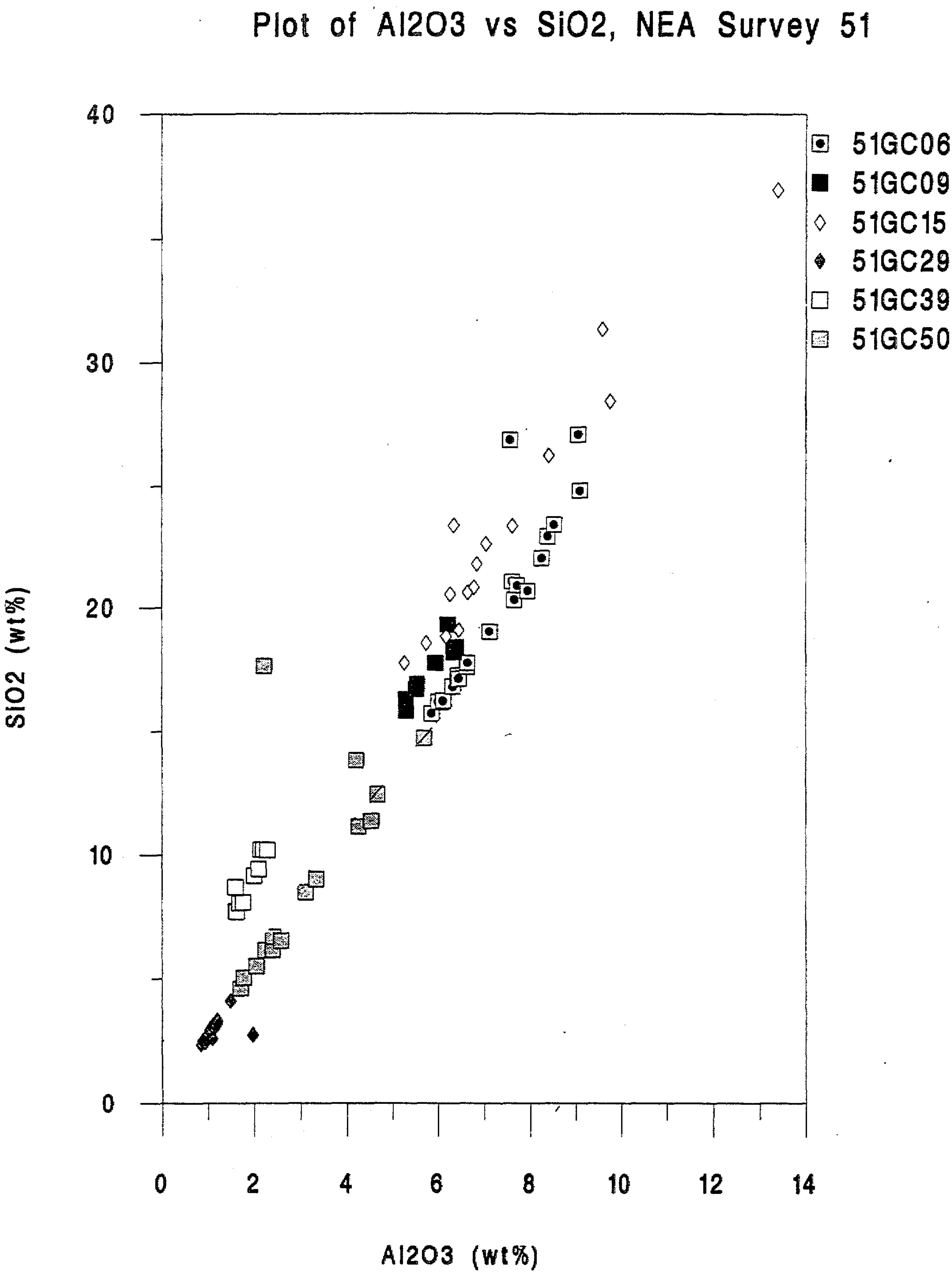
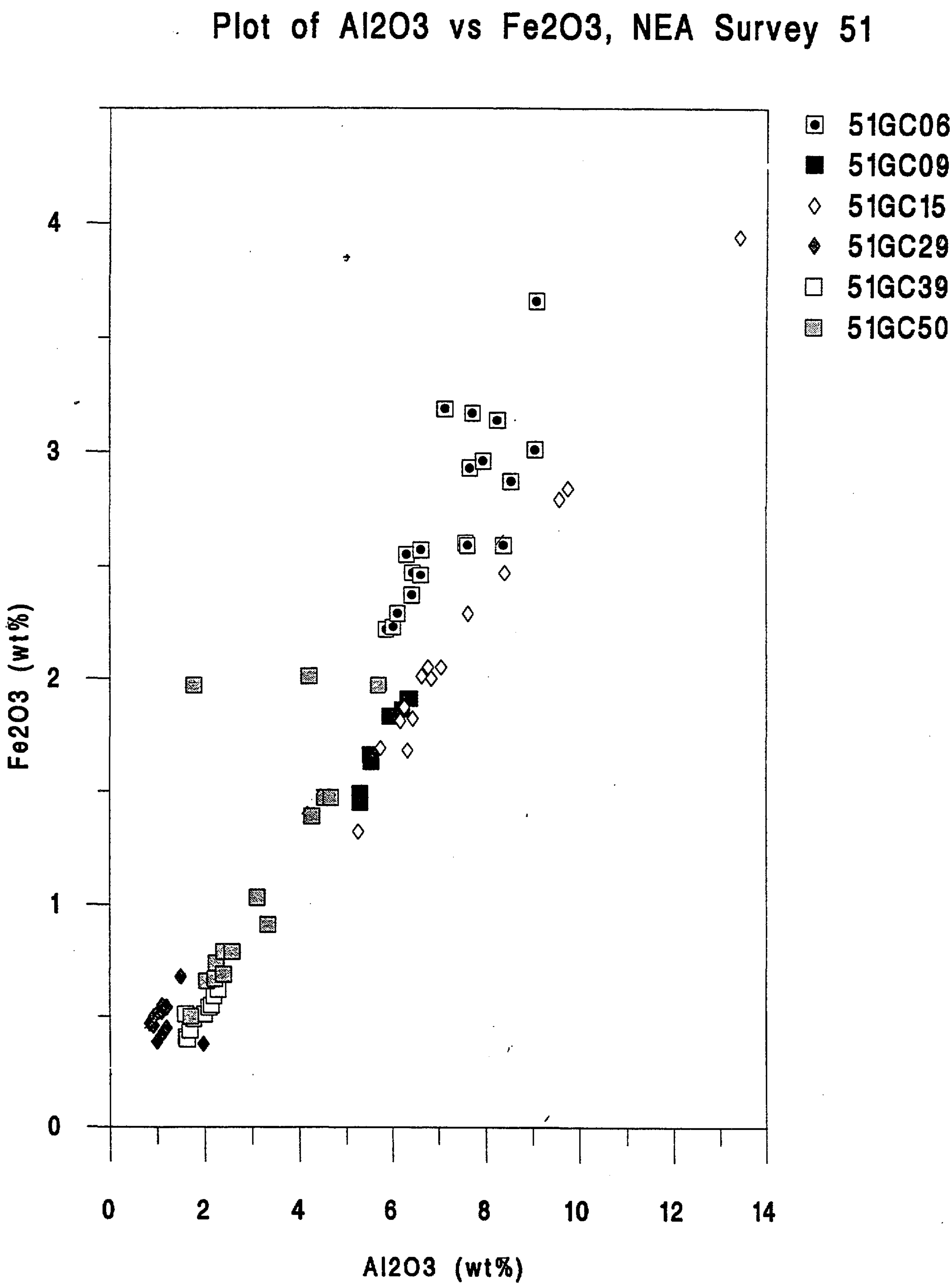
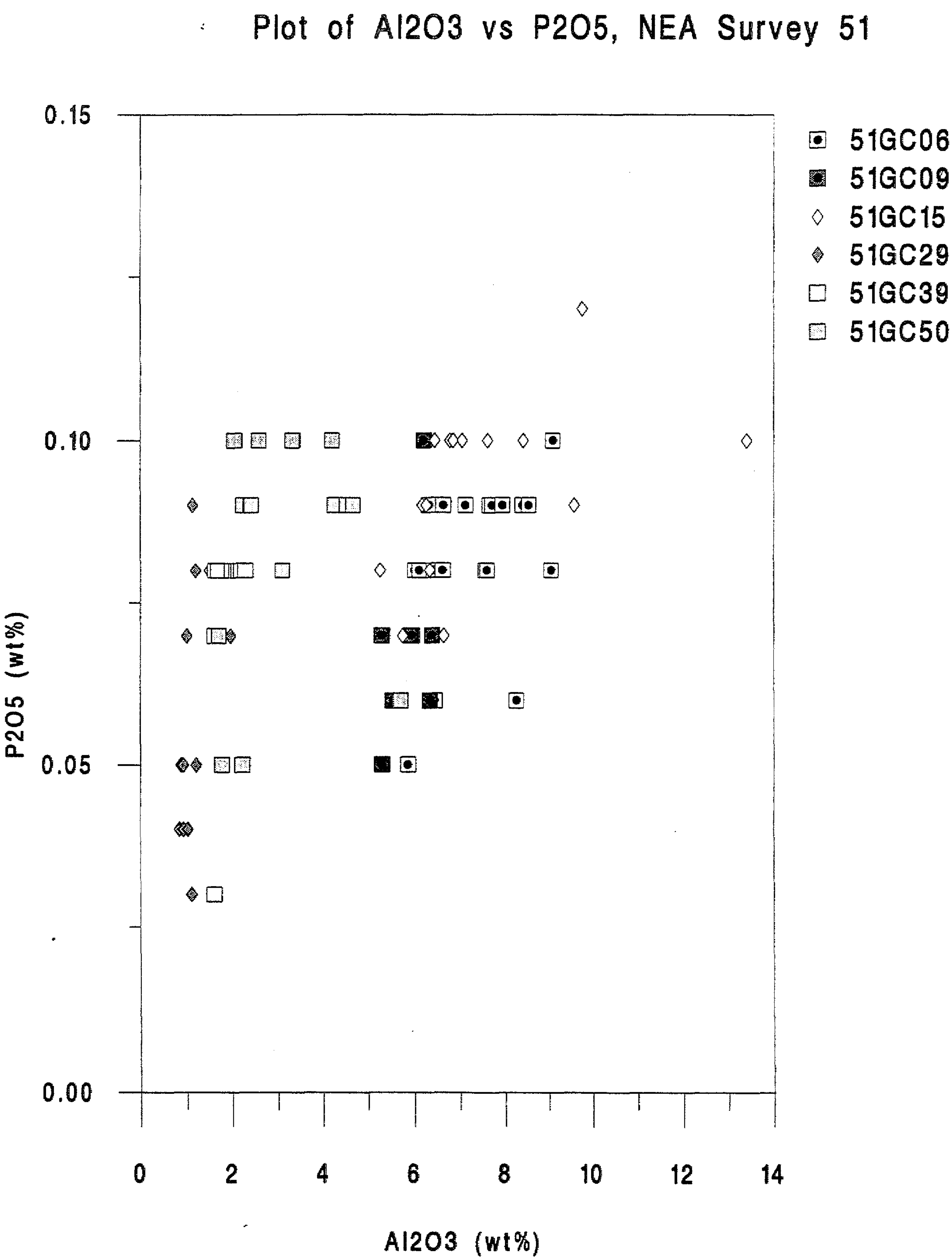
Appendix B: Major and trace element data plots of Al_2O_3 versus select elements

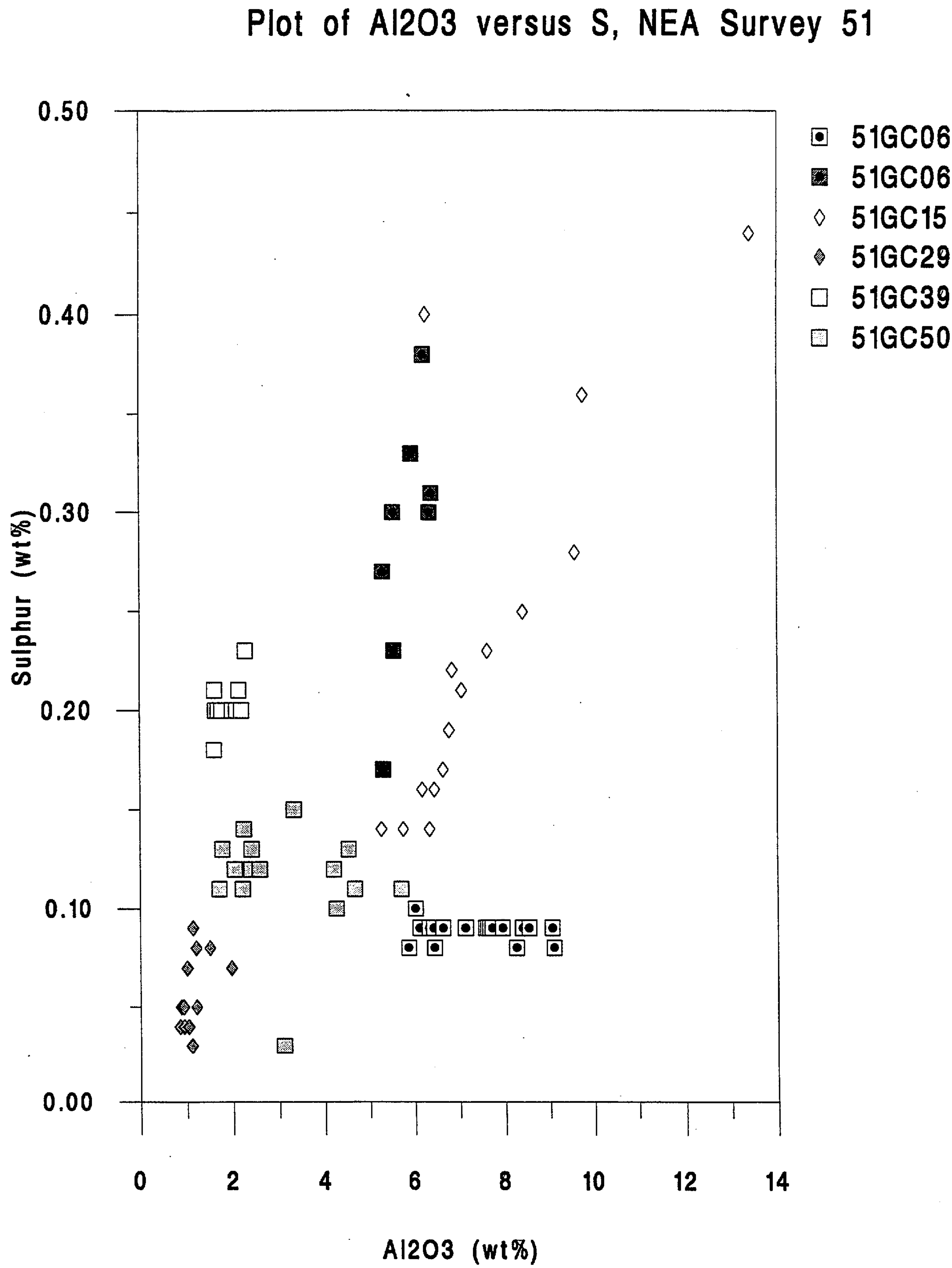
R9303302



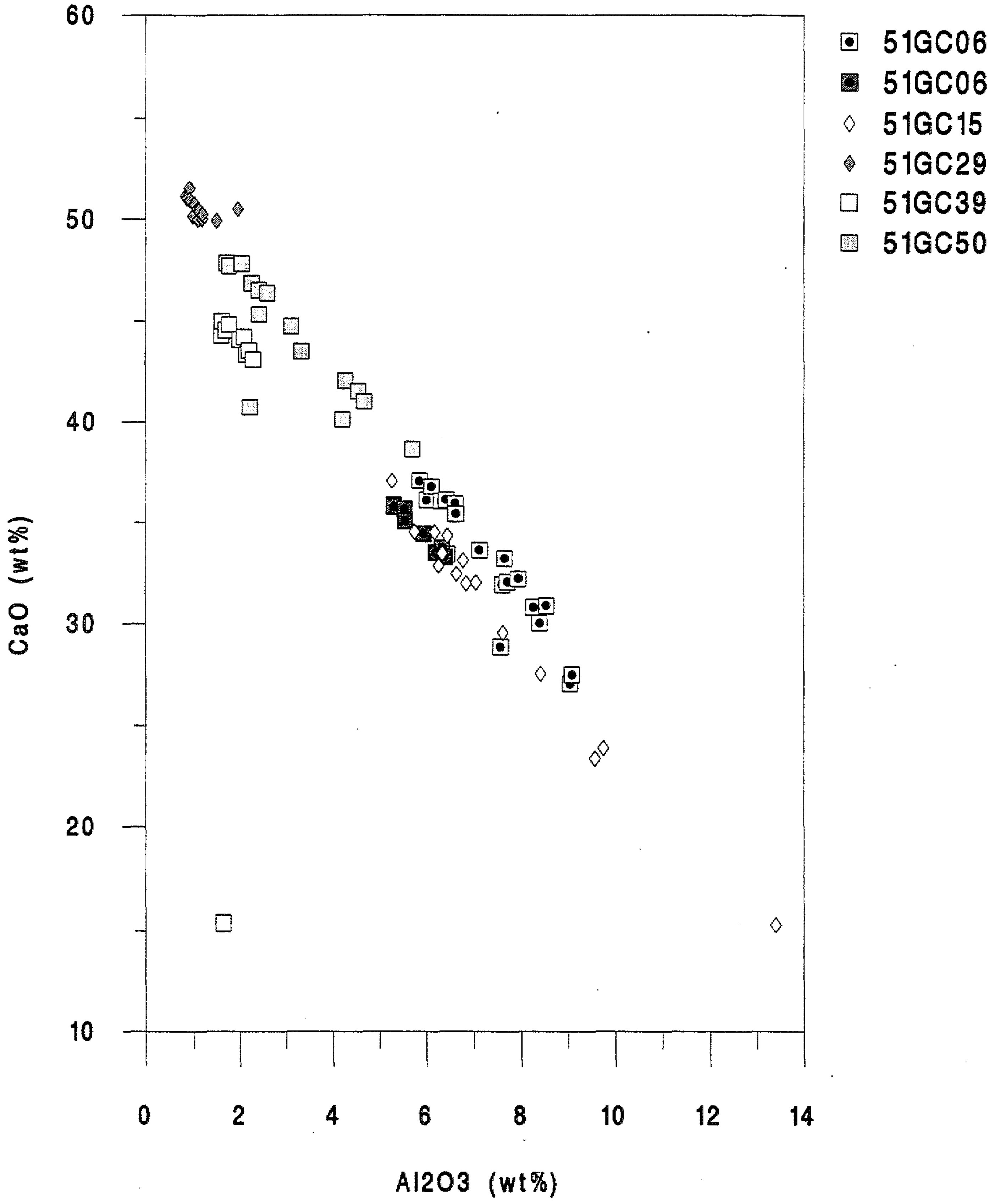
Plot of Al2O3 vs SiO2, NEA Survey 51
40
30
20
10
0
SiO2 (wt%)
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

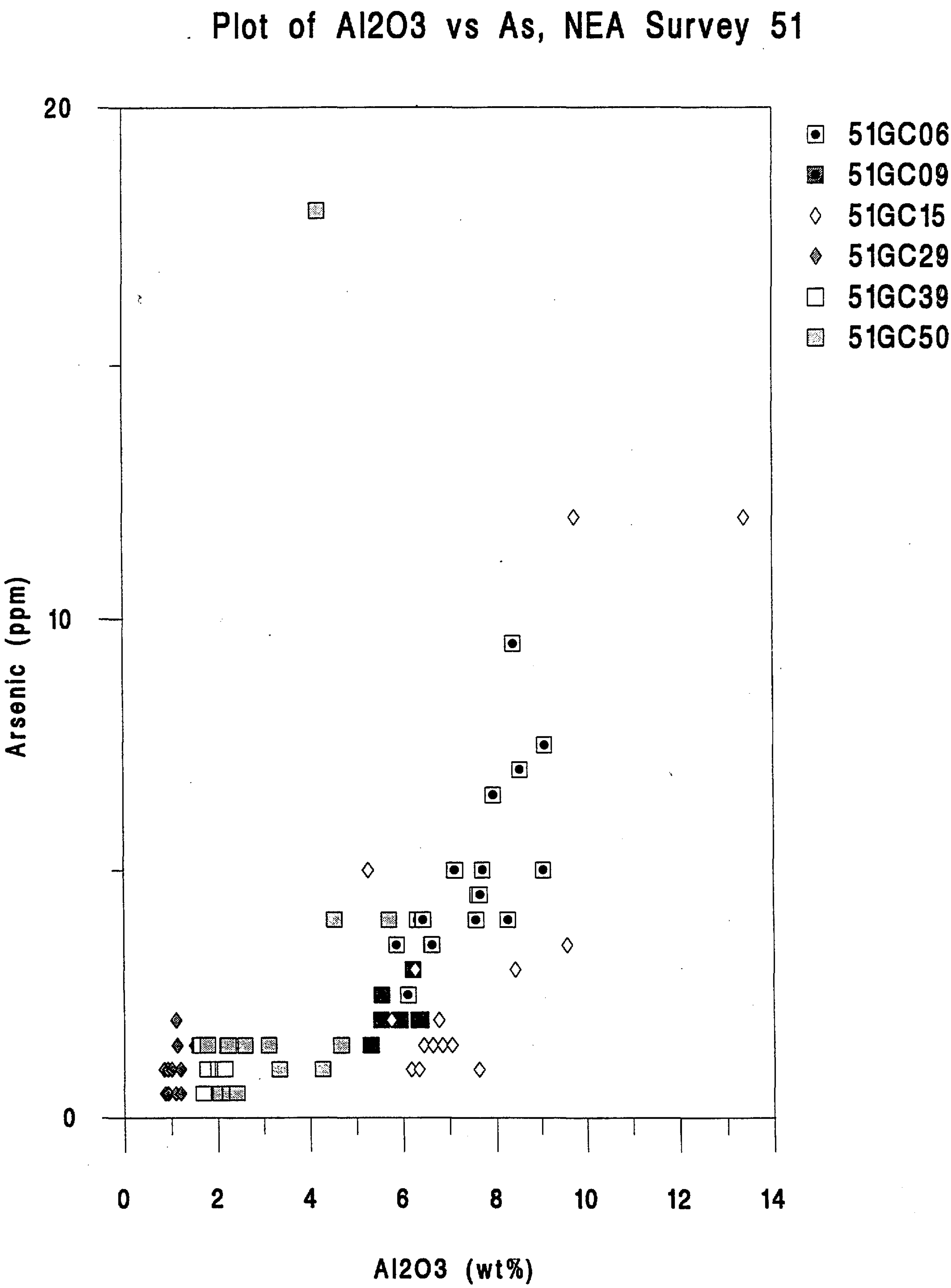

Plot of Al2O3 vs Fe2O3, NEA Survey 51
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50
Fe2O3 (wt%)
Al2O3 (wt%)
0
1
2
3
4
0
2
4
6
8
10
12
14


Plot of Al2O3 vs P2O5, NEA Survey 51
0.15
0.10
0.05
0.00
P2O5 (wt%)
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

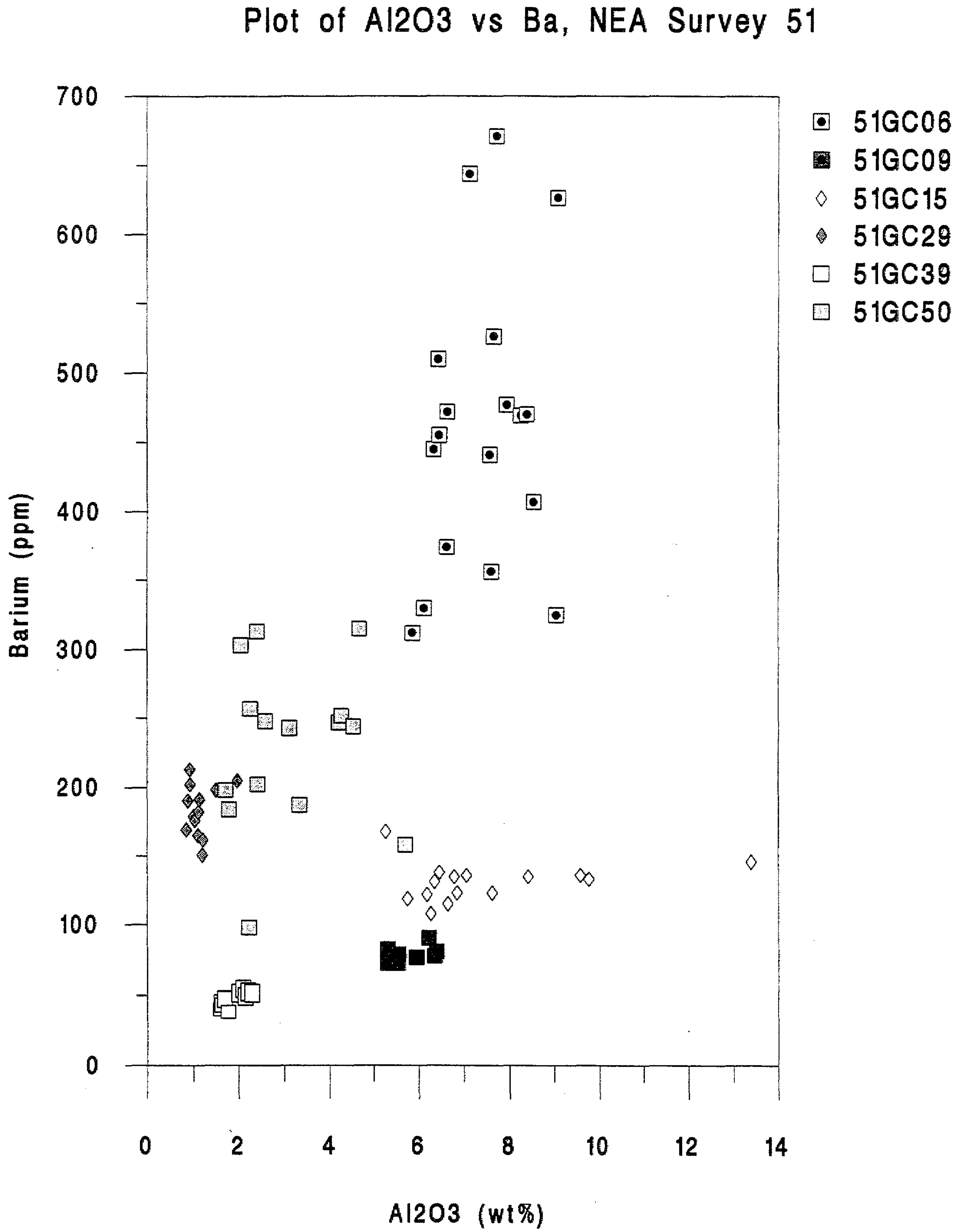

Plot of Al2O3 versus S, NEA Survey 51
Sulphur (wt%)
0.00
0.10
0.20
0.30
0.40
0.50
Al2O3 (wt%)
0
2
4
6
8
10
12
14
51GC06
51GC06
51GC15
51GC29
51GC39
51GC50

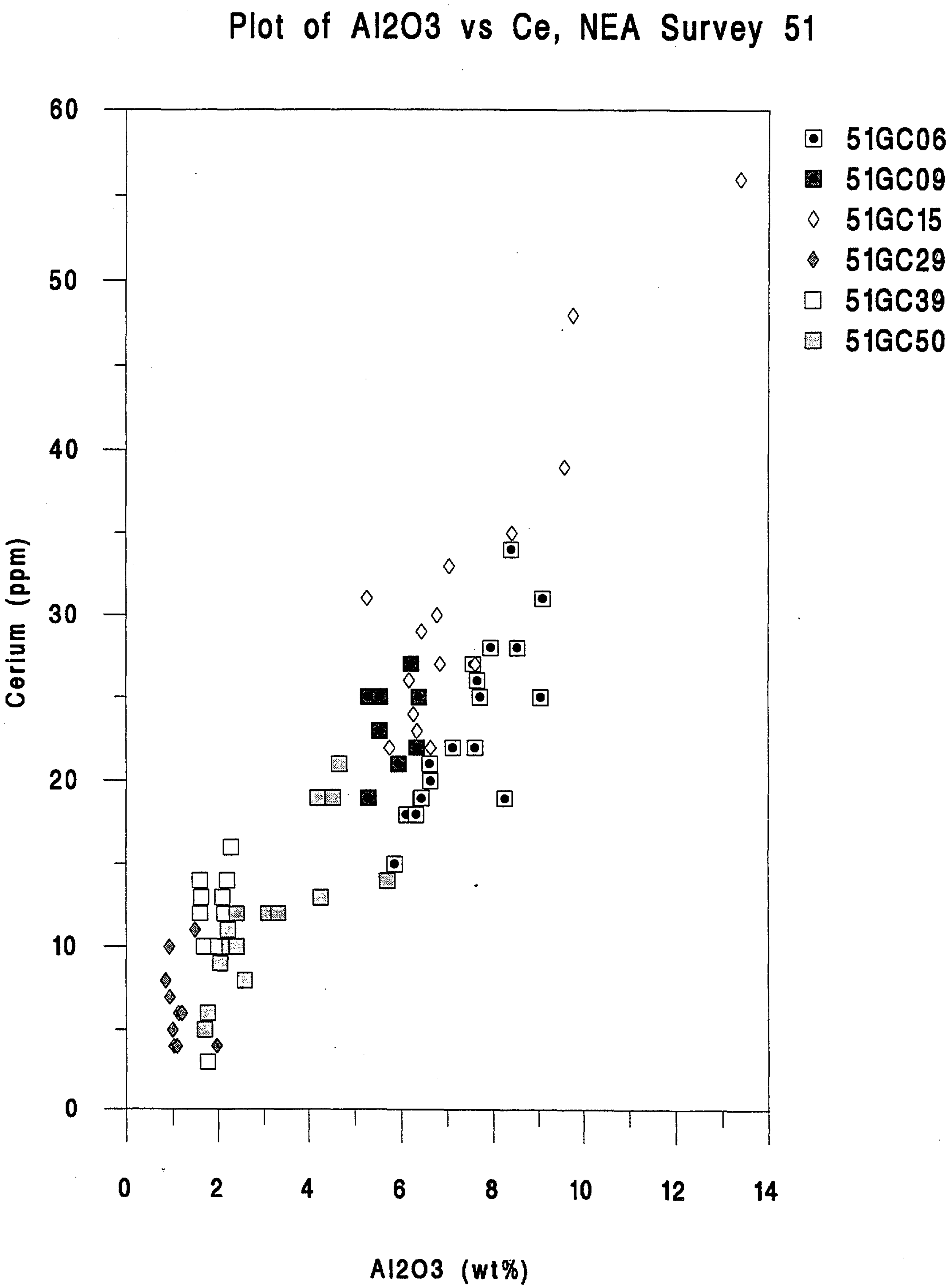
Plot of Al2O3 vs CaO, NEA Survey 51



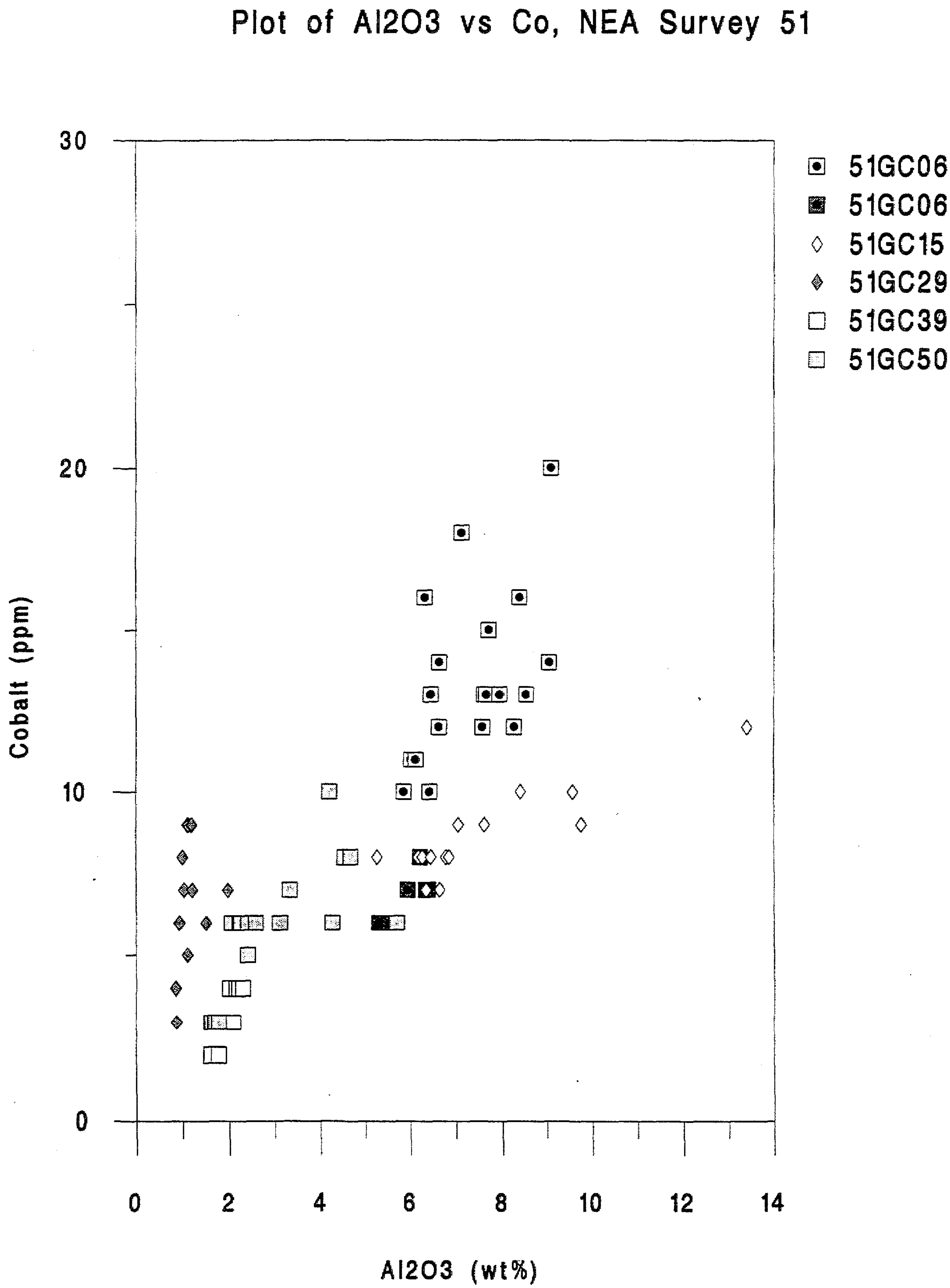


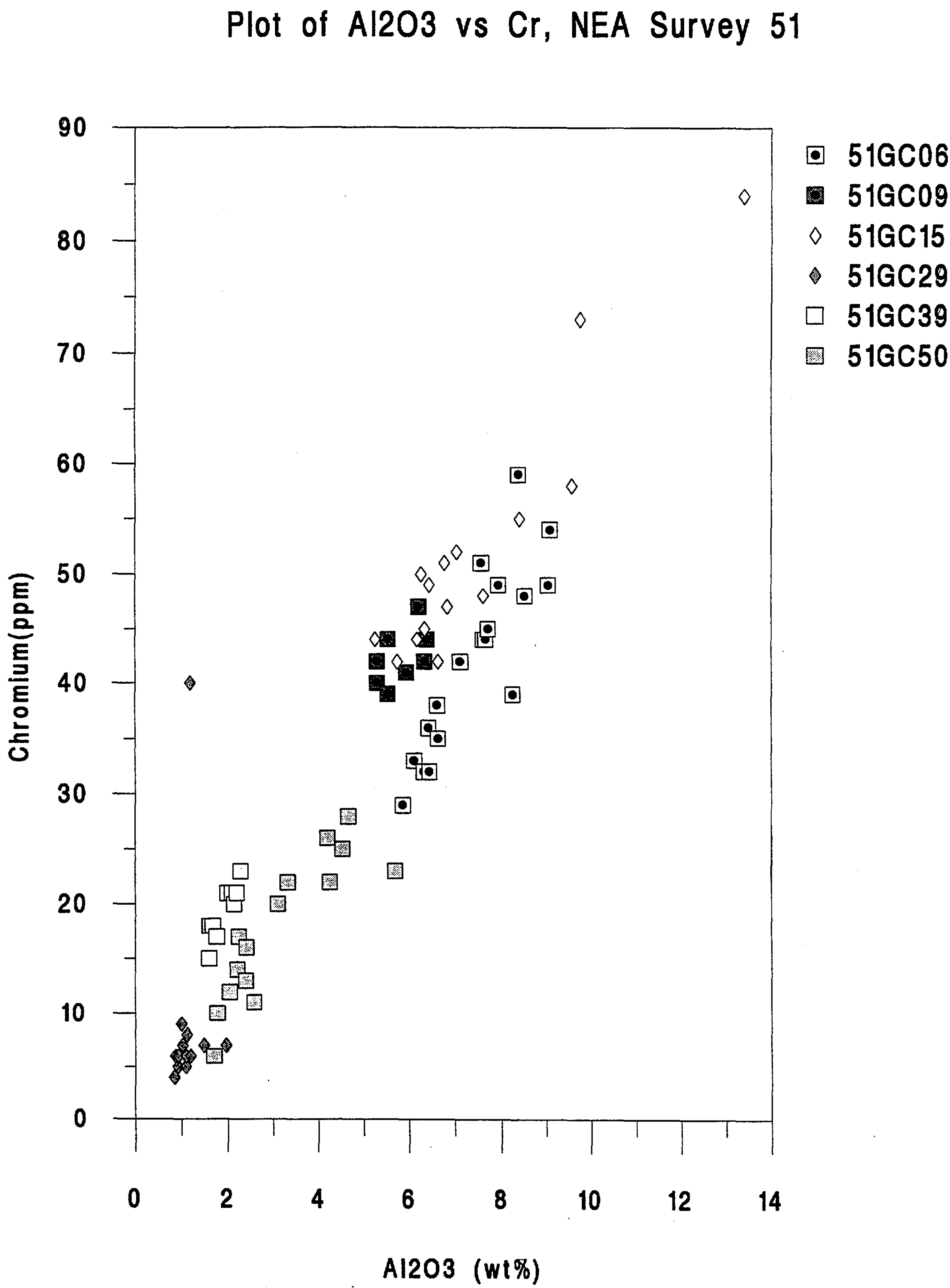
Plot of Al2O3 vs As, NEA Survey 51
20
10
0
Arsenic (ppm)
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

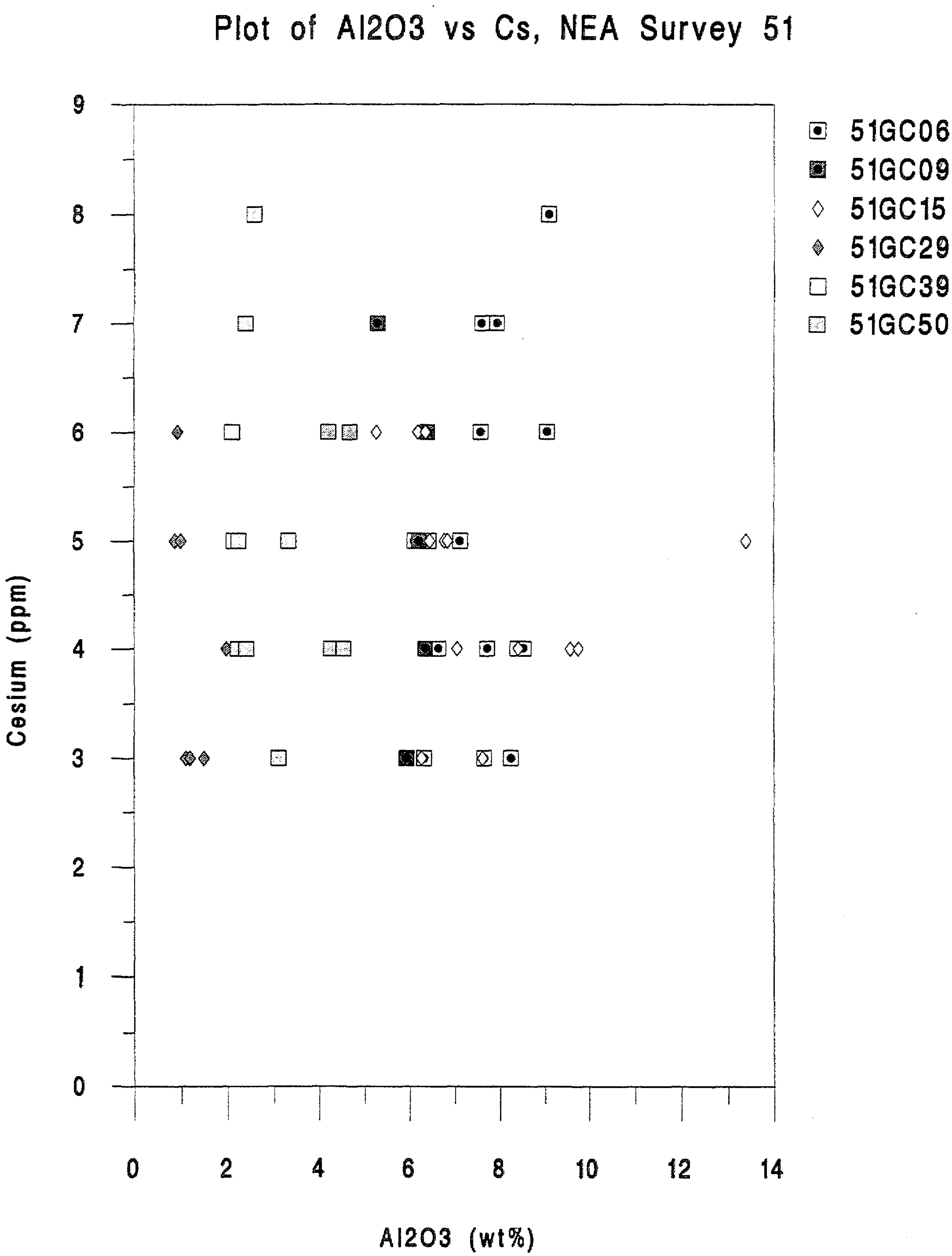

Plot of Al2O3 vs Ba, NEA Survey 51
700
600
500
400
300
200
100
0
Barium (ppm)
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

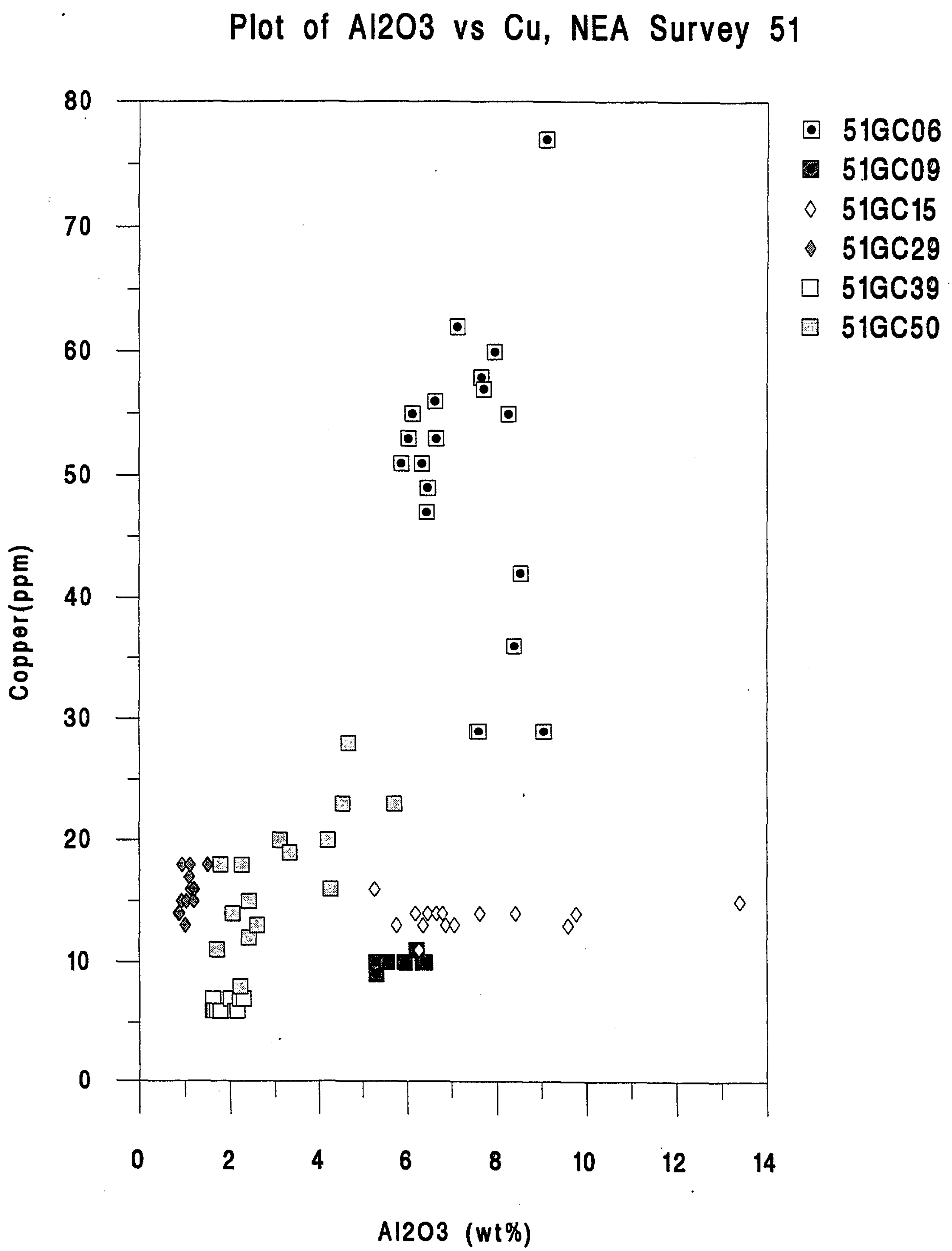


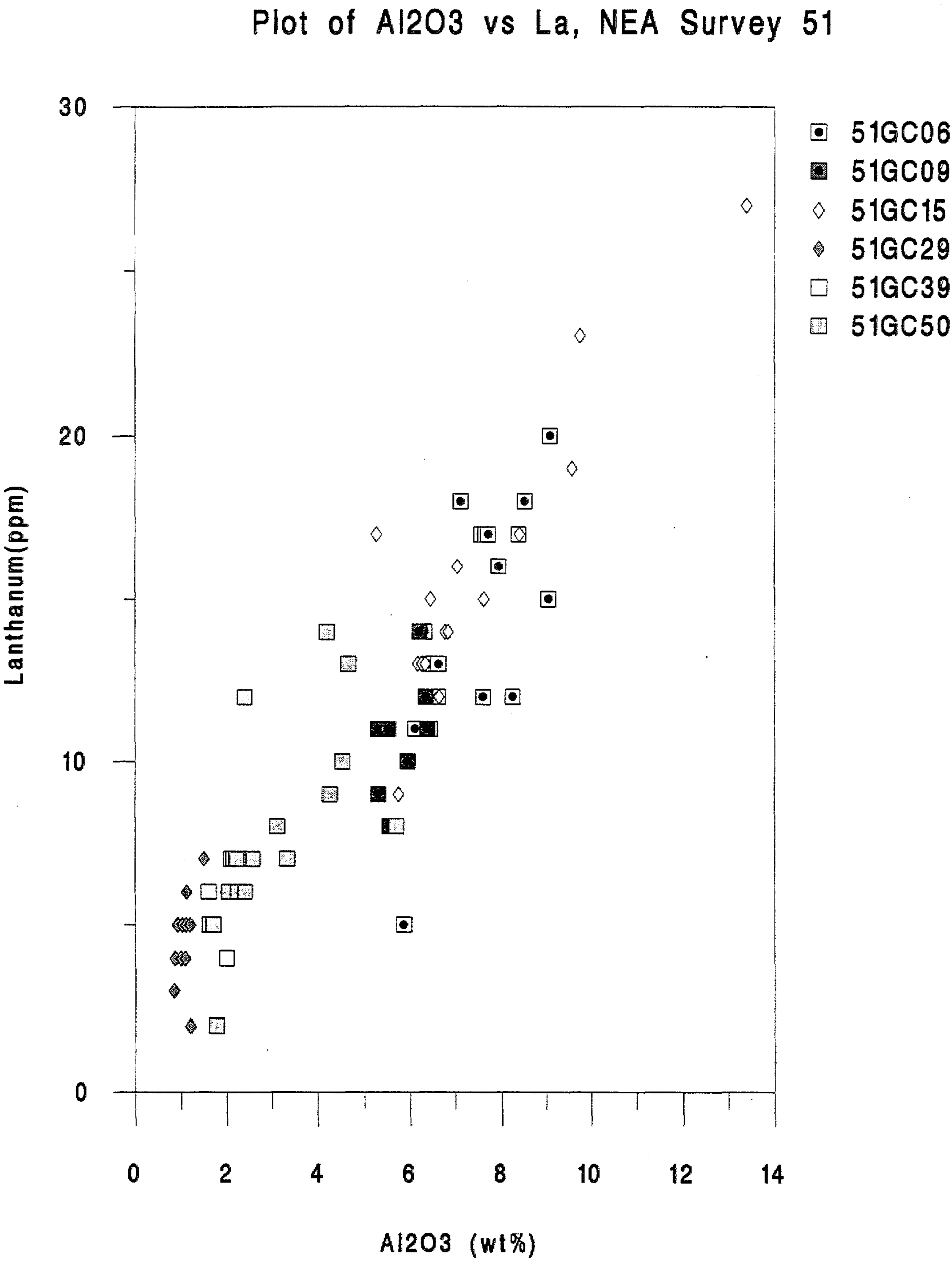
Plot of Al2O3 vs Ce, NEA Survey 51
Cerium (ppm)
0
10
20
30
40
50
60
Al2O3 (wt%)
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

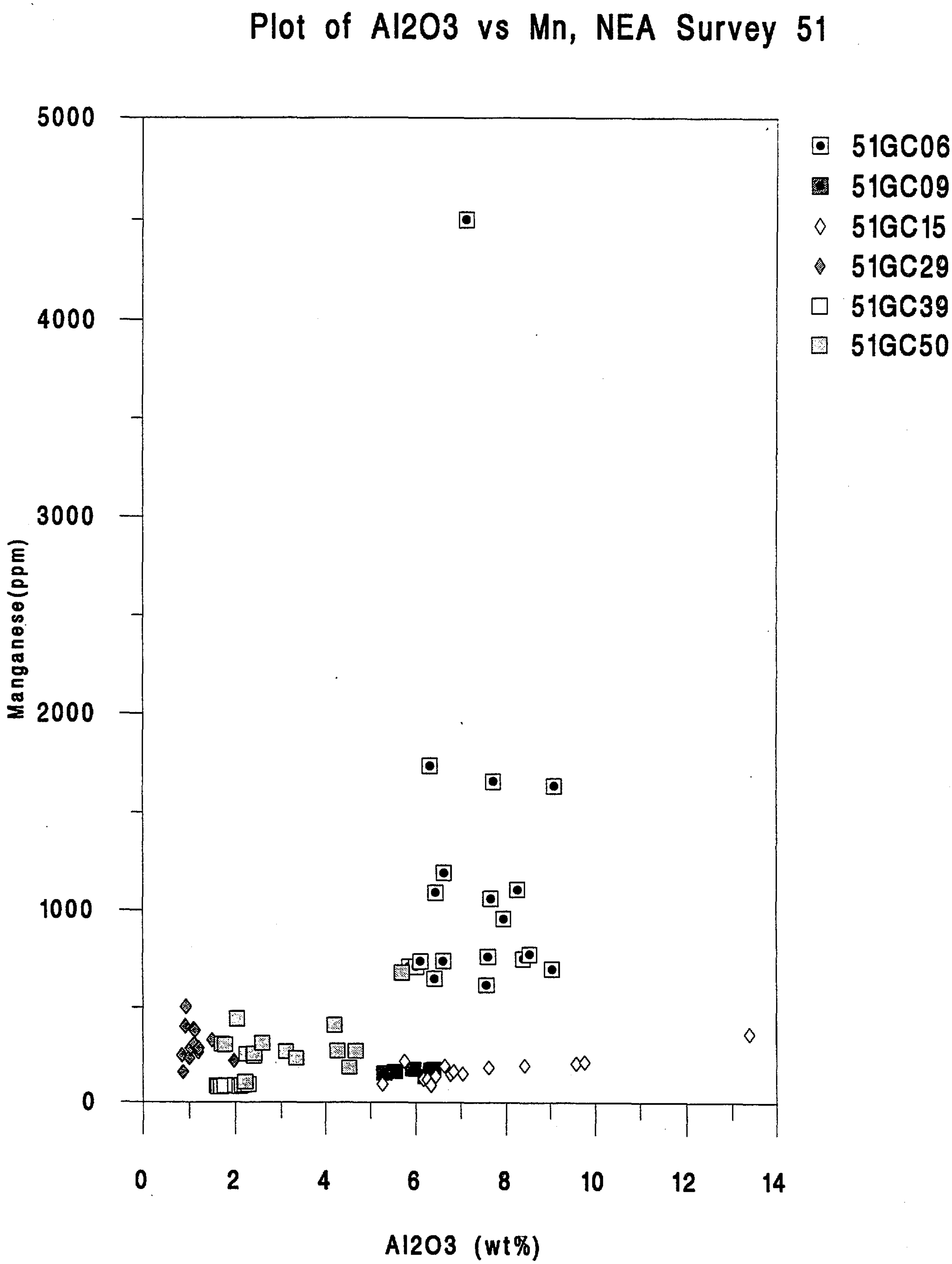

Plot of Al2O3 vs Co, NEA Survey 51
Cobalt (ppm)
30
20
10
0
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC06
51GC15
51GC29
51GC39
51GC50

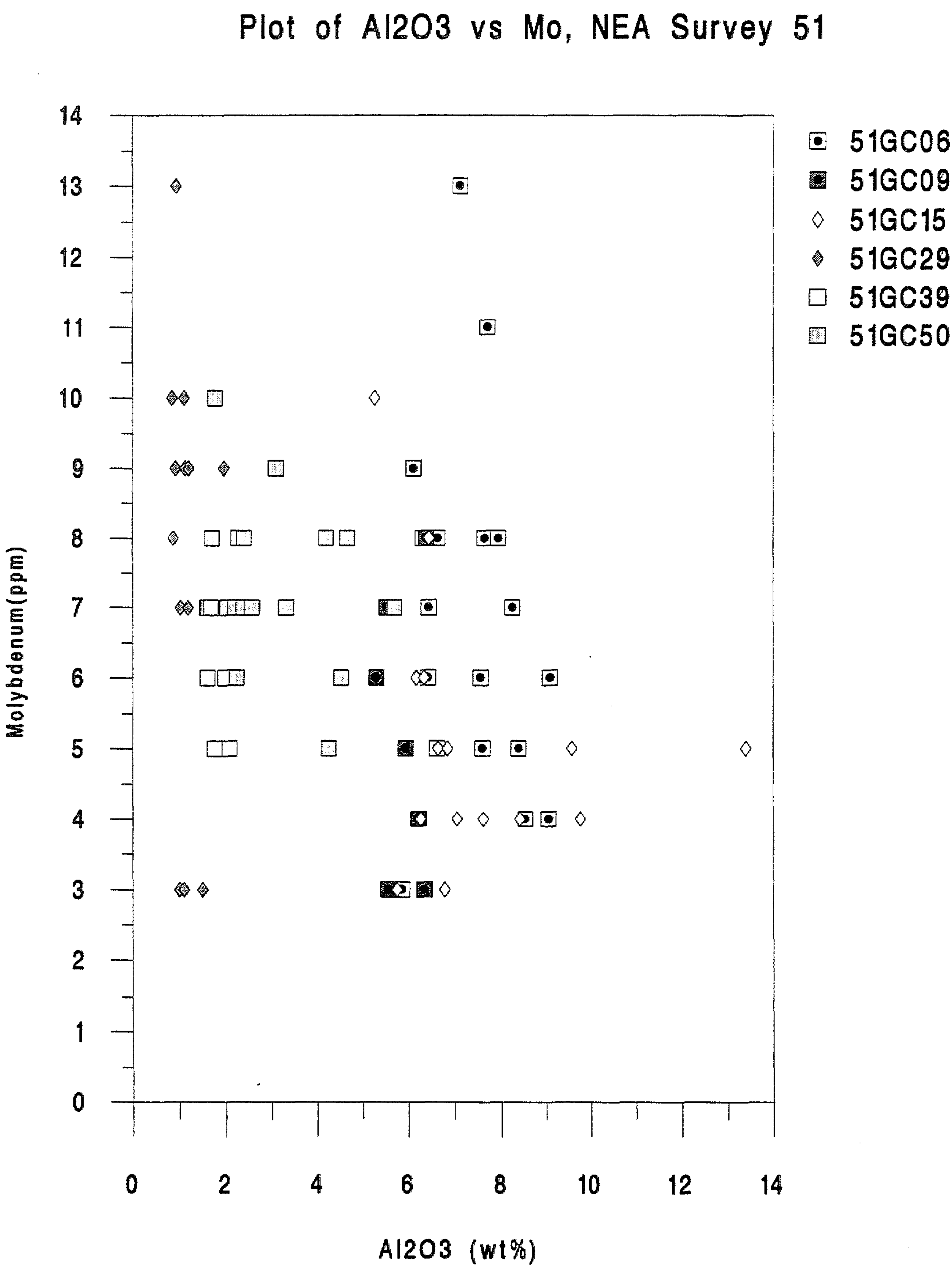

Plot of Al2O3 vs Cr, NEA Survey 51
Chromium(ppm)
Al2O3 (wt%)
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

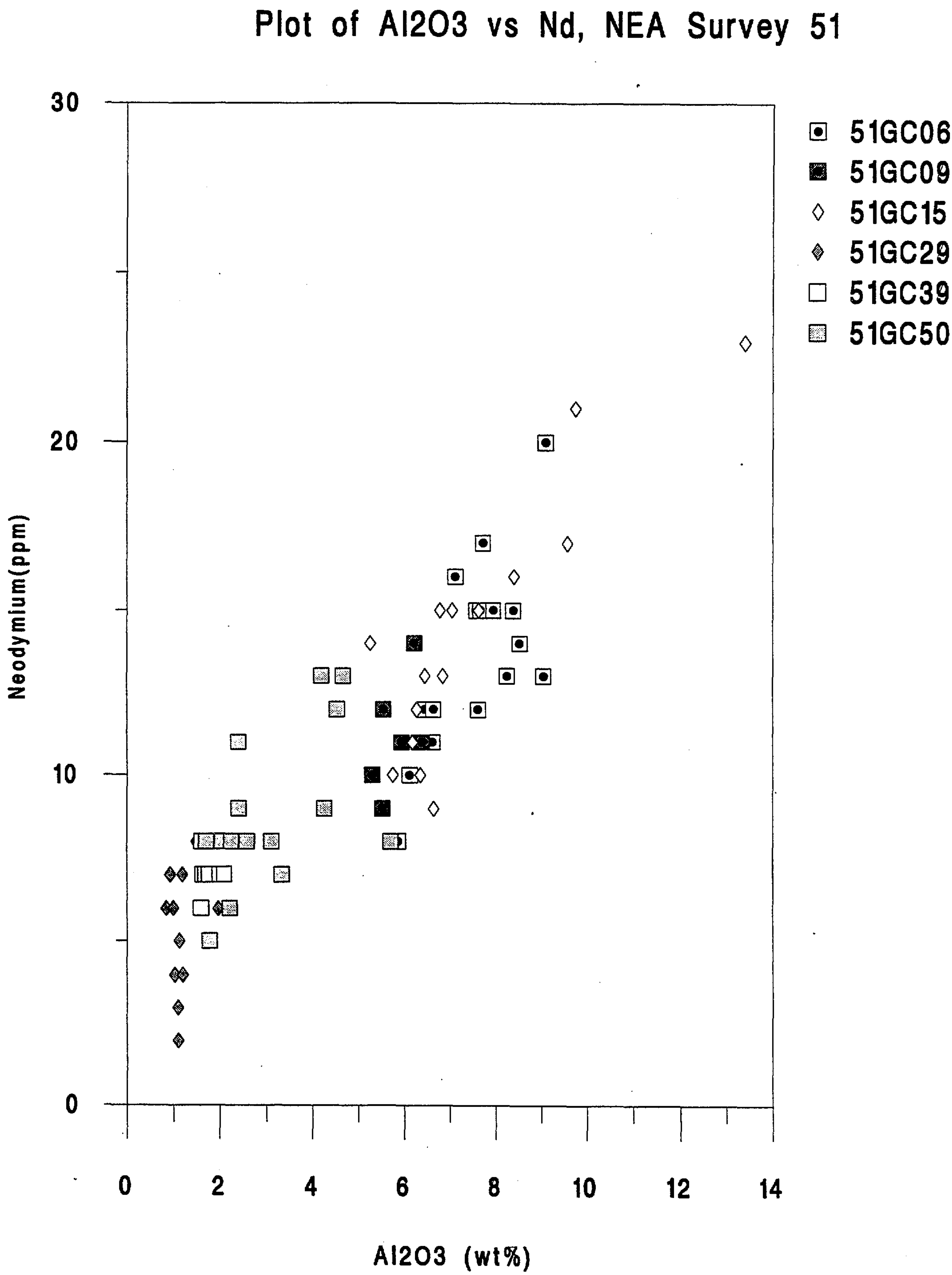

Plot of Al2O3 vs Cs, NEA Survey 51
Cesium (ppm)
Al2O3 (wt%)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Al2O3 vs Cu, NEA Survey 51
Copper(ppm)
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

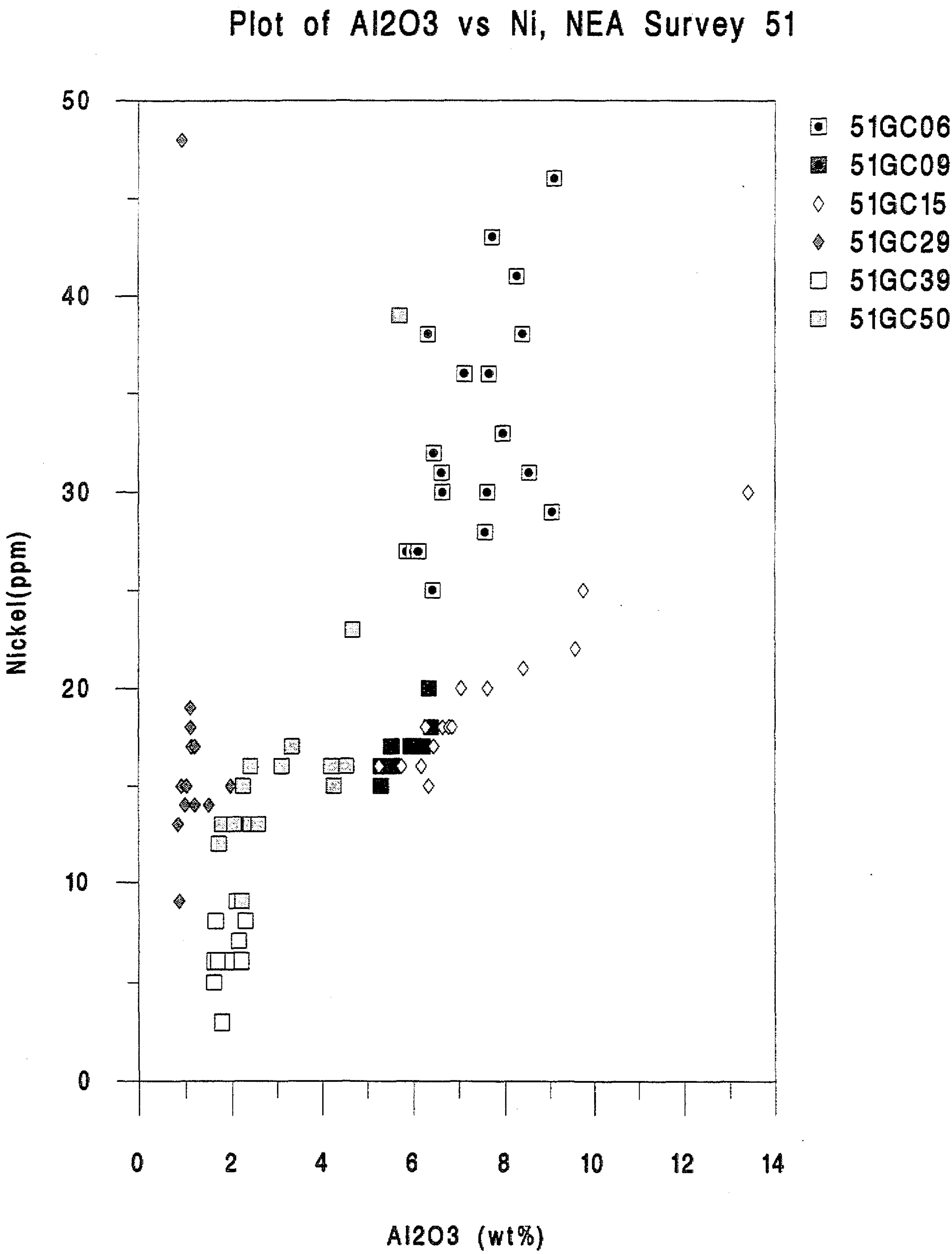

Plot of Al2O3 vs La, NEA Survey 51
Lanthanum(ppm)
30
20
10
0
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

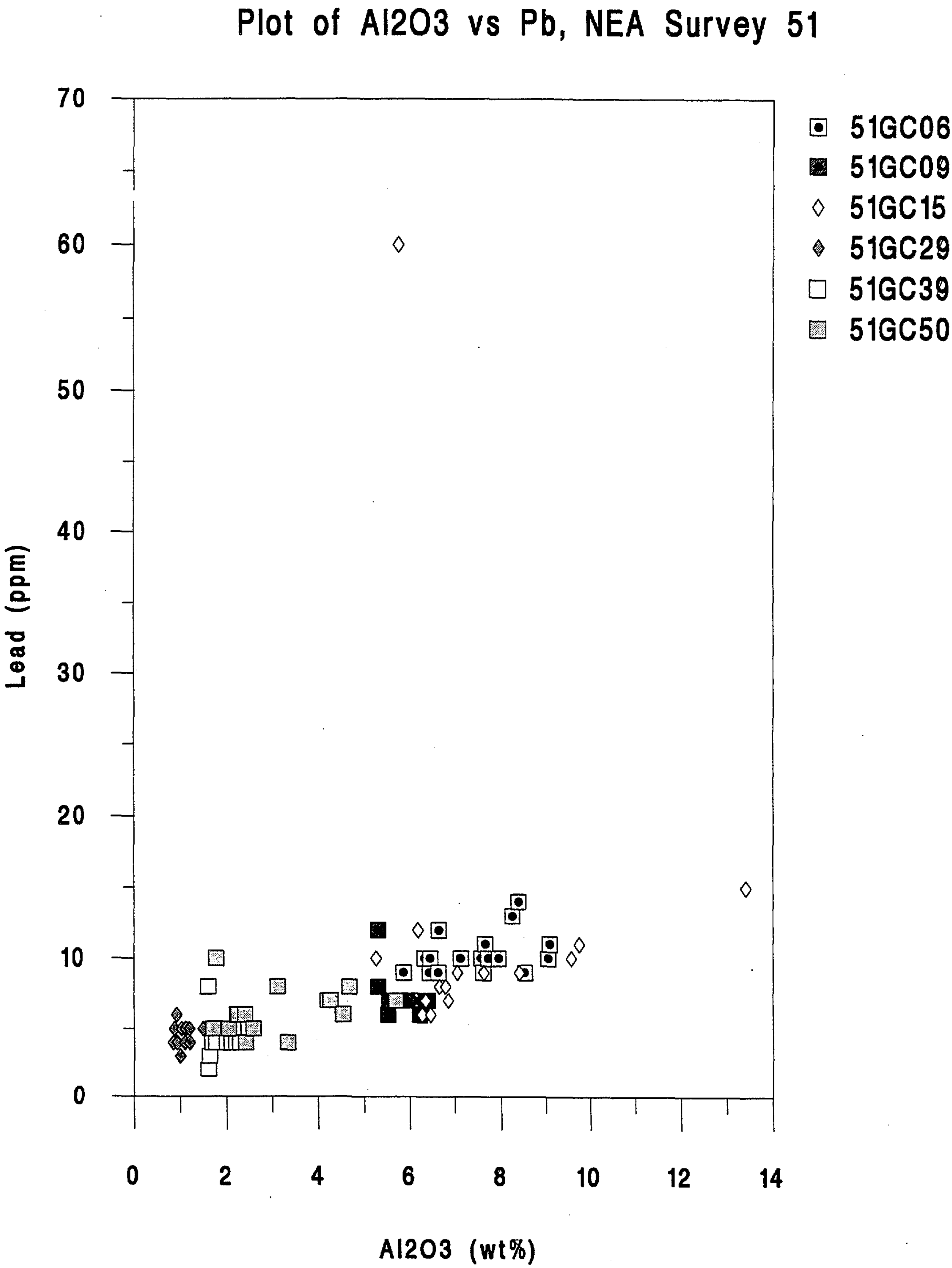

Plot of Al2O3 vs Mn, NEA Survey 51
Manganese (ppm)
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Al2O3 vs Mo, NEA Survey 51
Molybdenum(ppm)
Al2O3 (wt%)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

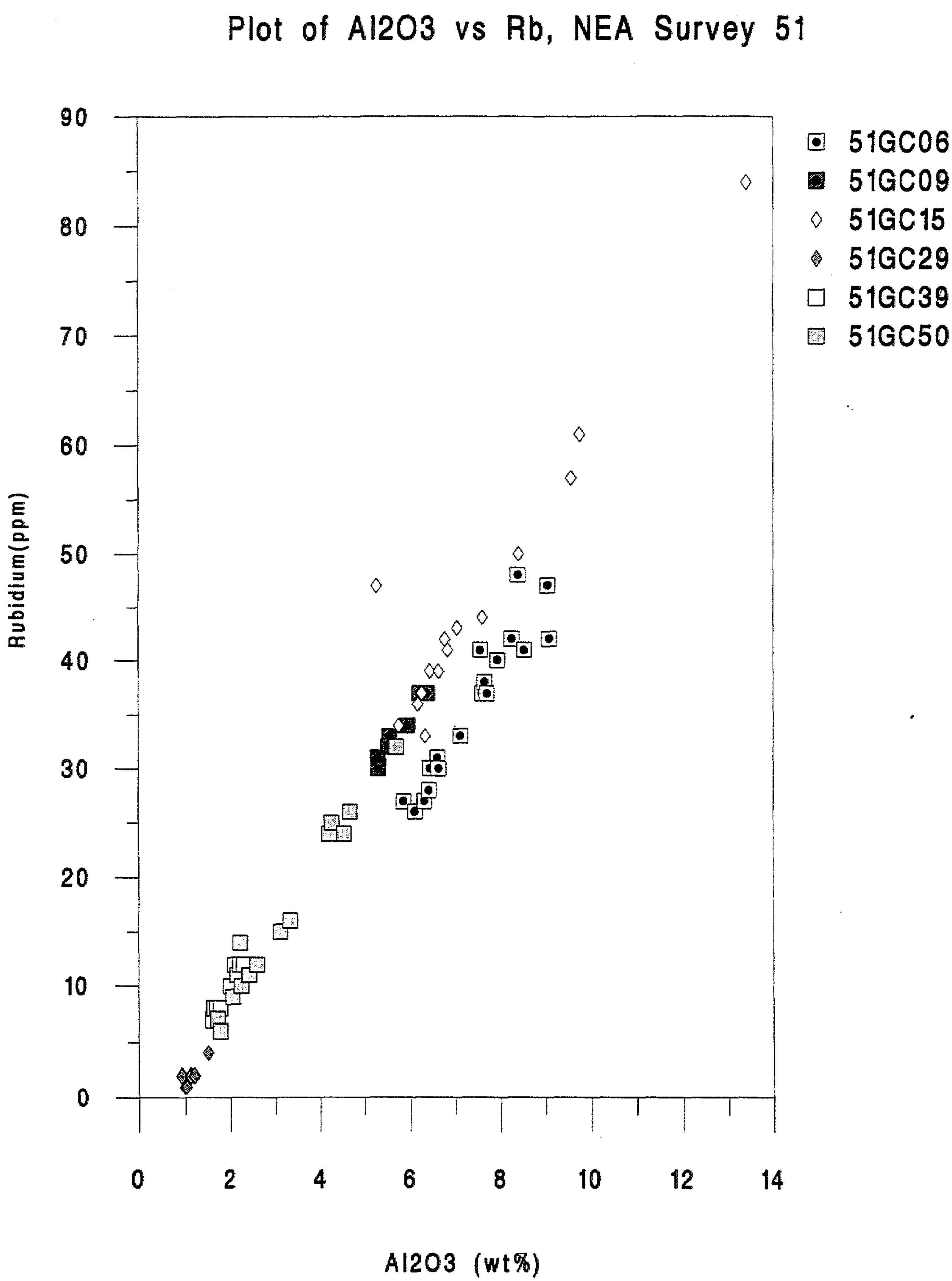


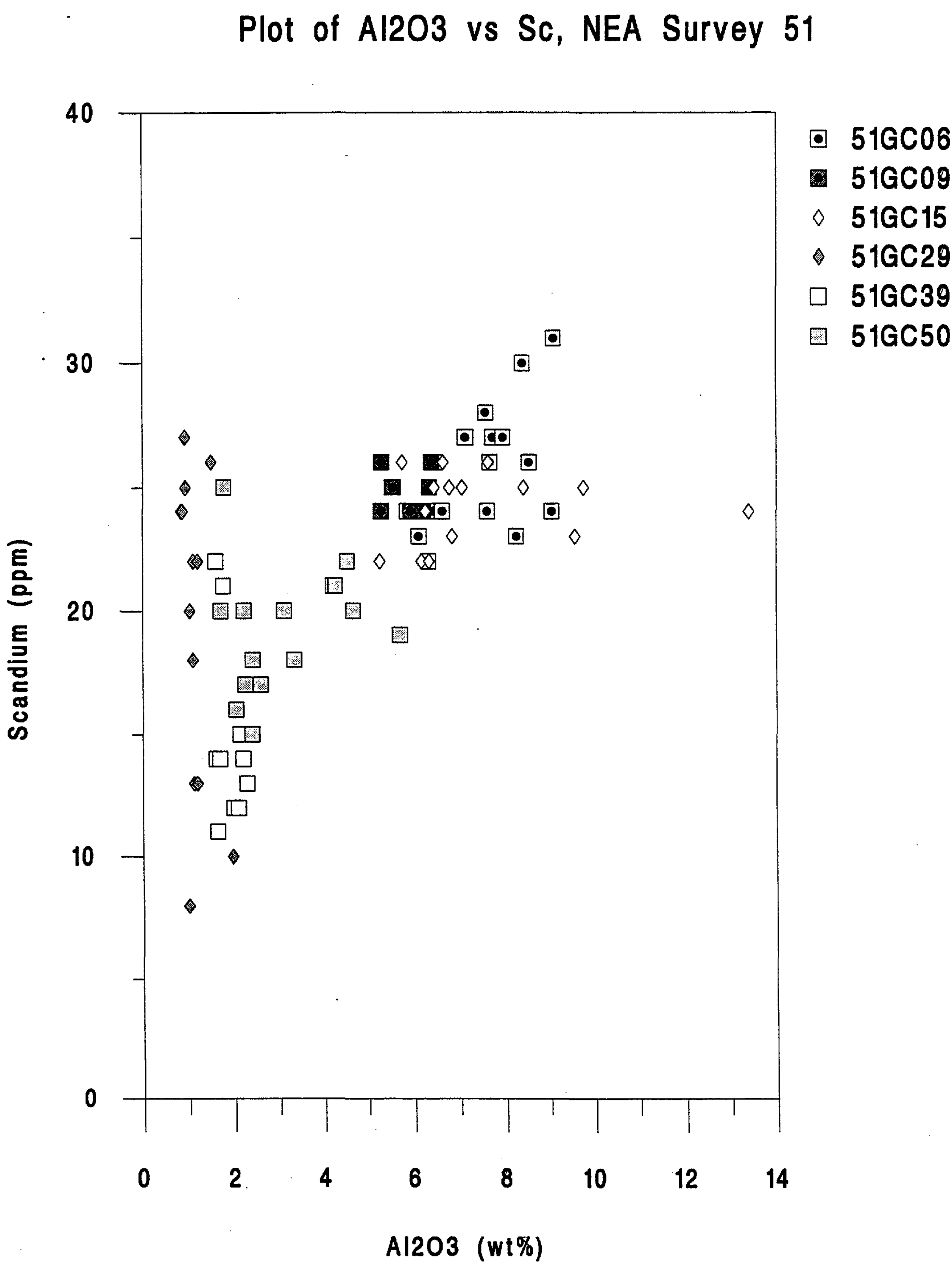
Plot of Al2O3 vs Nd, NEA Survey 51
Neodymium(ppm)
Al2O3 (wt%)
0
10
20
30
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Al2O3 vs Ni, NEA Survey 51
Nickel(ppm)
Al2O3 (wt%)
0
10
20
30
40
50
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



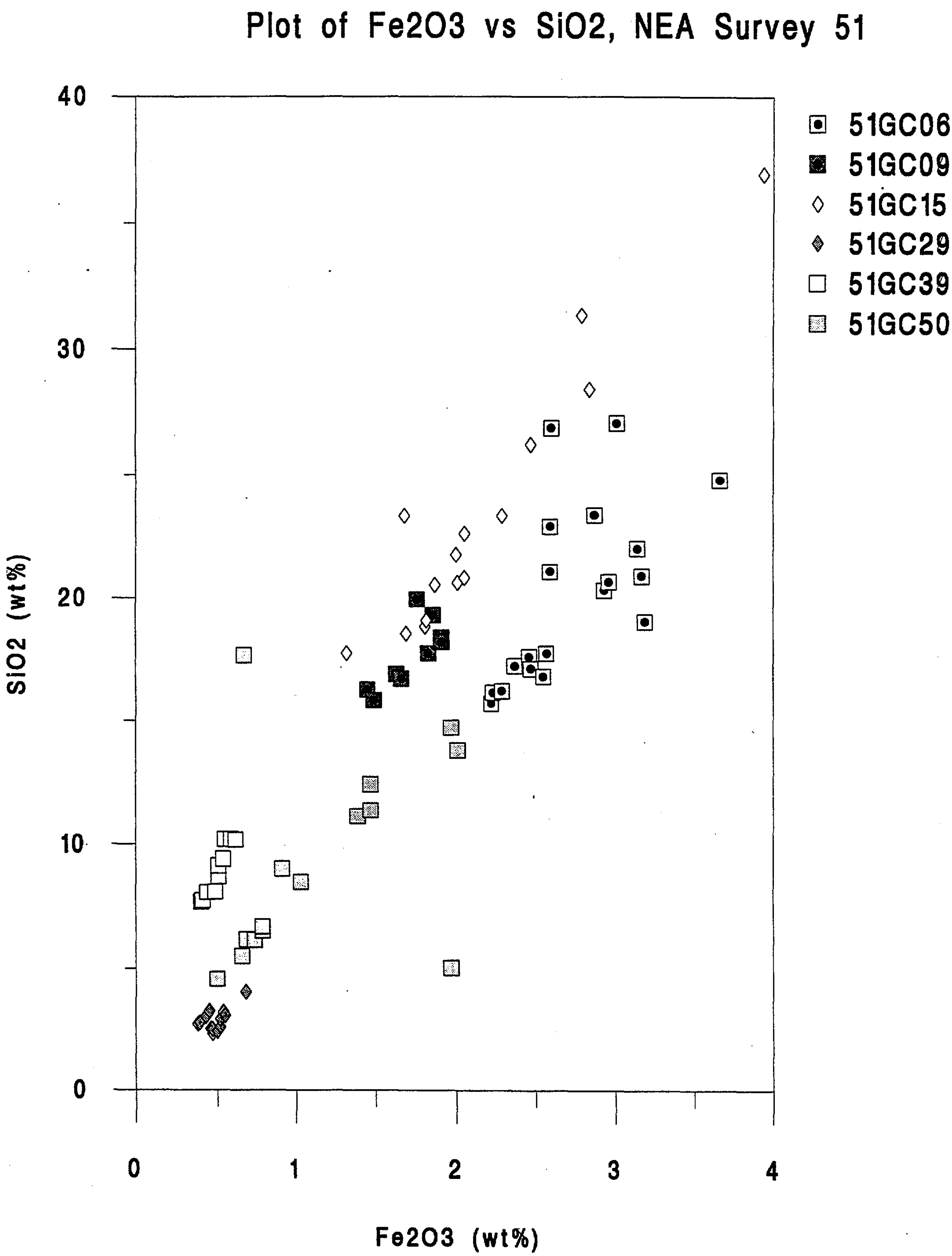
Plot of Al2O3 vs Pb, NEA Survey 51
Lead (ppm)
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12
14
Al2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

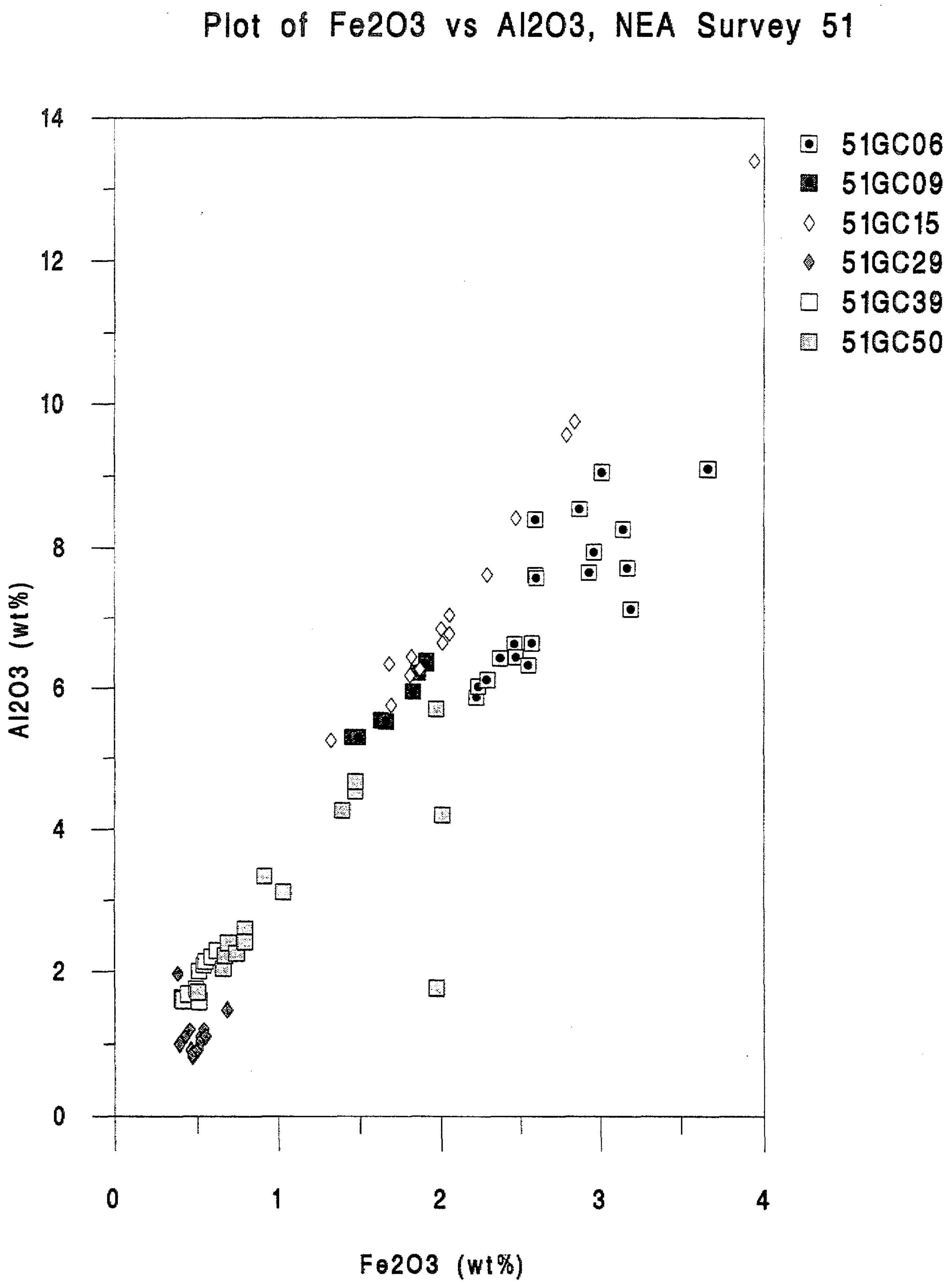

Plot of Al2O3 vs Rb, NEA Survey 51
Rubidium(ppm)
Al2O3 (wt%)
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



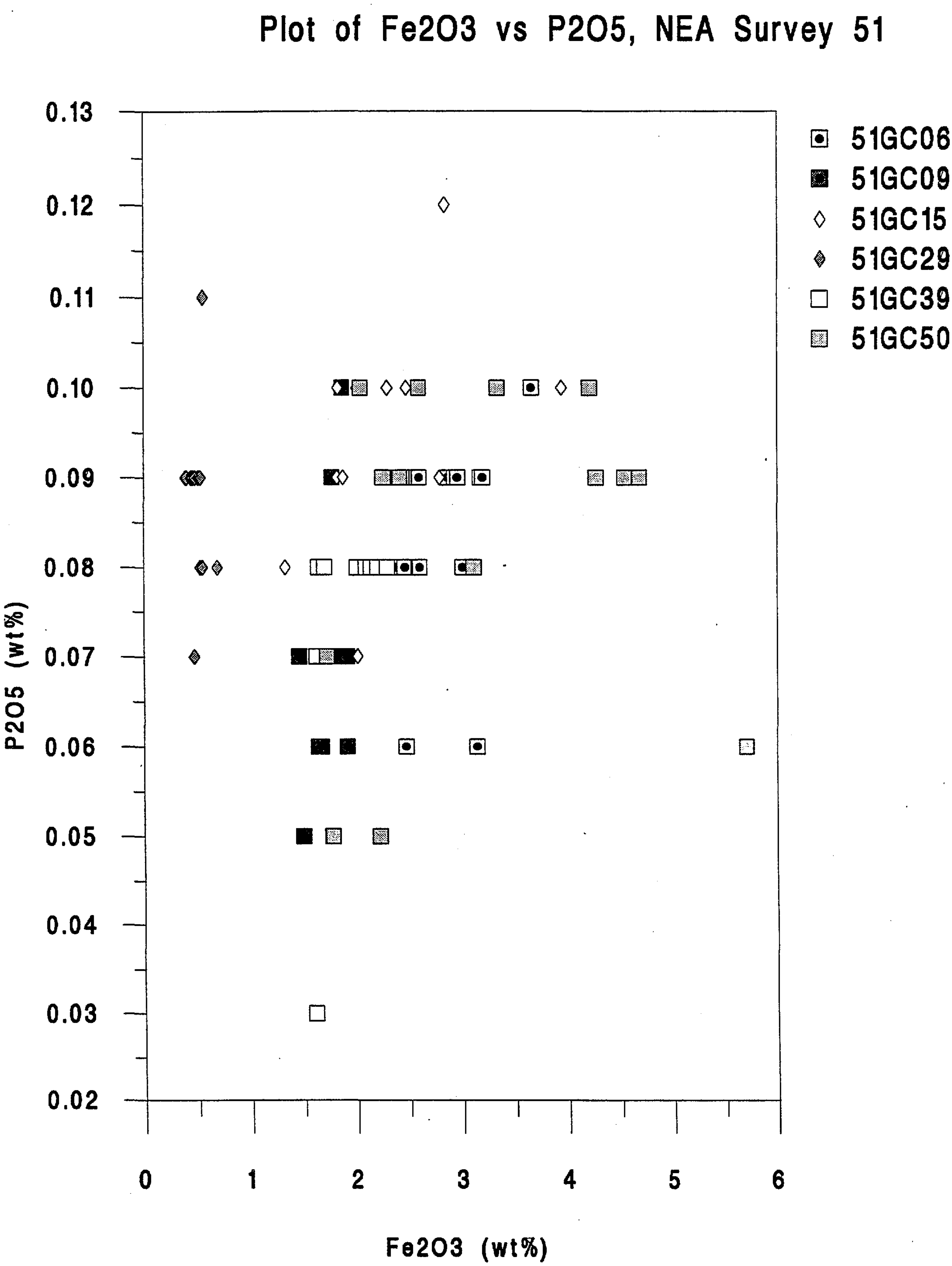
Plot of Al2O3 vs Sc, NEA Survey 51
Scandium (ppm)
Al2O3 (wt%)
0
10
20
30
40
0
2
4
6
8
10
12
14
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

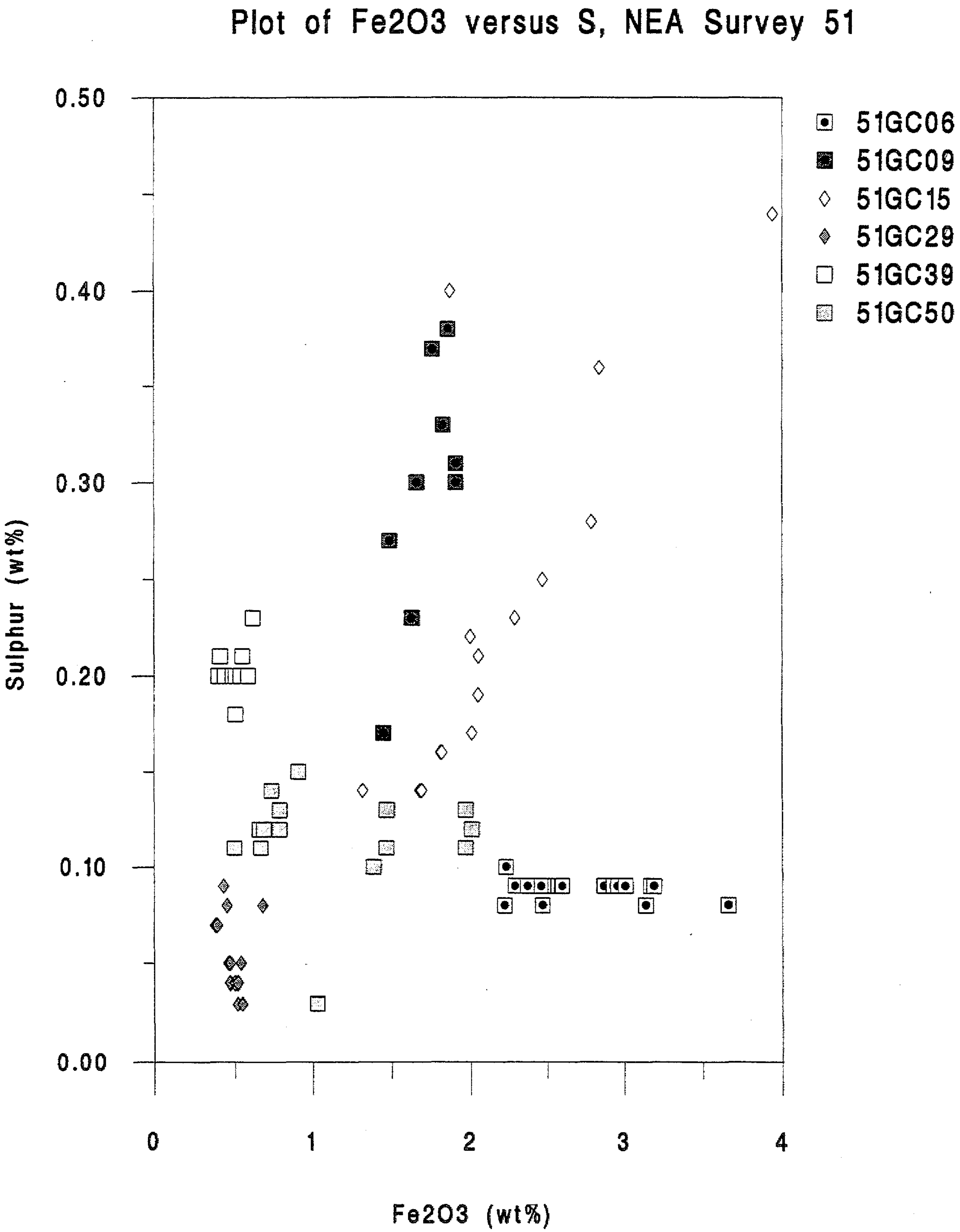
Appendix C: Major and trace element data plots of Fe_2O_3 versus select elements


Plot of Fe2O3 vs SiO2, NEA Survey 51
40
30
20
10
0
SiO2 (wt%)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

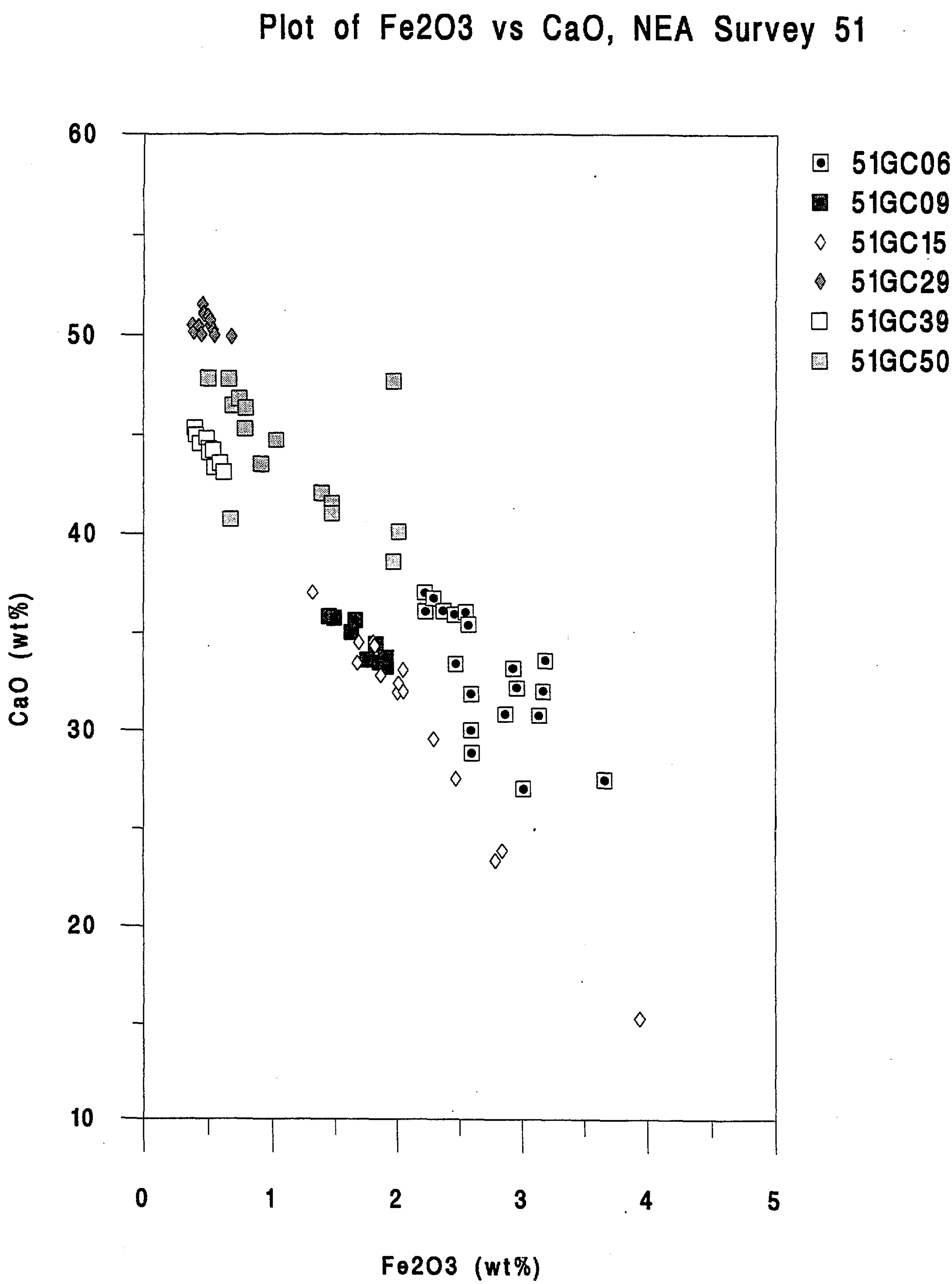


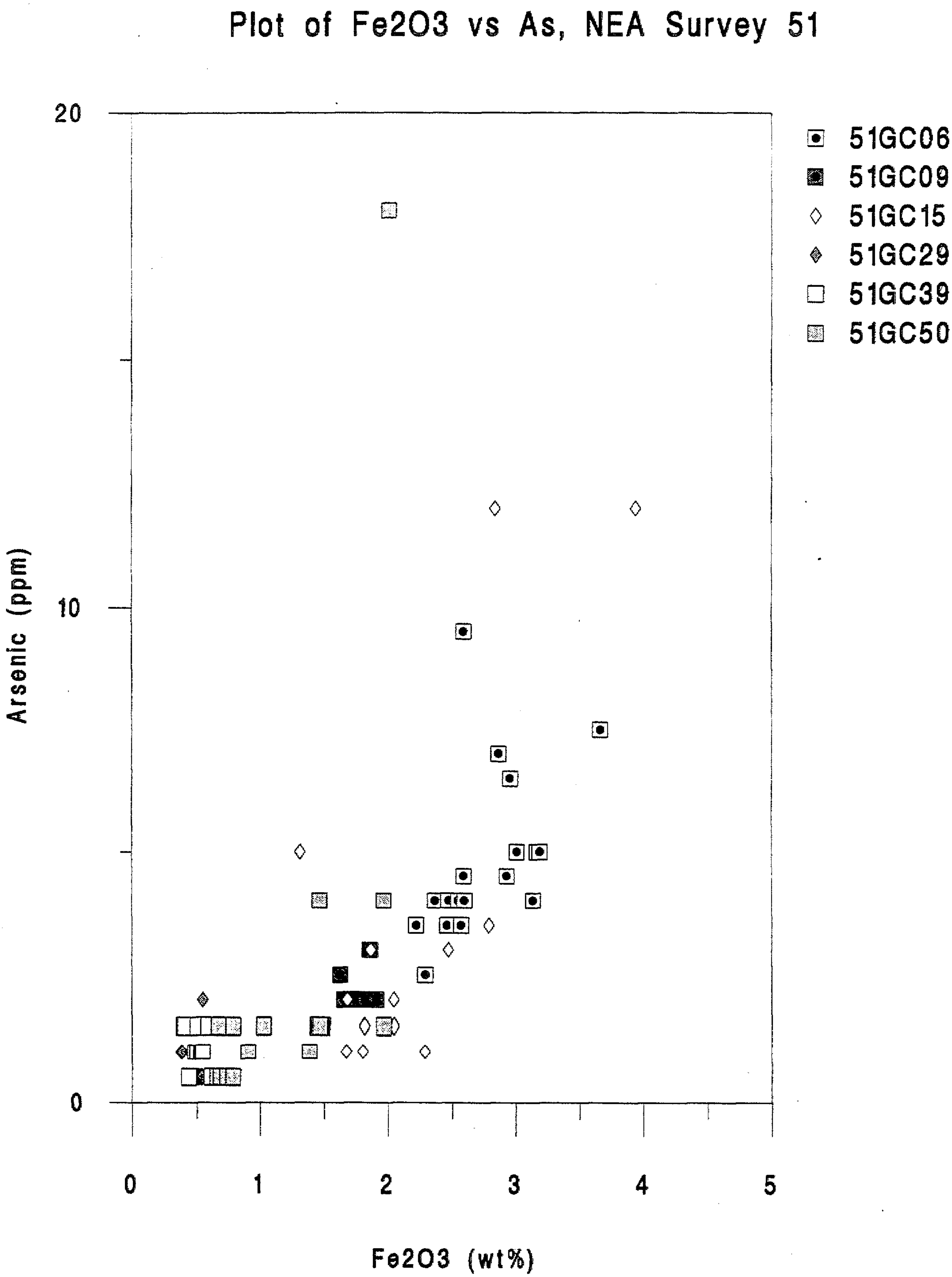
Plot of Fe2O3 vs Al2O3, NEA Survey 51
14
12
10
8
6
4
2
0
Al2O3 (wt%)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

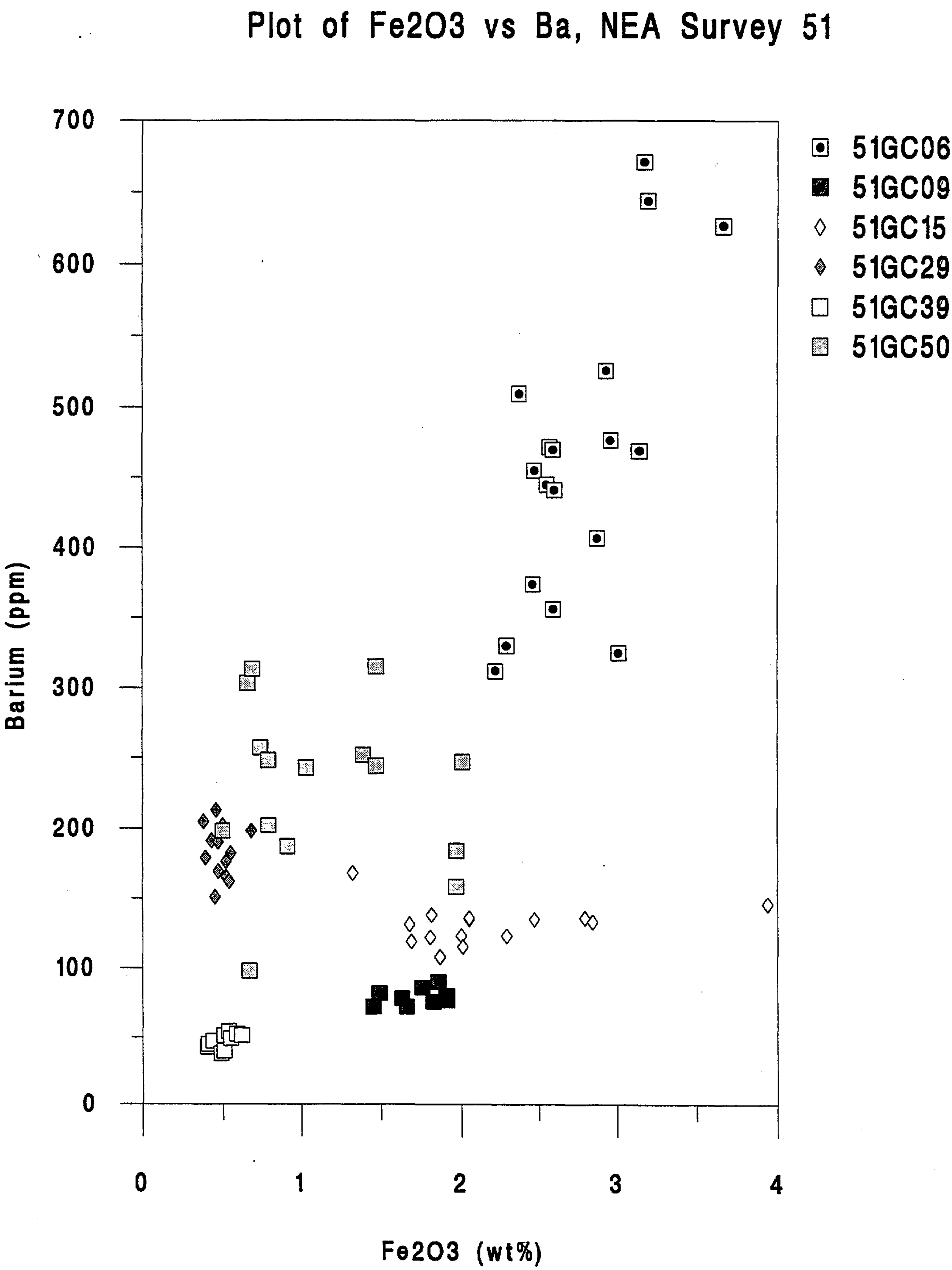

Plot of Fe2O3 vs P2O5, NEA Survey 51
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
P2O5 (wt%)
0
1
2
3
4
5
6
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



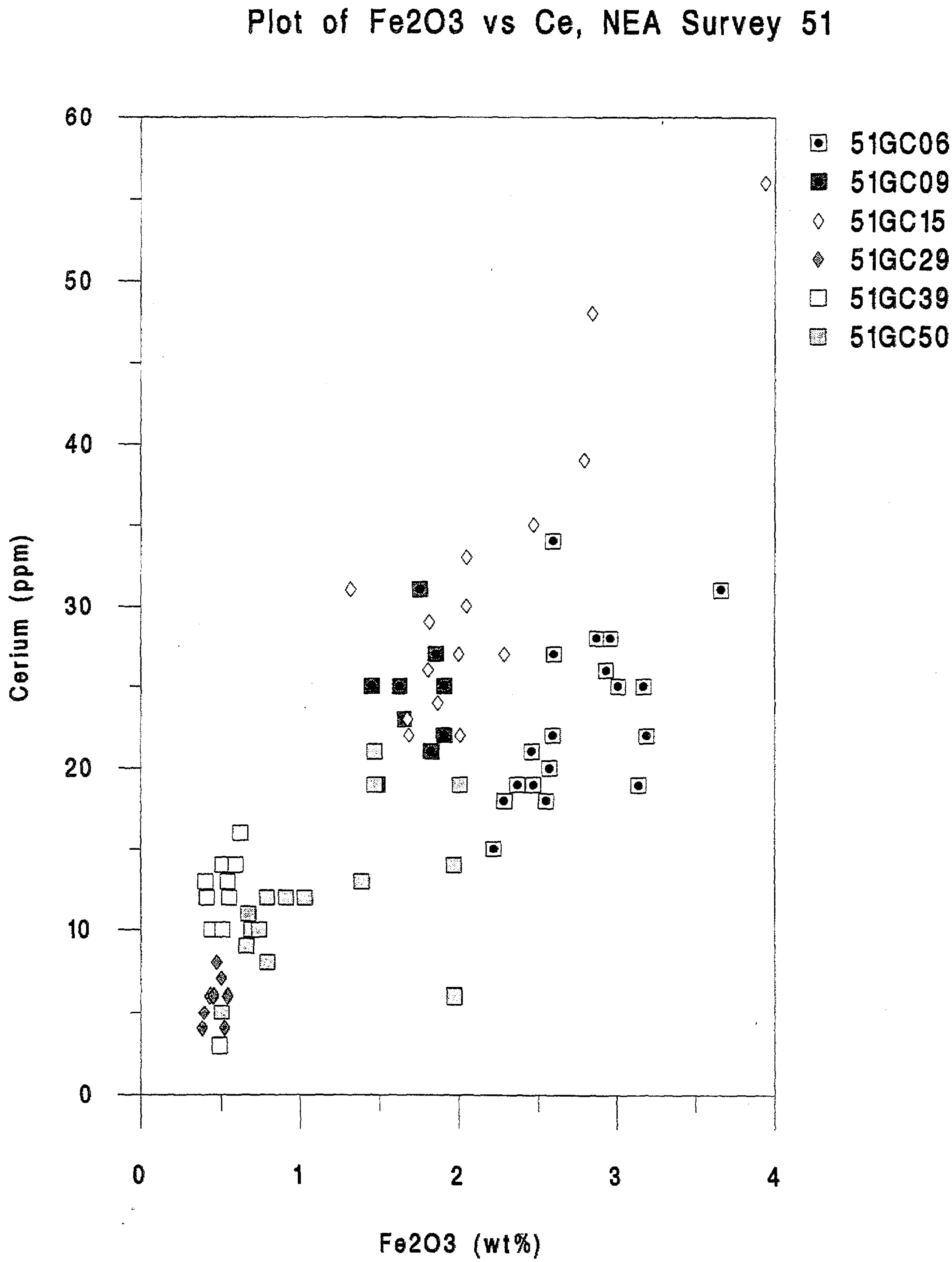
Plot of Fe2O3 versus S, NEA Survey 51
Sulphur (wt%)
0.50
0.40
0.30
0.20
0.10
0.00
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

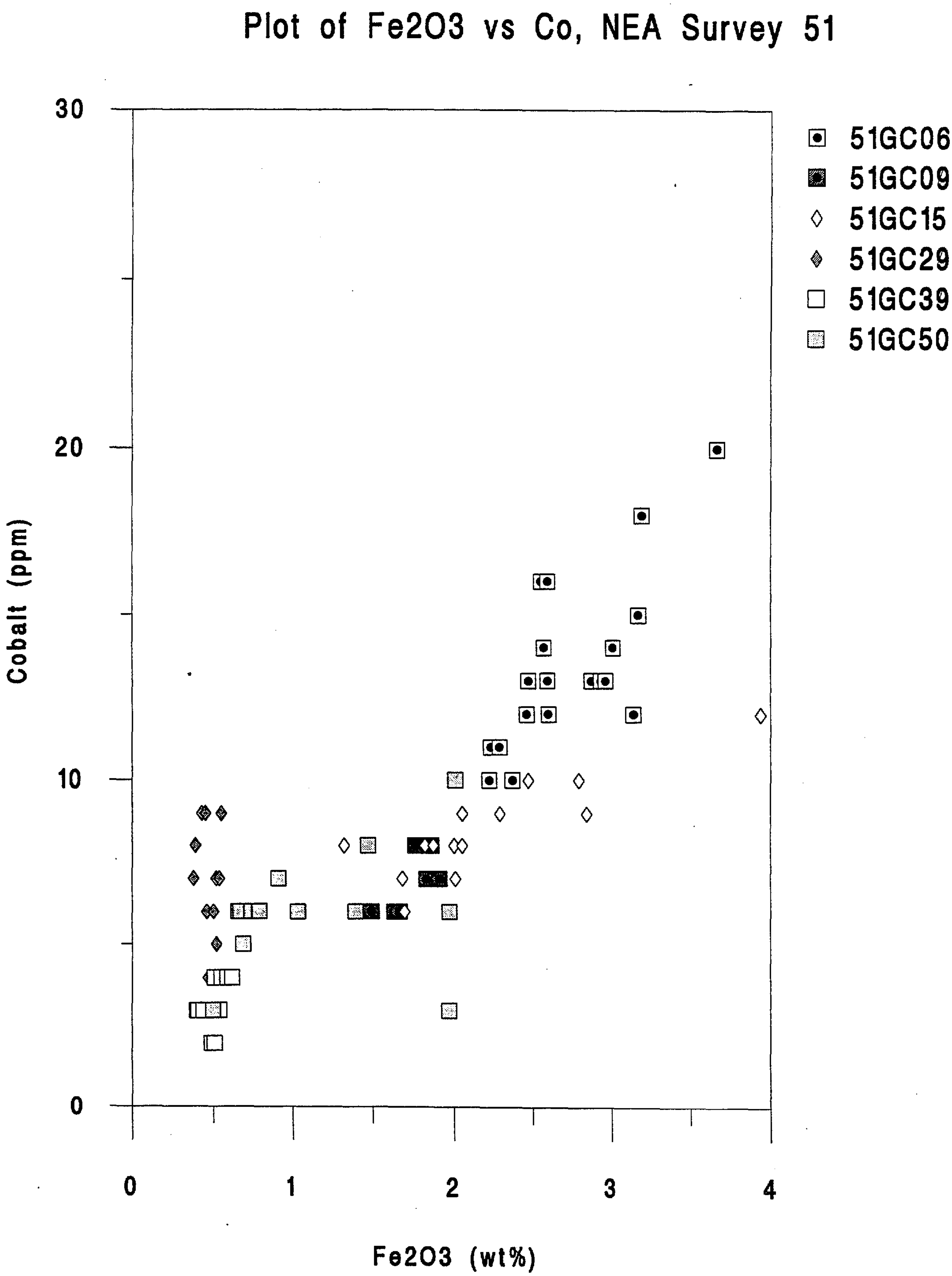

Plot of Fe2O3 vs CaO, NEA Survey 51
60
50
40
30
20
10
0
1
2
3
4
5
CaO (wt%)
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Fe2O3 vs As, NEA Survey 51
Arsenic (ppm)
20
10
0
0
1
2
3
4
5
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

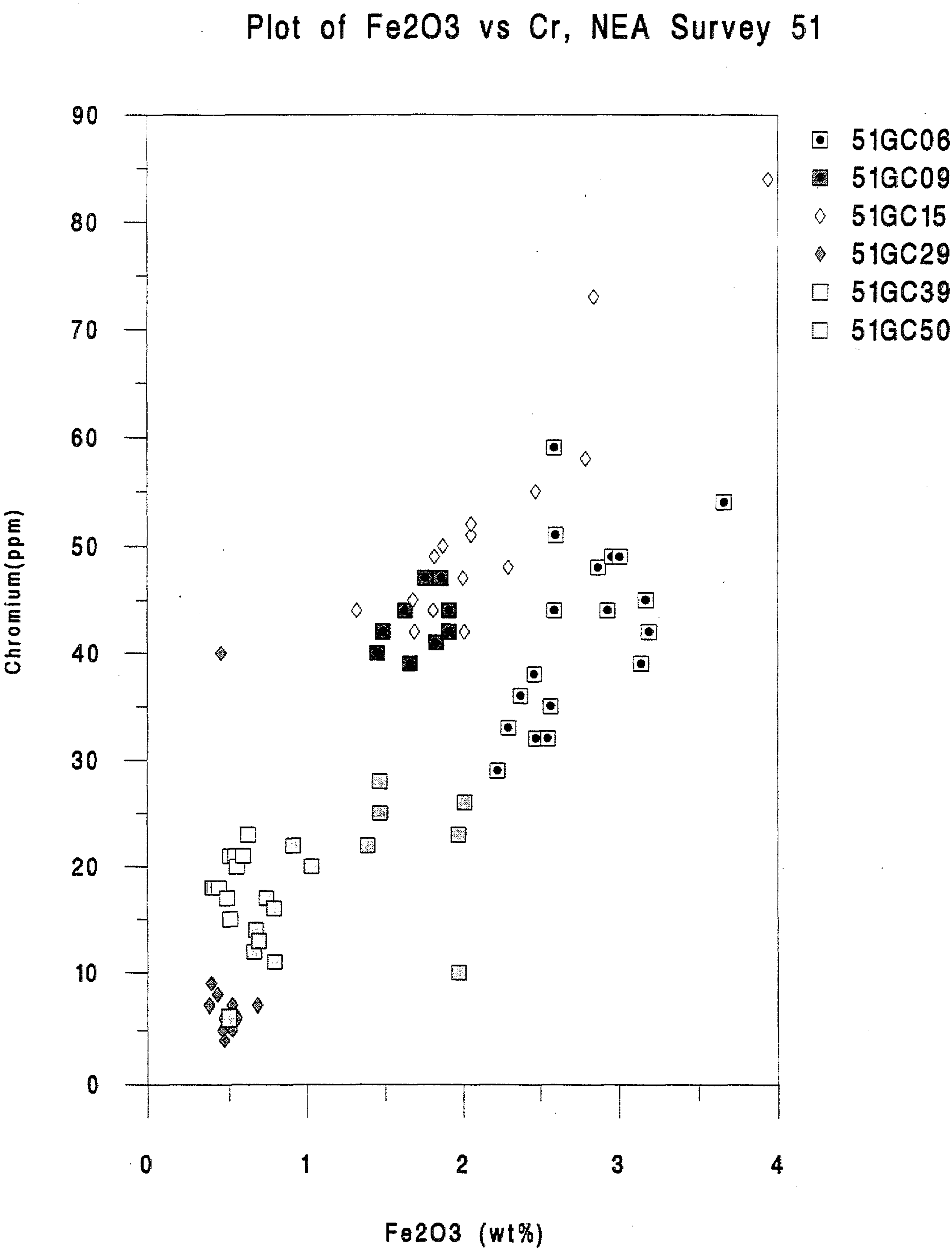


Plot of Fe2O3 vs Ba, NEA Survey 51
Barium (ppm)
Fe2O3 (wt%)
0
100
200
300
400
500
600
700
0
1
2
3
4
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

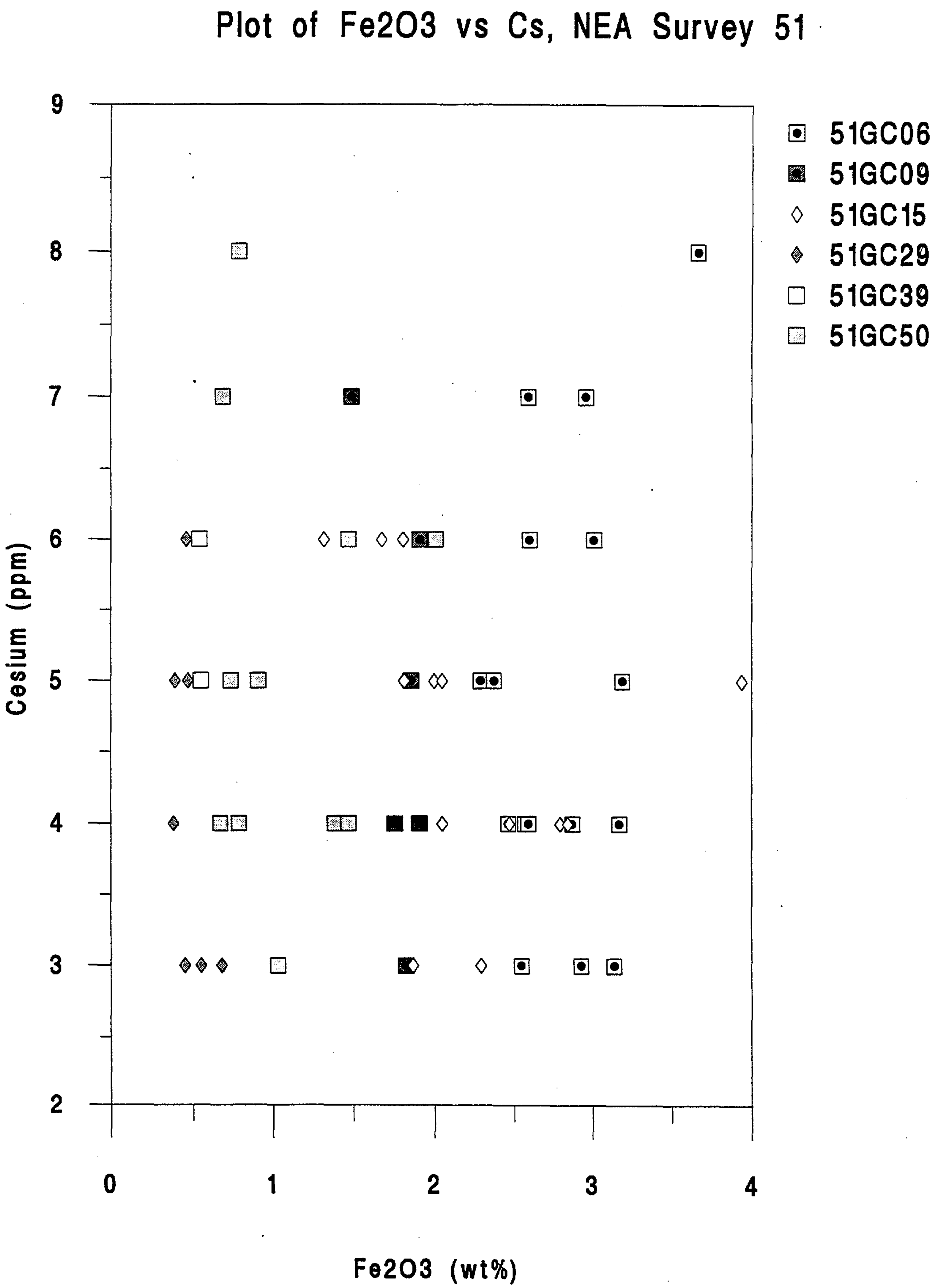

Plot of Fe2O3 vs Ce, NEA Survey 51
Cerium (ppm)
Fe2O3 (wt%)
0
10
20
30
40
50
60
0
1
2
3
4
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



Plot of Fe2O3 vs Co, NEA Survey 51
30
20
10
0
Cobalt (ppm)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

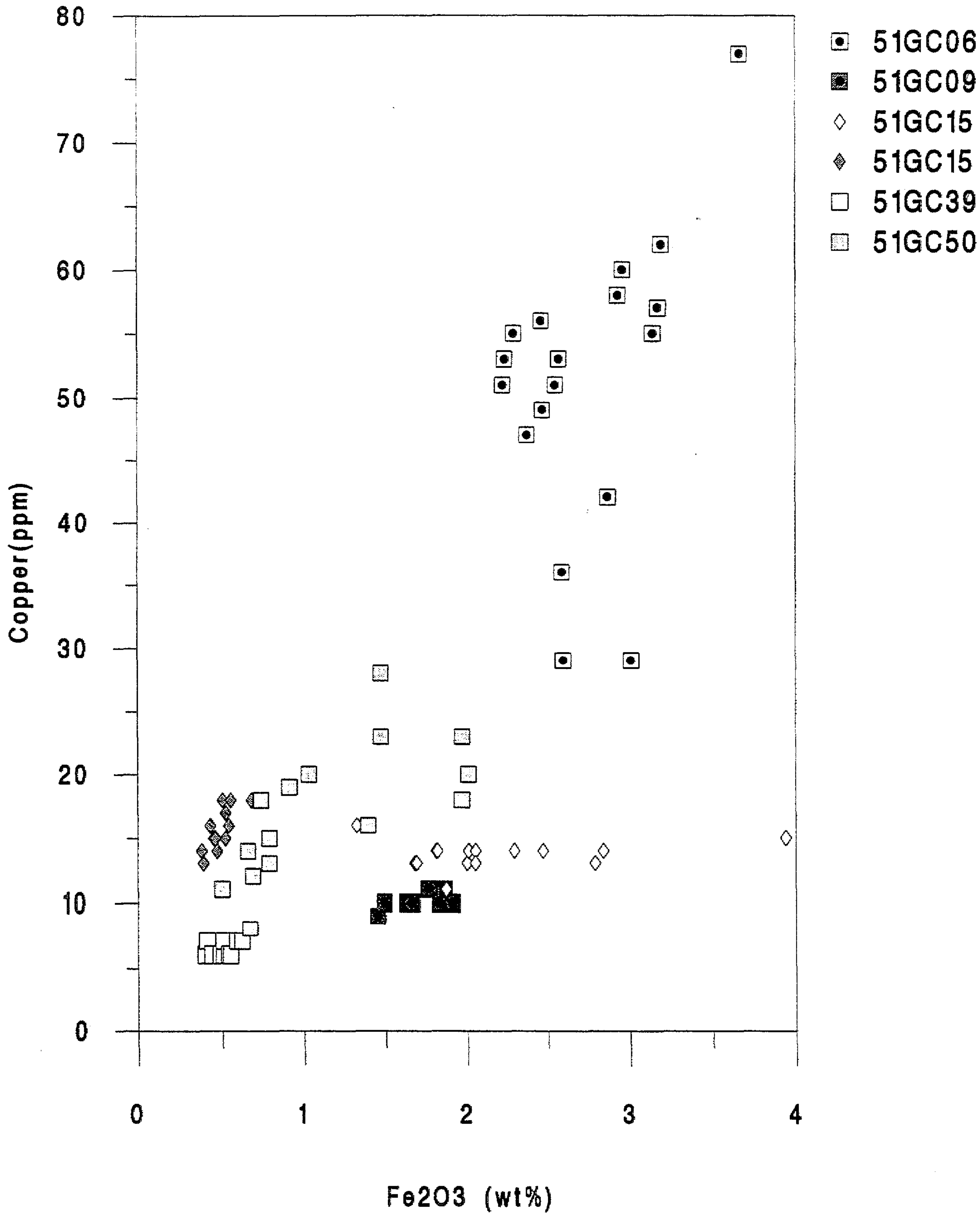


Plot of Fe2O3 vs Cr, NEA Survey 51
Chromium(ppm)
Fe2O3 (wt%)
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

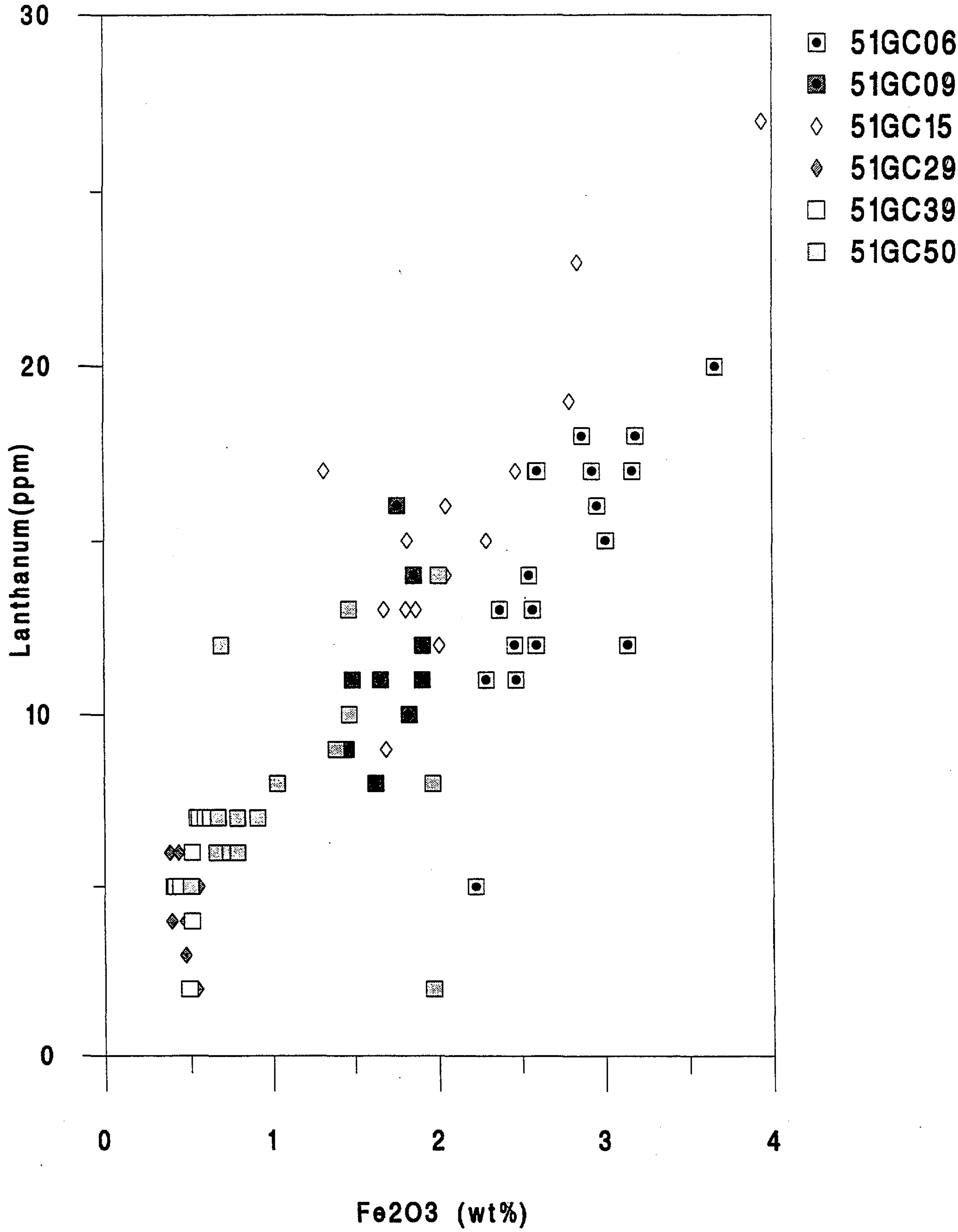


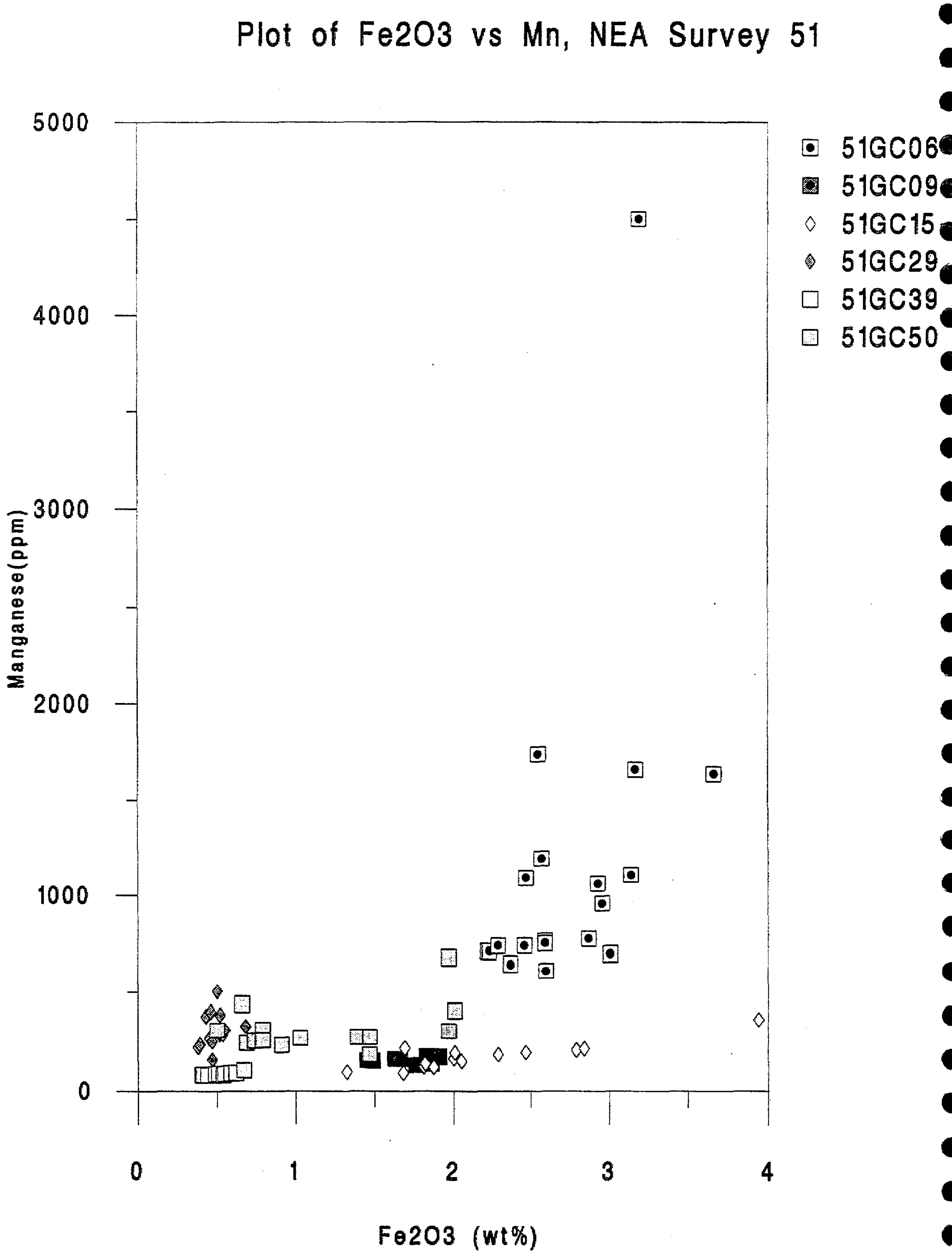
Plot of Fe2O3 vs Cs, NEA Survey 51
Cesium (ppm)
9
8
7
6
5
4
3
2
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

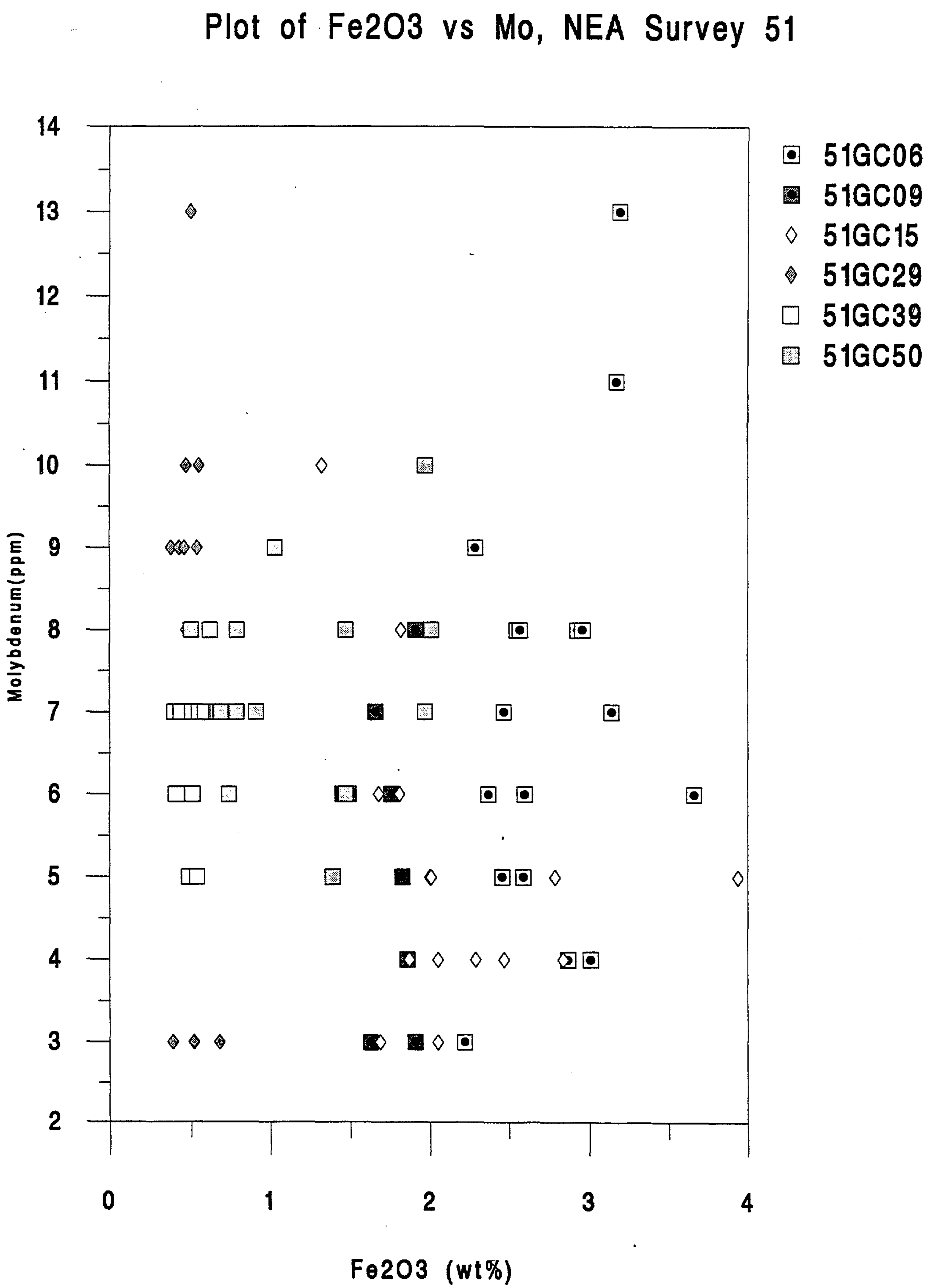
Plot of Fe2O3 vs Cu, NEA Survey 51



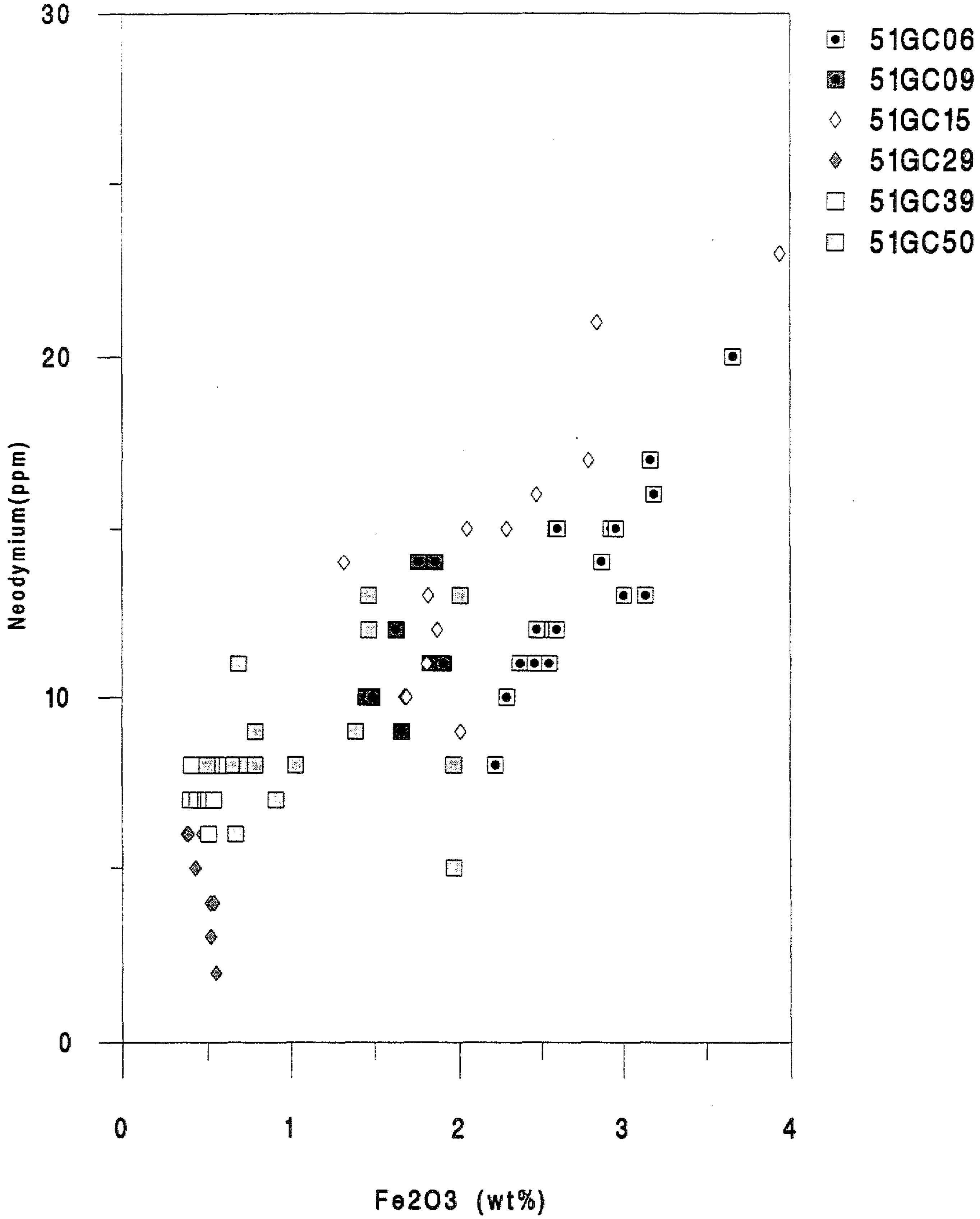
Plot of Fe2O3 vs La, NEA Survey 51

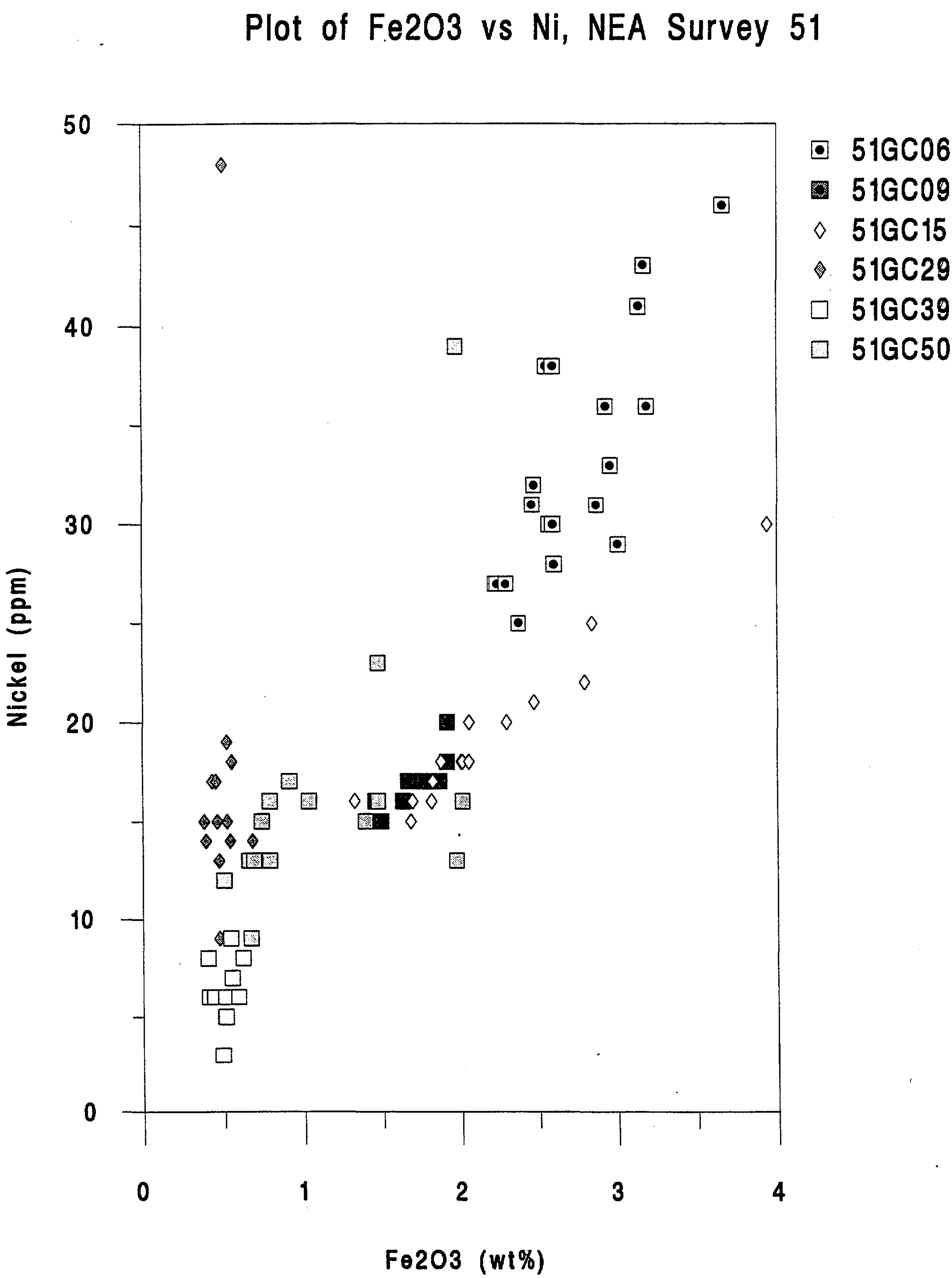


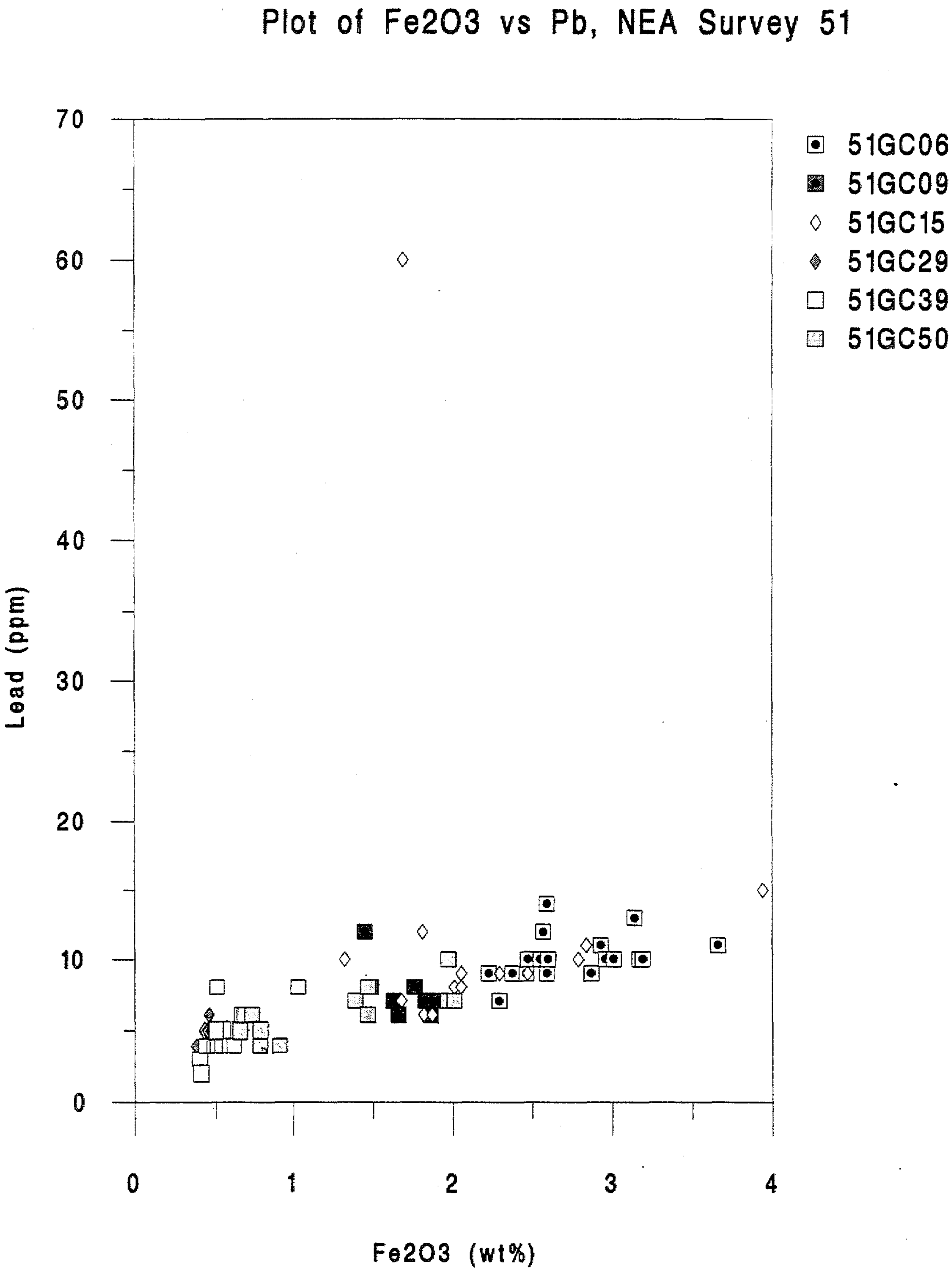

Plot of Fe2O3 vs Mn, NEA Survey 51
5000
4000
3000
2000
1000
0
Manganese(ppm)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Fe2O3 vs Mo, NEA Survey 51
Molybdenum(ppm)
14
13
12
11
10
9
8
7
6
5
4
3
2
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

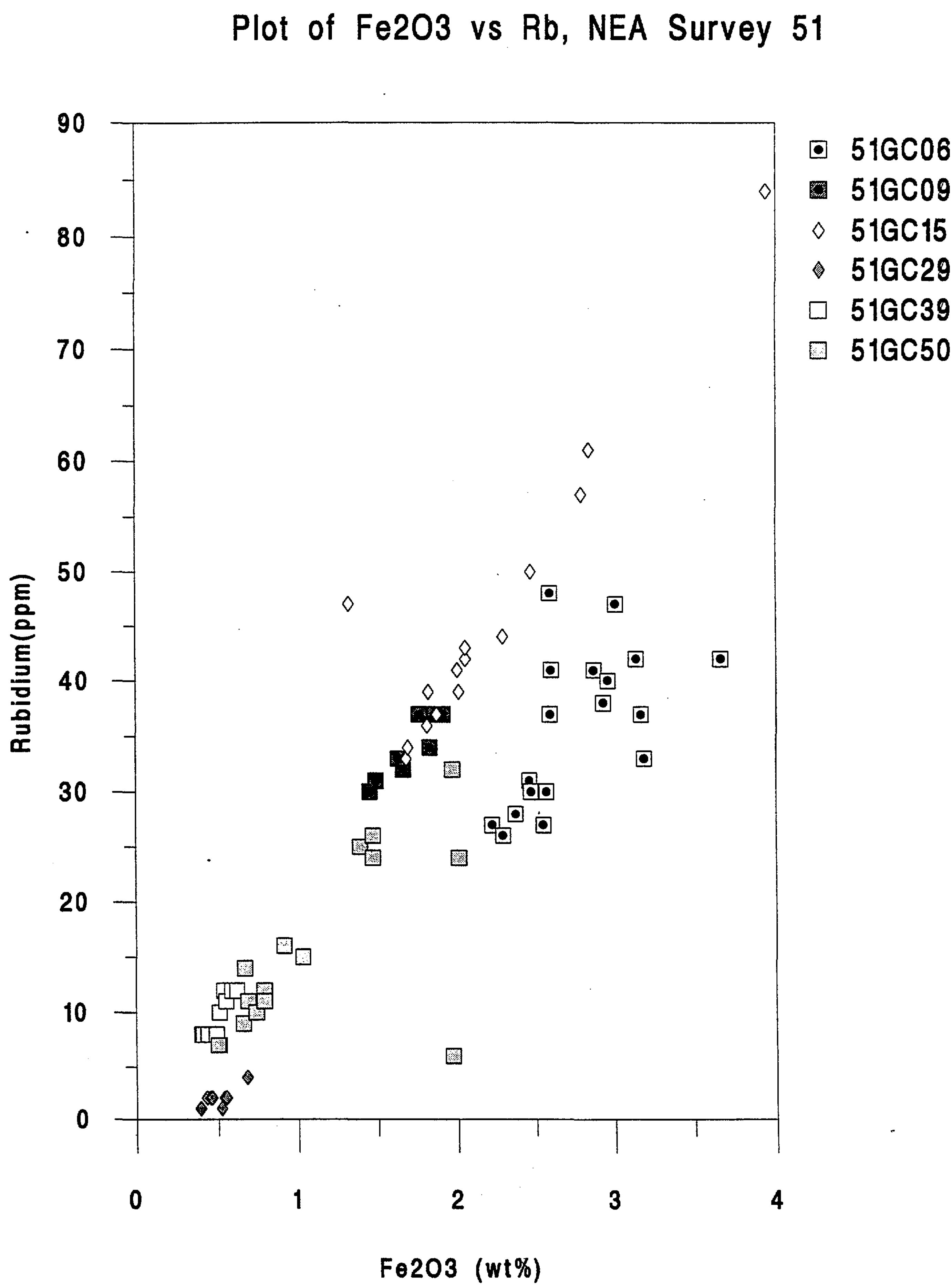
Plot of Fe2O3 vs Nd, NEA Survey 51

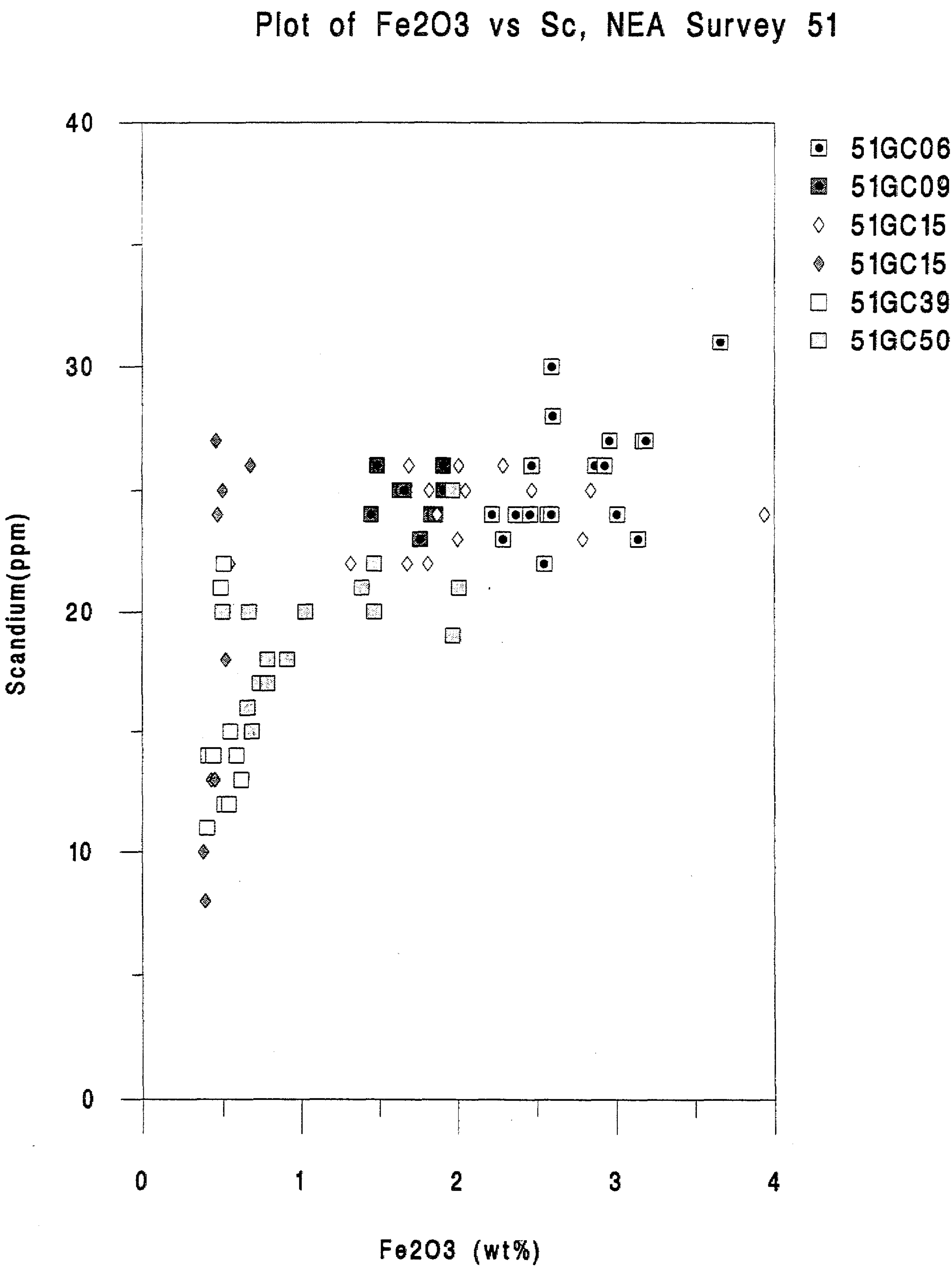



Plot of Fe2O3 vs Ni, NEA Survey 51
Nickel (ppm)
Fe2O3 (wt%)
0
10
20
30
40
50
0
1
2
3
4
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



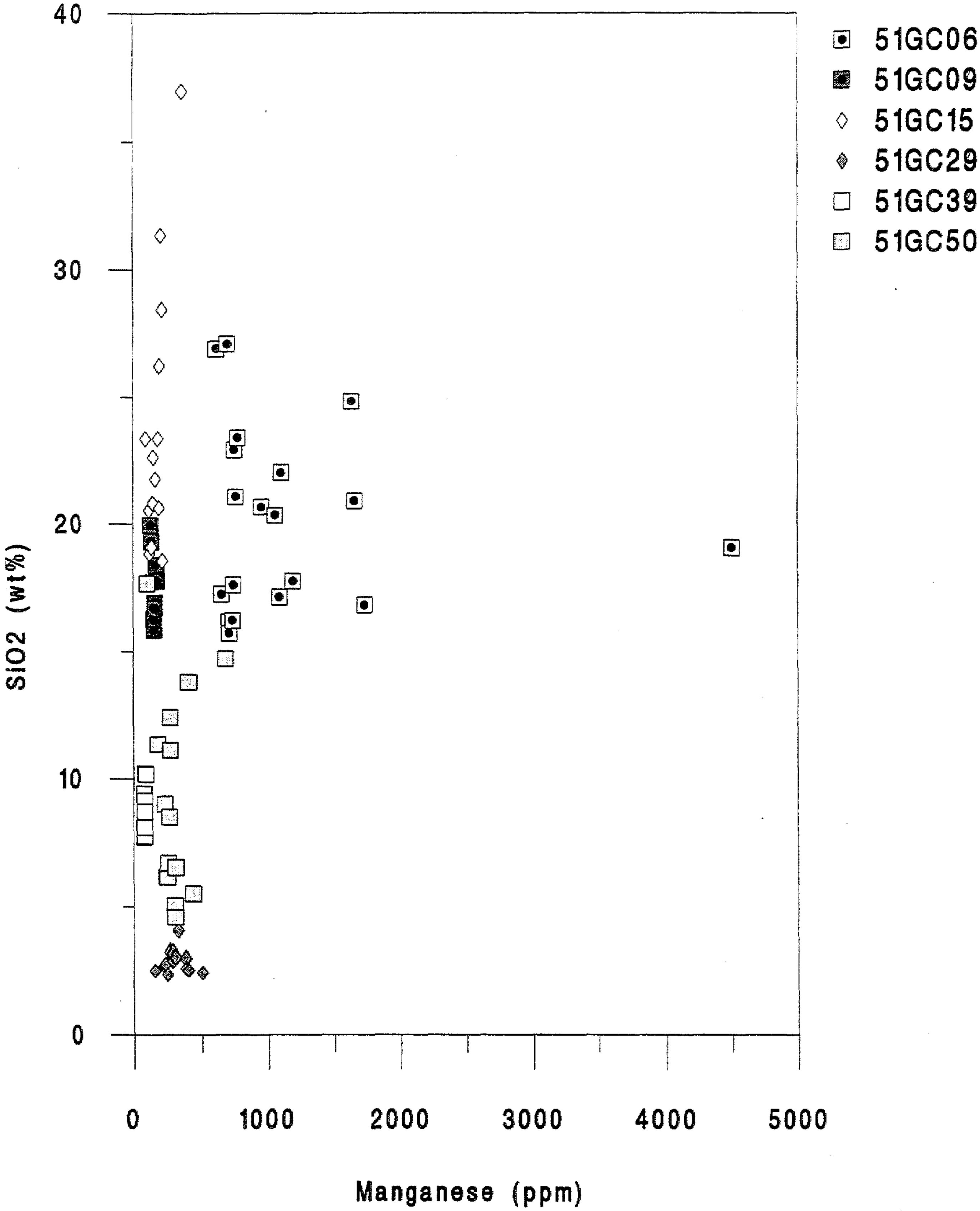
Plot of Fe2O3 vs Pb, NEA Survey 51
70
60
50
40
30
20
10
0
Lead (ppm)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

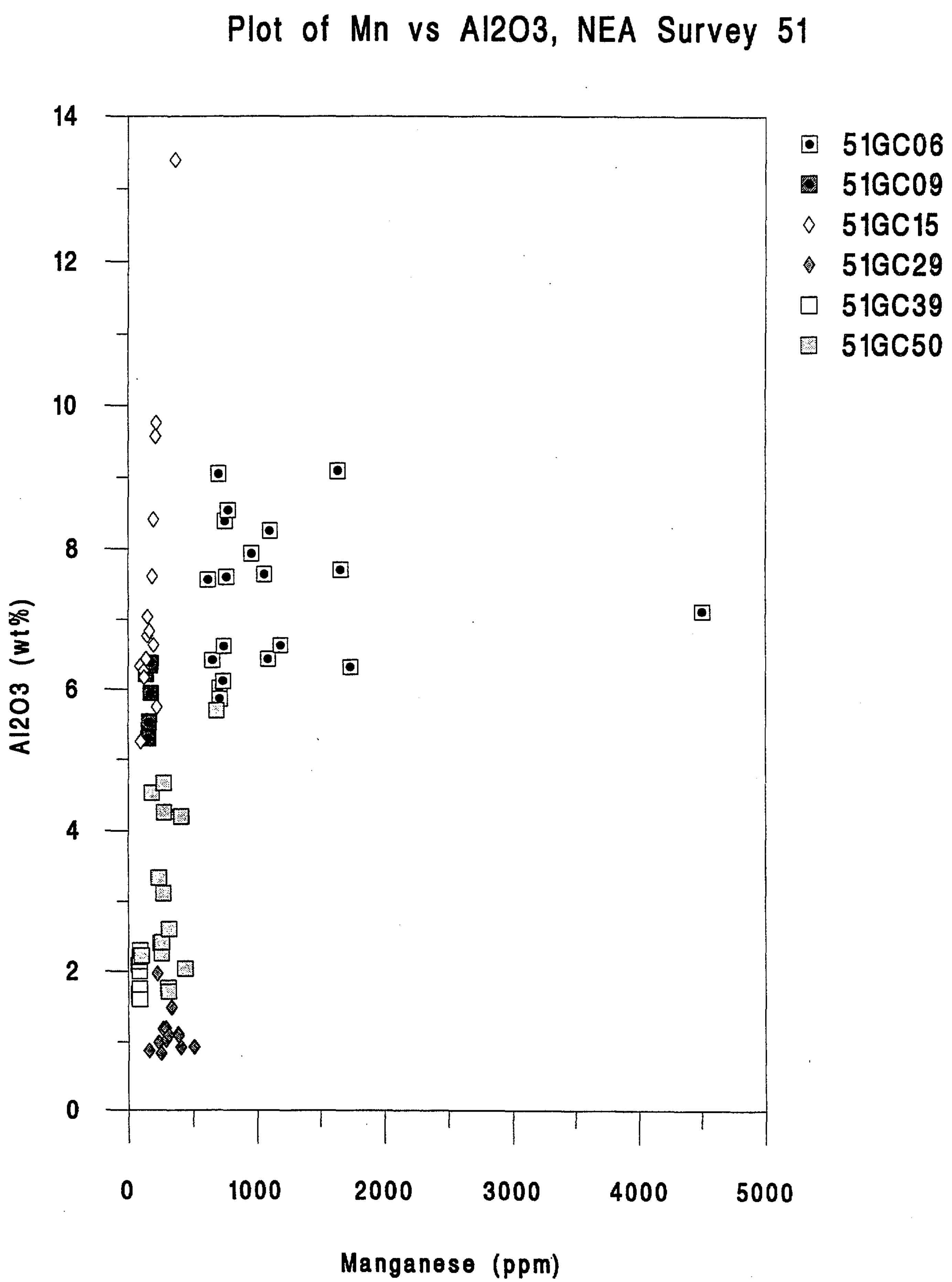

Plot of Fe2O3 vs Rb, NEA Survey 51
Rubidium(ppm)
Fe2O3 (wt%)
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

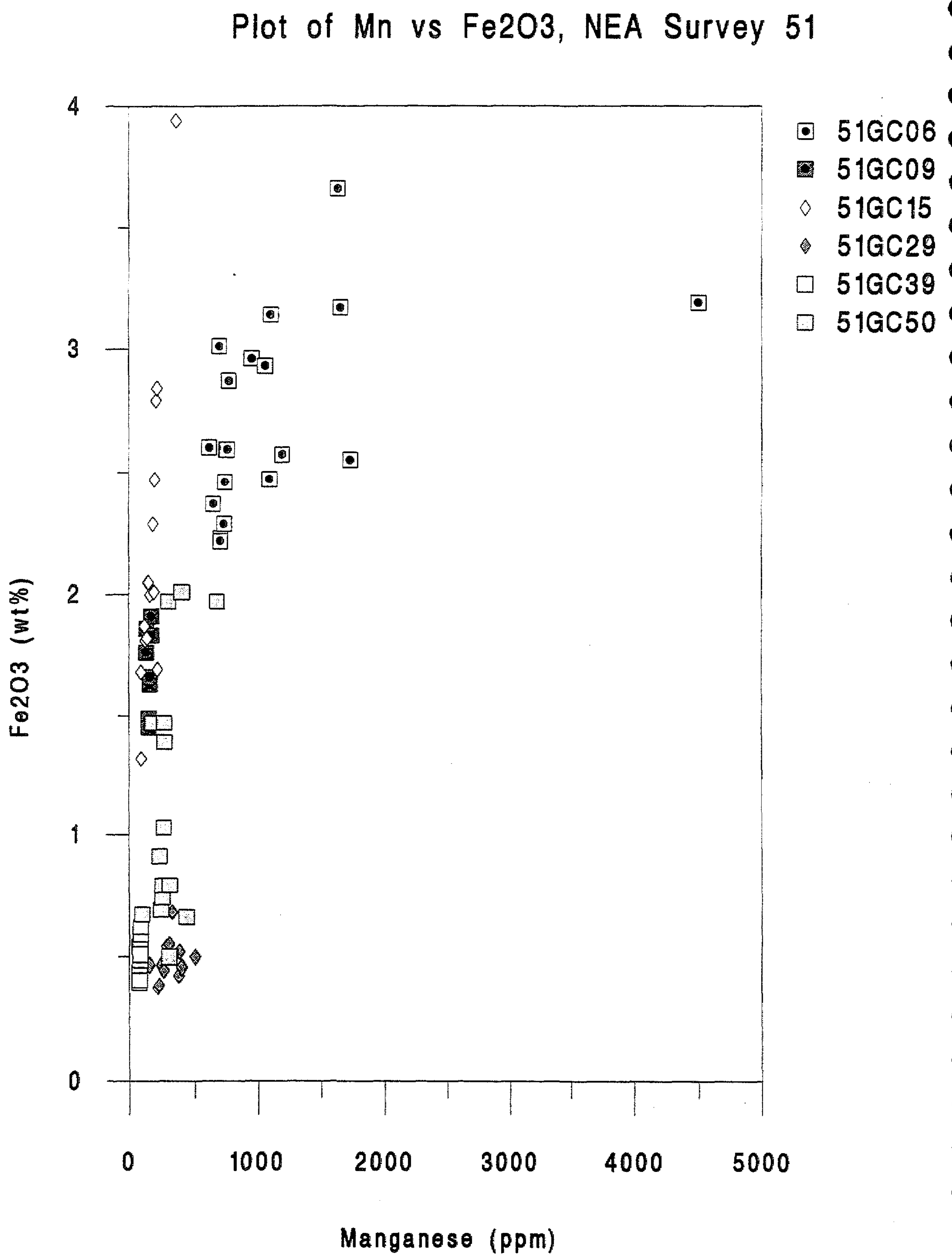

Plot of Fe2O3 vs Sc, NEA Survey 51
40
30
20
10
0
Scandium(ppm)
0
1
2
3
4
Fe2O3 (wt%)
51GC06
51GC09
51GC15
51GC15
51GC39
51GC50

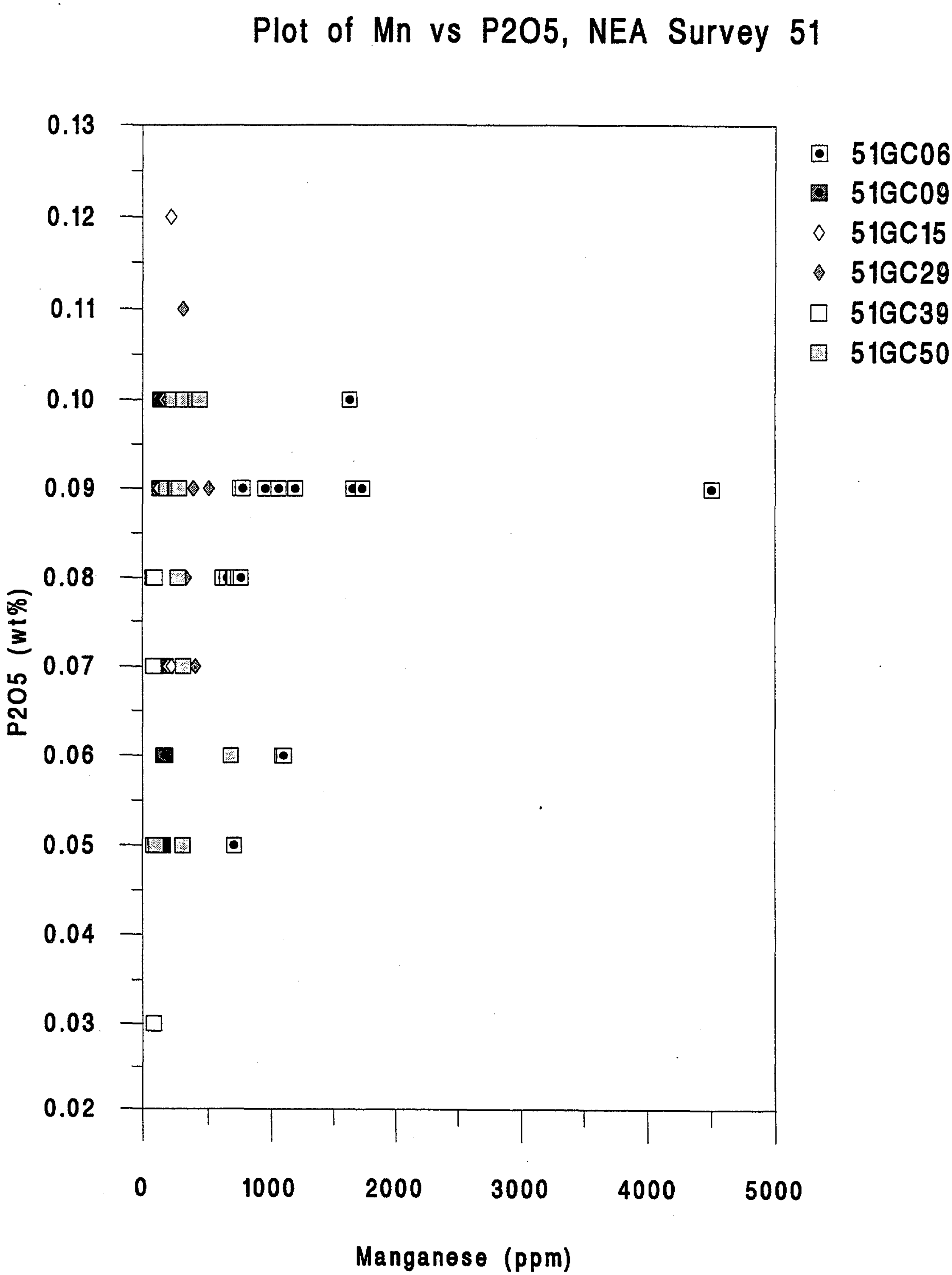
Appendix D: Major and trace element data plots of MnO_2 versus select elements

Plot of Mn vs SiO2, NEA Survey 51

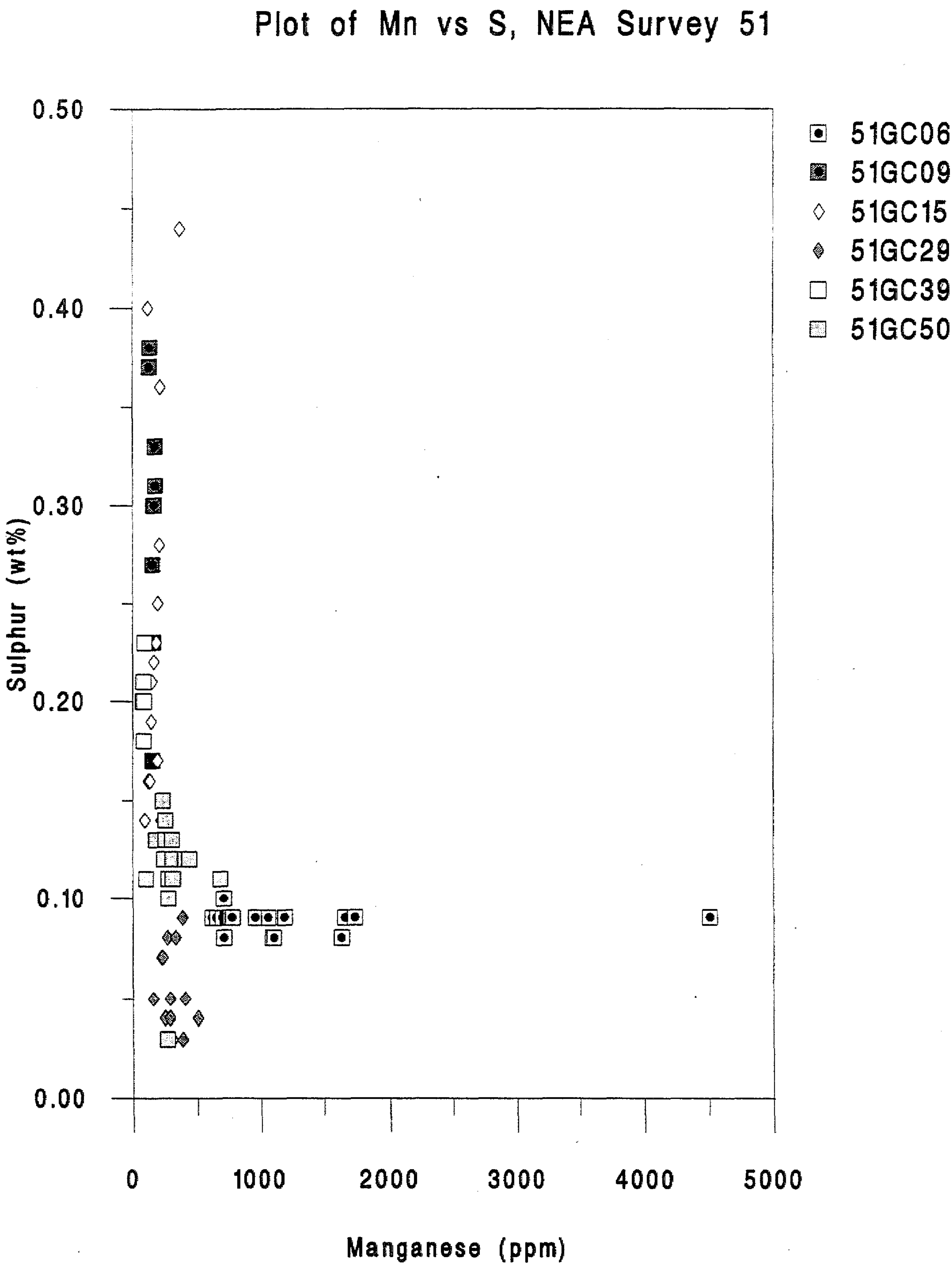


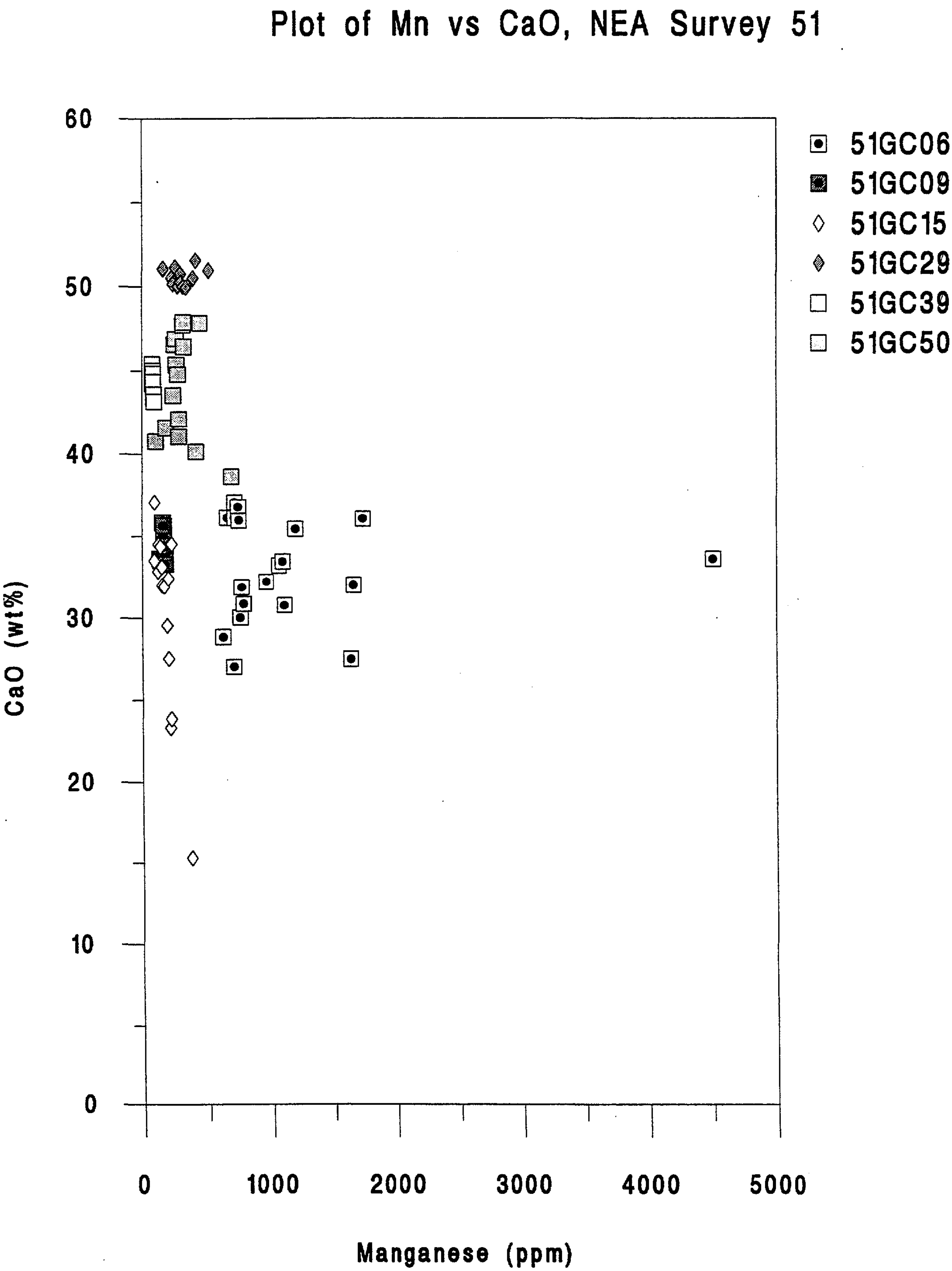

Plot of Mn vs Al2O3, NEA Survey 51
Al2O3 (wt%)
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

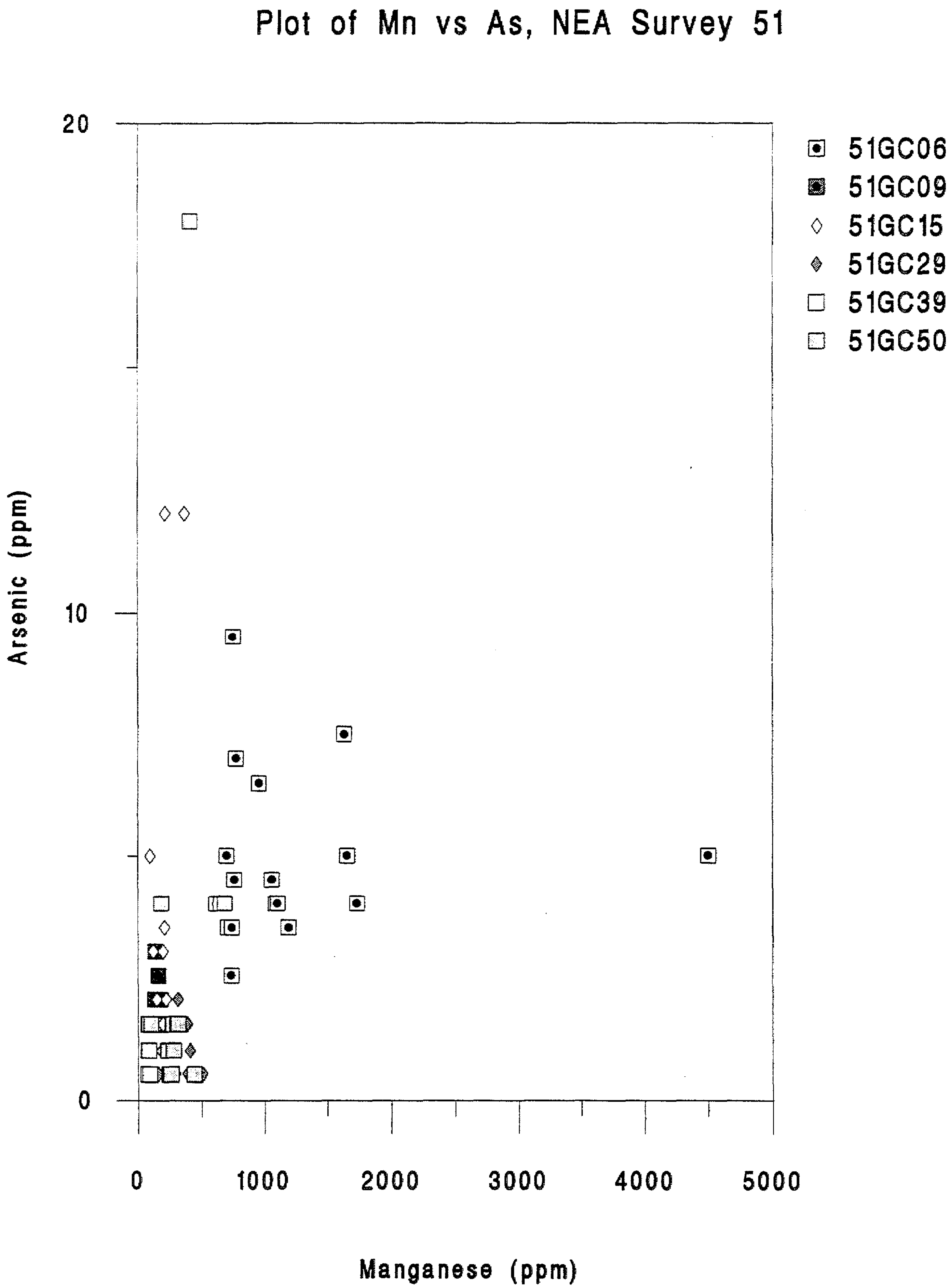

Plot of Mn vs Fe2O3, NEA Survey 51
Fe2O3 (wt%)
Manganese (ppm)
0
1
2
3
4
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

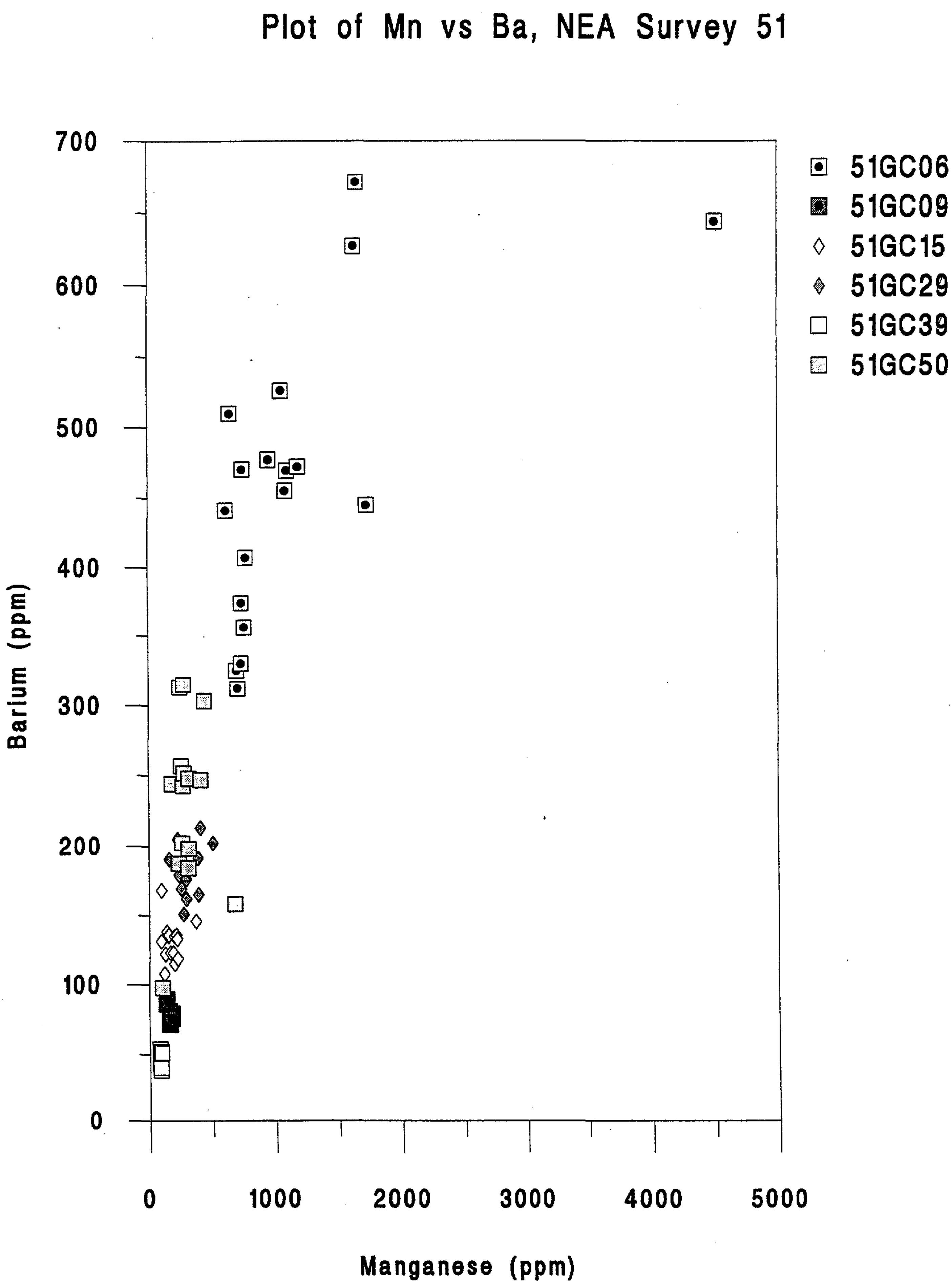


Plot of Mn vs P2O5, NEA Survey 51
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
P2O5 (wt%)
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Mn vs S, NEA Survey 51
0.50
0.40
0.30
0.20
0.10
0.00
Sulphur (wt%)
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

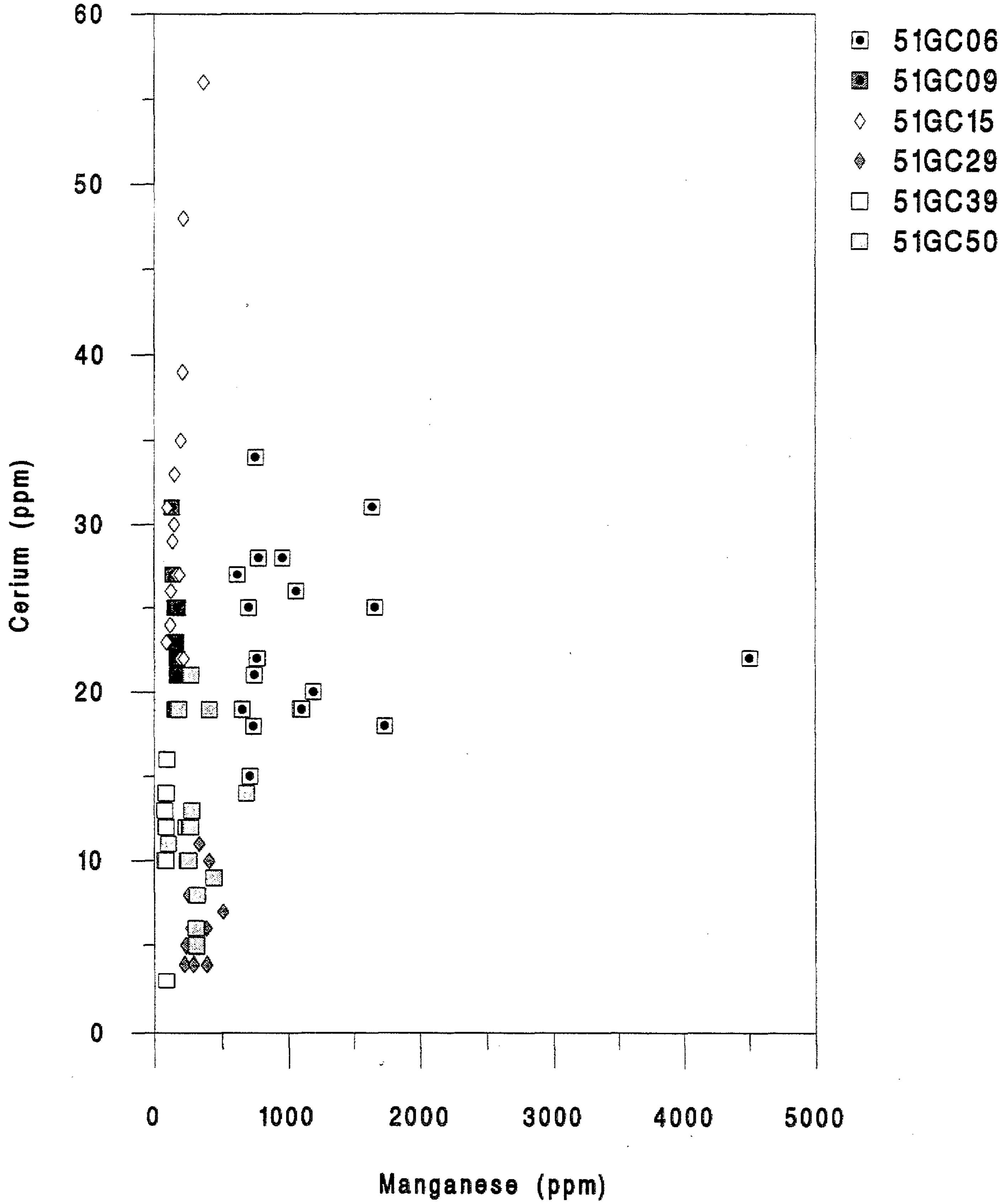

Plot of Mn vs CaO, NEA Survey 51
CaO (wt%)
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

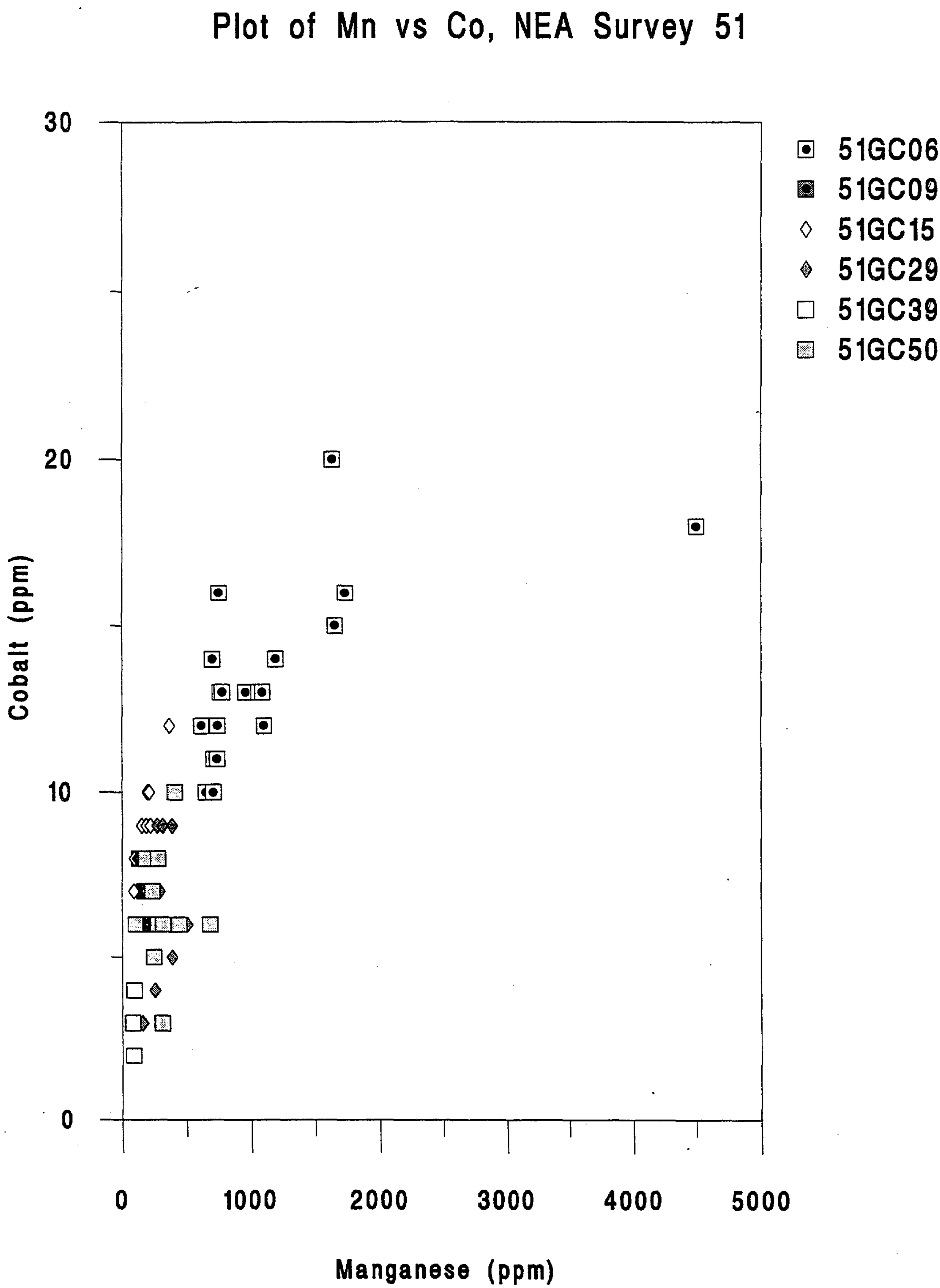

Plot of Mn vs As, NEA Survey 51
20
10
0
Arsenic (ppm)
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

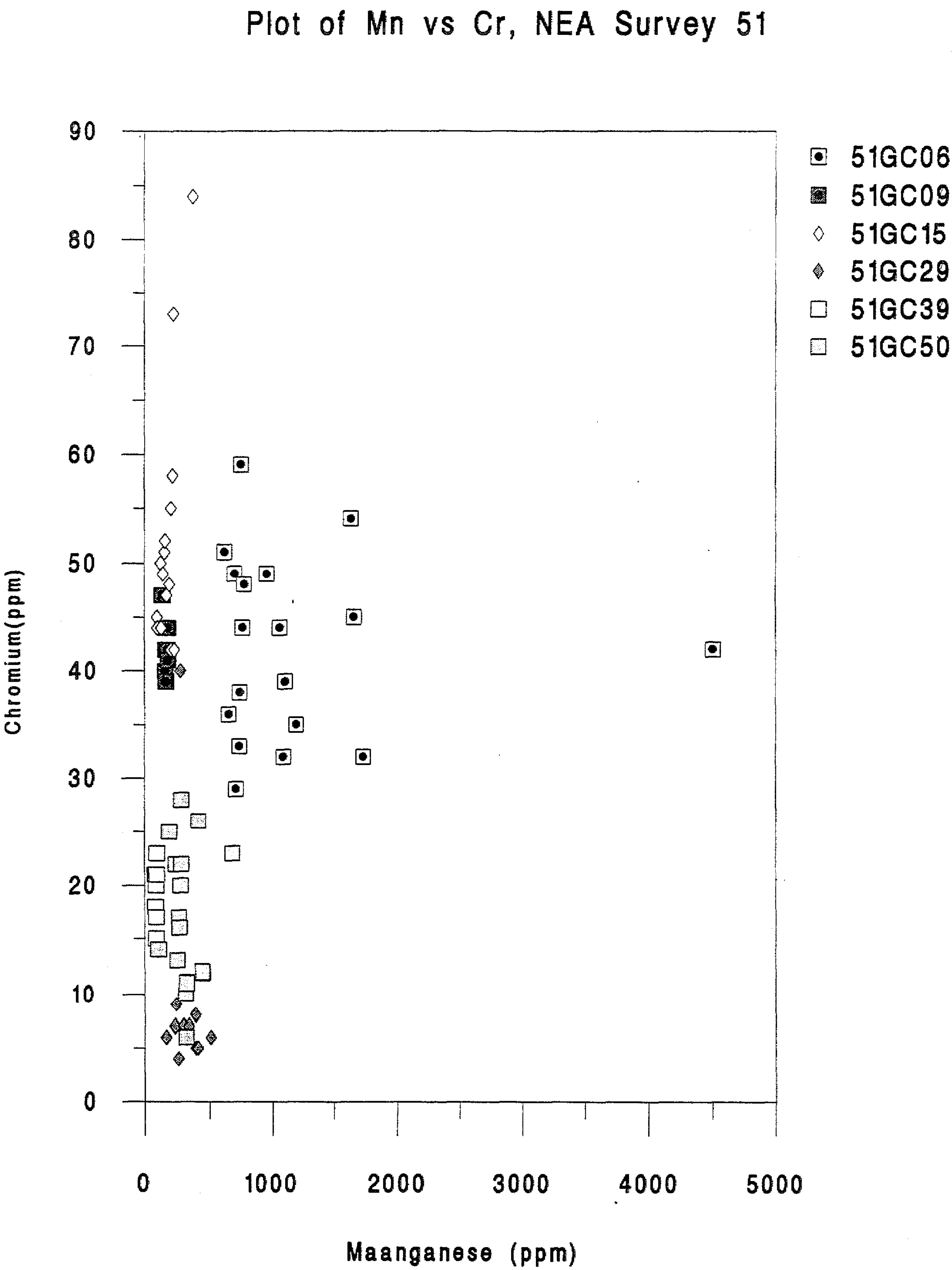


Plot of Mn vs Ba, NEA Survey 51
700
600
500
400
300
200
100
0
Barium (ppm)
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

Plot of Mn vs Ce, NEA Survey 51

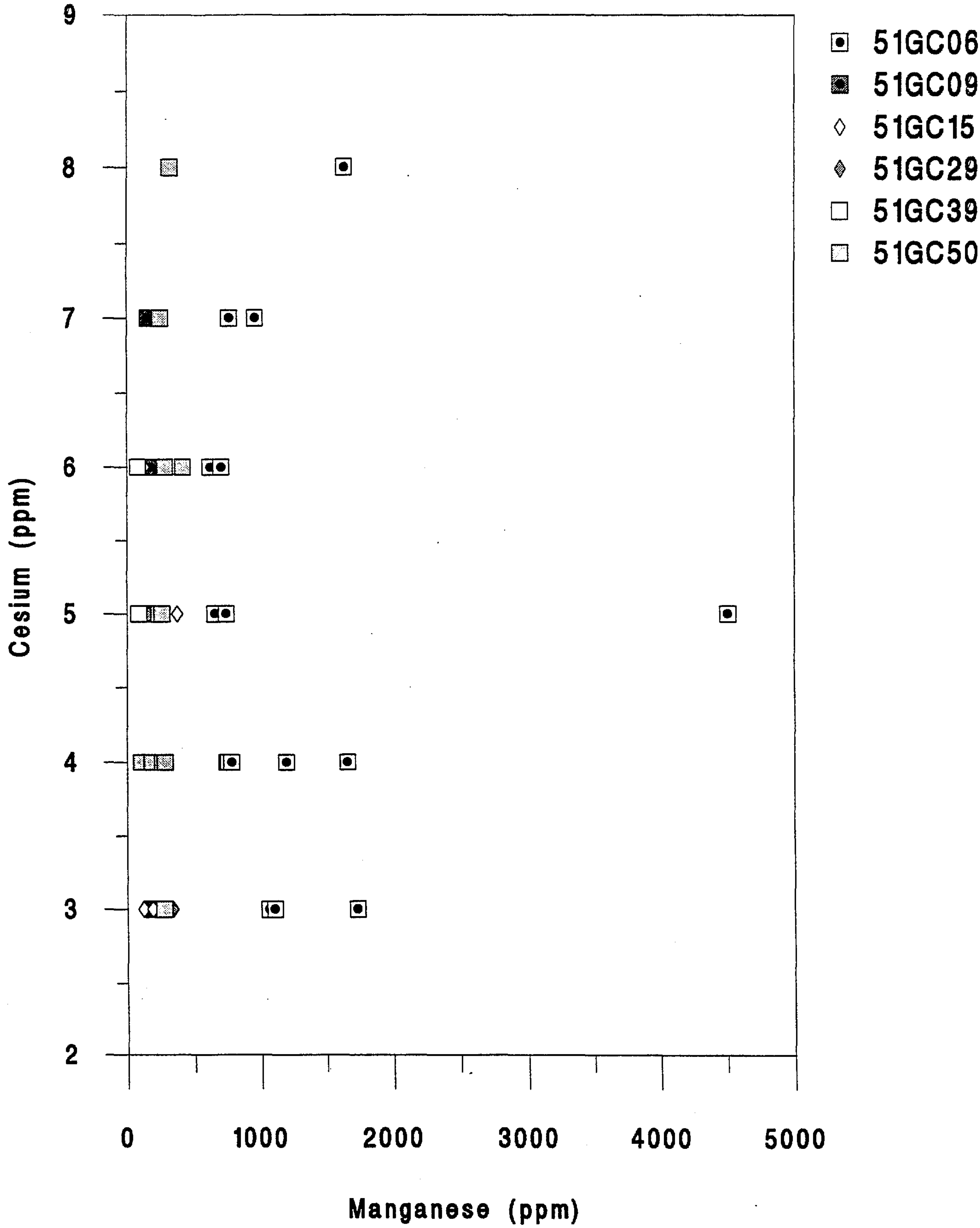


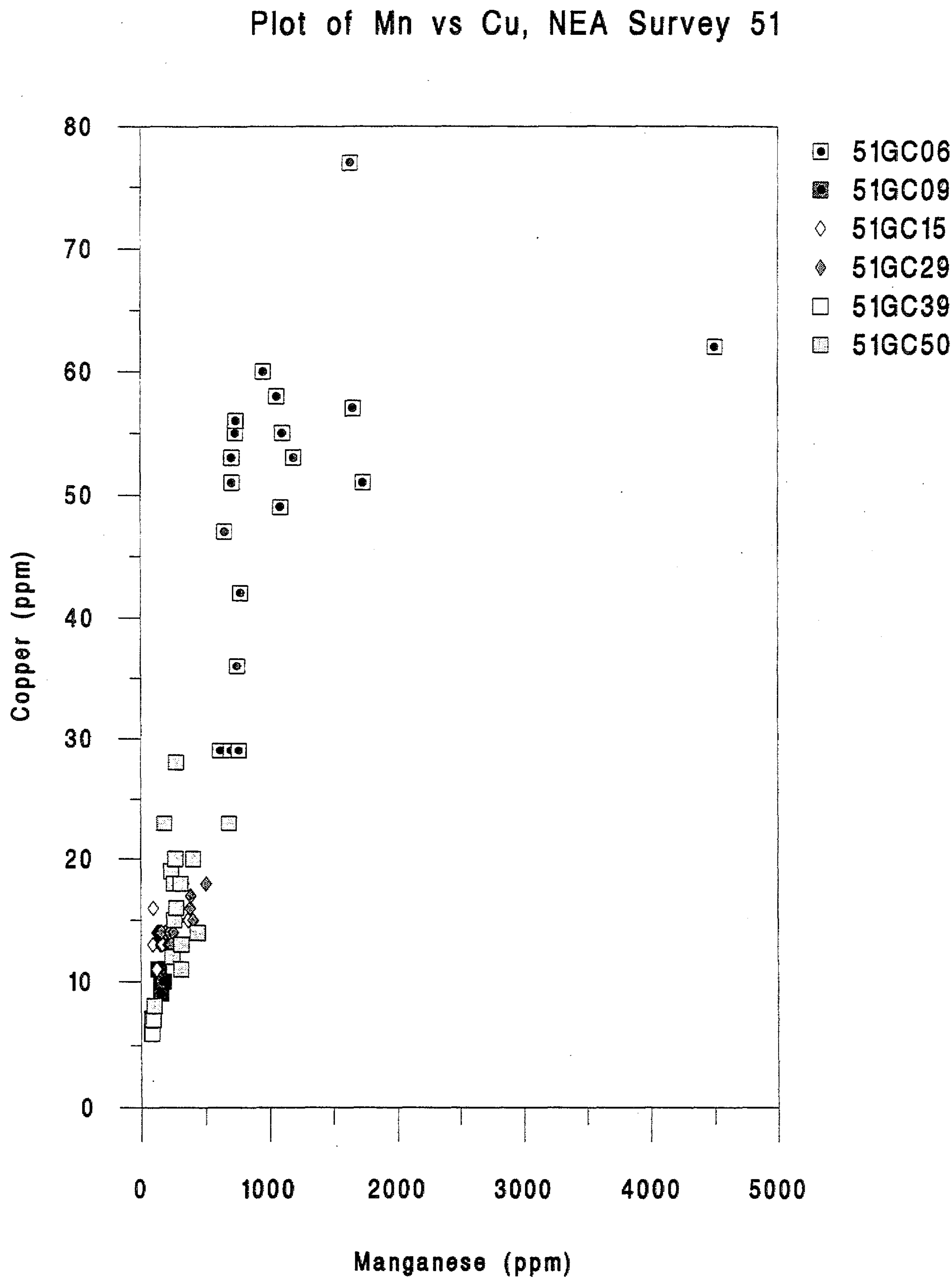

Plot of Mn vs Co, NEA Survey 51
Cobalt (ppm)
30
20
10
0
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

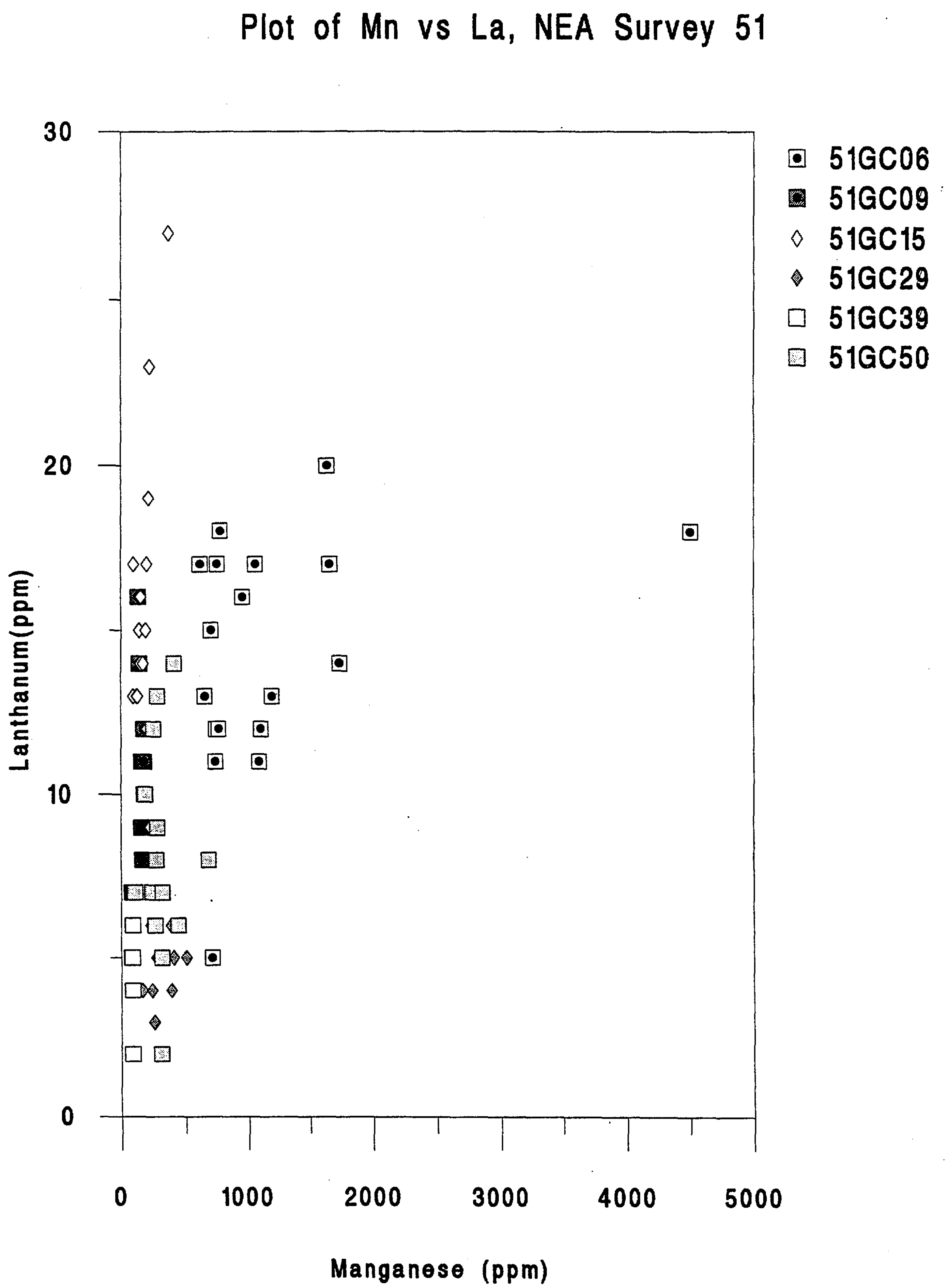


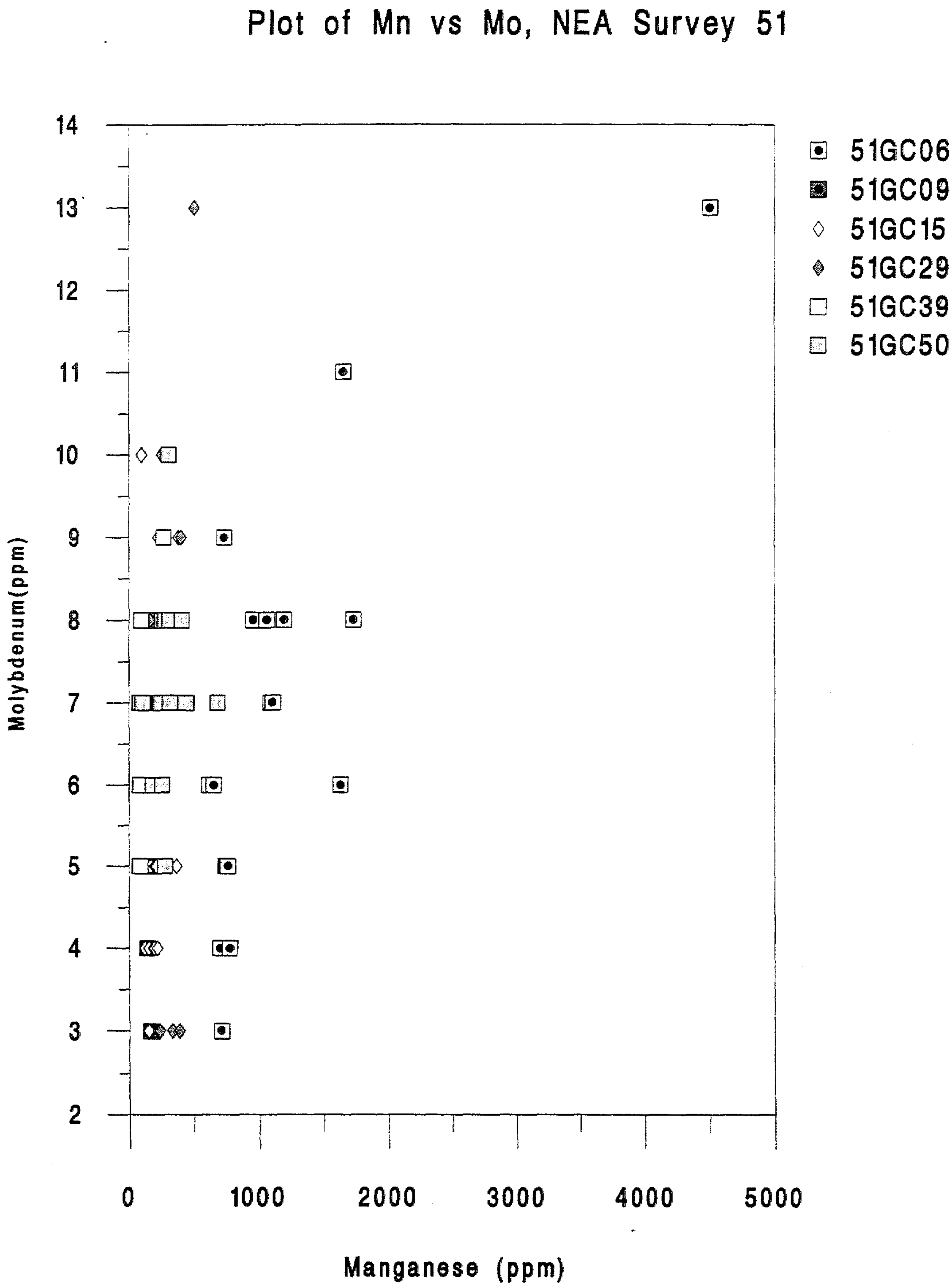
Plot of Mn vs Cr, NEA Survey 51
90
80
70
60
50
40
30
20
10
0
Chromium(ppm)
0
1000
2000
3000
4000
5000
Maanganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

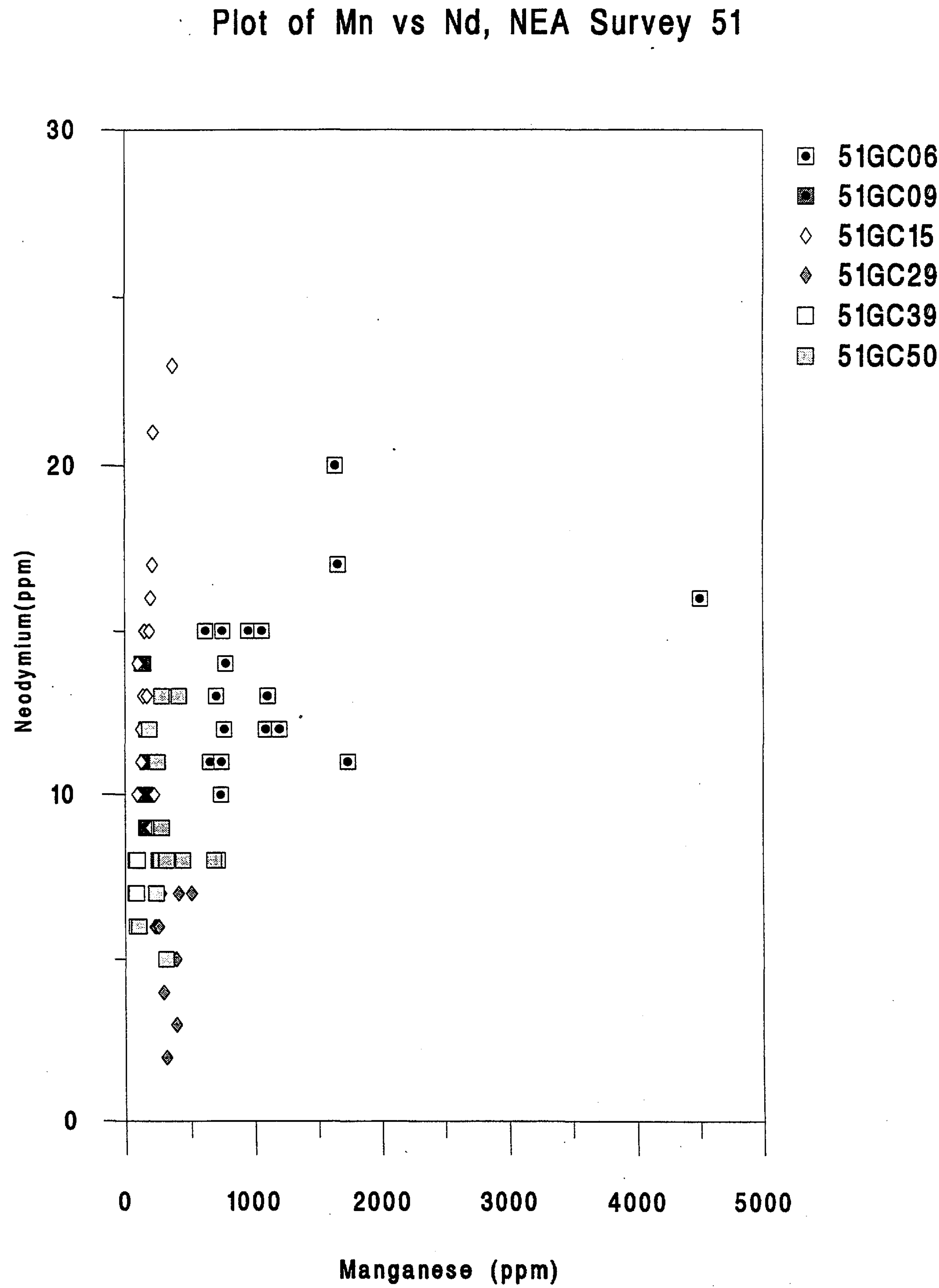
Plot of Mn vs Cs, NEA Survey 51



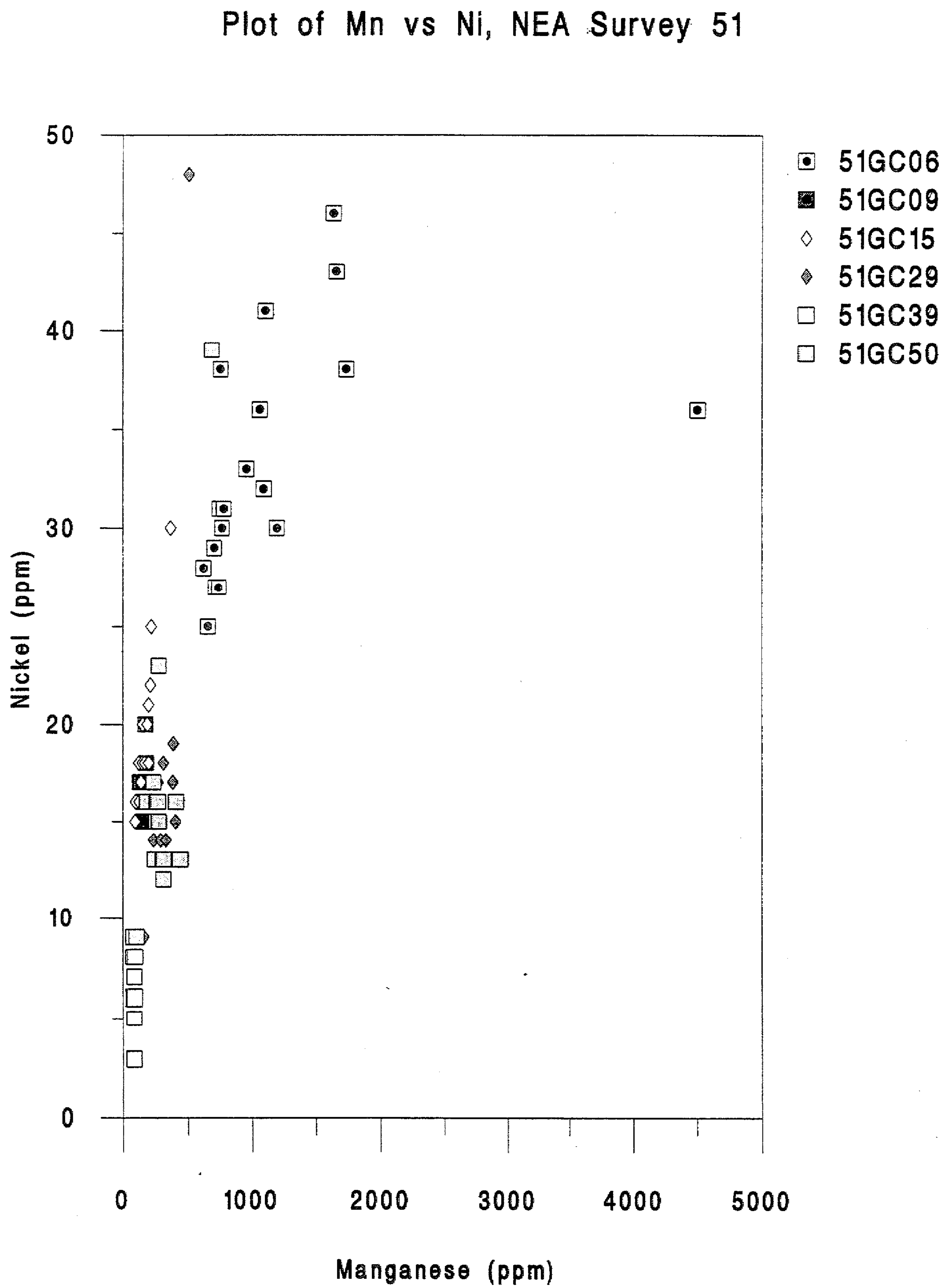

Plot of Mn vs Cu, NEA Survey 51
Copper (ppm)
0
10
20
30
40
50
60
70
80
Manganese (ppm)
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Mn vs La, NEA Survey 51
30
20
10
0
0
1000
2000
3000
4000
5000
Lanthanum(ppm)
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

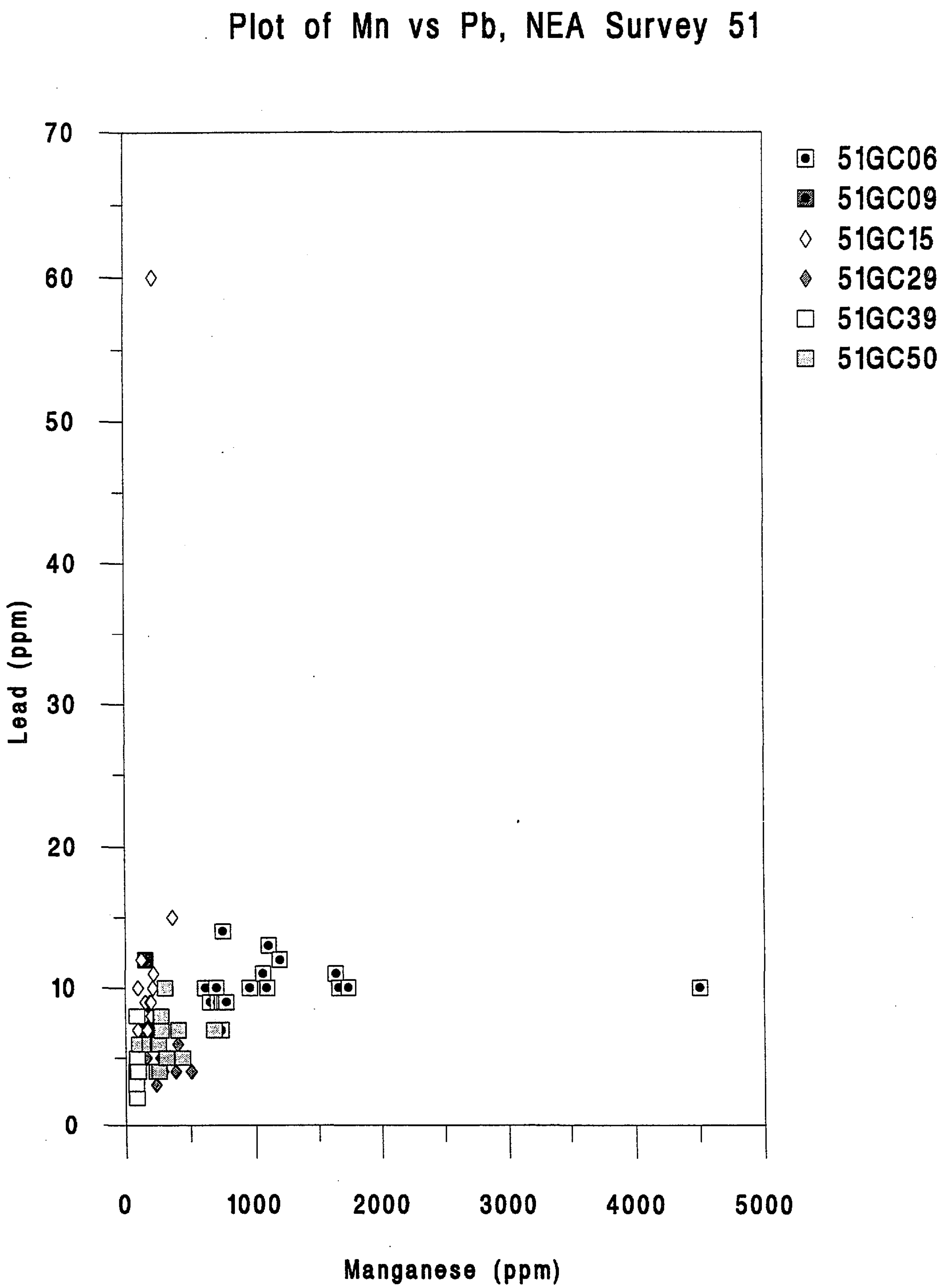

Plot of Mn vs Mo, NEA Survey 51
Molybdenum(ppm)
14
13
12
11
10
9
8
7
6
5
4
3
2
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

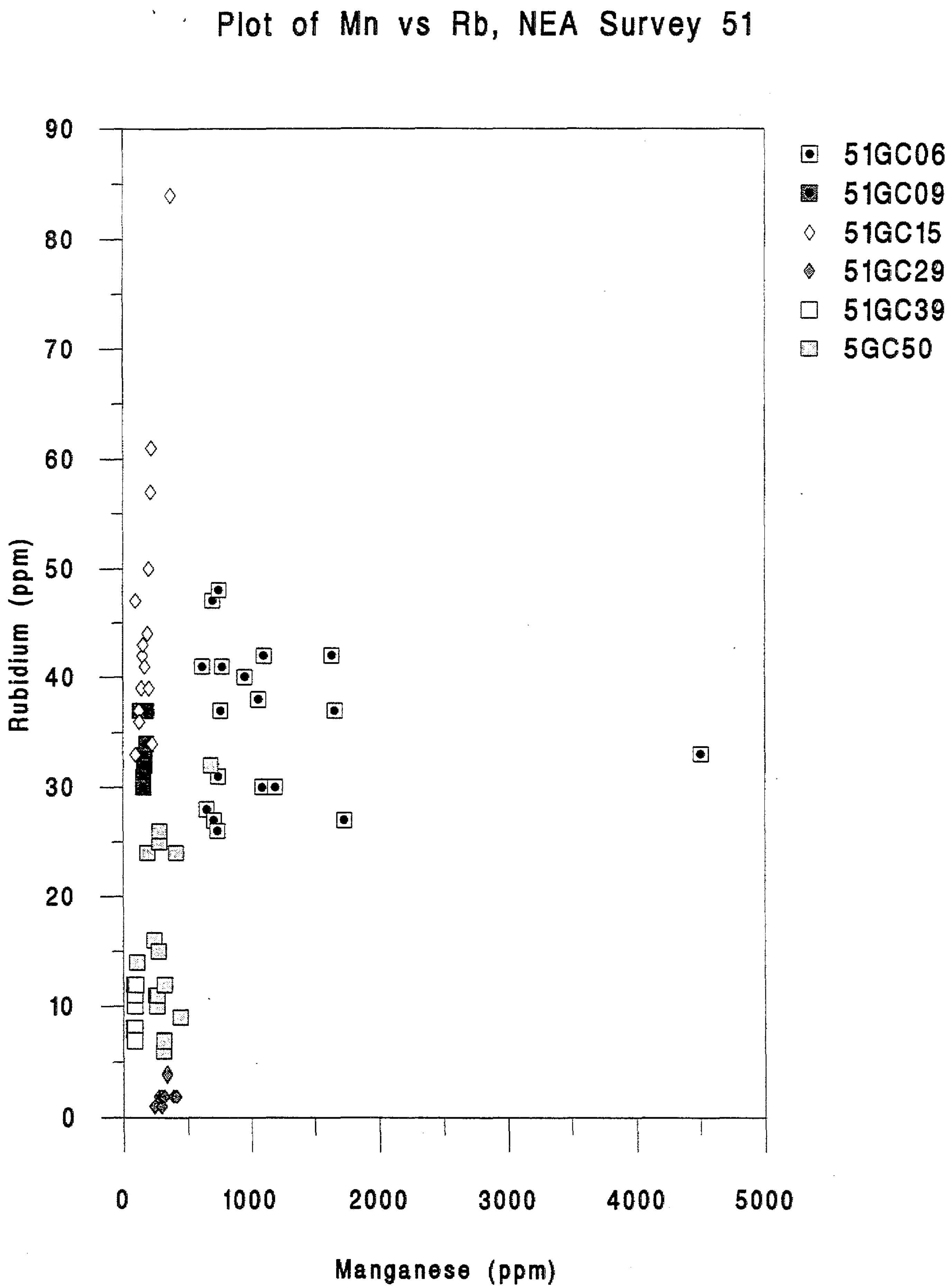


Plot of Mn vs Nd, NEA Survey 51
Neodymium(ppm)
Manganese (ppm)
0
10
20
30
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

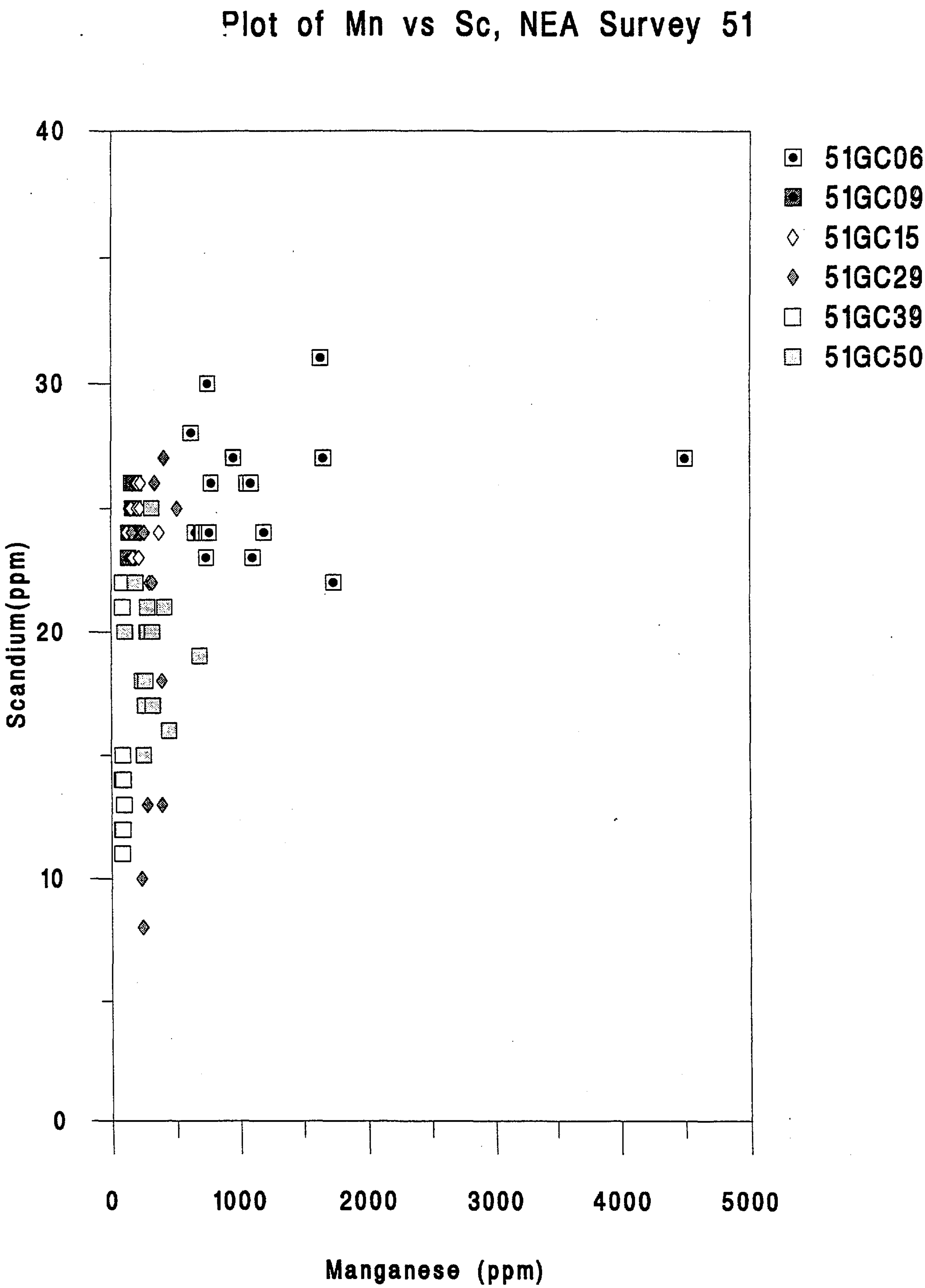


Plot of Mn vs Ni, NEA Survey 51
Nickel (ppm)
Manganese (ppm)
0
10
20
30
40
50
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50


Plot of Mn vs Pb, NEA Survey 51
Lead (ppm)
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
Manganese (ppm)
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50



Plot of Mn vs Rb, NEA Survey 51
Rubidium (ppm)
Manganese (ppm)
0
10
20
30
40
50
60
70
80
90
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
5GC50


Plot of Mn vs Sc, NEA Survey 51
Scandium(ppm)
Manganese (ppm)
0
10
20
30
40
0
1000
2000
3000
4000
5000
51GC06
51GC09
51GC15
51GC29
51GC39
51GC50

Appendix E: Down-core elemental ratios of cores collected off northeast Australia

Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)	Ba (ppm)
51GC006	0.75	6.02	3.19	0.08	0.03	16.16	7.55	0.29	0.17	
51GC006	2.25	5.86	3.10	0.05	0.02	15.70	7.34	0.29	0.17	312
51GC006	3.75	6.11	3.23	0.08	0.03	16.21	7.58	0.30	0.18	330
51GC006	6.75	6.62	3.50	0.08	0.03	17.58	8.22	0.32	0.19	374
51GC006	9.75	7.94	4.20	0.09	0.04	20.66	9.66	0.37	0.22	477
51GC006	14.75	7.65	4.05	0.09	0.04	20.31	9.49	0.36	0.22	526
51GC006	18.25	8.25	4.37	0.06	0.03	22.03	10.30	0.39	0.23	469
51GC006	21.75	7.71	4.08	0.09	0.04	20.89	9.76	0.37	0.22	671
51GC006	28.75	7.12	3.77	0.09	0.04	19.02	8.89	0.35	0.21	644
51GC006	40.75	6.63	3.51	0.09	0.04	17.74	8.29	0.32	0.19	472
51GC006	47.25	6.44	3.41	0.06	0.03	17.10	7.99	0.30	0.18	455
51GC006	53.75	6.42	3.40	0.08	0.03	17.23	8.05	0.31	0.19	510
51GC006	63.50	6.32	3.34	0.09	0.04	16.80	7.85	0.31	0.19	445
51GC006	73.50	9.09	4.81	0.10	0.04	24.81	11.60	0.44	0.26	627
51GC006	82.75	7.57	4.01	0.08	0.03	26.87	12.56	0.40	0.24	441
51GC006	91.75	7.61	4.03	0.08	0.03	21.06	9.84	0.38	0.23	356
51GC006	101.75	8.54	4.52	0.09	0.04	23.38	10.93	0.41	0.25	407
51GC006	111.25	8.39	4.44	0.09	0.04	22.91	10.71	0.41	0.25	470
51GC006	120.75	9.05	4.79	0.08	0.03	27.07	12.65	0.46	0.28	325

Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)	Rb/Al (ppm/wt%=10000)
51GC006	0.75	0.011	2.37	0.055	0.00	0.00	16.64	223	8.47	0.00
51GC006	2.25	0.007	2.37	0.056	100.60	9.35	16.44	229	8.71	8.71
51GC006	3.75	0.011	2.34	0.056	102.05	10.21	17.01	228	8.35	8.04
51GC006	6.75	0.010	2.35	0.055	106.75	10.85	15.98	211	8.85	8.85
51GC006	9.75	0.009	2.30	0.053	113.51	11.66	14.28	227	7.85	9.52
51GC006	14.75	0.010	2.34	0.053	129.92	10.87	14.33	262	8.89	9.39
51GC006	18.25	0.006	2.36	0.054	107.42	8.93	12.60	253	9.39	9.62
51GC006	21.75	0.010	2.39	0.054	164.44	11.03	13.97	406	10.54	9.07
51GC006	28.75	0.010	2.36	0.056	170.90	11.15	16.45	1194	9.55	8.76
51GC006	40.75	0.011	2.36	0.055	134.52	9.97	15.10	339	8.55	8.55
51GC006	47.25	0.008	2.35	0.053	133.50	9.39	14.38	320	9.39	8.80
51GC006	53.75	0.010	2.37	0.055	150.10	10.60	13.83	191	7.36	8.24
51GC006	63.50	0.012	2.35	0.056	133.04	9.57	15.25	519	11.36	8.07
51GC006	73.50	0.009	2.41	0.055	130.33	11.22	16.01	339	9.56	8.73
51GC006	82.75	0.009	3.13	0.060	110.08	12.73	7.24	154	6.99	10.23
51GC006	91.75	0.009	2.44	0.057	88.39	10.92	7.20	189	7.45	9.19
51GC006	101.75	0.009	2.42	0.054	90.05	10.62	9.29	171	6.86	9.07
51GC006	111.25	0.009	2.41	0.055	105.85	13.29	8.11	169	8.56	10.81
51GC006	120.75	0.007	2.64	0.058	67.85	10.23	6.05	146	6.05	9.81

Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
	53	710	27				47
29	51	710	27	27	1053	41	44
33	55	737	27	26	1050	46	46
38	56	740	31	31	1068	53	47
49	60	954	33	40	1051	74	55
44	58	1059	36	38	1029	74	54
39	55	1105	41	42	948	59	56
45	57	1656	43	37	967	80	57
42	62	4500	36	33	1008	78	54
35	53	1191	30	30	1036	67	51
32	49	1090	32	30	998	54	51
36	47	649	25	28	1054	64	49
32	51	1735	38	27	1052	57	49
54	77	1633	46	42	858	97	65
51	29	616	28	41	962	72	55
44	29	761	30	37	952	59	57
48	42	774	31	41	874	66	59
59	36	751	38	48	776	102	69
49	29	699	29	47	1042	63	57

Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
0	0.00	14.75
340	13.22	14.19
325	14.23	14.23
305	15.13	13.41
250	17.61	13.09
254	18.28	13.34
217	13.51	12.83
237	19.61	13.97
268	20.70	14.33
295	19.09	14.53
293	15.84	14.96
310	18.84	14.42
315	17.04	14.65
178	20.16	13.51
240	17.97	13.73
236	14.65	14.15
193	14.60	13.05
175	22.97	15.54
218	13.15	11.90

Survey	Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)
51	GC009	0-3	5.30	2.80	0.07	0.03	16.27	7.61	0.27
	GC009	10-13	5.54	2.93	0.06	0.03	16.89	7.89	0.27
	GC009	30-33	5.30	2.80	0.05	0.02	15.83	7.40	0.26
	GC009	50-53	5.52	2.92	0.06	0.03	16.69	7.80	0.28
	GC009	70-73	6.38	3.38	0.07	0.03	18.37	8.59	0.30
	GC009	90-93	6.34	3.36	0.06	0.03	18.18	8.50	0.31
	GC009	110-113	5.94	3.14	0.07	0.03	17.74	8.29	0.30
	GC009	130-133	6.21	3.29	0.10	0.04	19.30	9.02	0.31
	GC009	150-153			0.09	0.04	19.94	9.32	0.32

Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)
51	GC009	0-3	0.011	2.71	0.058	25.67	3.21	14.26	55.97
	GC009	10-13	0.009	2.69	0.055	26.60	3.41	15.01	55.93
	GC009	30-33	0.008	2.64	0.056	29.23	3.57	14.97	55.26
	GC009	50-53	0.009	2.67	0.057	24.65	3.42	13.35	56.14
	GC009	70-73	0.009	2.54	0.053	23.69	2.96	13.03	52.12
	GC009	90-93	0.008	2.53	0.055	22.95	2.98	12.52	51.26
	GC009	110-113	0.010	2.64	0.057	24.18	3.18	13.04	55.99
	GC009	130-133	0.013	2.74	0.057	27.38	3.35	14.30	42.29

Ti (wt%)	Ba (ppm)	Cu (ppm)	Cr (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
0.16	72	9	40	157	16	30	2747	30	28
0.16	78	10	44	164	16	33	2707	31	34
0.16	82	10	42	155	15	31	2730	26	29
0.17	72	10	39	164	17	32	2671	29	30
0.18	80	10	44	176	18	37	2513	34	34
0.19	77	10	42	172	20	37	2512	30	33
0.18	76	10	41	176	17	34	2529	29	31
0.19	90	11	47	139	17	37	2455	37	32
0.19	86	11	47	132	17	37	2499	36	29

Ni/Al (ppm/wt%=10000)	Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
5.70	10.70	979	10.70	9.98
5.46	11.26	923	10.57	11.60
5.35	11.05	973	9.27	10.34
5.82	10.95	914	9.93	10.27
5.33	10.96	744	10.07	10.07
5.96	11.03	749	8.94	9.83
5.41	10.82	804	9.22	9.86
5.17	11.26	747	11.26	9.74

Survey	Core	Depth (cm)	Al2O3 wt%	Al (wt%)	P2O5 wt%	P (wt%)	SiO2 wt%	Si (wt%)	TiO2 wt%	Ti (wt%)	Ba (ppm)
51	GC015	0-3	5.75	3.04	0.07	0.03	18.54	8.67	0.29	0.17	119
	GC015	9-12	6.17	3.27	0.09	0.04	18.82	8.80	0.31	0.19	122
	GC015	30-33	6.44	3.41	0.10	0.04	19.07	8.91	0.33	0.20	138
	GC015	50-53	6.64	3.51	0.07	0.03	20.61	9.63	0.33	0.20	115
	GC015	70-73	6.77	3.58	0.10	0.04	20.82	9.73	0.35	0.21	135
	GC015	90-93	7.04	3.73	0.10	0.04	22.62	10.57	0.37	0.22	136
	GC015	110-113	6.84	3.62	0.10	0.04	21.79	10.19	0.36	0.22	123
	GC015	130-133	7.62	4.03	0.10	0.04	23.34	10.91	0.39	0.23	123
	GC015	150-153	8.41	4.45	0.10	0.04	26.22	12.26	0.44	0.26	135
	GC015	170-173	9.57	5.06	0.09	0.04	31.34	14.65	0.52	0.31	136
	GC015	190-193	13.40	7.09	0.10	0.04	36.95	17.27	0.67	0.40	146
	GC015	215-218	9.76	5.17	0.12	0.05	28.44	13.29	0.51	0.31	133
	GC015	240-243	5.26	2.78	0.08	0.03	17.74	8.29	0.27	0.16	168
	GC015	265-268	6.34	3.36	0.08	0.03	23.35	10.91	0.31	0.19	131
	GC015	290-293	6.26	3.31	0.09	0.04	20.53	9.60	0.34	0.20	108

Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)	Rb/Al (ppm/wt%=10000)
51	GC015	0-3	0.010	2.85	0.057	39.10	13.80	4.27	72.29	5.26	11.17
	GC015	9-12	0.012	2.69	0.057	37.36	13.47	4.29	37.67	4.90	11.02
	GC015	30-33	0.013	2.62	0.058	40.49	14.38	4.11	40.78	4.99	11.44
	GC015	50-53	0.009	2.74	0.056	32.72	11.95	3.98	55.77	5.12	11.10
	GC015	70-73	0.012	2.72	0.059	37.68	14.23	3.91	41.86	5.02	11.72
	GC015	90-93	0.012	2.84	0.060	36.50	13.96	3.49	40.80	5.37	11.54
	GC015	110-113	0.012	2.81	0.060	33.98	12.98	3.59	45.86	4.97	11.33
	GC015	130-133	0.011	2.71	0.058	30.50	11.90	3.47	46.37	4.96	10.91
	GC015	150-153	0.010	2.75	0.059	30.33	12.36	3.15	44.26	4.72	11.23
	GC015	170-173	0.008	2.89	0.062	26.85	11.45	2.57	41.66	4.34	11.25
	GC015	190-193	0.006	2.44	0.057	20.59	11.84	2.12	51.89	4.23	11.84
	GC015	215-218	0.010	2.57	0.059	25.75	14.13	2.71	42.01	4.84	11.81
	GC015	240-243	0.013	2.98	0.058	60.35	15.81	5.75	34.84	5.75	16.88
	GC015	265-268	0.010	3.25	0.055	39.04	13.41	3.87	27.72	4.47	9.83
	GC015	290-293	0.012	2.90	0.062	32.60	15.09	3.32	36.52	5.43	11.17

Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
42	13	220	16	34	2586	32	34
44	14	123	16	36	2499	38	36
49	14	139	17	39	2531	42	35
42	14	196	18	39	2333	35	38
51	14	150	18	42	2376	42	37
52	13	152	20	43	2251	44	37
47	13	166	18	41	2254	39	35
48	14	187	20	44	2078	40	39
55	14	197	21	50	1946	50	40
58	13	211	22	57	1646	50	42
84	15	368	30	84	1098	74	51
73	14	217	25	61	1772	65	42
44	16	97	16	47	1746	51	33
45	13	93	15	33	2236	44	34
50	11	121	18	37	2252	40	38

Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
850	10.52	11.17
765	11.64	11.02
743	12.32	10.27
664	9.96	10.81
663	11.72	10.33
604	11.81	9.93
623	10.77	9.67
515	9.92	9.67
437	11.23	8.99
325	9.87	8.29
155	10.43	7.19
343	12.58	8.13
627	18.32	11.85
666	13.11	10.13
680	12.07	11.47

Survey	Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)
51	GC019	0-3	4.64	2.46	0.05	0.02	17.57	8.21	0.26	0.16
	GC019	30-33	5.47	2.89	0.05	0.02	14.77	6.90	0.26	0.16

Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)
51	GC019	0-3	0.009	3.34	0.063	129	11.81	10.99	193	8.96
	GC019	30-33	0.008	2.38	0.054	172	8.98	13.82	977	13.82

Ba (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
316	29	27	473	22	27	2157	27	36
498	26	40	2828	40	30	1323	34	44

Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
10.99	878	10.99	14.66
10.36	457	11.74	15.20

Survey	Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)
51	GC029	0-3	1.10	0.58	0.03	0.01	3.10	1.45	0.06	0.04
	GC029	6-12	1.09	0.58	0.03	0.01	2.64	1.23	0.06	0.04
	GC029	14-17	0.93	0.49	0.04	0.02	2.46	1.15	0.05	0.03
	GC029	20-23	0.84	0.44	0.04	0.02	2.36	1.10	0.05	0.03
	GC029	30-33	0.87	0.46	0.05	0.02	2.55	1.19	0.06	0.04
	GC029	40-43	1.03	0.55	0.04	0.02	2.95	1.38	0.07	0.04
	GC029	50-53	1.20	0.64	0.05	0.02	3.25	1.52	0.07	0.04
	GC029	70-73	1.49	0.79	0.08	0.03	4.06	1.90	0.09	0.05
	GC029	90-93	0.92	0.49	0.05	0.02	2.57	1.20	0.06	0.04
	GC029	130-133	1.12	0.59	0.09	0.04	3.07	1.43	0.06	0.04
	GC029	150-153	1.19	0.63	0.08	0.03	3.28	1.53	0.07	0.04
	GC029	170-173	1.97	1.04	0.07	0.03	2.77	1.29	0.06	0.04
	GC029	190-193	1.00	0.53	0.07	0.03	2.81	1.31	0.06	0.04

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Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)
51	GC029	0-3	0.022	2.49	0.062	313	10.31	30.92	536	30.92
	GC029	6-12	0.023	2.14	0.062	286	8.67	29.47	674	32.94
	GC029	14-17	0.035	2.34	0.061	410	12.19	36.57	1026	97.52
	GC029	20-23	0.039	2.48	0.067	380	9.00	31.49	571	29.24
	GC029	30-33	0.047	2.59	0.078	413	13.03	30.41	345	19.55
	GC029	40-43	0.032	2.53	0.077	323	12.84	27.52	532	27.52
	GC029	50-53	0.034	2.39	0.066	255	9.45	25.19	457	22.04
	GC029	70-73	0.044	2.41	0.068	251	8.88	22.83	420	17.75
	GC029	90-93	0.045	2.47	0.074	437	10.27	30.81	834	30.81
	GC029	130-133	0.066	2.42	0.061	322	13.50	26.99	648	28.68
	GC029	150-153	0.055	2.43	0.067	240	63.51	23.82	427	26.99
	GC029	170-173	0.029	1.24	0.035	197	6.71	13.43	215	14.39
	GC029	190-193	0.058	2.48	0.068	338	17.01	24.56	448	26.45

Ba (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
182	6	18	312	18	2	1902	9	22
165	5	17	389	19	1	1431	10	19
202	6	18	505	48	1	1412	10	19
169	4	14	254	13	1	1342	8	17
190	6	14	159	9	1	1312	9	18
176	7	15	290	15	1	1260	8	19
162	6	16	290	14	2	1251	6	19
198	7	18	331	14	4	1159	14	21
213	5	15	406	15	2	1142	14	18
191	8	16	384	17	2	1168	14	20
151	40	15	269	17	2	1304	13	19
205	7	14	224	15	1	1315	13	18
179	9	13	237	14	1	1263	12	17

Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
3.44	3267	15.46	37.79
1.73	2481	17.33	32.94
2.03	2869	20.32	38.60
2.25	3019	18.00	38.24
2.17	2849	19.55	39.09
1.83	2311	14.68	34.85
3.15	1970	9.45	29.92
5.07	1470	17.75	26.63
4.11	2345	28.75	36.97
3.37	1970	23.62	33.74
3.18	2071	20.64	30.17
0.96	1261	12.47	17.26
1.89	2386	22.67	32.12

Survey	Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)
51	GC039	0-3	1.60	0.85	0.03	0.01	8.71	4.07	0.10	0.06
	GC039	6-12	1.69	0.89	0.08	0.03	8.06	3.77	0.09	0.05
	GC039	12-15	1.63	0.86	0.08	0.03	7.70	3.60	0.09	0.05
	GC039	20-23	1.61	0.85	0.07	0.03	7.74	3.62	0.09	0.05
	GC039	30-33	1.76	0.93	0.05	0.02	8.09	3.78	0.11	0.07
	GC039	50-53	2.00	1.06	0.08	0.03	9.15	4.28	0.11	0.07
	GC039	70-73	2.09	1.11	0.08	0.03	9.42	4.40	0.12	0.07
	GC039	90-93	2.20	1.16	0.08	0.03	10.22	4.78	0.12	0.07
	GC039	110-113	2.14	1.13	0.08	0.03	10.22	4.78	0.12	0.07
	GC039	130-133	2.29	1.21	0.08	0.03	10.19	4.76	0.13	0.08

Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)
51	GC039	0-3	0.015	4.81	0.071	47.24	17.71	7.09	103.92	7.09
	GC039	6-12	0.039	4.21	0.060	52.55	20.12	6.71	89.44	7.83
	GC039	12-15	0.040	4.17	0.063	49.85	20.87	6.96	92.74	8.11
	GC039	20-23	0.036	4.25	0.063	52.81	21.12	8.22	97.41	9.39
	GC039	30-33	0.023	4.06	0.071	40.80	18.25	6.44	91.25	7.52
	GC039	50-53	0.033	4.04	0.062	48.18	19.84	6.61	82.19	6.61
	GC039	70-73	0.032	3.98	0.065	48.82	18.99	5.42	72.33	6.33
	GC039	90-93	0.030	4.10	0.062	44.66	18.04	6.01	76.44	6.87
	GC039	110-113	0.031	4.22	0.064	43.26	17.66	5.30	76.82	7.06
	GC039	130-133	0.029	3.93	0.064	42.08	18.98	5.78	75.91	6.60

Ba (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
40	15	6	88	6	7	2858	13	13
47	18	6	80	7	8	2985	12	11
43	18	6	80	7	8	3007	14	11
45	18	7	83	8	8	2839	11	11
38	17	6	85	7	8	2842	9	14
51	21	7	87	7	10	2815	14	14
54	21	6	80	7	12	2889	15	13
52	21	7	89	8	12	2755	16	14
49	20	6	87	8	11	2679	17	14
51	23	7	92	8	12	2695	16	15

Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
8.27	3375	15.35	15.35
8.94	3337	13.42	12.30
9.27	3486	16.23	12.75
9.39	3332	12.91	12.91
8.59	3051	9.66	15.03
9.45	2659	13.23	13.23
10.85	2612	13.56	11.75
10.31	2366	13.74	12.02
9.71	2365	15.01	12.36
9.90	2224	13.20	12.38

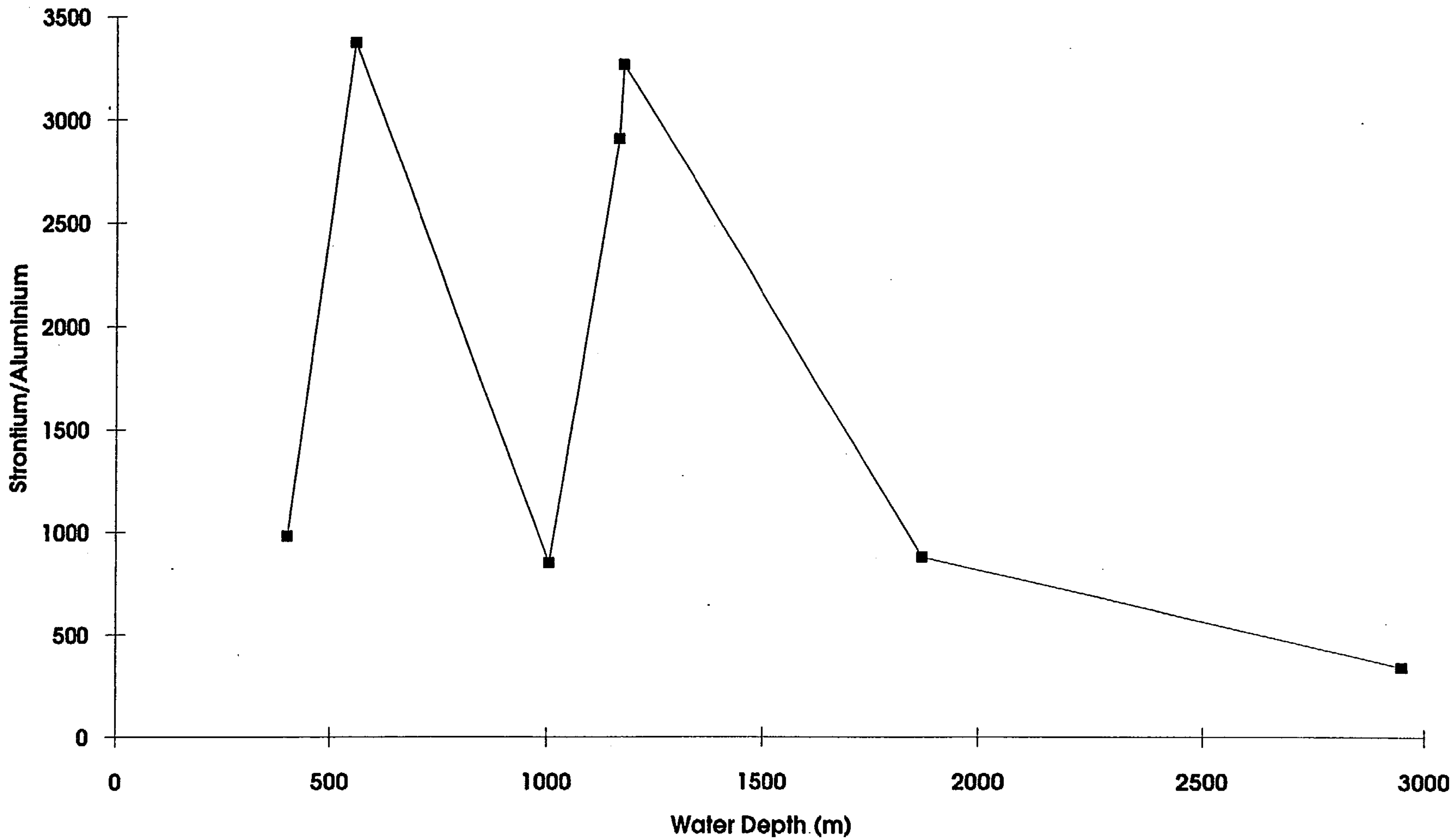
Survey	Core	Depth (cm)	Al2O3 (wt%)	Al (wt%)	P2O5 (wt%)	P (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)
51	GC050	0-3	1.77	0.94	0.05	0.02	5.03	2.35	0.10	0.06
	GC050	6-9	2.25	1.19	0.09	0.04	6.15	2.87	0.11	0.07
	GC050	12-15	3.11	1.65	0.08	0.03	8.50	3.97	0.17	0.10
	GC050	20-23	5.70	3.02	0.06	0.03	14.72	6.88	0.28	0.17
	GC050	31-33	4.53	2.40	0.09	0.04	11.36	5.31	0.22	0.13
	GC050	40-45	4.20	2.22	0.10	0.04	13.81	6.46	0.20	0.12
	GC050	50-53	2.22	1.17	0.05	0.02	17.64	8.25	0.12	0.07
	GC050	60-63	2.40	1.27	0.09	0.04	6.17	2.88	0.11	0.07
	GC050	70-73	1.71	0.91	0.07	0.03	4.58	2.14	0.09	0.05
	GC050	80-83	2.59	1.37	0.10	0.04	6.53	3.05	0.12	0.07
	GC050	105-108	4.26	2.25	0.09	0.04	11.14	5.21	0.20	0.12
	GC050	125-128	2.04	1.08	0.10	0.04	5.51	2.58	0.11	0.07
	GC050	145-148	4.67	2.47	0.09	0.04	12.43	5.81	0.23	0.14
	GC050	165-168	2.41	1.28	0.09	0.04	6.68	3.12	0.12	0.07
	GC050	190-193	3.33	1.76	0.10	0.04	9.02	4.22	0.17	0.10

Survey	Core	Depth (cm)	P/Al	Si/Al	Ti/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al (ppm/wt%=10000)
51	GC050	0-3	0.023	2.51	0.064	196	10.68	19.22	327.73	13.88
	GC050	6-9	0.033	2.41	0.055	216	14.28	15.12	215.82	12.60
	GC050	12-15	0.021	2.41	0.062	148	12.15	12.15	164.65	9.72
	GC050	20-23	0.009	2.28	0.056	52	7.62	7.62	226.08	12.93
	GC050	31-33	0.016	2.21	0.055	102	10.43	9.59	77.16	6.67
	GC050	40-45	0.020	2.90	0.054	111	11.70	9.00	184.45	7.20
	GC050	50-53	0.019	7.02	0.061	83	11.92	6.81	89.37	7.66
	GC050	60-63	0.031	2.27	0.052	246	10.23	9.45	193.67	10.23
	GC050	70-73	0.034	2.37	0.060	219	6.63	12.15	344.75	13.26
	GC050	80-83	0.032	2.23	0.052	181	8.02	9.48	230.53	9.48
	GC050	105-108	0.017	2.31	0.053	112	9.76	7.10	122.42	6.65
	GC050	125-128	0.040	2.39	0.061	281	11.11	12.97	408.46	12.04
	GC050	145-148	0.016	2.35	0.056	127	11.33	11.33	111.67	9.31
	GC050	165-168	0.031	2.45	0.056	158	12.54	11.76	203.85	12.54
	GC050	190-193	0.025	2.39	0.058	106	12.48	10.78	133.91	9.65

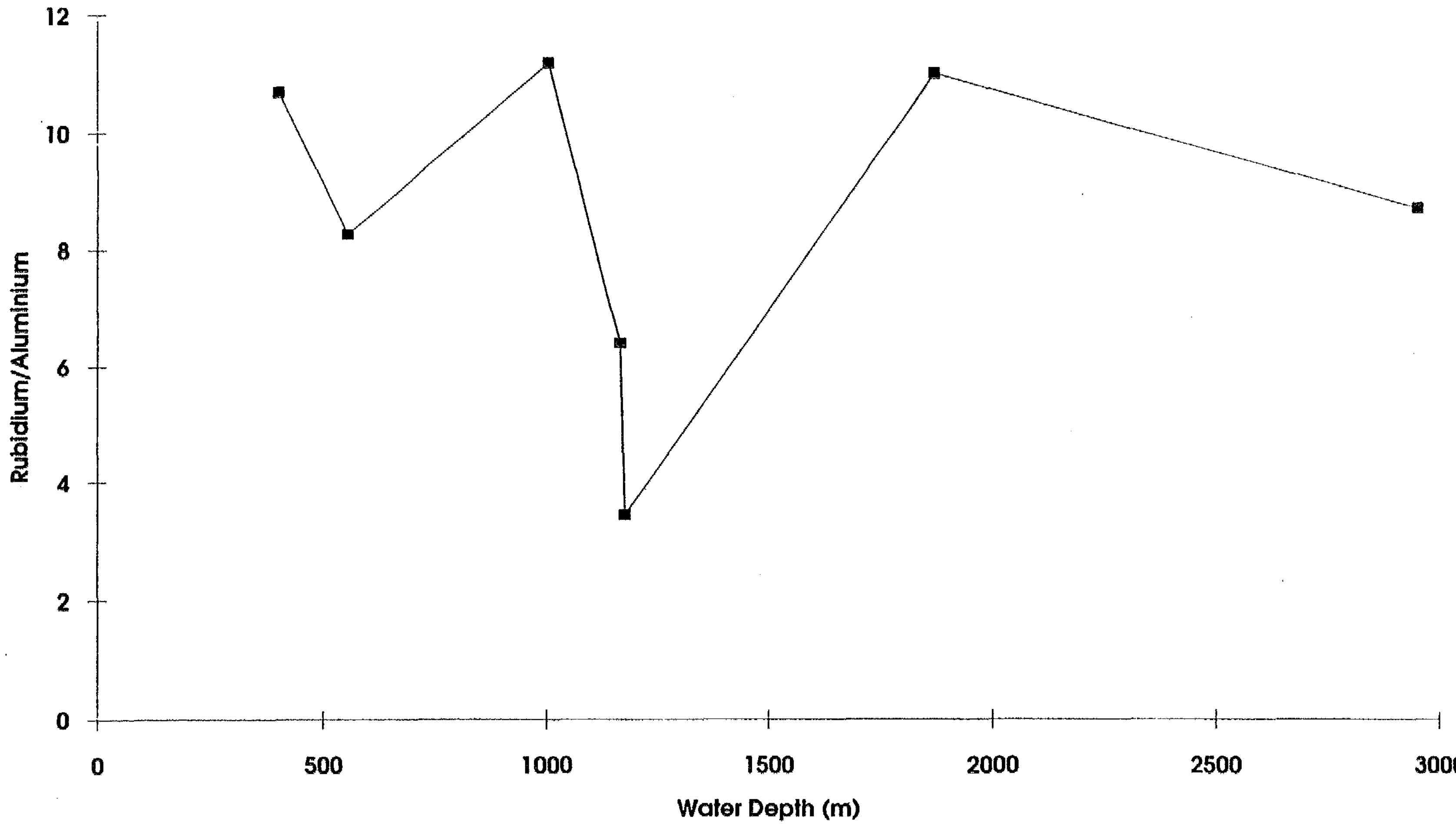
Ba (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
184	10	18	307	13	6	2721	9	21
257	17	18	257	15	10	2660	16	23
243	20	20	271	16	15	2508	21	27
158	23	23	682	39	32	2301	21	38
244	25	23	185	16	24	1883	25	33
247	26	20	410	16	24	1822	30	30
98	14	8	105	9	14	1500	14	16
313	13	12	246	13	11	1723	17	24
198	6	11	312	12	7	1632	10	21
248	11	13	316	13	12	1647	14	26
252	22	16	276	15	25	1516	24	29
303	12	14	441	13	9	1681	17	22
315	28	28	276	23	26	1814	36	35
202	16	15	260	16	11	2128	19	24
187	22	19	236	17	16	2104	25	31

Rb/Al (ppm/wt%=10000)	Sr/Al (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)
6.41	2905	9.61	22.42
8.40	2234	13.44	19.31
9.11	1524	12.76	16.40
10.61	763	6.96	12.60
10.01	785	10.43	13.76
10.80	820	13.50	13.50
11.92	1277	11.92	13.62
8.66	1357	13.38	18.89
7.73	1803	11.05	23.20
8.75	1202	10.21	18.97
11.09	672	10.65	12.86
8.34	1557	15.75	20.38
10.52	734	14.57	14.16
8.62	1668	14.90	18.82
9.08	1194	14.19	17.59

Core-top Sr/Al (ppm/wt%=10000) ratio versus water depth (m), northeast Australia cores



Core-top Rb/Al (ppm/wt%=10000) ratio versus water depth (m), northeast Australia cores



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