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GEOCHEMISTRY OF SURFACE SEDIMENTS FROM THE SOUTHERN AUSTRALIAN CONTINENTAL MARGIN INCLUDING OFFSHORE WEST TASMANIA, SOUTH AUSTRALIA AND VICTORIA

by D T Heggie, J L Lane and H H Veeh

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Continental Margin Transects

Geochemistry of surface sediments from the Southern Australian Continental Margin including offshore West Tasmania, South Australia and Victoria.

Projects: 121.13, 121.20 and 121.38

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EXECUTIVE SUMMARY

As part of Bureau of Mineral Resources (BMR) survey 67 using *Rig Seismic* offshore South Australia, Victoria and West Tasmania, many gravity cores were sampled and analysed for light hydrocarbons as part of the Continental Margins surface geochemistry project. Eight of those cores were analysed, both at sea and in Canberra, for a variety of complementary geochemical data. This Record provides a summary of the geochemical analyses subsequently conducted on those cores. The data presented here include (i) pore water metabolites (ii) geochemical analyses of major and trace element abundances (iii) radiochemical data and select palaeoceanographic indicators. Some of these data have been used to assist in the interpretation of the light hydrocarbon data, while much of the other data has applications to a variety of environmental and resource issues in southern Australia. These data (i) provide a data-base which can be used to assess long-term environmental change associated with anthropogenic discharges to the southern margins of Australia (ii) allow assessment of Late Quaternary and natural climatic change and (iii) provide clues to geochemical processes operating in the sediments which are important in identifying formation of some seafloor minerals including marine phosphorites and manganese crusts and nodules. This Record and these data also form part of a geochemical data-base which includes data from other parts of the Australian continental margin. These data will be used to systematically develop the basis for an understanding of the controls on the geochemical compositions of sediments from around Australia.

The pore water data indicate that the outer-shelf/upper-slope cores are probably sub-oxic to anoxic in character within the top few centimetres as a result of organic carbon burial and recycling in the core-tops. In contrast the lower-slope sediments are more oxic (oxic to sub-oxic) and these reflect generally lower rates of organic matter input into these sediments. Pore water silicate data in some cores suggest uptake of silica into the solid phases at depth, which may be indicative of glauconite formation in the sediments. Glauconite is often associated with modern phosphorite accumulations in sediments, although these data provide no direct clues to phosphorite formations in these sediments. The inventory of sedimentary manganese in the outer-shelf/upper-slope cores is generally significantly lower than that measured in lower-slope cores. This observation, and the pore water data which shows manganese remobilisation and recycling between pore waters and sediments, may help explain an important process contributing to the formation of abundant manganese crusts and nodules in the deep waters off West Tasmania including the South Tasman Rise.

The down-core distributions of some radiochemical species, including authigenic uranium and excess thorium 230 are being used to both determine sedimentation rates and assess Late Quaternary paleoceanography in the region. These data and several other potential palaeoceanographic indicators indicate down-core trends which may be indicative of natural palaeoceanographic and palaeochemcial changes between glacial and interglacial periods, but these cannot be assessed until these sediments have been dated. This dating is in progress at the Flinders University of South Australia.

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INTRODUCTION

As part of the Continental Margins Program many cores have been collected as part of the light hydrocarbon surface geochemistry program and offshore exploration for hydrocarbons. In an effort to systematically understand the controls on the chemical compositions of the sediments of the Australian continental margin, several of these cores have been analysed for a variety of other chemical components. This Record documents analyses conducted on several cores collected from the Southern Australian Continental Margin, specifically the surficial sediments of the Otway Basin, during BMR Survey 67 off South Australia, Victoria and West Tasmania. The locations of the cores collected are shown in (Figure 1) and summarised in Table 1. The light hydrocarbon geochemistry conducted on these cores has been summarised elsewhere (Exon and Lee, 1987; Exon and others, 1992) as have sedimentological analyses (Exon and others, 1989).

The objectives of the analyses on the cores reported here include (i) to contribute to the geochemical inventory for analysis of potential climatic change on the southern margin of Australia, particularly that area underlying the Sub-Tropical Convergence Zone (STCZ), a global oceanographic feature which circles the globe and which impinges onto the southern margin of Australia; (ii) to provide an inventory of the chemical compositions of sediment which may be used to identify and assess environmental impact and anthropogenic additions to the continental shelves and slopes of Southern Australia; and (iii) to document the solid phase inventories of biogenic and terrigenous materials in sediments of these areas with application to offshore mineral occurrences on the outer shelf and upper slope e.g. marine phosphorites and, on the lower slope and adjacent abyssal plain e.g marine manganese nodules and crusts. The analyses conducted on cores reported here include (i) major and minor element contents of sediments (ii) pore water metabolites as indicators of diagenetic processes ins sediments and their application to identifying marine mineral formations and assessing climatic change (iii) radiochemical contents of sediments as indicators of climatic change and determinations of sedimentation rates on the continental margins. These analyses are summarised in Table 2

The purpose of this Record is to assemble the data from an area, such that it can be utilised for additional analysis, and the data reported here is similar in format to those data assembled from Northeast and Western Australia. Hence, together these records provide an important data set to compare and contrast geochemical inventories and processes from different sectors of the outer shelf and lower slopes of Australia.

To assist with a general overview of the geochemical properties of these sediments, a number of plots have been produced. These plots include down-core profiles of the pore water metabolites and 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 study of continental margin sediments. These Atlantic down-core trends in the pore water profiles can be used as a guide for interpreting the down-core profiles of pore water data from Southern Australia.

To provide a preliminary perspective on controls on the chemical composition of sediments from this area (and to easily compare the chemical composition of these sediments with others) a variety of cross-plots have been assembled. 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. As a prelude to detailed palaeochemcial studies of the southern margin, several elements that may be indicative of biogenic and terrigenous sedimentation have been normalised to aluminium abundances, and these were plotted with depth (time) in the sediments. In addition, select elements, which are also potentially indicative of biogenic and terrigenous sedimentation and proxy indicators of depositional environment, have been plotted as a function of water depth to provide a spatial perspective on sedimentation processes on this part of the southern margin. These data will provide a direct comparison to those collected from BMR Survey 102 to the western southern margin of Australia (Feary and others, 1993)

The radiochemical properties of these sediments have been assembled to investigate uranium series geochemistry as proxy indicators of sedimentation processes and to determine sedimentation rates. The radiochemical analyses were conducted at Flinders University of South Australia and at this time an Honours student is working on these data.

This Record complements a large suite of sedimentological and other data assembled as part of this survey (Exon and Lee, 1987; Exon and others, 1989; and Exon and others, 1992).

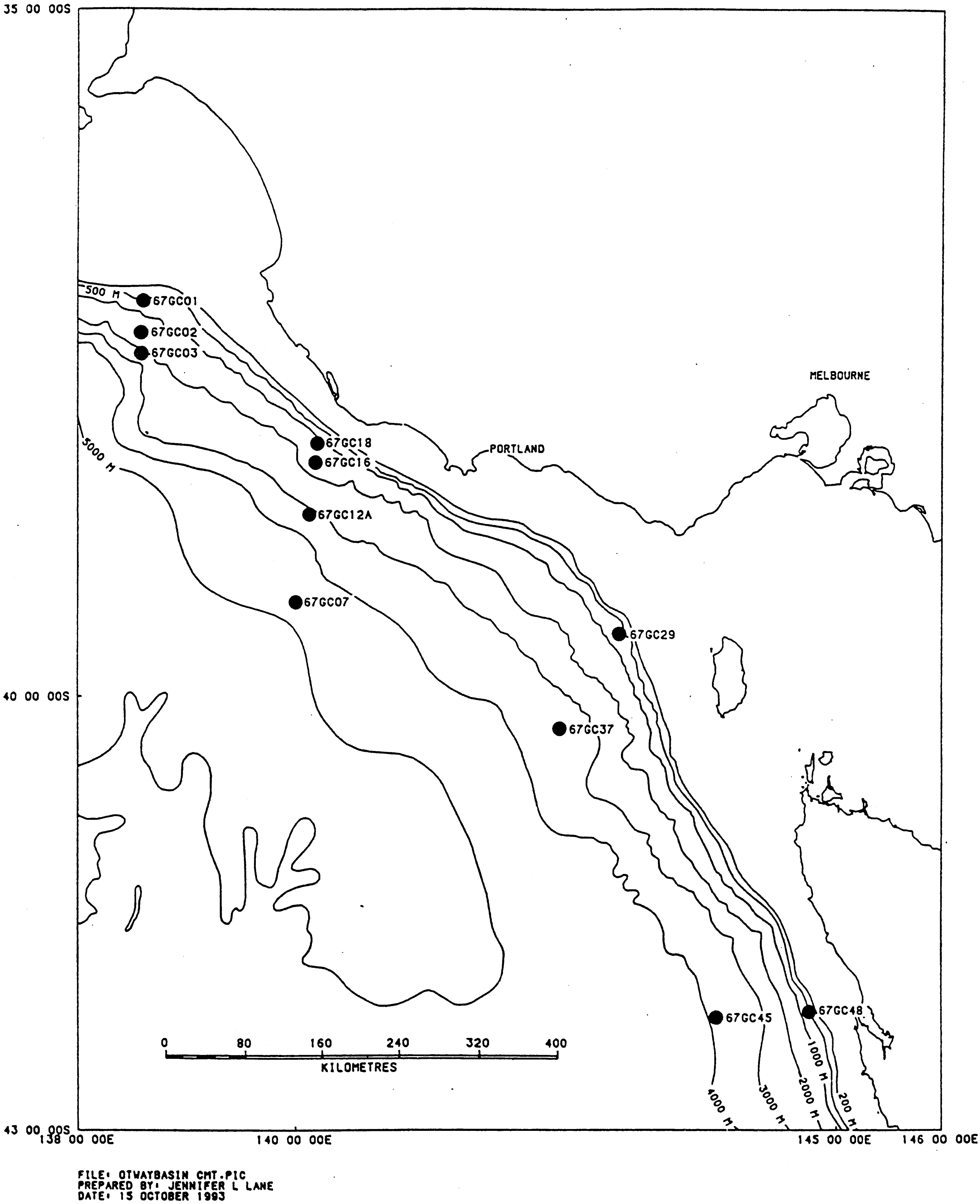


Figure 1. Location of cores collected from the southern Australian Continental Margin

Table 1 Location of cores collected from the continental margin offshore west Tasmania, south west Victoria and South Australia

Survey	Core	Longitude (deg,min)	Latitude (deg,min)	Water Depth (m)	Recovery (cm)	Location
67	GC01	138 35.8	37 10.2	425	220	Northwest part of western Otway Basin West of Beachport
67	GC02	138 34.7	37 23.9	1270	54	Northwest part of western Otway Basin West of Beachport
67	GC03	138 35.0	37 33.0	1476	310	Northwest part of western Otway Basin West of Beachport
67	GC07	139 59.2	39 20.1	4120	287	Western Otway Basin
67	GC12	140 07.1	38 42.6	3150	10	Western Otway Basin
67	GC12A	140 07.1	38 42.6	3133	306	Western Otway Basin
67	GC16	140 10.9	30 20.0	1650	196	Western Otway Basin
67	GC18	140 11.5	38 11.6	1035	233	Western Otway Basin
67	GC29	142 59.0	39 34.0	240	364	Eastern Otway Basin
67	GC37	142 25.2	40 14.1	3090	275	Eastern Otway Basin
67	GC45	143 52.2	42 13.9	3715	360	West Tasmanian Region
67	GC48	144 44.3	42 10.8	377	190	West Tasmanian region

Table 2 Summary of analyses performed on the cores collected offshore southern Australian

Survey	Core	Total samples Analysed	Pore Water	Solid Phase Majors	Solid Phase Trace	Radiochemistry	CaCO3 (%)	Organic carbon (%)	Opalline Silica (%)
67	GC01	13	13	12	12	-	-	-	-
67	GC02	7	7	-	-	-	-	-	-
67	GC03	14	14	-	-	-	-	-	-
67	GC07	16	15	16	16	-	-	-	-
67	GC12A	15	15	16	16	15	15	15	12
67	GC16	14	14	14	14	-	-	-	-
67	GC18	7	7	6	6	-	-	-	-
67	GC29	11	11	11	11	-	-	-	-
67	GC37	11	11	-	-	11*	-	-	11
67	GC45	16	15	16	16	15	15	15	14
67	GC48	9	9	9	9	-	-	-	-

* Radiochemistry data for core 67GC037 to be added once the analyses have been completed by The Flinders University of South Australia

METHODS

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, 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 conducted only on select cores.

Major and Minor Element Compositions

Major and trace element analyses were measured by x-ray fluorescence at AGSO with methods modified from those presented in Cruikshank and Pyke (1993).

Radiochemistry

Selected sediments from the Otway Basin were analysed for their radiochemical properties in order to determine sediment accumulation rates. The radiochemical analyses, percent calcium carbonate, organic carbon and percent opaline silica were carried out by Herb Veeh at Flinders University South Australia. The uranium-series data were obtained by alpha spectrometry at Flinders University as described by Veeh and others (in preparation). Briefly, the samples were dissolved and a calibrated $^{228}Th/^{232}U$ tracer was added. Uranium and thorium isotopes were then separated by a series of ion exchange chromatography in HCl and HNO_3 media. Uranium was further purified by solvent extraction (MIBK) and removal of Fe by di-isopropyl ether extraction. The uranium and thorium isotopes were electroplated onto stainless steel disks from a NH_4Cl solution, and isotope ratios between sample and tracer determined by alpha counting on a Canberra-Packard Quad Alpha multiple input system linked to a PC with dedicated software. The one-sigma counting statistics yield precisions of ±3% and ±7% for the uranium and thorium concentrations, respectively.

$CaCO_3$ and Organic Carbon

Calcium carbonate and organic carbon were determined by sequential colorimetric titration (Engleman and others, 1985) of the CO_2 released upon acidification of the finely ground sediments with phosphoric acid (to determine the $CaCO_3$ component), and upon oxidation with dichromate/sulphuric acid (to determine the organic carbon component), using an adaptation of the method described in Weliky and others (1983).

Opaline Silica

Biogenic opal was determined by selective extraction of silica into a Na_2CO_3 solution under controlled conditions as described by Mortlock and Froelich (1989), and measuring the dissolved silica concentration in the Na_2CO_3 solution by molybdate-blue spectrophotometry (Stickland and Parson, 1968).

RESULTS AND DISCUSSION

Pore Water Geochemistry

The assemblage of pore water data for eight cores from the Otway Basin are summarised in Tables 3-13. The down-core profiles for carbon dioxide, ammonia, silicate, manganese (pore water) and manganese (solid phase) are presented in Figures 3-13. The plots have not generally been interpreted in detail, but a systematic approach to assist in the interpretation of these plots is shown in the equations below, with the corresponding predicted down-core metabolite profiles below (Froelich and others, 1979) schematically represented in Figure 2.

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

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

Inspection of the data (Tables 3-13) and Figures 3-13 indicates the following features of the pore water data. In that suite of cores from the western survey area off South Australia, ammonia rises rapidly in the pore waters to concentrations in excess of typical bottom water concentrations, to >50 µmole/l in near-surface sediments. This is indicative of anoxic sediments and the onset of sulphate reduction. Pore water manganese is low and the inventory of manganese in sediments is about 50 ppm. With increasing water depth ammonia is low in surface sediments (indicating sub-oxic to oxic near surface sediments) but increases with increasing sediment depth. These results suggest a lower burial rate of organic carbon into these sediments as compared to those in shallower water (Figs. 3-5).

In those cores collected directly to the west of Portland (67GC07 through 67GC12; Figs. 6 through 8) a similar trend is observed in the pore water ammonia profiles i.e., interfacial ammonia concentrations are highest in shallow-water cores and lowest in deep-water cores. Pore water ammonia and total CO_2 increase with increasing depth in the sediment and this is indicative of increasing sulphate reduction. There is evidence of remobilisation of manganese through the pore fluids and a core-top enrichment of solid phase manganese in the deeper cores. In some cores pore water silicate rises above bottom-water concentrations with increasing depth in the sediment to a maximum concentration and subsequently decreases. These data suggest uptake on sedimentary phases and are perhaps indicative of glauconite formation. Similar results were found on the east Australian continental margin in an area where marine phosphorites are presently forming (O'Brien and Heggie, 1990)

Similar general comments apply to those data collected near King Island (67GC029, 037; Figs 10 and 11) and those off West Tasmania (67GC045, 048; Figs 12 and 13) and there is a significant enrichment in the core-top manganese inventory in the deep-water sediments off West Tasmania.

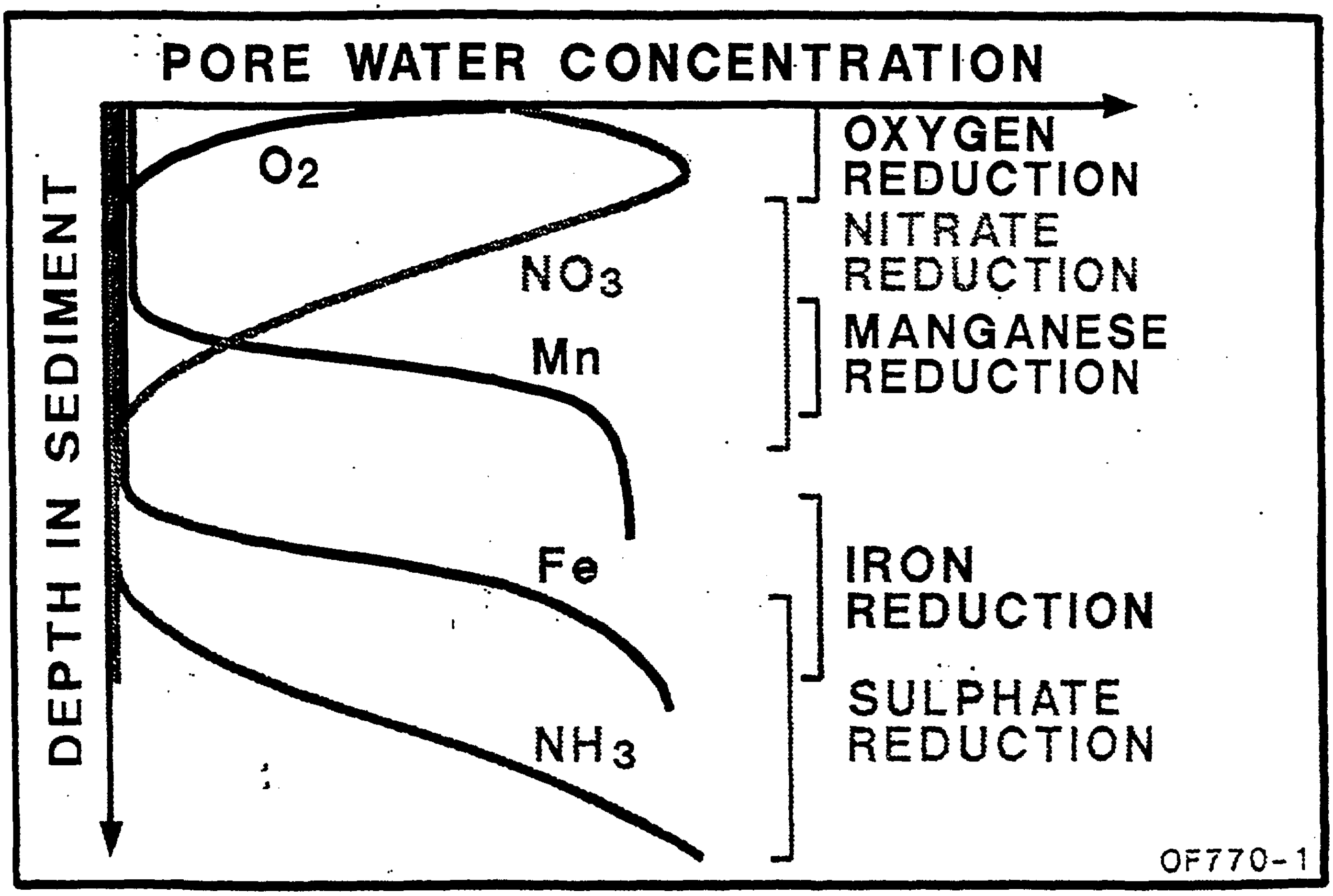


Figure 2 Schematic representation of trends in pore water profiles (After Froelich, 1979)

Table 3 Pore water results for core 67GC01

Survey	Core	Depth (cm)	NH3 (umol/l)	Mn (umol/l)
67	GC01	BW	0	0.1
	GC01	0-3	40.3	0.7
	GC01	10-13	61	
	GC01	20-23	58.6	0.7
	GC01	30-33	59.6	0.8
	GC01	70-73	48.7	1.1
	GC01	90-93	55.3	0.8
	GC01	110-113	51.9	0.5
	GC01	130-133	55.1	0.5
	GC01	150-153	65.6	0.5
	GC01	170-173	63.5	0.4
	GC01	190-193	69.8	0.4
	GC01	210-213	70.4	0.3

Table 4 Pore water results for core 67GC02

Survey	Core	Depth (cm)	NH3 (umol/l)	Mn (umol/l)
67	GC02	0-3	2.6	0.3
	GC02	6-9	11.5	1.8
	GC02	12-15	25.8	2.7
	GC02	18-21	35.6	4.6
	GC02	28-31	39.6	5
	GC02	34-37	58.5	3.8
	GC02	46-49	72.7	2.9

Table 5 Pore water results for core 67GC03

Survey	Core	Depth (cm)	NH3 (umol/l)	Mn (umol/l)
67	GC03	0-3	2	0.4
	GC03	9-12	16.2	2.2
	GC03	20-23	29.7	3
	GC03	30-33	41.6	4.7
	GC03	40-43	51.9	6.2
	GC03	50-53	54.7	4.5
	GC03	60-63	61.5	6.5
	GC03	70-73	77.2	5.3
	GC03	90-93	82.3	6.7
	GC03	110-113	87.7	1.5
	GC03	130-133	119.4	2.9
	GC03	150-153	122.4	3.2
	GC03	170-173	142.8	2.7
	GC03	190-193	132.6	2.7

Table 6 Pore water results for core 67GC07

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC07	0-3	326	2.5	0.1	2.049
	GC07	6-9	301	2	0.3	
	GC07	12-15	303	2.2	0.3	2.159
	GC07	20-23	303	2.3	0.5	2.153
	GC07	30-33	287	3.2	1.7	2.258
	GC07	40-43	315	2.6	1.9	
	GC07	50-53	271	1.8	3	2.253
	GC07	60-63	229	2.6	3.9	2.003
	GC07	80-83	202	3.8	8.8	2.173
	GC07	100-103		5.5	9.1	
	GC07	120-123		6.5	10.5	
	GC07	140-143	163	8.6	13.6	2.459
	GC07	160-163	133	8.6		
	GC07	180-183		9.2	18.2	
	GC07	200-203	130	10.3	22.1	2.043

Table 7 Pore water results for core 67GC12A

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC12A	0-3	271	3.1	0.2	2.322
	GC12A	7-11	339	1.5	<0.1	2.243
	GC12A	15-19	341	3.7	8.6	1.985
	GC12A	30-33	365	9.7	20.7	2.044
	GC12A	40-43	309	13.4	22.2	2.139
	GC12A	50-53		16.6	19.9	
	GC12A	60-63	292	19.7	17.6	2.219
	GC12A	70-73	276	23.5	17.3	2.216
	GC12A	80-83	228	26.4		2.14
	GC12A	90-93	271	27.4	70.6	2.255
	GC12A	110-113	243	30.4	19.1	2.449
	GC12A	130-133	236	30.4	21.2	2.59
	GC12A	150-153	258	18.4	21.6	2.137
	GC12A	170-173	221	44.5	19.9	
	GC12A	191.50	211			1.449

Table 8 Pore water results for core 67GC16

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC16	0-3	274	8	4.4	2.006
	GC16	6-9	296	19.5	8.5	2.075
	GC16	12-15	407	20.9	4.3	2.133
	GC16	20-23		29	5.4	2.332
	GC16	30-33	433	36.9	3.5	2.254
	GC16	40-43	405	46.6	4.9	2.5
	GC16	50-53	325			2.202
	GC16	60-63	469	58.1	5	
	GC16	70-73	404	68.6	6.6	2.808
	GC16	90-93	354	80.6	8.7	3.1
	GC16	110-113	296	98.4	8.6	3.486
	GC16	130-133	297	98.9	5.1	3.908
	GC16	150-153	282	107.6		
	GC16	166-169	266	157	4.8	4.271

Table 9 Pore water results for core 67GC18

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC18	0-3	313	62.4	10.7	2.483
	GC18	10-13	513	101.2	1.3	2.983
	GC18	30-33	169			2.173
	GC18	40-43	746	257.6	1.3	5.629
	GC18	70-73	877	350.8	2	6.507
	GC18	130-133	846	538.8	1.9	9.043
	GC18	160-163	1040	605.6	3	10.942

Table 10 Pore water results for core 67GC29

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC29	0-3		22.7	1.1	
	GC29	10-13	190	37.1	5.8	2.244
	GC29	31-33	183	44.1	4.2	2.445
	GC29	50-53	174	53.1	1.4	2.427
	GC29	70-73	190	58	0.6	2.529
	GC29	90-93	229	65.9	0.7	2.661
	GC29	110-113	200	65.6	0.4	2.451
	GC29	130-133	208	80.6	0.3	2.533
	GC29	150-153	181	82.4	0.4	2.458
	GC29	170-173	198	97.3	0.3	2.61
	GC29	190-193	238	94	0.3	2.669

Table 11 Pore water results for core 67GC37

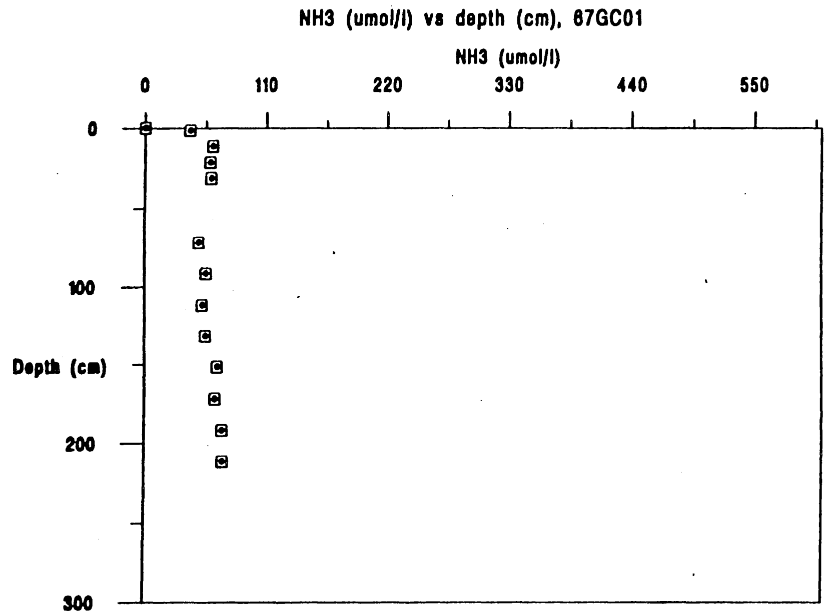
Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC37	0-3	197	2.2	0.1	1.928
		10-13	228	2.9	0.2	2.129
		30-33	246	16.4	7.2	2.213
		50-53	234	36.7	7.7	2.432
		70-73	250	48.4	7.3	2.432
		90-93	244	56.9	7.4	2.628
		110-113	264	76.1	8.4	2.763
		130-133	282	84.1	7.9	2.942
		150-153	292	92.5	8.9	2.623
		170-173	275	93	9.5	3.05
		190-193		97.5	10.8	

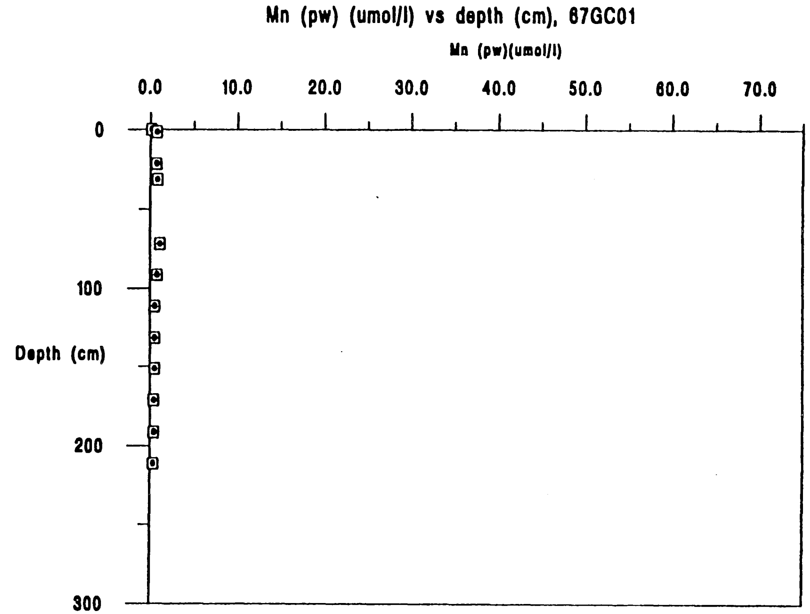
Table 12 Pore water results for core 67GC45

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC45	0-3	219	0.8	0.2	1.993
	GC45	6-9	253	1.4	0.3	2.209
	GC45	14-17	251	<0.5	1.9	2.237
	GC45	20-23	244	1.5	3.9	2.167
	GC45	30-33	226	6.2	5.1	1.685
	GC45	40-43	263	7.9	6.6	1.964
	GC45	50-53	278	14.4	7.6	2.162
	GC45	60-63	251	17.5	7.9	2.034
	GC45	70-73	258	18	10	2.197
	GC45	90-93	268	26.4	11.3	2.315
	GC45	110-113	270	35.2	11.5	2.471
	GC45	130-133	254	33.2	12.7	2.517
	GC45	150-153	251	35.9	14.3	2.491
	GC45	170-173	240	42.6	15.3	1.988
	GC45	190-193	222			1.999

Table 13 Pore water results for core 67GC48

Survey	Core	Depth (cm)	SiO2 (umol/l)	NH3 (umol/l)	Mn (umol/l)	CO2 (mmol/l)
67	GC48	0-3	117	18.8	0.3	2.114
	GC48	10-13	119	25.2	7.3	2.082
	GC48	30-33	185	30.3	1.5	2.146
	GC48	50-53	168	33.6	1	2.051
	GC48	70-73	195	33.5	0.9	2.07
	GC48	100-103	153	25	0.8	1.654
	GC48	120-123	151	29.6	0.7	2.008
	GC48	140-143	157	27.2	0.6	2.067
	GC48	160-163	156	23.6	0.6	1.999





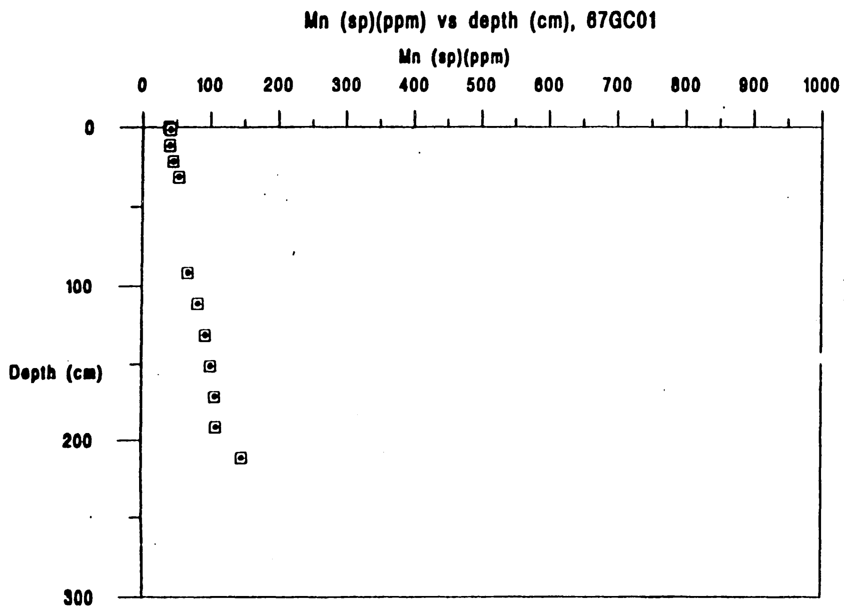
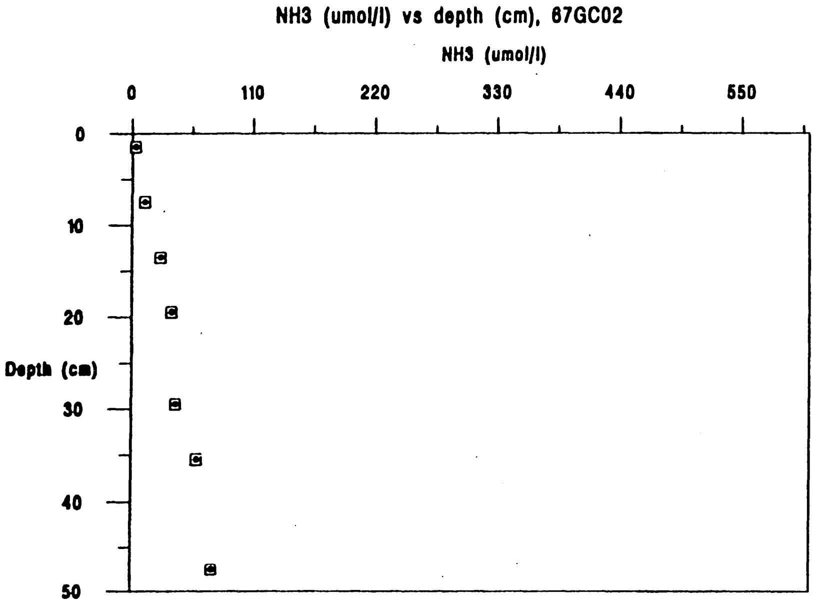


Figure 3. Down-core profiles of NH_3 (µmol/l), Mn-pore water (µmol/l) and Mn-solid phase (ppm) for core 67GC01



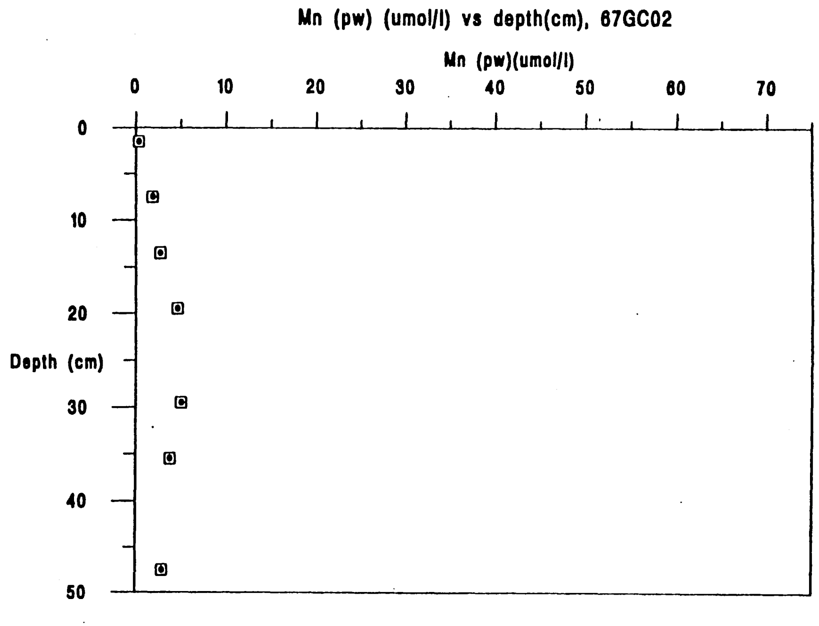
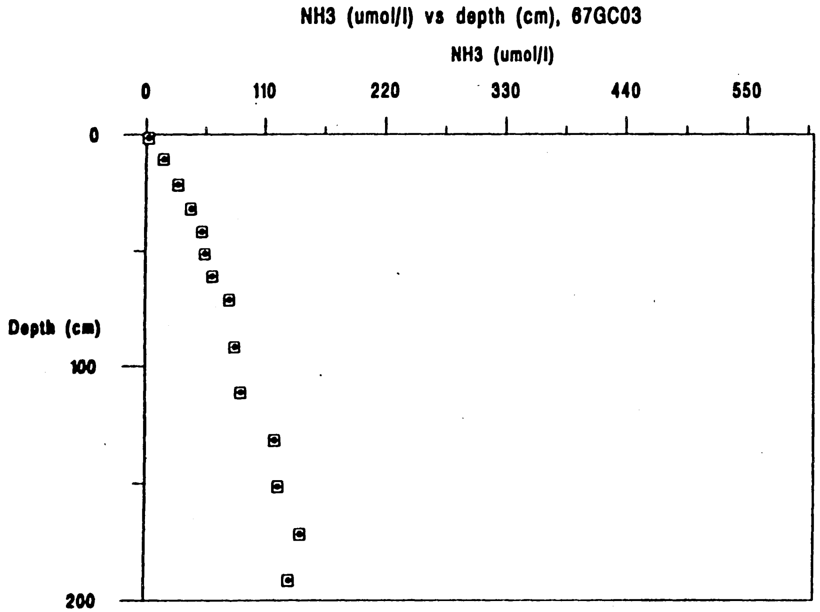


Figure 4. Down-core profiles of NH_3 (µmol/l) and Mn-pore water (µmol/l) for core 67GC02



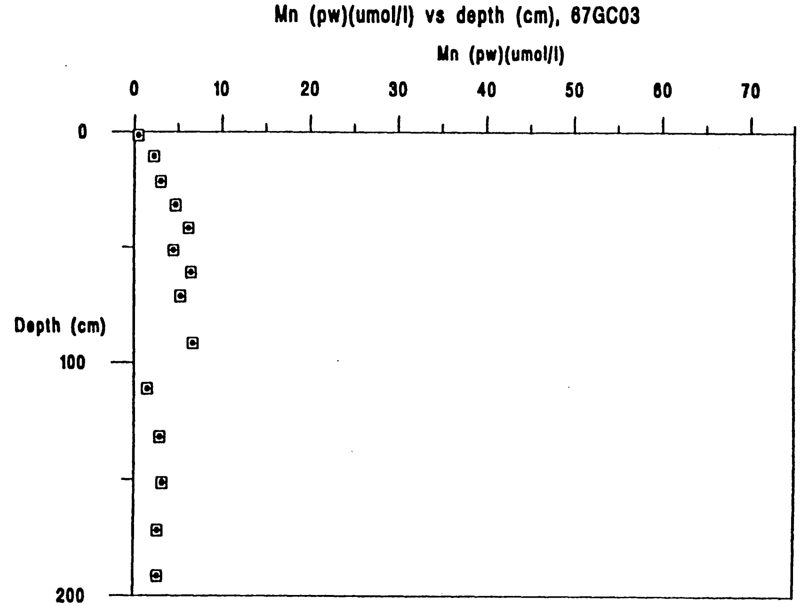


Figure 5. Down-core profiles of NH_3 (µmol/l) and Mn-pore water (µmol/l) for core 67GC03

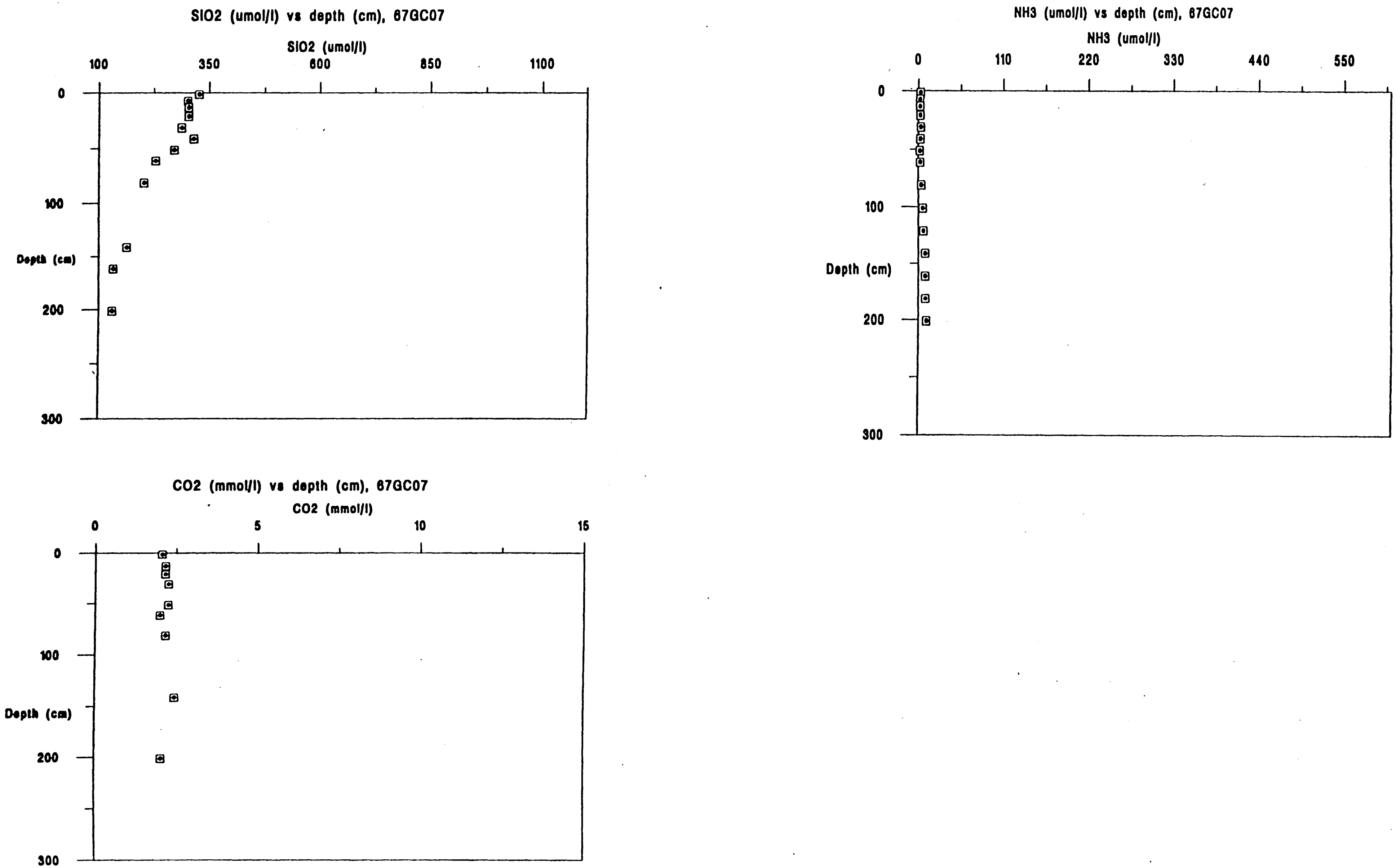


Figure 6a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC07

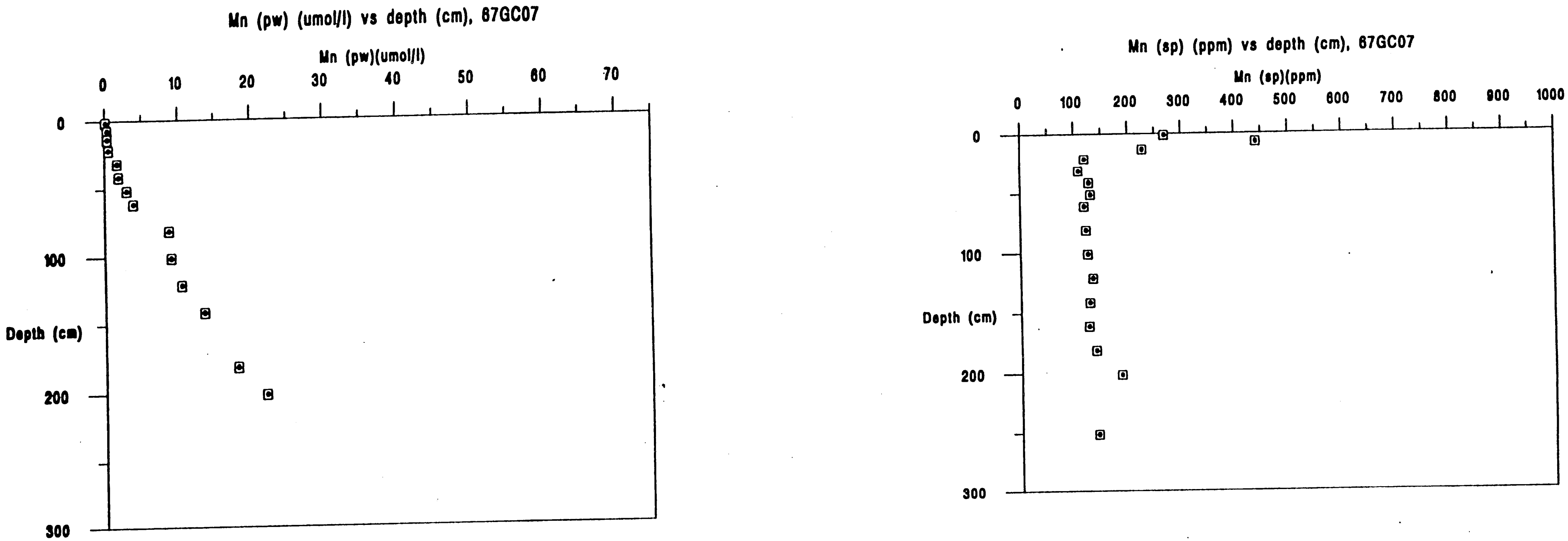
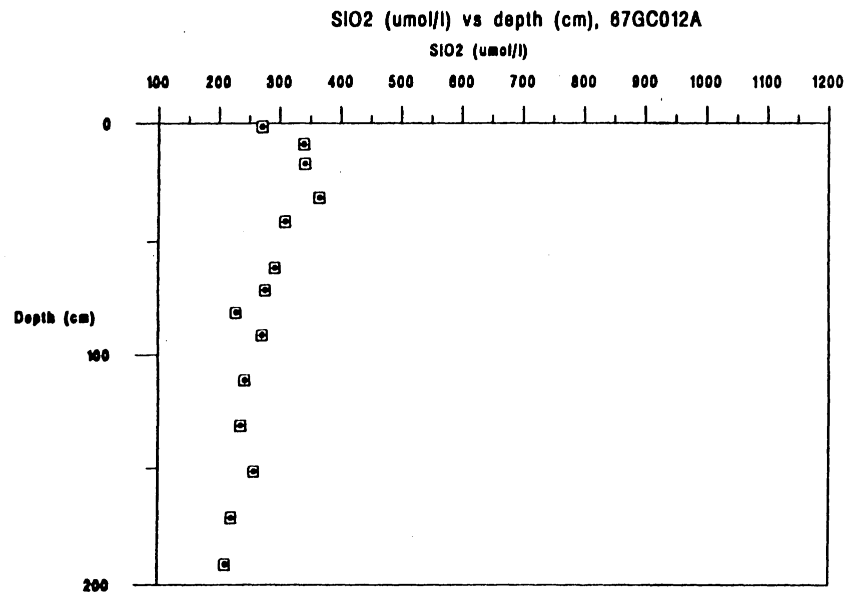
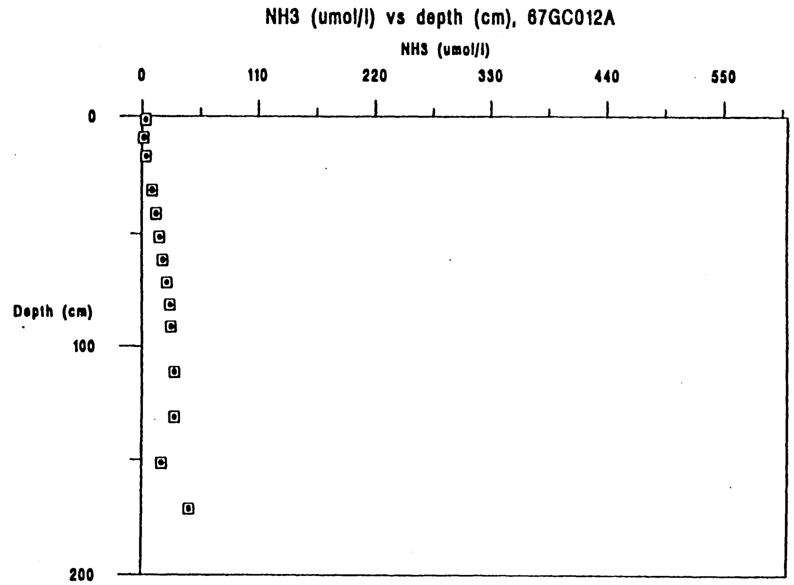


Figure 6b. Down-core profiles of Mn-pore water (µmol/l) and Mn-solid phase (ppm) for core 67GC07





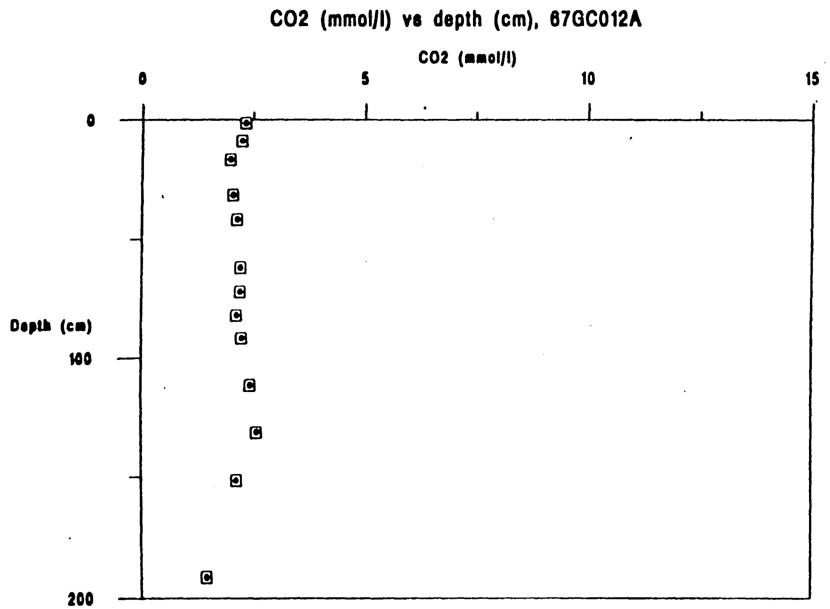
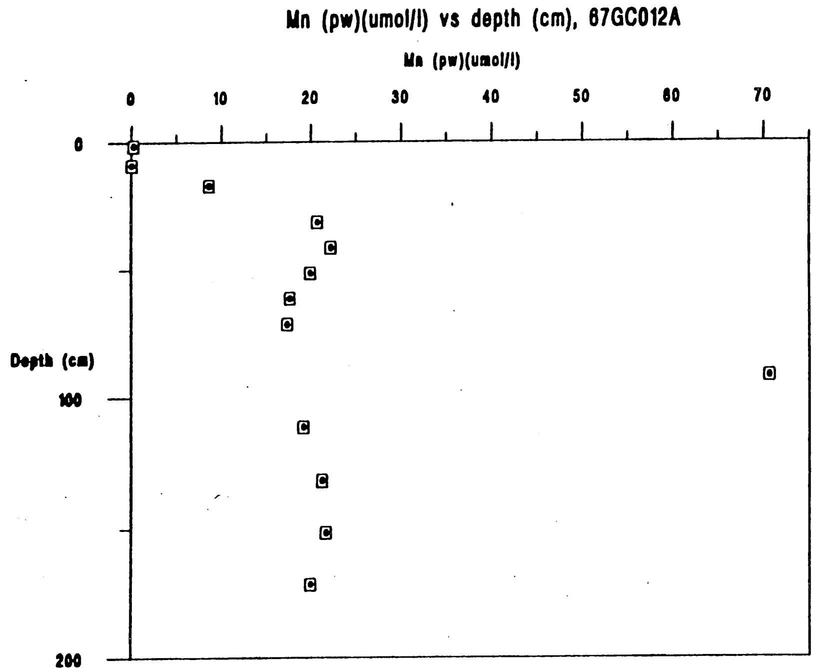


Figure 7a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC12A



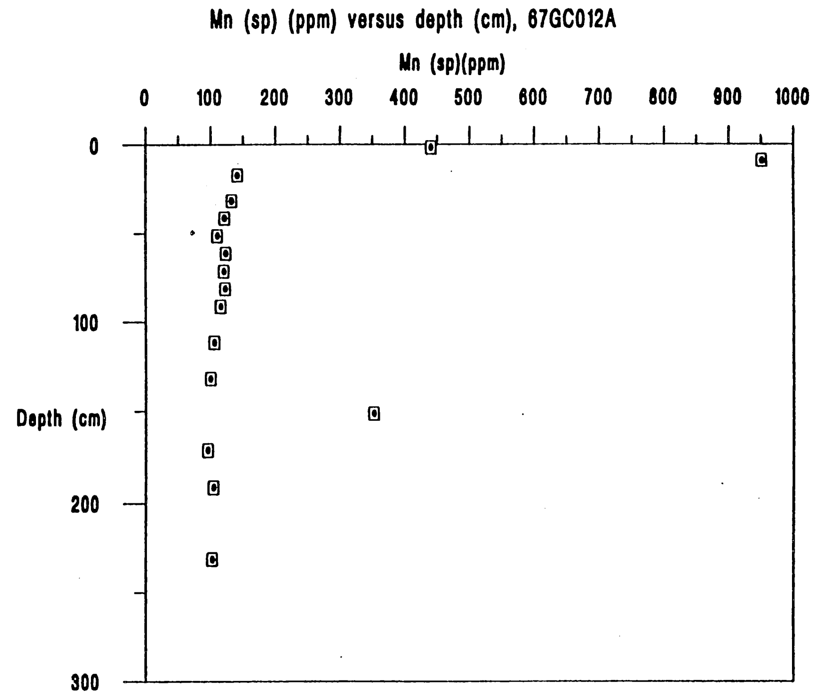
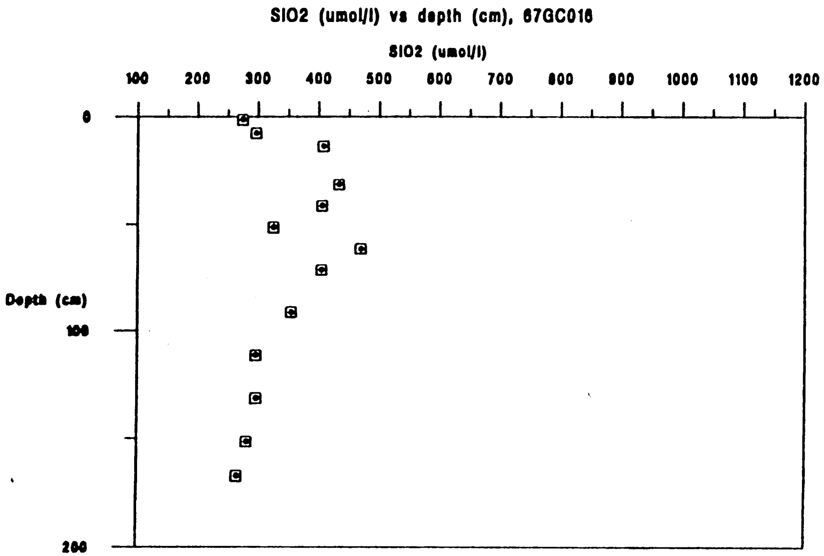
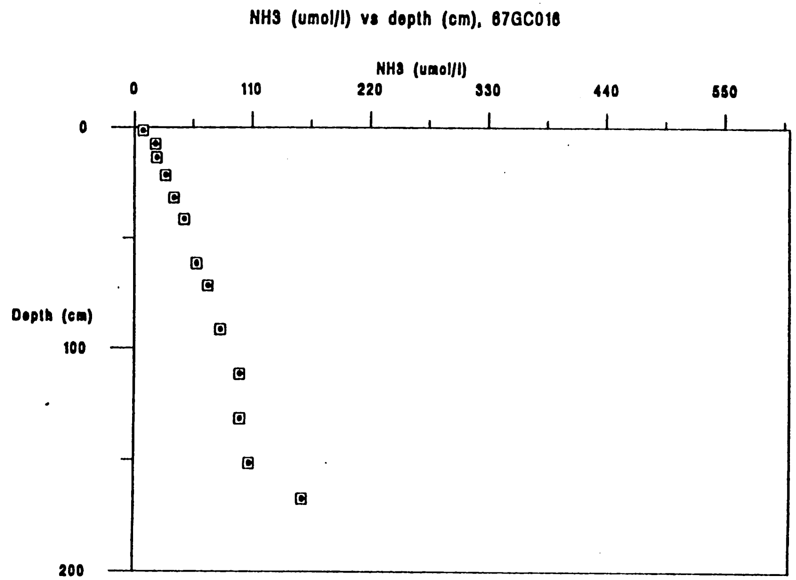


Figure 7b. Down-core profiles of Mn-pore water (μmol/l) and Mn-solid phase (ppm) for core 67GC12A





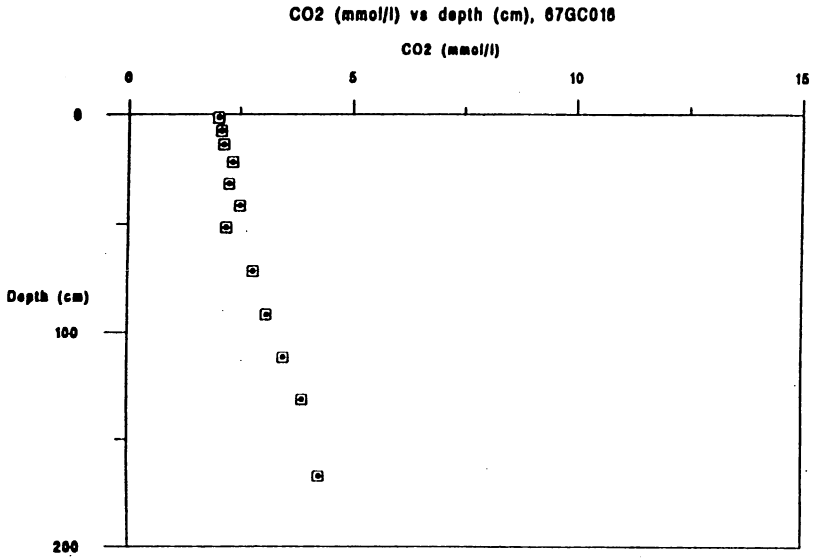


Figure 8a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC16

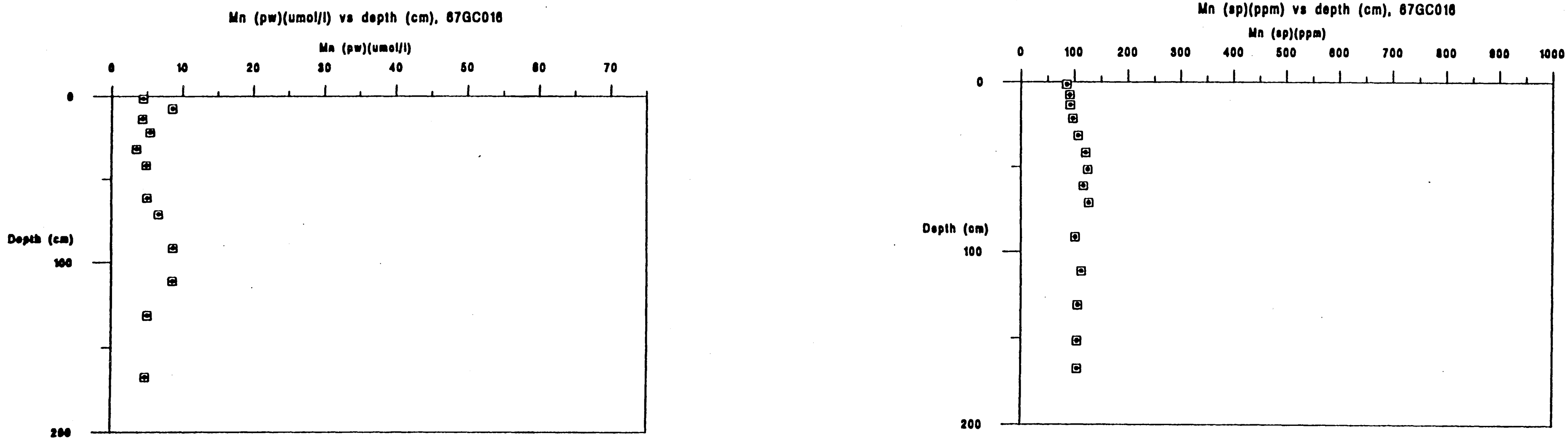
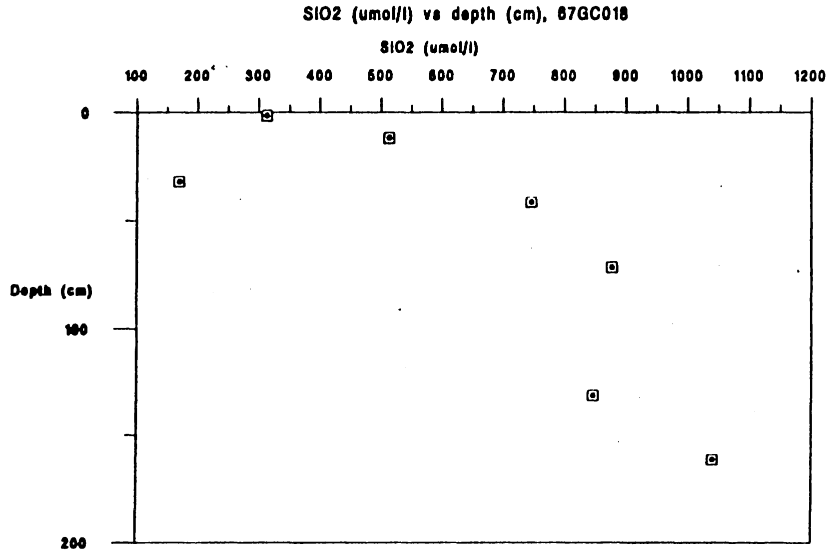
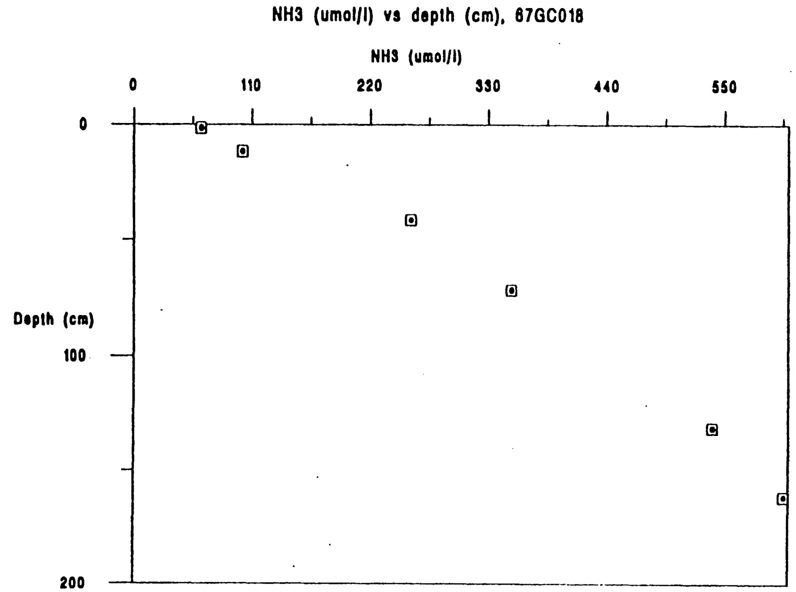


Figure 8b. Down-core profiles of Mn-pore water (µmol/l) and Mn-solid phase (ppm) for core 67GC16





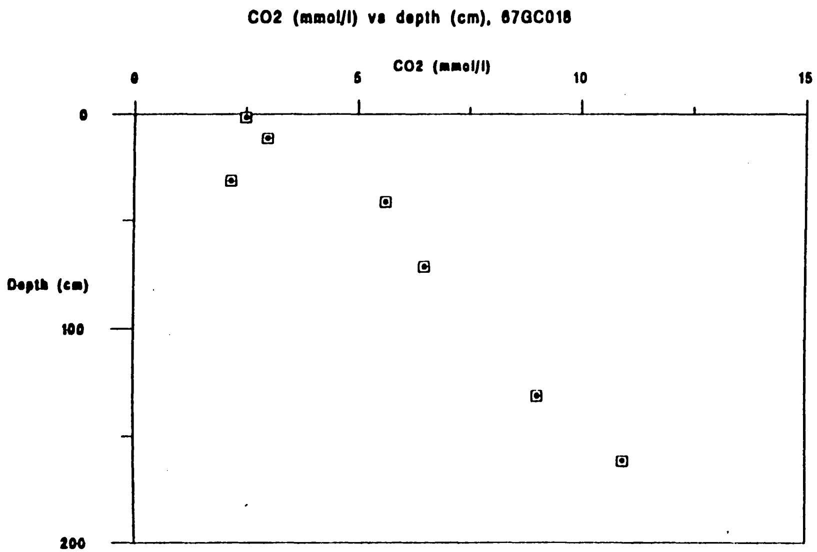
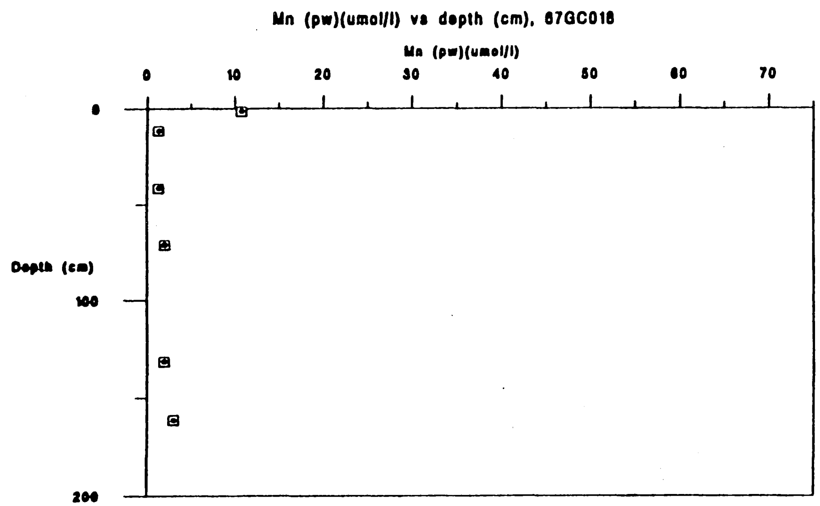


Figure 9a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC18



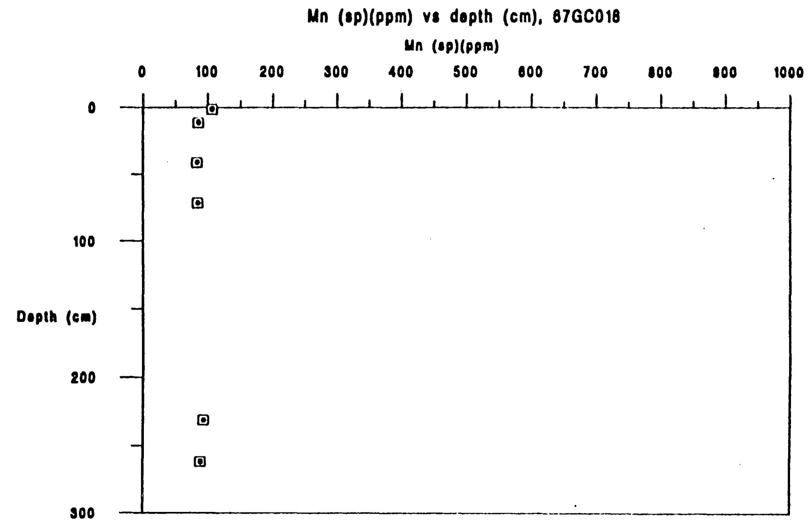
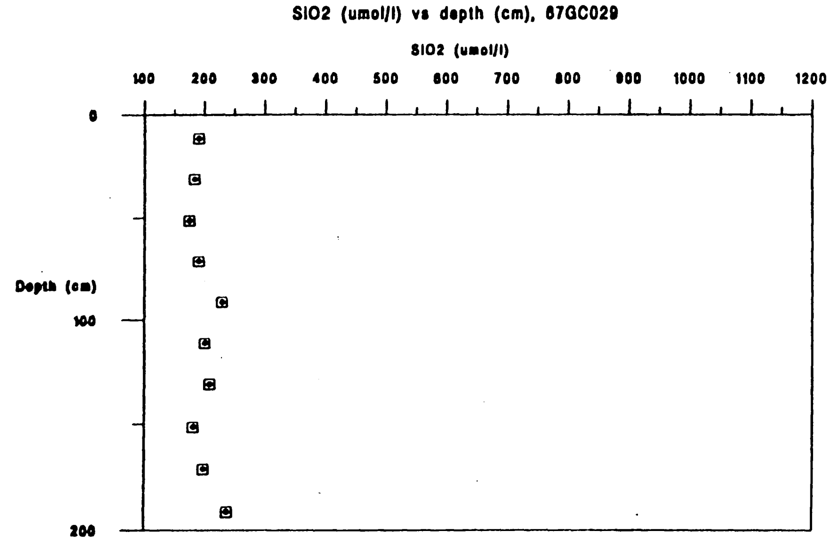
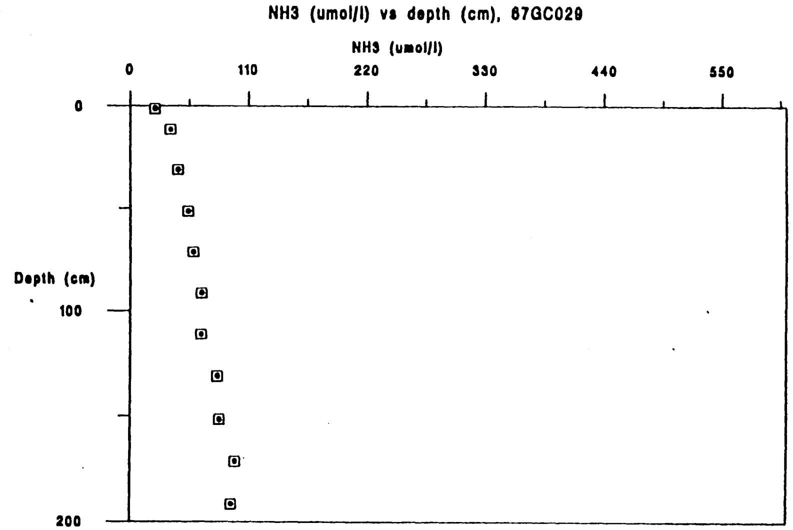


Figure 9b. Down-core profiles of Mn-pore water (μmol/l) and Mn-solid phase (ppm) for core 67GC18





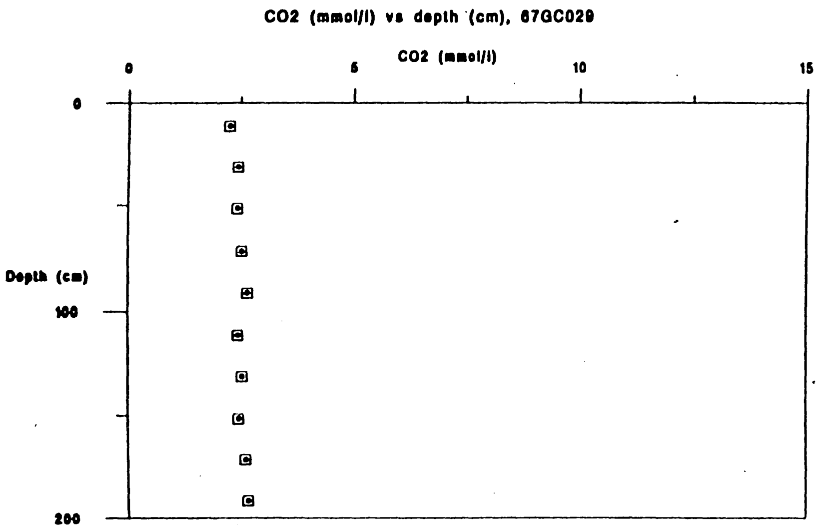
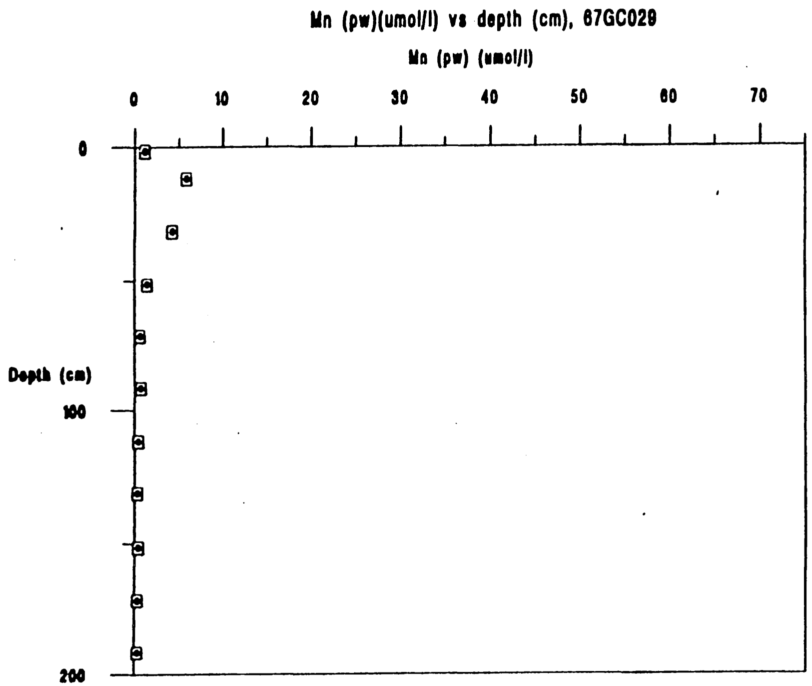


Figure 10a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC29



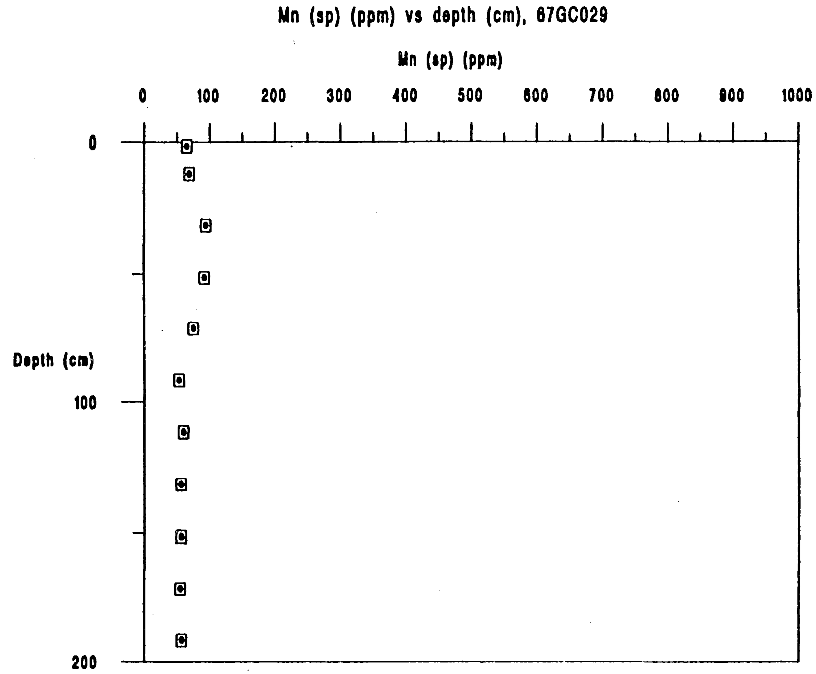


Figure 10b. Down-core profiles of Mn-pore water (µmol/l) and Mn-solid phase (ppm) for core 67GC29

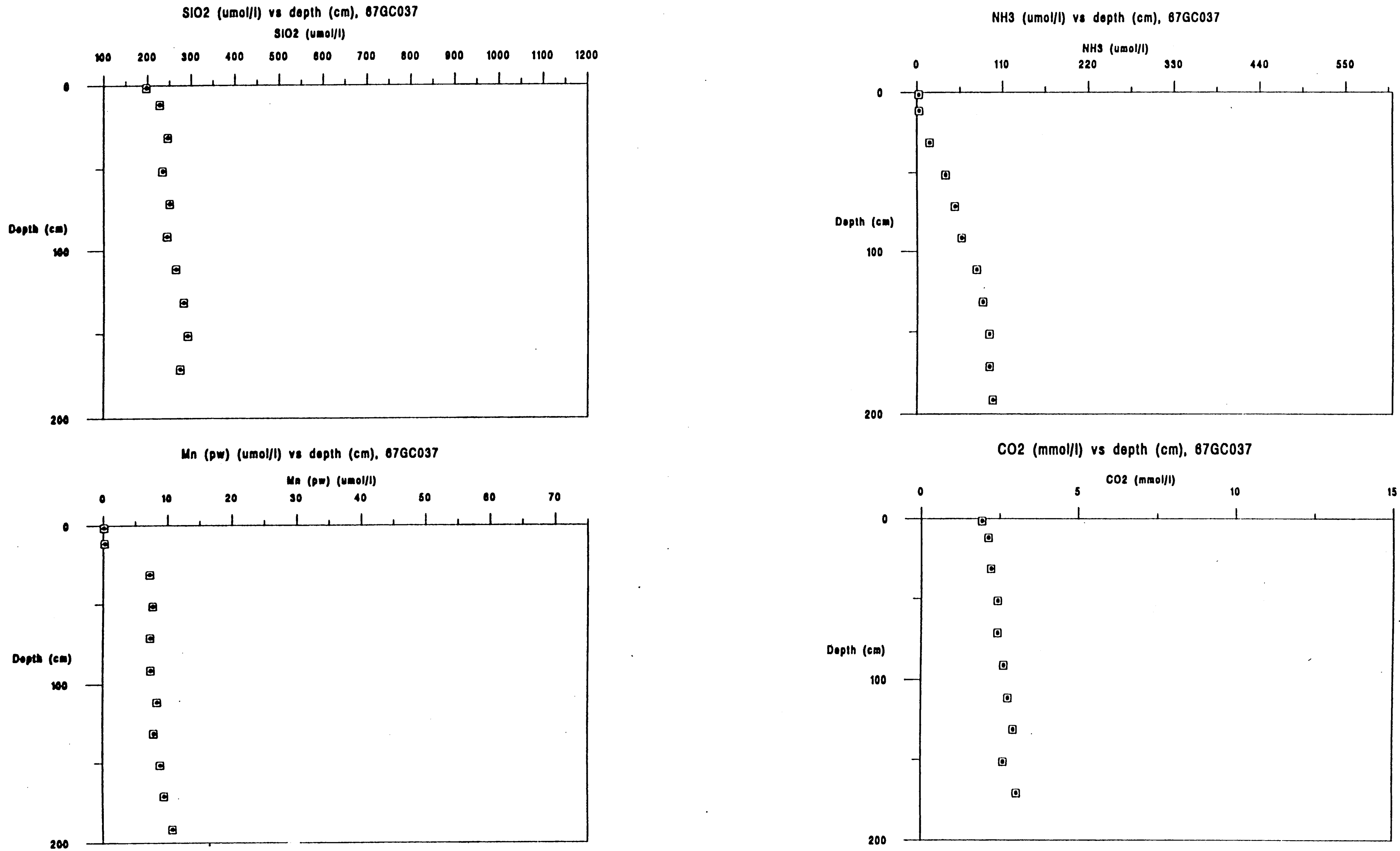
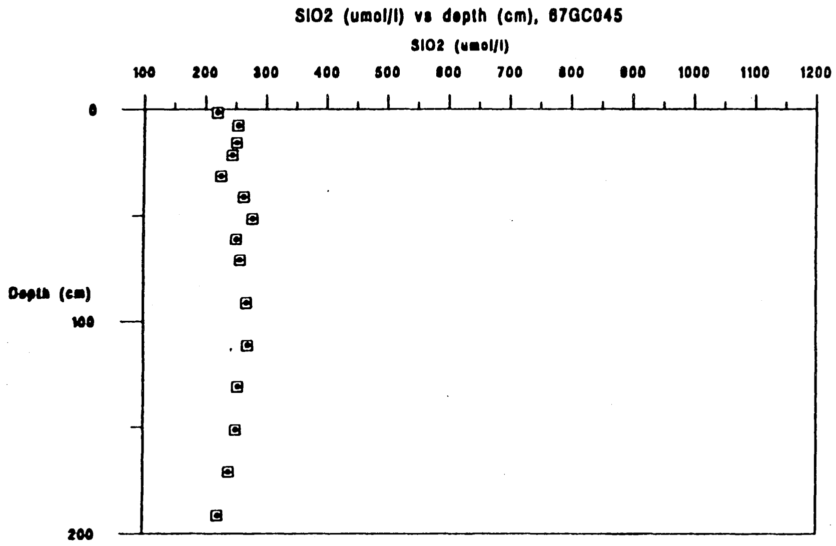
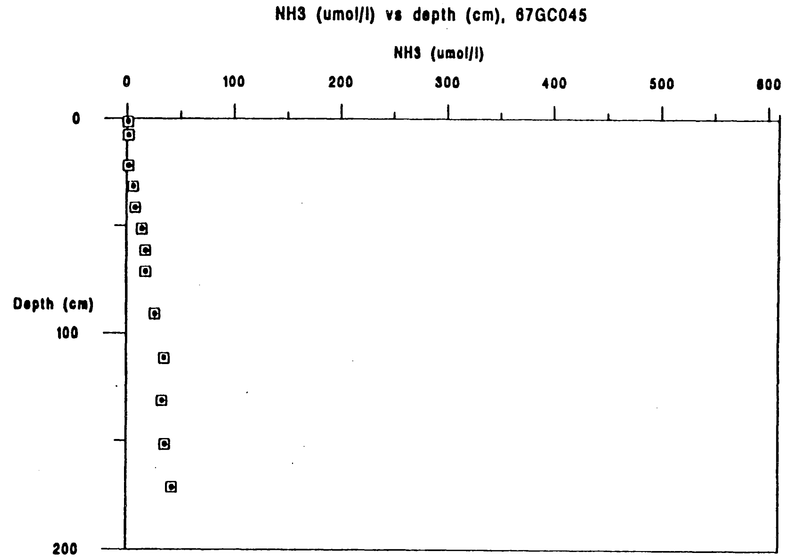


Figure 11. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l), Mn-pore water (µmol/l) and CO_2 (mmol/l) for core 67GC37





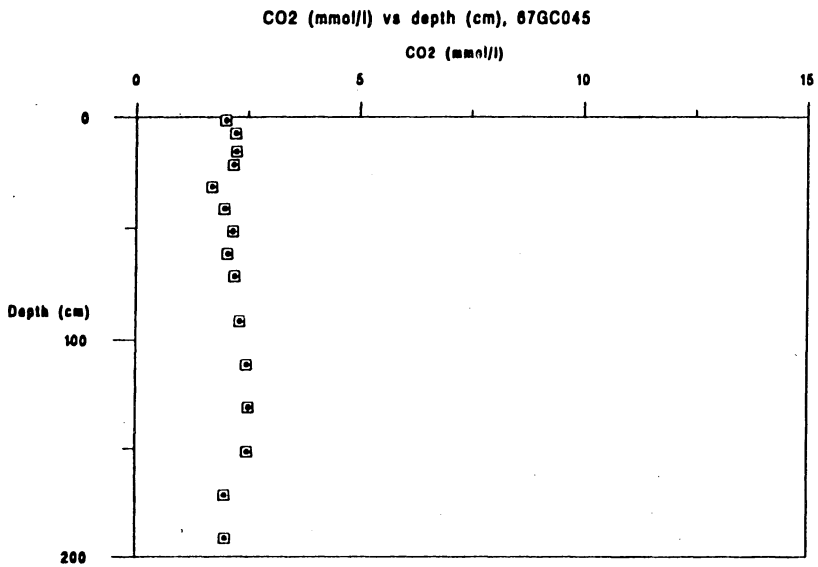
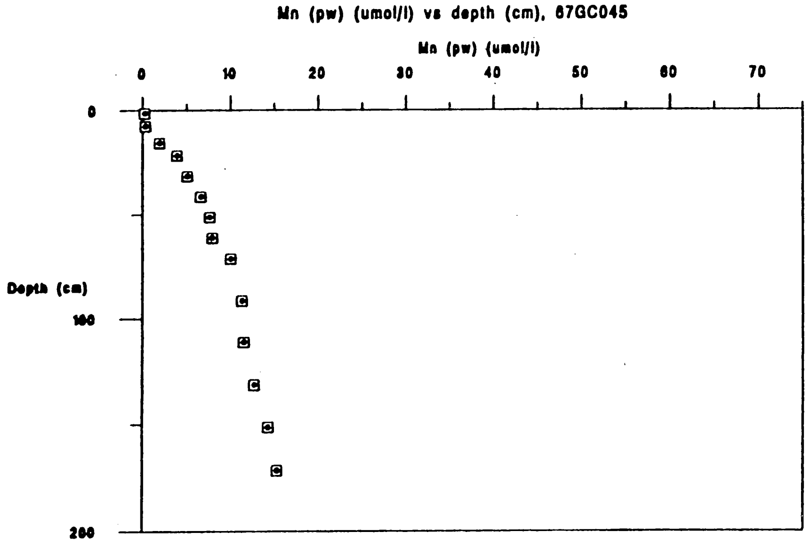


Figure 12a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC45



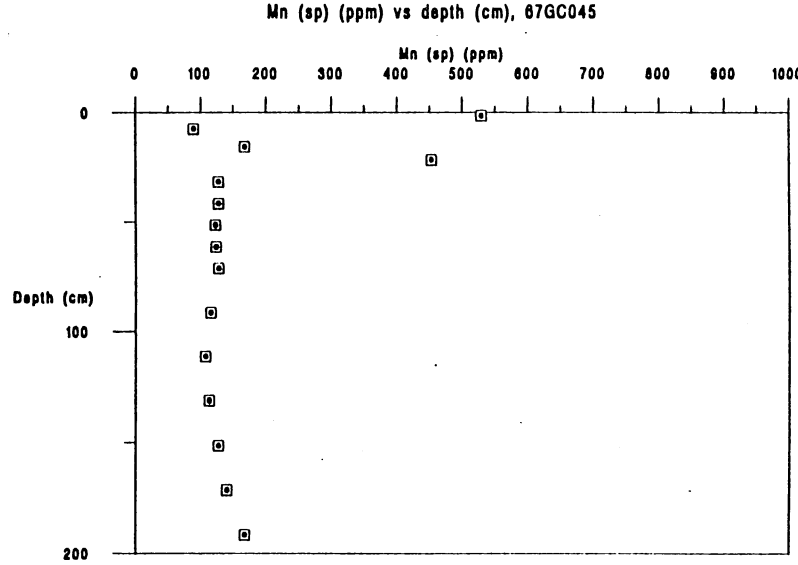
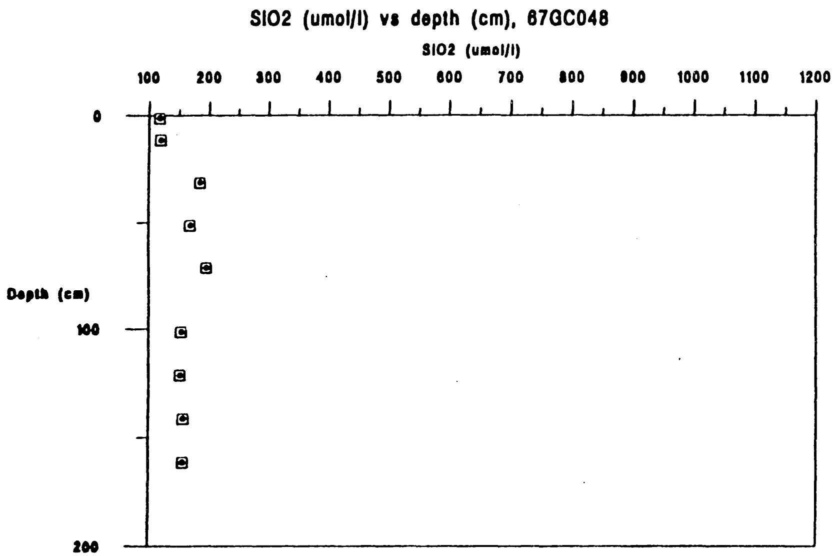
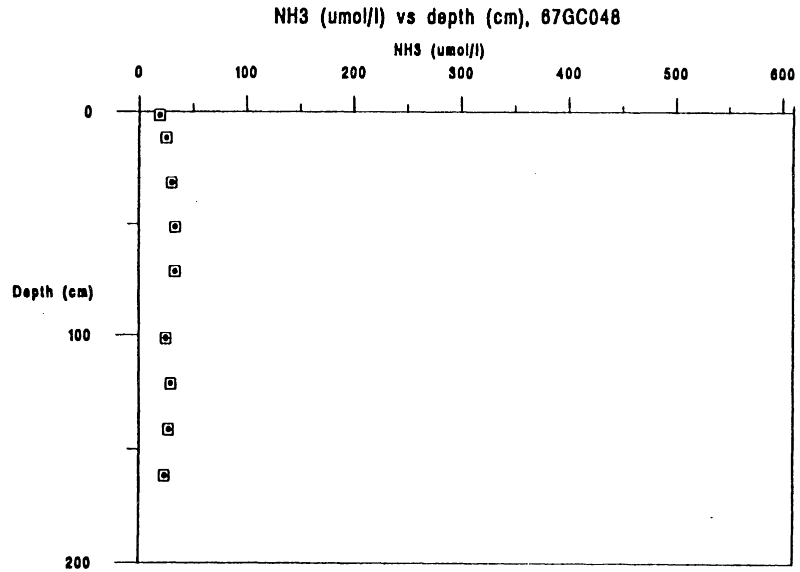


Figure 12b. Down-core profiles of Mn-pore water (μmol/l) and Mn-solid phase (ppm) for core 67GC45





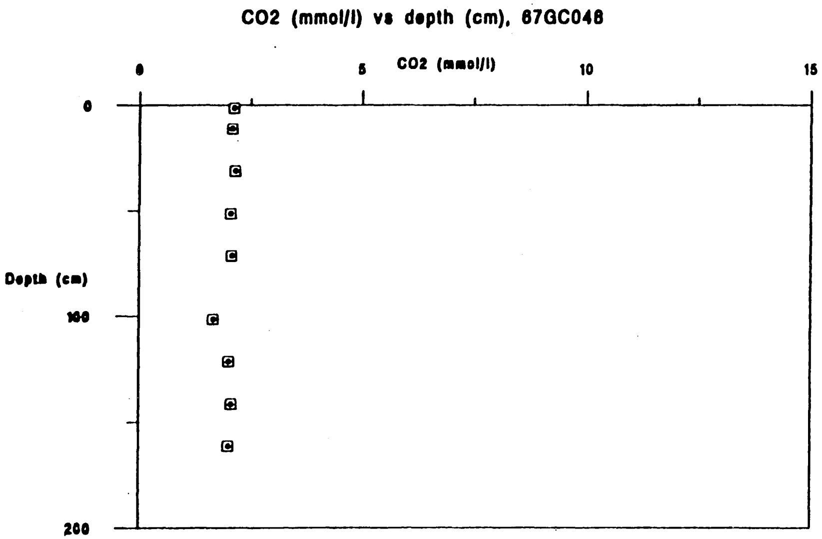


Figure 13a. Down-core profiles of SiO_2 (µmol/l), NH_3 (µmol/l) and CO_2 (mmol/l) for core 67GC48

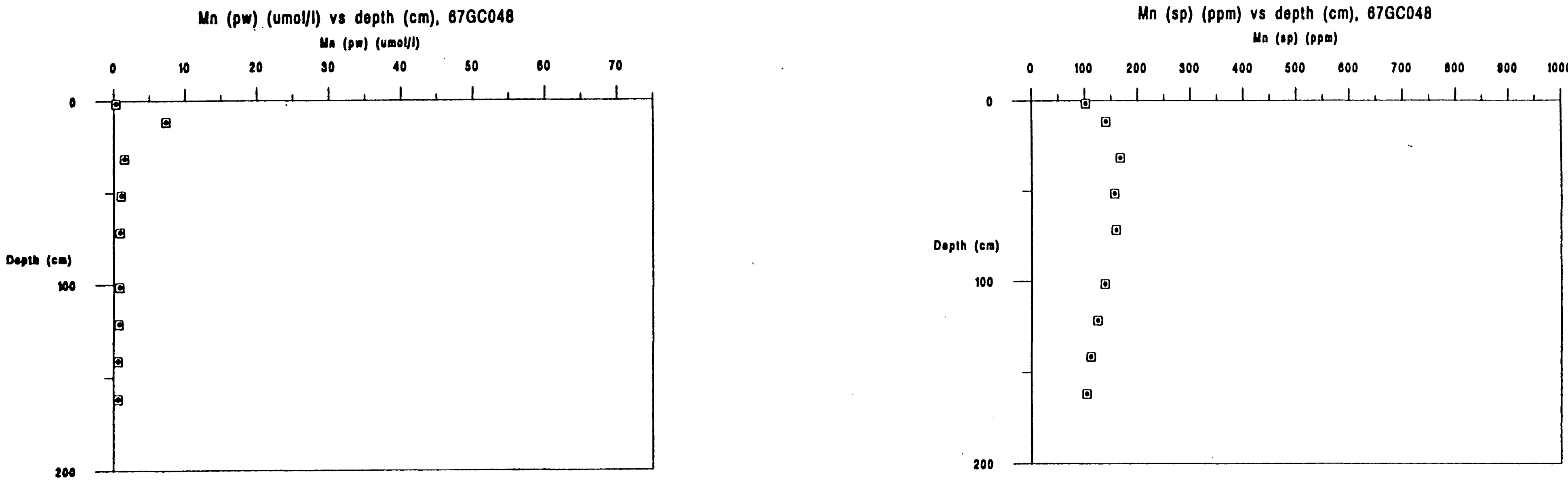


Figure 13b. Down-core profiles of Mn-pore water (μmol/l) and Mn-solid phase (ppm) for core 67GC48

Solid phase major and trace element abundances

The major and minor element analyses performed on eight cores from the Otway Basin are presented in Tables 15-22. The analytical methods used in determining the major and minor elemental compositions of sediments are discussed in Cruikshank and Pyke (1993).

A summary of the ranges of elemental concentrations are presented in Table 23. 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 surveyed in the Otway Basin during BMR Survey 67, and furthermore, with concentrations measured from other parts of the Australian margin. These plots include Al_2O_3 versus all elements (Appendix 1). Because iron oxyhydroxides (Fe_2O_3) and manganese oxyhydroxides (MnO_2) are major controls on trace element compositions in marine sediments, several plots show iron as Fe_2O_3 with select major and trace elements (Appendix 2) and plot manganese as MnO_2 versus other select major and trace elements (Appendix 3).

Several of the trace elements measured (cerium, cobalt, chromium, copper, nickel, neodymium, lead, rubidium, strontium, vanadium, zinc and zirconium) show a positive 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. In contrast, most elements when plotted with manganese indicate two trends in the core-plots which suggest a primary depositional control on these elements by manganese oxyhydroxides, but there are also trends which indicate high manganese and no significant increases in other elements. This trend is indicative of a significant remobilisation of manganese and fractionation from sedimentary particles.

To provide a preliminary investigation of oceanographic/geochemical processes operating on this margin, the abundance of several elements has been normalised to the aluminium abundance and plotted as a function of water depth. The element/aluminium ratios are summarised in Table 14. The plots are summarised in Figures 14 through 26. The elements chosen were those that exist in different oxidation states in sea water and sediments (manganese, chromium and vanadium), those that are scavenged or incorporated into biogenic matter as it settles through the water column, including those mentioned above and copper, barium, zinc, strontium and phosphorous and those that may be terrigenous indictors (titanium, silicon and rubidium). The plots of these data versus water depth appear to fall into three different types, and not according to the distinctions made above. Figures 14 through 18 indicate that vanadium, chromium, phosphorous, silicon and strontium show high element /aluminium ratios in the outer shelf/upper slope sediments (at depths<1000m) as compared to the outer-slope/abyssal plain sediments. The strontium, total silicon (some component of which is biogenic silica) and phosphorus suggest that high biogenic inputs to these sediments are preserved in the solid phase. Vanadium and chromium are also enriched, because in addition to deposition with biogenic debris their redox chemistry supports an additional flux of metal from oxic bottom-water to sub-oxic or anoxic sediments. These processes add a reduced component to the total metal inventory in these sediments.

In contrast to these elements, barium, copper and manganese show significant enrichments in lower-slope and abyssal plain sediments as compared to outer-shelf/upper slope sediments (Figs. 19 through 21). The reasons for these variations are also probably related to the different chemistries of these elements in sediments, but probably involves dissolution (or little preservation) in outer shelf/upper-slope sediments and enrichment and preservation in lower-slope and abyssal plain sediments. This process may be important for manganese because the low inventories of manganese in the pore fluids and the generally low inventories in the solid phases in the sub-oxic/anoxic outer-shelf/upper slope sediments, suggest manganese has been dissolved from these sediments and re-deposited offshore. This process may be important in explaining the abundance of manganese nodules and crusts found off West Tasmania and the South Tasman Rise. While we can only speculate from these data, the hypothesis presented here is testable if additional data can be obtained.

Zinc, nickel and germanium (Figs 22 through 24) show enrichments both in outer-shelf/upper-slope sediments (water depths <1000 m) and in abyssal plain depths (water depths > 3000 m) compared to lower-slope cores. Rubidium and titanium show no particular trends (Figs. 25 and 26).

The relative abundances of these elements (normalised to aluminium) in sediments from the southern margins of South Australia, Victoria and West Tasmania are compared with those from north-east Australia in Table 14 below.

Table 14. 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 15 Major and trace element analyses for core 67GC01

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC01	0-3	5.15	0.01	0.89	0.28	0.15	0.12	0	1.69	47.25	1	0.17	0.09	1500	43.35
	GC01	10-13	5.49	0.01	0.91	0.3	0.12	0.16	0	1.79	47.24	1.01	0.18	0.08	1700	42.84
	GC01	20-23	5.91	0.02	1.04	0.35	0.21	0.13	0	1.84	46.78	1.01	0.2	0.08	1700	42.62
	GC01	30-33	6.49	0.02	1.25	0.39	0.23	0.14	0	1.93	46.38	1.03	0.23	0.08	1800	42.05
	GC01	50-53	6.41	0.03	1.17	0.43	0.24	0.17	0	1.98	46.3	0.97	0.25	0.08	2000	42.22
	GC01	90-93	8.83	0.07	2.32	0.84	0.65	0.17	0	2.1	43.11	0.94	0.41	0.09	2600	41.04
	GC01	110-113	12.8	0.13	3.01	1.09	0.88	0.19	0	2.23	39.95	0.96	0.54	0.09	2800	38.94
	GC01	130-133	15.39	0.14	3.51	1.32	1.1	0.2	0	2.19	38.26	0.99	0.63	0.09	3100	37.2
	GC01	150-153	20.06	0.17	3.63	1.28	1.06	0.2	0	2.24	35.52	1.03	0.73	0.08	3100	34.98
	GC01	170-173	20.08	0.19	4.36	1.57	1.33	0.22	0	2.21	34.86	0.99	0.82	0.08	3300	34.53
	GC01	190-193	19.15	0.21	4.53	1.67	1.44	0.21	0	2.2	35.19	1	0.81	0.08	3400	34.85
	GC01	210-213	25.2	0.26	5.64	2.05	1.73	0.29	0	2.18	30.46	1.05	0.95	0.08	4300	31.72

Table 15 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC01	0-3	1	2.5	57	3	10	<2	19	0	3	<1	<0.5	<2	10	6	38	6	<2
		10-13	1	2	43	<2	7	0	17	0	2	<1	0.5	<2	3	7	41	7	<2
		20-23	2	1.5	47	3	9	0	18	0	2	<1	0.5	<2	9	8	40	7	<2
		30-33	2	2.5	67	<2	<5	<2	18	0	3	2	<0.5	<2	11	8	45	7	2
		50-53	2	2.5	45	<2	9	<2	18	0	2	<1	<0.5	<2	10	8	53	7	2
		90-93	2	4	82	<2	12	<2	31	0	4	4	0.5	<2	14	13	67	7	3
		110-113	2	5	66	<2	23	<2	32	0	2	3	1	<2	15	16	82	7	3
		130-133	2	5.5	93	<2	21	<2	37	0	3	4	0.5	3	8	16	93	7	3
		150-153	2	5.5	93	<2	34	<2	36	0	4	4	1	3	11	16	101	7	4
		170-173	2	5	106	<2	28	<2	45	0	5	6	1	3	13	19	107	9	5
		190-193	2	4	109	2	29	<2	46	0	4	5	1.5	<2	16	21	109	9	4
		210-213	2	6	149	<2	30	<2	49	0	6	8	1.5	3	22	25	147	9	8

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC01	0-3	10	8	13	0	1	16	<1	7	2218	3	<2	2	9	<3	6	9	29
		10-13	3	8	<2	0	2	23	<1	5	2198	<2	<2	1.5	18	<3	6	9	34
		20-23	4	8	<2	0	3	13	<1	6	2182	<2	<2	1.5	13	<3	7	9	35
		30-33	8	9	<2	0	5	21	<1	3	2178	<2	<2	2.5	18	<3	6	10	34
		50-53	6	10	5	0	5	20	<1	5	2183	<2	<2	1.5	12	<3	6	9	39
		90-93	13	14	2	0	12	21	<1	4	2224	<2	<2	1.5	26	<3	8	16	49
		110-113	13	14	4	0	20	25	<1	5	2081	<2	2	2	30	<3	10	19	66
		130-133	13	13	3	0	22	21	<1	5	2022	3	3	3	29	<3	11	19	95
		150-153	5	13	4	0	26	26	<1	5	1893	3	4	2.5	32	<3	12	20	131
		170-173	12	14	5	0	32	24	<1	6	1865	4	5	3	40	<3	12	24	105
		190-193	16	17	6	0	35	28	<1	4	1871	<2	3	3	40	<3	12	26	104
		210-213	13	18	7	0	42	26	<1	7	1638	<2	6	3	51	<3	19	30	140

Table 16 Major and trace element analyses for core 67GC07

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC07	0-3	21.34	0.25	6.27	2.34	2.16	0.16	0.01	0.98	33.66	1.16	0.93	0.08	700	32.91
	GC07	6-9	20.91	0.28	6.53	2.52	2.39	0.12	0.03	0.96	33.88	1.19	0.9	0.07	700	32.69
	GC07	12-15	23.87	0.33	7.99	3.03	2.83	0.18	0.01	0.96	30.59	1.14	1.08	0.06	700	30.87
	GC07	20-23	28.83	0.4	9.23	3.49	3.26	0.21	0.01	1.08	26.04	1.27	1.23	0.07	800	28.28
	GC07	30-33	25.15	0.35	8.17	3.13	2.93	0.18	0	1.02	29.18	1.34	1.09	0.07	800	30.44
	GC07	40-43	39.55	0.61	13.19	4.67	4.37	0.27	0.01	1.46	14.19	1.87	1.67	0.08	1000	22.62
	GC07	50-53	32.05	0.48	9.77	4.68	4.48	0.18	0.01	1.17	22.64	1.49	1.22	0.08	700	26.37
	GC07	60-63	32.93	0.49	10.2	6.01	5.75	0.23	0.01	1.3	20.23	1.65	1.42	0.09	800	25.63
	GC07	80-83	27.72	0.41	9.02	2.95	2.65	0.27	0.01	1.11	26.96	1.41	1.35	0.06	900	28.93
	GC07	100-103	45.61	0.79	15.43	5.56	5.09	0.42	0.01	1.6	7.79	2.15	2.07	0.08	1500	18.81
	GC07	120-123	47.59	0.78	14.6	5.28	4.72	0.5	0.01	1.62	7.51	2.11	2.18	0.08	2400	18.06
	GC07	140-143	44.86	0.74	14.68	5.77	5.34	0.39	0.01	1.6	8.78	2.08	2.15	0.08	1100	19.17
	GC07	160-163	41.76	0.67	14.24	4.97	4.53	0.4	0.01	1.62	11.51	2.02	2.19	0.08	1400	20.83
	GC07	180-183	27.42	0.41	8.55	3.08	2.74	0.31	0.01	1.14	27.22	1.47	1.37	0.07	1000	29.19
	GC07	200-203	18.63	0.26	6.01	2.14	1.88	0.23	0.01	0.87	36.08	1.12	0.97	0.07	600	33.82
	GC07	250-253	42.11	0.66	13.88	4.91	4.38	0.48	0.01	1.59	11.47	1.99	2.07	0.08	1800	21.08

Table 16 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC07	0-3	2	3	699	<2	27	4	49	0	50	7	1	3	23	24	269	6	5
		6-9	2	3	709	<2	30	4	49	0	43	8	1	<2	24	24	441	5	4
		12-15	2	3	832	<2	34	6	50	0	37	9	2	<2	14	28	228	5	9
		20-23	2	5	906	<2	39	4	64	0	38	12	2	4	24	34	120	3	10
		30-33	2	3.5	632	<2	24	3	53	0	43	10	1.5	2	17	29	109	5	7
		40-43	3	3	667	<2	46	6	75	0	67	16	2.5	<2	28	45	128	3	12
		50-53	2	6	533	<2	37	4	58	0	36	11	2	2	22	30	131	5	9
		60-63	3	6.5	541	<2	34	4	62	0	29	13	2	3	23	34	119	3	9
		80-83	2	2	611	<2	35	3	48	0	71	10	2	<2	18	33	122	4	8
		100-103	3	4	439	<2	51	10	70	0	54	17	2.5	4	18	53	125	2	15
		120-123	2	7.5	681	<2	50	10	77	0	67	18	2.5	4	25	55	134	3	14
		140-143	3	2.5	486	<2	46	6	76	0	36	17	2.5	3	29	51	128	2	14
		160-163	3	3	756	<2	43	8	79	0	123	16	2.5	4	22	57	126	3	12
		180-183	2	2.5	504	<2	26	3	48	0	32	10	1.5	<2	21	34	139	5	10
		200-203	2	1	513	<2	26	<2	43	0	18	8	1	<2	14	24	186	5	6
		250-253	3	7.5	699	<2	43	8	70	0	54	17	2.5	3	20	51	142	4	12

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC07	0-3	15	22	12	0	40	31	<1	5	1049	<2	3	1	50	<3	17	49	84
		6-9	14	27	8	0	42	27	<1	5	1020	3	5	<0.5	58	<3	17	47	81
		12-15	15	25	10	0	53	30	<1	6	895	<2	6	1	62	<3	19	52	91
		20-23	17	24	12	0	63	25	<1	6	711	<2	7	0.5	69	<3	21	59	119
		30-33	13	21	8	0	50	29	<1	6	877	3	5	<0.5	56	<3	20	57	95
		40-43	23	32	15	0	79	21	2	6	465	4	9	<0.5	79	<3	25	75	147
		50-53	18	26	13	0	55	28	<1	6	733	<2	7	<0.5	74	<3	21	62	124
		60-63	14	30	12	0	60	24	<1	9	638	3	6	0.5	81	<3	21	62	111
		80-83	18	26	10	0	56	24	3	8	799	2	6	5.5	78	<3	20	58	107
		100-103	23	46	19	0	87	15	3	7	305	<2	9	5	122	<3	26	78	174
		120-123	21	37	18	0	91	18	1	5	274	3	9	3.5	89	<3	25	79	191
		140-143	25	31	16	0	87	19	1	6	326	5	8	1	111	<3	24	74	159
		160-163	20	44	17	0	91	19	3	4	372	<2	10	3.5	96	<3	25	84	145
		180-183	20	23	9	0	57	23	<1	5	813	3	5	3.5	50	<3	22	51	103
		200-203	16	17	6	0	38	33	<1	6	1169	<2	3	1	42	<3	17	38	79
		250-253	18	41	16	0	84	18	2	5	375	2	8	3.5	93	<3	23	80	162

Table 17 Major and trace element analyses for core 67GC12A

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC12A	0-3	18.25	0.2	5.13	1.93	1.79	0.13	0.03	0.85	36.46	1.28	0.75	0.09	900	34.96
	GC12A	7-11	18.87	0.21	5.36	2.01	1.93	0.07	0.07	0.87	36.02	1.92	1.04	0.09	800	33.46
	GC12A	15-19	19.71	0.21	5.43	2.21	2.04	0.15	0	0.93	35.32	1.34	0.91	0.08	800	33.78
	GC12A	30-33	21.79	0.26	6.32	2.57	2.33	0.22	0	1.13	32.9	1.28	1.16	0.08	800	32.44
	GC12A	40-43	23.45	0.3	7.03	2.89	2.6	0.26	0.01	1.2	30.84	1.4	1.29	0.09	900	31.43
	GC12A	50-53	22.52	0.3	7.16	2.59	2.32	0.24	0	1.04	31.59	1.48	1.23	0.08	1000	31.92
	GC12A	60-63	23.53	0.32	7.48	3.33	3.04	0.26	0.01	1.08	30.35	1.57	1.35	0.09	1000	30.82
	GC12A	70-73	28.71	0.4	9.36	3.9	3.49	0.37	0.01	1.24	24.87	1.59	1.54	0.08	1200	28.21
	GC12A	80-83	29.33	0.42	9.77	3.56	3.18	0.34	0.01	1.2	24.52	1.65	1.56	0.08	1300	27.8
	GC12A	90-93	31.42	0.45	10.54	3.81	3.4	0.37	0.01	1.26	22.18	2.23	1.83	0.08	2100	26.03
	GC12A	110-113	31.12	0.45	10.76	3.92	3.52	0.36	0.01	1.26	21.95	2.25	1.78	0.09	2300	26.22
	GC12A	130-133	30.62	0.44	10.58	3.87	3.45	0.38	0.01	1.31	21.87	2.44	1.83	0.09	2700	26.73
	GC12A	150-153	20.73	0.26	6.21	2.39	2.16	0.21	0.03	1	33.57	1.61	1.04	0.09	1000	33.01
	GC12A	170-173	27.48	0.4	9.18	3.57	3.18	0.35	0.01	1.18	25.41	1.86	1.5	0.09	2200	29.13
	GC12A	190-193	32.64	0.48	10.98	4.08	3.68	0.36	0.01	1.3	20.37	1.94	1.69	0.1	2600	26.19
	GC12A	230-233	31.52	0.47	11.38	4.42	4.02	0.36	0.01	1.36	20.14	2.27	1.74	0.1	3300	26.31

Table 17 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC12A	0-3	2	4.5	589	<2	24	2	37	0	32	6	1.5	4	9	19	440	7	5
	GC12A	7-11	2	3	672	<2	15	5	40	0	37	7	1.5	<2	17	21	951	7	5
	GC12A	15-19	2	3.5	572	<2	18	2	39	0	24	8	1.5	<2	15	21	141	6	6
	GC12A	30-33	2	3.5	672	3	32	<2	50	0	29	7	1.5	3	23	27	132	7	8
	GC12A	40-43	3	2.5	556	<2	28	4	49	0	38	8	1.5	<2	18	31	121	4	5
	GC12A	50-53	3	3.5	472	<2	19	6	40	0	42	9	1.5	<2	16	30	110	6	6
	GC12A	60-63	3	3.5	631	<2	29	5	49	0	27	9	1.5	3	18	31	123	6	6
	GC12A	70-73	3	4	519	<2	32	5	51	0	30	10	2	<2	10	37	120	4	8
	GC12A	80-83	3	4.5	577	<2	32	6	53	0	31	11	1.5	2	23	40	122	6	10
	GC12A	90-93	3	7.5	530	<2	28	8	50	0	32	12	2	3	20	43	115	4	11
	GC12A	110-113	3	5	454	<2	28	8	51	0	32	11	1.5	<2	13	46	105	5	9
	GC12A	130-133	3	4	544	<2	27	8	51	0	40	12	2	<2	13	45	99	4	11
	GC12A	150-153	3	3.5	520	<2	31	7	33	0	30	8	1.5	<2	15	25	352	5	5
	GC12A	170-173	3	4	418	<2	25	7	44	0	37	9	1.5	<2	14	36	95	6	9
	GC12A	190-193	3	5	362	<2	32	9	48	0	42	12	2	<2	15	43	104	5	9
	GC12A	230-233	4	5	329	<2	25	9	52	0	34	12	1.5	<2	21	43	102	3	9

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC12A	0-3	19	29	6	0	30	27	<1	6	1136	<2	4	1	45	<3	18	38	73
	GC12A	7-11	15	29	8	0	34	25	<1	4	1137	2	4	<0.5	45	<3	17	41	78
	GC12A	15-19	3	207	7	0	36	21	<1	6	1108	<2	4	1	40	<3	17	39	85
	GC12A	30-33	12	236	6	0	45	28	<1	6	1017	3	4	1	49	<3	17	44	91
	GC12A	40-43	15	24	8	0	51	27	1	6	960	<2	5	4	64	<3	19	52	92
	GC12A	50-53	9	24	9	0	50	23	<1	6	993	<2	4	3	51	<3	17	46	94
	GC12A	60-63	17	26	10	0	48	28	1	9	935	<2	5	0.5	52	<3	19	46	89
	GC12A	70-73	13	29	11	0	63	21	1	7	773	<2	6	2	60	<3	21	56	104
	GC12A	80-83	17	29	12	0	67	20	2	5	749	4	7	3	63	<3	22	55	112
	GC12A	90-93	18	31	12	0	75	18	<1	5	688	<2	8	3	63	<3	23	61	119
	GC12A	110-113	16	29	14	0	73	17	<1	5	645	<2	8	2.5	61	<3	23	58	114
	GC12A	130-133	17	31	12	0	74	16	1	3	680	<2	7	2	64	<3	23	59	109
	GC12A	150-153	10	23	6	0	41	27	<1	5	1057	3	4	1.5	43	<3	18	42	83
	GC12A	170-173	13	27	9	0	61	15	1	7	776	<2	5	3	50	<3	21	57	102
	GC12A	190-193	15	32	12	0	74	14	1	4	649	5	7	3	55	<3	22	64	114
	GC12A	230-233	15	33	13	0	70	16	1	7	648	3	6	2	58	<3	21	66	110

Table 18 Major and trace element analyses for core 67GC16

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC16	0-3	19.21	0.2	5.09	1.9	1.58	0.29	0	1	34.82	1.57	0.86	0.1	1200	35.17
	GC16	6-9	20.12	0.19	4.91	1.78	1.5	0.25	0	1.05	34.53	1.39	0.81	0.1	1300	35.03
	GC16	12-15	20.91	0.21	5.26	1.9	1.63	0.24	0	1.13	33.98	1.4	0.89	0.1	1600	34.07
	GC16	20-23	20.87	0.21	5.42	1.98	1.66	0.29	0	1.15	33.63	1.42	0.88	0.1	1600	34.21
	GC16	30-33	22.38	0.22	5.38	1.93	1.64	0.26	0	1.19	33.18	1.29	0.93	0.09	1500	33.29
	GC16	40-43	23.56	0.25	5.65	2.06	1.76	0.27	0	1.3	31.89	1.39	1.05	0.09	1900	32.6
	GC16	60-63	26.78	0.33	7.43	2.83	2.5	0.3	0.01	1.56	27.69	1.41	1.36	0.1	2500	30.28
	GC16	70-73	22.81	0.26	5.81	2.09	1.8	0.26	0	1.31	32.56	1.19	1.03	0.09	1900	32.69
	GC16	90-93	33.73	0.46	9.66	3.23	2.77	0.41	0.01	1.25	22.26	1.66	1.66	0.09	2500	25.8
	GC16	110-113	30.3	0.4	9.31	3.13	2.71	0.38	0.01	1.25	24.33	1.42	1.45	0.08	3600	27.99
	GC16	130-133	31.04	0.42	9.09	3.34	2.92	0.38	0	1.3	23.55	1.6	1.38	0.09	4700	27.76
	GC16	150-153	27.73	0.39	9.28	3.54	3.16	0.34	0.01	1.47	24.62	1.78	1.45	0.1	4700	29.2
	GC16	166-169	23.19	0.32	7.41	2.78	2.49	0.26	0	1.37	30.11	1.64	1.26	0.1	2700	31.57
	GC16	166-169	23.19	0.32	7.41	2.78	2.49	0.26	0	1.37	30.11	1.64	1.26	0.1	2700	31.57

Table 18 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC16	0-3	3	1.5	345	<2	25	5	39	0	16	6	1	3	11	19	85	4	5
		6-9	3	2.5	345	<2	15	5	42	0	17	6	1	<2	10	19	91	6	3
		12-15	3	4	321	<2	29	6	43	0	16	6	1	3	18	22	92	5	5
		20-23	4	3.5	370	<2	19	6	41	0	16	6	0.5	<2	14	22	97	6	5
		30-33	4	2	370	<2	21	6	45	0	16	7	1.5	<2	21	23	107	5	5
		40-43	3	3.5	440	<2	32	5	55	0	16	7	1	<2	20	25	121	4	4
		60-63	3	5	344	<2	26	7	49	0	17	10	1.5	4	14	31	125	5	8
		70-73	2	3.5	456	<2	35	5	44	0	18	7	1	3	20	24	117	5	5
		90-93	3	5.5	438	<2	44	11	65	0	20	11	1.5	2	24	37	127	5	10
		110-113	3	6.5	328	<2	31	11	58	0	19	11	2	<2	14	40	101	5	8
		130-133	3	7.5	317	<2	32	11	59	0	19	10	2	2	16	35	113	6	10
		150-153	3	4	266	<2	29	9	55	0	19	10	1.5	3	14	34	106	6	7
		166-169	3	4.5	292	<2	24	8	38	0	17	9	1.5	<2	16	27	105	5	8
		166-169	3	4.5	292	<2	24	8	38	0	17	9	1.5	<2	16	27	105	5	8

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC16	0-3	10	19	27	0	29	22	1	5	1578	<2	3	2	48	<3	16	36	89
		6-9	10	21	15	0	30	23	<1	4	1586	<2	3	3	49	<3	14	34	81
		12-15	13	22	6	0	33	27	<1	8	1590	4	4	4	49	<3	14	37	87
		20-23	7	20	6	0	34	22	<1	6	1546	4	4	3.5	51	<3	14	38	94
		30-33	15	20	6	0	38	26	<1	6	1584	5	4	4	53	<3	16	38	105
		40-43	16	20	6	0	40	23	<1	4	1463	4	5	4.5	51	<3	16	40	116
		60-63	14	23	7	0	53	24	<1	5	1217	<2	5	4	58	<3	18	47	117
		70-73	16	21	7	0	42	30	1	6	1413	<2	4	4	56	<3	17	41	100
		90-93	20	30	12	0	68	24	1	7	768	<2	7	4	84	<3	22	56	138
		110-113	15	26	12	0	66	18	<1	4	1018	<2	7	4.5	60	<3	20	52	118
		130-133	19	28	11	0	61	24	1	4	1179	<2	7	3.5	59	<3	21	55	119
		150-153	13	26	10	0	59	19	2	5	1272	2	6	3.5	62	<3	18	53	103
		166-169	12	24	10	0	44	21	<1	5	1427	<2	4	3.5	55	<3	17	45	91
		166-169	12	24	10	0	44	21	<1	5	1427	<2	4	3.5	55	<3	17	45	91

Table 19 Major and trace element analyses for core 67GC18

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC18	0-3	21.84	0.2	4.81	1.75	1.46	0.26	0	1.86	32.23	1.37	0.83	0.11	2700	34.75
	GC18	10-13	18.91	0.15	3.92	1.38	1.1	0.25	0	1.72	35.33	1.23	0.7	0.1	2900	36.31
	GC18	40-43	18.56	0.13	3.53	1.25	0.97	0.25	0	1.76	35.88	1.12	0.61	0.1	3000	36.79
	GC18	70-73	18.95	0.13	3.26	1.16	0.9	0.23	0	1.83	36.24	1.06	0.57	0.09	3200	36.42
	GC18	230-233	20.77	0.13	3.24	1.15	0.89	0.23	0	1.87	35.28	1.15	0.63	0.1	3400	35.36
	GC18	260-263	20.36	0.15	3.49	1.21	0.92	0.26	0	1.9	35.28	1.16	0.66	0.1	3500	35.37

Table 19 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC18	0-3	2	5	130	<2	23	6	45	0	6	7	1	<2	16	18	106	6	3
		10-13	3	4	126	<2	13	6	38	0	5	5	<0.5	<2	13	16	85	6	4
		40-43	3	3.5	122	<2	22	5	36	0	5	4	1	<2	14	15	83	7	4
		70-73	2	3.5	112	<2	21	5	32	0	5	4	1	<2	13	13	84	9	4
		230-233	2	3.5	100	2	26	5	32	0	4	4	1	<2	16	12	93	7	3
		260-263	3	2.5	111	<2	26	4	33	0	4	4	1	<2	16	14	89	7	4

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC18	0-3	14	19	12	0	25	26	<1	4	1686	<2	4	2	49	<3	14	28	99
		10-13	7	15	6	0	21	25	<1	4	1852	<2	3	2.5	40	<3	11	23	83
		40-43	13	15	5	0	19	28	<1	7	1856	3	4	2.5	37	<3	12	22	95
		70-73	11	15	5	0	18	26	<1	5	1925	3	3	3.5	33	<3	11	19	86
		230-233	9	14	5	0	20	22	<1	5	1869	<2	2	2	29	<3	11	18	98
		260-263	17	14	5	0	20	24	<1	6	1847	<2	3	1.5	34	<3	12	20	92

Table 20 Major and trace element analyses for core 67GC29

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC29	0-3	11.49	0.07	1.78	0.62	0.51	0.1	0	1.71	42.99	1.03	0.31	0.07	1400	39.79
	GC29	10-13	11.53	0.06	2.11	0.65	0.53	0.11	0	1.76	43.17	1.08	0.35	0.08	1500	39.09
	GC29	30-33	17.76	0.18	4.71	1.55	1.31	0.22	0	2.1	35.61	0.96	0.69	0.08	3700	36.01
	GC29	50-53	16.42	0.19	4.72	1.64	1.4	0.22	0	2.21	35.78	0.98	0.69	0.09	4300	36.88
	GC29	70-73	12.81	0.12	3.03	1.06	0.88	0.16	0	2.19	39.73	1.02	0.44	0.08	3300	39.21
	GC29	90-93	9.03	0.06	1.72	0.62	0.49	0.12	0	2.32	43.18	1.03	0.3	0.07	2600	41.44
	GC29	110-113	9.72	0.07	2.06	0.71	0.59	0.11	0	2.24	42.3	1.09	0.35	0.07	2700	41.13
	GC29	130-133	9.14	0.06	1.79	0.67	0.5	0.15	0	2.38	42.98	1.04	0.31	0.07	2800	41.29
	GC29	150-153	9.76	0.06	1.87	0.65	0.51	0.13	0	2.29	42.56	1.04	0.31	0.07	2600	41.14
	GC29	170-173	9.55	0.05	1.89	0.64	0.5	0.13	0	2.23	42.66	1.07	0.33	0.07	2500	41.27
	GC29	190-193	8.6	0.06	1.88	0.7	0.57	0.12	0	2.31	43.2	1.03	0.31	0.07	2700	41.57

Table 20 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC29	0-3	3	2.5	95	<2	13	3	21	0	5	<1	<0.5	<2	14	8	65	5	3
	GC29	10-13	3	1.5	90	<2	18	3	23	0	3	2	<0.5	<2	16	9	69	5	<2
	GC29	30-33	3	5	142	<2	28	5	44	0	8	5	1	<2	20	22	94	6	6
	GC29	50-53	4	6.5	118	<2	34	4	50	0	8	6	1	<2	21	22	92	7	4
	GC29	70-73	3	5.5	97	<2	24	3	43	0	5	3	0.5	<2	13	15	75	7	4
	GC29	90-93	3	3	61	<2	27	3	27	0	2	2	<0.5	<2	11	10	53	5	2
	GC29	110-113	4	3.5	92	<2	15	3	33	0	2	2	0.5	<2	18	11	60	7	<2
	GC29	130-133	3	4	80	<2	18	2	26	0	3	1	<0.5	<2	16	10	56	7	<2
	GC29	150-153	4	3.5	72	<2	22	0	29	0	3	2	0.5	<2	14	11	56	7	2
	GC29	170-173	4	3	85	<2	20	2	30	0	3	2	<0.5	<2	7	10	55	7	2
	GC29	190-193	3	4.5	79	<2	17	2	27	0	4	2	0.5	<2	11	11	57	7	<2

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC29	0-3	15	9	14	0	8	7	<1	5	1973	<2	<2	1	21	<3	8	11	72
	GC29	10-13	14	10	20	0	8	11	<1	4	1998	<2	<2	0.5	19	3	9	13	78
	GC29	30-33	15	17	6	0	30	11	<1	6	1763	2	3	5.5	52	<3	13	25	83
	GC29	50-53	21	18	50	0	30	14	<1	3	1774	<2	3	4	55	<3	13	26	78
	GC29	70-73	14	14	2	0	16	10	<1	2	2037	<2	<2	4.5	37	<3	11	18	70
	GC29	90-93	13	10	<20	0	6	3	<1	5	2179	<2	<2	2.5	22	<3	10	11	61
	GC29	110-113	14	11	<2	0	10	14	<1	4	2196	<2	<2	3	29	<3	9	13	58
	GC29	130-133	16	10	20	0	7	10	<1	6	2127	<2	<2	2.5	24	<3	9	12	62
	GC29	150-153	13	9	2	0	9	5	<1	4	2120	3	<2	2	19	<3	9	12	54
	GC29	170-173	10	10	<20	0	9	4	<1	3	2171	<2	<2	2	23	<3	9	12	61
	GC29	190-193	13	12	<2	0	8	27	<1	3	2202	2	<2	2	29	<3	9	14	45

Table 21 Major and trace element analyses for core 67GC45

Survey	Core	Sample Depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC45	0-3	11.56	0.14	3.51	1.49	1.38	0.1	0.03	0.72	42.46	1.04	0.5	0.08	700	38.42
	GC45	6-10	11.38	0.14	3.43	1.43	1.29	0.13	0	0.72	42.79	1.08	0.51	0.07	700	38.39
	GC45	14-17	12.54	0.16	3.77	1.82	1.69	0.12	0	0.81	41.61	1.14	0.56	0.07	700	37.44
	GC45	14-17	12.54	0.16	3.77	1.82	1.69	0.12	0	0.81	41.61	1.14	0.56	0.07	700	37.44
	GC45	20-23	16.4	0.23	4.88	2.39	2.26	0.12	0.03	1.02	37.6	1.2	0.68	0.08	700	35.42
	GC45	30-33	18.89	0.24	5.23	3.15	2.84	0.28	0	1.16	34.5	1.39	0.86	0.09	900	34.44
	GC45	40-43	21.74	0.27	6.53	2.64	2.18	0.41	0	1.22	32.91	1.38	1.09	0.08	900	32.11
	GC45	50-53	21.38	0.3	6.64	2.46	2.06	0.36	0	1.19	32.45	1.42	1.08	0.08	1000	32.94
	GC45	60-63	21.88	0.3	6.57	2.59	2.2	0.35	0	1.24	31.83	1.6	1.02	0.09	1100	32.8
	GC45	70-73	21.55	0.32	6.68	2.7	2.33	0.33	0.01	1.23	31.72	1.75	1.02	0.09	1300	32.85
	GC45	90-93	23.71	0.33	7.36	2.91	2.57	0.31	0	1.21	29.74	1.64	1.15	0.08	1500	31.74
	GC45	110-113	25.6	0.37	8.06	3.25	2.86	0.35	0	1.26	27.6	1.72	1.25	0.09	2000	30.66
	GC45	130-133	20.46	0.29	6.17	2.61	2.31	0.27	0	1.13	33.04	1.55	1	0.08	1800	33.51
	GC45	150-153	28.69	0.42	9.3	3.62	3.13	0.44	0.01	1.31	24.41	1.76	1.38	0.09	2300	28.83
	GC45	170-173	18.06	0.24	5.6	2.26	2.02	0.22	0	0.9	36.29	1.29	0.89	0.11	900	34.3
	GC45	190-193	14.11	0.16	4.18	1.74	1.51	0.21	0	0.78	40.25	1.16	0.77	0.08	700	36.72

Table 21 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC45	0-3	4	4.5	1007	<2	16	5	33	0	39	5	1	<2	22	15	529	9	2
	GC45	6-10	4	2.5	964	<2	22	3	36	0	41	4	0.5	<2	14	15	89	6	4
	GC45	14-17	4	4	998	<2	17	4	44	0	34	5	<0.5	<2	15	17	167	6	2
	GC45	14-17	4	4	998	<2	17	4	44	0	34	5	<0.5	<2	15	17	167	6	2
	GC45	20-23	4	5	865	<2	19	10	53	0	42	6	1	<2	24	21	453	6	6
	GC45	30-33	4	2.5	761	<2	29	4	55	0	31	7	1.5	<2	18	23	127	5	4
	GC45	40-43	4	2	883	<2	25	5	60	0	37	7	1	<2	21	27	127	5	5
	GC45	50-53	4	2	979	<2	36	5	63	0	41	7	1.5	<2	23	30	122	7	7
	GC45	60-63	4	2	878	<2	30	5	65	0	39	8	1.5	<2	20	30	123	4	7
	GC45	70-73	4	3.5	1011	<2	13	5	58	0	39	8	2	<2	15	30	127	7	7
	GC45	90-93	4	3	708	<2	27	5	67	0	42	7	1.5	<2	21	34	115	4	8
	GC45	110-113	4	4.5	461	<2	24	6	56	0	38	9	1.5	<2	17	33	107	6	7
	GC45	130-133	4	3.5	521	<2	23	5	50	0	33	7	1.5	<2	18	27	113	5	8
	GC45	150-153	4	3.5	619	<2	40	5	69	0	45	10	2	2	21	32	127	4	8
	GC45	170-173	4	1.5	731	<2	25	3	45	0	35	7	1	<2	13	22	140	6	5
	GC45	190-193	4	1	818	<2	25	3	35	0	25	5	1	<2	16	17	167	6	2

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC45	0-3	18	23	65	0	19	30	<1	5	1292	<2	2	<0.5	43	<3	16	34	49
	GC45	6-10	14	14	30	0	19	29	<1	6	1283	<2	<2	0.5	39	<3	17	33	45
	GC45	14-17	12	17	4	0	21	28	<1	5	1262	<2	3	<0.5	44	<3	16	35	52
	GC45	14-17	12	174	0	0	21	28	<1	5	1262	<2	3	<0.5	44	<3	16	35	52
	GC45	20-23	12	23	6	0	27	27	<1	5	1135	<2	3	1	63	<3	15	42	65
	GC45	30-33	17	29	6	0	31	27	1	6	1040	<2	4	<0.5	72	<3	15	46	66
	GC45	40-43	14	28	7	0	42	32	<1	7	959	<2	4	5.5	77	<3	18	51	76
	GC45	50-53	24	29	8	0	42	30	1	6	934	7	4	4.5	87	<3	19	53	84
	GC45	60-63	16	29	90	0	37	25	1	6	917	<2	3	3	83	<3	19	47	77
	GC45	70-73	10	28	7	0	39	28	<1	9	875	<2	3	3	78	<3	18	53	79
	GC45	90-93	13	317	0	0	45	24	1	6	829	3	4	3	83	<3	18	53	81
	GC45	110-113	15	29	9	0	47	25	1	6	814	<2	4	4	76	<3	18	50	89
	GC45	130-133	14	26	8	0	35	23	1	6	955	<2	3	2	65	<3	17	45	76
	GC45	150-153	17	34	11	0	56	22	1	7	761	2	5	5.5	87	<3	23	61	97
	GC45	170-173	18	21	5	0	35	29	<1	5	1077	<2	4	2	48	<3	19	43	61
	GC45	190-193	20	224	0	0	27	25	2	8	1153	<2	3	3	57	<3	18	34	59

Table 22 Major and trace element analyses for core 67GC48

Survey	Core	Sample depth (cm)	SiO2 (wt%)	TiO2 (wt%)	Al2O3 (wt%)	Fe2O3t (wt%)	Fe2O3 (wt%)	FeO (wt%)	MnO (wt%)	MgO (wt%)	CaO (wt%)	Na2O (wt%)	K2O (wt%)	P2O5 (wt%)	S (ppm)	LOI
67	GC48	0-3	9.17	0.07	2.35	1.08	0.78	0.27	0	1.85	42.77	1.13	0.41	0.11	2300	40.87
	GC48	10-13	13.06	0.13	3.45	1.42	0.98	0.4	0	1.9	39.8	1.17	0.62	0.11	2900	38.1
	GC48	30-33	17.71	0.2	9.19	2.1	1.49	0.55	0	2.01	35.69	1.33	0.89	0.12	5500	30.28
	GC48	50-53	17.52	0.18	6.17	1.92	1.39	0.48	0	1.89	35.79	1.21	0.86	0.11	5200	33.88
	GC48	70-73	18.97	0.22	5.8	2.04	1.46	0.52	0	2.08	34.41	1.13	0.91	0.12	5200	33.87
	GC48	100-103	16.63	0.2	4.83	1.81	1.3	0.46	0	2.06	36.37	1.02	0.75	0.11	5300	35.74
	GC48	120-123	15.68	0.19	4.36	1.73	1.26	0.42	0	1.88	37.29	1.02	0.7	0.11	5400	36.55
	GC48	140-143	14.14	0.16	3.71	1.48	1.07	0.37	0	2	38.66	1.06	0.64	0.1	4900	37.6
	GC48	160-163	13	0.15	3.68	1.39	1.02	0.33	0	2.01	39.5	1.04	0.59	0.09	4100	38.18

Table 22 (cont)

Survey	Core	Sample Depth (cm)	Ag (ppm)	As (ppm)	Ba (ppm)	Bi (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Ga (ppm)	Ge (ppm)	Hf (ppm)	La (ppm)	Li (ppm)	Mn (ppm)	Mo (ppm)	Nb (ppm)
67	GC48	0-3	4	8	94	<2	21	2	38	0	5	3	1	<2	18	13	102	6	4
	GC48	10-13	2	6	139	<2	16	3	51	0	8	4	1	<2	19	18	140	5	4
	GC48	30-33	2	9	173	2	31	4	66	0	11	6	1	<2	13	24	167	8	6
	GC48	50-53	2	7	174	<2	32	4	64	0	8	6	1.5	3	23	24	156	7	3
	GC48	70-73	2	6.5	173	<2	33	4	70	0	10	6	1.5	<2	15	27	159	7	5
	GC48	100-103	2	6.5	153	<2	28	3	64	0	9	6	1	<2	16	23	138	7	7
	GC48	120-123	2	6	149	<2	26	4	60	0	8	6	0.5	<2	19	22	124	6	6
	GC48	140-143	2	5	130	<2	26	3	53	0	7	4	1	<2	16	20	112	4	5
	GC48	160-163	2	5	119	<2	25	2	57	0	6	4	0.5	2	22	20	104	7	3

Survey	Core	Sample Depth (cm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sc (ppm)	Se (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
67	GC48	0-3	11	13	57	0	12	24	<1	8	2448	<2	<2	2.5	59	<3	8	22	34
	GC48	10-13	11	18	40	0	19	29	<1	8	2327	<2	3	2	70	<3	11	25	50
	GC48	30-33	10	26	6	0	31	28	<1	5	2230	5	3	3	84	<3	12	32	62
	GC48	50-53	14	257	0	0	30	29	<1	4	2276	<2	4	2.5	76	<3	12	32	67
	GC48	70-73	17	25	6	0	32	26	1	4	1628	2	4	2.5	84	<3	14	32	66
	GC48	100-103	16	267	0	0	27	29	<1	7	1907	<2	3	2	84	<3	11	29	68
	GC48	120-123	9	24	6	0	24	27	<1	6	2163	<2	3	2	76	<3	12	27	61
	GC48	140-143	16	21	60	0	21	25	<1	6	1991	4	2	2.5	71	<3	11	24	54
	GC48	160-163	14	184	0	0	21	25	<1	4	1948	<2	2	3	64	<3	10	23	47

Table 23 Range in concentration of major and minor elements present in the sediments from the Otway Basin

Element	Minimum	Maximum
SiO2 (wt%)	0	50
TiO2 (wt%)	0	1
Al2O3 (wt%)	0	16
Fe2O3 (wt%)	0	6
FeO (wt%)	0	0.6
MnO (wt%)	0	0.1
MgO (wt%)	0	2.5
CaO (wt%)	0	50
Na2O (wt%)	0	2.5
K2O (wt%)	0	2.2
P2O5 (wt%)	0	0.5
Sulphur (wt%)	500	6000
Silver (ppm)	0	5
Arsenic (ppm)	0	9
Barium (ppm)	0	1200
Bismuth (wt%)	0	4
Cerium (ppm)	0	60
Cobalt (ppm)	0	12
Chromium (ppm)	0	80
Cesium (ppm)	0	0
Copper (ppm)	0	140
Gallium (ppm)	0	20
Germanium (ppm)	0	3
Hafnium (ppm)	0	5
Lanthanum (ppm)	0	30
Lithium (ppm)	0	60
Manganese (ppm)	0	1000
Molybdenum (ppm)	0	9
Niobium (ppm)	0	20
Neodymium (ppm)	0	25
Nickel (ppm)	0	50
Lead (ppm)	0	70
Praseodymium (ppm)	0	0
Rubidium (ppm)	0	100
Scandium (ppm)	0	35
Selenium (ppm)	0	4
Tin (ppm)	0	10
Strontium (ppm)	0	2500
Tantalum (ppm)	0	10
Thorium (ppm)	0	10
Uranium (ppm)	0	6
Vanadium (ppm)	0	140
Wolfram (ppm)	0	<3
Yttrium (ppm)	5	30
Zinc (ppm)	5	200
Zirconium (ppm)	5	90

Table 24 Core-top elemental ratios and water depths for cores from the southern Australia continental margin

Core	Depth (cm)	Water Depth (m)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=100000)	Cr/Al (ppm/wt%=100000)	Cu/Al (ppm/wt%=100000)	Ge/Al (ppm/wt%=100000)	Mn/Al (ppm/wt%=100000)	Ni/Al (ppm/wt%=100000)	Rb/Al (ppm/wt%=100000)	Sr/Al (ppm/wt%=100000)	V/Al (ppm/wt%=100000)	Zn/Al (ppm/wt%=100000)
67GC29	0-3	240	5.70	0.045	0.032	100.84	22.29	5.31	0.531	69.00	9.55	8.49	2094	22.29	11.68
67GC48	0-3	377	3.45	0.034	0.039	75.58	30.55	4.02	0.804	82.01	10.45	9.65	1968	47.44	17.69
67GC01	0-3	425	5.11	0.013	0.083	121.01	40.34	6.37	1.062	80.68	16.98	2.12	4709	19.11	19.11
67GC18	0-3	1035	4.01	0.047	0.019	51.07	17.68	2.36	0.393	41.64	7.46	9.82	662	19.25	11.00
67GC16	0-3	1650	3.33	0.045	0.016	128.07	14.48	5.94	0.371	31.55	7.05	10.77	586	17.82	13.36
67GC12A	0-3	3133	3.14	0.044	0.014	216.94	13.63	11.79	0.552	162.06	10.68	11.05	418	16.57	14.00
67GC45	0-3	3715	2.91	0.075	0.019	542.09	17.76	20.99	0.538	284.77	12.38	10.23	696	23.15	18.30

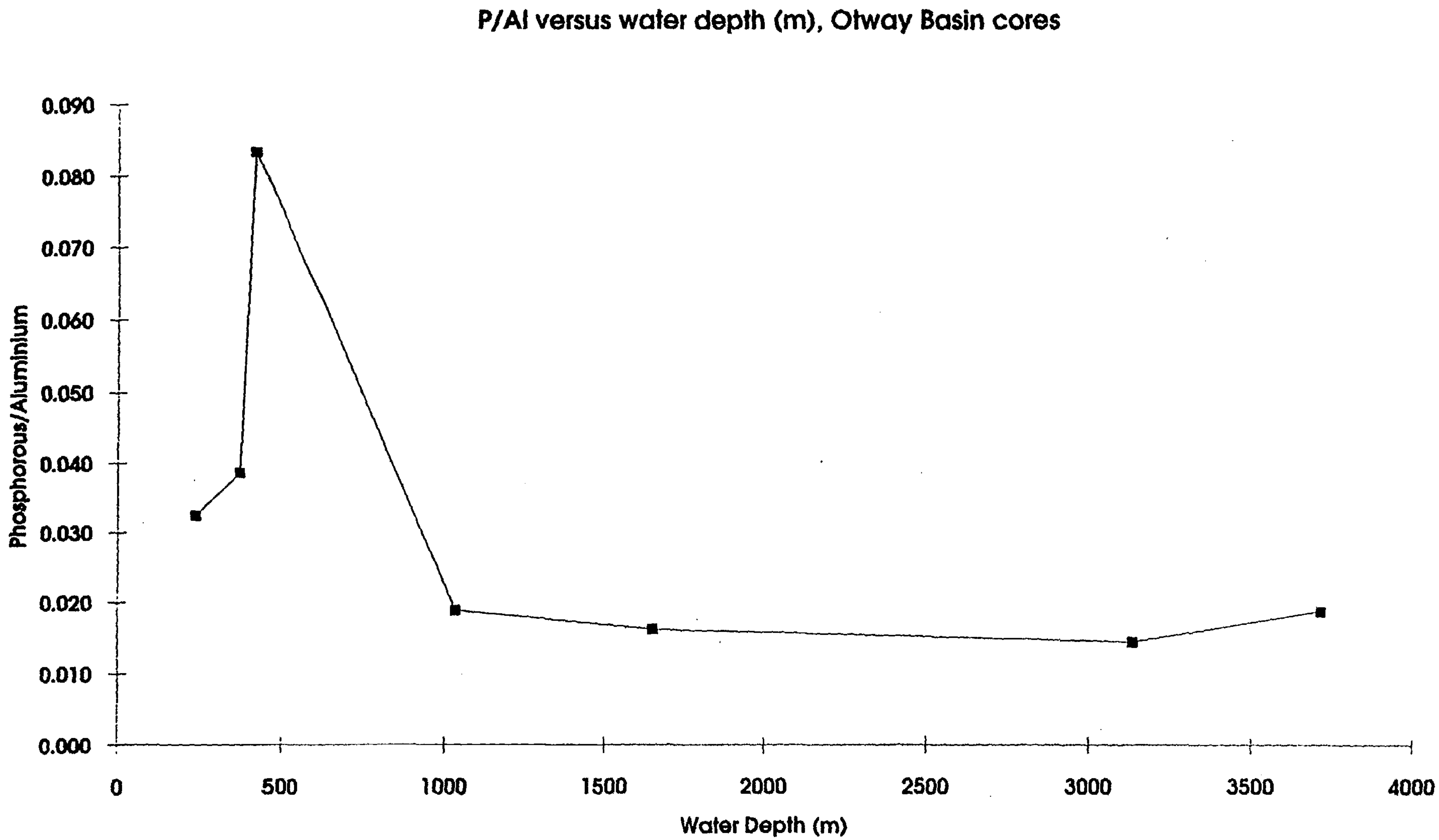


Figure 14 Core-top phosphorous/Aluminium ratio plotted as a function of water depth

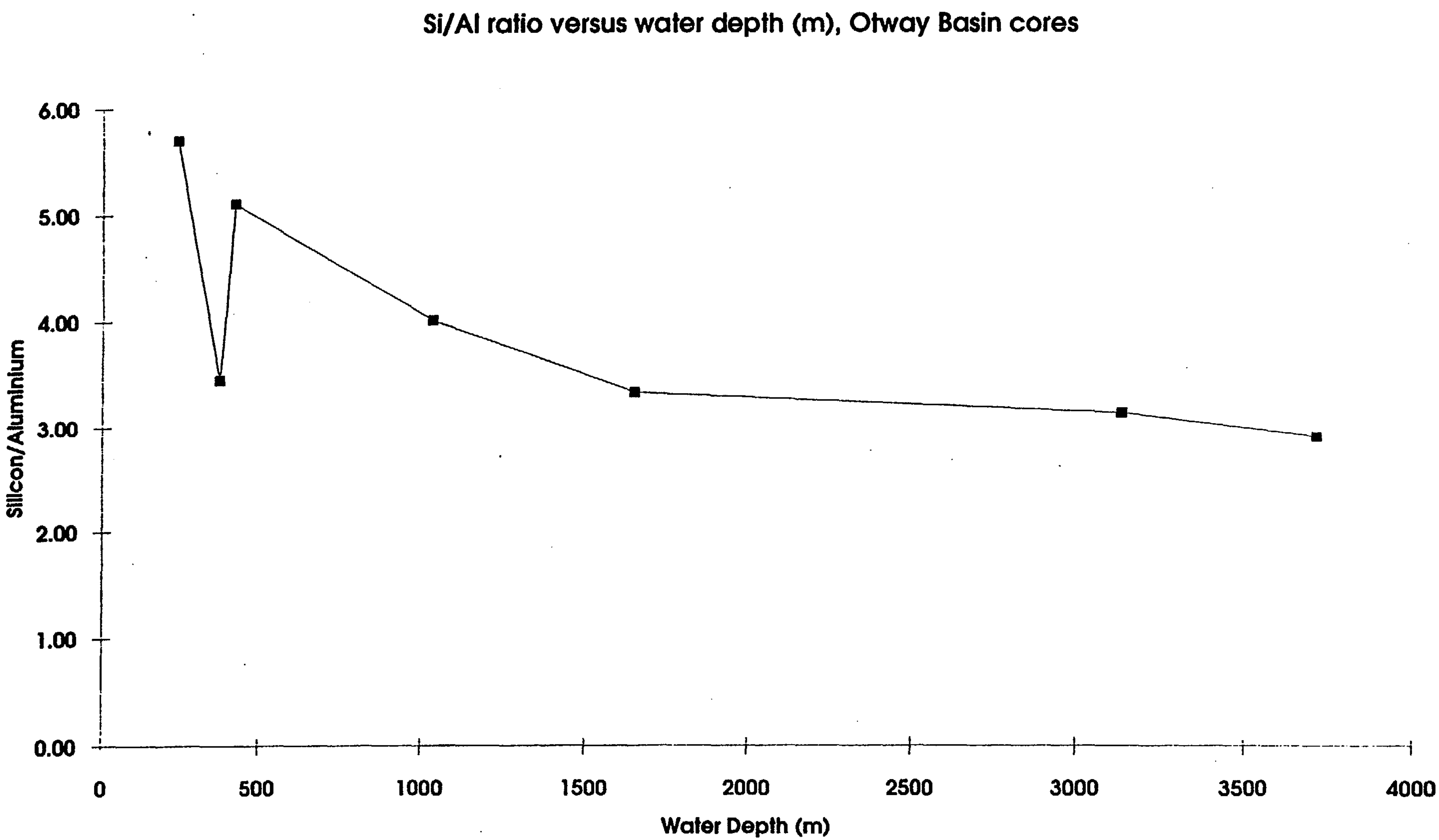


Figure 15 Core-top Silicon/Aluminium ratio plotted as a function of water depth

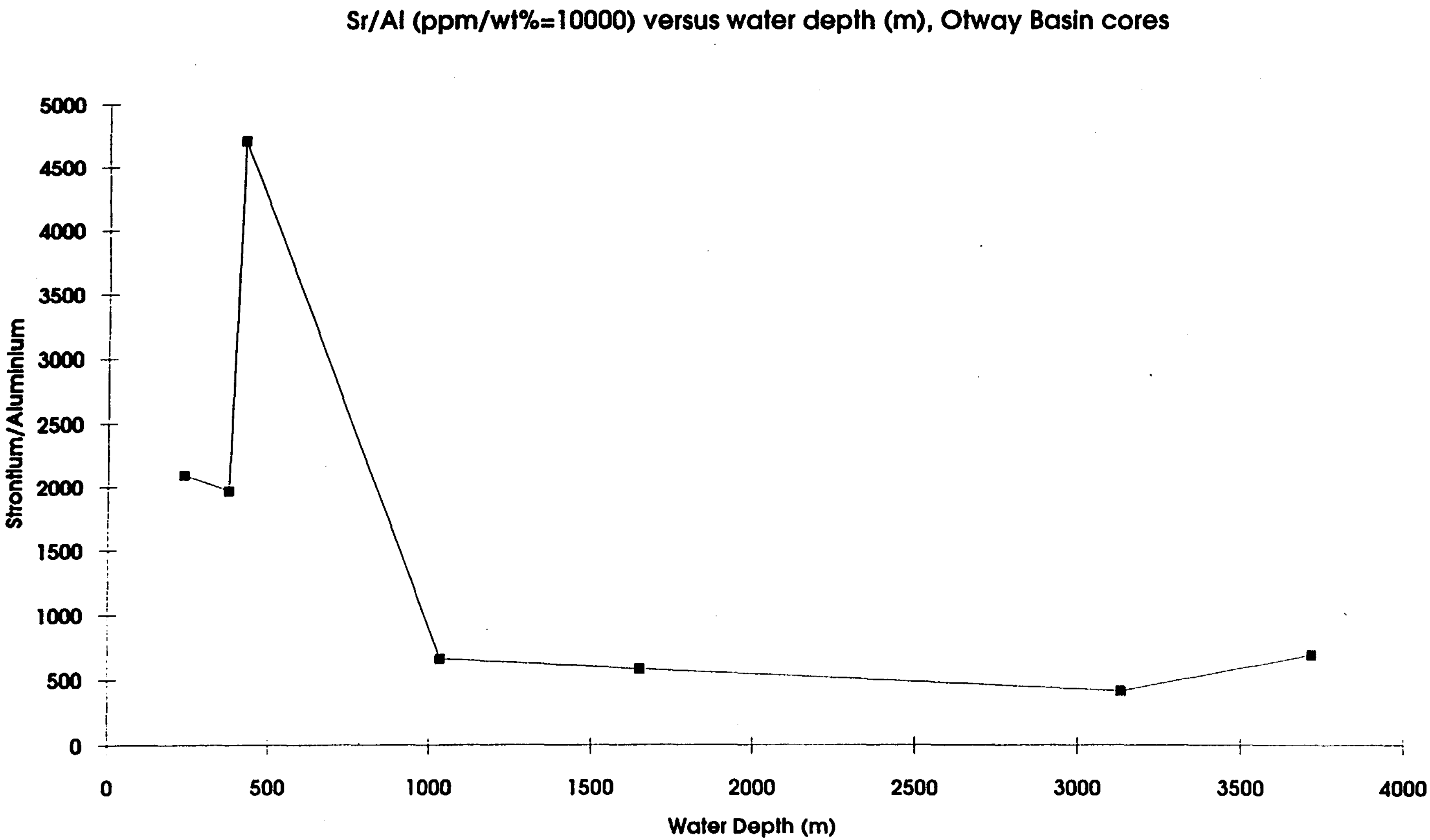


Figure 16 Core-top Strontium/Aluminium ratio plotted as a function of water depth

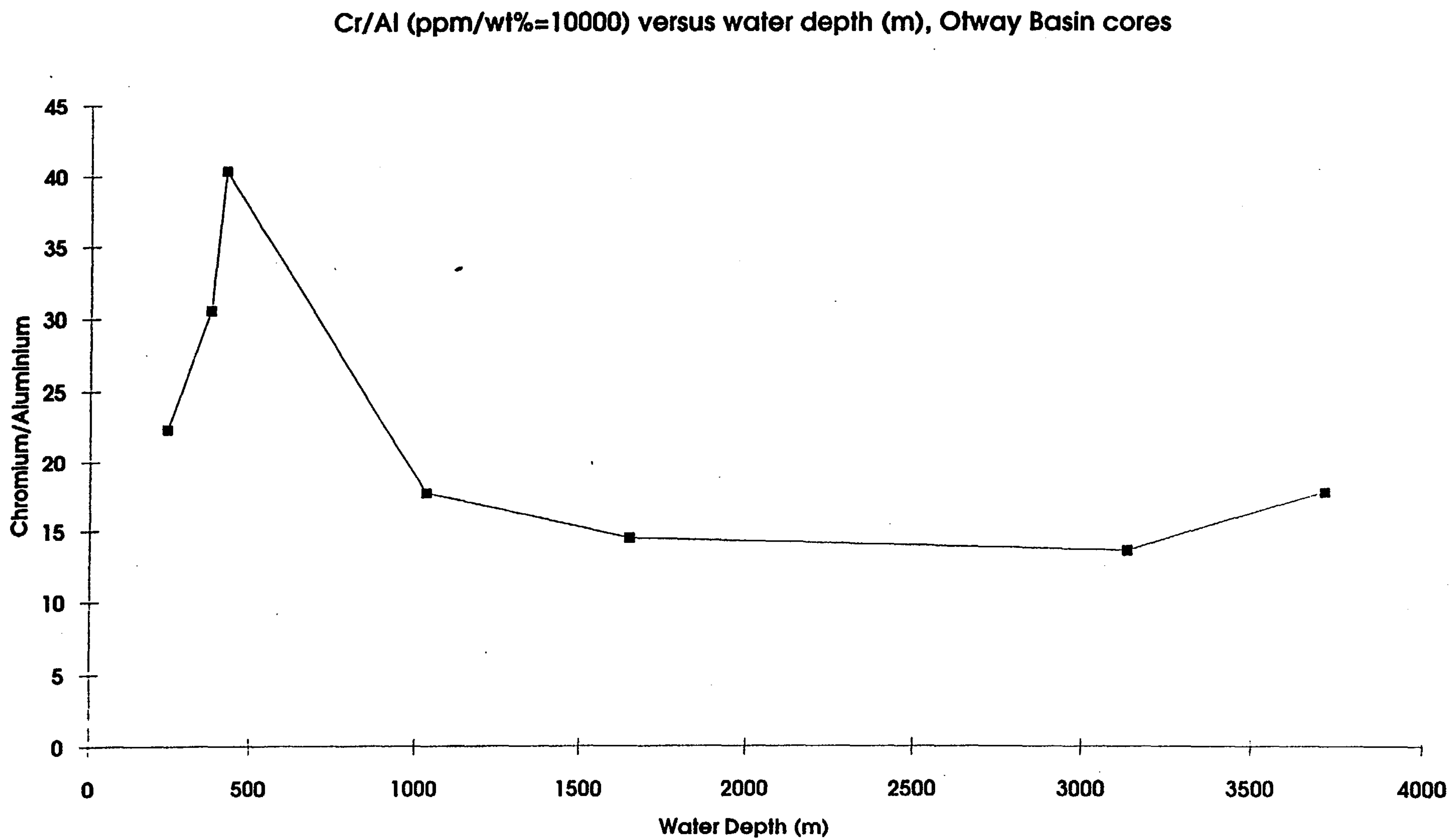


Figure 17 Core-top Chromium/Aluminium ratio plotted as a function of water depth

V/Al (ppm/wt%=10000) versus water depth (m), Otway Basin cores

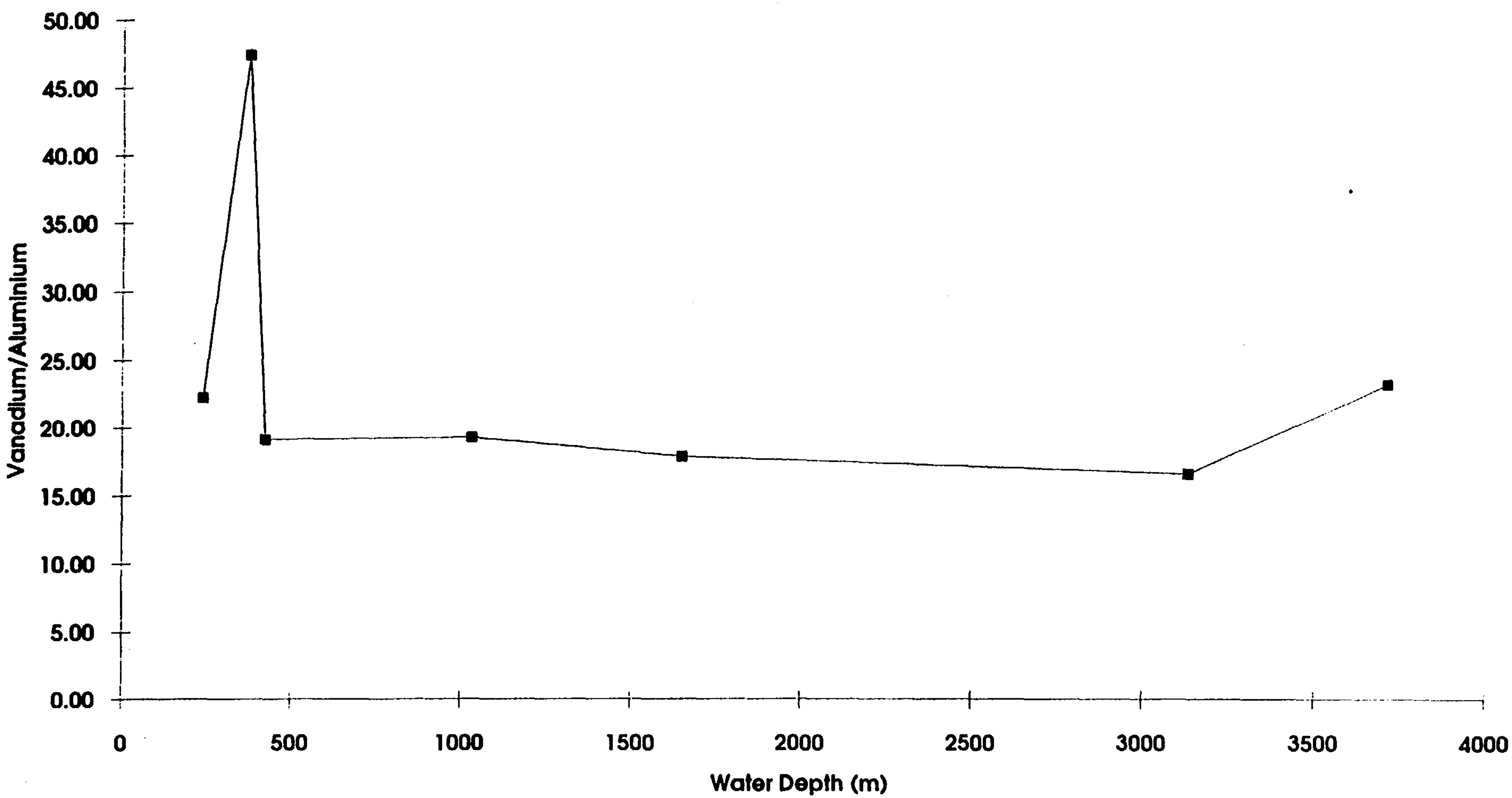


Figure 18 Core-top Vanadium/Aluminium ratio plotted as a function of water depth

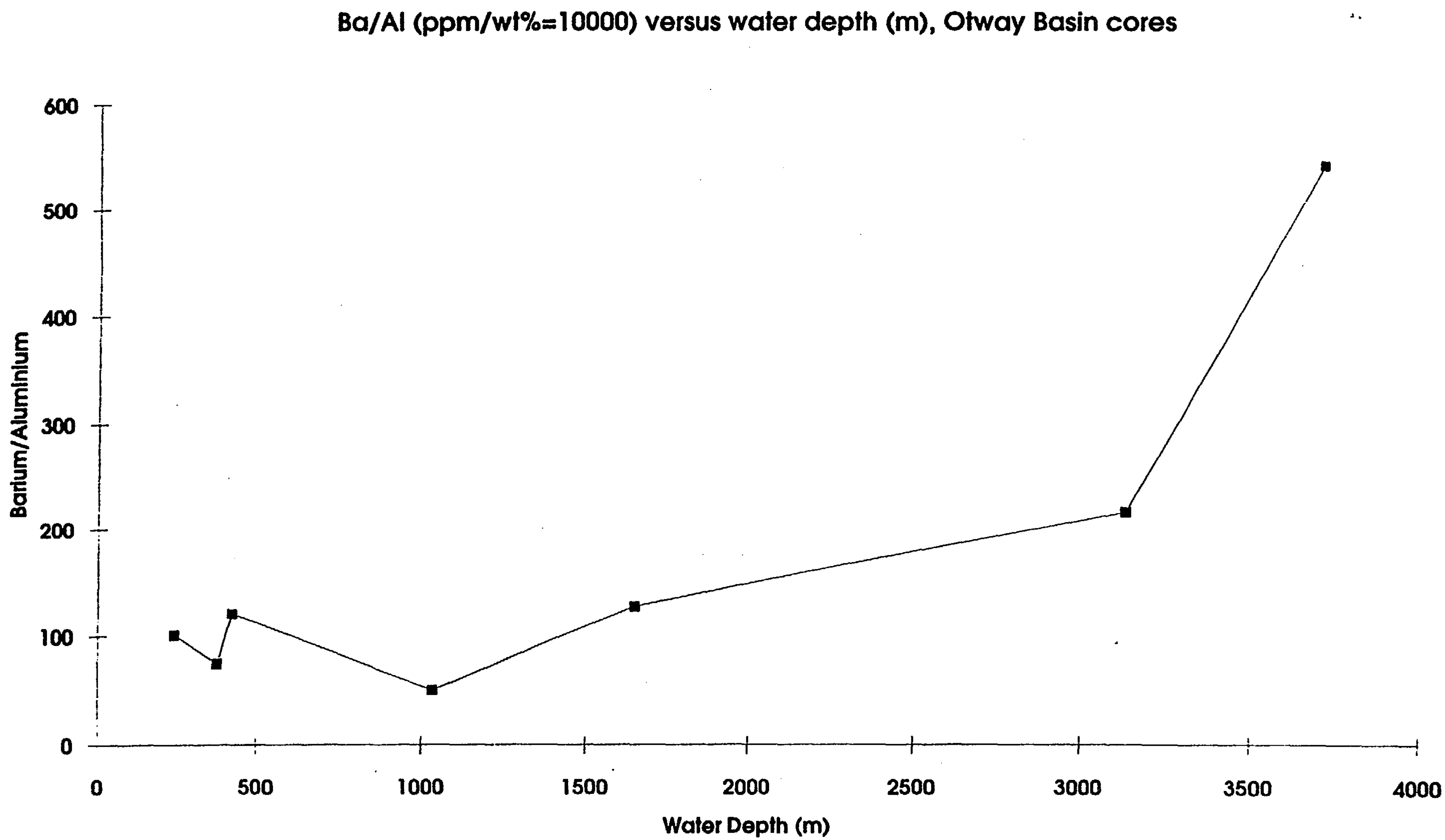


Figure 19 Core-top Barium/Aluminium ratio plotted as a function of water depth

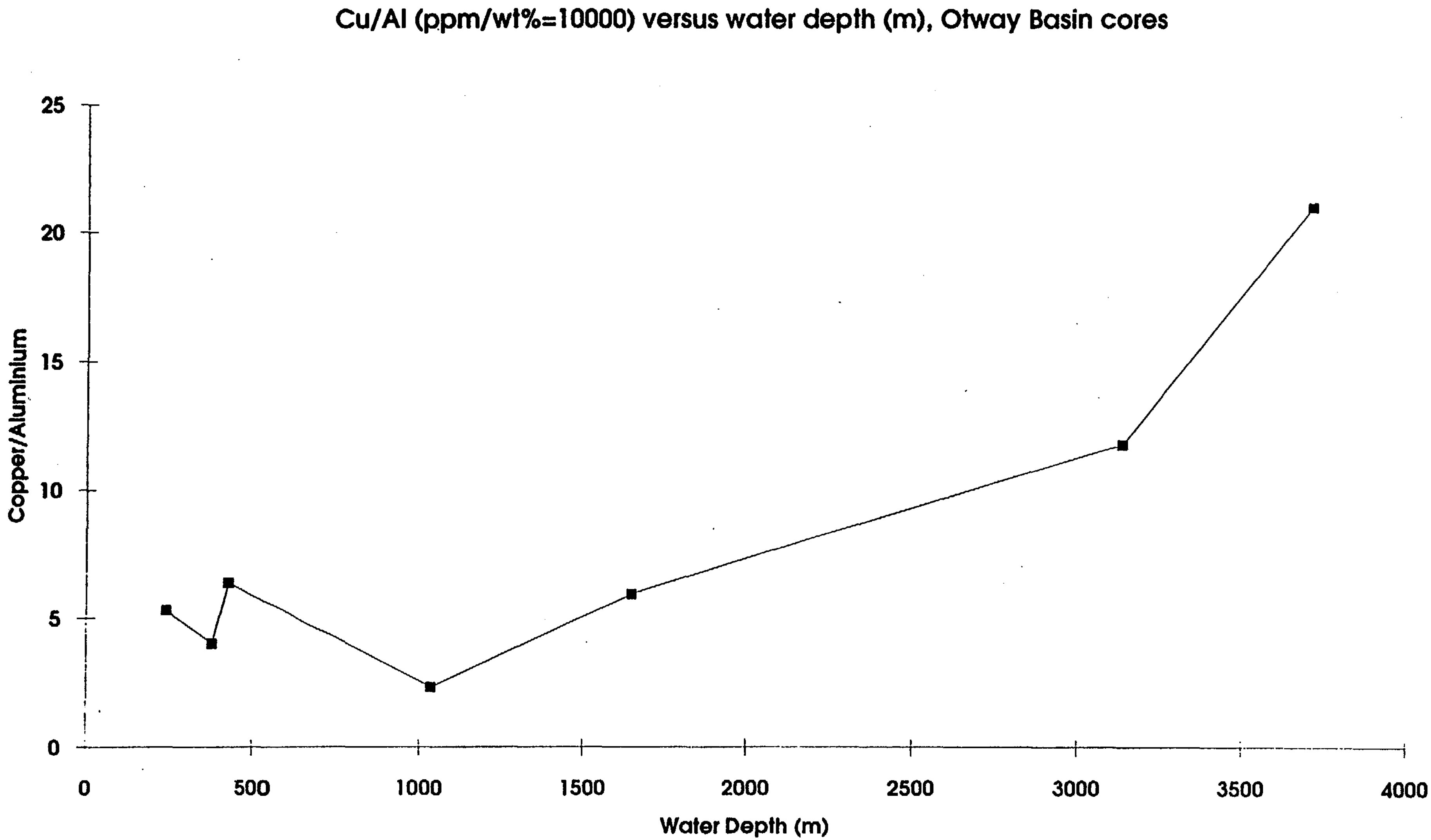


Figure 20 Core-top Copper/Aluminium ratio plotted as a function of water depth

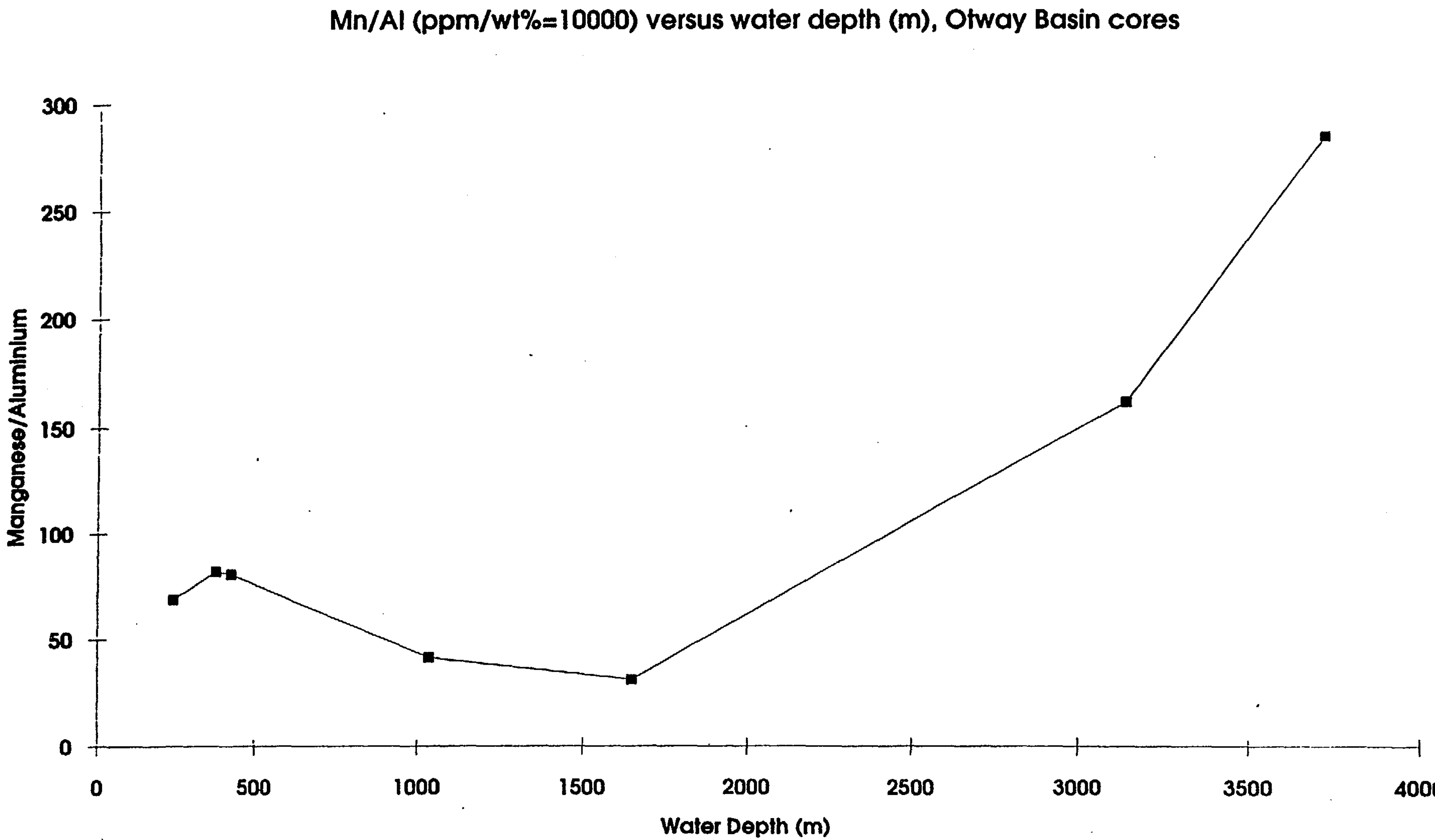


Figure 21 Core-top Manganese/Aluminium ratio plotted as a function of water depth

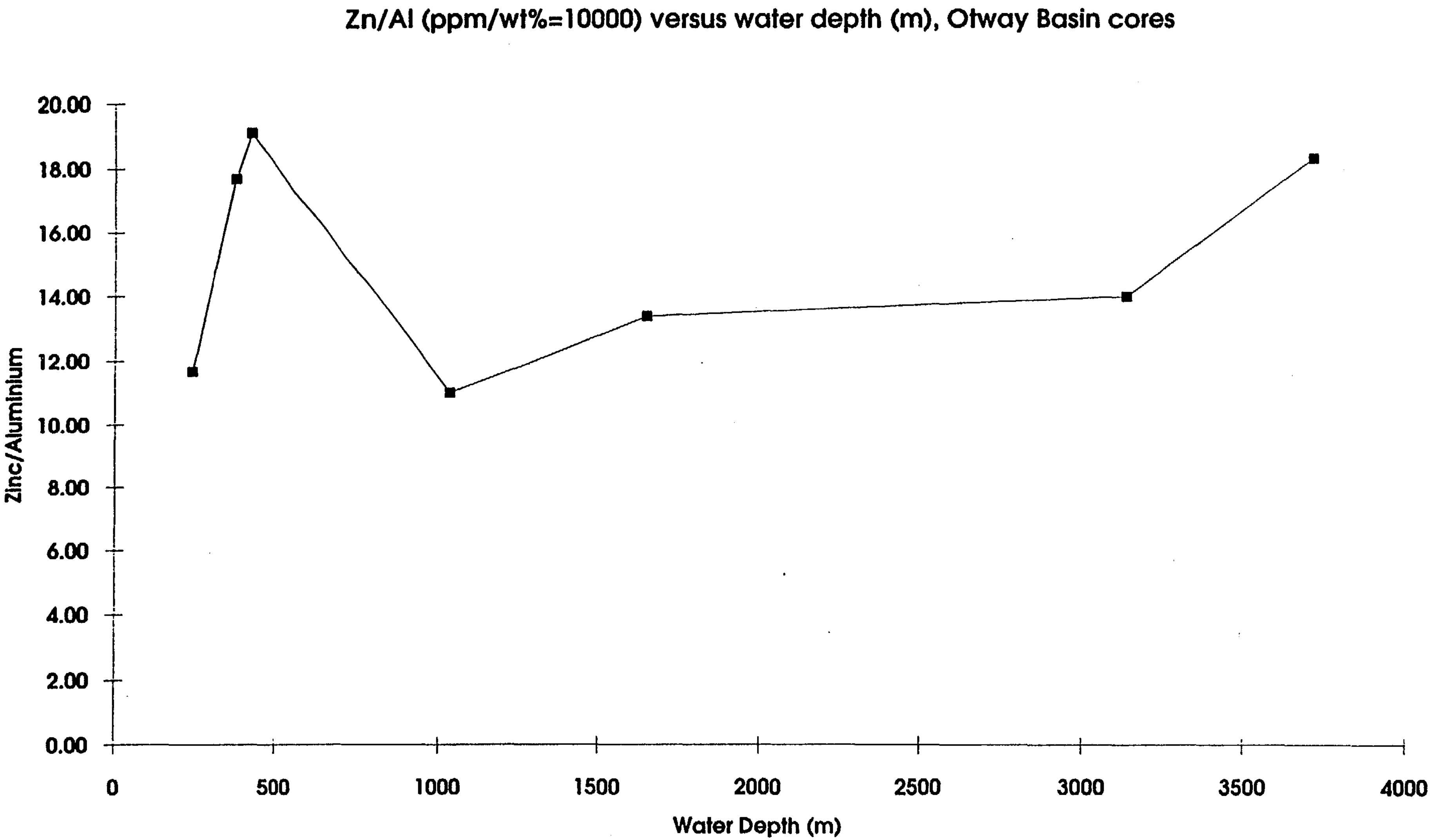


Figure 22 Core-top Zinc/Aluminium ratio plotted as a function of water depth

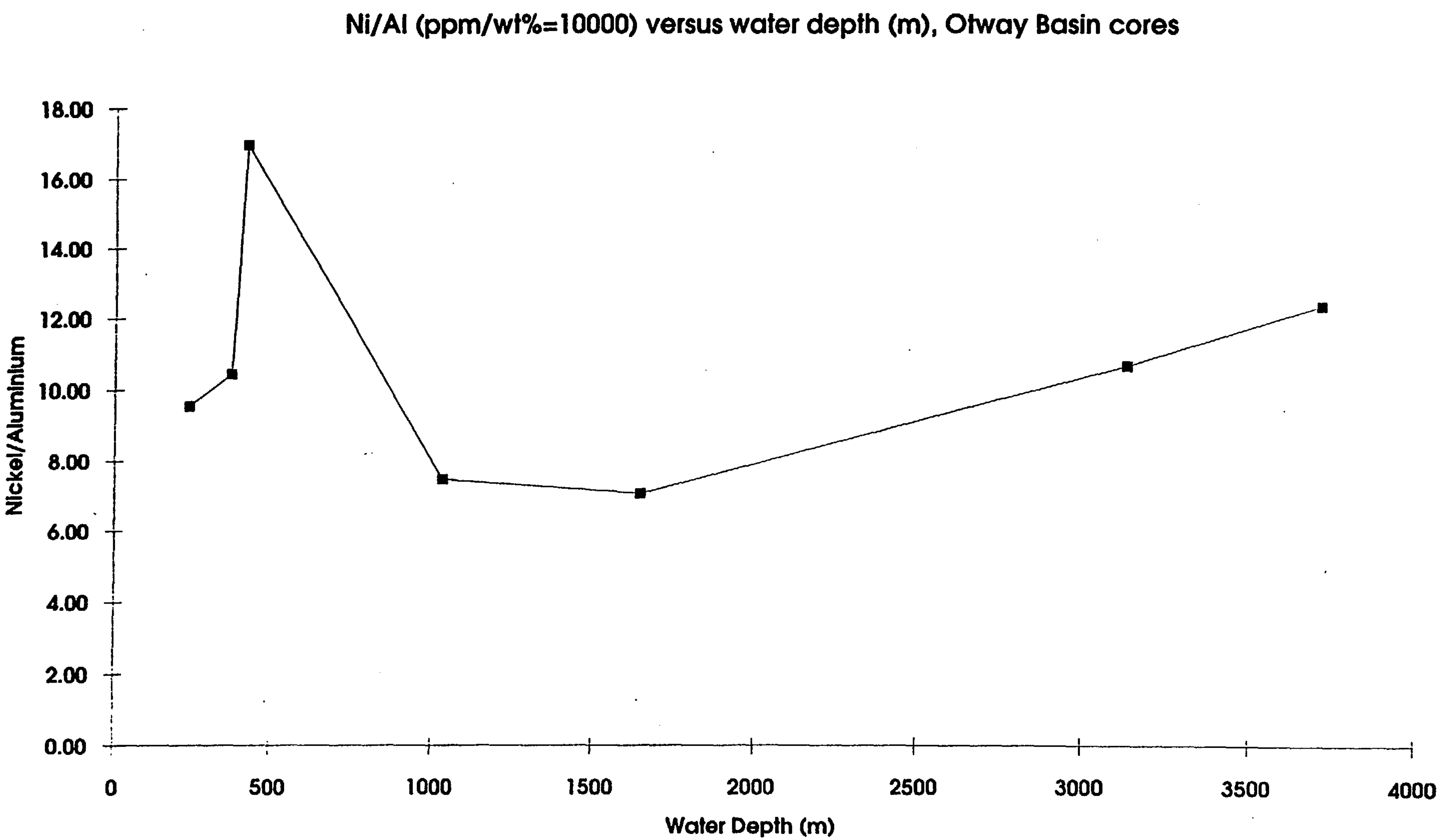


Figure 23 Core-top Nickel/Aluminium ratio plotted as a function of water depth

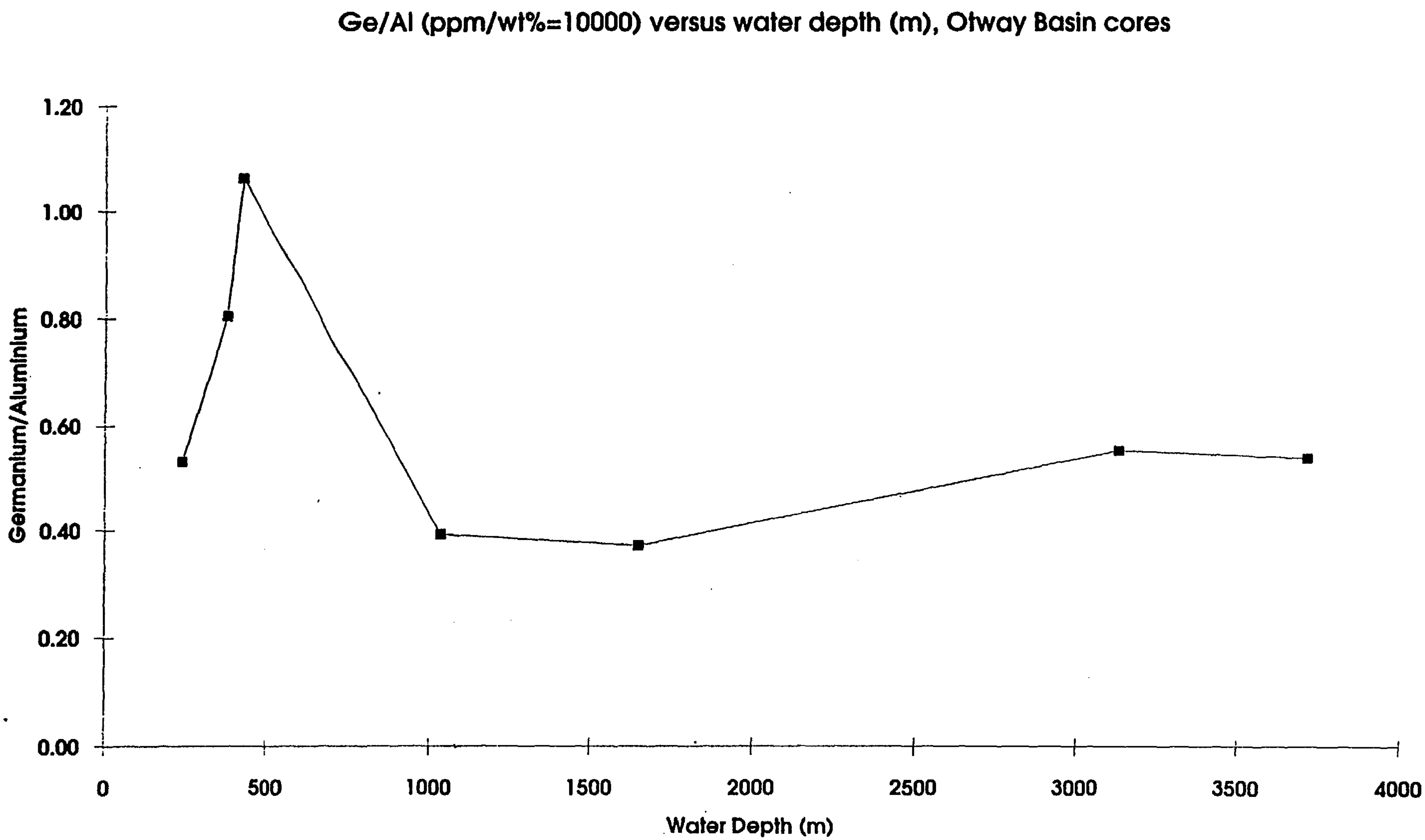


Figure 24 Core-top Germanium/Aluminium ratio plotted as a function of water depth

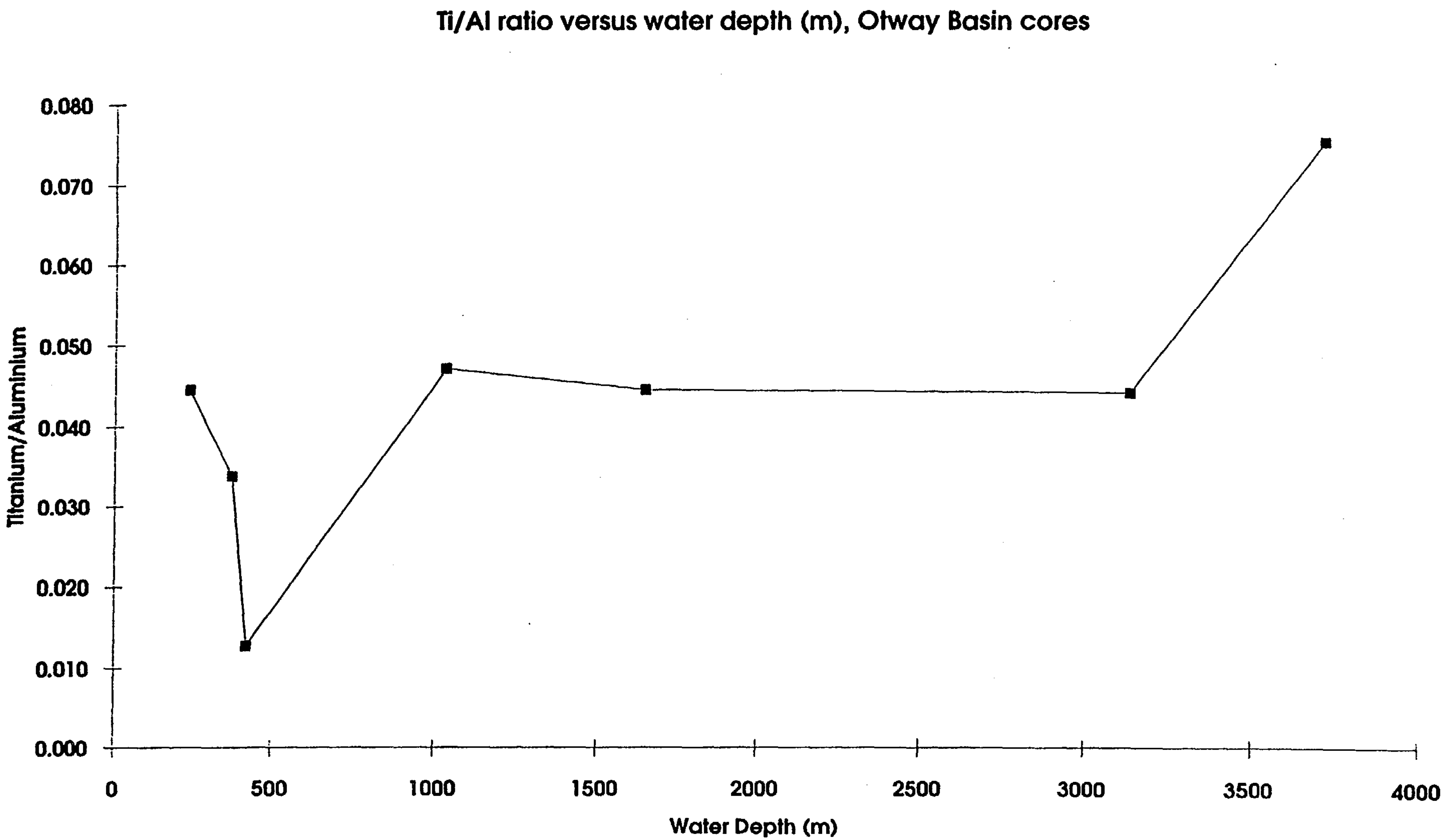


Figure 25 Core-top Titanium/Aluminium ratio plotted as a function of water depth

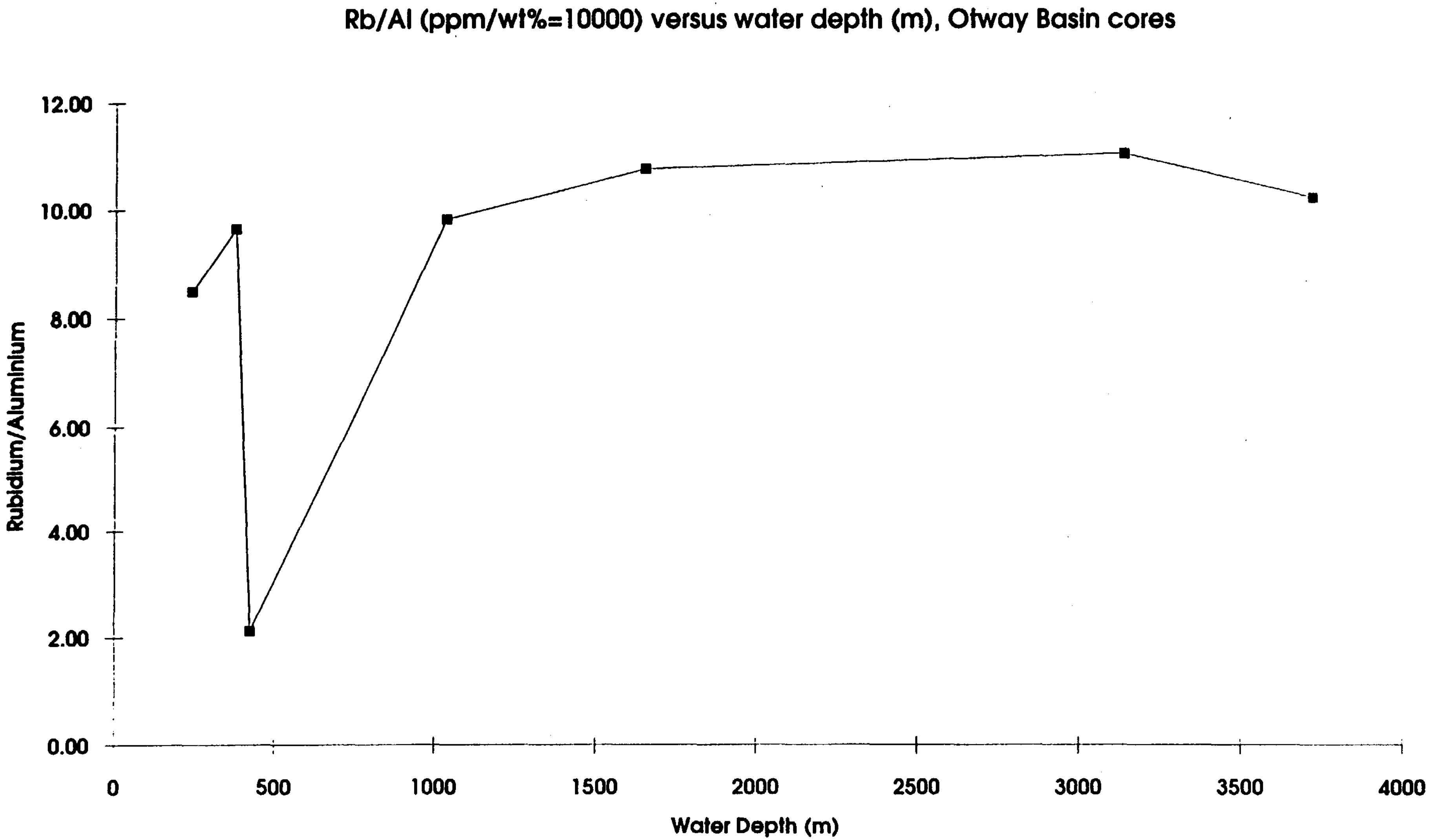


Figure 26 Core-top Rubidium/Aluminium ratio plotted as a function of water depth

Radiochemical data and palaeoceanographic indicators in sediments.

The sediments from two cores, 67GC12 and 67GC45, collected from the Otway Basin were analysed for their radiochemical properties to determine sedimentation rates. The results of these analyses are assembled in Tables 25-27, along with calcium carbonate, organic carbon and opaline silica contents of these sediments. An additional core, 67GC37, is presently being analysed at Flinders University of South Australia as part of a postgraduate degree and these data will ultimately form part of the data-base from the southern margin.

The down-core distributions of authigenic uranium in cores 67GC12A and 67GC45 show enrichments at depths of around 30-40 cm, and these are probably indicative of zones of precipitation of authigenic uranium which has diffused into the sediments from bottom waters and precipitated under anoxic conditions. The depth of this transition is being investigated as a possible palaeoceanographic indicator, and this work is continuing at Flinders University. The excess ^{230}Th shown here will be used to calculate sedimentation rates on this margin at Flinders University. The down-core distributions of calcium carbonate, organic carbon and opaline silica show variations which may be related to glacial/interglacial periods, changes in sea-level and palaeoceanographic conditions. However, until these cores have been dated these variations cannot be related to specific time-periods.

Several of those elements discussed previously phosphorus, barium, copper, germanium, nickel, strontium and zinc, the redox species including manganese, vanadium and chromium, and rubidium, total silicate and titanium have been normalised to the corresponding aluminium abundance and these data for several cores are summarised in Appendix 4. Select profiles of data from two cores 67GC12A (Victoria) and 67GC45 (West Tasmania) collected between water depths of about 3100 and 3800 m, are illustrated in Figures 27 through 36. These include down-core profiles of phosphorus, barium, chromium, manganese and nickel. All other data-plots are included in Appendix 4. The element /aluminium abundance ratios for phosphorus, and chromium (and several other elements in the Appendix) are similar in the core-tops, indicating similar fluxes of these materials to the seafloor over this geographic area. The barium/aluminium ratio in the core from West Tasmania has about twice the abundance of barium than the core from offshore Victoria, and these comparisons suggest (because barium has often been used as a proxy indicator of diatom productivity), an increased flux of organic matter to the seafloor at this more southern location. The down-core distributions of phosphorus, barium and chromium are similar between sites, and suggest similar palaeoceanographic conditions in both regions. However, the down-core variations cannot be discussed in detail until sedimentation rates can be determined. The down-core distribution of manganese is very different from those mentioned above, and these differences reflect the diagenetic influence of manganese remobilisation and redistribution in sediments. Similarly, nickel which is known to be recycled with manganese, shows similar down-core distributions, and the elements are therefore not useful palaeoceanographic indicators.

Table 25 Radiochemical data, percent calcium carbonate, percent organic-carbon and percent opaline silica for core 67GC12A

Survey	Core	Depth (cm)	CaCO3 (%)	Corg (%)	Opal (%)	U (ppm)	Th (ppm)	234U/238U	230Th (dpm/g)	230Thx (dpm/g)
67	GC12A	0-3	64.2	0.48	0.57	0.85	4.75	0.96+/-0.05	7.69	7.06
		7-12	63.2	0.42	0.44	0.89	4.39	0.99+/-0.04	7.24	6.58
		15-19	62.1	0.38	0.48	0.84	3.88	0.95+/-0.04	5.78	5.16
		30-33	57.7	0.38	0.56	1.49	4.43	1.06+/-0.03	5.99	5.12
		40-43	53.9	0.43	0.58	4.6	4.24	1.13+/-0.02	4.6	3.77
		50-53	55.7	0.32	0.48	2.81	4.73	1.09+/-0.02	5.44	4.51
		60-63	53	0.34	0.59	1.41	4.6	1.06+/-0.03	5.3	4.33
		70-73	43.5	0.48	0.69	2	6.2	1.04+/-0.02	5.03	3.81
		80-83	42.8	0.48	0.72	-	-	-	-	-
		90-93	38.7	0.46	0.68	3.8	6.03	1.05+/-0.02	4.78	3.59
		110-113	38.3	0.46	0.79	3.05	6.38	1.03+/-0.03	4.82	3.57
		130-133	38.1	0.63	0.91	3.42	6.74	1.09+/-0.02	6.02	4.69
		150-153	58.9	0.4	-	1.68	4.43	1.10+/-0.02	6.46	5.42
		170-173	44.5	0.64	-	-	-	-	-	-
		190-193	35.4	0.59	-	3.41	6.94	1.10+/-0.02	4.39	3.03

Table 26 Percent opaline silica content of core 67GC37

Survey	Core	Depth (cm)	Opal %
67	GC037	0-3	0.39
		10-14	0.43
		30-33	0.51
		50-53	0.4
		70-73	0.52
		90-93	0.52
		110-113	0.46
		130-133	0.52
		150-153	0.48
		170-173	0.53
		190-193	0.51

Table 27 Radiochemical data, percent calcium carbonate, percent organic-carbon and percent opaline for core 67GC45

Survey	Core	Depth (cm)	CaCO3 (%)	Corg (%)	Opal (%)	U (ppm)	Th (ppm)	234U/238U	230Th (dpm/g)	230Thx (dpm/g)
67	GC45	0-3	74.8	0.36	0.71	0.58	2.45	0.96+/-0.04	11.82	11.39
	GC45	6-10	75.5	0.32	0.72	0.57	2.61	1.00+/-0.04	11.25	10.83
	GC45	14-17	74.2	0.22	0.71	0.58	2.57	0.97+/-0.04	8.99	8.56
	GC45	20-23	66.4	0.25	0.7	0.71	3.33	0.93+/-0.03	6.71	6.18
	GC45	30-33	60.8	0.53	0.74	0.9	3.76	0.93+/-0.03	6	5.33
	GC45	40-43	58.2	0.43	0.69	5.91	4.37	1.07+/-0.02	5.59	4.73
	GC45	50-53	57.3	0.54	0.71	4.03	4.32	1.09+/-0.03	5.36	4.52
	GC45	60-63	56.2	0.48	0.73	3.13	4.26	1.07+/-0.02	5.63	4.79
	GC45	70-73	55.9	0.48	0.81	3.87	3.66	1.06+/-0.02	6.86	6.14
	GC45	90-93	52.6	0.45	0.84	3.33	2.73	1.11+/-0.02	5.15	4.62
	GC45	110-113	48.6	0.48	0.92	4.33	4.6	1.08+/-0.02	4.35	3.45
	GC45	130-133	58.5	0.42	0.72	2.93	3.48	1.04+/-0.02	4.52	3.84
	GC45	150-153	43.1	0.57	0.93	5.47	5.07	1.09+/-0.03	4.05	4.18
	GC45	170-173	63.5	0.27	0.77	1.43	2.78	1.09+/-0.03	4.05	3.5
	GC45	190-193	70.6	0.35	-	1.99	2.46	1.19+/-0.05	2.31	1.83

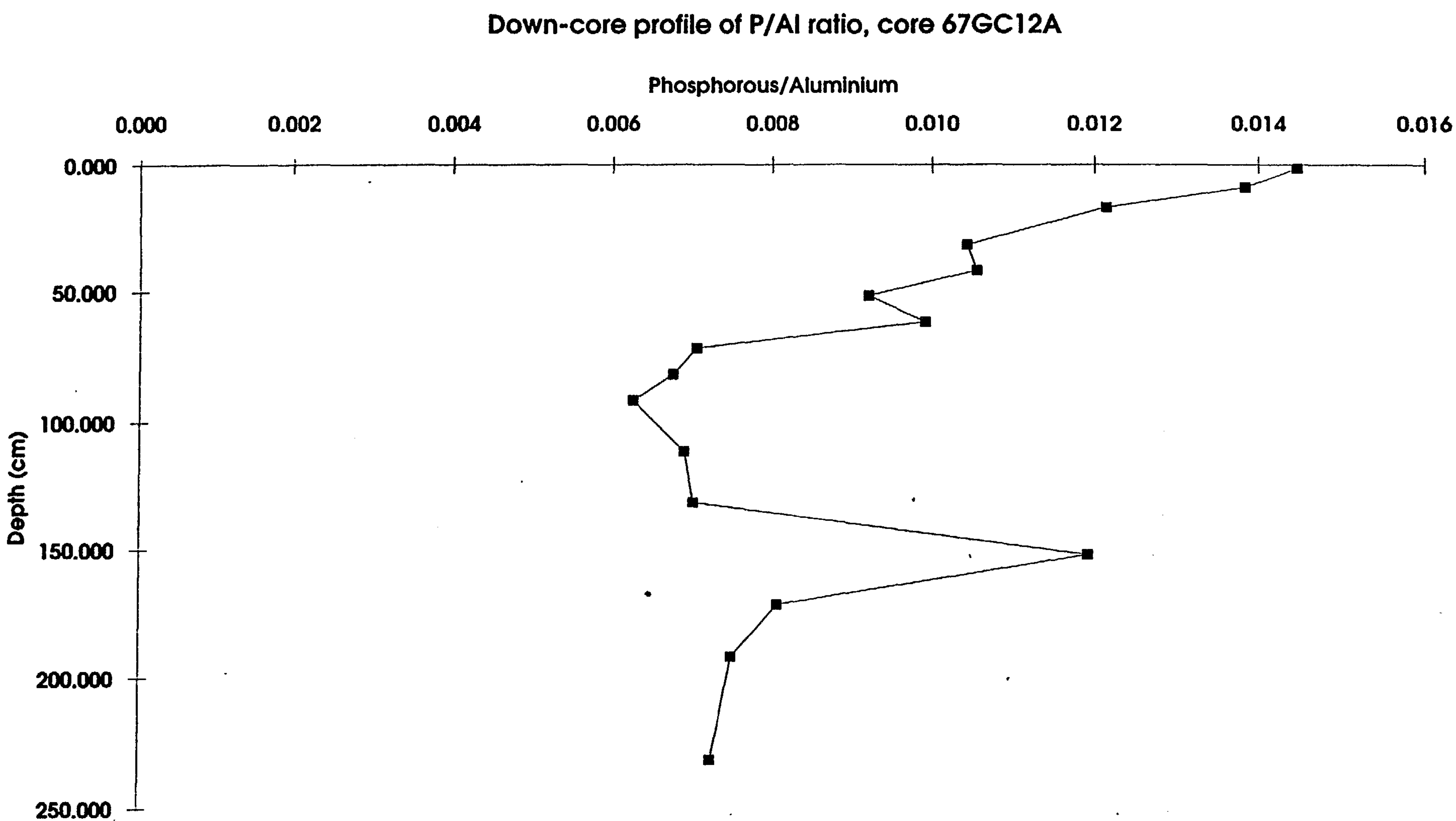


Figure 27 Down core profile of Phosphorous/Aluminium ratio, core 67GC12A

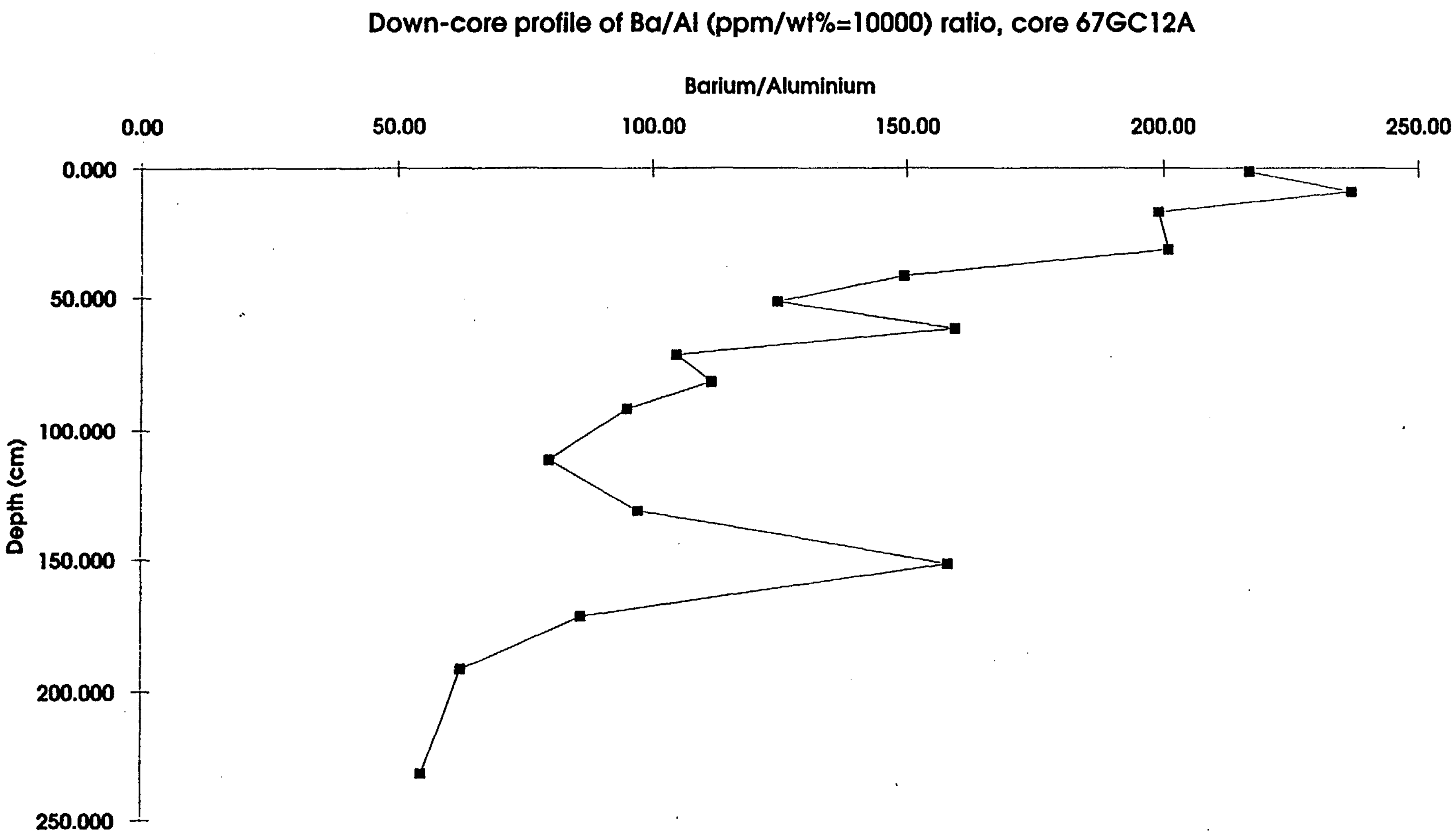


Figure 28 Down core profile of Barium/Aluminium ratio, core 67GC12A

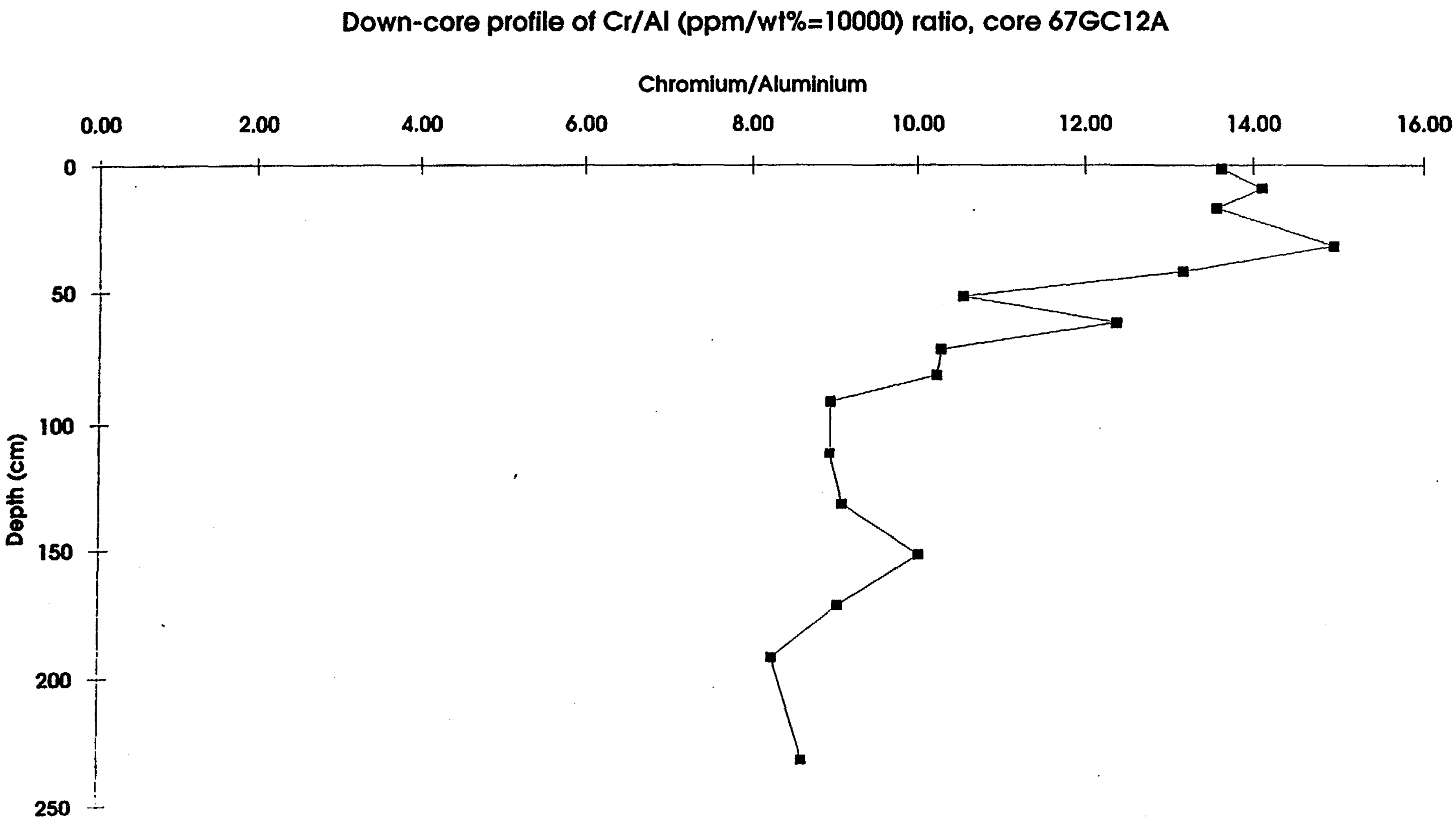


Figure 29 Down core profile of Chromium/Aluminium ratio, core 67GC12A

Down-core profile of Mn/Al (ppm/wt%=10000) ratio, core 67GC12A

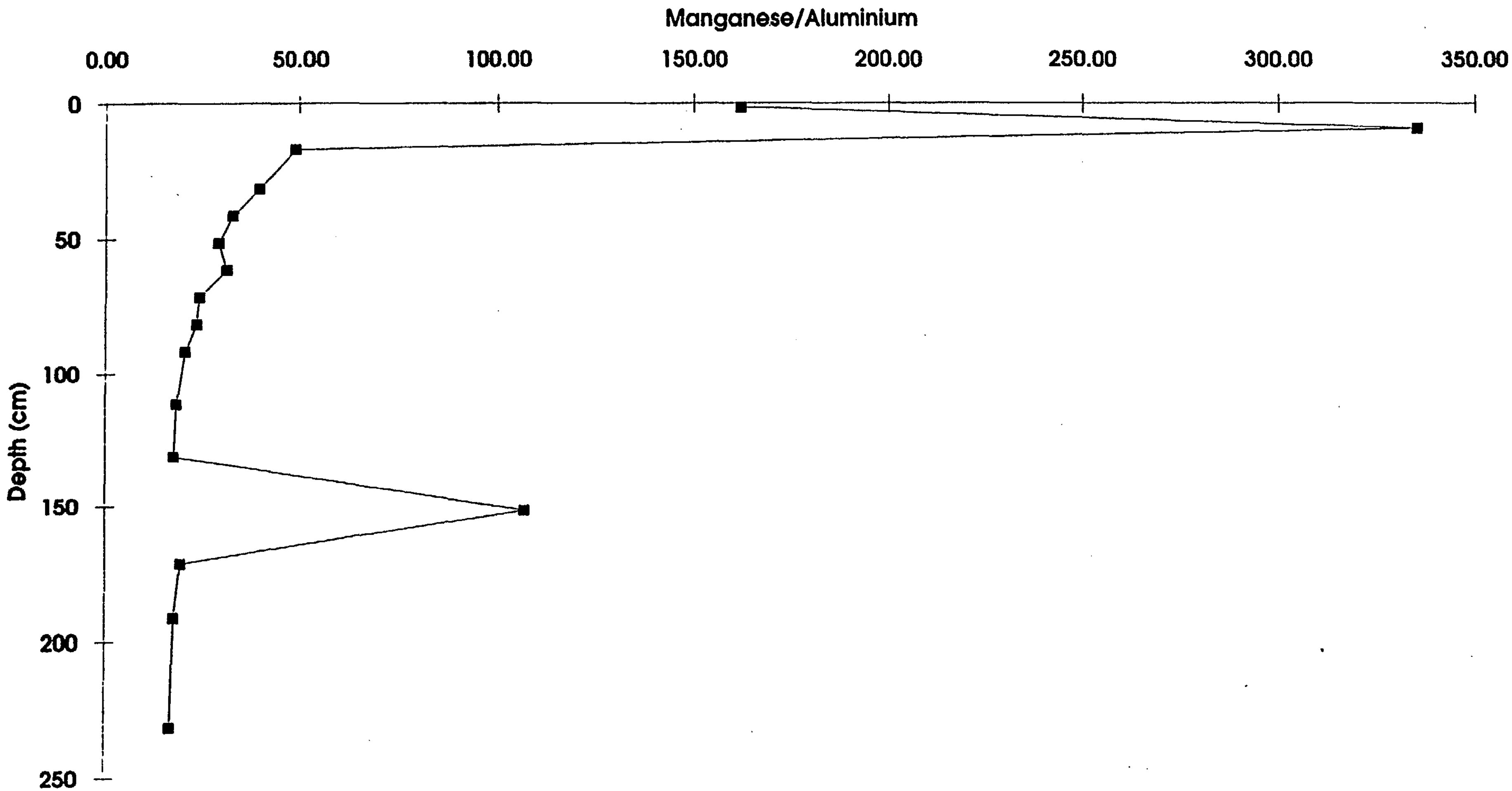


Figure 30 Down core profile of Manganese/Aluminium ratio, core 67GC12A

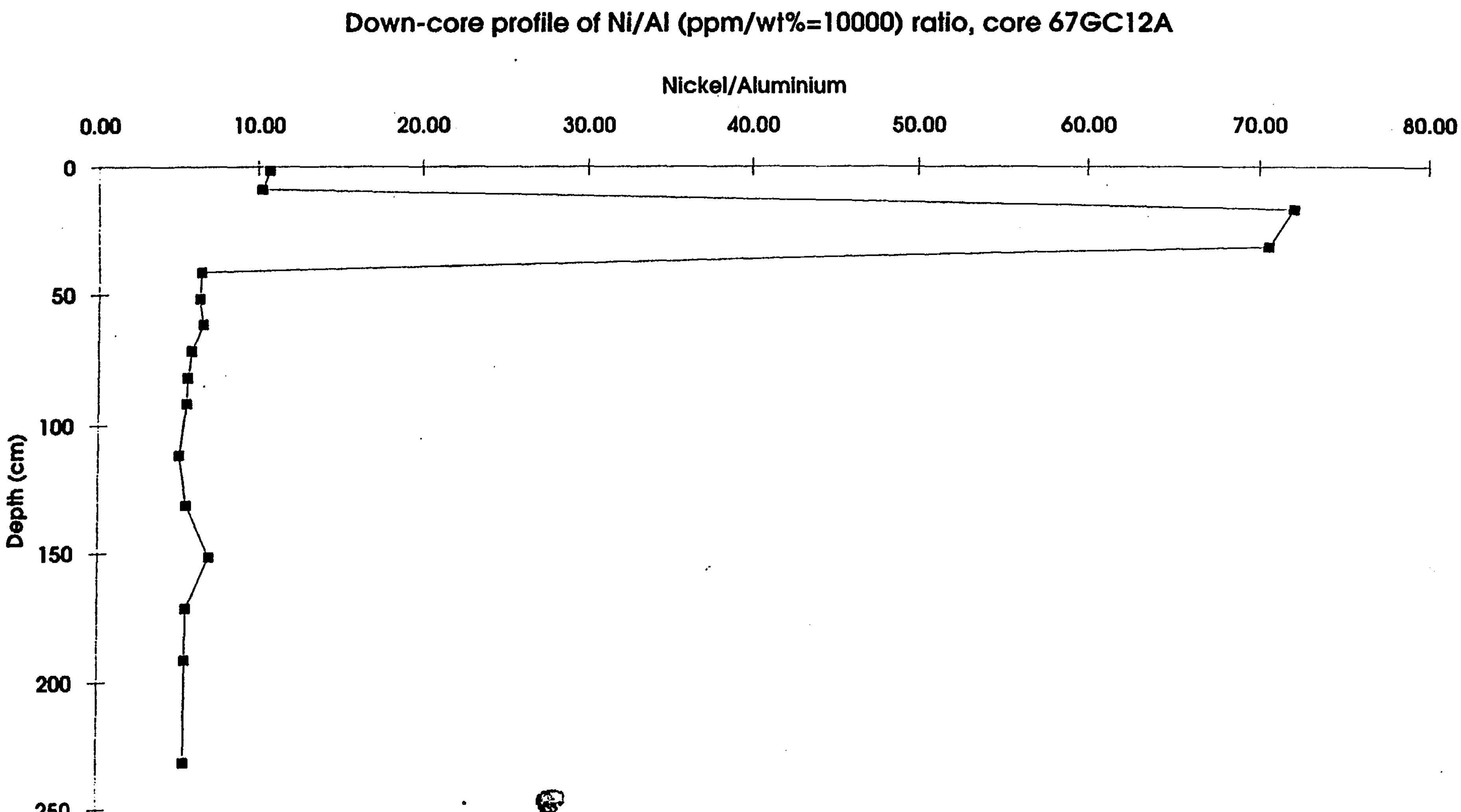


Figure 31 Down core profile of Nickel/Aluminium ratio, core 67GC12A

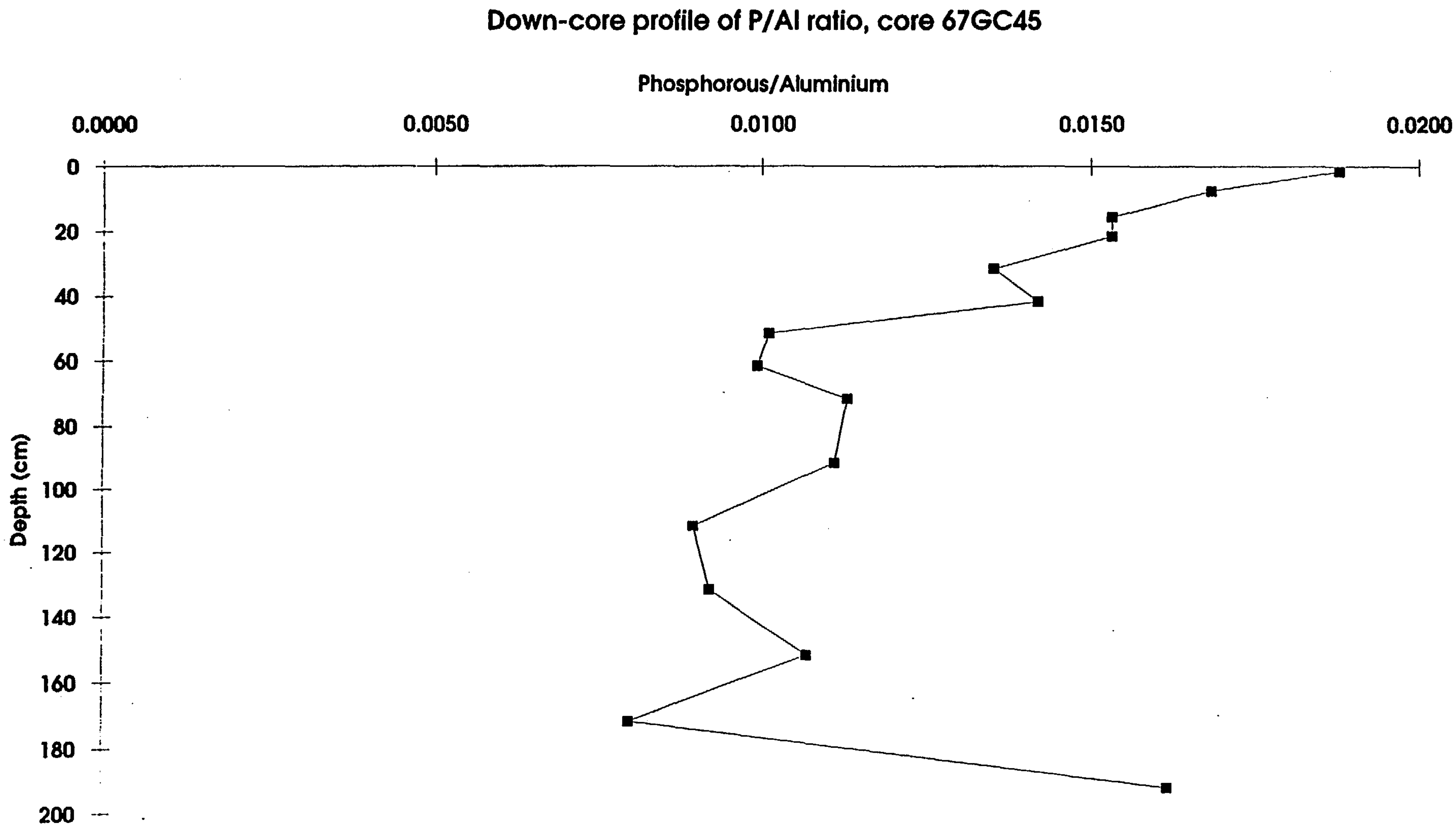


Figure 32 Down core profile of Phosphorous/Aluminium ratio, core 67GC45

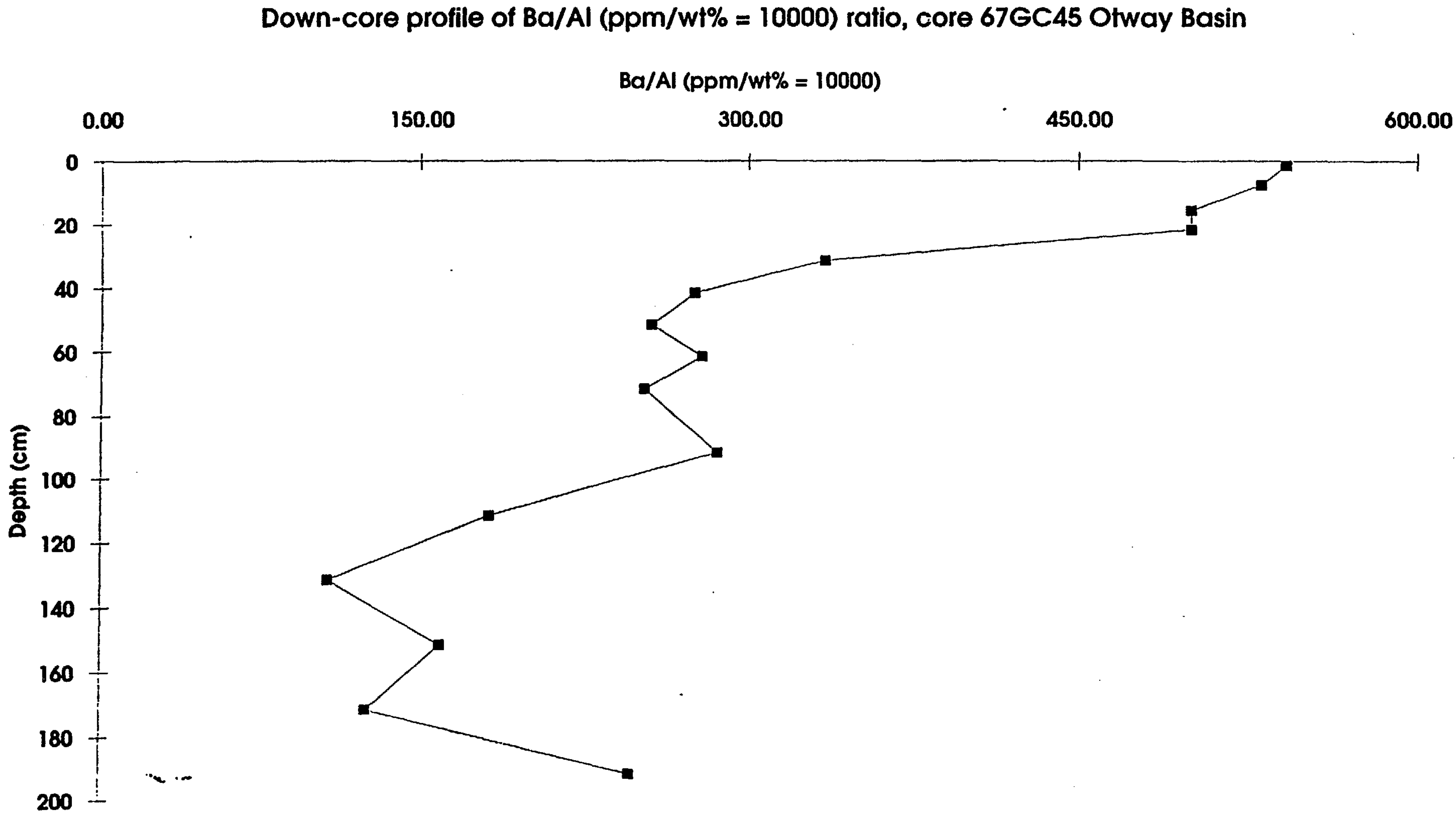


Figure 33   Down core profile of Barium/Aluminium ratio, core 67GC45

Down-core profile ofCr/Al (ppm/wt% = 10000) ratio, core 67GC45 Otway Basin

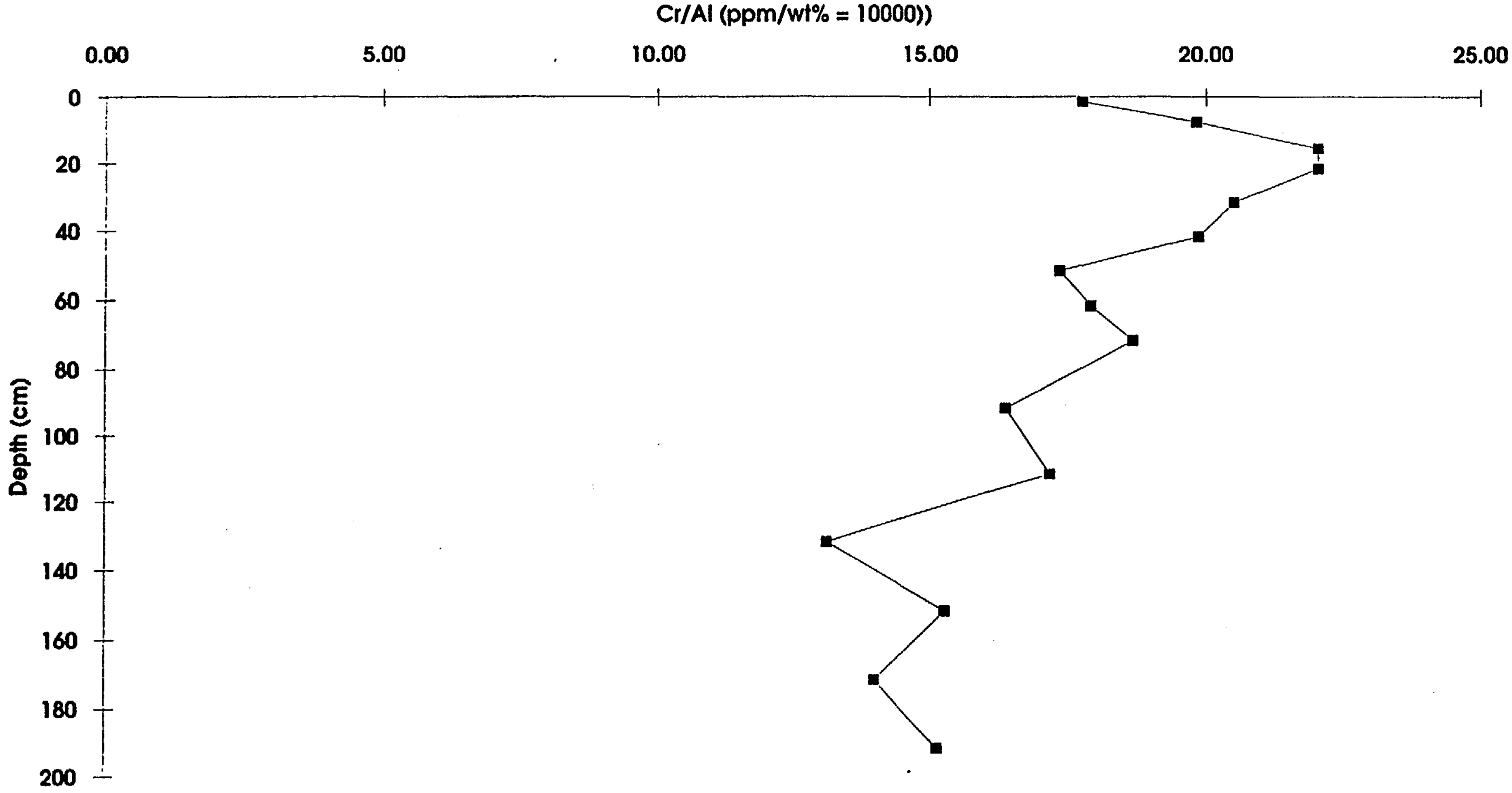


Figure 34 Down core profile of Chromium/Aluminium ratio, core 67GC45

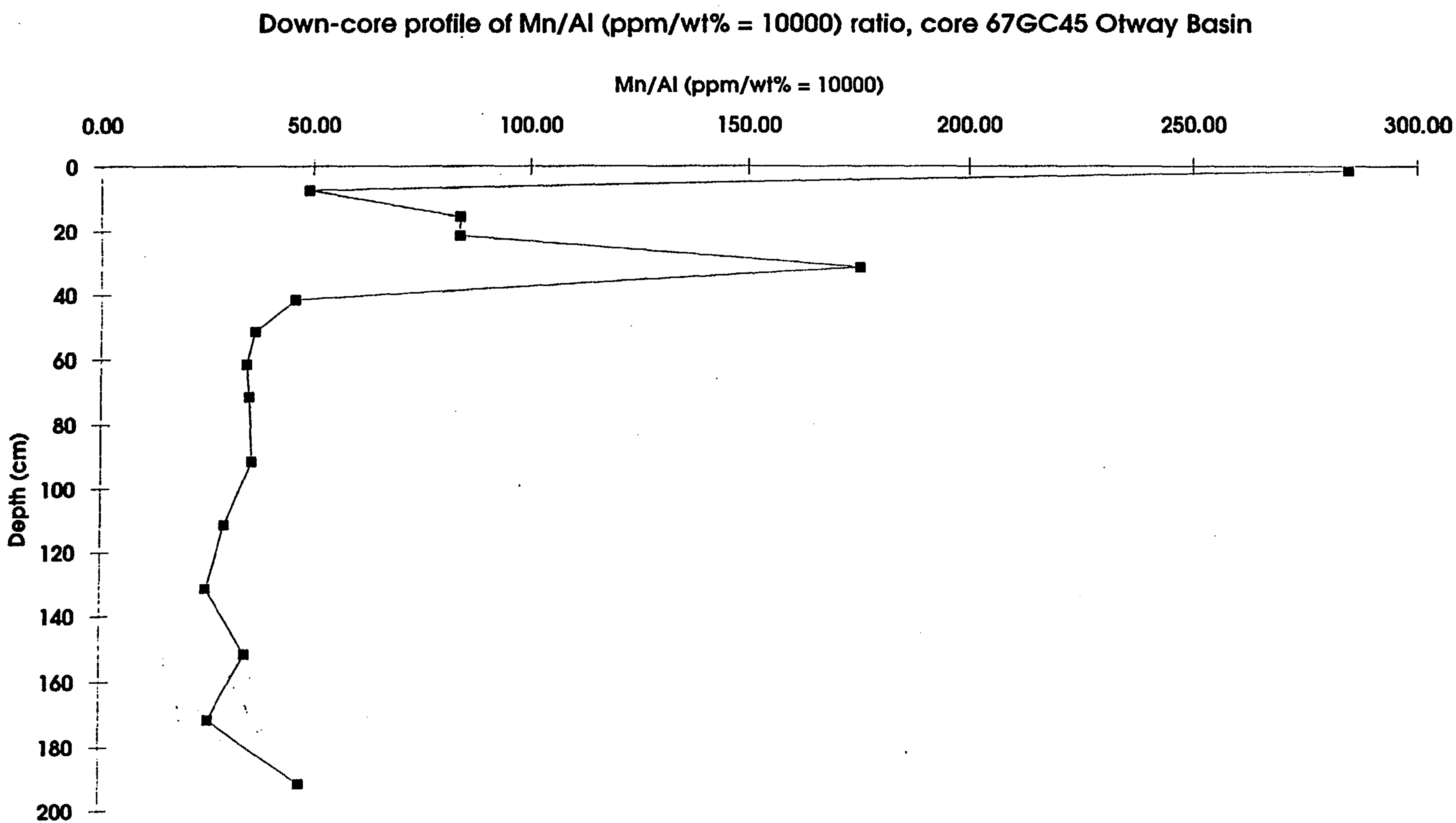


Figure 35 Down core profile of Manganese/Aluminium ratio, core 67GC45

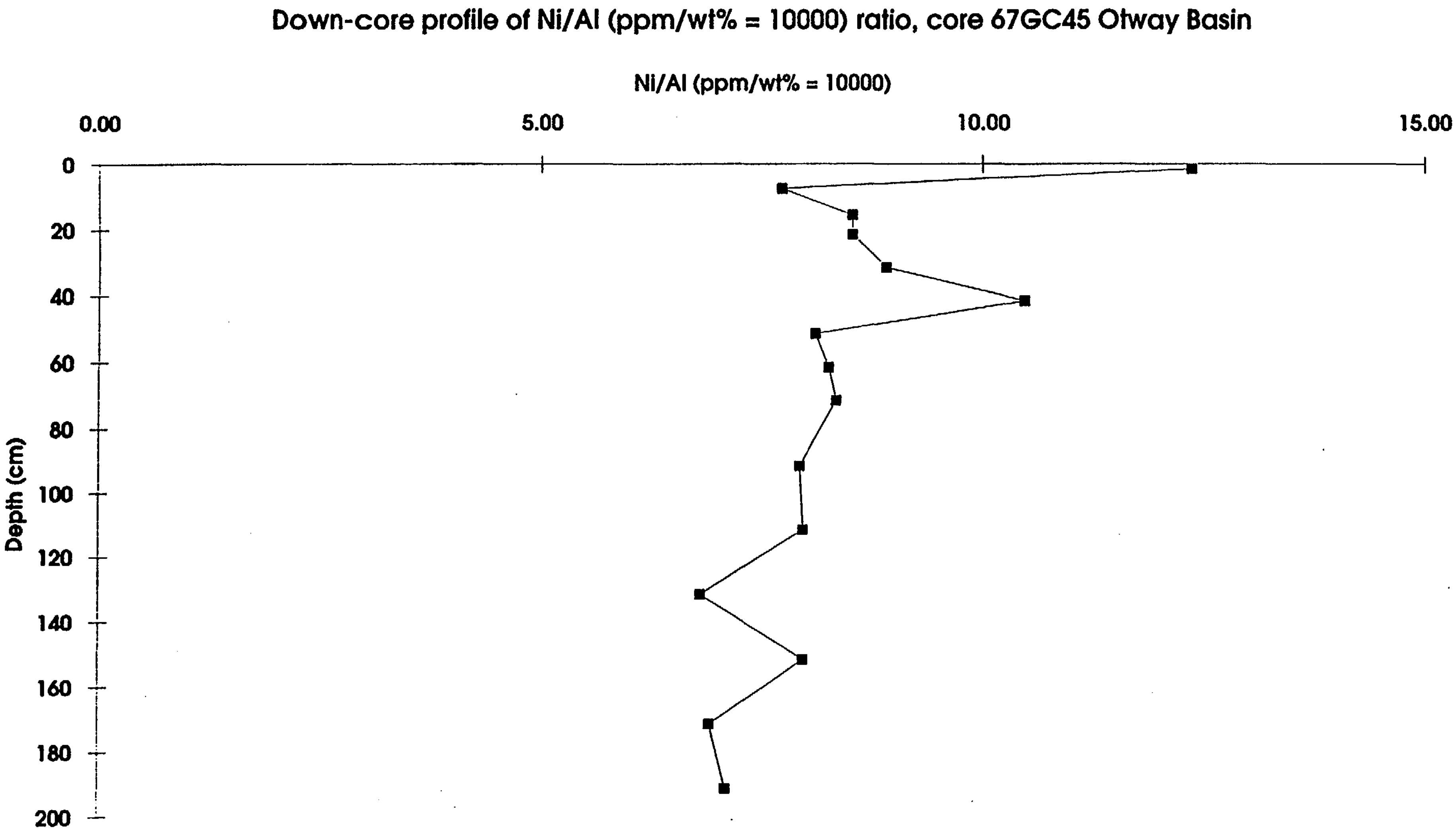


Figure 36 Down core profile of Nickel/Aluminium ratio, core 67GC45

SUMMARY

As part of BMR Survey 67 to offshore Victoria, South Australia and West Tasmania, a number of gravity cores have been analysed for a variety of geochemical properties and parameters. These cores analysed here were collected from water depths of between 377 and 4120 m. Many of the cores analysed here were also analysed for light hydrocarbon abundances and the geochemical data presented here complements existing data from this area (Exon and Lee, 1987; Exon and others, 1989 and Exon and others, 1992).

The major and minor element abundance for those gravity cores which were analysed for pore water metabolites are included here, along with additional pore water analyses conducted in Canberra. A brief perusal of the pore water data indicates elevated concentrations of ammonia which is indicative of sulphate reduction and anoxic sediments in the core-tops on those cores from the outer-shelf/upper slope. With increasing water depth, the surficial sediments appear to be sub-oxic with manganese reduction and remobilisation occurring in the top few tens of centimetres. Pore water silicate profiles show maxima in the sediments and these may be indicative of silica uptake in the sediments associated with glauconite formation. In general, 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 and manganese).

When the abundances of select elements were normalised to aluminium and plotted as a function of water depth, results were obtained which are indicative of modern oceanographic/sedimentological processes occurring on this margin. First, phosphorus, silicon and strontium indicated higher abundances of these elements on the outer-shelf/upper slope than on the lower slope and this is indicative of increased biogenic material inputs to these sediments. In contrast, manganese, barium and copper indicated higher abundances of these elements in the lower-slope cores than the outer-shelf/upper-slope cores. Manganese, we hypothesise is recycled from anoxic upper-slope cores, as indicated by the low manganese inventory in those sediments, transported offshore by advective or mixing processes and subsequently scavenged from the deep -water column by a relatively high flux of sinking biogenic particulates near the edge of the STCZ (Sub-Tropical Convergence Zone). Because the surficial sediments of those lower-slope cores are oxic, manganese is preserved in those cores. These processes may be important in explaining, in part, the high abundances of manganese crusts and nodules found on the West Tasmanian margin and further south on the South Tasman Rise.

The radiochemical data assembled will be used to calculate sedimentation rates from three cores: from the lower-slopes of the West Tasmania margin, south of King Island, and offshore Victoria. The down-core variations of several potential palaeoceanographic indictors indicate significant changes which may be indicative of sea-level change, glacial/interglacial changes in sea water chemistry, and the flux of organic matter from sea water into the sediments. However, these variations cannot be assessed until several of these cores have been dated.

The data set assembled here, of baseline levels of many elements including some heavy metals, can be used to assess long-term environmental change and anthropogenic inputs to the outer-shelf/upper slope of the Southern Australian continental margin.

ACKNOWLEDGEMENTS

We thank the Master and crew of RV Rig Seismic for assistance during collection of these cores, and AGSO co-chief scientists N.F. Exon and C.S. Lee for co-ordination of shipboard activities and the AGSO technical and scientific staff for assistance in processing the cores. XRF analyses were conducted by John Pyke at AGSO. The radiochemistry analyses, calcium carbonate, organic carbon and opaline silica analyses were conducted at The Flinders University in South Australia. We thank N. Exon for a review of this document.

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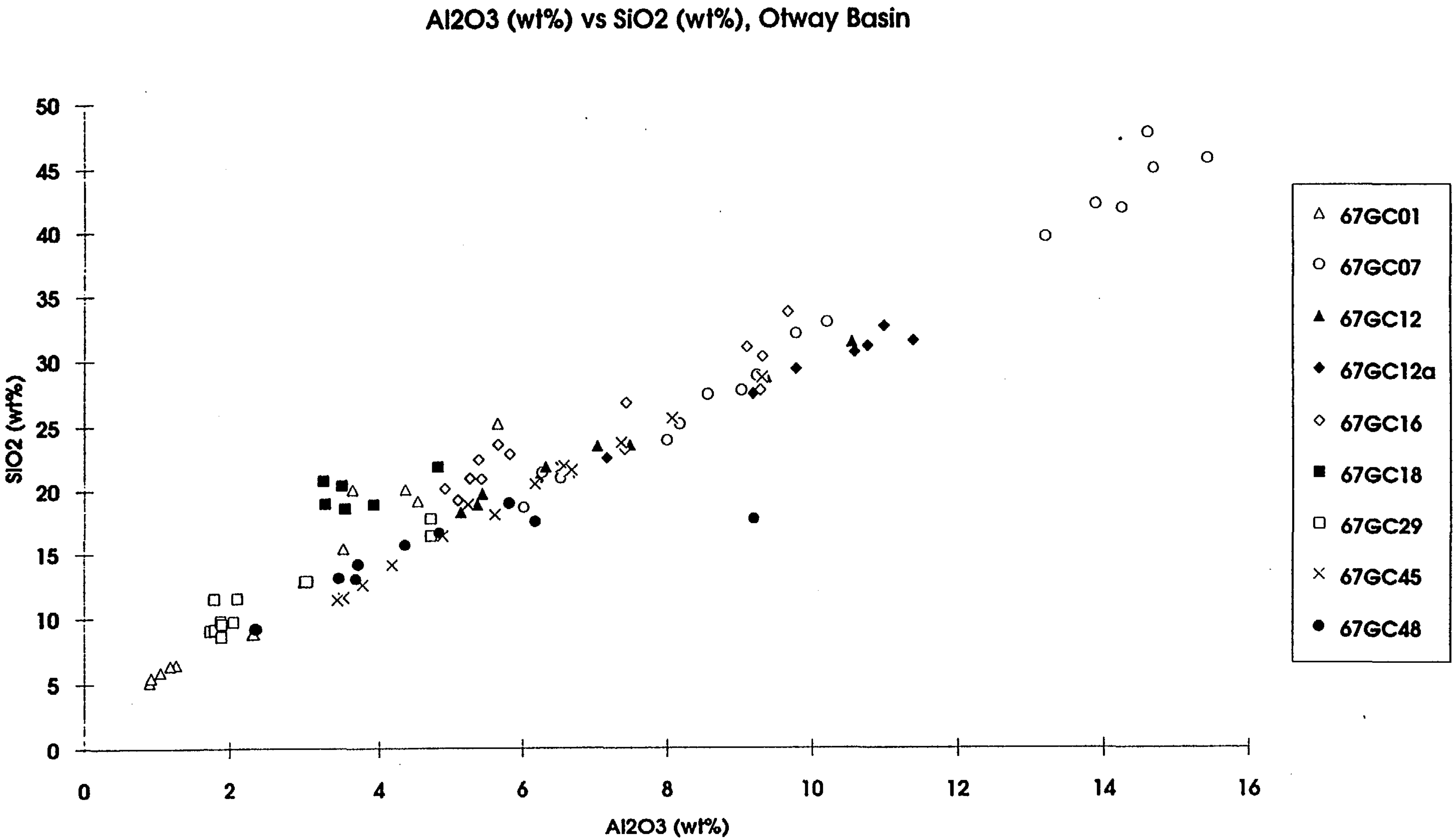
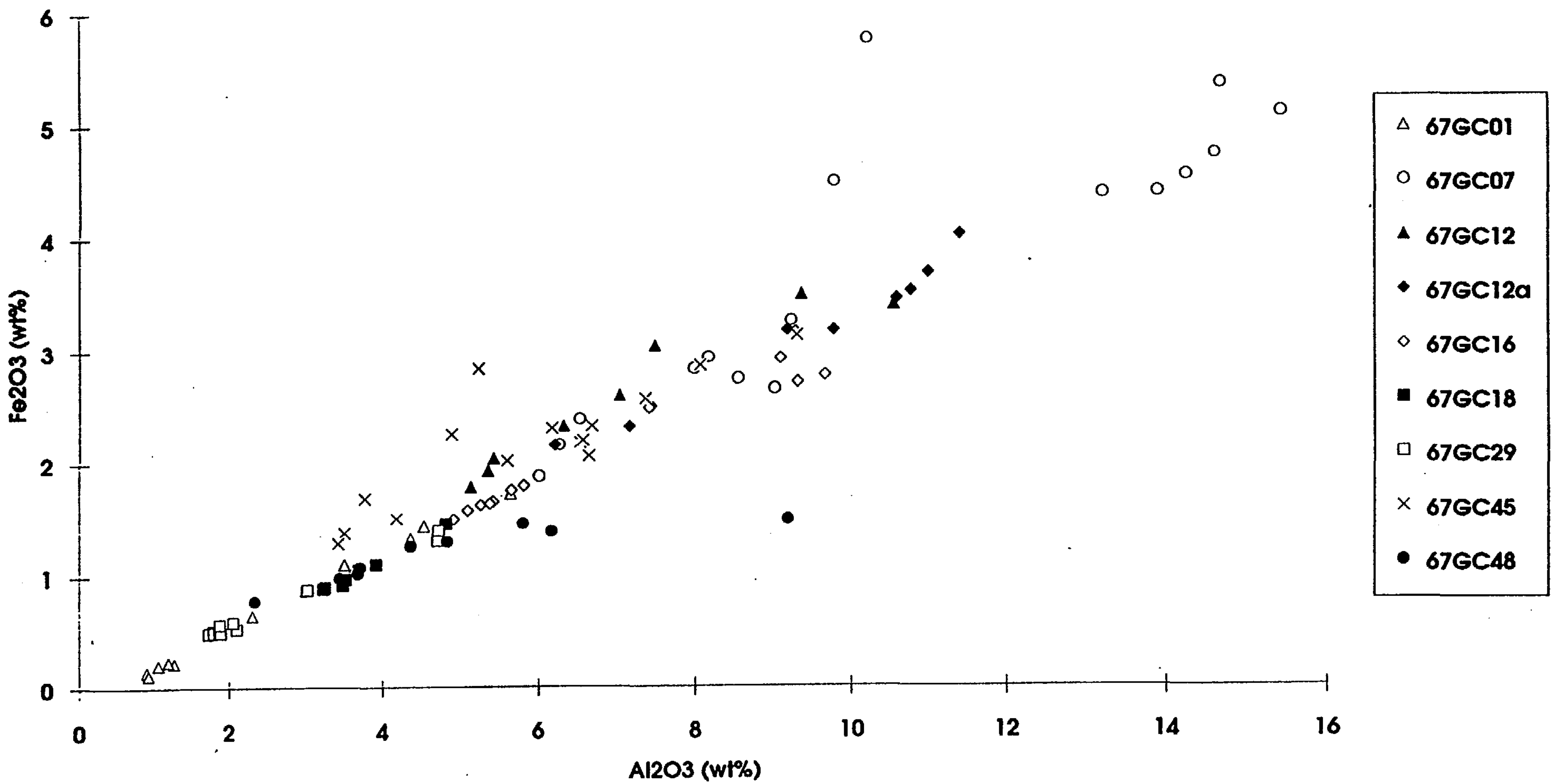
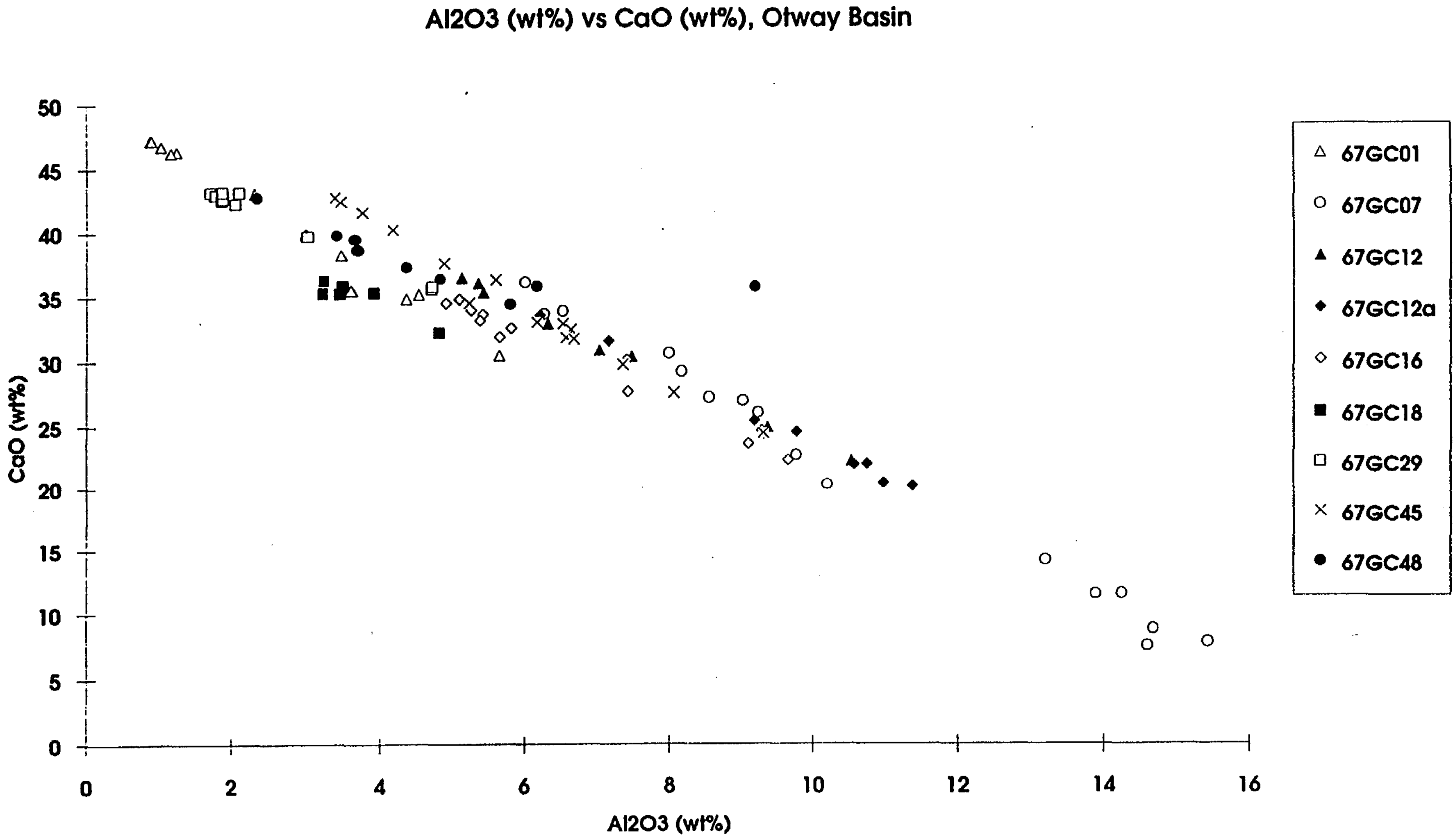
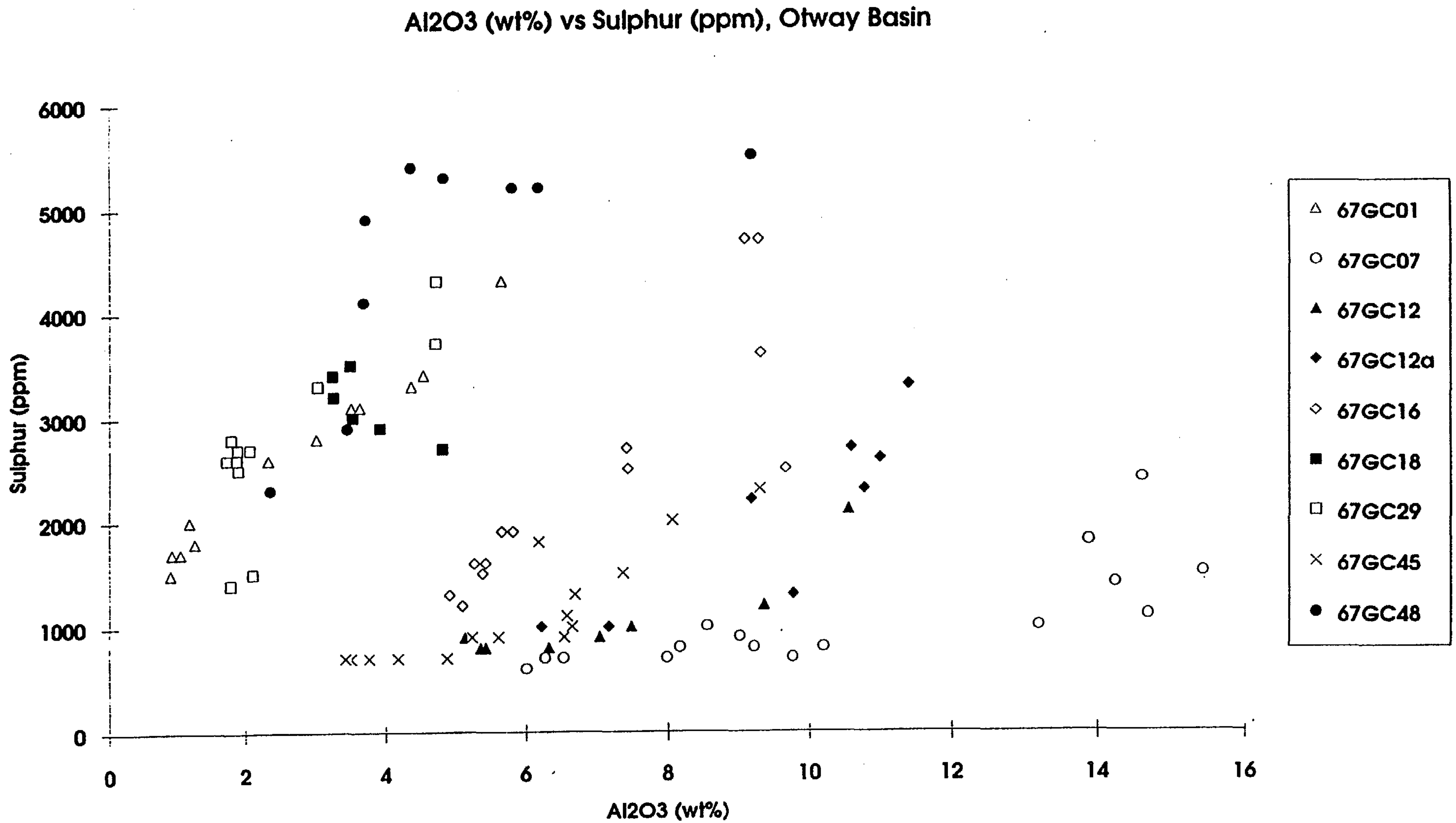
Appendix 1. Al_2O_3 with select major and trace elements


Al2O3 (wt%) vs SiO2 (wt%), Otway Basin
SiO2 (wt%)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

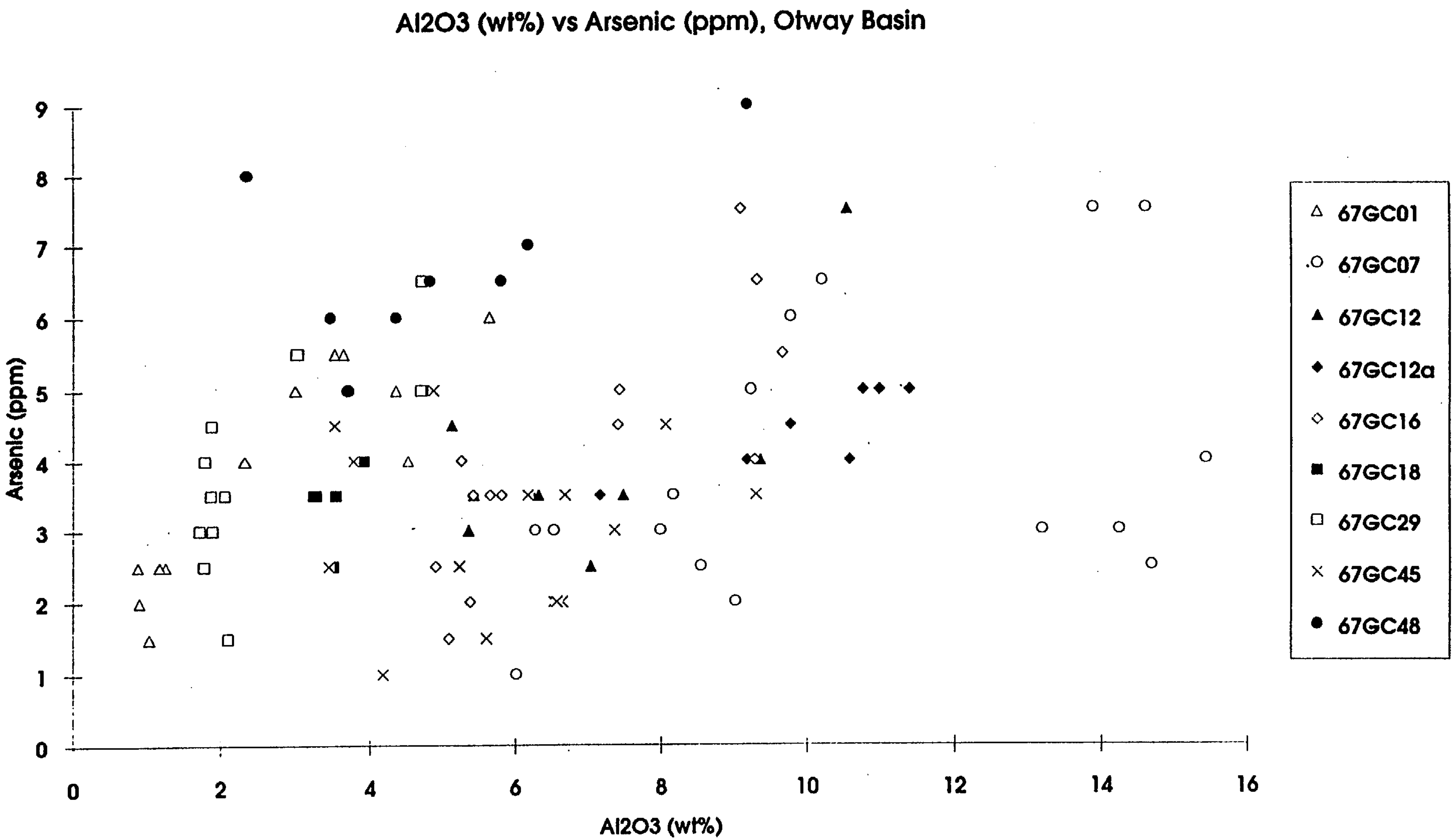
Al2O3 (wt%) vs Fe2O3 (wt%), Otway Basin




Al2O3 (wt%) vs CaO (wt%), Otway Basin
CaO (wt%)
Al2O3 (wt%)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48



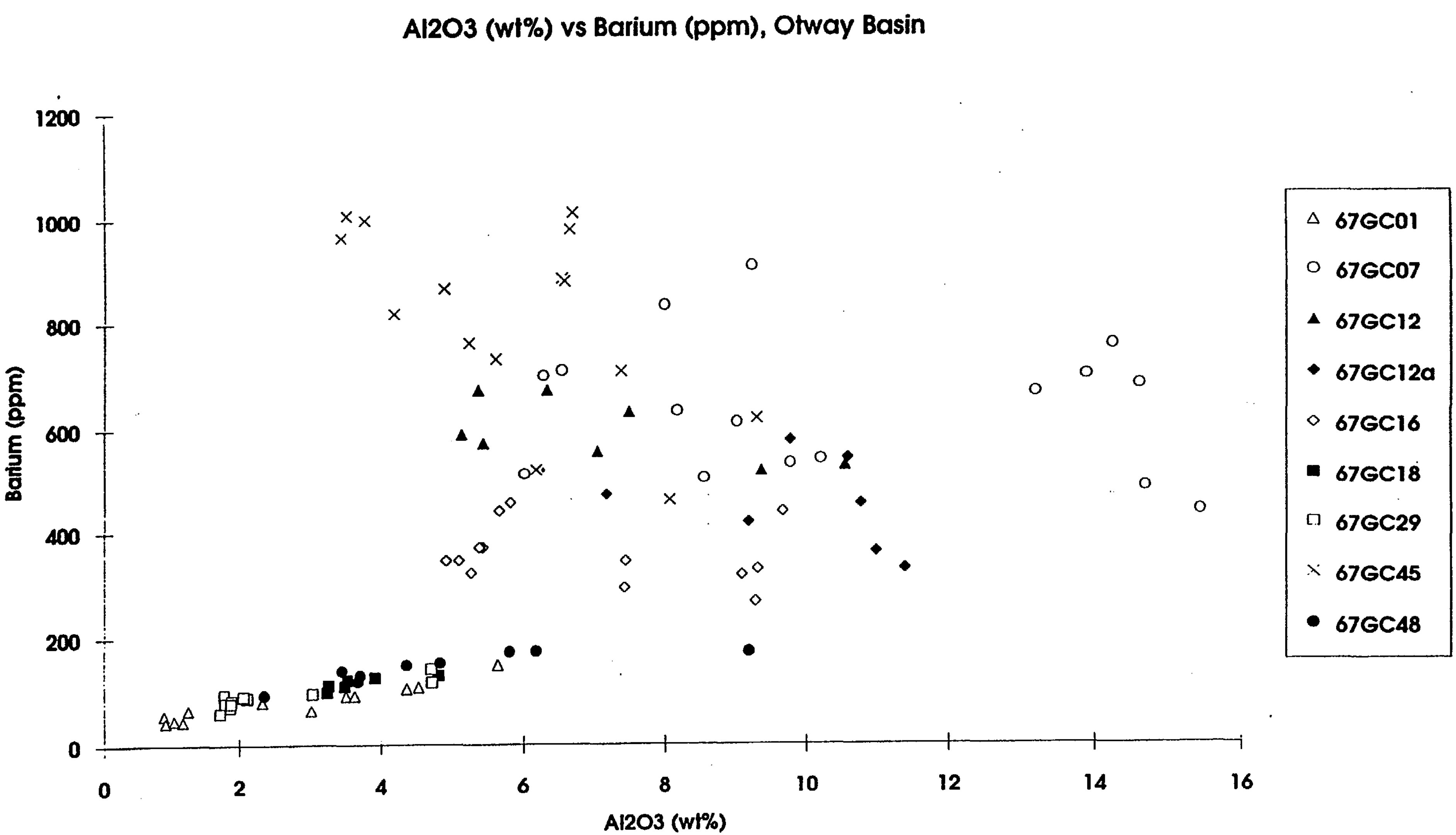
Al2O3 (wt%) vs Sulphur (ppm), Otway Basin
Sulphur (ppm)
6000
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48



Al2O3 (wt%) vs Arsenic (ppm), Otway Basin
Arsenic (ppm)
Al2O3 (wt%)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

A6

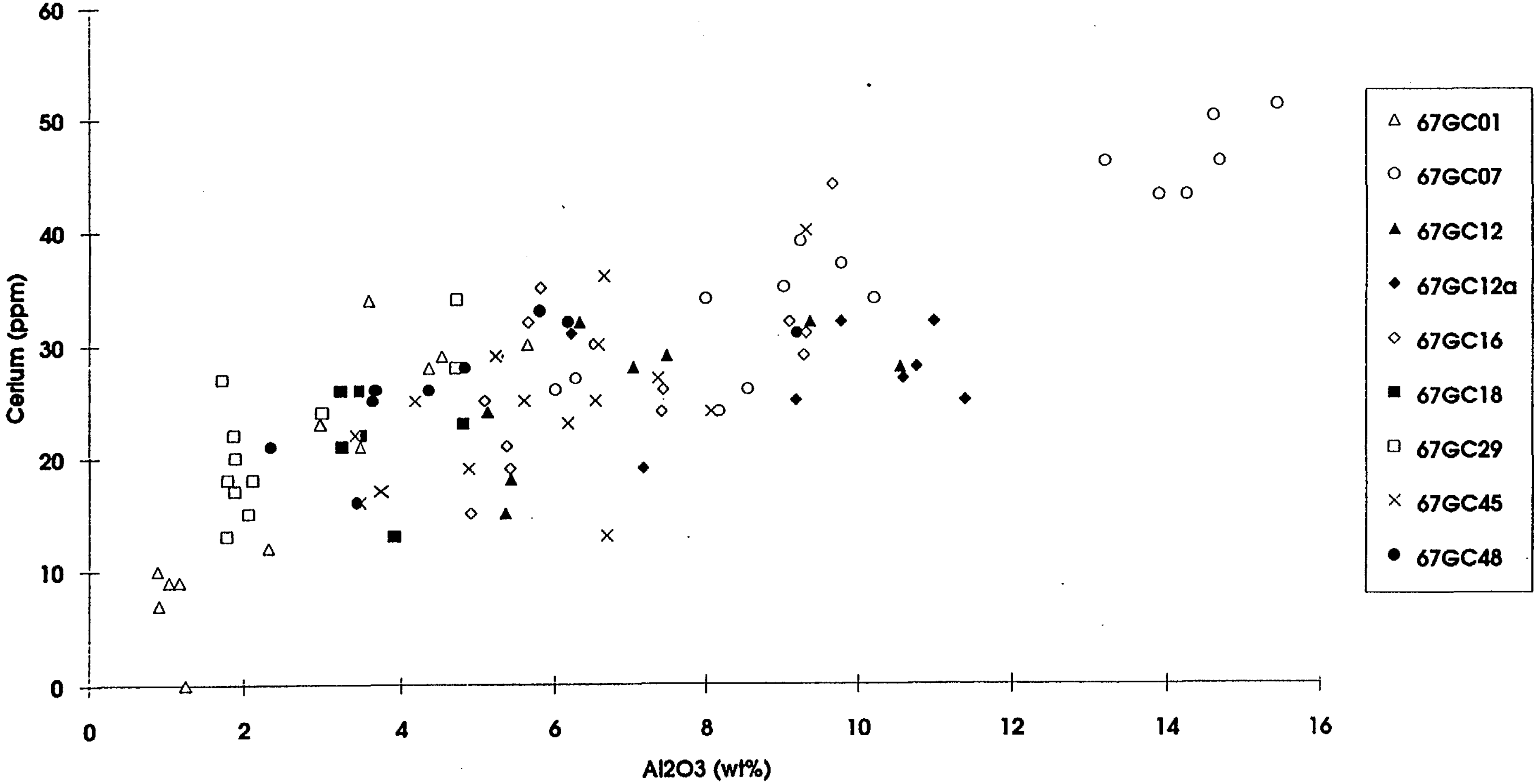
R9308702

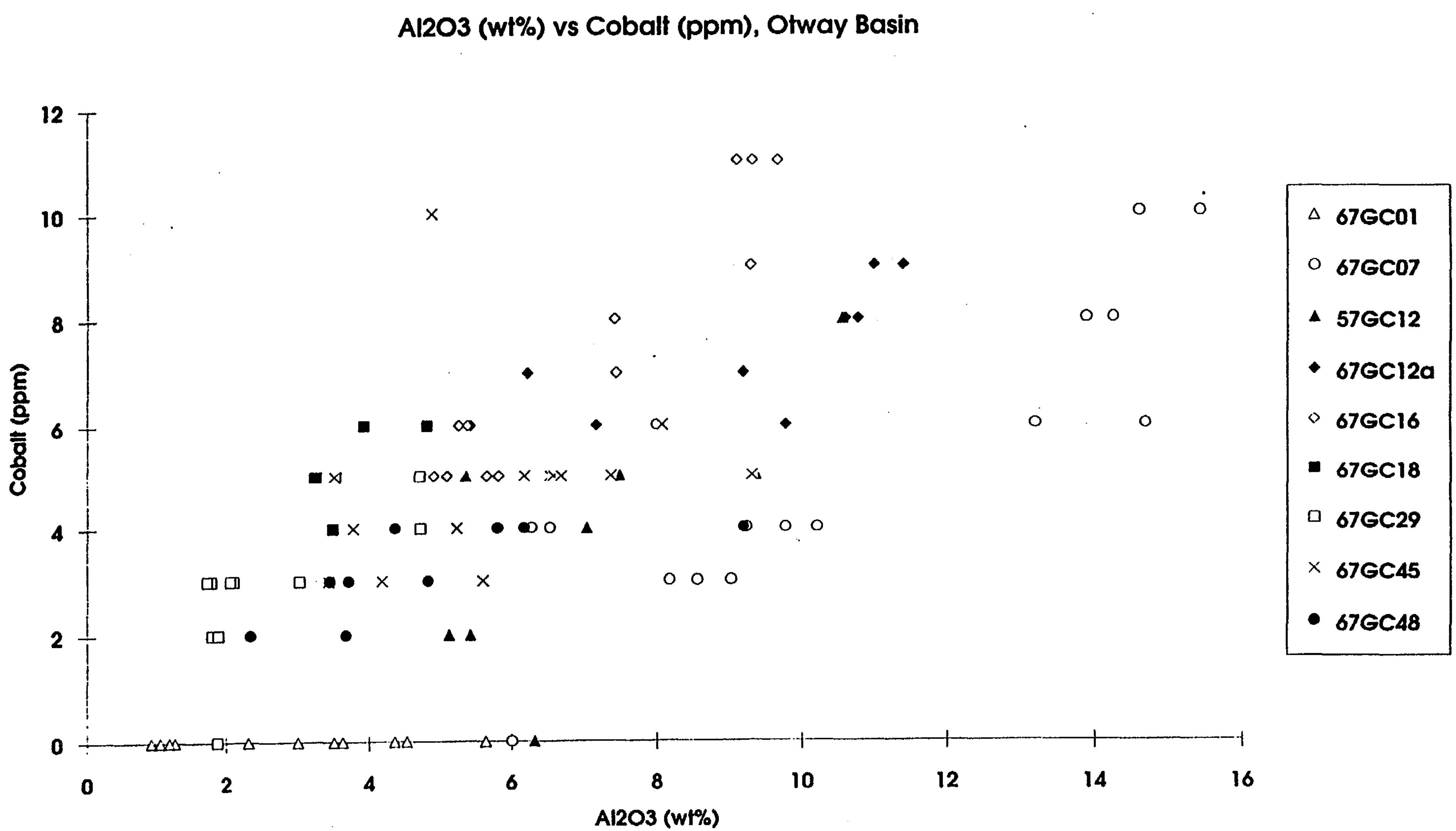


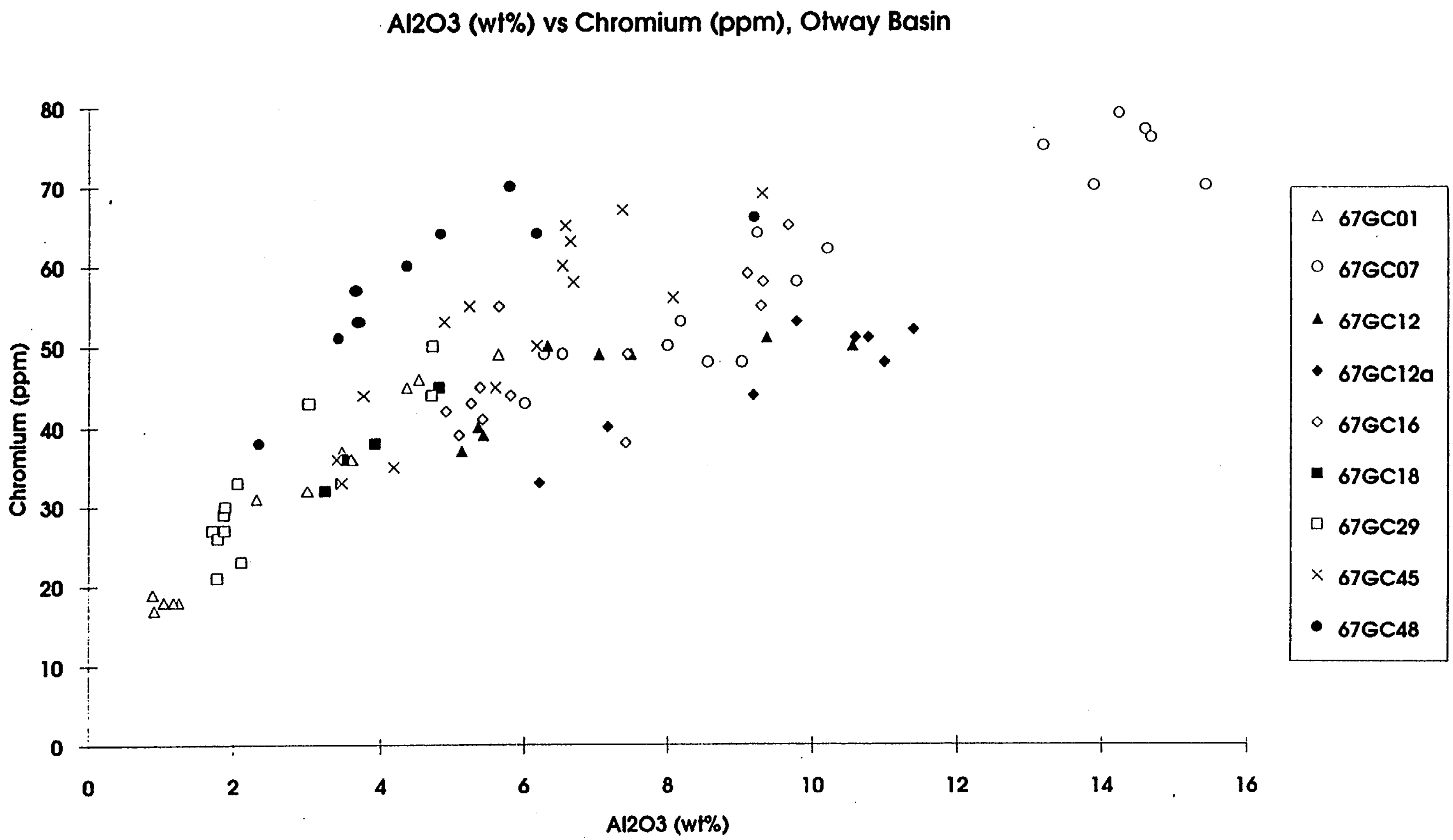
Al2O3 (wt%) vs Barium (ppm), Otway Basin
Barium (ppm)
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

A7

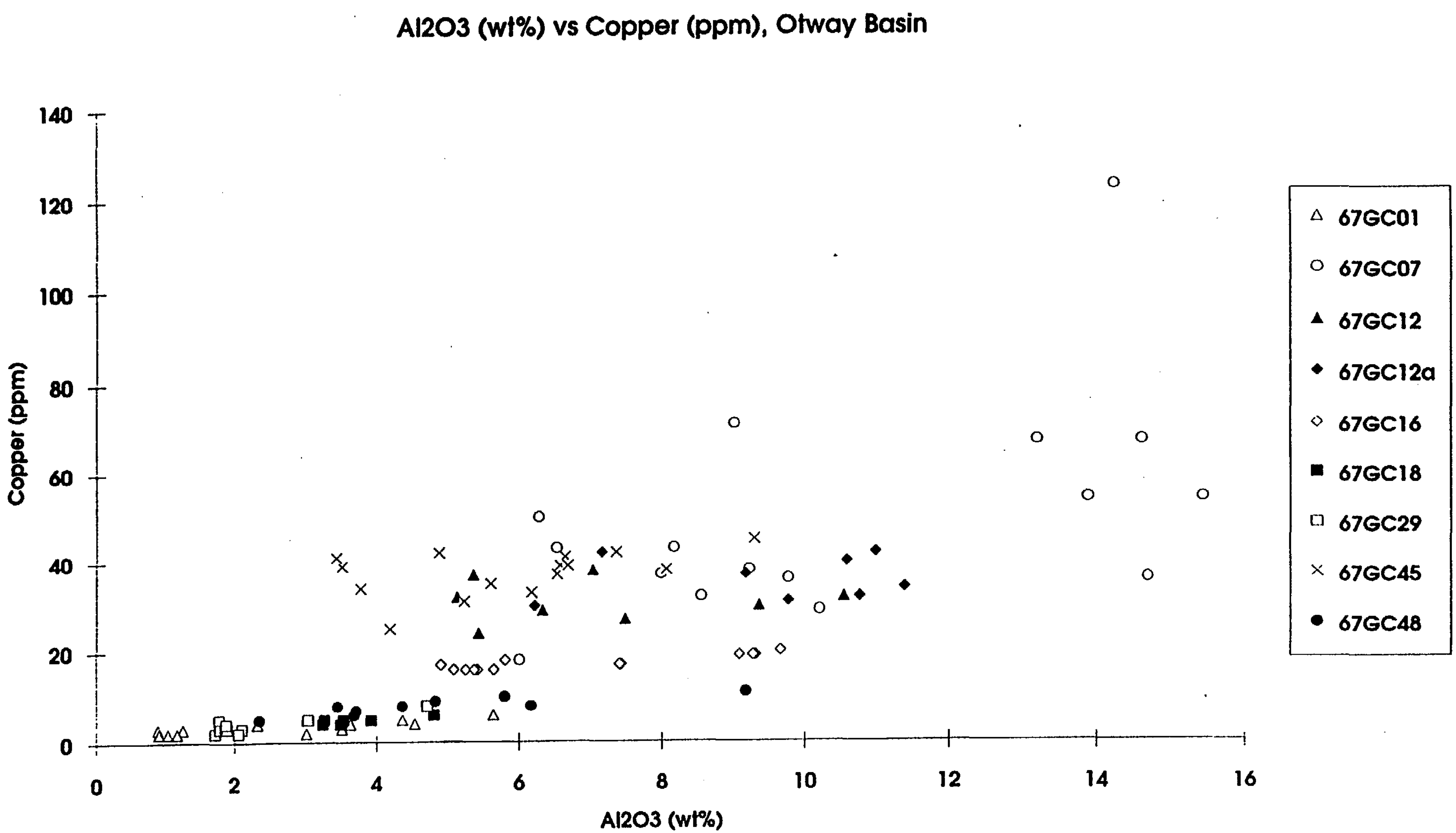
Al2O3 (wt%) vs Cerium (ppm), Otway Basin




Al2O3 (wt%) vs Cobalt (ppm), Otway Basin
Cobalt (ppm)
Al2O3 (wt%)
0
2
4
6
8
10
12
14
16
67GC01
67GC07
57GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

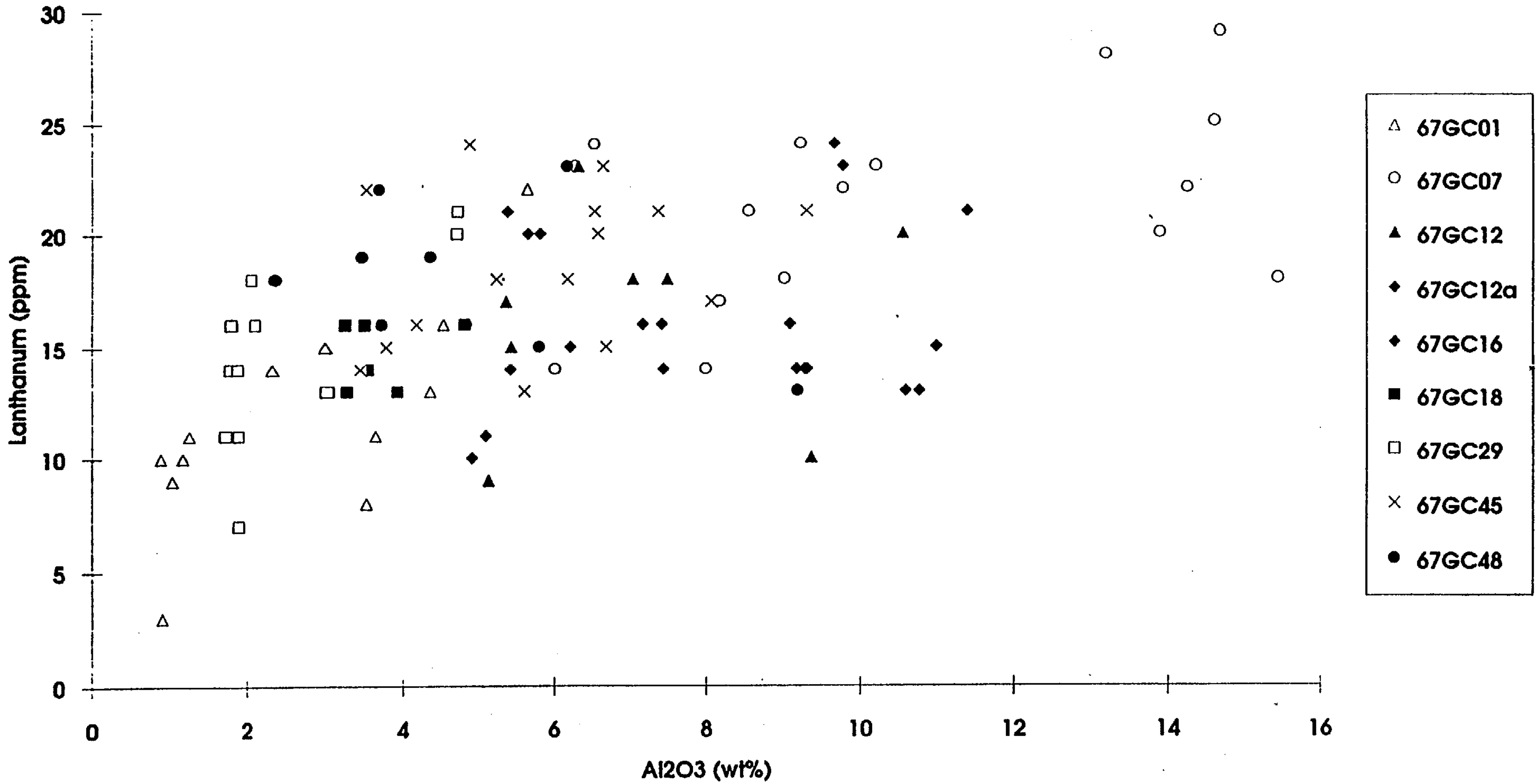


Al2O3 (wt%) vs Chromium (ppm), Otway Basin
Chromium (ppm)
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

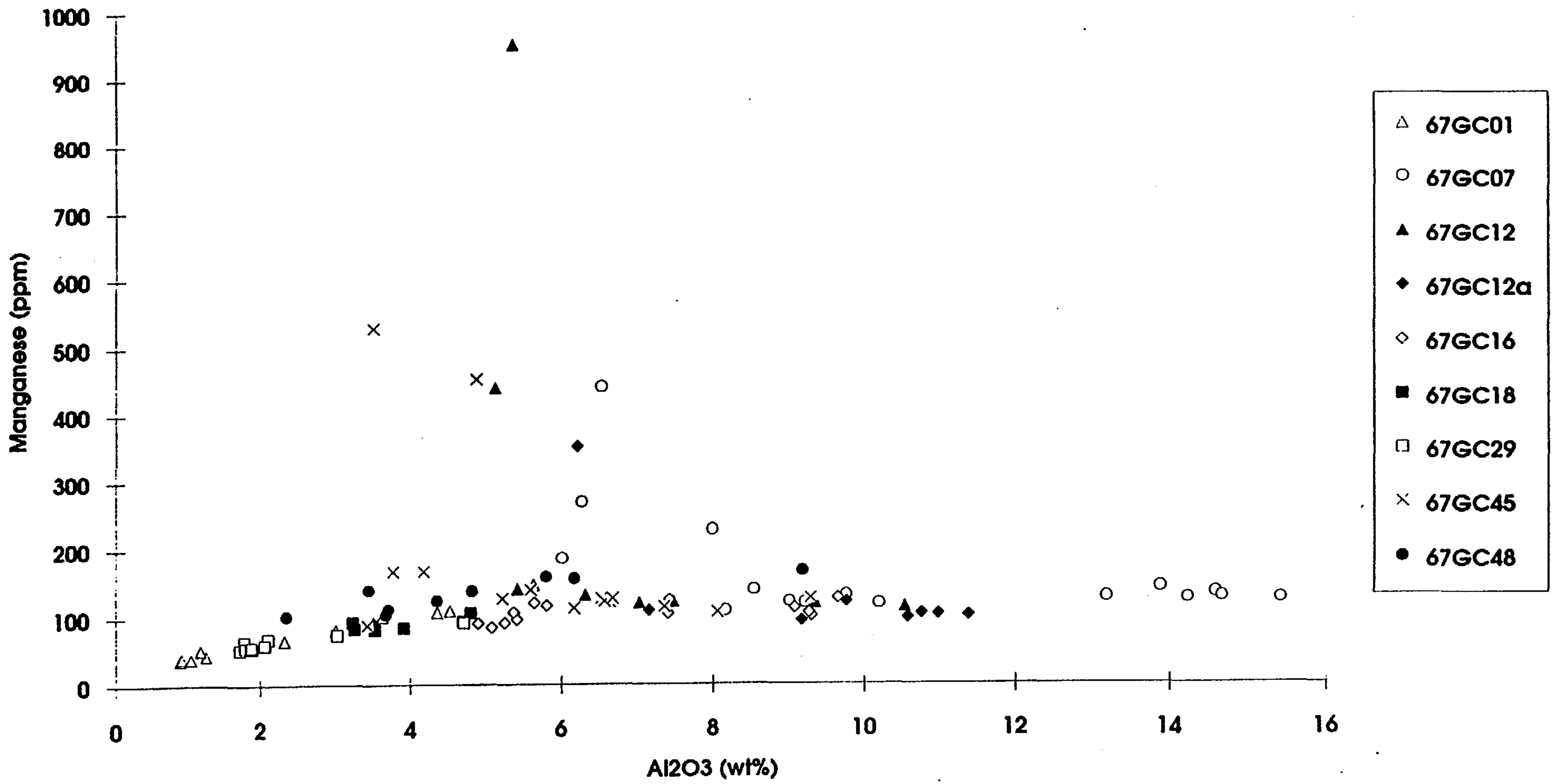


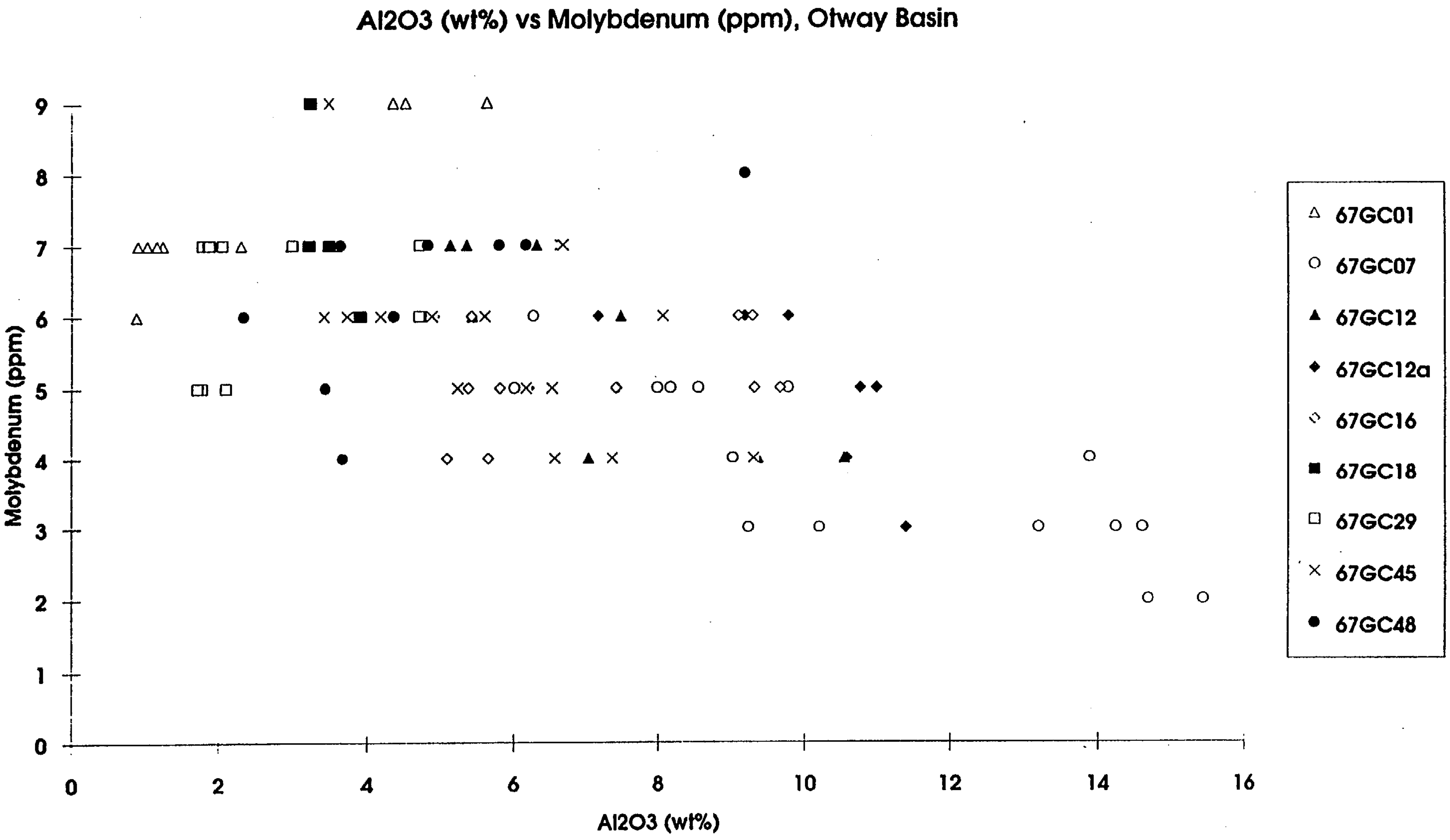
Al2O3 (wt%) vs Copper (ppm), Otway Basin
Copper (ppm)
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Al2O3 (wt%) vs Lanthanum (ppm), Otway Basin

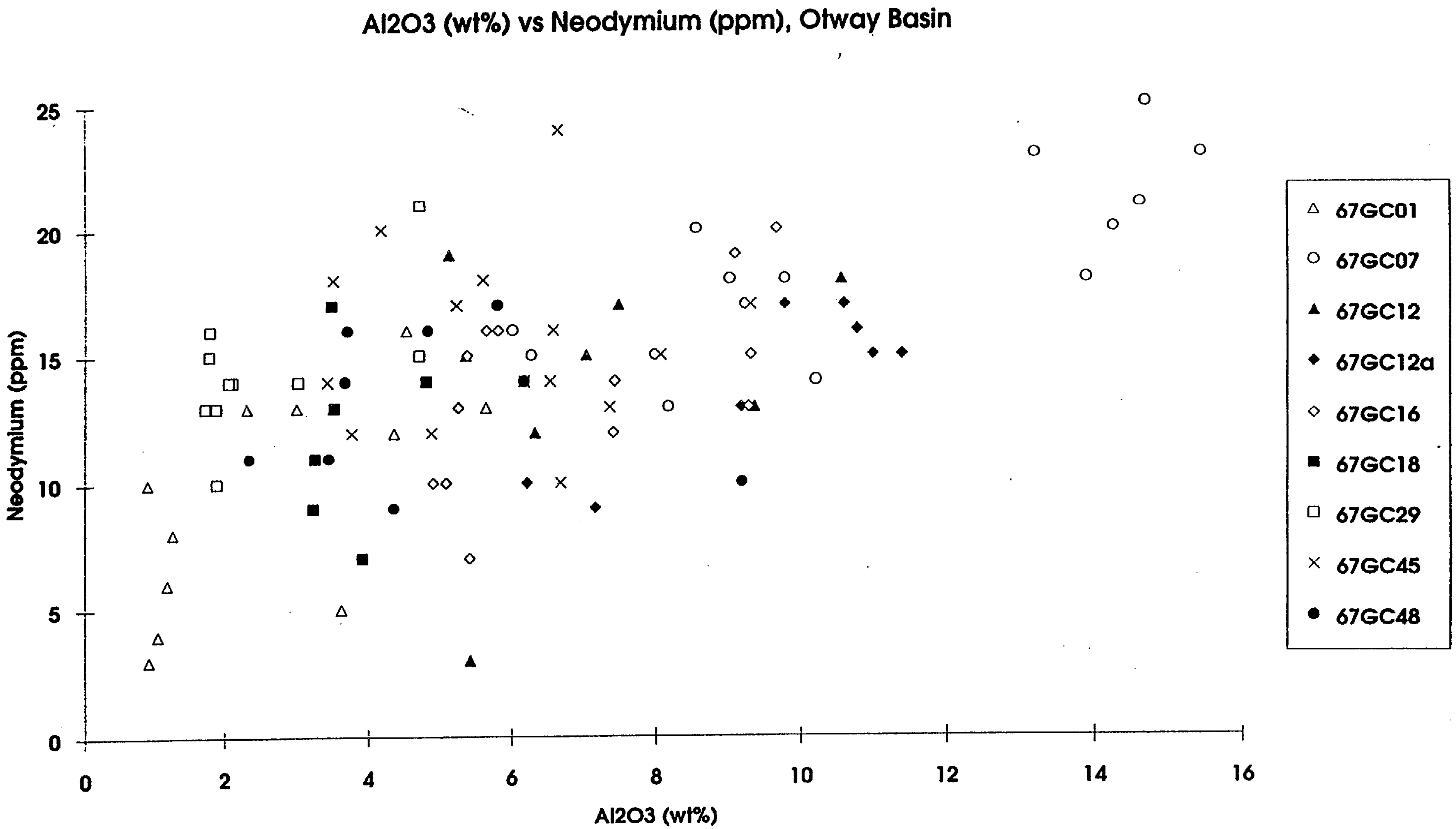


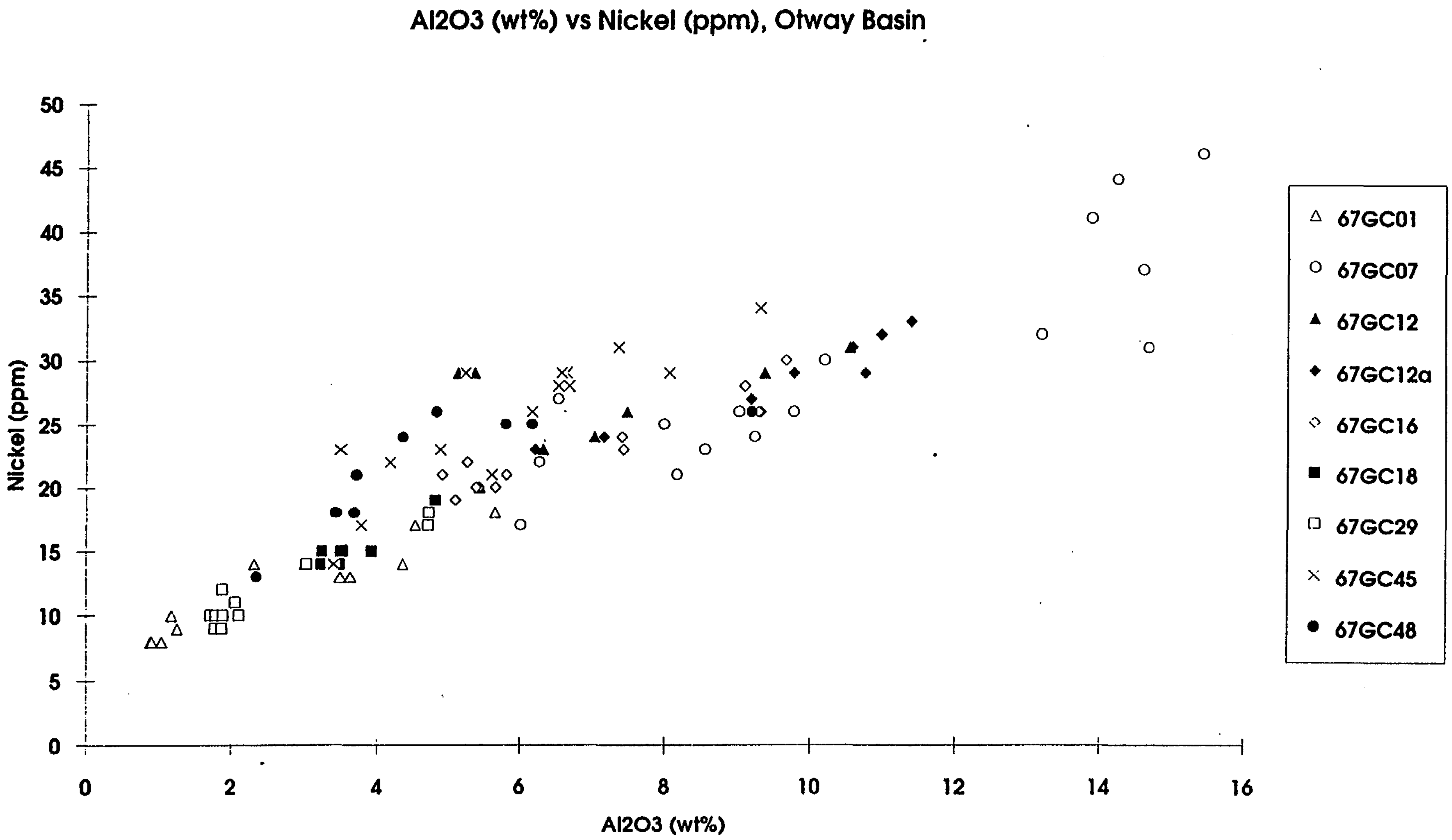
Al2O3 (wt%) vs Manganese (ppm), Otway Basin





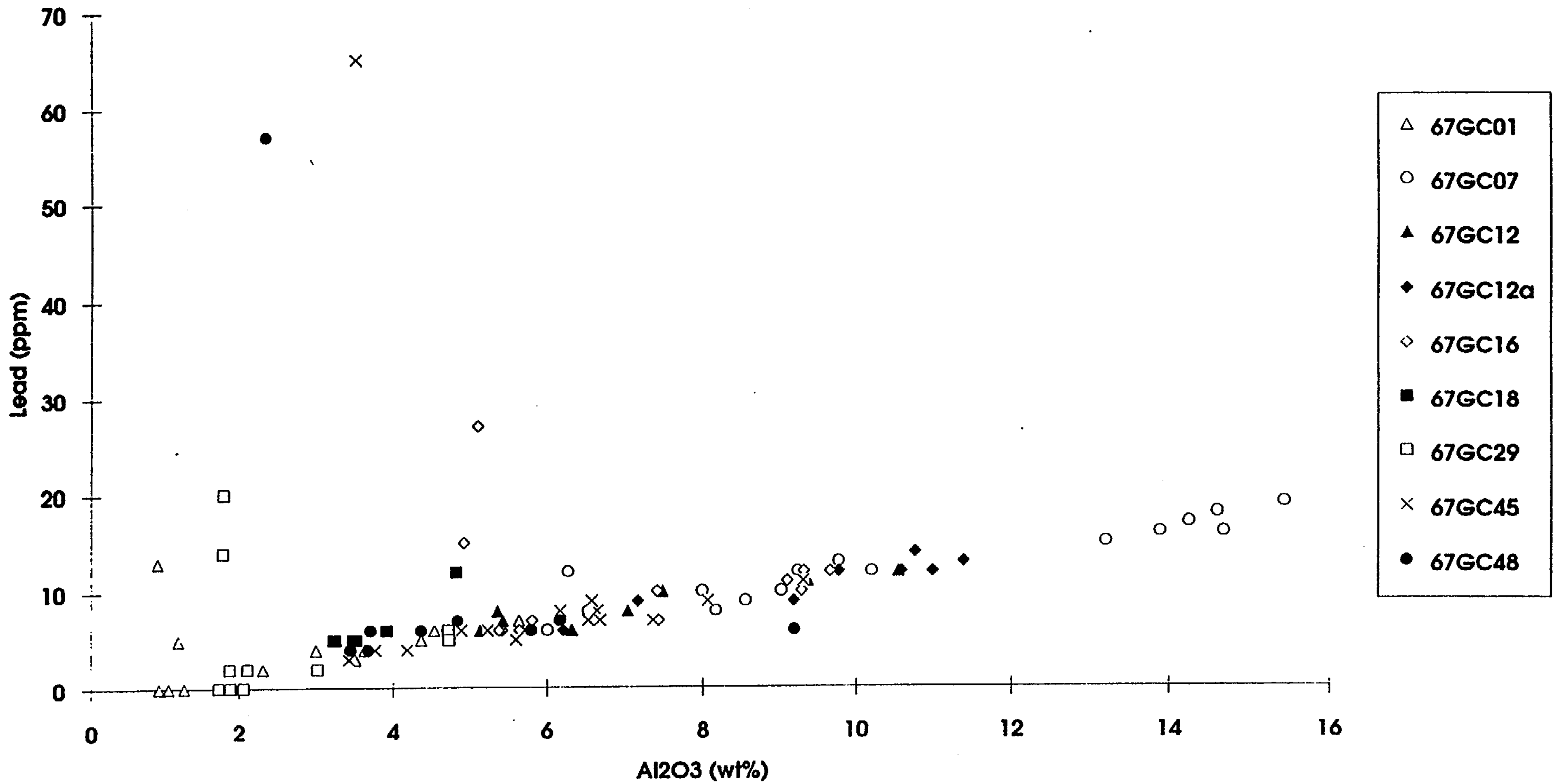
Al2O3 (wt%) vs Molybdenum (ppm), Otway Basin
Molybdenum (ppm)
Al2O3 (wt%)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48


Al2O3 (wt%) vs Neodymium (ppm), Otway Basin
Neodymium (ppm)
Al2O3 (wt%)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

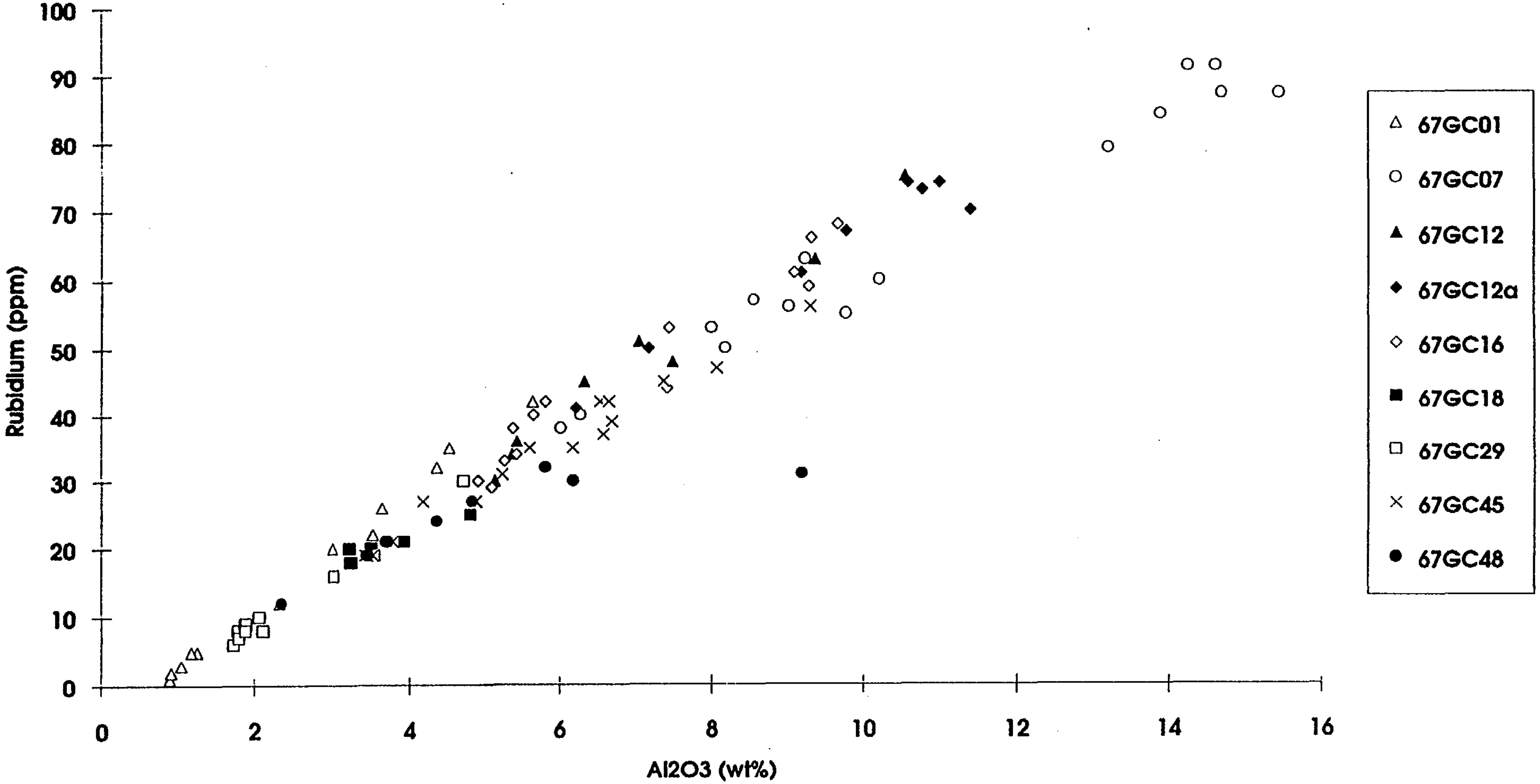


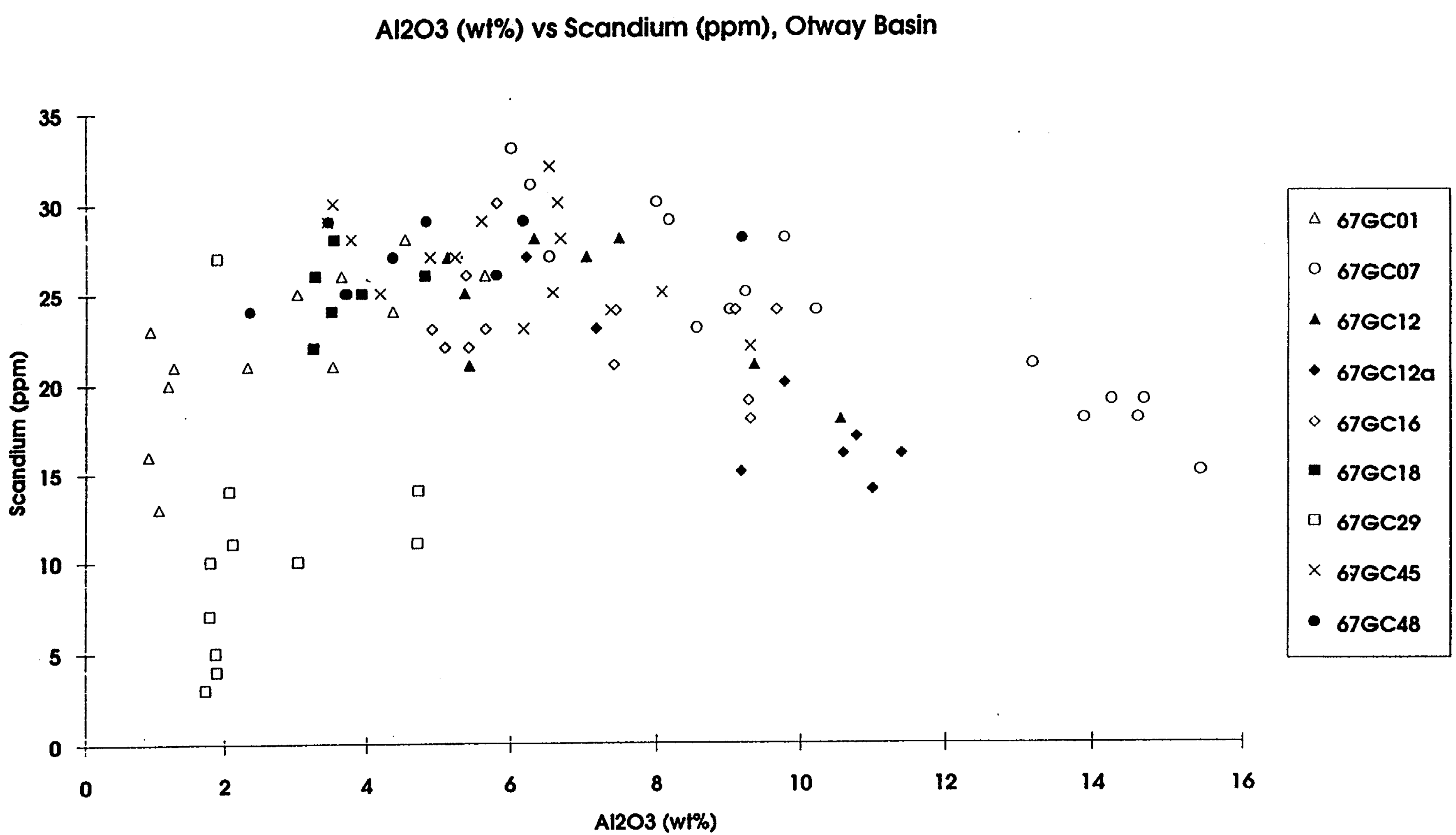
Al2O3 (wt%) vs Nickel (ppm), Otway Basin
Nickel (ppm)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Al2O3 (wt%) vs Lead (ppm), Otway Basin

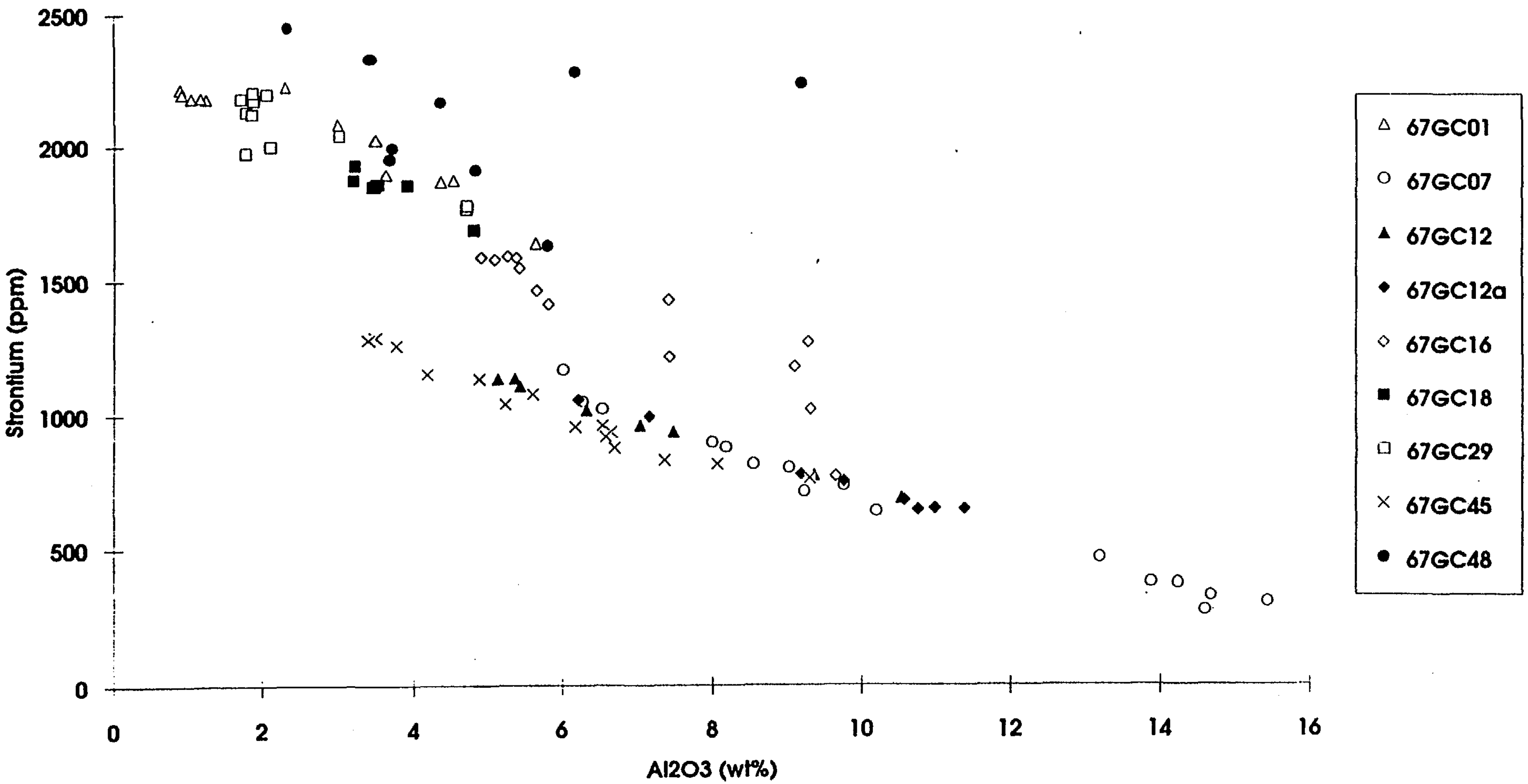


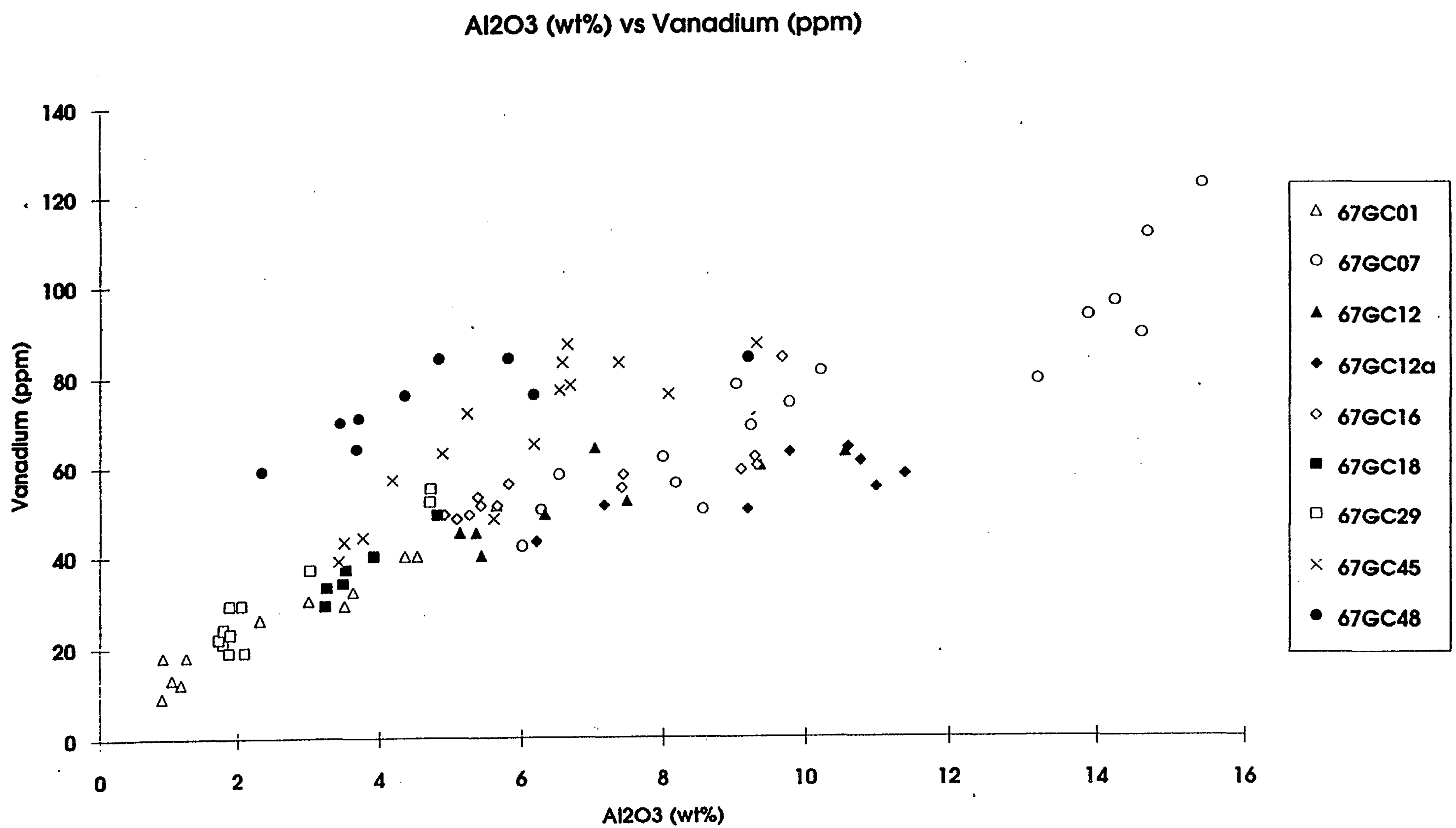
Al2O3 (wt%) vs Rubidium (ppm), Otway Basin

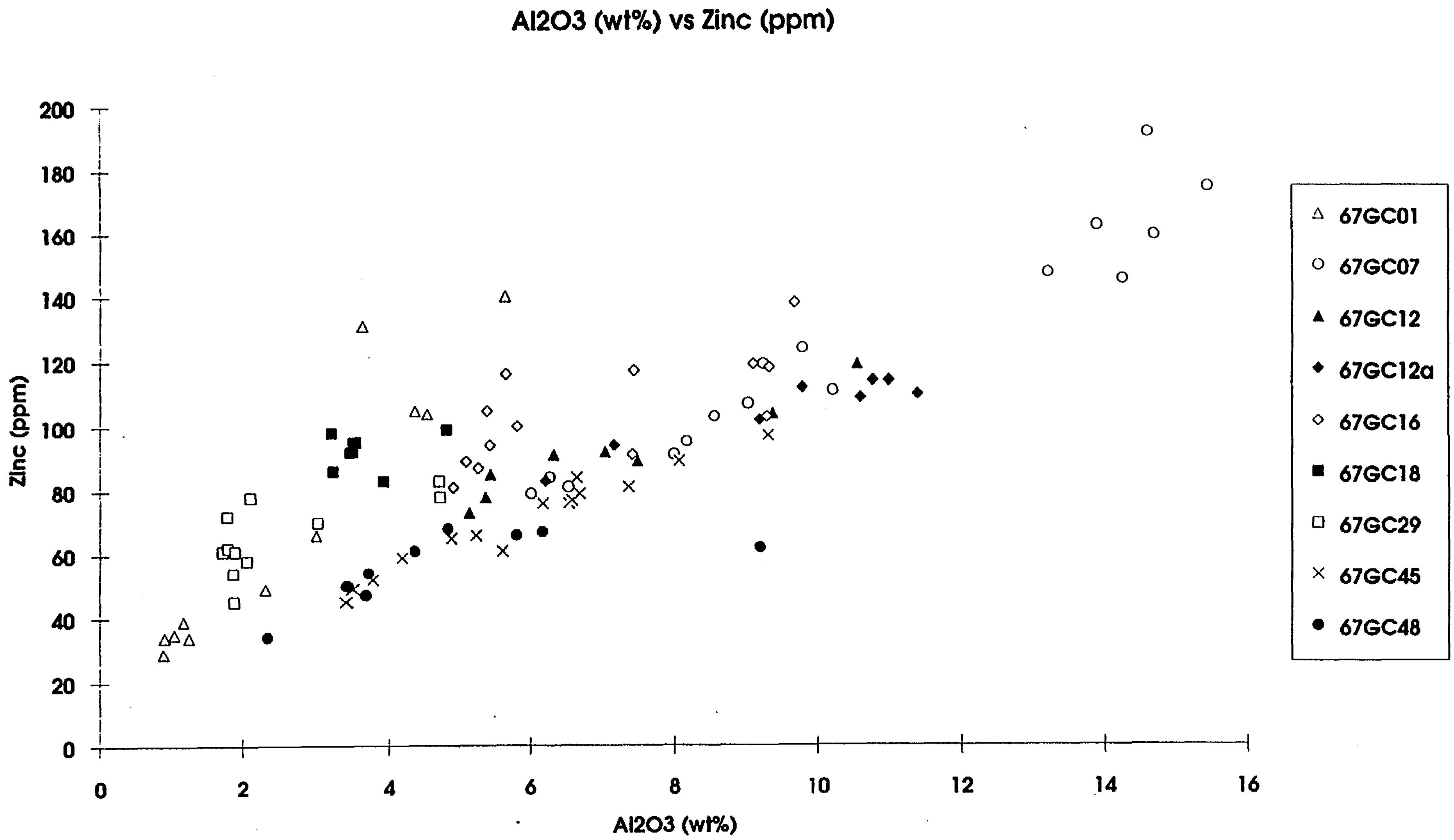


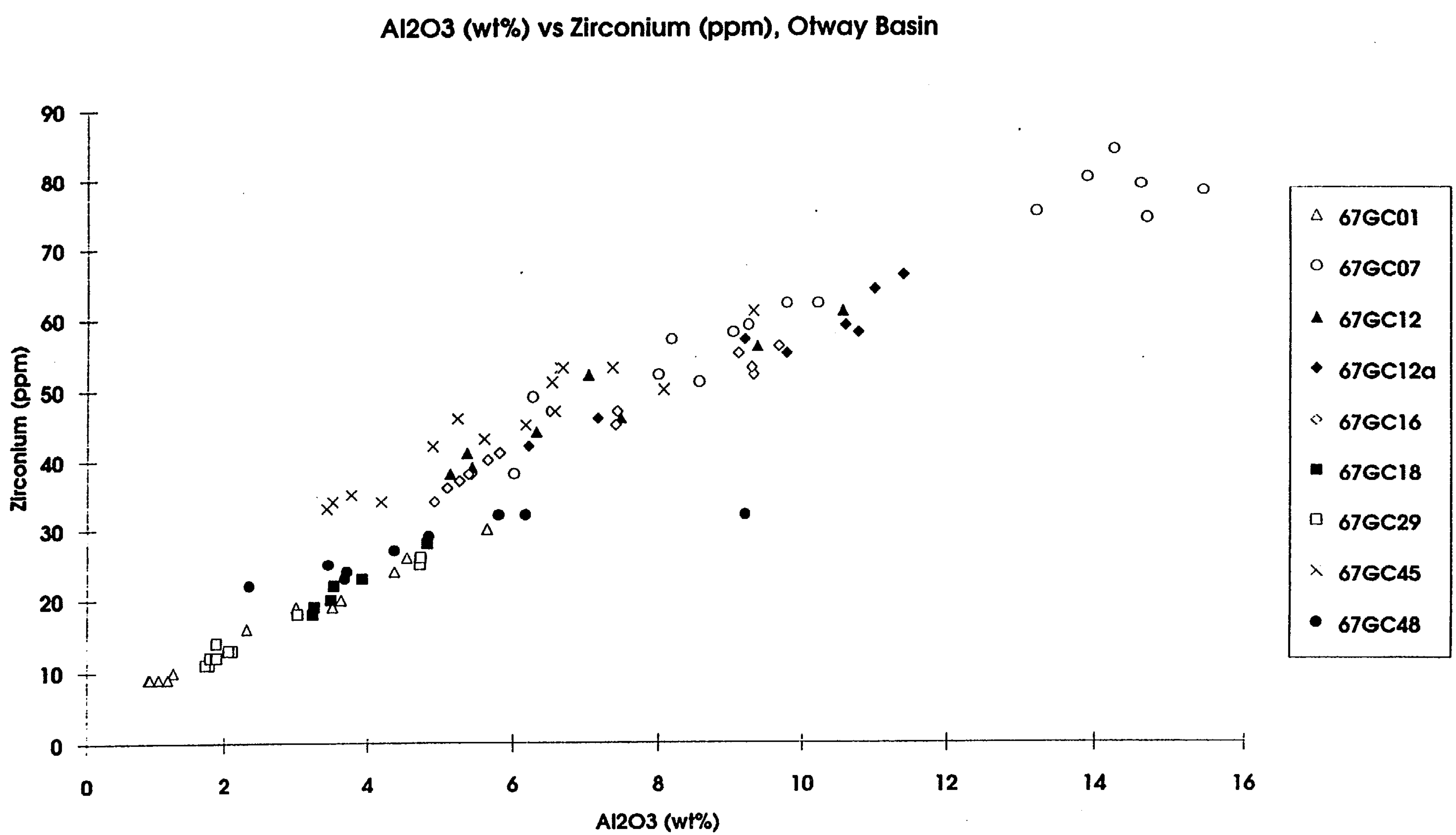

Al2O3 (wt%) vs Scandium (ppm), Otway Basin
Scandium (ppm)
Al2O3 (wt%)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Al2O3 (wt%) vs Strontium (ppm), Otway Basin

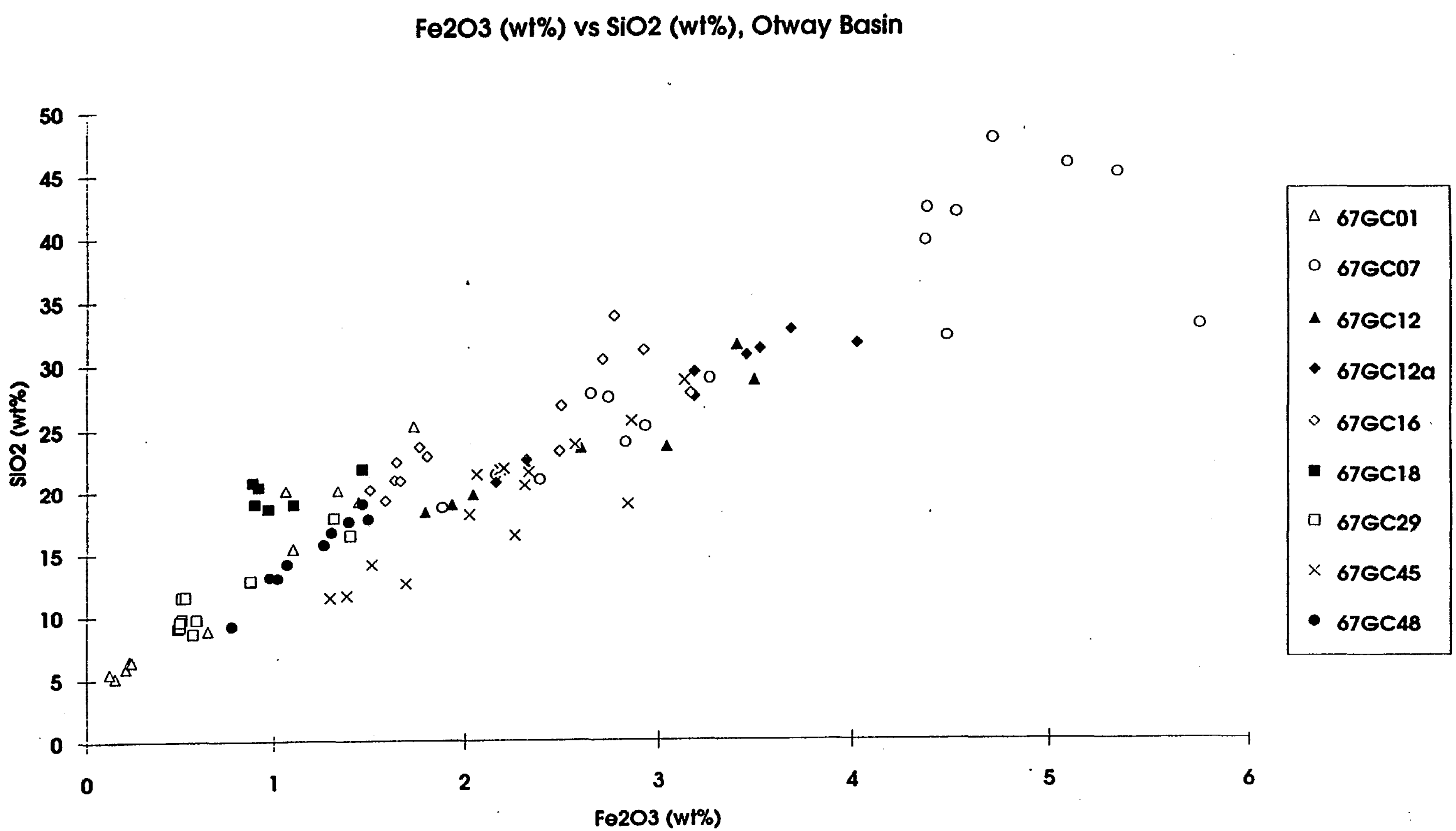



Al2O3 (wt%) vs Vanadium (ppm)
Vanadium (ppm)
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

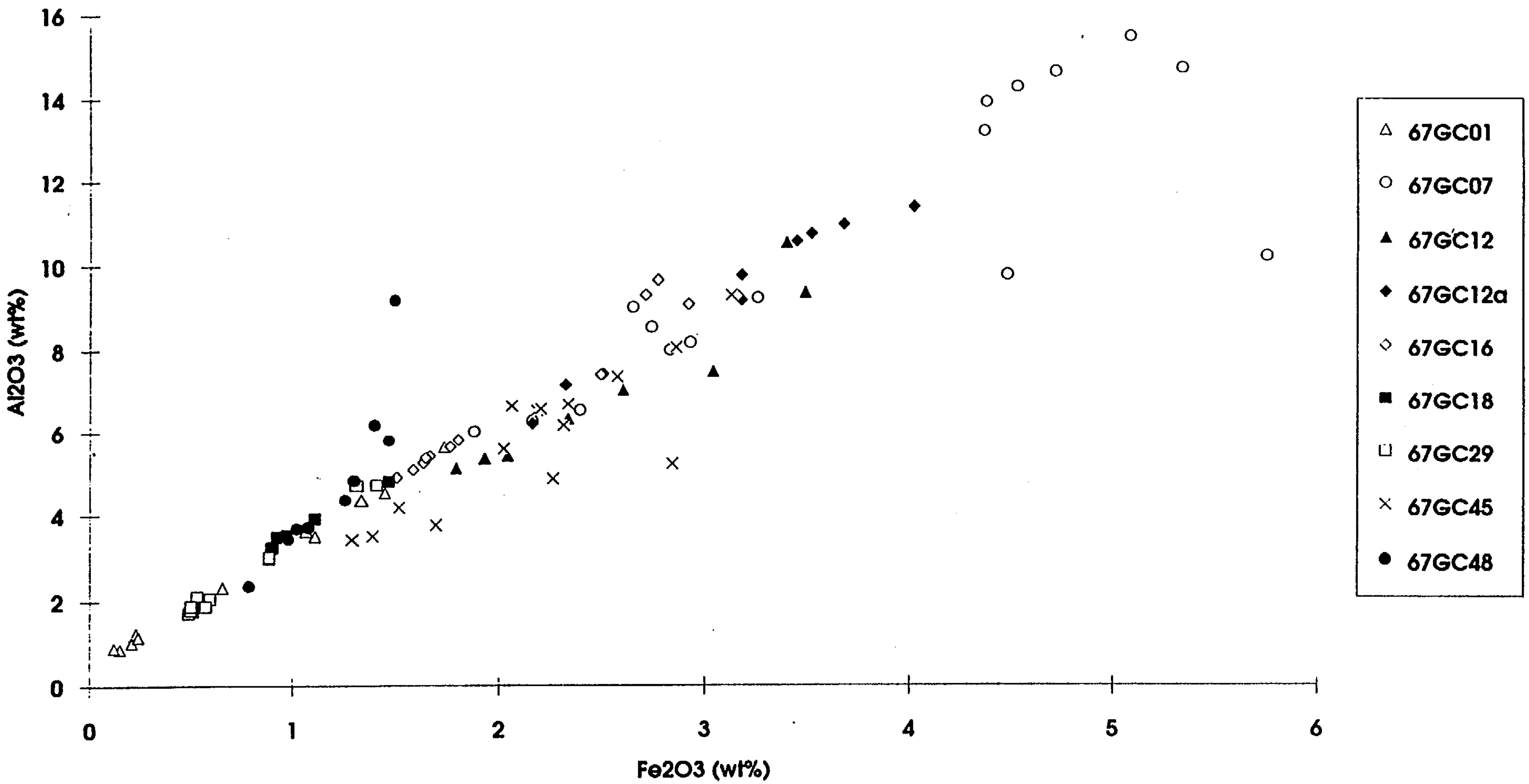

Al2O3 (wt%) vs Zinc (ppm)
Zinc (ppm)
Al2O3 (wt%)
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6
8
10
12
14
16
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48


Al2O3 (wt%) vs Zirconium (ppm), Otway Basin
Zirconium (ppm)
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
16
Al2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

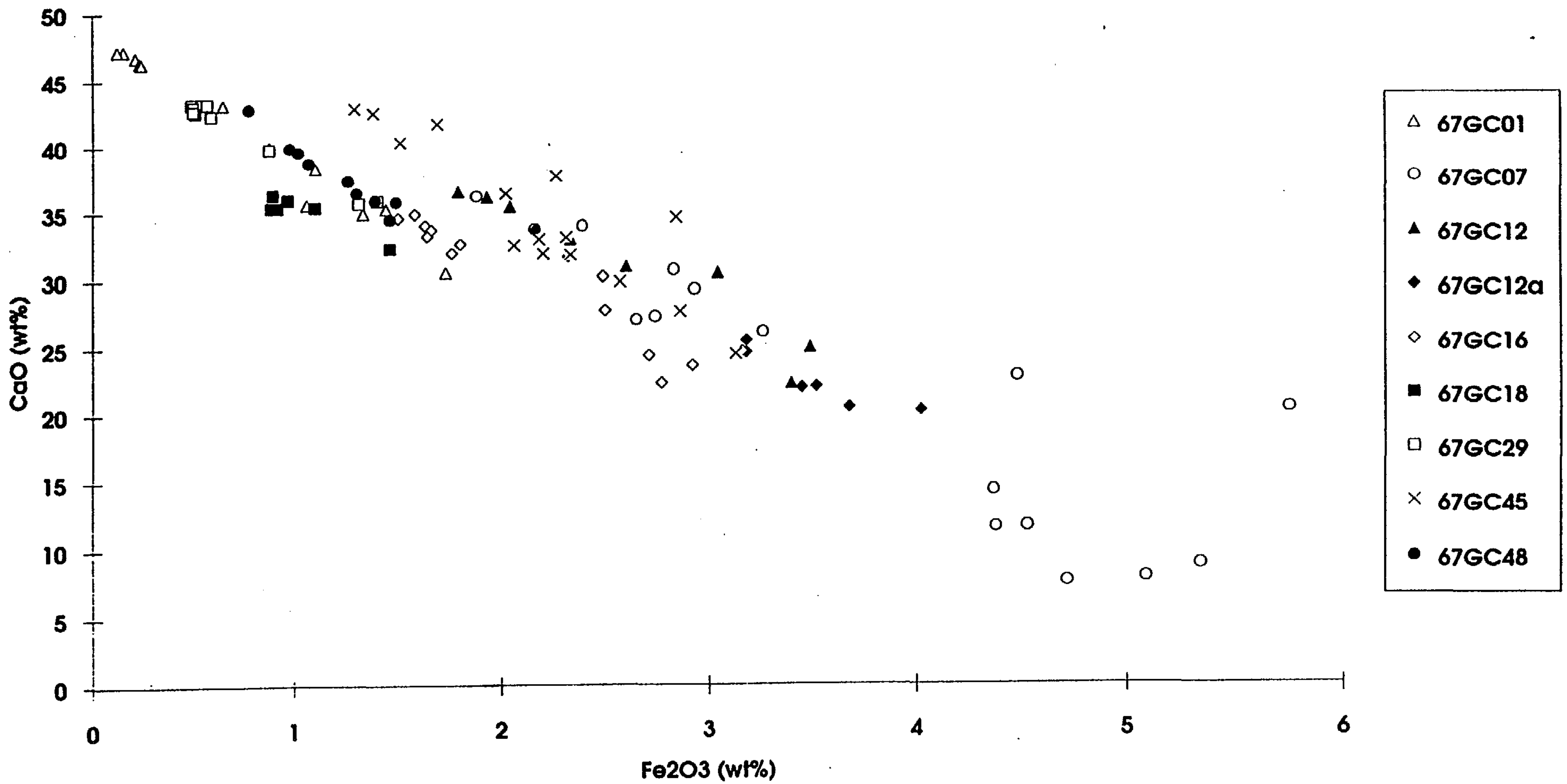
Appendix 2. Fe2O3 with select major and trace elements


Fe2O3 (wt%) vs SiO2 (wt%), Otway Basin
SiO2 (wt%)
Fe2O3 (wt%)
0
5
10
15
20
25
30
35
40
45
50
0
1
2
3
4
5
6
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

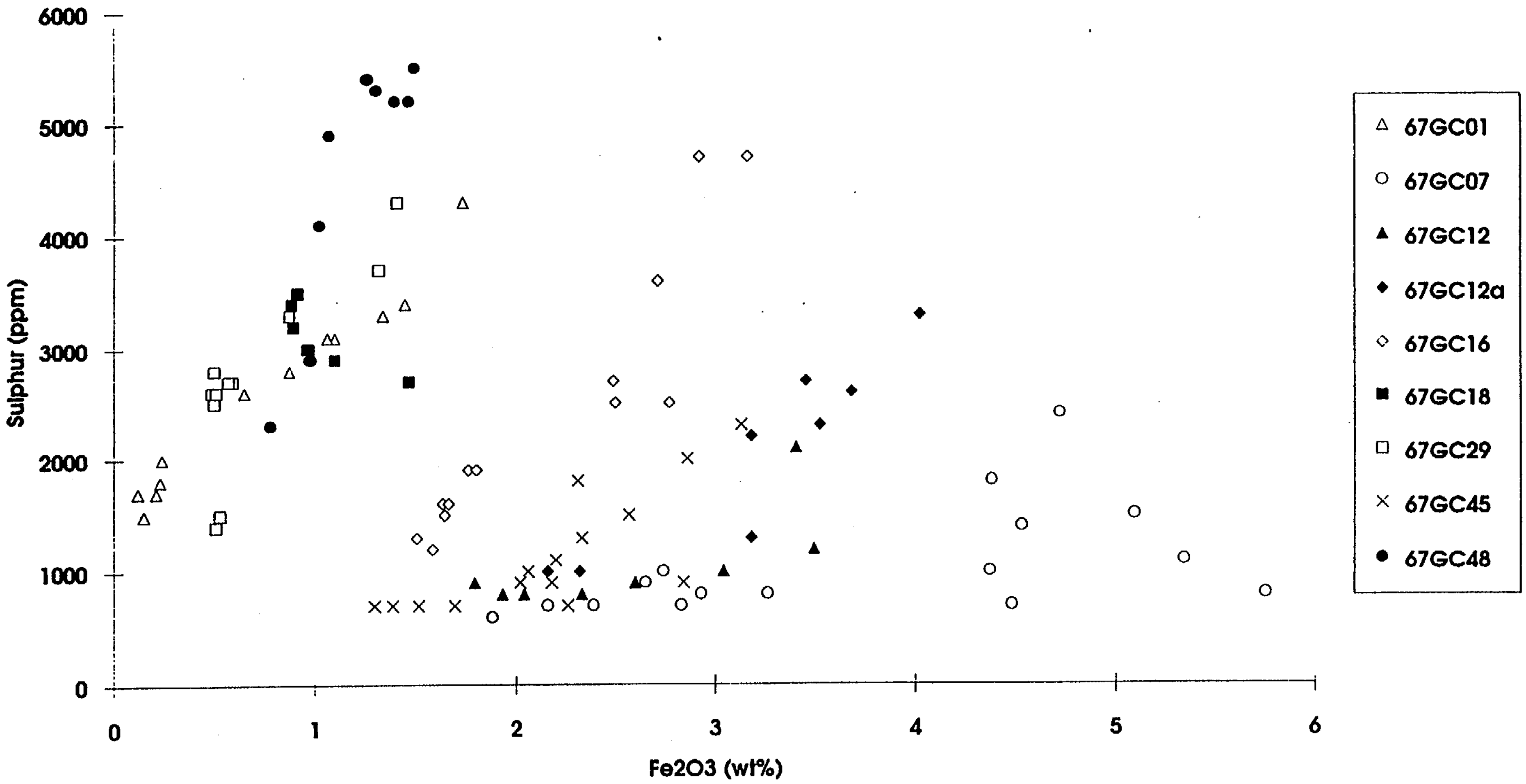
Fe2O3 (wt%) vs Al2O3 (wt%), Otway Basin

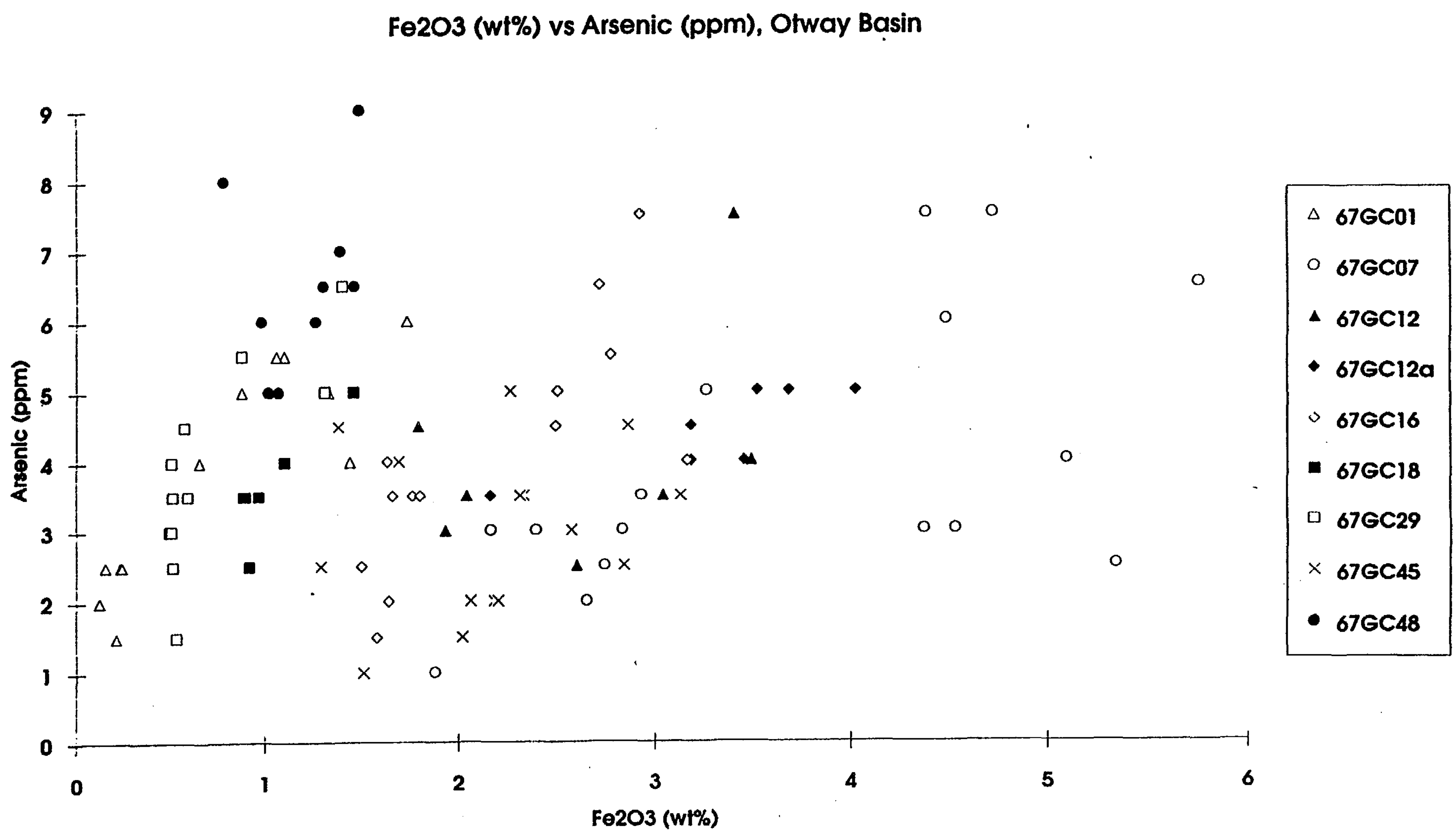


Fe2O3 (wt%) vs CaO (wt%), Otway Basin

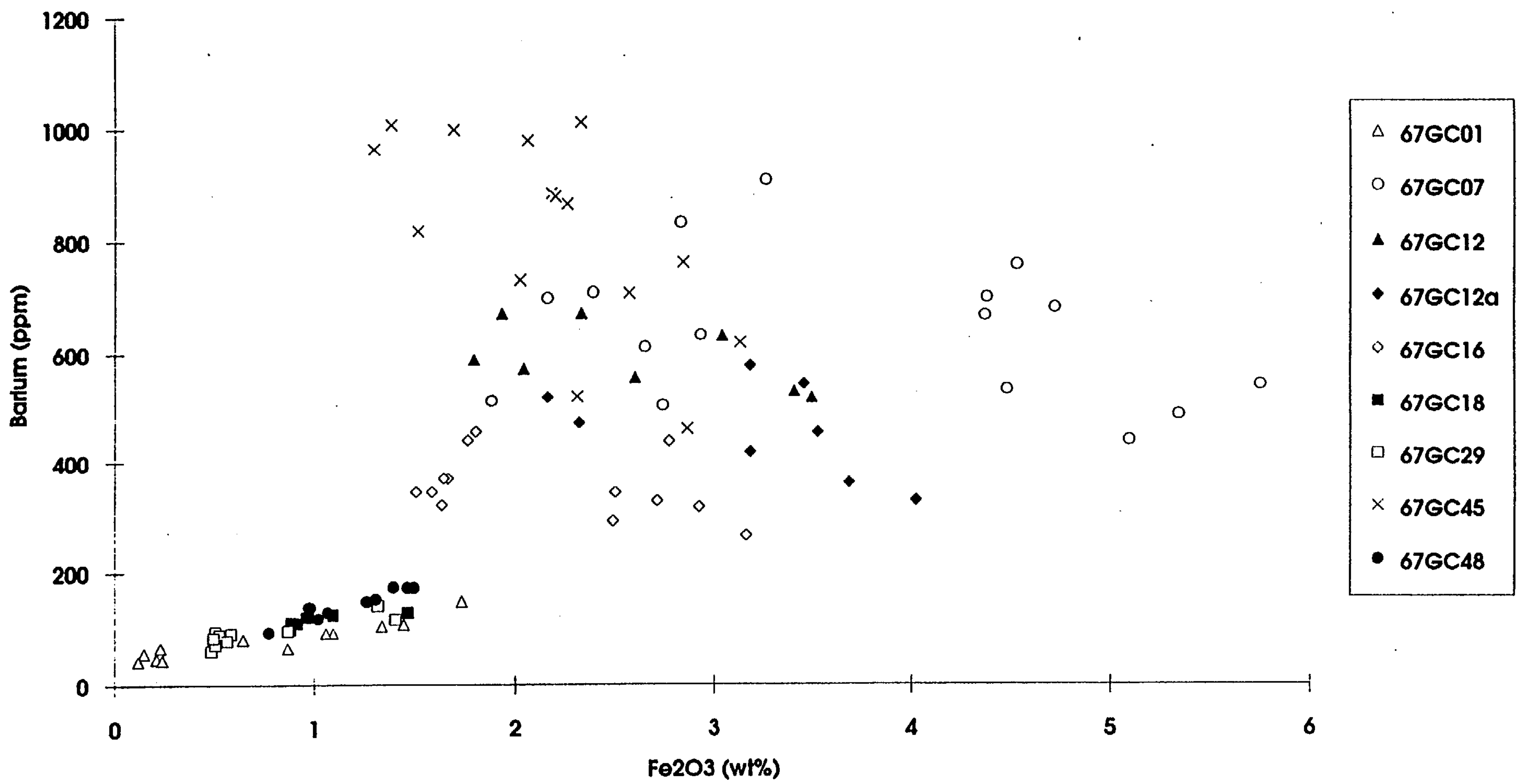


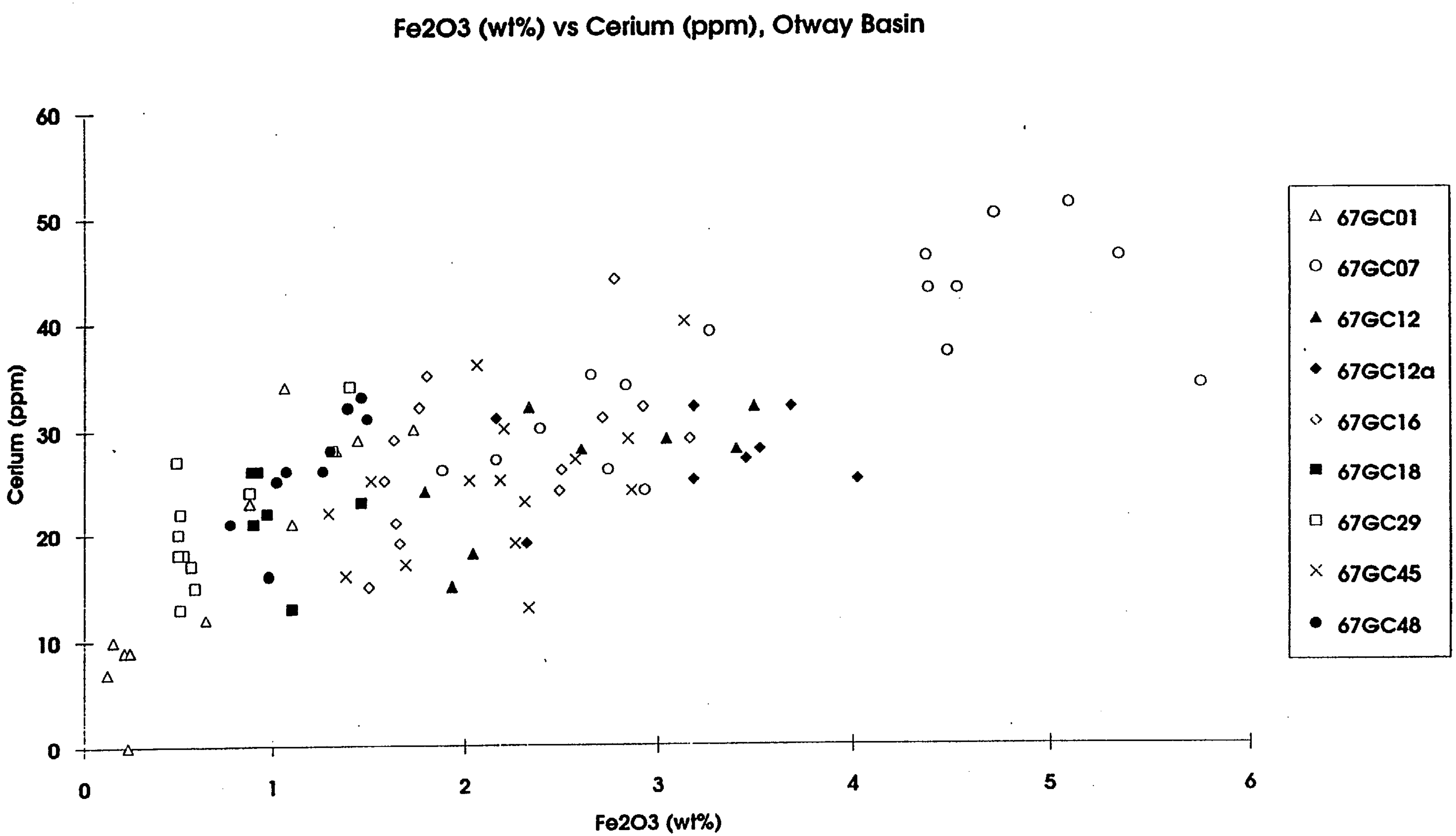
Fe2O3 (wt%) vs Sulphur (ppm), Otway Basin




Fe2O3 (wt%) vs Arsenic (ppm), Otway Basin
Arsenic (ppm)
0
1
2
3
4
5
6
7
8
9
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

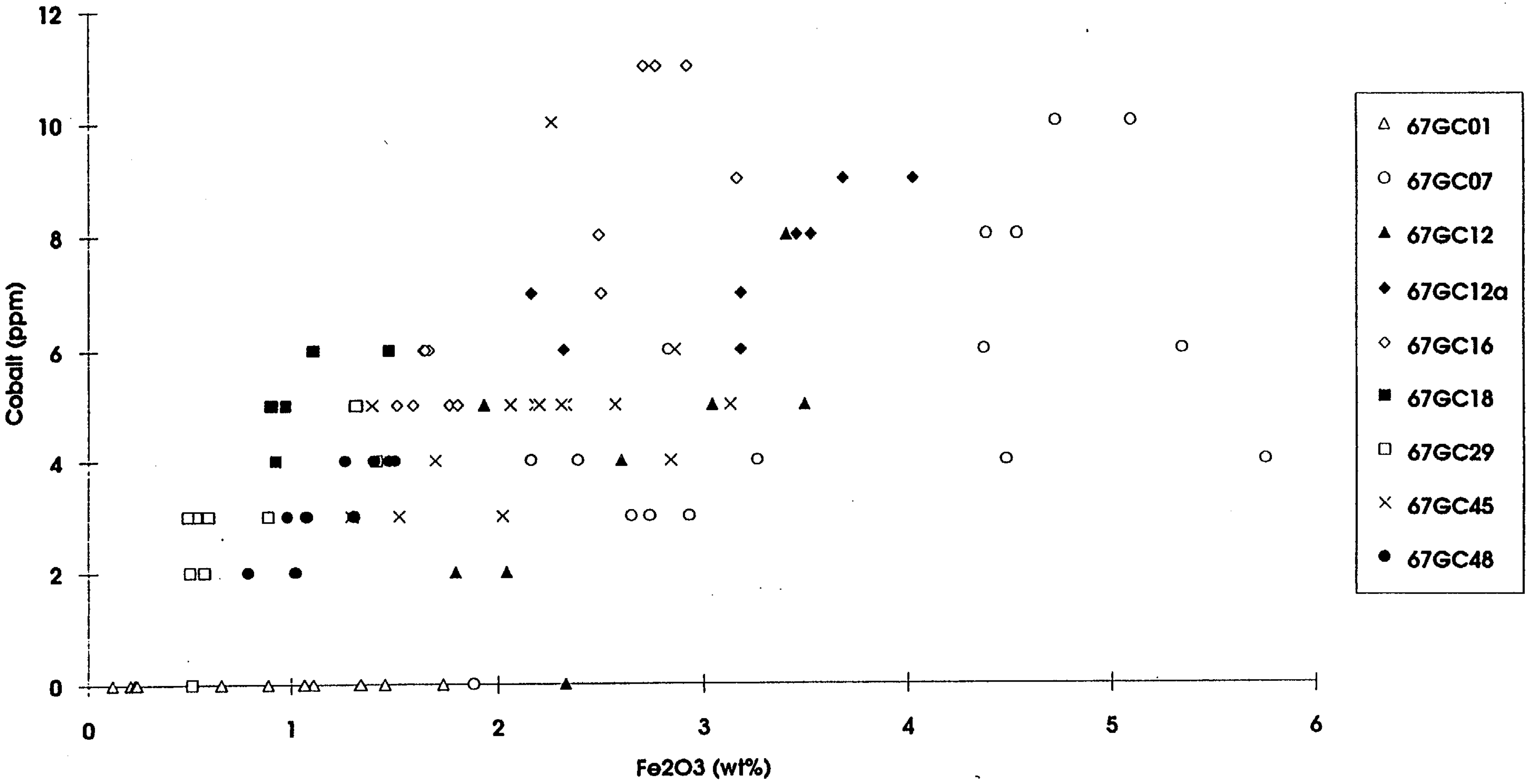
Fe2O3 (wt%) vs Barium (ppm), Otway Basin

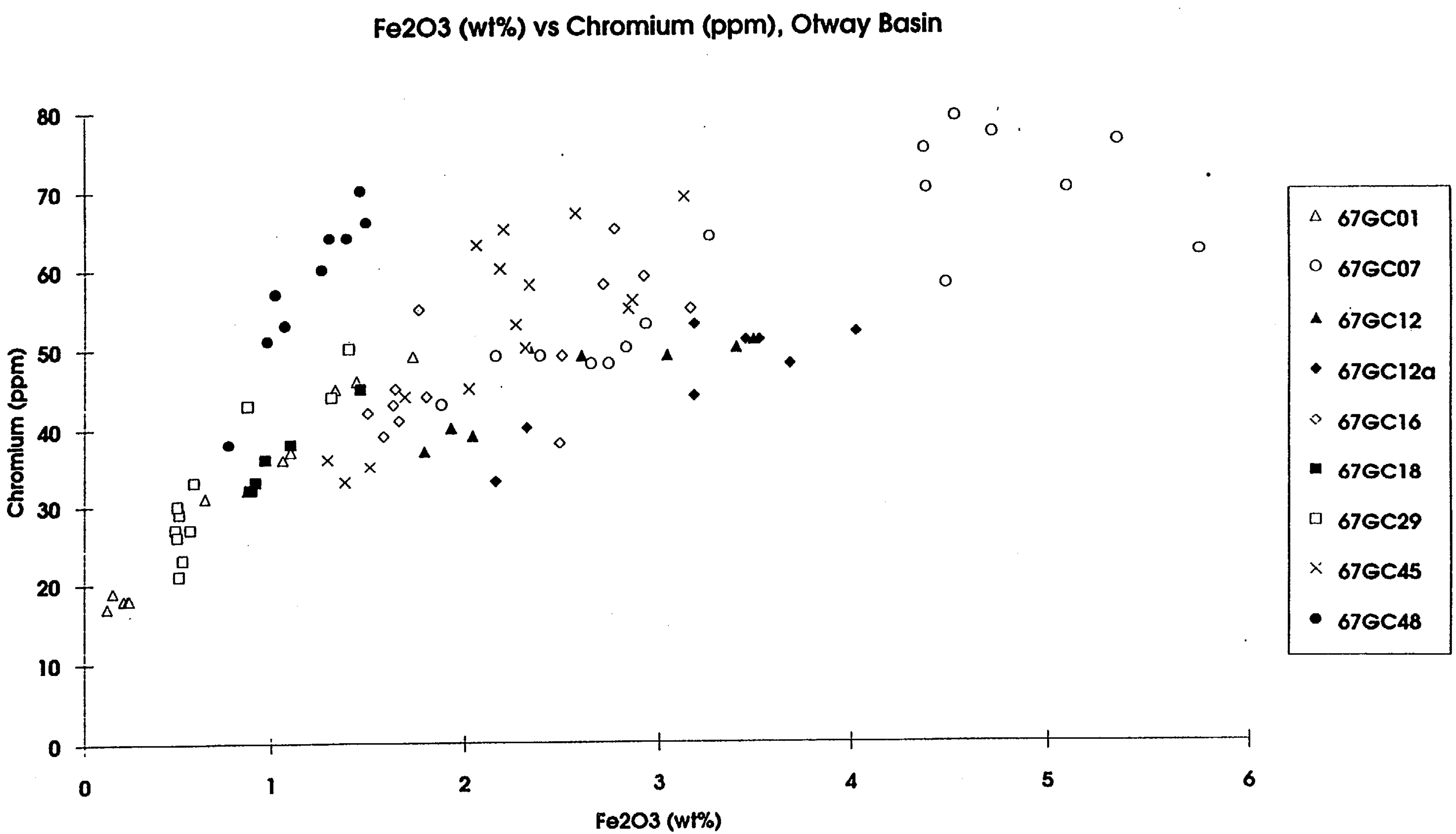




Fe2O3 (wt%) vs Cerium (ppm), Otway Basin
Cerium (ppm)
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

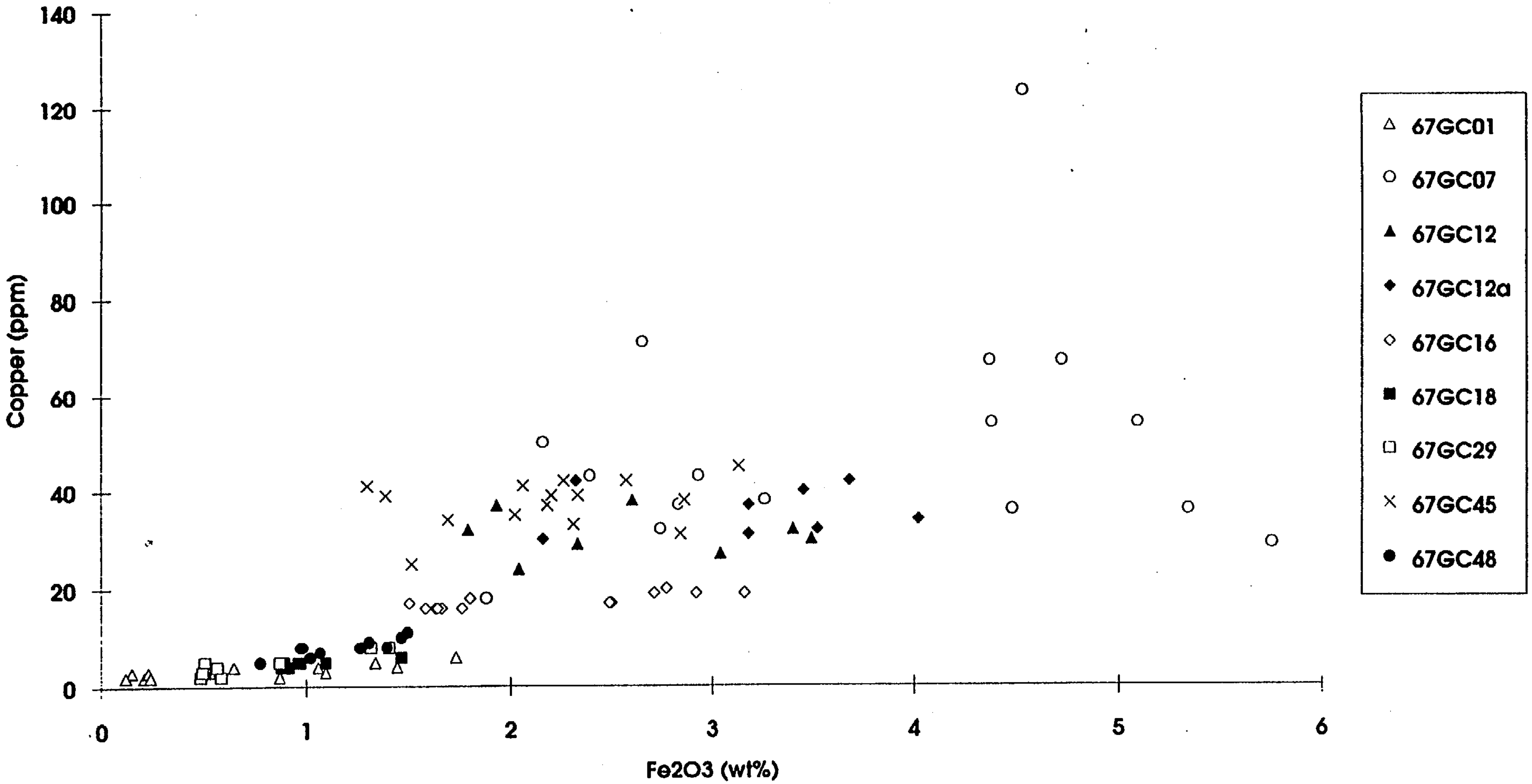
Fe2O3 (wt%) vs Cobalt (ppm), Otway Basin



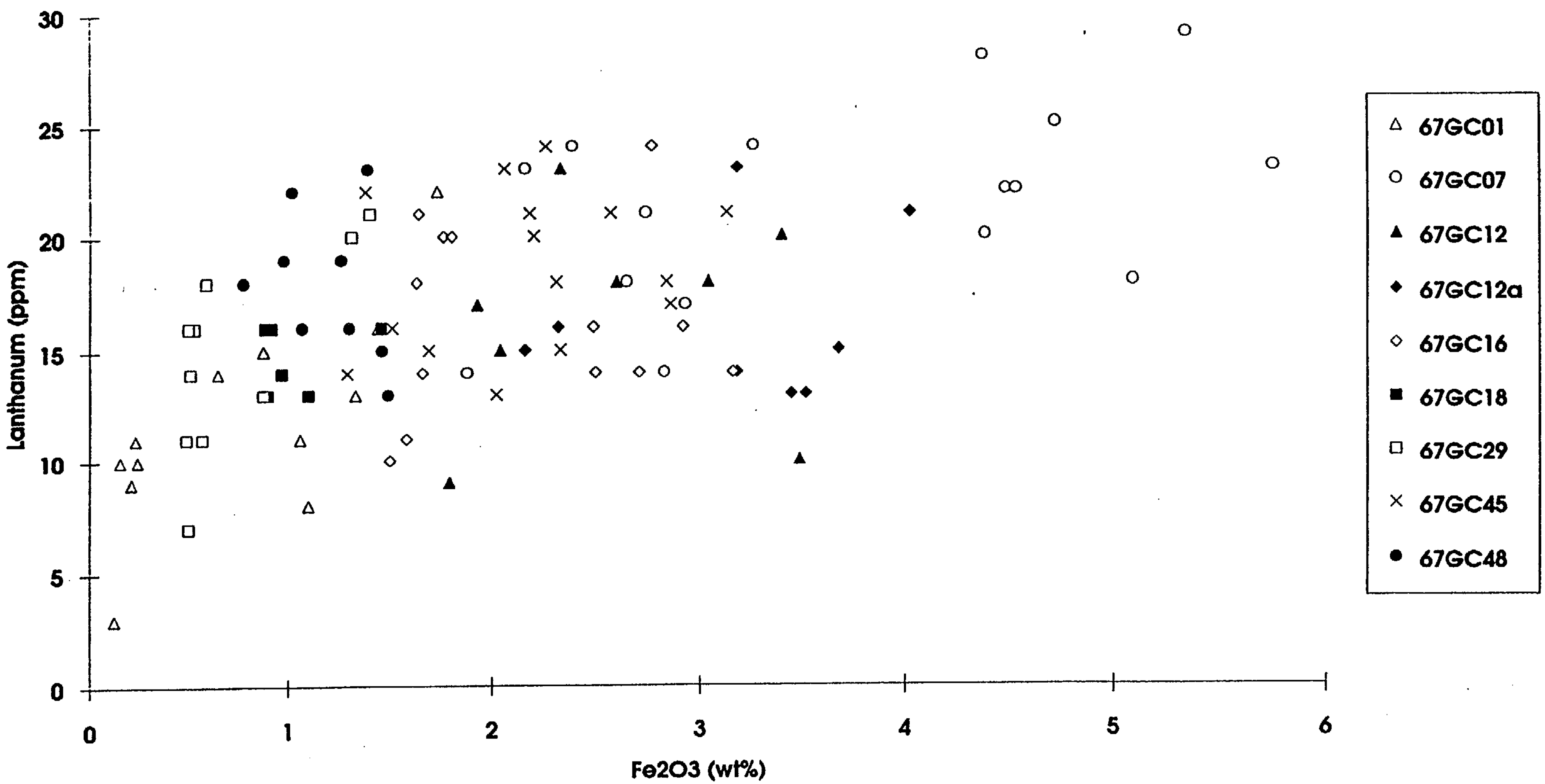


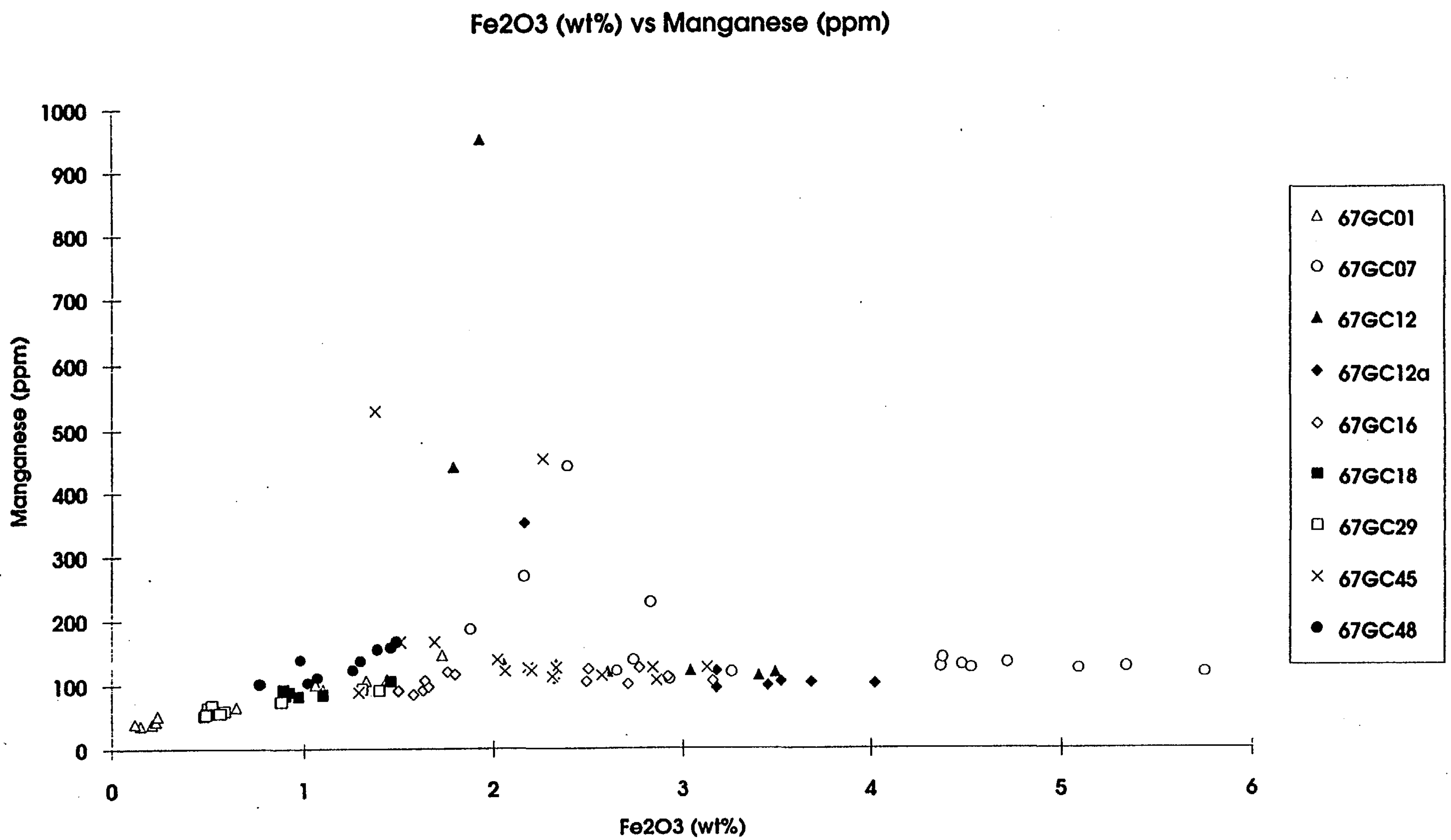
Fe2O3 (wt%) vs Chromium (ppm), Otway Basin
Chromium (ppm)
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Fe2O3 (wt%) vs Copper (ppm), Otway Basin



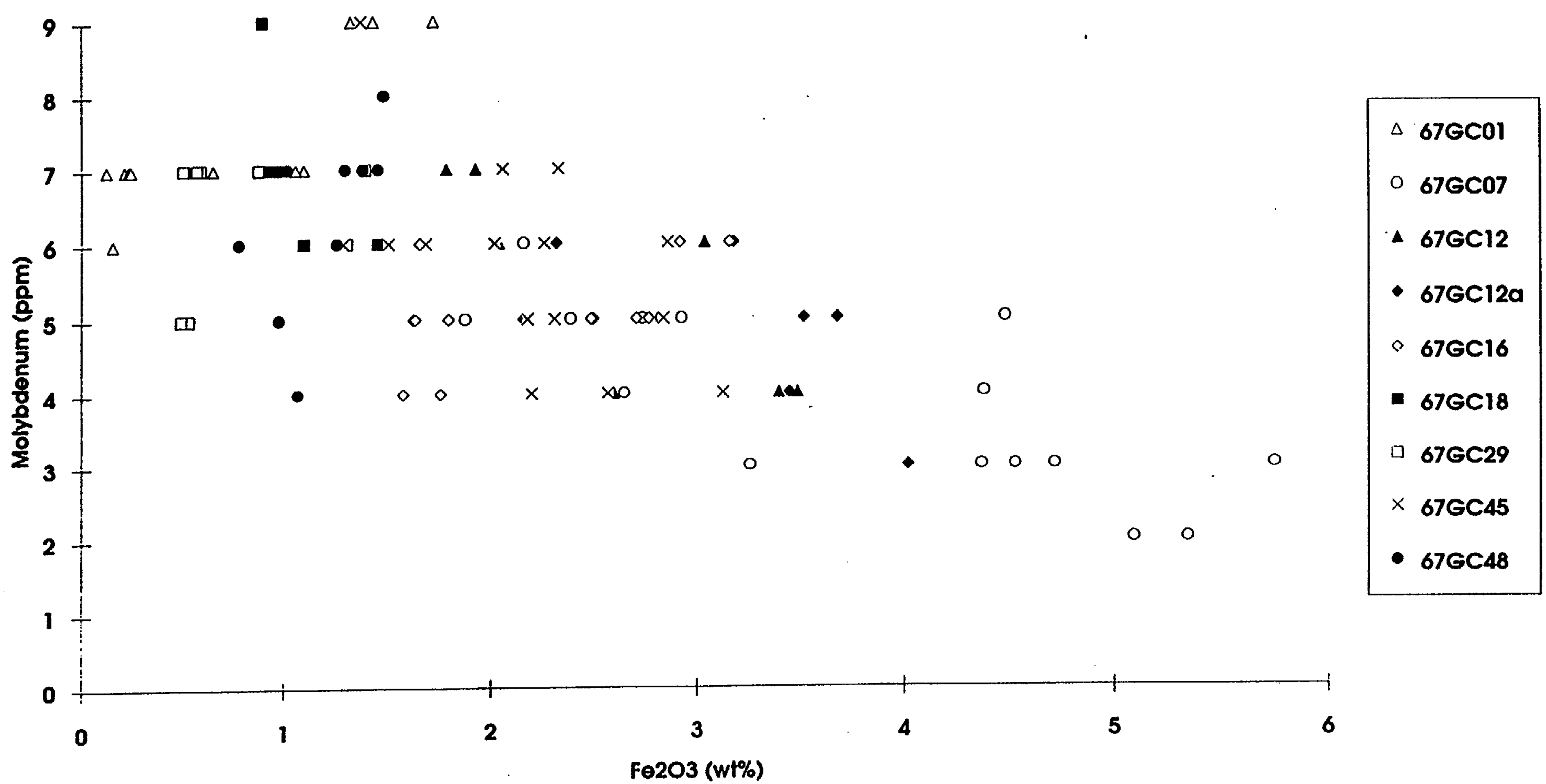
Fe2O3 (wt%) vs Lanthanum (ppm), Otway Basin



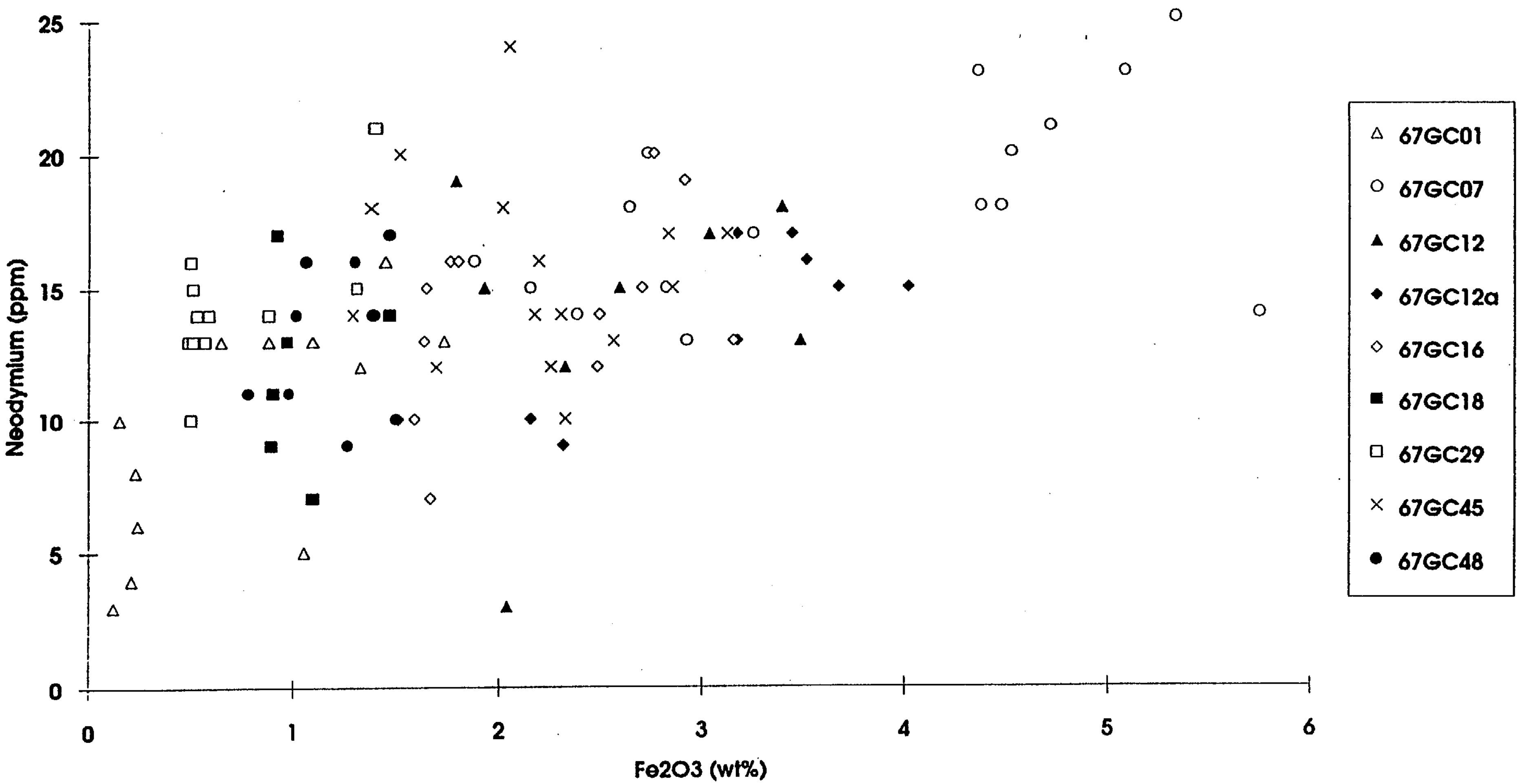


Fe2O3 (wt%) vs Manganese (ppm)
Manganese (ppm)
1000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

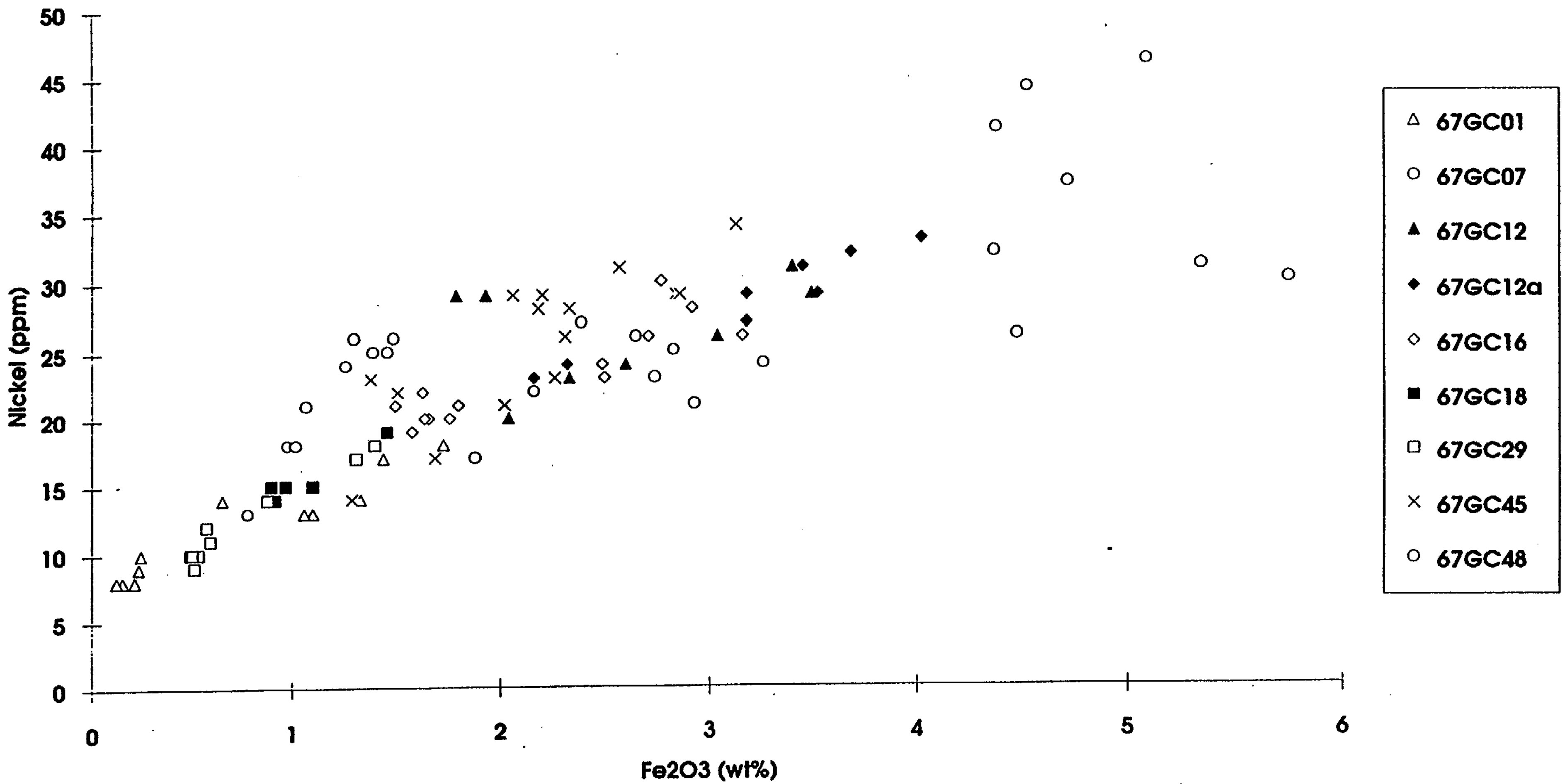
Fe2O3 (wt%) vs Molybdenum (ppm), Otway Basin



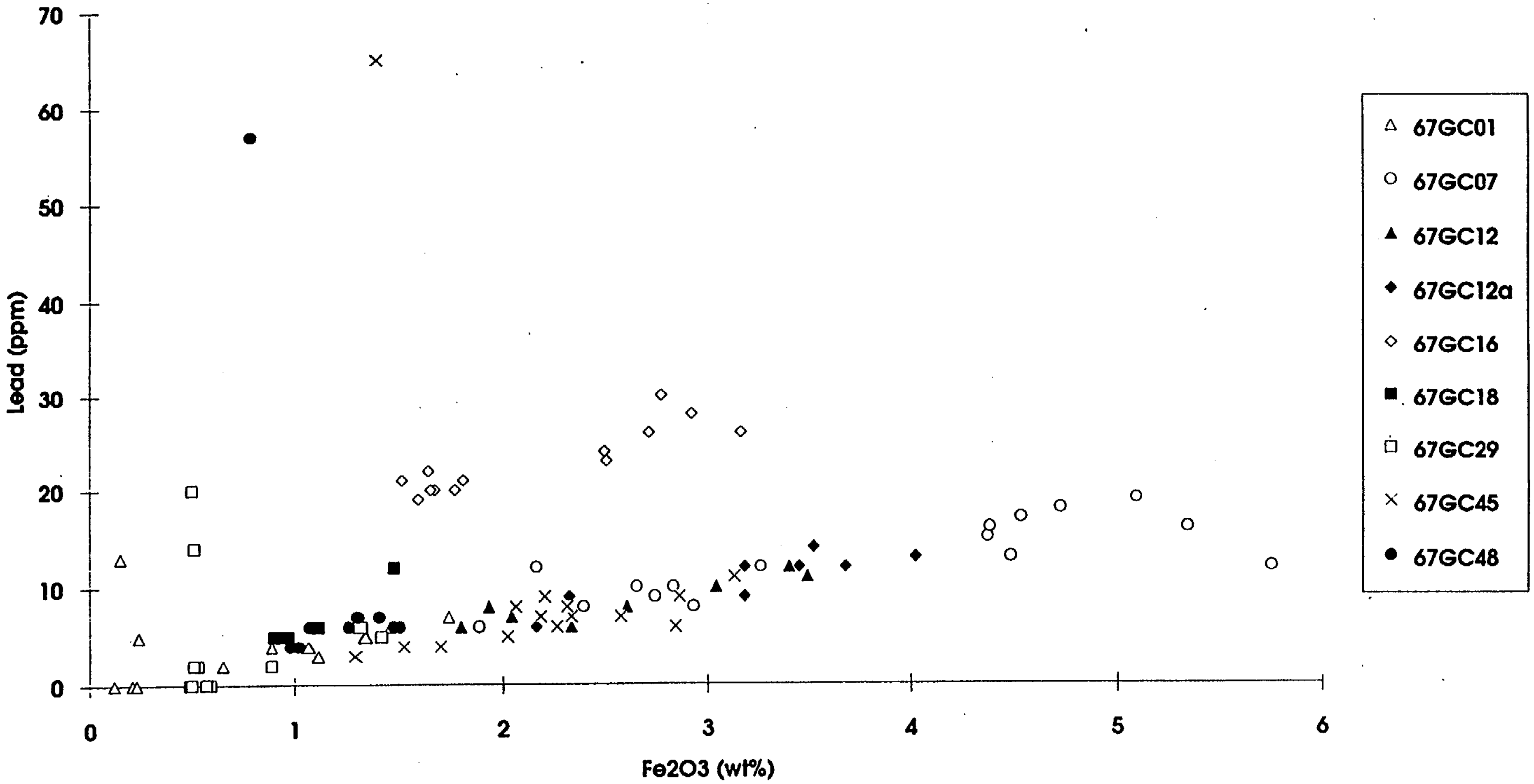
Fe2O3 (wt%) vs Neodymium (ppm), Otway Basin

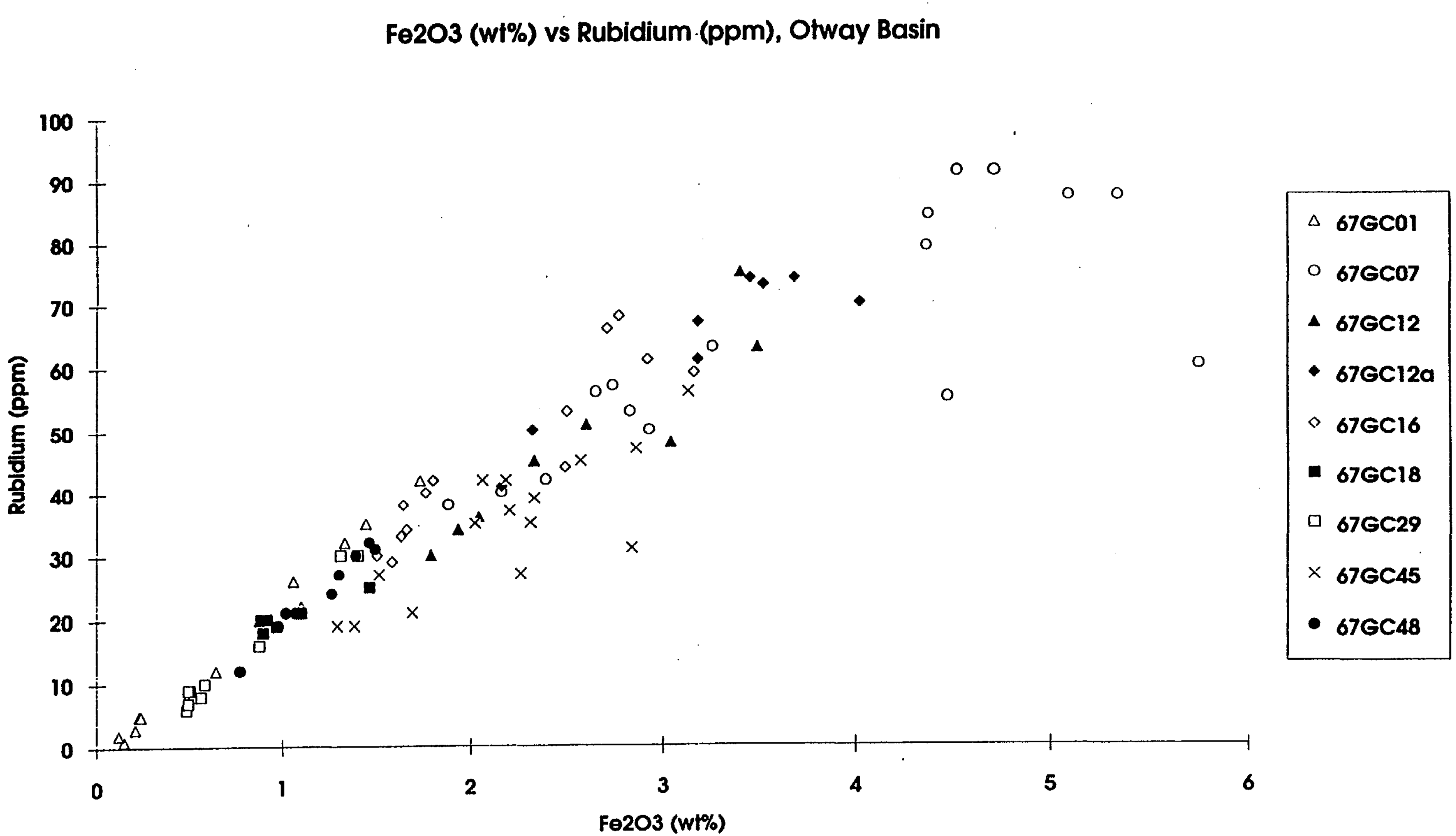


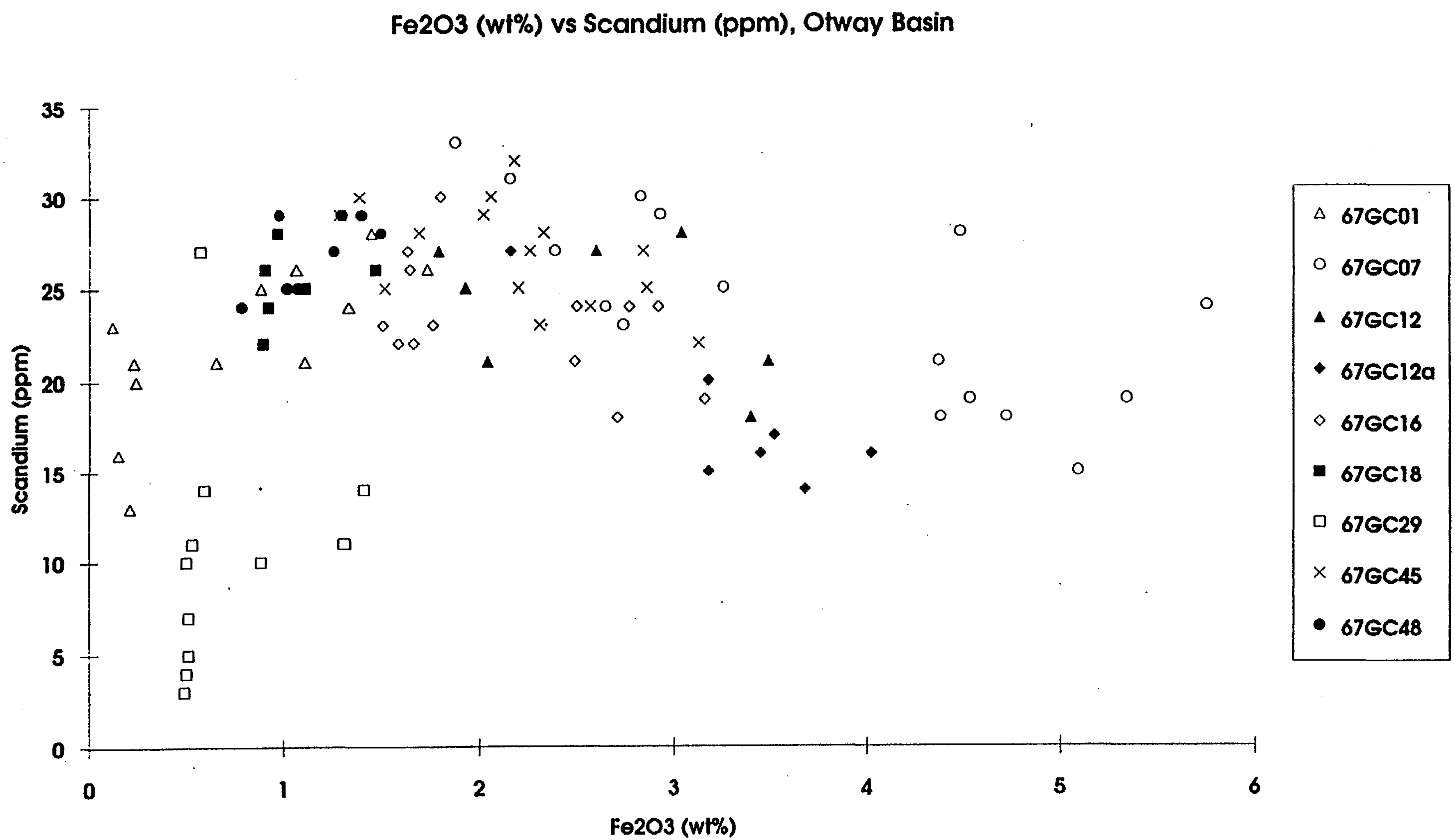
Fe2O3 (wt%) vs Nickel (ppm), Otway Basin



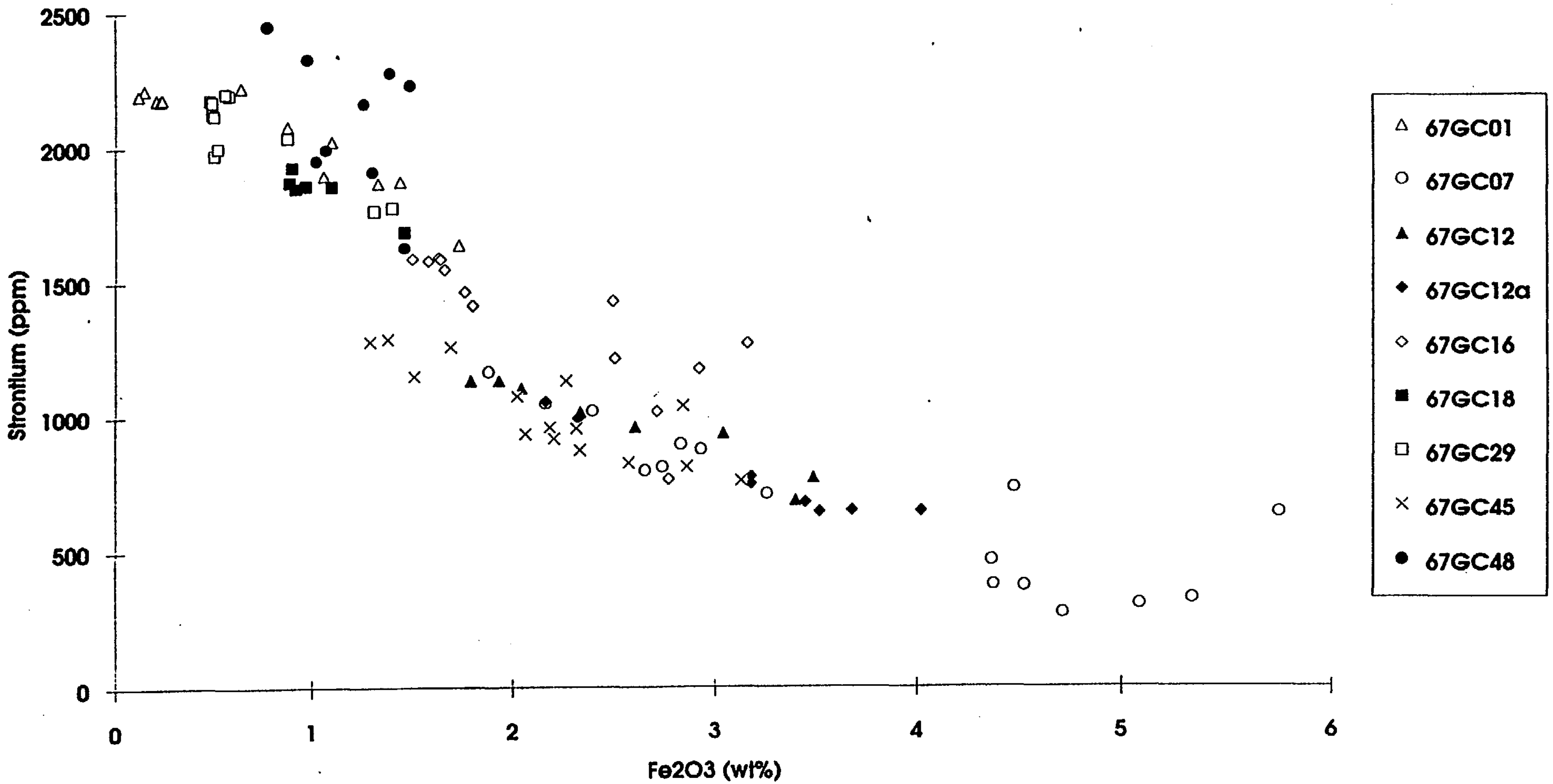
Fe2O3 (wt%) vs Lead (ppm), Otway Basin

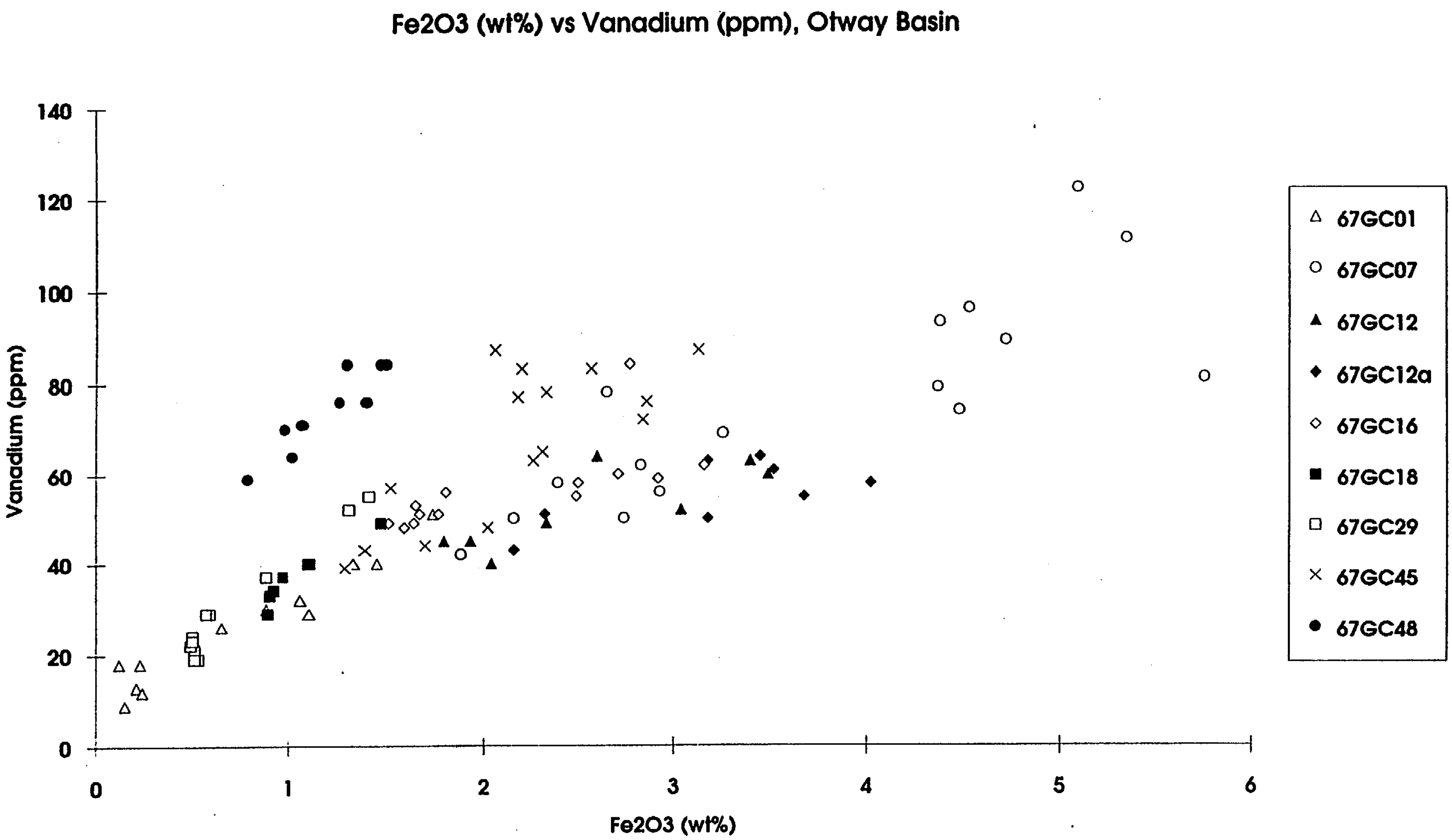


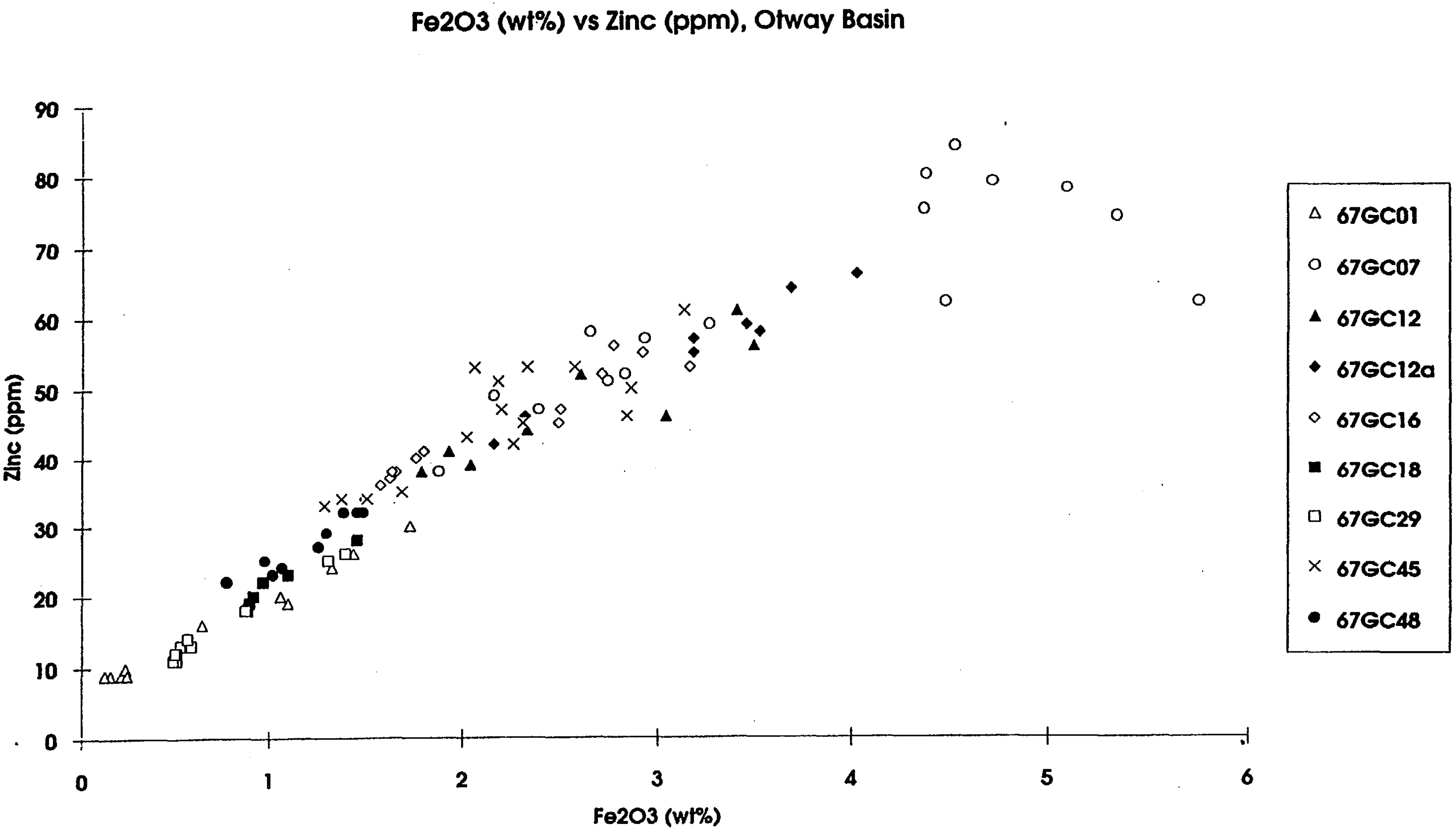

Fe2O3 (wt%) vs Rubidium (ppm), Otway Basin
Rubidium (ppm)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48


Fe2O3 (wt%) vs Scandium (ppm), Otway Basin
Scandium (ppm)
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

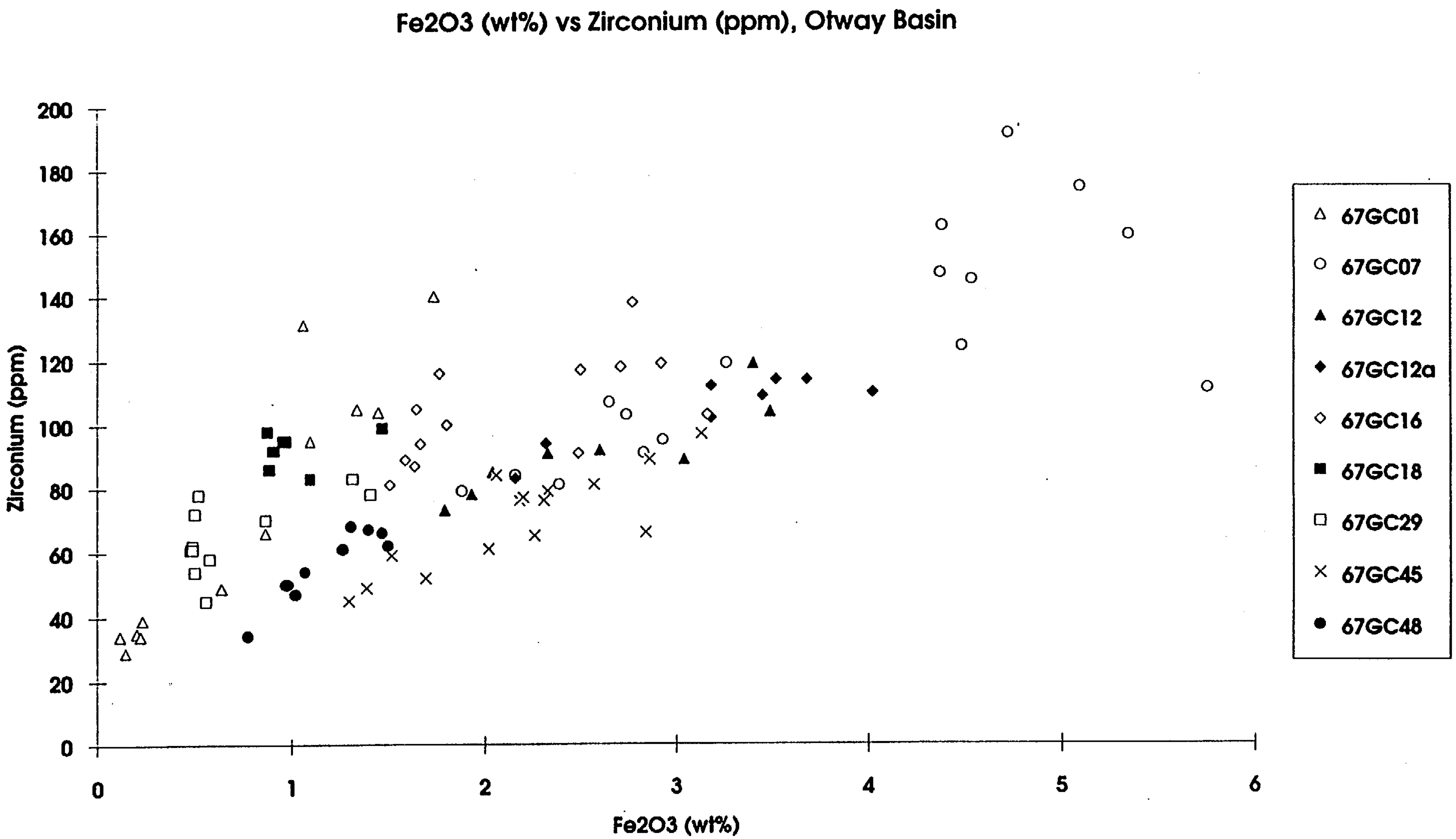
Fe2O3 (wt%) vs Strontium (ppm), Otway Basin




Fe2O3 (wt%) vs Vanadium (ppm), Otway Basin
Vanadium (ppm)
Fe2O3 (wt%)
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48



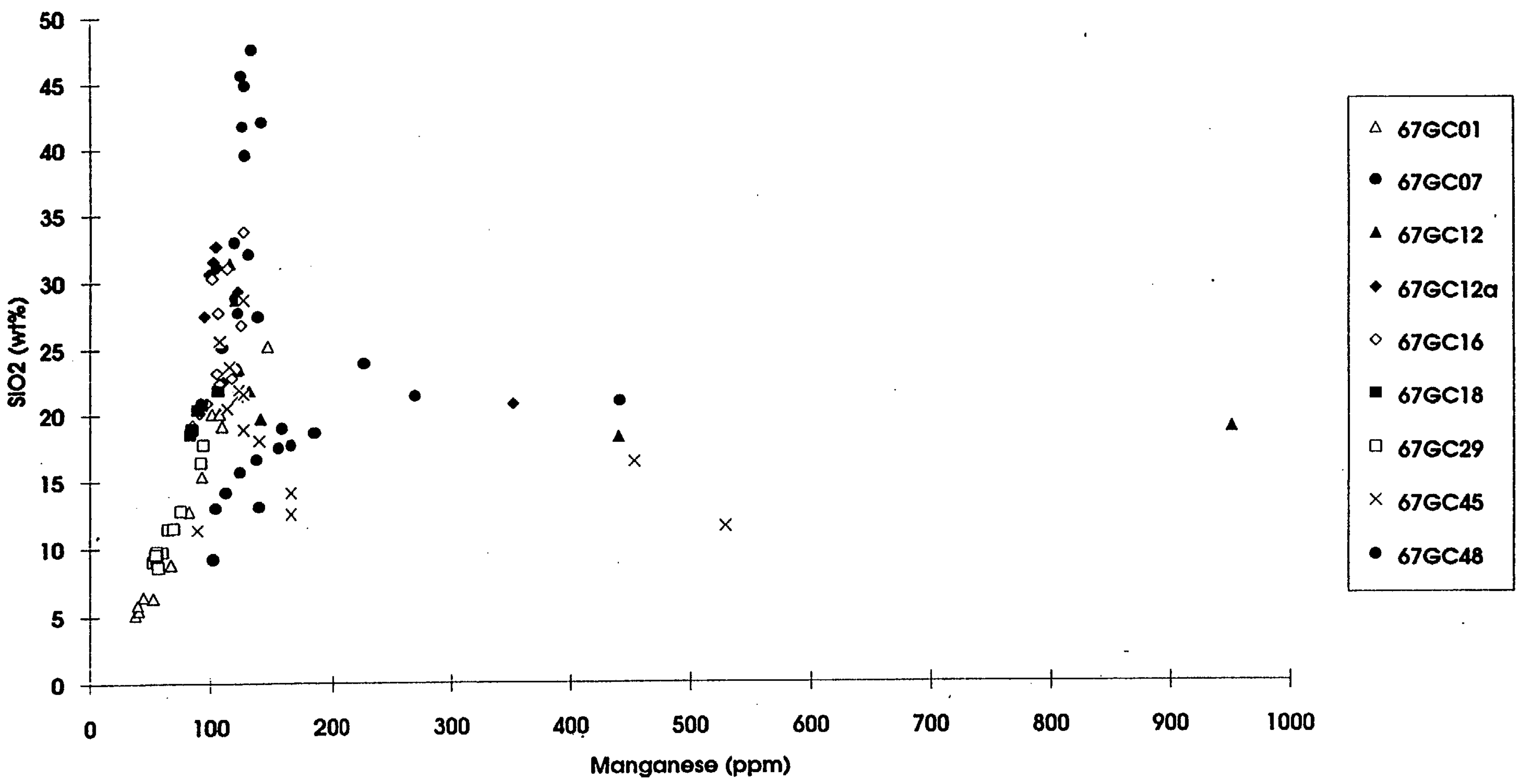
Fe2O3 (wt%) vs Zinc (ppm), Otway Basin
Zinc (ppm)
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48



Fe2O3 (wt%) vs Zirconium (ppm), Otway Basin
Zirconium (ppm)
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
Fe2O3 (wt%)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

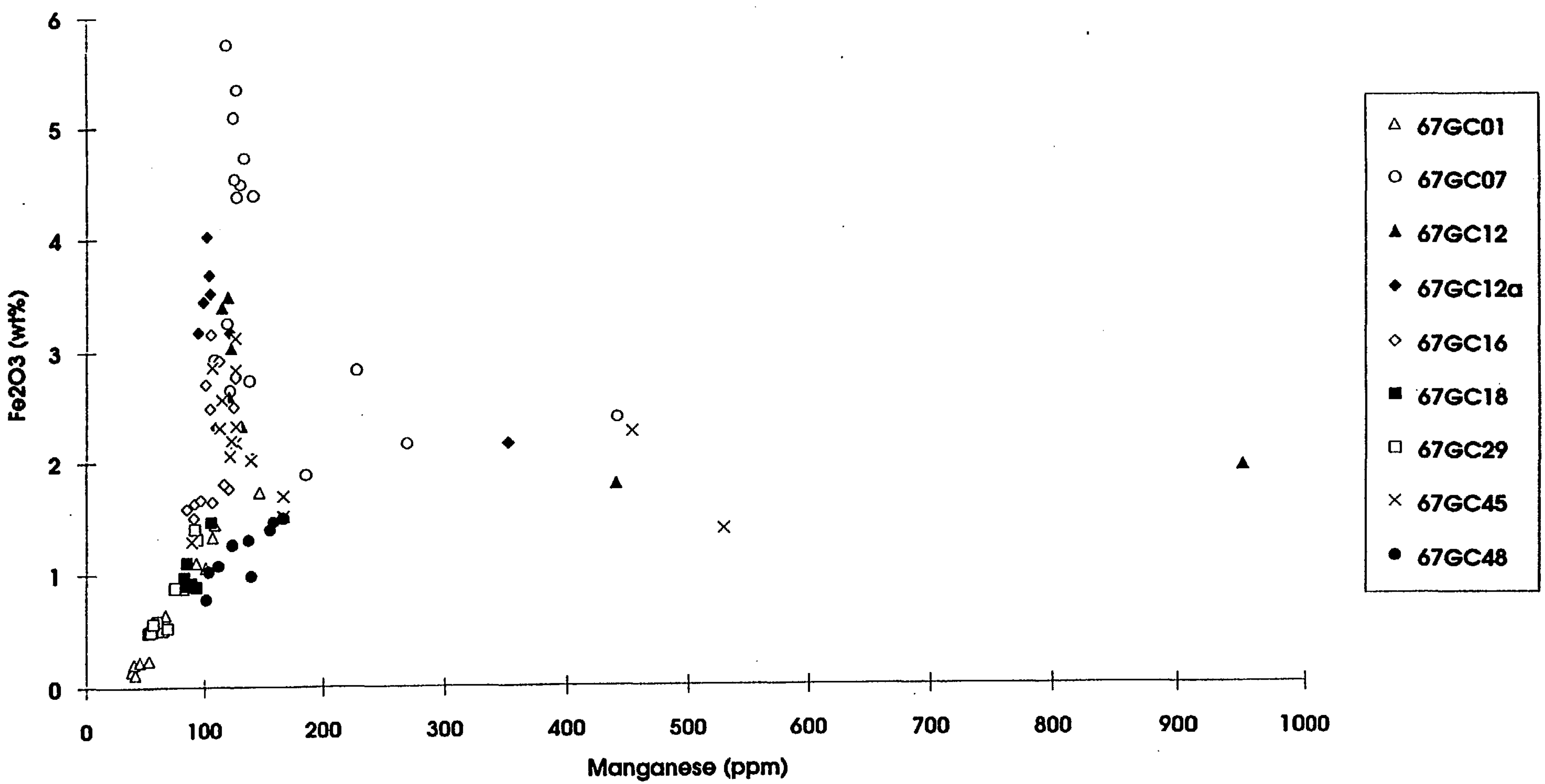
Appendix 3. Manganese with select major and trace elements

Manganese (ppm) vs SiO2 (wt%), Otway Basin

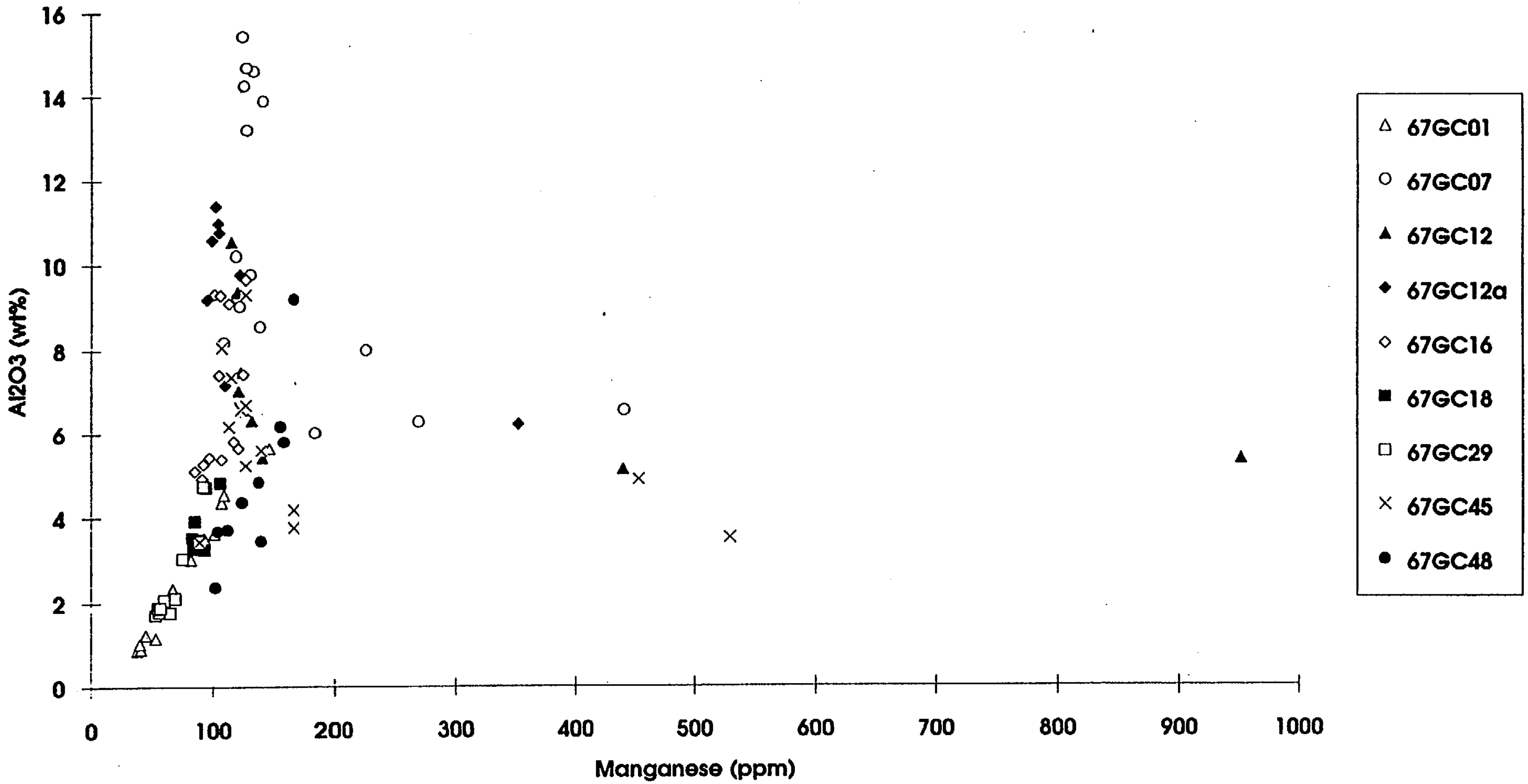


C2

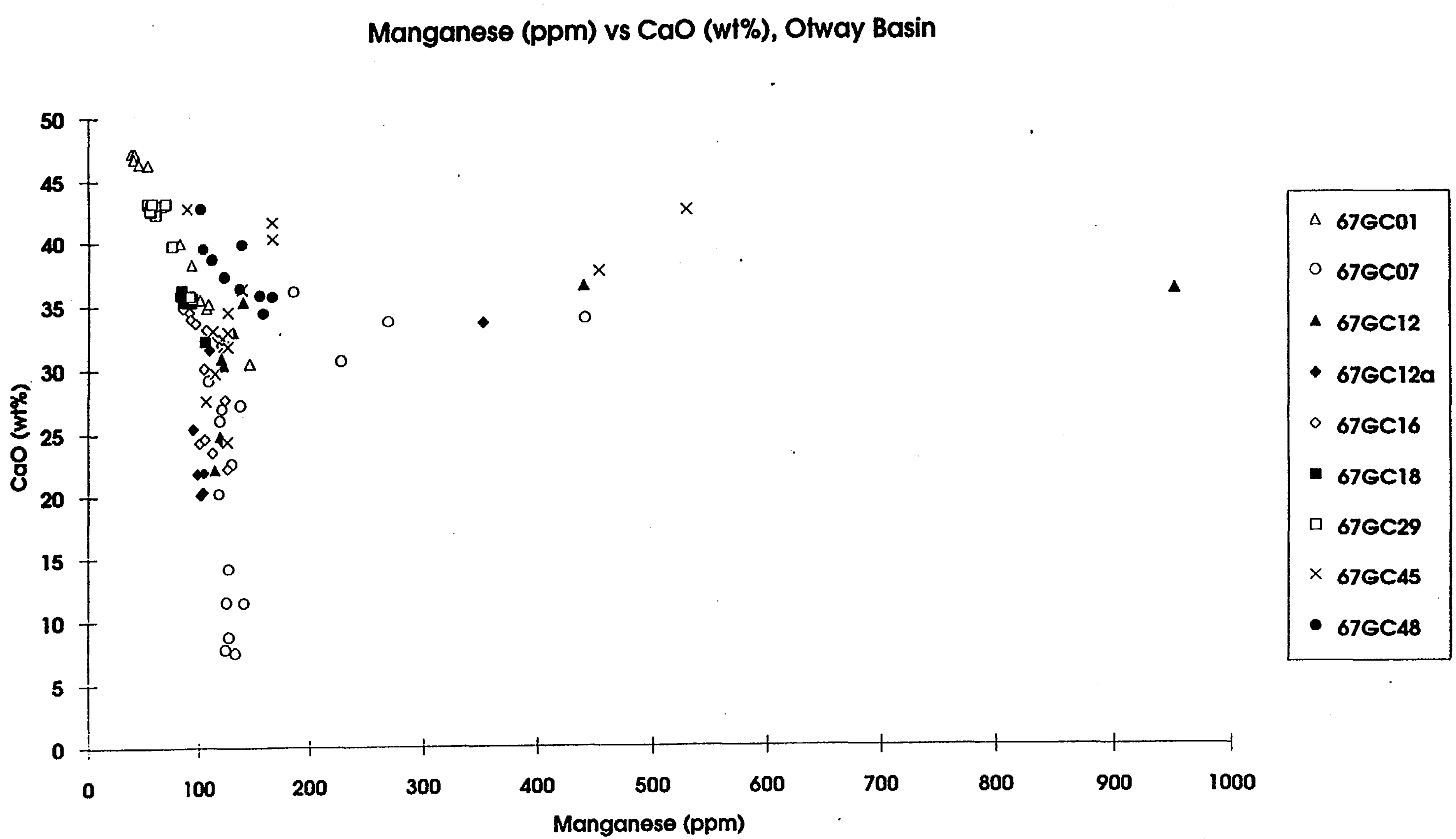
Manganese (ppm) vs Fe2O3 (wt%), Otway Basin



Manganese (ppm) vs Al2O3 (wt%), Otway Basin

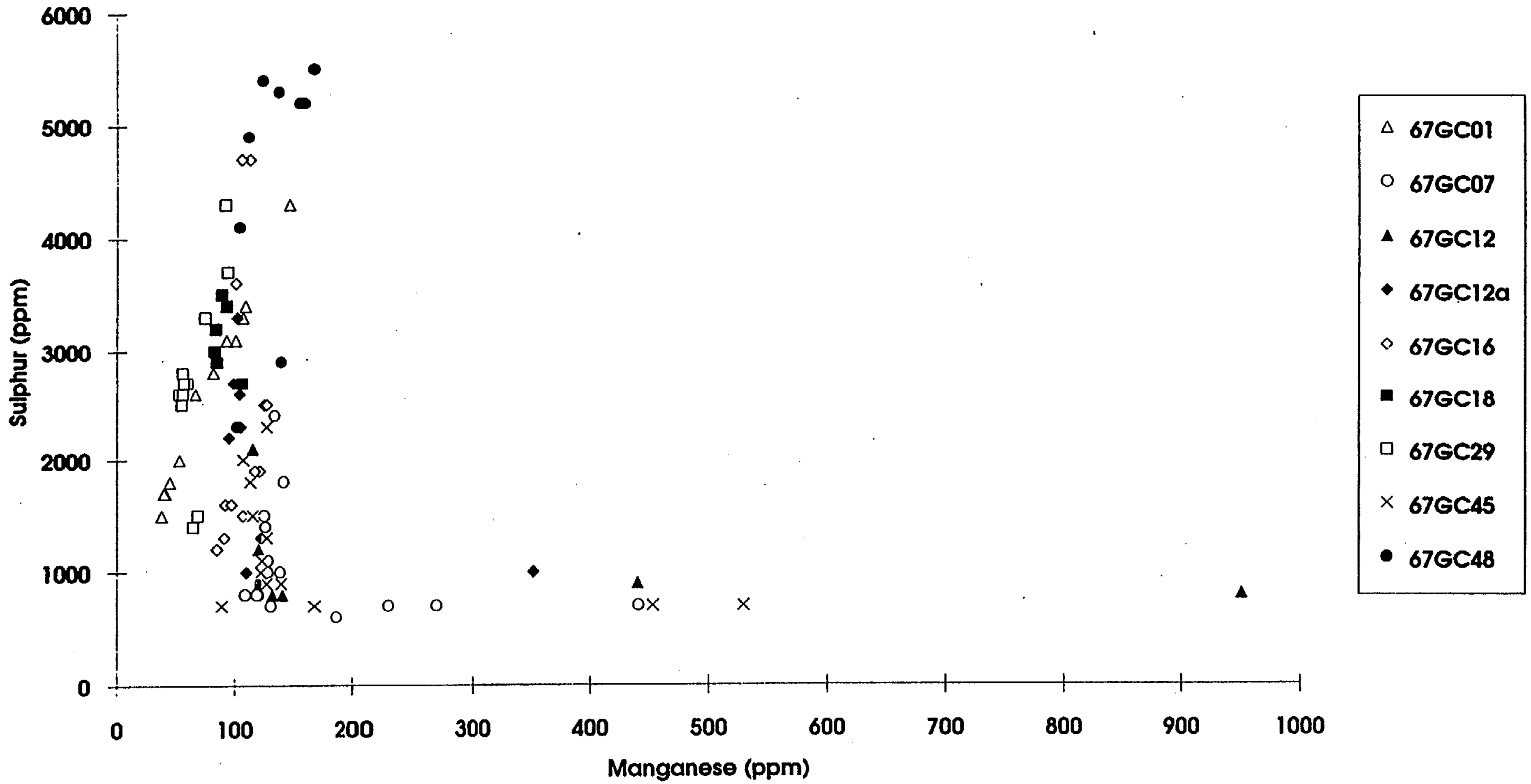


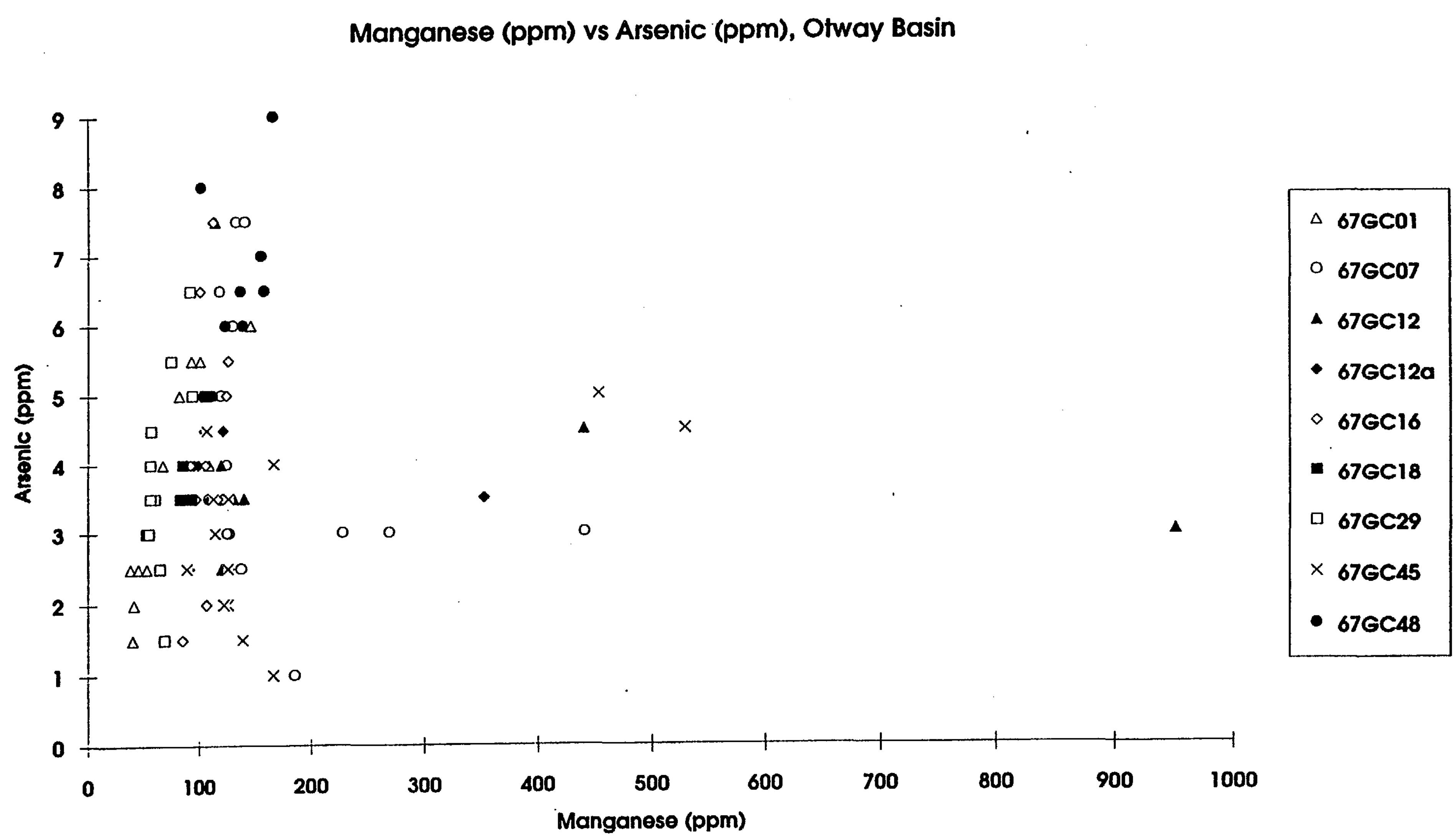
C4


Manganese (ppm) vs CaO (wt%), Otway Basin
CaO (wt%)
50
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
Manganese (ppm)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

C5

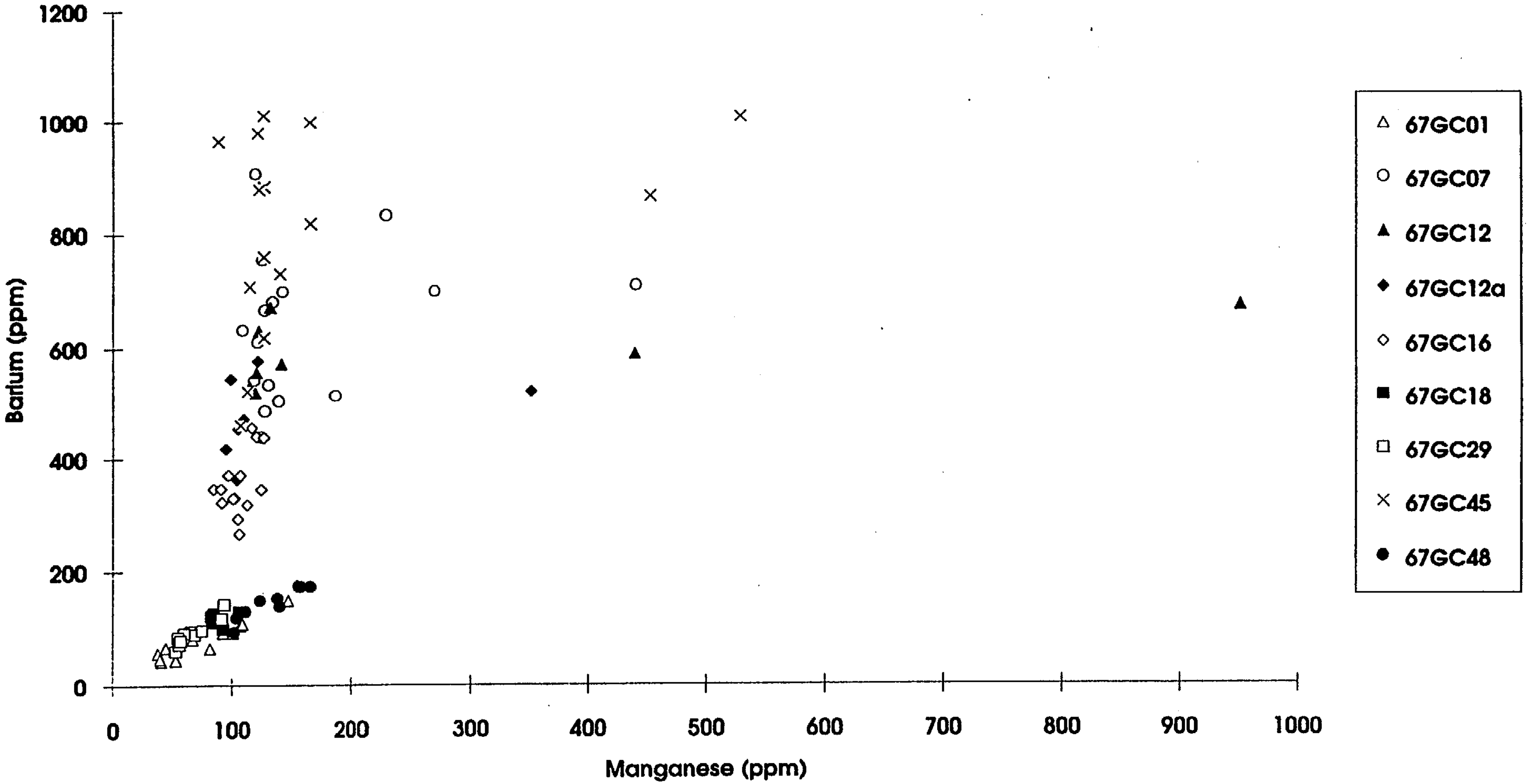
Manganese (ppm) vs Sulphur (ppm), Otway Basin





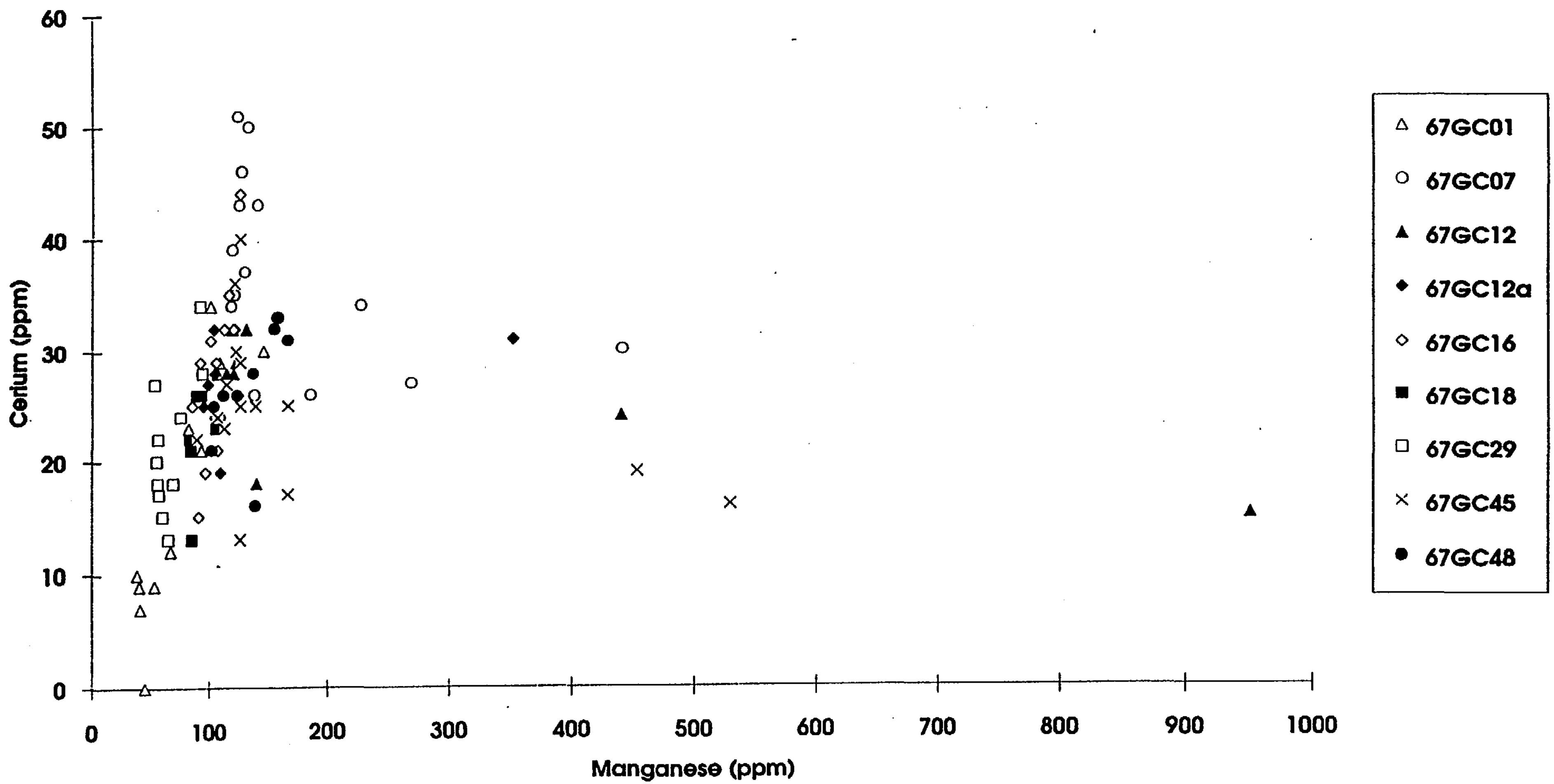
Manganese (ppm) vs Arsenic (ppm), Otway Basin
Arsenic (ppm)
0
1
2
3
4
5
6
7
8
9
0
100
200
300
400
500
600
700
800
900
1000
Manganese (ppm)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Manganese (ppm) vs Barium (ppm), Otway Basin

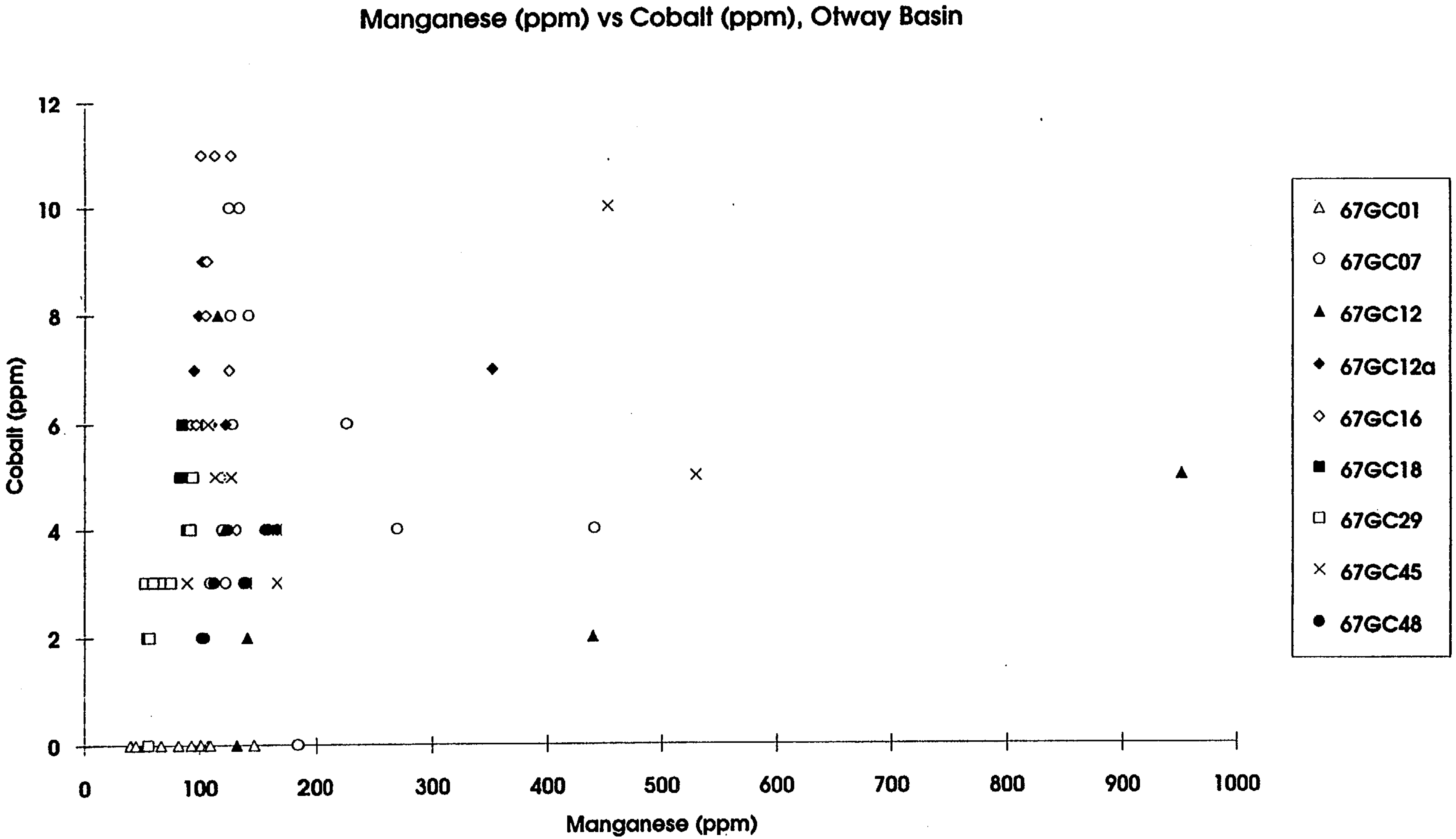


C8

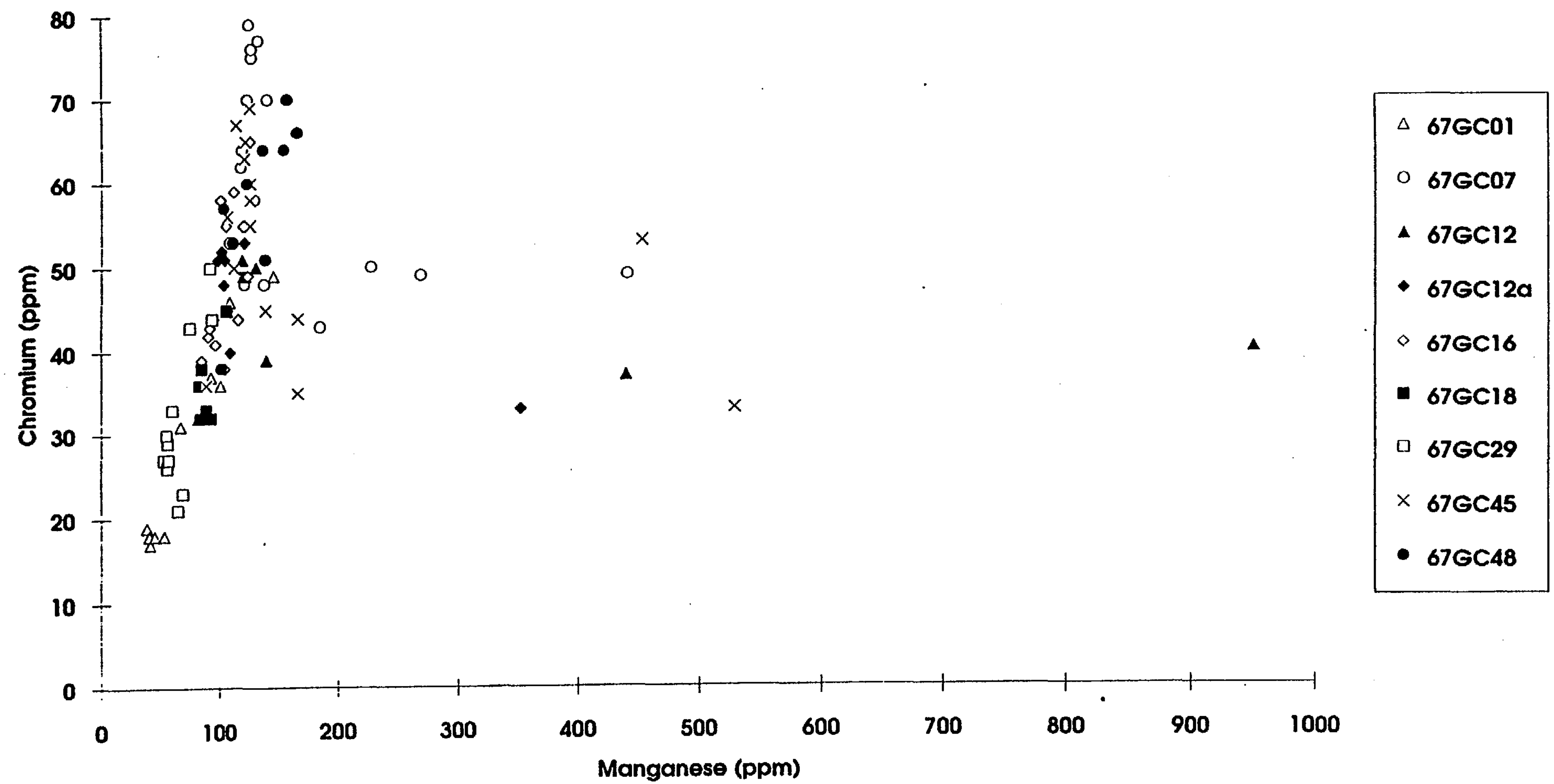
Manganese (ppm) vs Cerium (ppm), Otway Basin

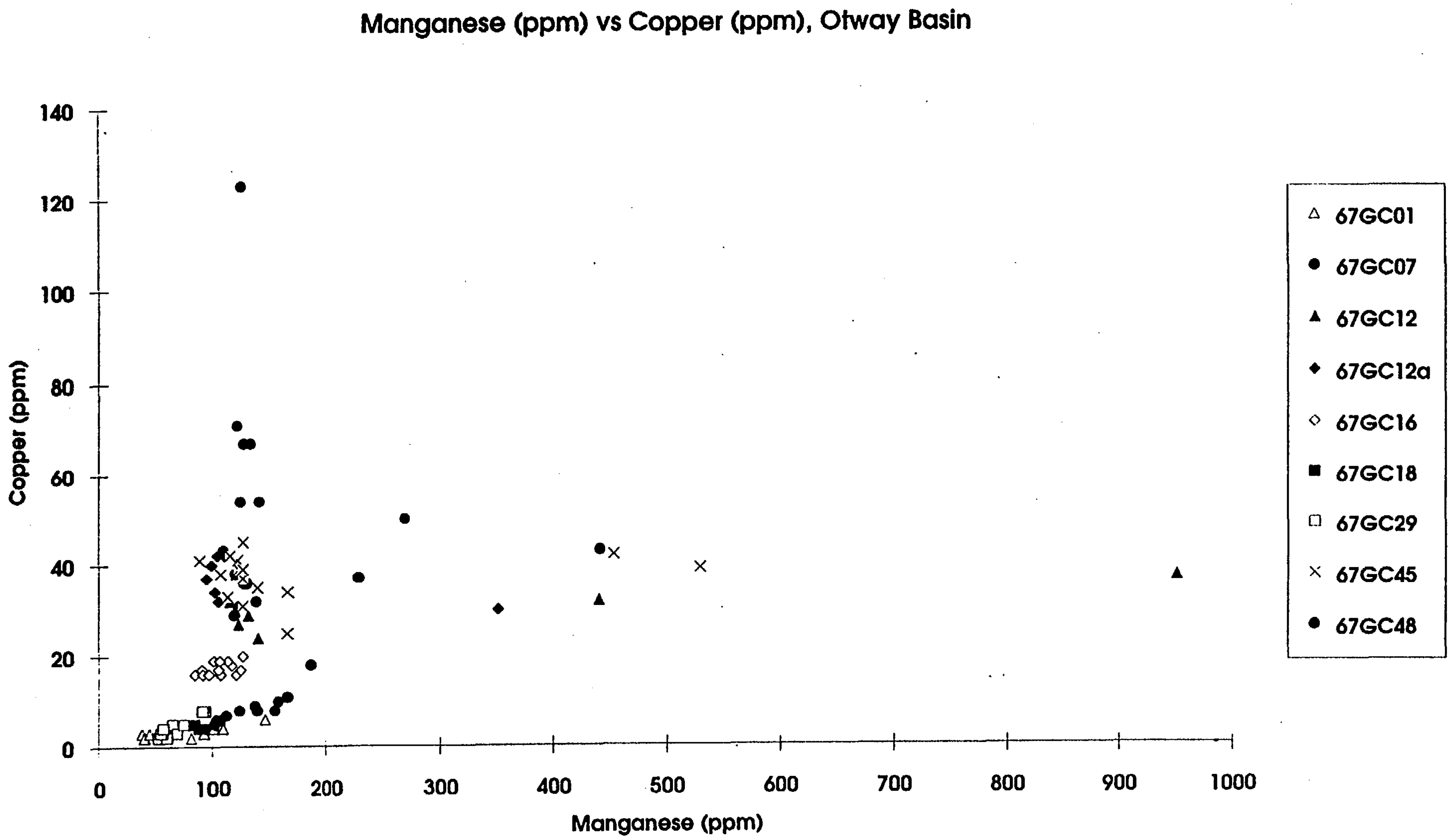


C9

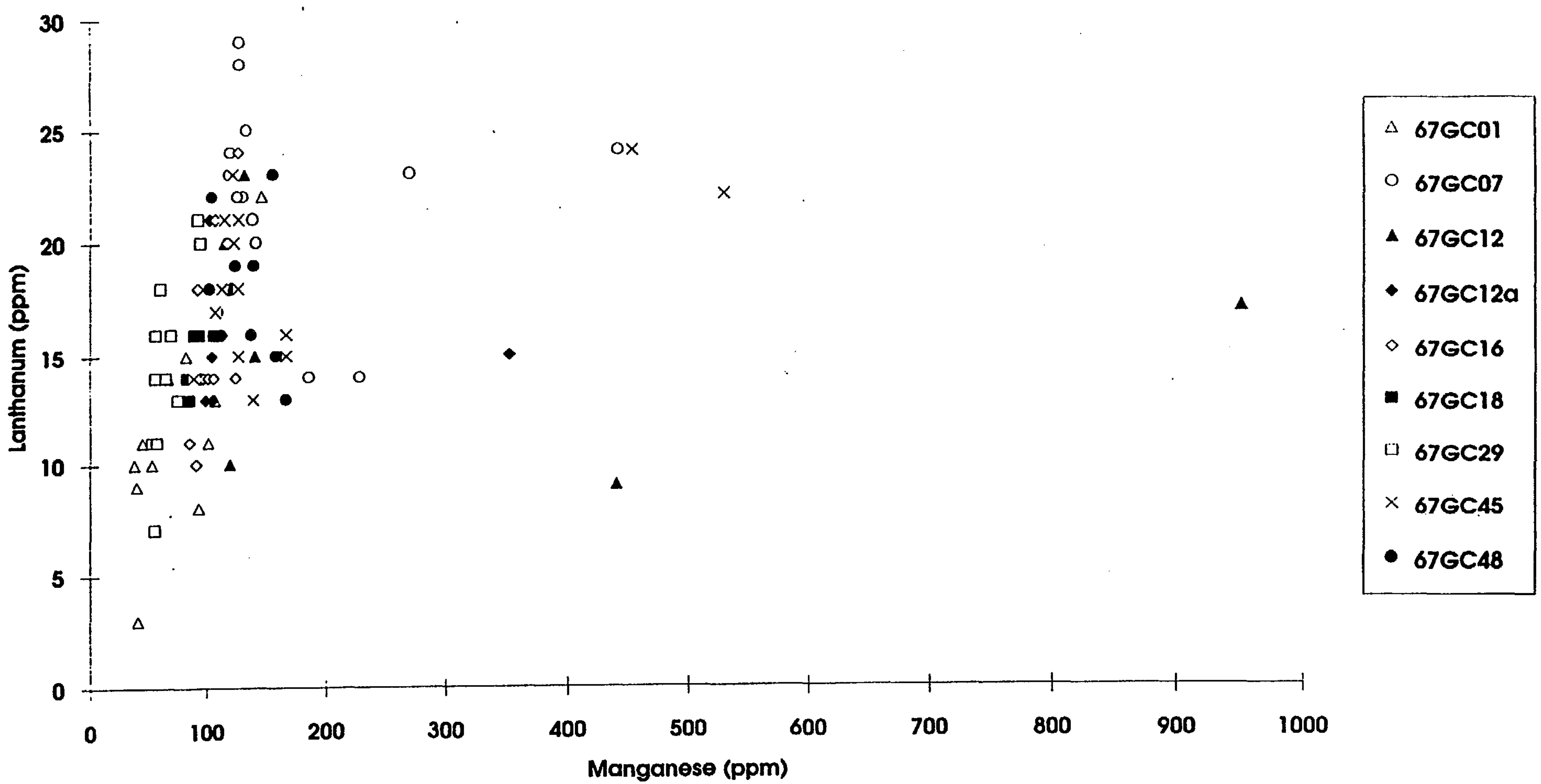

Manganese (ppm) vs Cobalt (ppm), Otway Basin
Cobalt (ppm)
Manganese (ppm)
0
2
4
6
8
10
12
0
100
200
300
400
500
600
700
800
900
1000
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Manganese (ppm) vs Chromium (ppm), Otway Basin

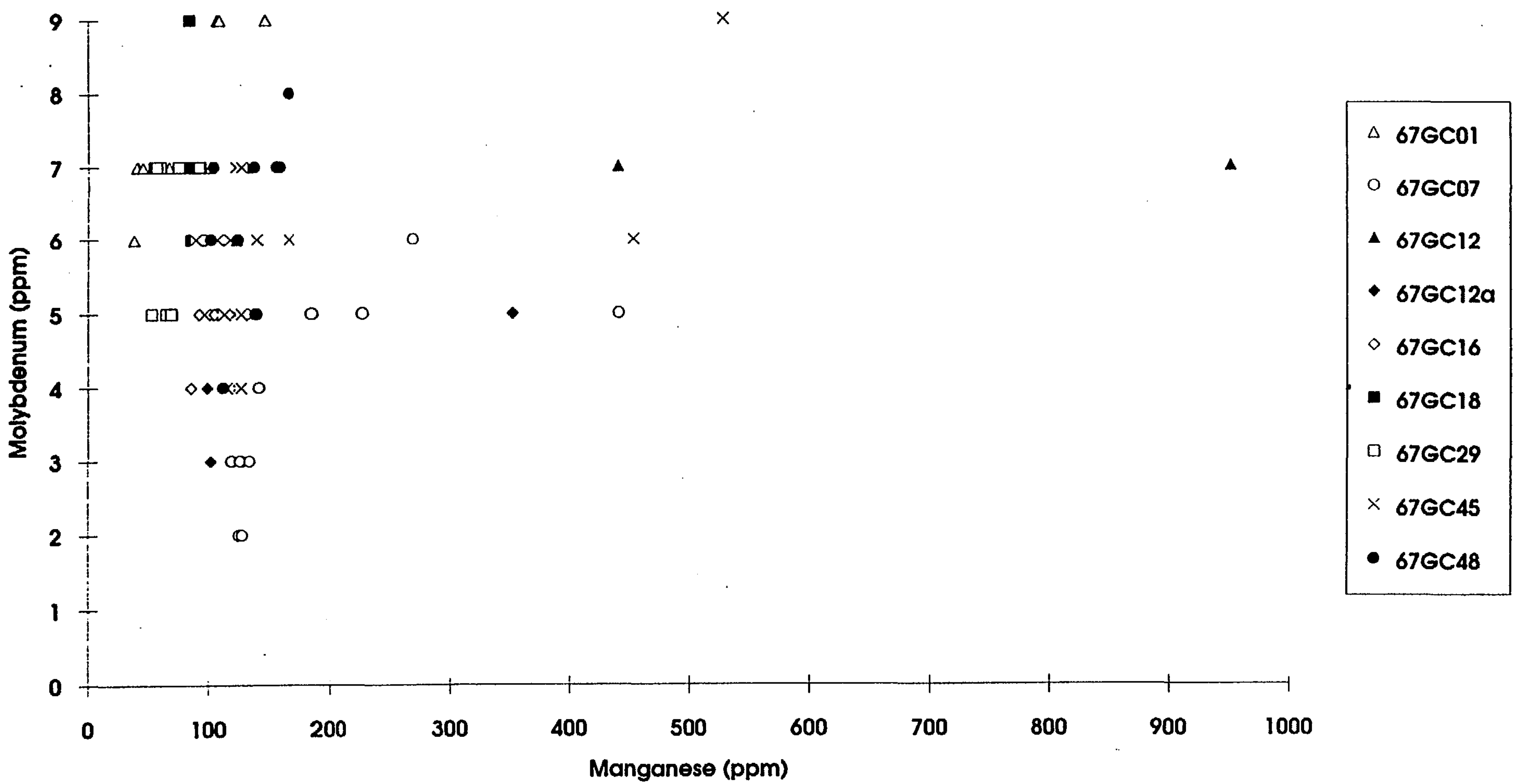



Manganese (ppm) vs Copper (ppm), Otway Basin
Copper (ppm)
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000
Manganese (ppm)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

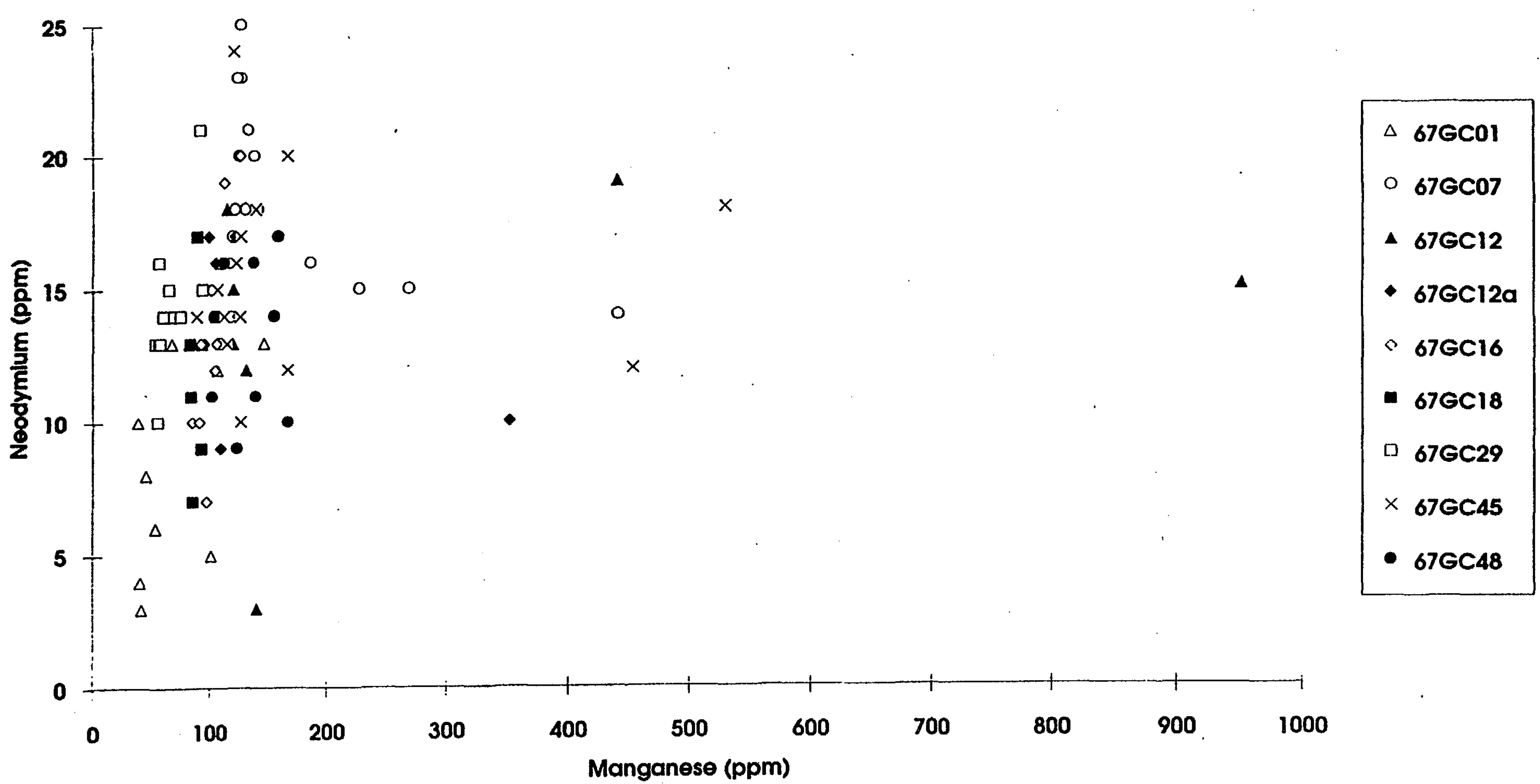
Manganese (ppm) vs Lanthanum (ppm), Otway Basin



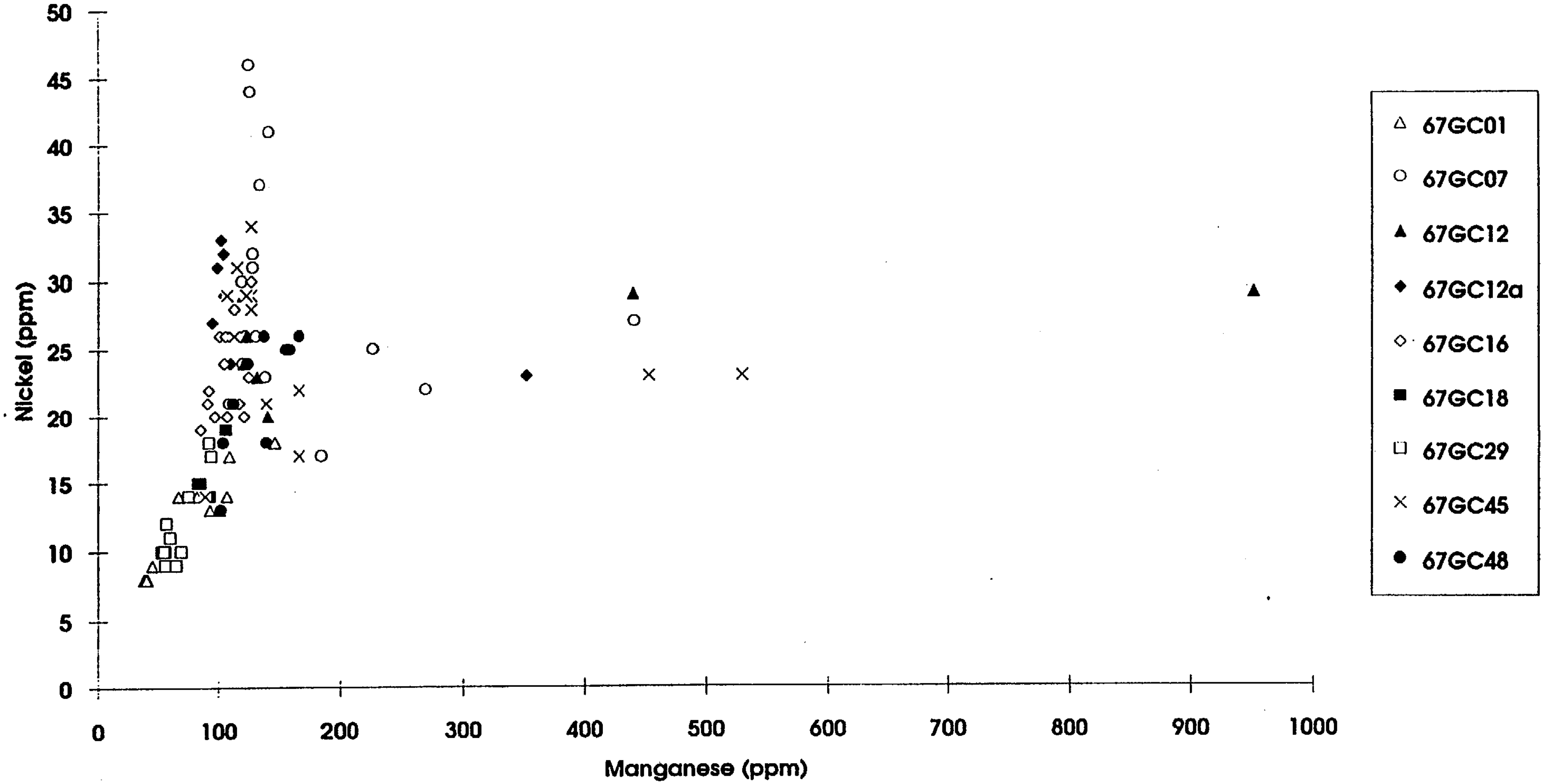
Manganese (ppm) vs Molybdenum (ppm), Otway Basin



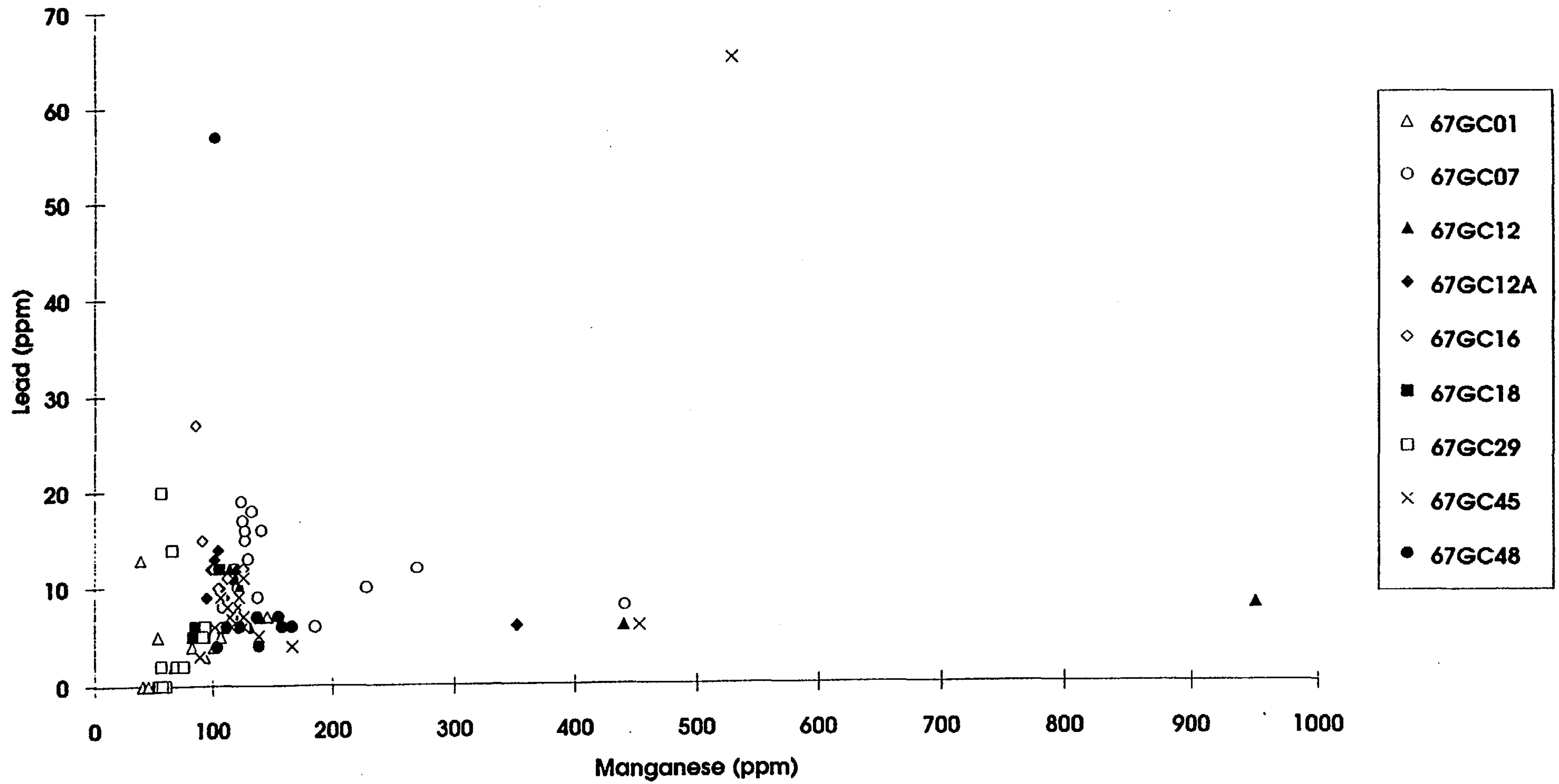
Manganese (ppm) vs Neodymium (ppm), Otway Basin



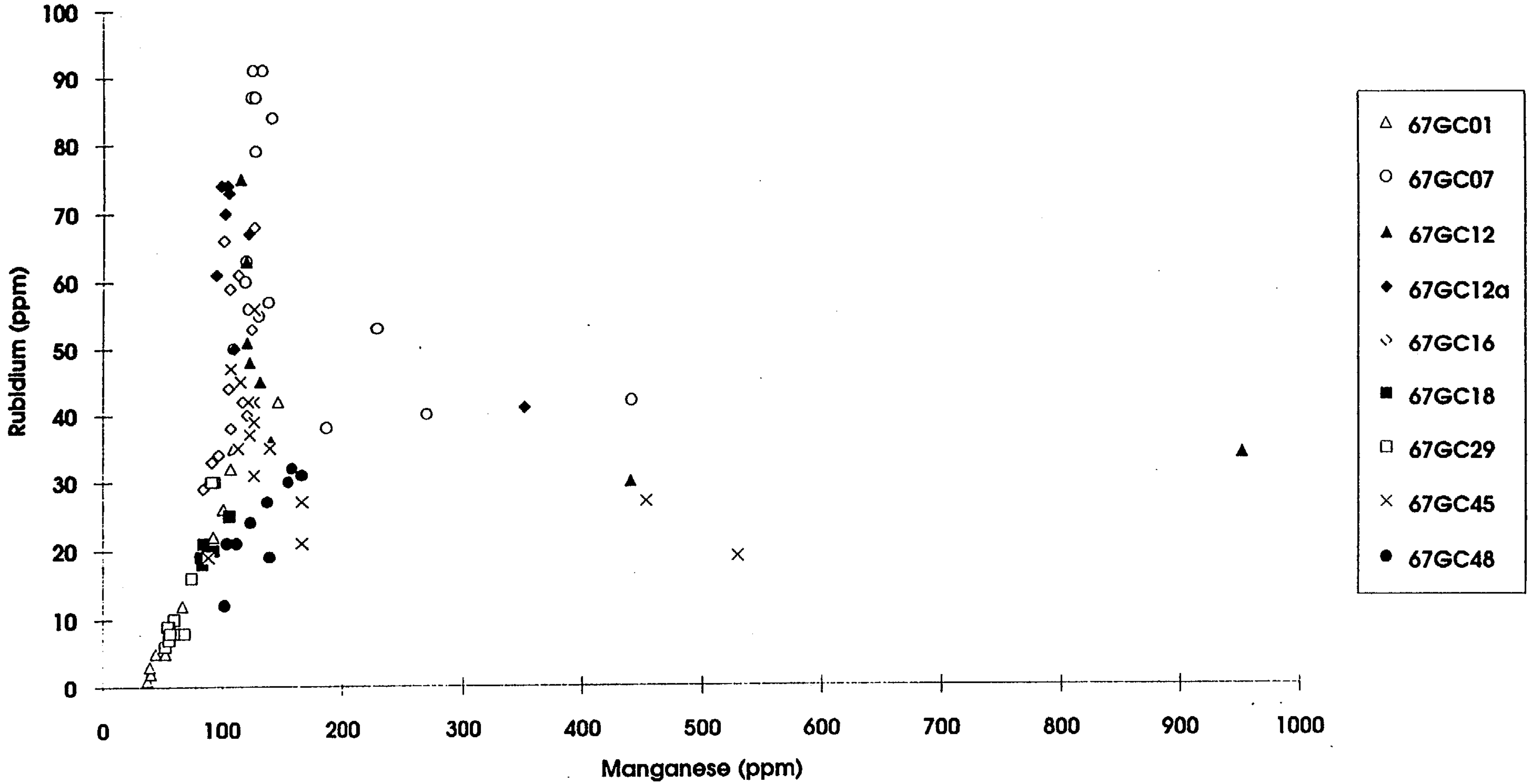
Manganese (ppm) vs Nickel (ppm), Otway Basin

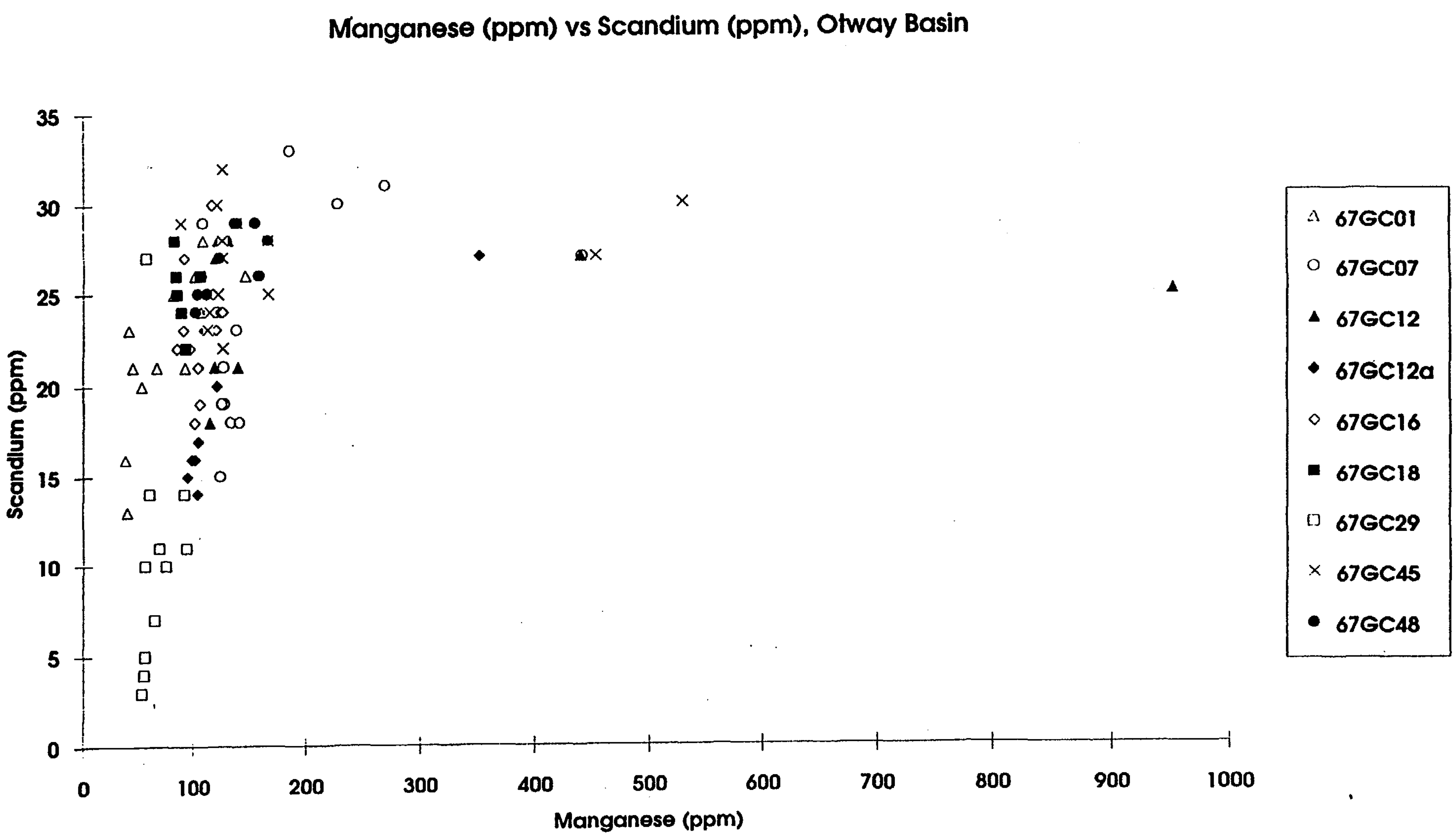


Manganese (ppm) vs Lead (ppm), Otway Basin

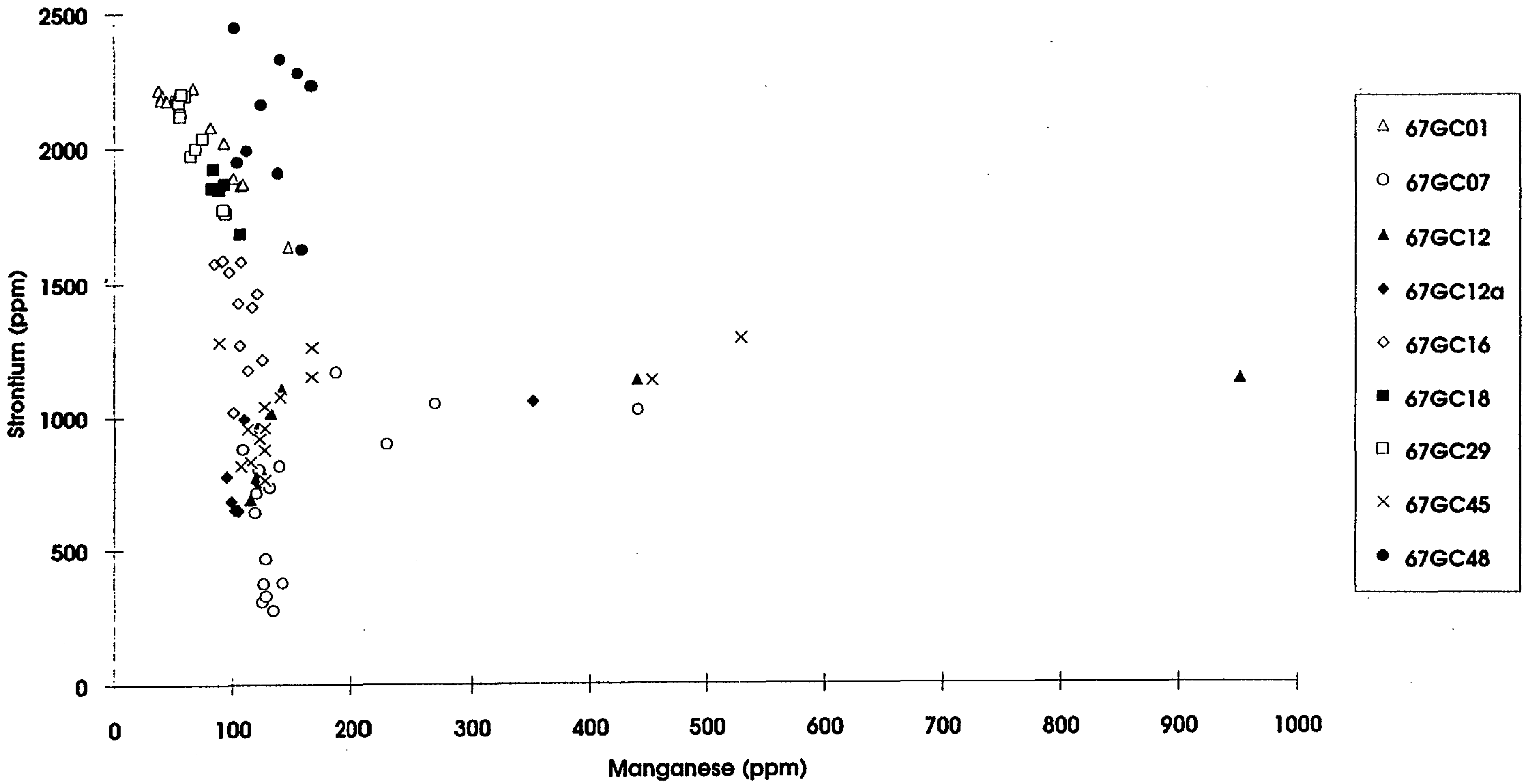


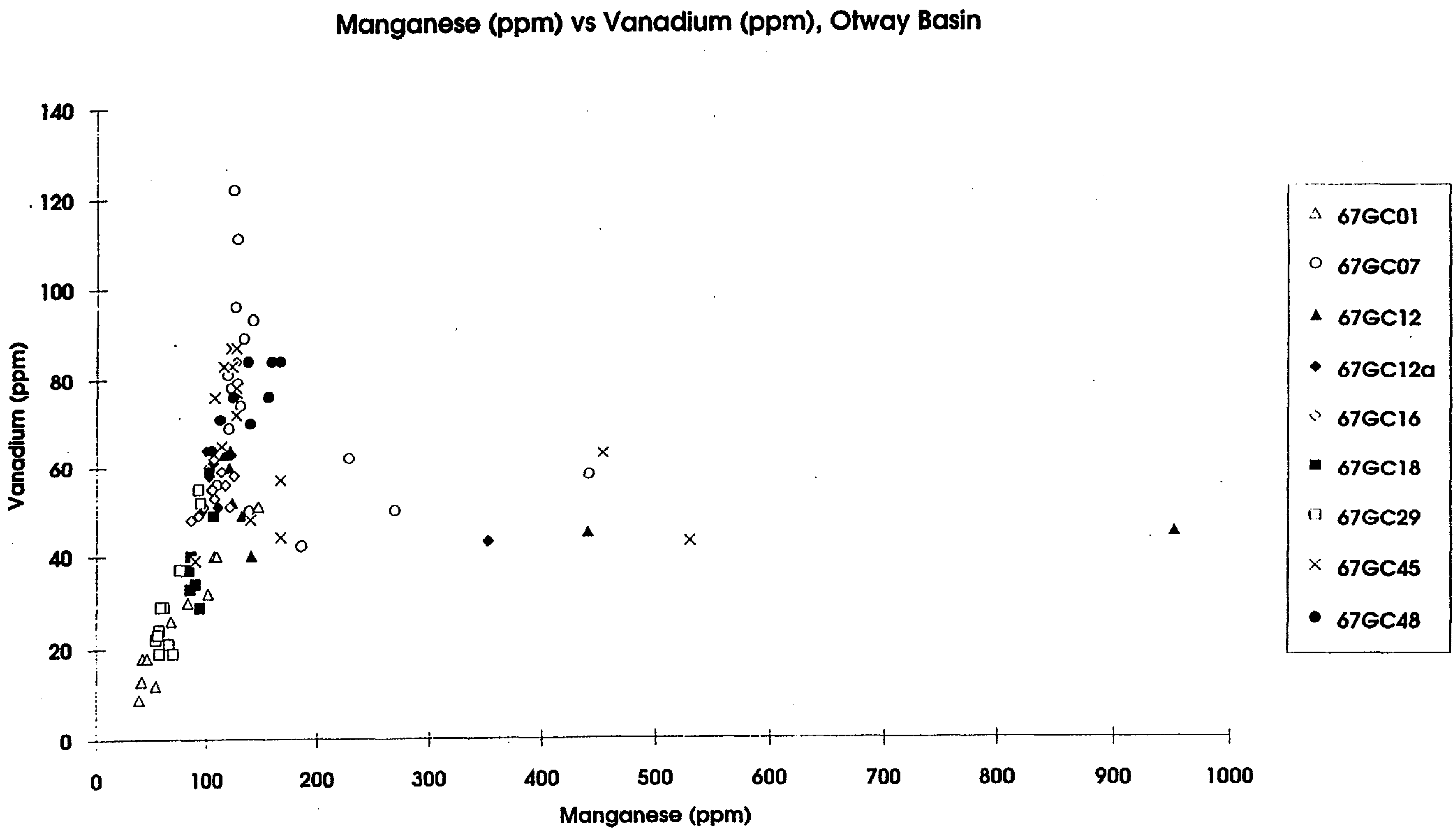
Manganese (ppm) vs Rubidium (ppm), Otway Basin




Manganese (ppm) vs Scandium (ppm), Otway Basin
Scandium (ppm)
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
Manganese (ppm)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

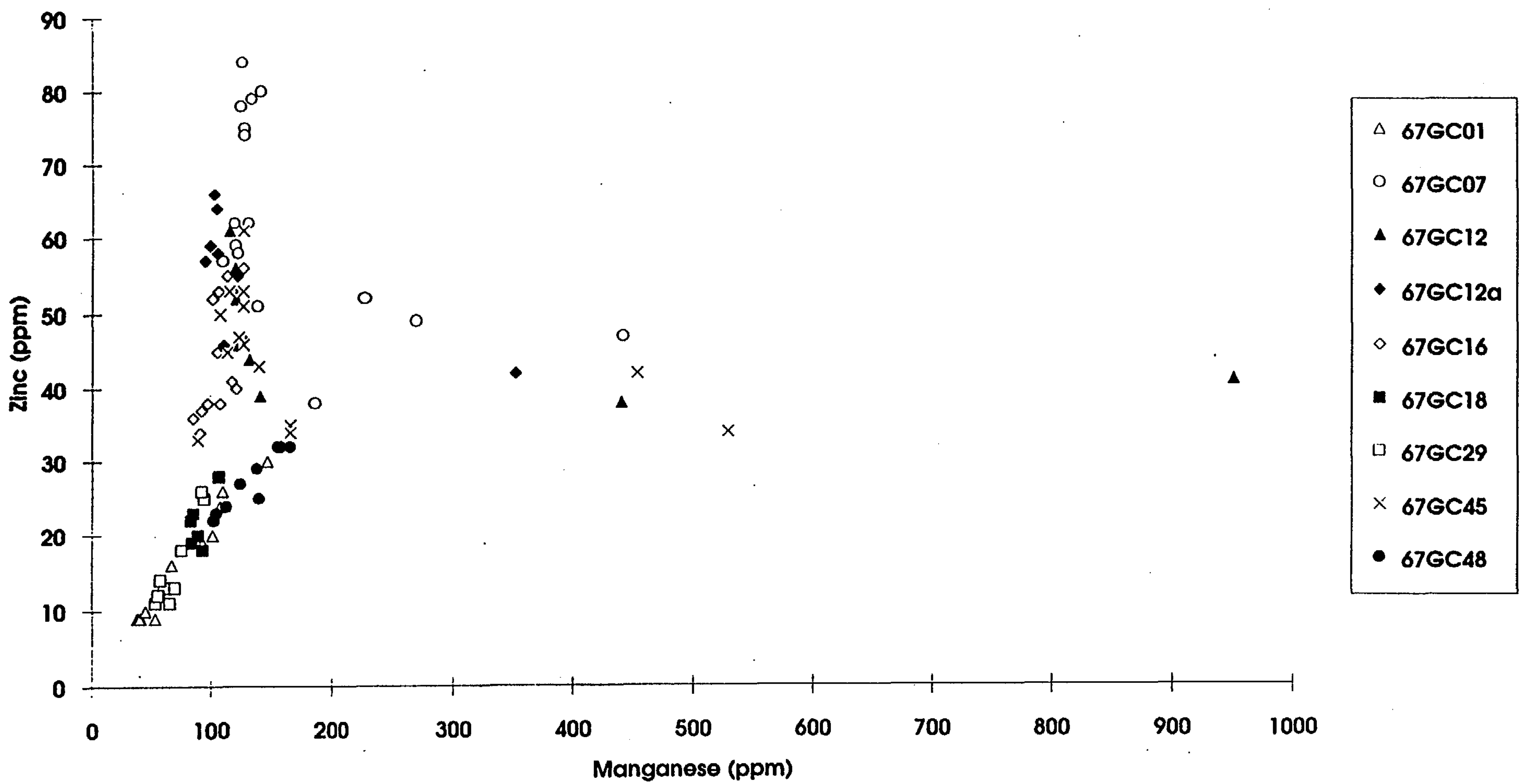
Manganese (ppm) vs Strontium (ppm), Otway Basin



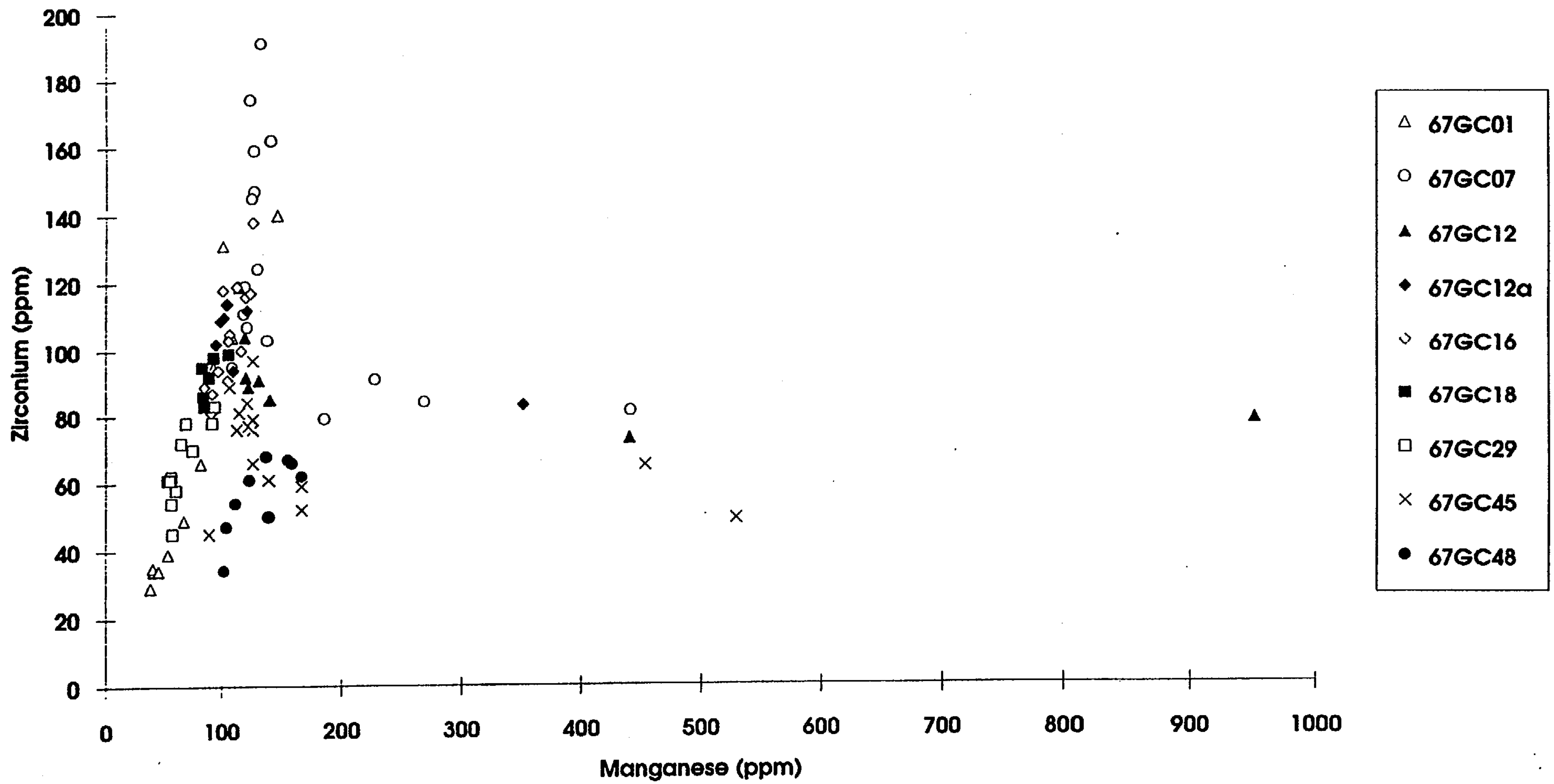


Manganese (ppm) vs Vanadium (ppm), Otway Basin
Vanadium (ppm)
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000
Manganese (ppm)
67GC01
67GC07
67GC12
67GC12a
67GC16
67GC18
67GC29
67GC45
67GC48

Manganese (ppm) vs Zinc (ppm), Otway Basin



Manganese (ppm) vs Zirconium (ppm), Otway Basin



Appendix 4: Down-core elemental ratios of cores collected off South Australia, west Victoria and Tasmania

Core	Sample depth (cm)	Al2O3 (wt%)	Al (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)	P2O5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ge (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
GC48	0-3	2.35	1.24	9.17	4.29	0.070	0.042	0.110	0.048	94	38	5	1	102	13	12	2448	59	22
GC48	10-13	3.45	1.63	13.06	6.10	0.130	0.078	0.110	0.048	139	51	8	1	140	18	19	2327	70	25
GC48	30-33	9.19	4.86	17.71	8.28	0.200	0.120	0.120	0.052	173	66	11	1	167	26	31	2230	84	32
GC48	50-53	6.17	3.27	17.52	8.19	0.160	0.108	0.110	0.048	174	64	8	1.5	156	257	30	2276	76	32
GC48	70-73	5.80	3.07	18.97	8.87	0.220	0.132	0.120	0.052	173	70	10	1.5	159	25	32	1628	84	32
GC48	100-103	4.83	2.56	16.63	7.77	0.200	0.120	0.110	0.048	153	64	9	1	138	267	27	1907	84	29
GC48	120-123	4.36	2.31	15.68	7.33	0.190	0.114	0.110	0.048	149	60	8	0.5	124	24	24	2163	76	27
GC48	140-143	3.71	1.96	14.14	6.61	0.160	0.096	0.100	0.044	130	53	7	1	112	21	21	1991	71	24
GC48	160-163	3.68	1.95	13.00	6.08	0.150	0.090	0.090	0.039	119	57	6	0.5	104	184	21	1948	64	23

Core	Sample depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Ge/Al (ppm/wt%=10000)	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)
GC48	0-3	3.45	0.034	0.039	75.58	30.55	4.02	0.804	82.01	10.45	9.65	1968	47.44	17.69
GC48	10-13	3.34	0.043	0.026	76.13	27.93	4.38	0.548	76.68	9.86	10.41	1274	38.34	13.69
GC48	30-33	1.70	0.025	0.011	35.57	13.57	2.26	0.206	34.34	5.35	6.37	458	17.27	6.58
GC48	50-53	2.51	0.033	0.015	53.29	19.60	2.45	0.459	47.77	78.70	9.19	697	23.27	9.80
GC48	70-73	2.89	0.043	0.017	56.36	22.60	3.26	0.489	51.80	8.14	10.42	530	27.37	10.42
GC48	100-103	3.04	0.047	0.019	59.85	25.04	3.52	0.391	53.99	104.45	10.56	746	32.86	11.34
GC48	120-123	3.18	0.049	0.021	64.57	26.00	3.47	0.217	53.74	10.40	10.40	937	32.94	11.70
GC48	140-143	3.37	0.049	0.022	66.21	26.99	3.57	0.509	57.04	10.70	10.70	1014	36.16	12.22
GC48	160-163	3.12	0.046	0.020	61.10	29.27	3.08	0.257	53.40	94.47	10.78	1000	32.86	11.81

Core	Depth	Al_2O_3 (wt%)	Al (wt%)	SiO_2 (wt%)	Si (wt%)	TiO_2 (wt%)	Ti (wt%)	P_2O_5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ge (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
67GC01	0-3	0.89	0.47	5.15	2.41	0.010	0.006	0.09	0.039	57	19	3	0.5	38	8	1	2218	9	9
67GC01	10-13	0.91	0.48	5.49	2.57	0.010	0.006	0.08	0.035	43	17	2	0.5	41	8	2	2198	18	9
67GC01	20-23	1.04	0.56	5.91	2.76	0.020	0.012	0.08	0.035	47	18	2	0.5	40	8	3	2182	13	9
67GC01	30-33	1.25	0.66	6.49	3.03	0.020	0.012	0.08	0.035	67	18	3	0.5	45	9	5	2178	18	10
67GC01	50-53	1.17	0.62	6.41	3.00	0.030	0.018	0.08	0.035	45	18	2	0.5	53	10	5	2183	12	9
67GC01	90-93	2.32	1.23	8.83	4.13	0.070	0.042	0.09	0.039	82	31	4	0.5	67	14	12	2224	26	16
67GC01	110-113	3.01	1.59	12.80	5.98	0.130	0.078	0.09	0.039	66	32	2	1	82	14	20	2081	30	19
67GC01	130-133	3.51	1.86	15.39	7.19	0.140	0.084	0.09	0.039	93	37	3	0.5	93	13	22	2022	29	19
67GC01	150-153	3.63	1.92	20.06	9.38	0.170	0.102	0.08	0.035	93	36	4	1	101	13	26	1893	32	20
67GC01	170-173	4.36	2.31	20.06	9.39	0.190	0.114	0.08	0.035	106	45	5	1	107	14	32	1865	40	24
67GC01	190-193	4.53	2.40	19.15	8.95	0.210	0.126	0.08	0.035	109	46	4	1.5	109	17	35	1871	40	26
67GC01	210-213	5.64	2.98	25.20	11.78	0.260	0.156	0.08	0.035	149	49	6	1.5	147	18	42	1638	51	30

Core	Depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=100000)	Cr/Al (ppm/wt%=100000)	Cu/Al (ppm/wt%=100000)	Ge/Al (ppm/wt%=100000)	Mn/Al (ppm/wt%=100000)	Ni/Al (ppm/wt%=100000)	Rb/Al (ppm/wt%=100000)	Sr/Al (ppm/wt%=100000)	V/Al (ppm/wt%=100000)	Zn/Al (ppm/wt%=100000)	Depth (cm)
67GC01	0-3	5.11	0.01	0.08	121.01	40.34	6.37	1.06	80.68	16.98	2.12	4709	19.11	19.11	0-3
67GC01	10-13	5.33	0.01	0.07	89.28	35.30	4.15	1.04	85.13	16.61	4.15	4564	37.37	18.69	10-13
67GC01	20-23	5.02	0.02	0.06	85.39	32.70	3.63	0.91	72.67	14.53	5.45	3964	23.62	16.35	20-23
67GC01	30-33	4.59	0.02	0.05	101.28	27.21	4.53	0.76	68.02	13.60	7.56	3292	27.21	15.12	30-33
67GC01	50-53	4.84	0.03	0.06	72.67	29.07	3.23	0.81	85.59	16.15	8.07	3525	19.38	14.53	50-53
67GC01	90-93	3.36	0.03	0.03	66.78	25.25	3.26	0.41	54.57	11.40	9.77	1811	21.18	13.03	90-93
67GC01	110-113	3.76	0.05	0.02	41.43	20.09	1.26	0.63	51.47	8.79	12.55	1306	18.83	11.93	110-113
67GC01	130-133	3.87	0.05	0.02	50.06	19.92	1.61	0.27	50.06	7.00	11.84	1088	15.61	10.23	130-133
67GC01	150-153	4.88	0.05	0.02	48.41	18.74	2.08	0.52	52.57	6.77	13.53	985	16.66	10.41	150-153
67GC01	170-173	4.07	0.05	0.02	45.94	19.50	2.17	0.43	46.37	6.07	13.87	808	17.33	10.40	170-173
67GC01	190-193	3.73	0.06	0.01	45.46	19.19	1.67	0.63	45.46	7.09	14.60	780	16.68	10.84	190-193
67GC01	210-213	3.95	0.05	0.01	49.92	16.42	2.01	0.50	49.25	6.03	14.07	549	17.09	10.05	210-213

Core	Sample Depth (cm)	Al2O3 (wt%)	Al (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)	P2O5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ge (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
GC12A	0-3	5.13	2.715008	18.25	8.53061693	0.2	0.120	0.09	0.039	589	37	32	1.5	440	29	30	1136	45	38
GC12A	7-11	5.36	2.836734	18.87	8.820320793	0.21	0.126	0.09	0.039	672	40	37	1.5	951	29	34	1137	45	41
GC12A	15-19	5.43	2.873781	19.71	9.212958284	0.21	0.126	0.08	0.035	572	39	24	1.5	141	207	36	1108	40	39
GC12A	30-33	6.32	3.344806	21.79	10.1852035	0.26	0.156	0.08	0.035	672	50	29	1.5	132	236	45	1017	49	44
GC12A	40-43	7.03	3.720667	23.45	10.96112997	0.3	0.180	0.09	0.039	556	49	38	1.5	121	24	51	960	64	52
GC12A	50-53	7.16	3.789368	22.52	10.52642418	0.3	0.180	0.08	0.035	472	40	42	1.5	110	24	50	993	51	46
GC12A	60-63	7.48	3.958725	23.53	10.99852402	0.32	0.192	0.09	0.039	631	49	27	1.5	123	26	48	935	52	46
GC12A	70-73	9.36	4.953699	28.71	13.41978855	0.4	0.240	0.08	0.035	519	51	30	2	120	29	63	773	60	56
GC12A	80-83	9.77	5.170668	29.33	13.70959241	0.42	0.252	0.08	0.035	577	53	31	1.5	122	29	67	749	63	55
GC12A	90-93	10.54	5.578204	31.42	14.68651189	0.45	0.270	0.08	0.035	530	50	32	2	115	31	75	688	63	61
GC12A	110-113	10.76	5.694637	31.12	14.54628421	0.45	0.270	0.09	0.039	454	51	32	1.5	105	29	73	645	61	58
GC12A	130-133	10.58	5.599374	30.62	14.31257142	0.44	0.264	0.09	0.039	544	51	40	2	99	31	74	680	64	59
GC12A	150-153	6.21	3.286689	20.73	9.689732381	0.26	0.156	0.09	0.039	520	33	30	1.5	352	23	41	1067	43	42
GC12A	170-173	9.18	4.858436	27.48	12.84465506	0.4	0.240	0.09	0.039	418	44	37	1.5	95	27	61	776	50	57
GC12A	190-193	10.98	5.81107	32.64	15.2567711	0.48	0.288	0.1	0.044	362	48	42	2	104	32	74	649	55	64
GC12A	230-233	11.38	6.022767	31.52	14.73325445	0.47	0.282	0.1	0.044	329	52	34	1.5	102	33	70	648	58	65

Core	Sample Depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Ge/Al (ppm/wt%=10000)	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)	Sample Depth (cm)
GC12A	0-3	3.14	0.04	0.01	216.94	13.63	11.79	0.55	162.06	10.68	11.05	418	16.57	14.00	1.5
GC12A	7-11	3.11	0.04	0.01	236.89	14.10	13.04	0.53	335.24	10.22	11.99	401	15.86	14.45	9
GC12A	15-19	3.21	0.04	0.01	199.04	13.57	8.35	0.52	49.06	72.03	12.53	386	13.92	13.57	17
GC12A	30-33	3.06	0.06	0.01	200.91	14.95	8.67	0.45	39.46	70.56	13.45	304	14.65	13.15	31.5
GC12A	40-43	2.95	0.06	0.01	149.44	13.17	10.21	0.40	32.52	6.45	13.71	258	17.20	13.98	41.5
GC12A	50-53	2.78	0.06	0.01	124.56	10.56	11.08	0.40	29.03	6.33	13.19	262	13.46	12.14	51.5
GC12A	60-63	2.78	0.06	0.01	159.39	12.38	6.82	0.38	31.07	6.57	12.13	236	13.14	11.62	61.5
GC12A	70-73	2.71	0.06	0.01	104.77	10.30	6.06	0.40	24.22	5.85	12.72	156	12.11	11.30	71.5
GC12A	80-83	2.66	0.06	0.01	111.59	10.25	6.00	0.29	23.59	5.61	12.96	145	12.18	10.64	81.5
GC12A	90-93	2.63	0.06	0.01	95.01	8.96	5.74	0.36	20.62	5.56	13.45	123	11.29	10.94	91.5
GC12A	110-113	2.56	0.06	0.01	79.72	8.96	5.62	0.26	18.44	5.09	12.82	113	10.71	10.19	111.5
GC12A	130-133	2.56	0.06	0.01	97.15	9.11	7.14	0.36	17.68	5.54	13.22	121	11.43	10.54	131.5
GC12A	150-153	2.95	0.06	0.01	158.22	10.04	9.13	0.46	107.10	7.00	12.47	322	13.08	12.78	151.5
GC12A	170-173	2.64	0.06	0.01	86.04	9.06	7.62	0.31	19.55	5.56	12.56	160	10.29	11.73	171.5
GC12A	190-193	2.63	0.06	0.01	62.29	8.26	7.23	0.34	17.90	5.51	12.73	112	9.46	11.01	191.5
GC12A	230-233	2.45	0.06	0.01	54.63	8.63	5.65	0.25	16.94	5.48	11.62	108	9.63	10.96	231.5

Core	Sample Depth (cm)	Al_2O_3 (wt%)	Al (wt%)	SiO_2 (wt%)	Si (wt%)	TiO_2 (wt%)	Ti (wt%)	P_2O_5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ge (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
GC16	0-3	5.09	2.69	19.21	8.98	0.2	0.120	0.1	0.044	345	39	16	1	85	19	29	1578	48	36
	6-9	4.91	2.60	20.12	9.40	0.19	0.114	0.1	0.044	345	42	17	1	91	21	30	1586	49	34
	12-15	5.26	2.78	20.91	9.77	0.21	0.126	0.1	0.044	321	43	16	1	92	22	33	1590	49	37
	20-23	5.42	2.87	20.87	9.76	0.21	0.126	0.1	0.044	370	41	16	0.5	97	20	34	1546	51	38
	30-33	5.38	2.85	22.38	10.46	0.22	0.132	0.09	0.039	370	45	16	1.5	107	20	38	1584	53	38
	40-43	5.66	2.99	23.56	11.01	0.25	0.150	0.09	0.039	440	55	16	1	121	20	40	1463	51	40
	60-63	7.43	3.93	26.78	12.52	0.33	0.198	0.1	0.044	344	49	17	1.5	125	23	53	1217	58	47
	70-73	5.81	3.07	22.81	10.66	0.26	0.156	0.09	0.039	456	44	18	1	117	21	42	1413	56	41
	90-93	9.66	5.11	33.73	15.77	0.46	0.276	0.09	0.039	438	65	20	1.5	127	30	68	768	84	56
	110-113	9.31	4.93	30.3	14.16	0.4	0.240	0.08	0.035	328	58	19	2	101	26	66	1018	60	52
	130-133	9.09	4.81	31.04	14.51	0.42	0.252	0.09	0.039	317	59	19	2	113	28	61	1179	59	55
	150-153	9.28	4.91	27.73	12.96	0.39	0.234	0.1	0.044	266	55	19	1.5	106	26	59	1272	62	53
	166-169	7.41	3.92	23.19	10.84	0.32	0.192	0.1	0.044	292	38	17	1.5	105	24	44	1427	55	45
	166-169	7.41	3.92	23.19	10.84	0.32	0.192	0.1	0.044	292	38	17	1.5	105	24	44	1427	55	45

Core	Sample Depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=100000)	Cr/Al (ppm/wt%=100000)	Cu/Al (ppm/wt%=100000)	Ge/Al (ppm/wt%=100000)	Mn/Al (ppm/wt%=100000)	Ni/Al (ppm/wt%=100000)	Rb/Al (ppm/wt%=100000)	Sr/Al (ppm/wt%=100000)	V/Al (ppm/wt%=100000)	Zn/Al (ppm/wt%=100000)
GC16	0-3	3.33	0.045	0.016	128.07	14.48	5.94	0.371	31.55	7.06	10.77	586	17.82	13.36
	6-9	3.62	0.044	0.017	132.77	16.16	6.54	0.385	35.02	8.08	11.54	610	18.86	13.08
	12-15	3.51	0.045	0.016	115.31	15.45	5.75	0.359	33.06	7.90	11.85	571	17.60	13.29
	20-23	3.40	0.044	0.015	128.99	14.29	5.58	0.174	33.82	6.97	11.85	539	17.78	13.25
	30-33	3.67	0.046	0.014	129.95	15.60	5.62	0.527	37.58	7.02	13.35	556	18.61	13.35
	40-43	3.68	0.050	0.013	147.15	18.39	5.35	0.334	40.47	6.69	13.38	489	17.06	13.38
	60-63	3.18	0.050	0.011	87.48	12.46	4.32	0.381	31.79	5.85	13.48	309	14.75	11.95
	70-73	3.47	0.051	0.013	148.30	14.31	5.85	0.325	38.06	6.83	13.66	460	18.21	13.33
	90-93	3.08	0.054	0.008	85.67	12.71	3.91	0.293	24.84	5.87	13.30	150	16.43	10.95
	110-113	2.87	0.049	0.007	66.57	11.77	3.86	0.406	20.50	5.28	13.39	207	12.18	10.55
	130-133	3.02	0.052	0.008	65.89	12.26	3.95	0.416	23.49	5.82	12.68	245	12.26	11.43
	150-153	2.64	0.048	0.009	54.16	11.20	3.87	0.306	21.58	5.29	12.01	259	12.62	10.79
	166-169	2.76	0.049	0.011	74.46	9.69	4.33	0.382	26.77	6.12	11.22	364	14.02	11.47
	166-169	2.76	0.049	0.011	74.46	9.69	4.33	0.382	26.77	6.12	11.22	364	14.02	11.47

Survey	Core	Depth (cm)	Mn (ppm)	TiO2 (wt%)	Ti (wt%)	Al2O3 (wt%)	Al (wt%)	SiO2 (wt%)	Si (wt%)	P2O5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	V (ppm)	Zn (ppm)	Ge (ppm)	Rb (ppm)	Sr (ppm)
67	GC18	1.50	106	0.20	0.12	4.81	2.55	21.84	10.21	0.11	0.048	130	45	6	19	49	28	1	25	1686
		11.50	65	0.15	0.09	3.92	2.07	18.91	8.84	0.1	0.044	126	38	5	15	40	23	0.5	21	1852
		41.50	83	0.13	0.08	3.63	1.87	18.56	8.68	0.1	0.044	122	36	5	15	37	22	1	19	1856
		71.50	84	0.13	0.08	3.26	1.73	18.95	8.86	0.09	0.039	112	32	5	15	33	19	1	18	1925
		231.50	93	0.13	0.08	3.24	1.71	20.77	9.71	0.1	0.044	100	32	4	14	29	18	1	20	1869
		261.50	89	0.15	0.09	3.49	1.85	20.36	9.52	0.1	0.044	111	33	4	14	34	20	1	20	1847

Survey	Core	Depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Ge (ppm/wt%=10000)	Mn/Al (ppm/wt%=10000)	Ni/Al n/wt%=10	Rb (ppm/wt%=10000)	Sr (ppm/wt%=10000)	V/Al (ppm/wt%=10000)	Zn/Al (ppm/wt%=10000)	Depth (cm)
67	GC18	1.50	4.01	0.047	0.019	51.07	17.68	2.36	0.39	41.64	7.46	9.82	662	19.25	11.00	1.50
		11.50	4.26	0.043	0.021	60.73	18.32	2.41	0.24	40.97	7.23	10.12	893	19.28	11.09	11.50
		41.50	4.64	0.042	0.023	65.30	19.27	2.68	0.54	44.43	8.03	10.17	993	19.80	11.78	41.50
		71.50	5.13	0.045	0.023	64.92	18.56	2.90	0.58	48.69	8.69	10.43	1116	19.13	11.01	71.50
		231.50	5.66	0.045	0.025	58.32	18.66	2.33	0.58	54.24	8.16	11.66	1090	16.91	10.50	231.50
		261.50	5.15	0.049	0.024	60.10	17.87	2.17	0.54	48.18	7.58	10.83	1000	18.41	10.83	261.50

Elemental ratios core 67GC29

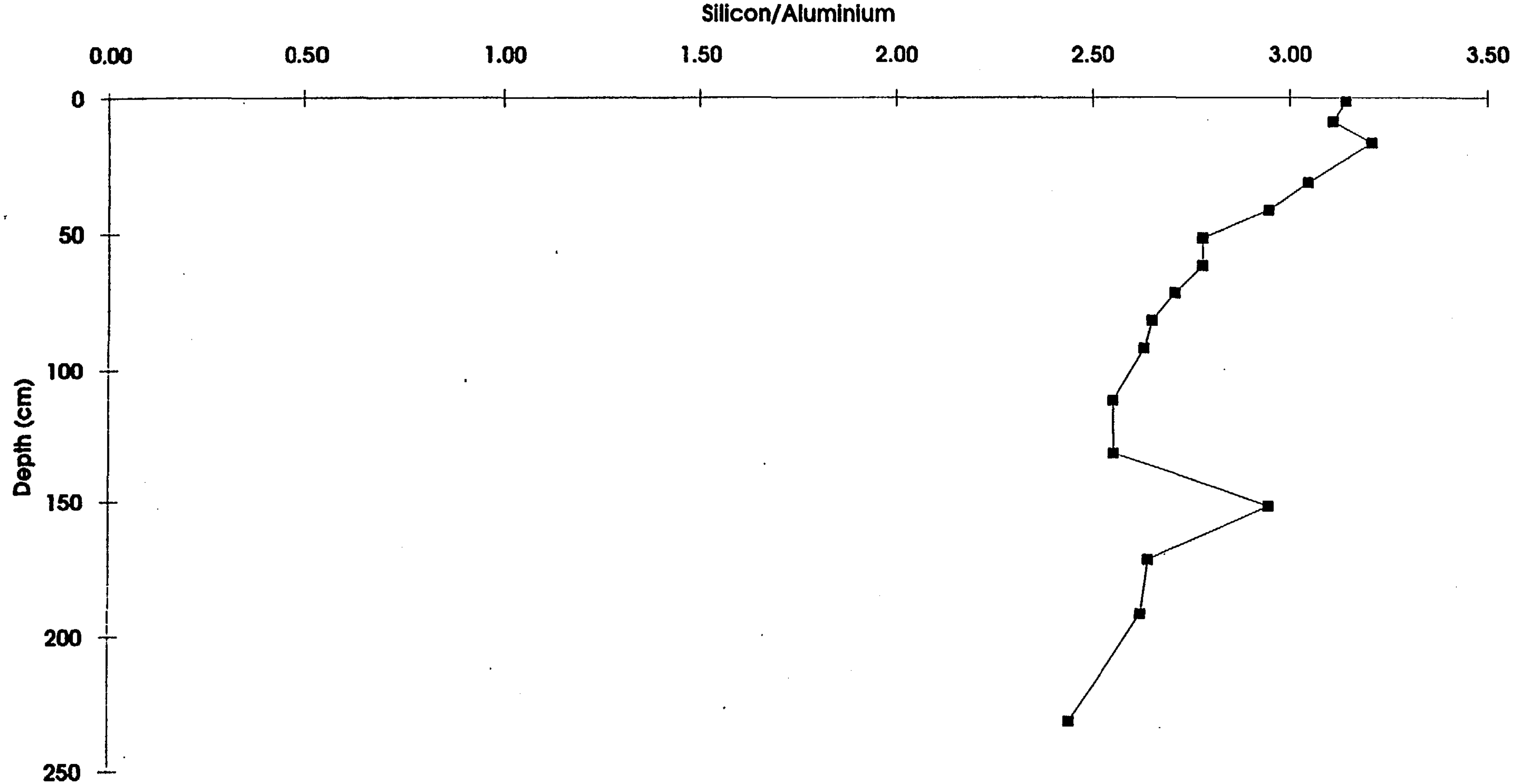
Core	Sample Depth (cm)	Al2O3 (wt%)	Al (wt%)	SiO2 (wt%)	Si (wt%)	TiO2 (wt%)	Ti (wt%)	P2O5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ge (ppm)	Mn (ppm)	Ni (ppm)	Rb (ppm)	Sr (ppm)	V (ppm)	Zn (ppm)
GC29	0-3	1 78	0.942	11 49	5.37	0 07	0.042	0.07	0.031	95	21	5	0.5	65	9	8	1973	21	11
GC29	10-13	2 11	1.117	11.53	5 39	0 06	0.036	0.08	0.035	90	23	3	0.5	69	10	8	1998	19	13
GC29	30-33	4 71	2.493	17.76	8 30	0.18	0.108	0.08	0.035	142	44	8	1	94	17	30	1763	52	25
GC29	50-53	4 72	2.498	16 42	7.68	0 19	0.114	0.09	0.039	118	50	8	1	92	18	30	1774	55	26
GC29	70-73	3 03	1.604	12 81	5.99	0 12	0.072	0.08	0.035	97	43	5	0.5	75	14	16	2037	37	18
GC29	90-93	1 72	0.910	9.03	4 22	0 06	0.036	0.07	0.031	61	27	2	0.5	53	10	6	2179	22	11
GC29	110-113	2.06	1.090	9.72	4 54	0.07	0.042	0 07	0.031	92	33	2	0.5	60	11	10	2196	29	13
GC29	130-133	1 79	0.947	9.14	4.27	0 06	0.036	0.07	0.031	80	26	3	0.5	56	10	7	2127	24	12
GC29	150-153	1 87	0.990	9.76	4 56	0 06	0.036	0 07	0 031	72	29	3	0.5	56	9	9	2120	19	12
GC29	170-173	1 69	1.000	9.55	4 46	0 06	0.030	0.07	0 031	85	30	3	0.5	55	10	9	2171	23	12
GC29	190-193	1 88	0 995	8 6	4 02	0 06	0 036	0 07	0 031	79	27	4	0 5	57	12	8	2202	29	14

Core	Sample Depth (cm)	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt%=10000)	Cr/Al (ppm/wt%=10000)	Cu/Al (ppm/wt%=10000)	Ge/Al (ppm/wt%=10000)	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)
GC29	0-3	5 70	0.045	0.032	101	22 29	6.31	0.531	69.00	9.55	8 49	2094	22.29	11.68
GC29	10-13	4 83	0.032	0 031	81	20 60	2.69	0.448	61.79	8.95	7.16	1789	17.01	11.64
GC29	30-33	3 33	0.043	0.014	57	17.65	3.21	0.401	37.71	6.82	12.04	707	20.86	10.03
GC29	50-53	3.07	0 046	0.016	47	20 02	3.20	0.400	36.83	7.21	12.01	710	22.02	10.41
GC29	70-73	3 73	0.045	0.022	60	26 81	3.12	0.312	46.77	8.73	9.98	1270	23.07	11.22
GC29	90-93	4 64	0.040	0.034	67	29.66	2.20	0.549	58.22	10.99	6.59	2394	24.17	12.08
GC29	110-113	4 17	0.038	0.028	64	30 27	1.83	0.459	55.03	10.09	9.17	2014	26.60	11.92
GC29	130-133	4.51	0.038	0.032	64	27.45	3.17	0.528	59.11	10.56	7.39	2245	25.33	12.67
GC29	150-153	4.61	0.036	0.031	73	29.30	3.03	0.505	56.58	9.09	9.09	2142	19.20	12.13
GC29	170-173	4.46	0.030	0.031	85	29.99	3.00	0.500	54.99	10.00	9.00	2170	22.99	12.00
GC29	190-193	4.04	0.036	0 031	79	27.14	4.02	0.503	57.29	12.06	8.04	2213	29.15	14.07

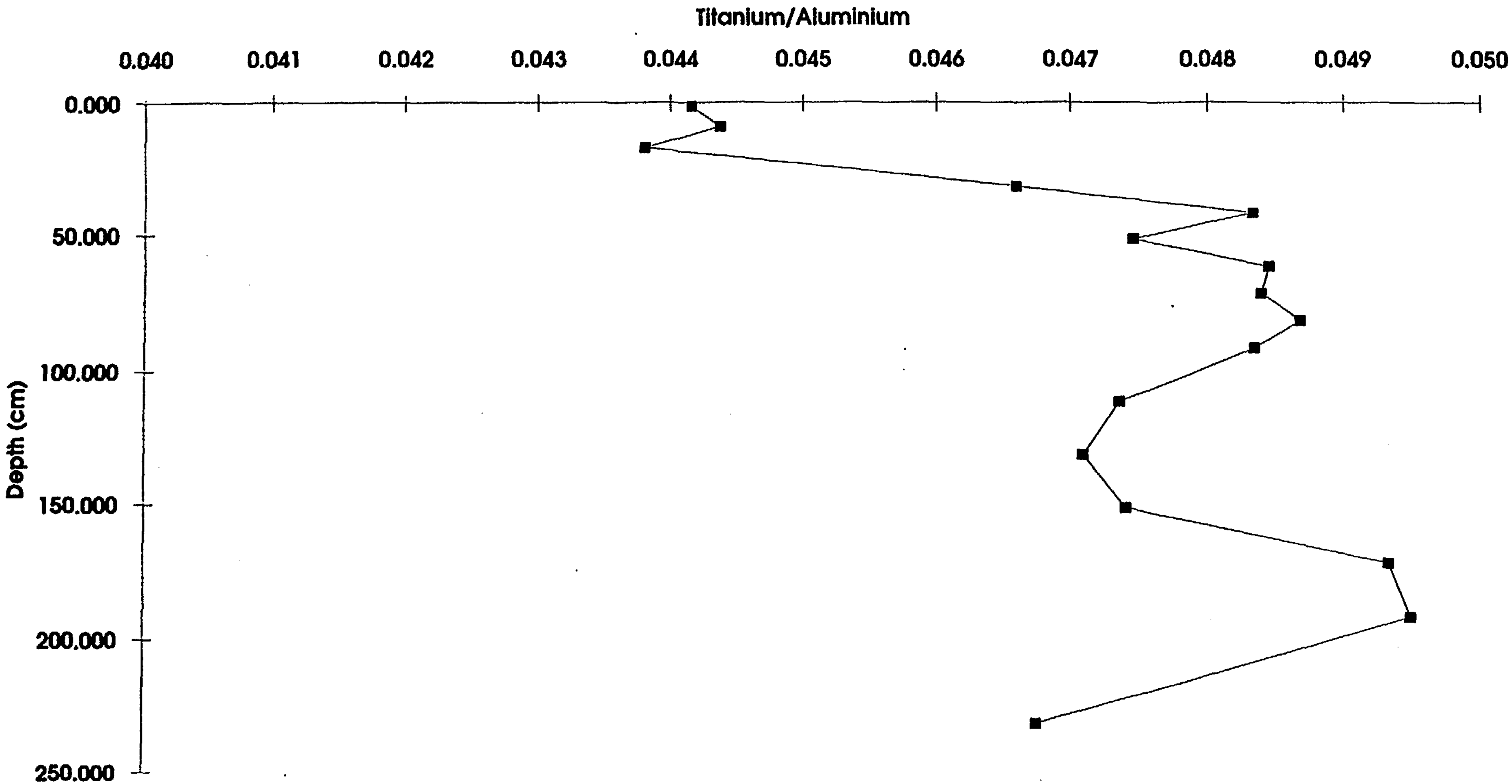
Survey	Core	Depth (cm)	Mn (ppm)	TiO2 (wt%)	Ti (wt%)	Al2O3 (wt%)	Al (wt%)	SiO2 (wt%)	Si (wt%)	P2O5 (wt%)	P (wt%)	Ba (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	V (ppm)	Zn (ppm)	Ge (ppm)	Rb (ppm)	Sr (ppm)
67	GC45	1.5	529	0.14	0.08	3.51	1.86	11.56	5.40	0.08	0.03	1007	33	39	23	43	34	1	19	1292
		7.5	89	0.14	0.08	3.43	1.82	11.38	5.32	0.07	0.03	964	36	41	14	39	33	0.5	19	1283
		15.5	167	0.16	0.10	3.77	2.00	12.54	5.86	0.07	0.03	998	44	34	17	44	35	0.5	21	1262
		15.5	167	0.16	0.10	3.77	2.00	12.54	5.86	0.07	0.03	998	44	34	17	44	35	0.5	21	1262
		21.5	453	0.23	0.14	4.88	2.58	16.4	7.67	0.08	0.03	865	53	42	23	63	42	1	27	1135
		31.5	127	0.24	0.14	5.23	2.77	18.89	8.83	0.09	0.04	761	55	31	29	72	45	1.5	31	1040
		41.5	127	0.27	0.16	6.53	3.46	21.74	10.16	0.08	0.03	883	60	37	28	77	51	1	42	959
		51.5	122	0.30	0.18	6.64	3.51	21.38	9.99	0.08	0.03	979	63	41	29	87	53	1.5	42	934
		61.5	123	0.30	0.18	6.57	3.48	21.88	10.23	0.09	0.04	878	65	39	29	83	47	1.5	37	917
		71.5	127	0.32	0.19	6.68	3.54	21.55	10.07	0.09	0.04	1011	58	39	28	78	53	2	39	875
		91.5	115	0.33	0.20	7.36	3.90	23.71	11.08	0.08	0.03	708	67	42	31	83	53	1.5	45	829
		111.5	107	0.37	0.22	8.06	4.27	25.6	11.97	0.09	0.04	461	56	38	29	76	50	1.5	47	814
		131.5	113	0.29	0.17	6.17	3.27	20.46	9.56	0.08	0.03	521	50	33	26	65	45	1.5	35	965
		151.5	127	0.42	0.25	9.30	4.92	28.69	13.41	0.09	0.04	619	69	45	34	87	61	2	56	761
		171.5	140	0.24	0.14	6.60	2.96	18.06	8.44	0.11	0.06	731	45	35	21	48	43	1	35	1077
		191.5	167	0.16	0.10	4.18	2.21	14.11	6.60	0.08	0.03	818	35	25	22	57	34	1	27	1153

Survey	Core	Si/Al	Ti/Al	P/Al	Ba/Al (ppm/wt% = 10000)	Cr/Al (ppm/wt% = 10000)	Cu/Al (ppm/wt% = 10000)	Ge/Al (ppm/wt% = 10000)	Mn/Al v/wt% = 1(	Ni/Al m/wt% = 10(	Rb/Al v/wt% = 1(	Sr/Al (ppm/wt% = 10000)	V/Al (ppm/wt% = 10000)	Zn/Al (ppm/wt% = 10000)	Depth (cm)
67	GC45	2.91	0.075	0.019	542.09	17.76	20.99	0.538	284.77	12.38	10.23	696	23.15	18.30	1.5
		2.93	0.077	0.017	531.04	19.83	22.59	0.275	49.03	7.71	10.47	707	21.48	18.18	7.5
		2.94	0.080	0.015	500.19	22.06	17.04	0.251	83.70	8.52	10.53	633	22.06	17.54	15.5
		2.94	0.080	0.015	500.19	22.06	17.04	0.251	83.70	8.52	10.53	633	22.06	17.54	21.5
		2.97	0.089	0.014	334.92	20.52	16.26	0.387	175.40	8.91	10.45	439	24.39	16.26	31.5
		3.19	0.087	0.014	274.93	19.87	11.20	0.542	45.88	10.48	11.20	376	26.01	16.62	41.5
		2.94	0.078	0.010	256.50	17.36	10.71	0.289	36.75	8.10	12.15	277	22.28	14.76	51.5
		2.84	0.085	0.010	278.59	17.93	11.67	0.427	34.72	8.25	11.95	266	24.76	15.08	61.5
		2.94	0.086	0.011	252.51	18.69	11.22	0.431	35.37	8.34	10.64	264	23.87	13.52	71.5
		2.85	0.091	0.011	285.97	16.41	11.03	0.566	35.92	7.92	11.03	248	22.06	14.99	91.5
		2.85	0.085	0.009	181.76	17.20	10.78	0.385	29.52	7.96	11.55	213	21.31	13.61	111.5
		2.81	0.087	0.009	108.07	13.13	8.91	0.352	25.08	6.80	11.02	191	17.82	11.72	131.5
		2.93	0.069	0.011	159.55	15.31	10.11	0.459	34.61	7.96	10.72	292	19.91	13.78	151.5
		2.72	0.085	0.008	125.76	14.02	9.14	0.406	25.80	6.91	11.38	155	17.68	12.39	171.5
		2.86	0.081	0.016	246.65	15.18	11.81	0.337	47.24	7.09	11.81	363	16.20	14.51	191.5

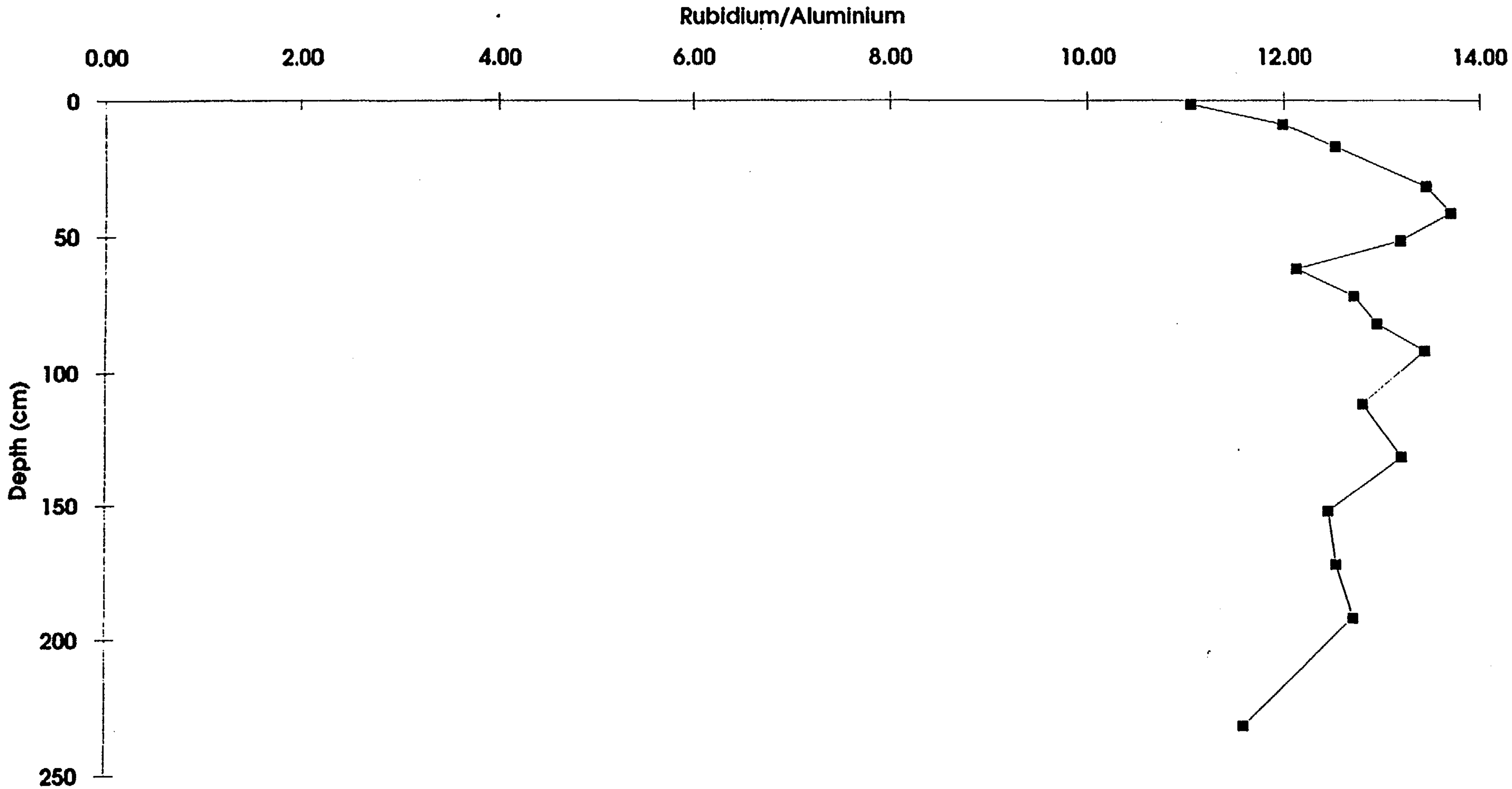
Down-core profile of Si/Al ratio, core 67GC12A

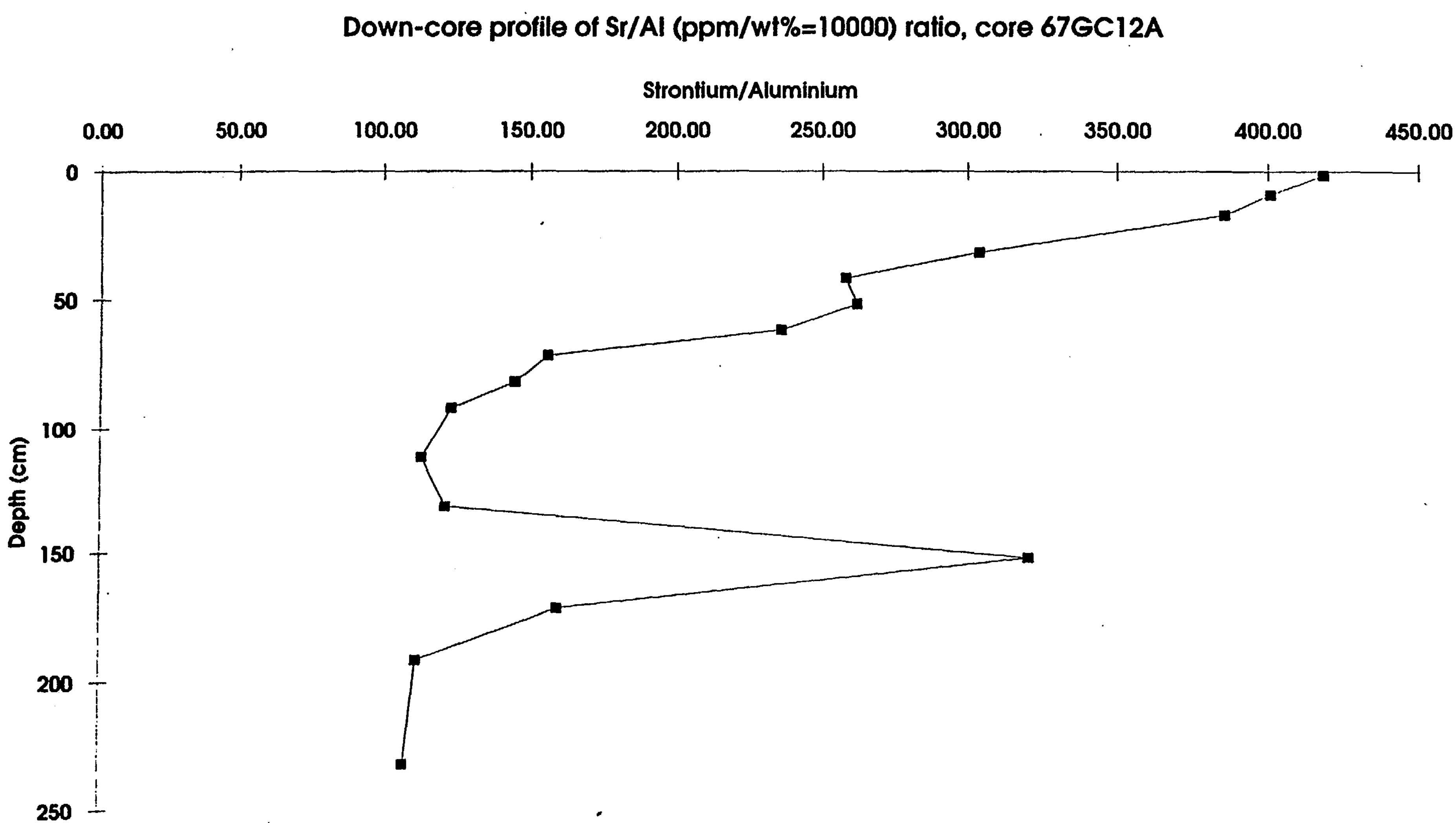


Down-core profile of Ti/Al ratio, core 67GC12A



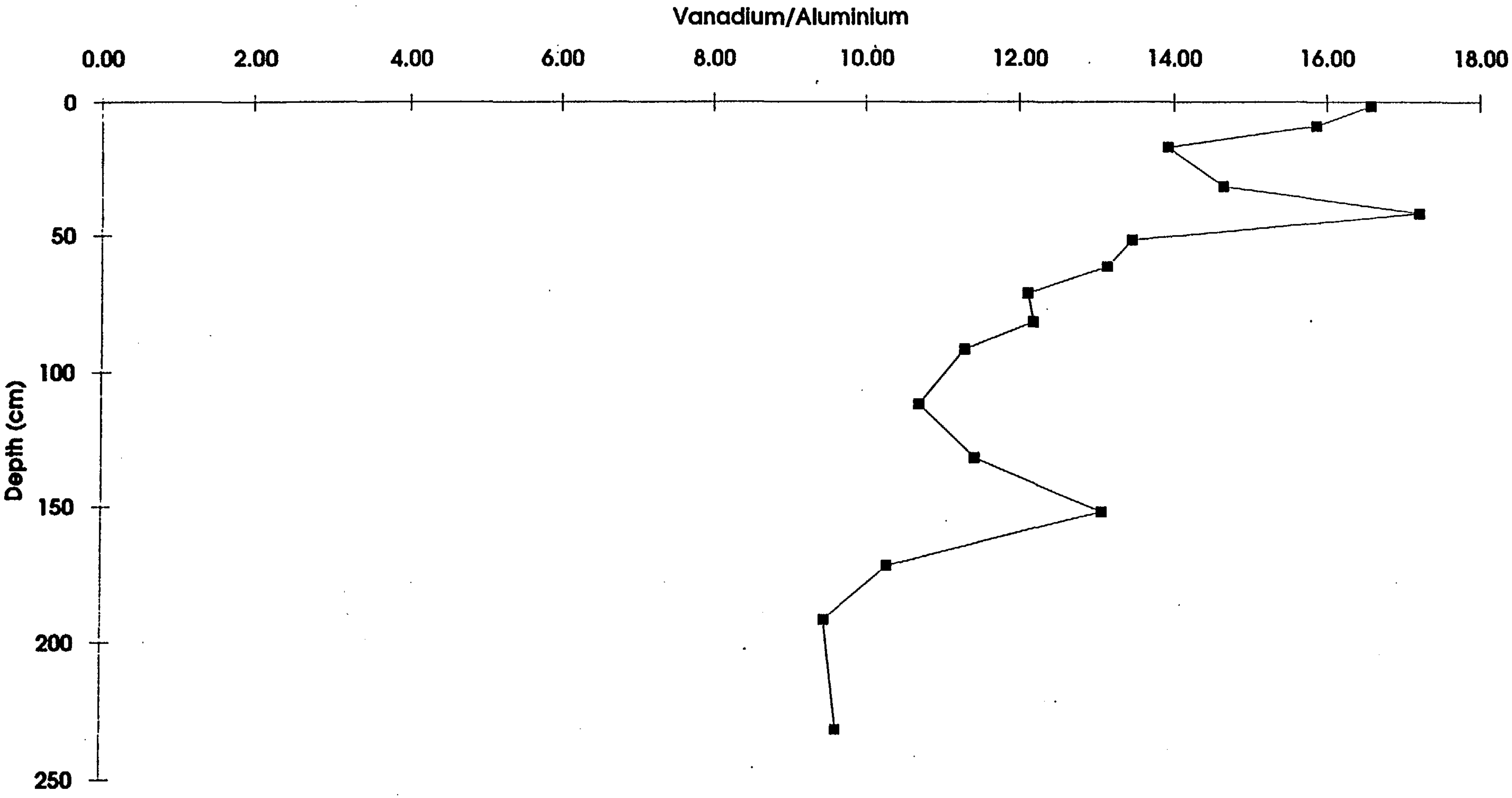
Down-core profile of Rb/Al (ppm/wt%=10000) ratio, core 67GC12A



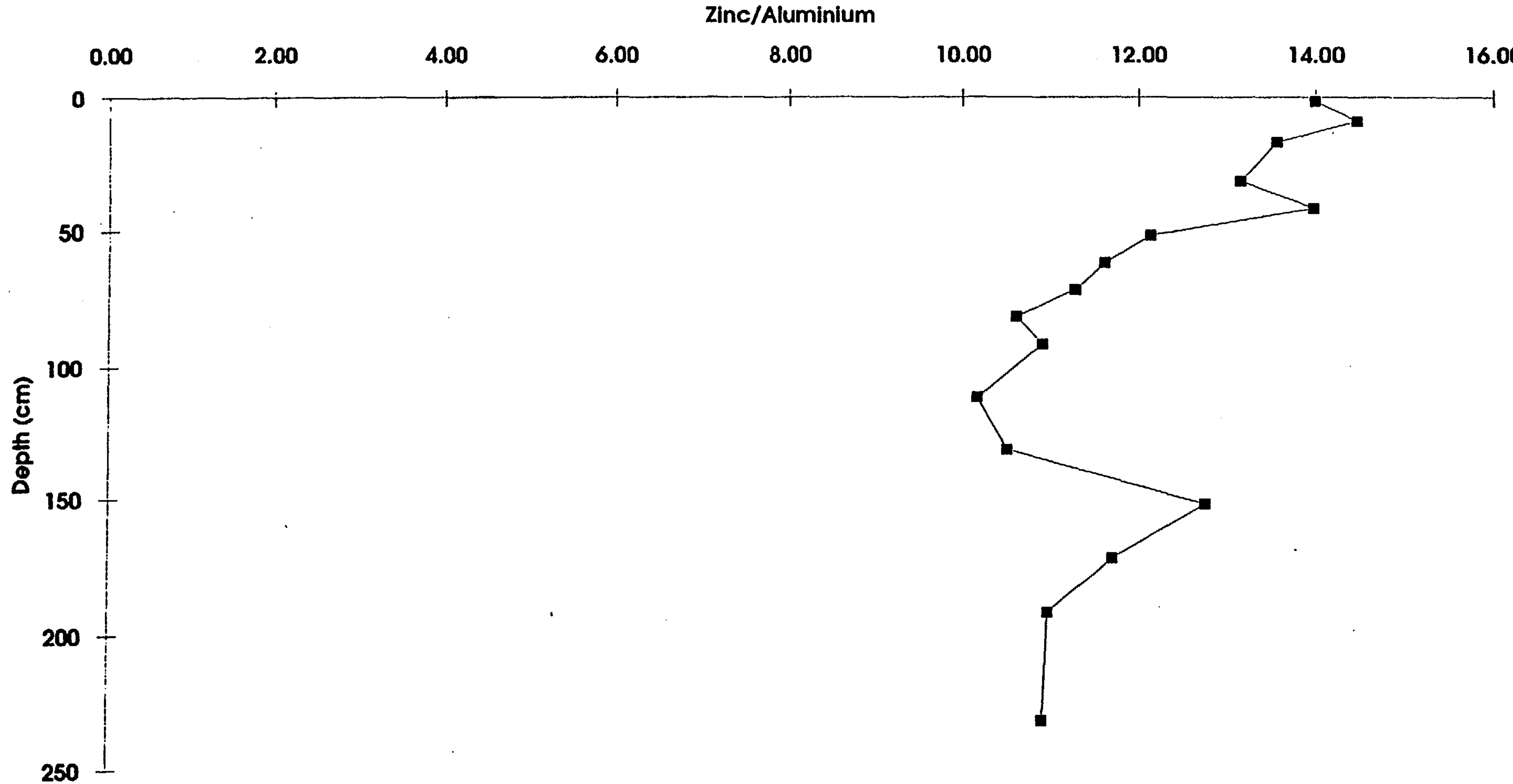

Down-core profile of Sr/Al (ppm/wt%=10000) ratio, core 67GC12A
Strontium/Aluminium
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
Depth (cm)
0
50
100
150
200
250

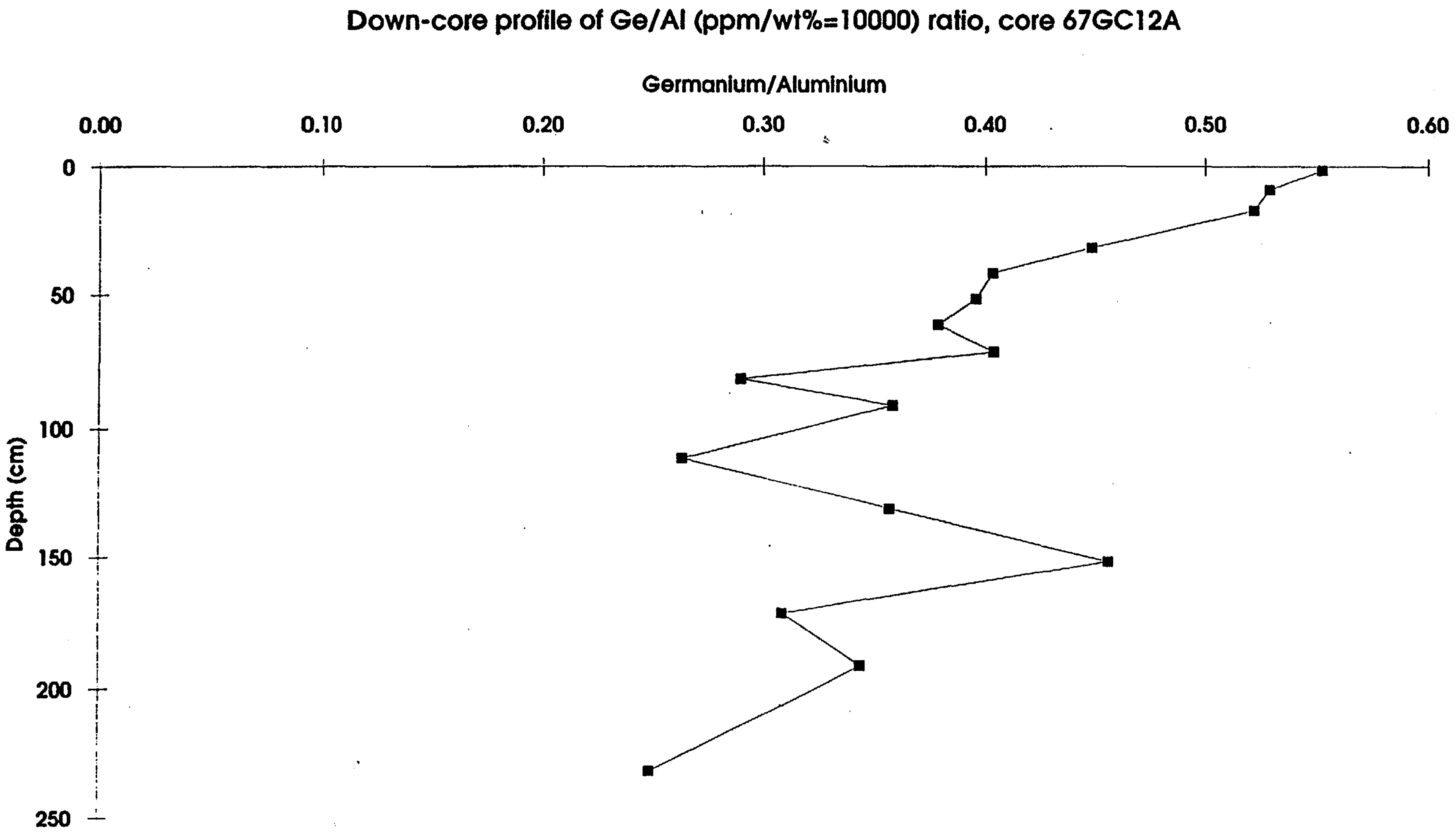
D12

Down-core profile of V/Al (ppm/wt%=10000) ratio, core 67GC12A

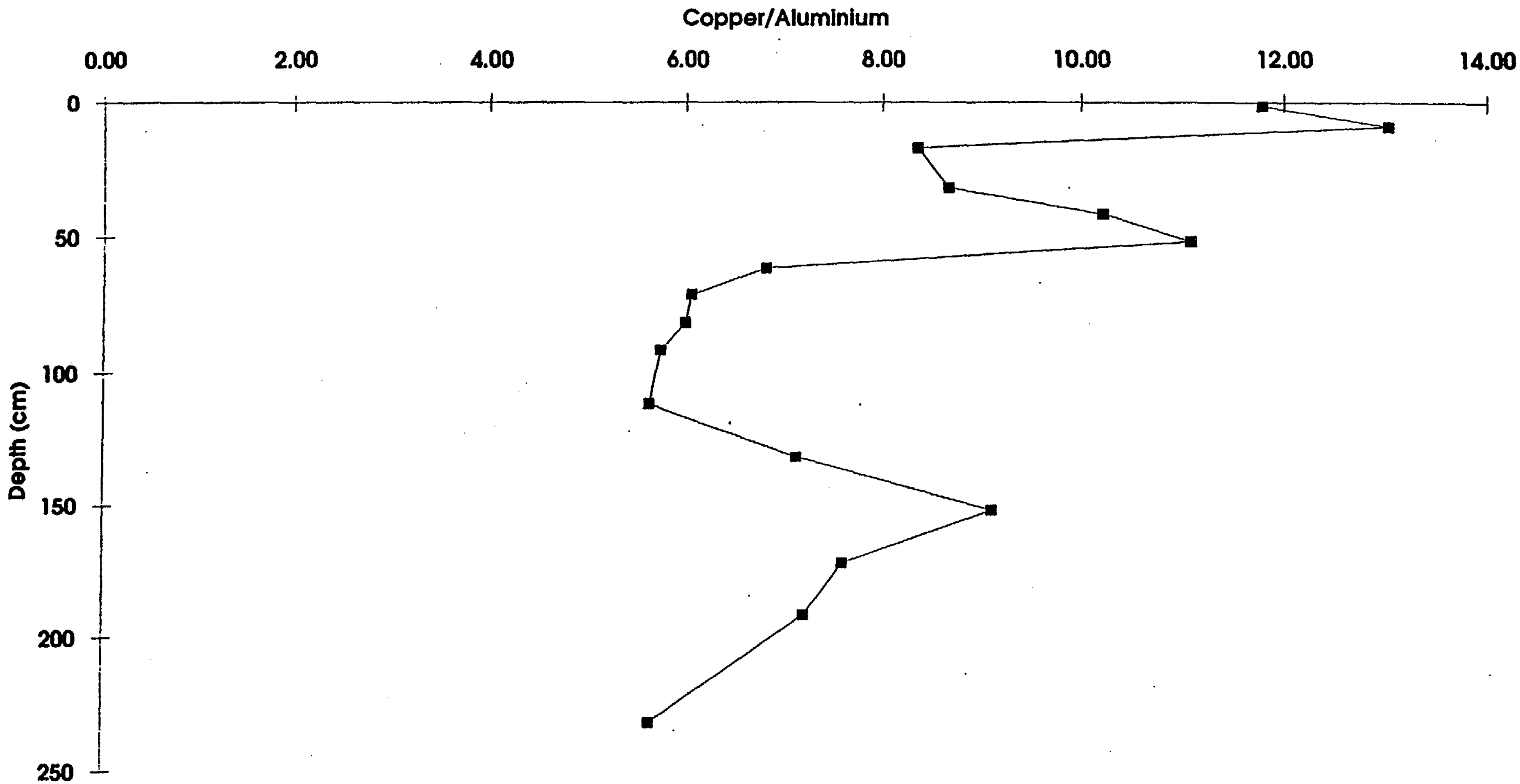


Down-core profile of Zn/Al (ppm/wt%=10000) ratio, core 67GC12A

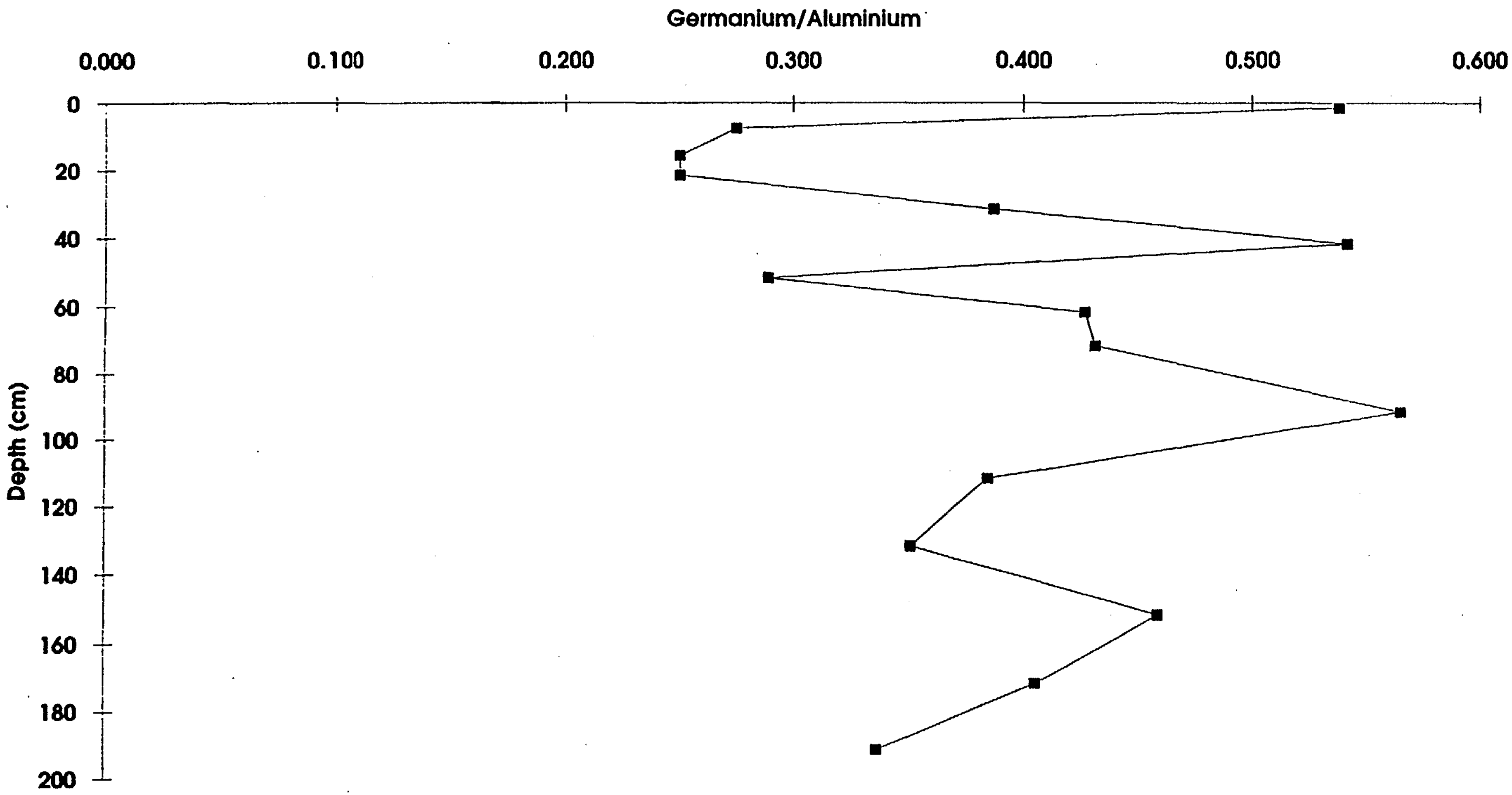



Down-core profile of Ge/Al (ppm/wt%=10000) ratio, core 67GC12A
Germanium/Aluminium
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Depth (cm)
0
50
100
150
200
250

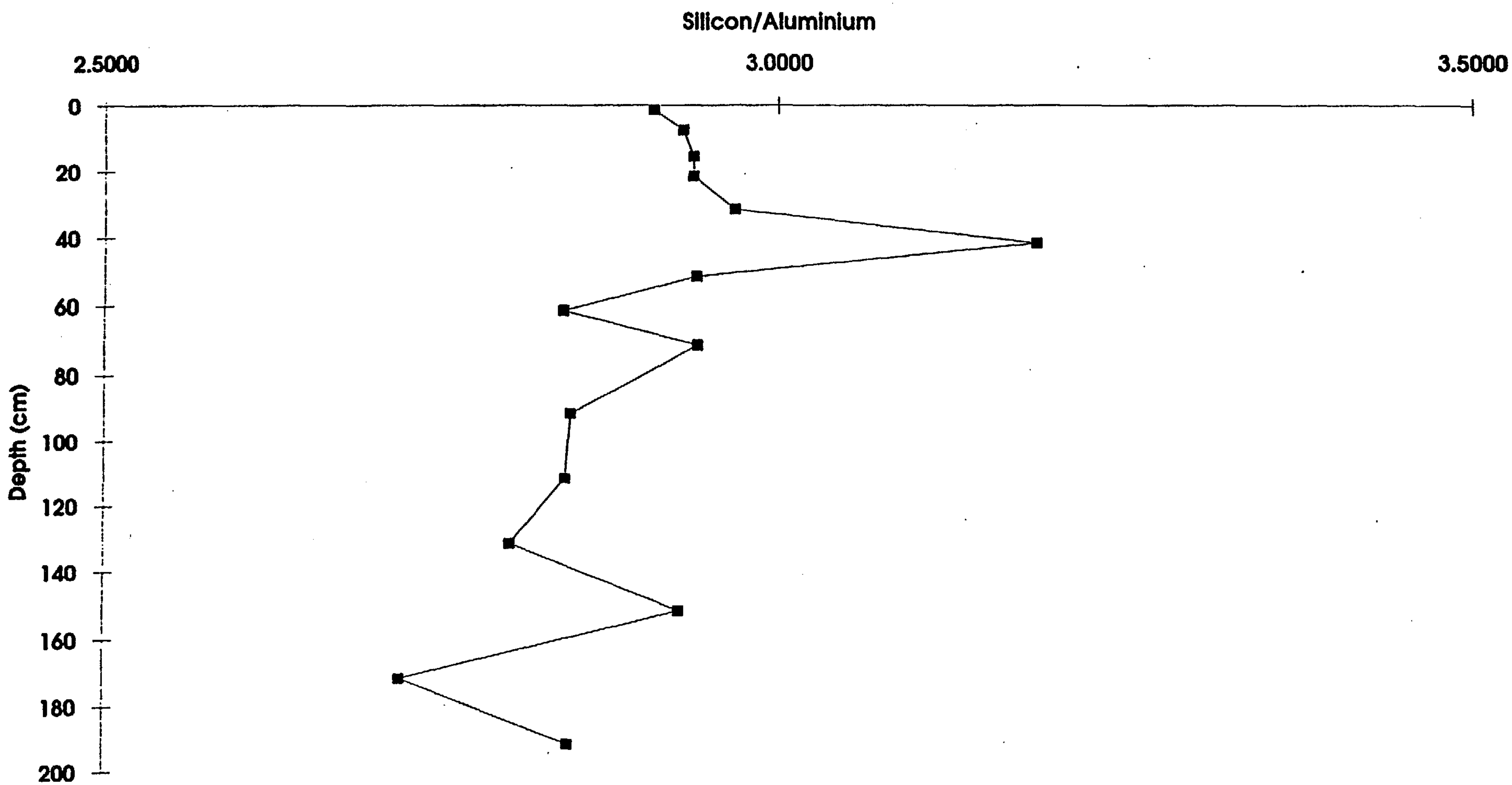
Down-core profile of Cu/Al (ppm/wt%=10000) ratio, core 67GC12A



Down-core profile of Ge/Al (ppm/wt%=10000) ratio, core 67GC45

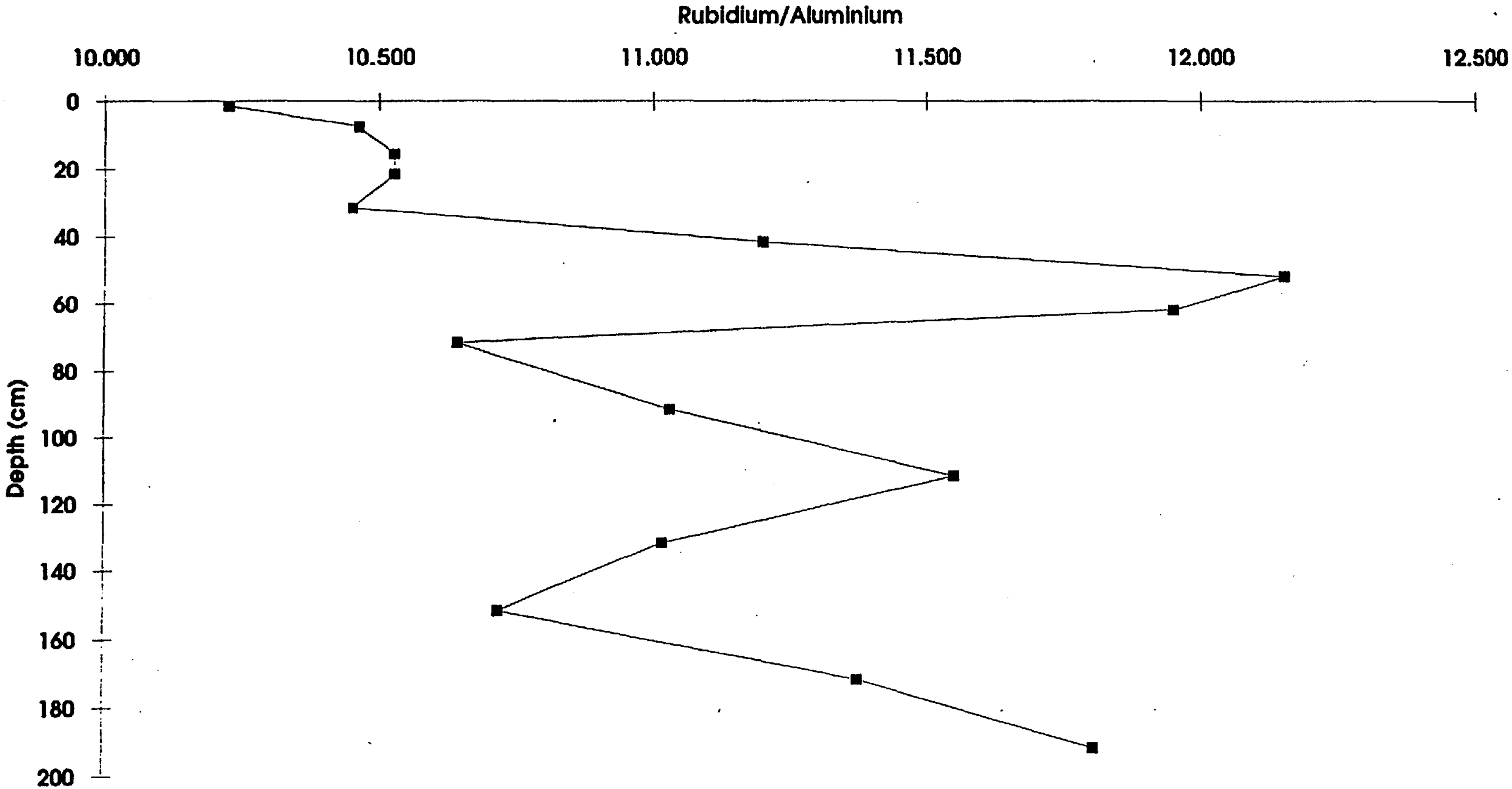


Down-core profile of Si/Al ratio, core 67GC45



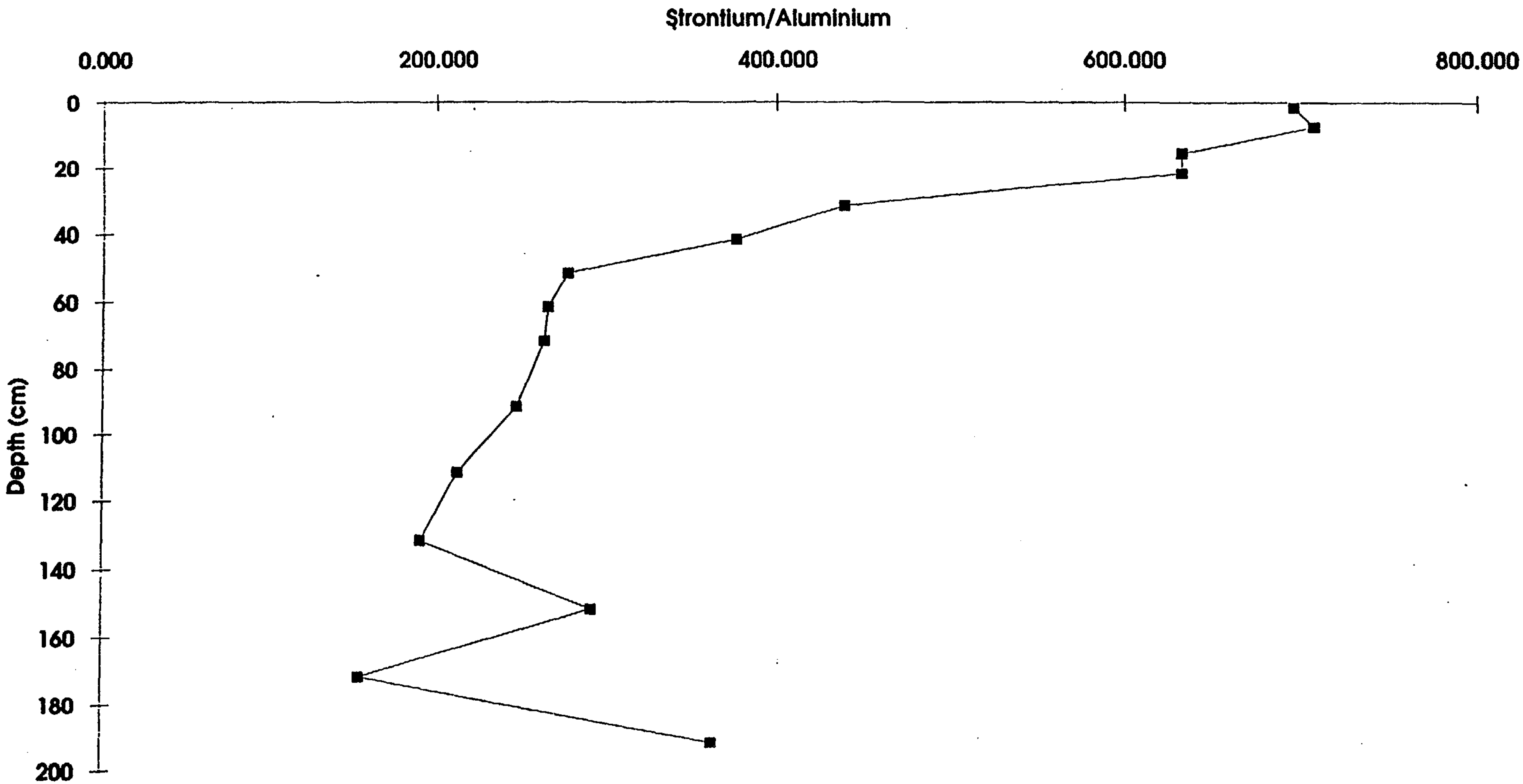
D18

Down-core profile of Rb/Al (ppm/wt%=10000) ratio, core 67GC45

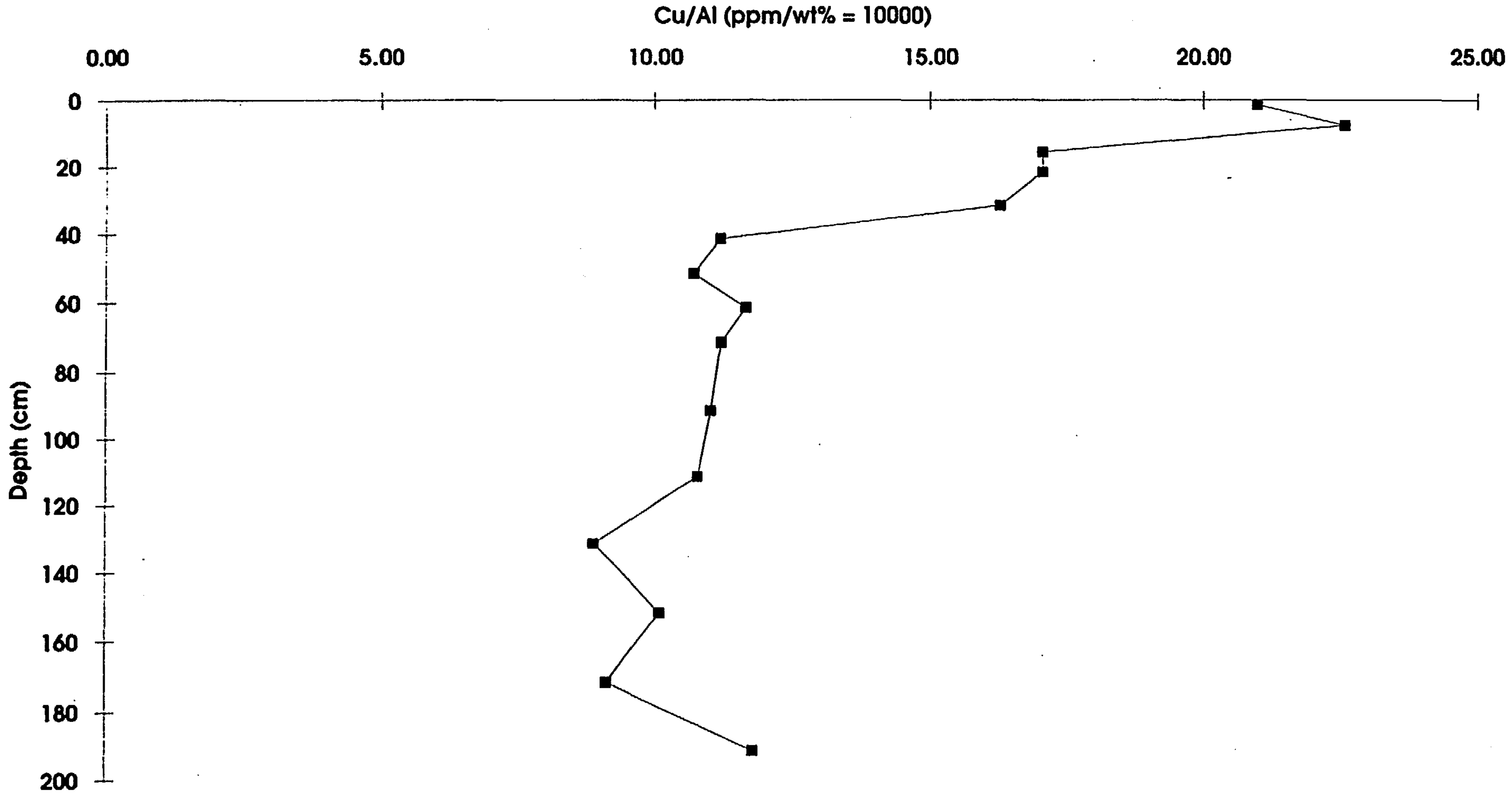


D19

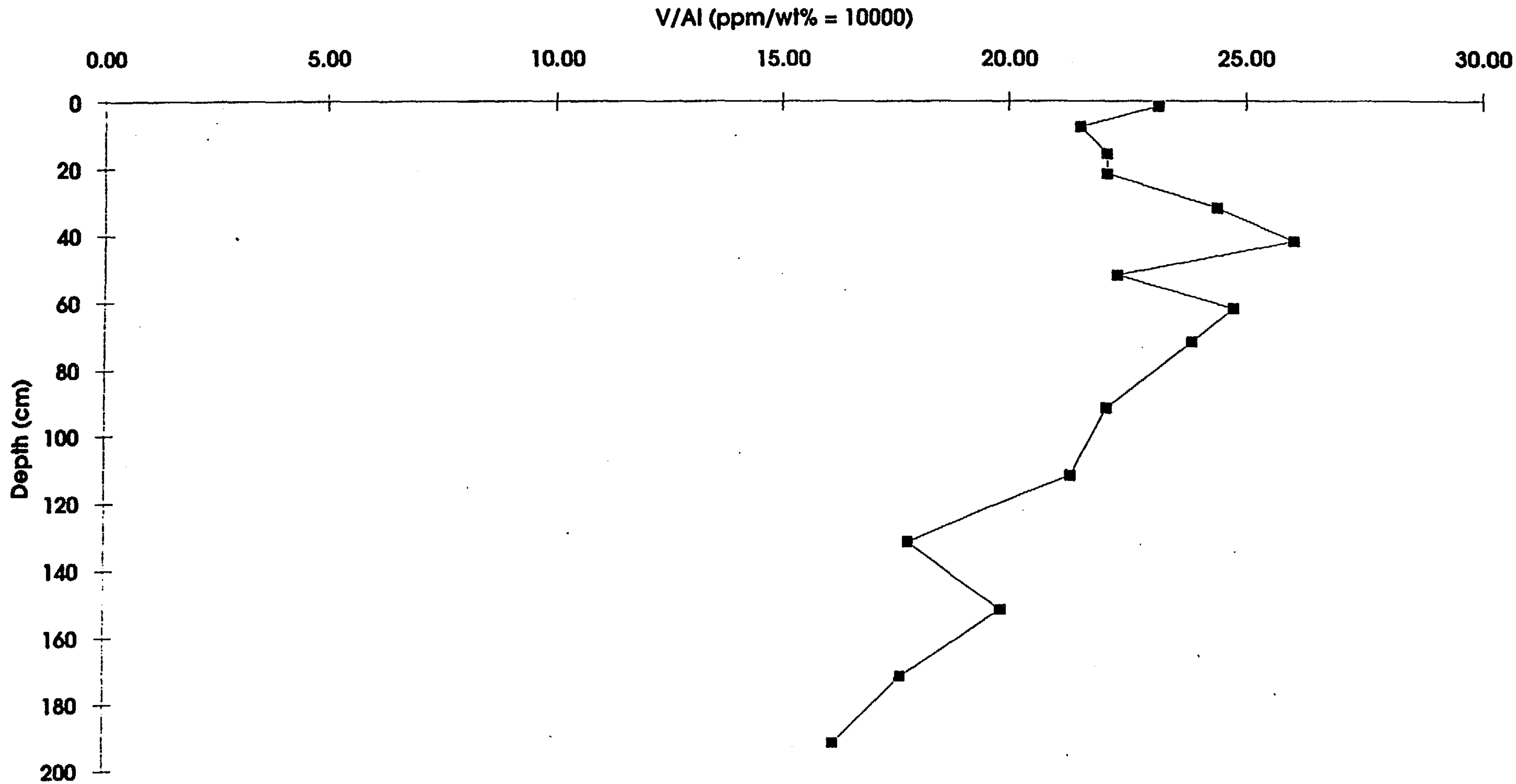
Down-core profile of Sr/Al (ppm/wt%=10000) ratio, core 67GC45



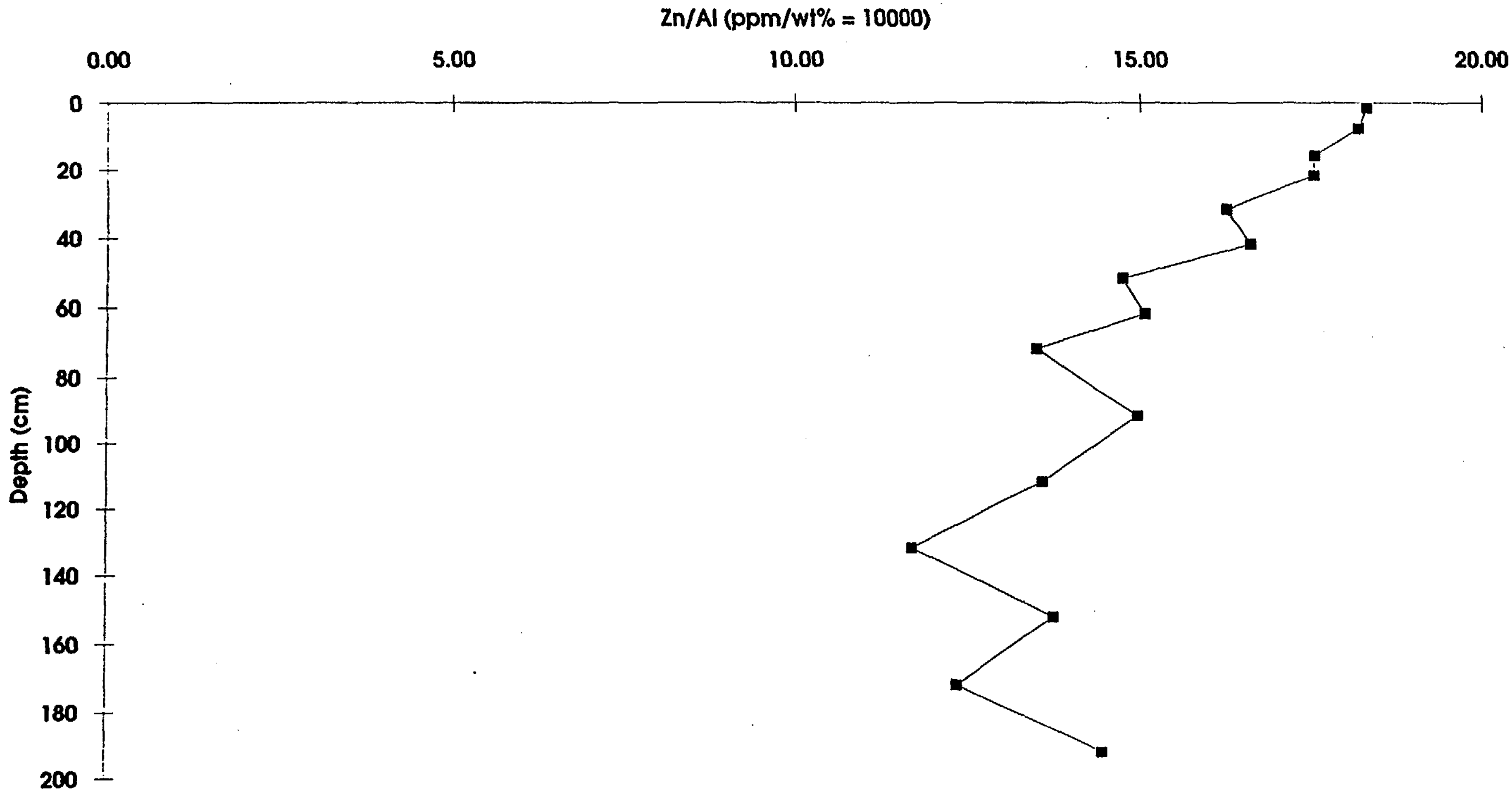
Down-core profile of Cu/Al (ppm/wt% = 10000) ratio, core 67GC45 Otway Basin



Down-core profile of V/Al (ppm/wt% = 10000) ratio, core 67GC45 Otway Basin



Down-core profile of Zn/Al (ppm/wt% = 10000) ratio, core 67GC45 Otway Basin



Down-core profile of Ti/Al ratio, core 67GC45 Otway Basin