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APPENDIX 1

GRAPHIC LOGS AND DECOMPACTION CALCULATION

Logs for drill holes east of the Hellyer mine (HL 80, MAC 11 and MAC 19; Fig. 2) have not been drawn up due to the lack of shale. In HL 80 (closest to the Hellyer ore deposit Fig. 2) this is probably due to erosion because the shale is exposed at the surface near the hinge of the anticline. The Que River Shale in MAC 11 (60 m east of the Hellyer orebody Fig. 2) consists of approximately 20 m of sandstone, muddy sandstone and shale. The sandstone exhibits an irregular banding, defined by mud lenses. Although the shale is unlaminated, it may have originally been laminated, the laminations being destroyed by loading of sediments caused by the influx of volcanic sandstones. In MAC 19 (the eastern-most of the drill holes studied, Fig. 2), the Que River Shale is between 5 and 10 m thick and contains volcanoclastic clasts. It occurs along a faulted contact between the underlying basalt and overlying Southwell Subgroup.

DECOMPACTION CALCULATION

In order to establish the actual thickness of a sedimentary column at any time in the geological past, the effect of compaction due to sediment loading must be calculated and reversed. Ruby and Hubbert (1960) showed that for normal pressures, porosity (f) is exponentially related to depth of burial (z) by the function:

$$f = f_0 e^{-cz}$$

where f_0 = surface porosity, c = compaction factor, z is depth in kilometres f = compacted porosity.

The burial depth of the Que River Shale was calculated using average thickness of overlying units (Fig. 6).





Unit	Thickness	Source
Tertiary Basalt	900 m	Pemberton et al, 1991
Gordon Group	400 m	Pemberton et al, 1991
Owen Conglomerate	1010 m	Pemberton et al, 1991
Mount Cripps Subgroup	900 m	Corbett, 1992
Southwell Subgroup	1000 m	Corbett, 1992
Total		4.21 km

Sclater and Christie (1980) have defined the average surface porosity for north sea black shales at 0.63 g/cm^3 and porosity of compacted shale at 2.72 g/cm^3 . These values agree with those found by Wells (1989) for late Neogene sedimentary basin in New Zealand and are used as average values for the Que River Shale giving a compaction factor of approximately 30%, this is used to calculate the uncompacted thickness of shale ($\approx 162.5\text{m}$).

Log Key

Lithology

Unit

-  URS - Upper Rhyolitic Sequence (equivalent to Southwell Subgroup in text)
-  QRS - Que River Shale
-  PLS - Pillow Lava Sequence (equivalent to the Upper Basalts and Andesites)
-  - Sandstone to Volcaniclastic layers

Colour

- Gy - Grey
Bk - Black
Gn - Green
Pk - Pink
Or - Orange
Ye - Yellow
DGy - Dark Grey

Type

- Sh - Shale
Ss - Sandstone
Vc - Volcaniclastic
B - Basalt
R - Rhyolite
D - Dacite
A - Andesite

Mineralisation

Texture

- Ds - Disseminated
Vn - Vein
Fb - Framboidal
Bn - Banded
No - Nodular
JP - Joint Plane
IP - Inter Pillow

Type

Py - Pyrite
Sp - Sphalerite
Gn - Galena

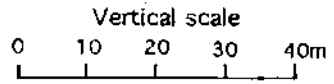
Content

tr - trace
1, 2, 3, etc - Higher number more intense mineralisation

Veining

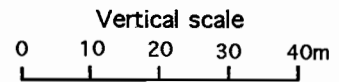
Co - Carbonate
Qz - Quartz
Py - Pyrite
Sp - Sphalerite
Gn - Galena
Dominant mineralogy listed first

Depth		Lithology			Mineralisation			Veining		Comments		
		unit	colour	type	depth	tex	min	type	ext			
0.0	4.0	QRS	bk	Sh	4.0			Qz	5.0	Top of hole		
10.0										QzCo	8.1	Finely laminated shale
20.0										CoSp	11.3	
30.0										Co	15.2	
32.5									Ds	Pytr		
33.5					GyYe	D/A						
40.0					Bk	Sh				Co	36.4	Dacitic-Andesitic lavas, intrusive, baked contacts
44.1					GyGn	A						
46.2												
50.0												48.1
54.00					56.0							
55.00					58.0	Vn	Py1	Co		Sandy laminations, microscours		
60.0					60.0					Finely laminated shale		
70.0						NoBn	Py3					
70.6		PLS	GyGn	B	70.6			Co	70.6	Contact sharp, very minor peperites Vesicular pillow lavas and minor shale		



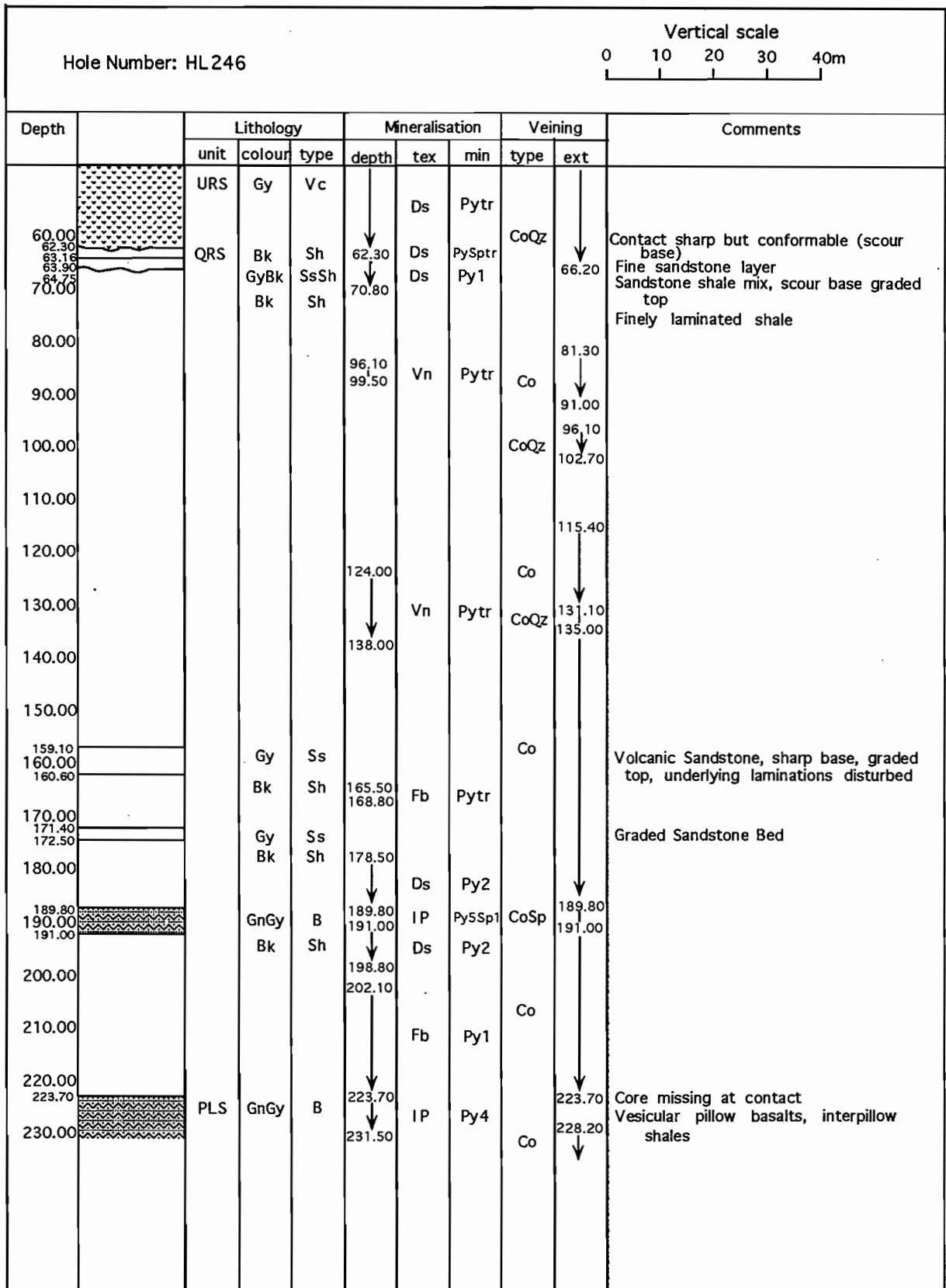
Hole Number: MAC 15

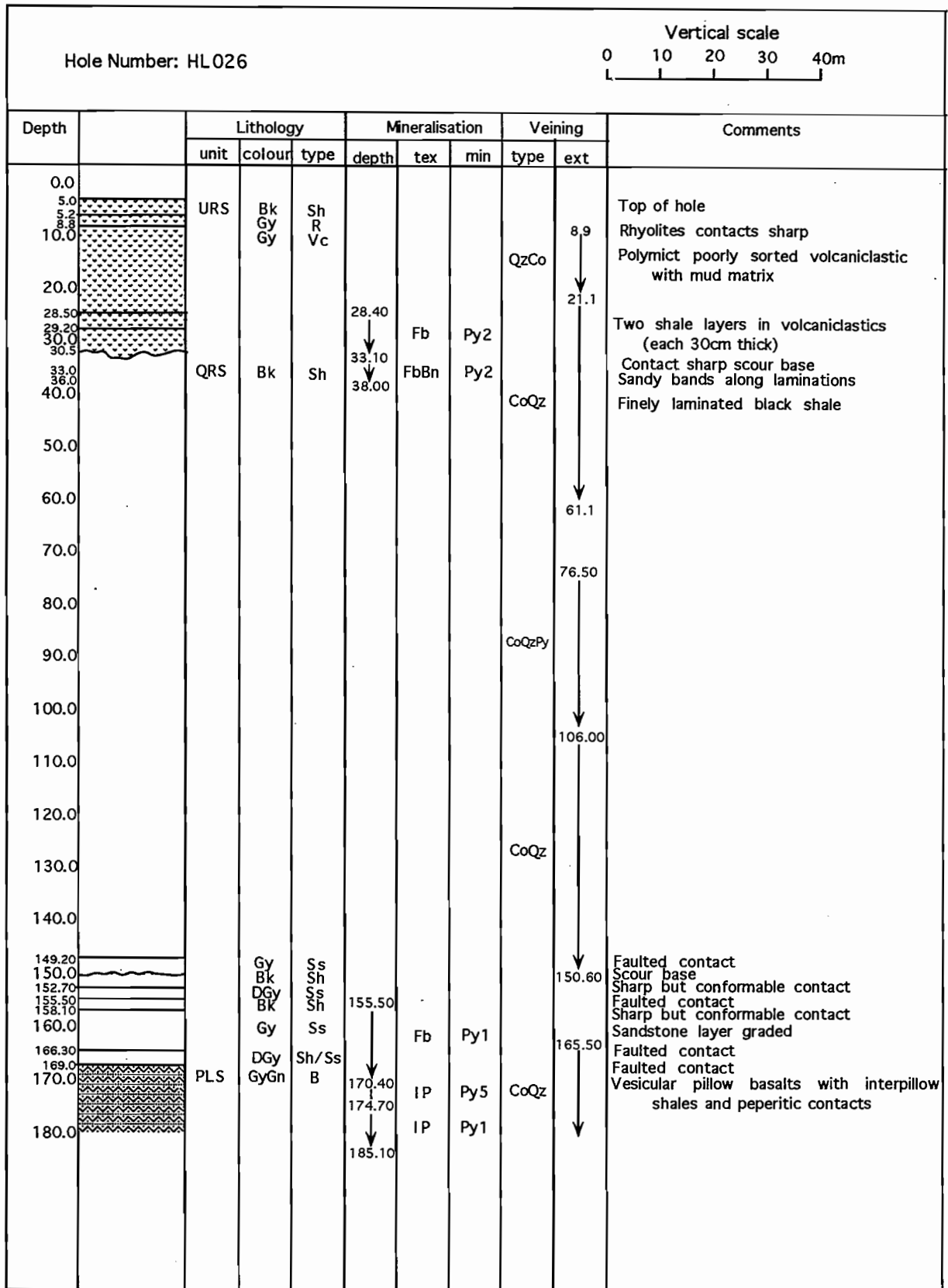
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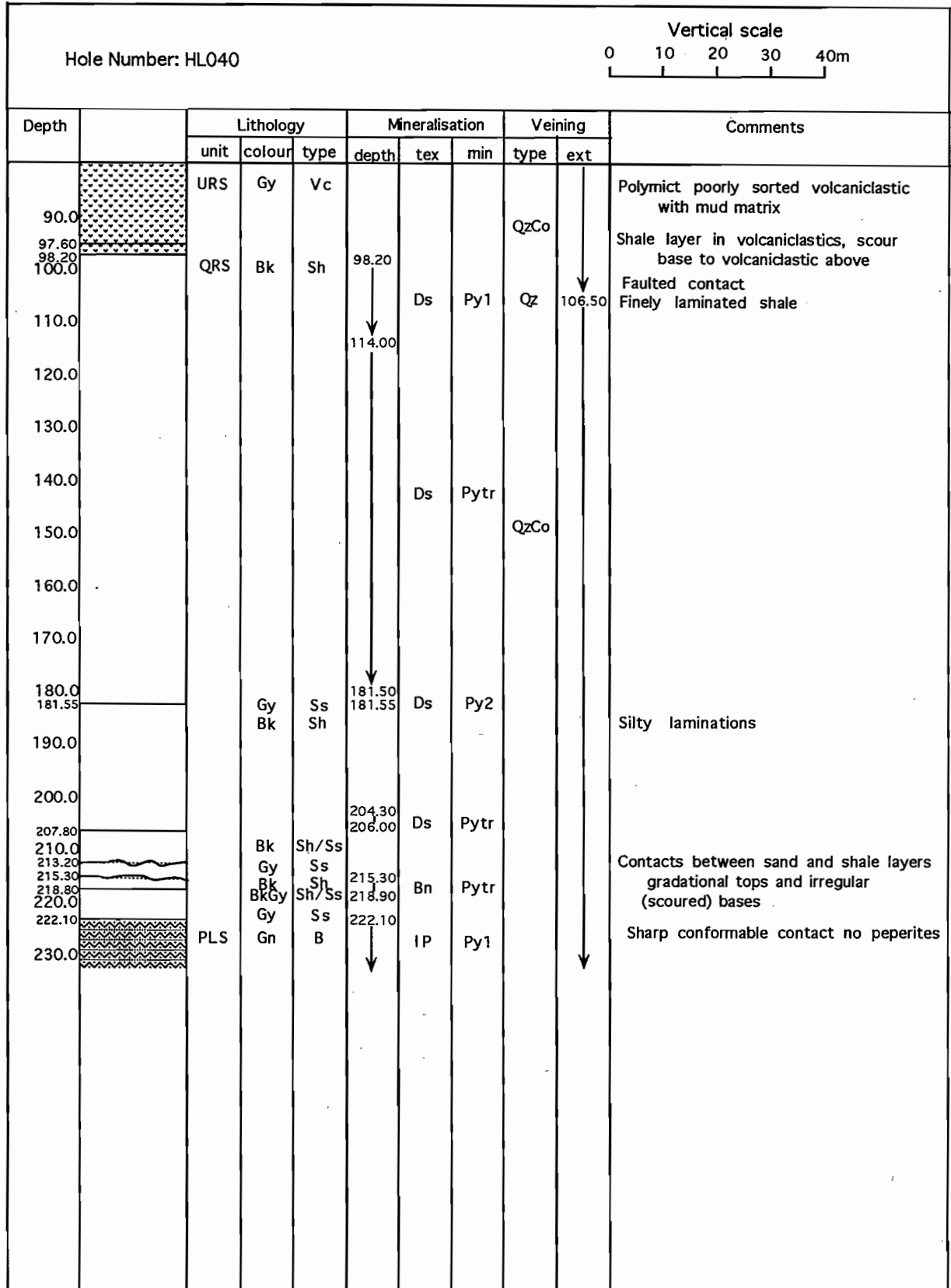


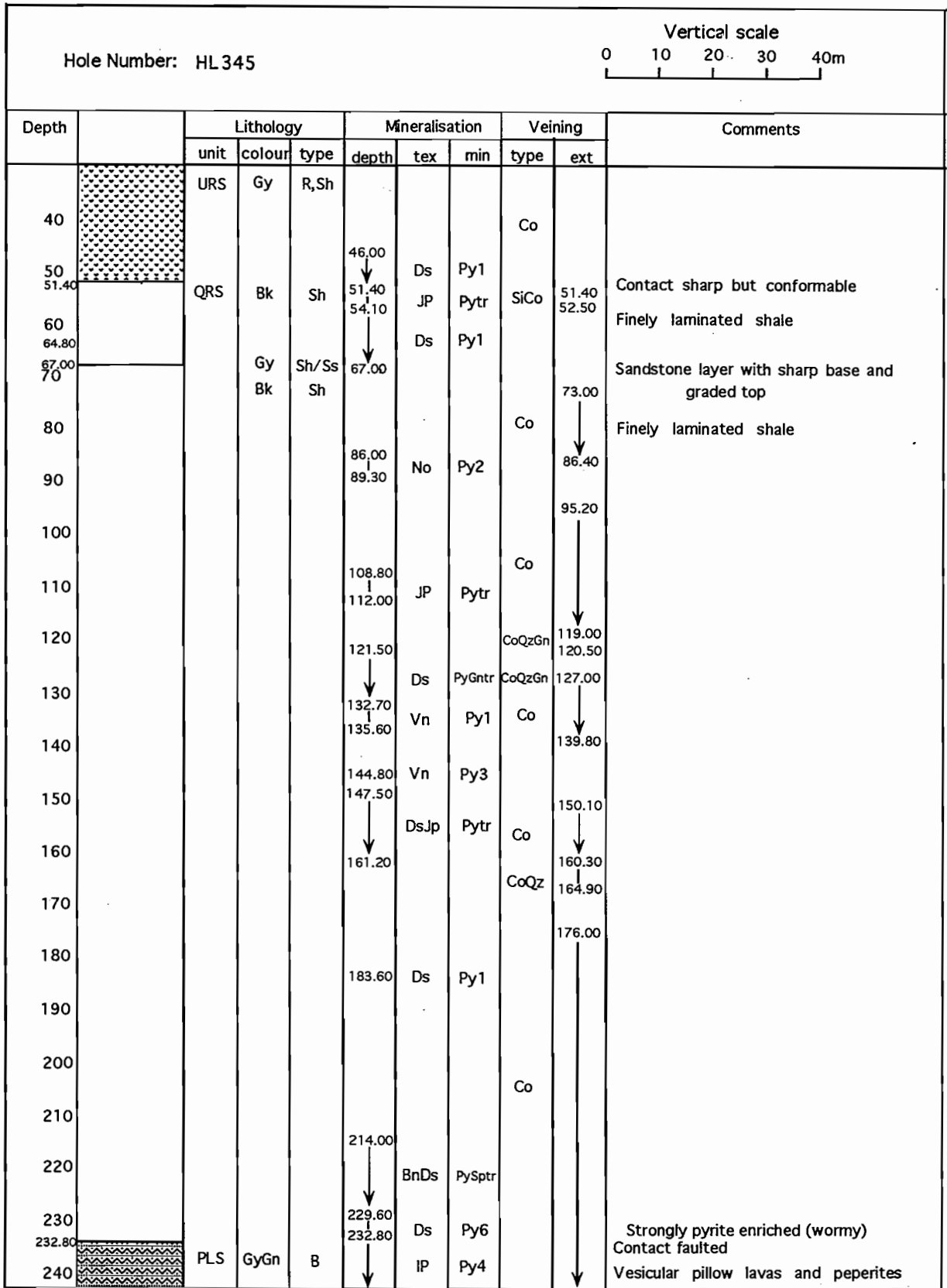
Depth	Lithology			Mineralisation			Veining		Comments		
	unit	colour	type	depth	tex	min	type	ext			
0.0 2.00	QRS	Bk	Sh						Top of hole Finely laminated shale		
10.0											
20.0											
30.0											
40.0											
50.0											
60.0 64.30 64.50		PkOr Bk	Vc Sh	64.50					Polymict fine grained volcanic sandstone with a sharp top and scour base Finely laminated shale, laminations often silty		
70.0											
80.0					DsBn	Pytr					
90.0				85.50							
99.70				98.00	BnNo	Py2					
100.0	PLS	GnBr	B	98.40	FbBn	Py4			Faulted contact Pillow basalts with minor inter pillow sediment		
101.10				NoBn	Py5						
104.10				VnDs	Py8						
111.0				VnDs	Py5						
113.0				VnDs	Py1						
							Py	101.10			
							CoQzPy	111.00			

Hole Number: MAC 10										Vertical scale 0 10 20 30 40m				
Depth	Lithology			Mineralisation			Veining		Comments					
	unit	colour	type	depth	tex	min	type	ext						
0.0										Top of hole Finely laminated shale				
6.0	QRS	Bk	Sh											
10.0														
20.0									QzCo		21.0			
30.0									QzCo		35.00			
40.0							42.30	Vn	Pytr					
50.0														
60.0														
70.0							72.10	Vn	Py1			68.10		
80.0											CoQz	82.00		
90.0										Co	89.00 91.50			
100.0									69-70m Possible shear/fault					
110.0														
117.4	PLS	GyGn	B	115.70	Ds	Py1								
120.0				117.40 120.00	IP	Py2	Co	117.4						
									Sharp contact possibly faulted Vesicular pillow basalts and interpillow shale					









Hole Number: HL469										Vertical scale				
										0	10	20	30	40m
Depth		Lithology			Mineralisation			Veining		Comments				
		unit	colour	type	depth	tex	min	type	ext					
450.0		URS	Gy	Vc	454.70									
458.10					↓	DsFbVn	Py2							
460.0		QRS	Bk	Sh	460.40			Co	459.80	Contact irregular (scour)				
									↓	Top 3m shale reworked when soft				
					468.00		Bn	Py2	464.00					
470.0					↓	BnVn	Py2	CoQz	↓	Finely laminated shale				
473.70					471.60				470.30					
474.10			GyBk	SsSh	476.40									
					479.60		BnVn	Py2	478.70	Sandy mudstone layer				
480.0					↓					Sandy laminations				
					480.60									
					484.90		BnVn	Py4						
			Bk	Sh	↓			CoQz		Finely laminated shale				
					487.30									
490.0					490.00		Bn	Py2						
					↓									
					491.50				495.40					
500.0								Co						
									↓					
510.0									511.60					
					517.40									
					↓	JP	Pytr							
520.0					521.40				521.70					
								CoQz						
									↓					
530.0					533.80				531.70					
						JPBn	Py1							
540.0					↓				540.00					
					546.30		BnVn	Py2	↓					
					↓			CoQz	↓					
549.30					549.30				549.30	End of Hole				

APPENDIX 2

GEOCHEMICAL METHODOLOGY

DEGREE OF PYRITISATION

The method depends on relatively simple analytical methodology, which can be applied to sediments of Paleozoic and younger ages up to at least greenschist metamorphic grade and which has a sound theoretical basis supported by studies of modern sediments (Berner, 1970; Raiswell and Al-Biatty, 1989).

$$\text{DOP} = \text{Pyrite Fe} / (\text{HCl-extractable Fe} + \text{Pyrite Fe})$$

The HCl extractable Fe was determined by the method of Berner (1970) as modified by Raiswell et al., (1988). About 0.1 g of crushed rock (<60 mesh) was brought to the boil over a one minute period in a test tube with 5 ml of concentrated HCl, then simmered for exactly one more minute. The reaction was carefully quenched by filling the tube with distilled water and washing both sediment and solution into a 200 ml volumetric flask (Fe < 1%) or a 500 ml volumetric flask (for <2.5% Fe). After standing for several hours, the upper part of the solution is clear enough to be aspirated directly into an atomic absorption spectrophotometer. Raiswell et al., (1988) found that good precision (2-8%) was obtainable with this technique. Berner (1970) states that this treatment completely dissolves iron in fine grained reagent hematite, limonite, goethite and chlorite but not pyrite.

Pyrite sulfur was determined using the sulfur values from XRF data and back calculating to get pyrite Fe. Samples used for DOP and Organic carbon determinations are shown on figure 2.1

ORGANIC CARBON DETERMINATIONS

In order to determine the best method for measuring the Organic carbon content of the Que River Shales four tests were carried out. The first three involved acid attack while the fourth involved

FIGURE 2.1: Schematic representation of lithologies in drill holes surrounding the Hellyer deposit. Showing the position of samples for DOP, % organic Carbon and % Sulphur calculations.

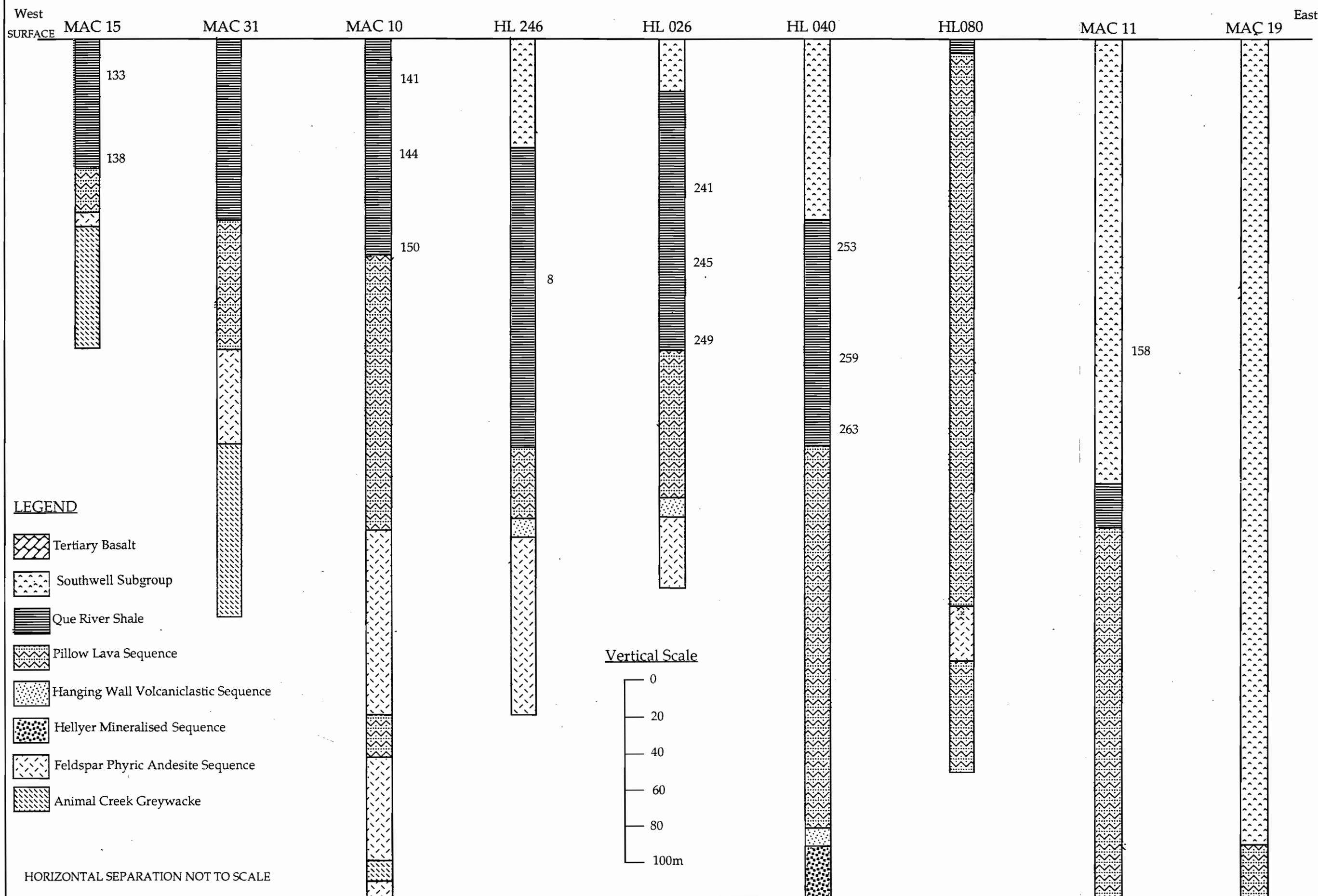
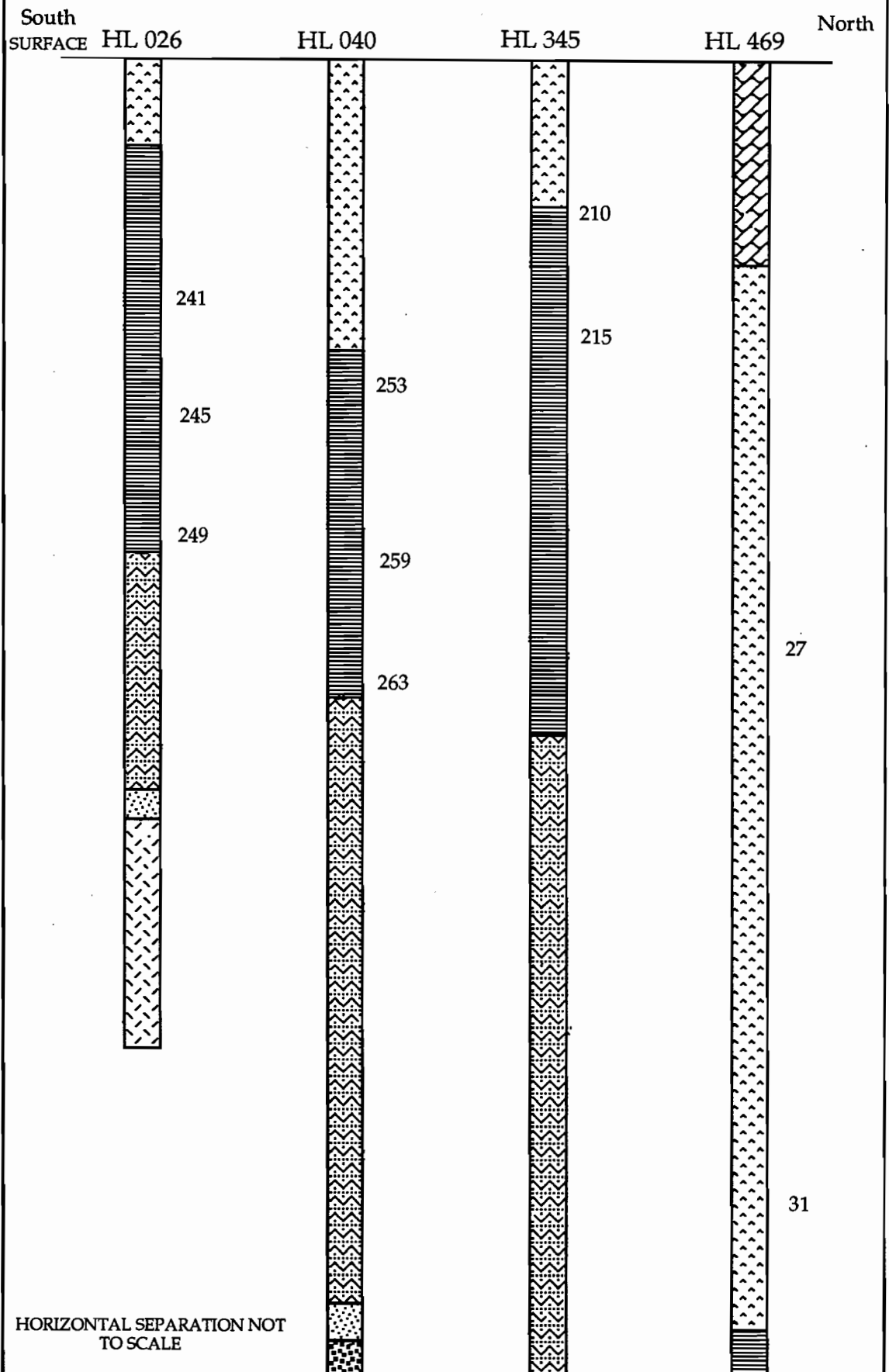


FIGURE 2.1 B: Position of samples for DOP, % organic carbon and % sulphur



ashing the samples at high temperature. All tests were conducted on one sample of finely ground Que River Shale.

Method

For the first three tests approximately 2 g of sample was weighed into a test tube and then the tube was half to three quarters filled with acid:

Tube 1: Dilute HCl (2M)

Tube 2: Concentrated HCl (10M)

Tube 3: H₃PO₄

All three tubes were then heated in a waterbath at 60°C for 6 hours, centrifuged, washed twice with distilled water and left to dry overnight in an oven at 70°C, then reweighed.

The fourth test was based on the ashing technique of Krom and Berner (1982), where approximately 2 g of sample is weighed into a crucible and then ashed in a furnace at 450°C overnight, the sample is then reweighed.

The treated samples and two untreated samples were then analysed for percentage carbon and sulfur using the Karlo Erber Elemental analyser (Riddle, 1993). The results are shown in Table 2.1 :

method	test tube	tt + samp	end wt	%C analysed	%C actual	average	%S analysed	%S total
	wt	wt						
Remove Carbonate Carbon								
2M HCl	57.5378	59.5383	59.284	1.12	0.98		1.54	1.34
			9					
10MHC	57.2475	59.249	58.971	1.08	0.93	0.95	1.50	1.29
I			6					
H ₃ PO ₄	57.953	59.9527	59.555	1.17	0.94		1.60	1.28
			7					
Remove Organic Carbon								
Ashing	5.43404	7.4211	7.3762	0.2	0.20		1.22	1.19
			5					
Ashing	6.65808	8.60574	8.5613	0.16	0.16	0.18	1.17	1.14
					sum	1.12		
Nil					1.04			1.79
Nil					1.14			1.77

Discussion

The ashing technique was chosen as the method to be used as it is the simplest and less messy than the acid attack techniques while giving comparable results. There is some concern with the ashing method that sulfur may be converted to SO₂ during ashing causing a weight gain in samples and thus not giving a true result when calculate back to actual weight percent Carbon however the consistency of the results between ashing and acid attack suggests that this is not occurring (although further tests are in progress by McGoldrick). Further tests will also see if siderite is broken down however the method should be valid for the Que River Shale samples as they are unlikely to contain siderite.

Accuracy The Karlo Erber has an accuracy of about 0.15% for carbon and sulphur while Krom and Berner (1983) state that there method gives results within $\pm 0.1\%$ of the total organic carbon present.

SULPHUR ISOTOPE METHOD

Eighteen pyrite samples comprising 14 pyrite nodules, 2 laminated pyrite samples, a mixed sample and a euhedral vein pyrite were selected for sulphur isotope analysis (Fig 2.2). The samples were drilled and then combusted with an excess CuO in vacuo to produce SO₂ before being analysed on a VG Sira Series II stable isotope mass spectrometer in the Central Science Laboratory at the University of Tasmania. Stable isotope results are expressed in standard (δ) notation relative to Canyon Diablo trilobite (CDT). Sample reproducibility was typically ± 0.2 permil and analytical uncertainty was less than ± 0.1 permil (Gemmell and Large 1992). The results are summarised in table 3 and Fig. 6 and distribution plotted on Fig. 7.

X-RAY DIFFRACTION (XRD)

XRD analyses to determine approximate mineralogical composition of 5 samples, 3 from the Que River Shale Formation and two from the Lower shale Facies, were performed by R. Bottrill and R.N. Wolley at Tasmanian Development and Resources. The samples were run on an automated Philips A-ray diffractometer system: PW 1729 generator, PW 1050 goniometer, PW 1710 printing recorder and microprocessor, with nickel-filtered copper radiation at 40kV/30mA, a graphite monochromator (PW1752), sample spinner and a proportional detector (sealed gas filled, PW1711). The samples were calibrated with the addition of an internal standard of natural quartz. The quantitative mineralogy was determined by manual search-match methods. The six strongest peaks of

FIGURE 2.2 A: Schematic representation of lithologies in drill holes surrounding the Hellyer deposit.
 Showing the distribution of pyrite samples used for sulphur isotope analysis.

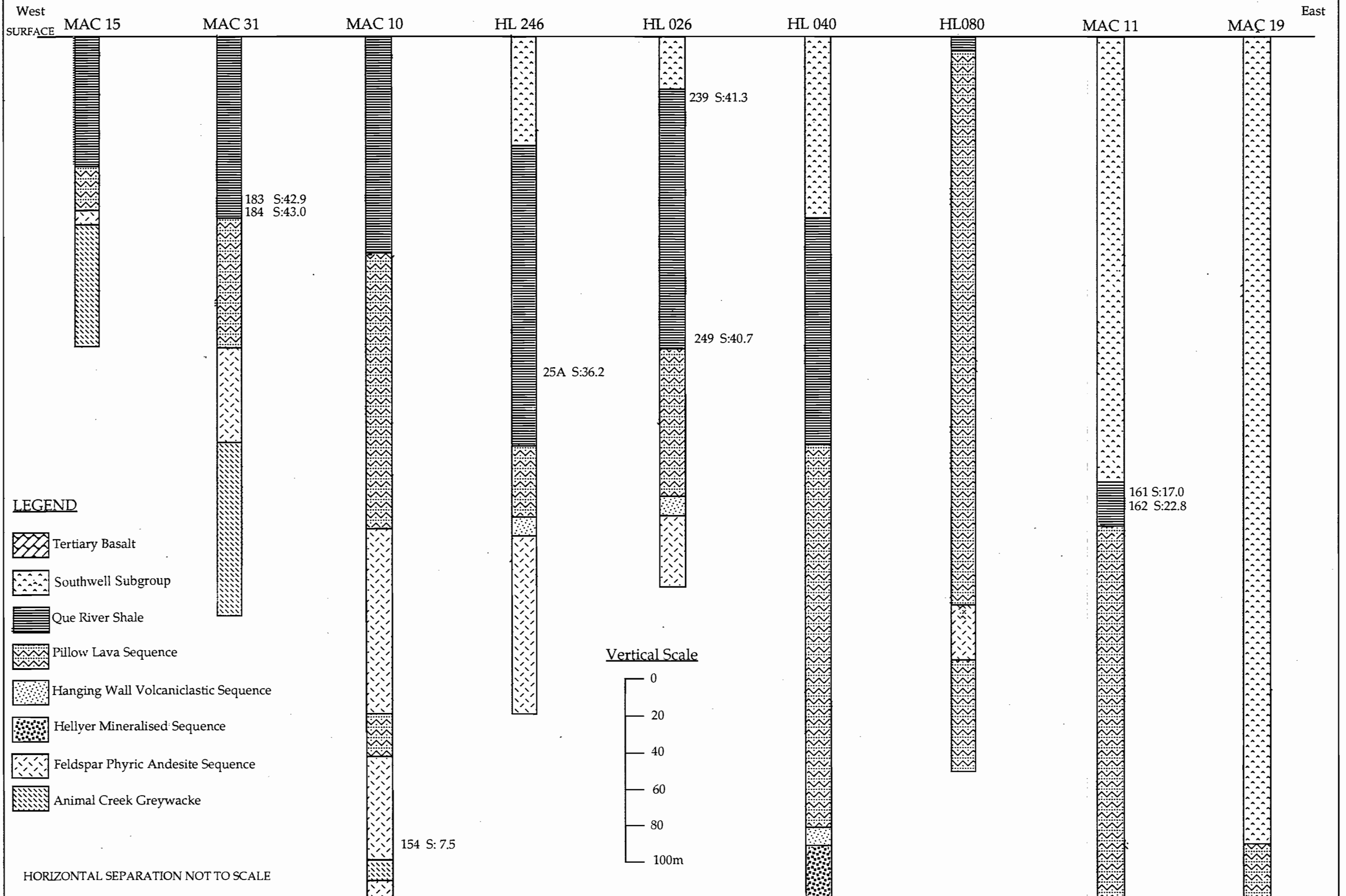
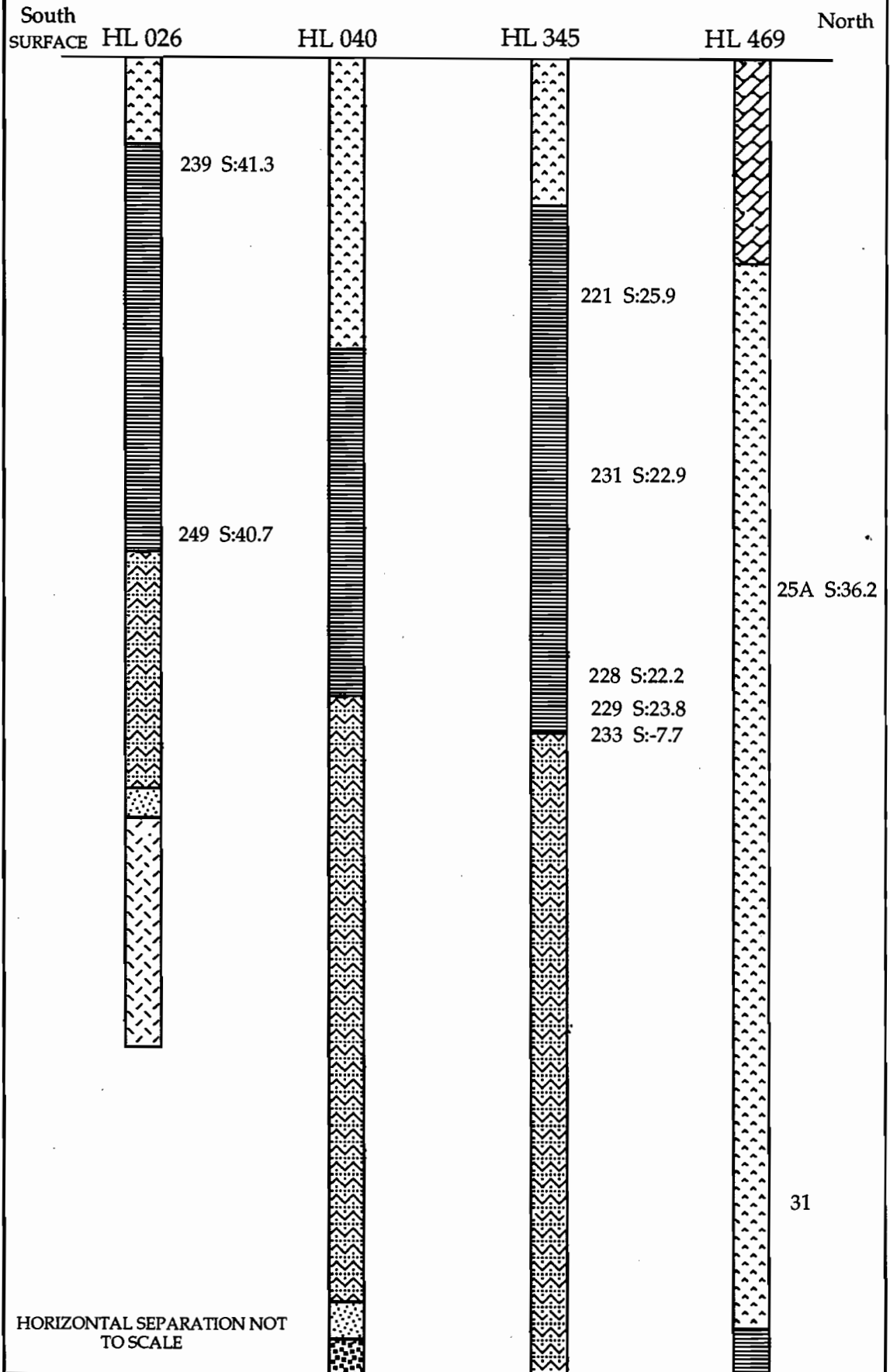


FIGURE 2.2 B: Distribution of pyrite samples use dfor sulphur isotope analysis and results.



the iron-titanium oxides were used for cell dimension refinement, using the excell templates of Novak and Colville (1989). The Results are listed in Table 1.

X-RAY FLOURESCENCE (XRF)

45 samples from the Que River Shale Formation, 5 from the Southwell Subgroup and one from the Upper Basalts and Andesites were chosen for major element analysis (SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , MnO , MgO , CaO , Na_2O , K_2O , P_2O_5 , BaO and S) by X-ray fluorescence (XRF), Refer to Riddle (1993) for principles of XRF. The Que River Shale samples were selected at regular intervals from 8 holes (Fig.) with a higher sample density in holes over the Hellyer massive sulphide orebody (HL 026 and HL 040: Fig. 2). Shale units within the Southwell subgroup and Upper Basalts and Andesites were also analysed for comparison.

Samples were collected with a preference for pure shale ie unsheared, unaltered and poorly veined. Samples were prepared by removing any veining or pyrite nodules present and then a minimum of 500 g of core was crushed using a jaw crusher. Approximately 50g of the crushed rock was then ground in a tungsten carbide mill to produce a powder.

Fusion discs for major element analysis were prepared using an altered silicate method; 3.7125 g of Norrish Flux, 0.7700 g of sample and 0.3850 g of Lithium Nitrate were mixed in a 10% gold/platinum crucible and preignited at 700°C for ten minutes to retain sulphur prior to fusion at 1050°C in a muffle furnace. The ignition loss was determined by heating approximately 2 g of each sample at 1000°C overnight. Owing to the high sulphide content in many samples, the ignition loss was high. The discs were then analysed by P. Robinson on a Philips PW 1480 X-Ray Spectrometer in the Geology Department of the University of Tasmania. Matrix absorption corrections were calculated using Philips tabulated alpha factors produced using the De Jongh model as published in the Philips PW 1480 X-Ray spectrometer software manual.

From the results of the major element analysis (Table 1) a subset of 36 samples were chosen for trace element analysis, these samples were chosen to cover the variation within the Que River shale observed in the major element data with a concentration of samples around the ore body.

Trace element pills were produced using 6 g of sample bound with 0.7ml of PVA (2.5% in 1:1 water:ethanol) solution and cased in boric acid. The pills were analysed on the Philips PW 1480 X-Ray Spectrometer by P. Robinson in the Geology Department of the University of Tasmania.

Table 2 shows the specification for each element. Absorption corrections for the ScMo and Rh tubes were done using the Compton scatter method while corrections for the Au tube were done using alpha tables of coefficients from the major element composition.

Table: 1 Major and trace element analysis for selected samples from the Que River Shale, the underlying shale in Upper Basalt horizon and shales from with in the Southwell Subgroup.

MAJOR ELEMENTS													
Locality*	Hole	Depth(m)	SiO2	TiO2	Al2O3	FeO*	MnO	MgO	CaO	Na2O	K2O	P2O5	S
Que River Shale Formation													
1 (3)	HL246	77.30	65.88	0.59	12.37	5.06	0.04	2.64	1.95	0.91	2.83	0.13	1.40
2 (5)	HL246	97.80	64.81	0.53	12.22	5.16	0.04	2.53	2.29	0.43	3.16	0.12	1.67
3 (8)	HL246	127.30	69.22	0.46	12.17	4.05	0.04	2.24	2.40	0.24	2.88	0.09	0.89
4 (12)	HL246	168.50	66.65	0.61	11.81	4.94	0.04	2.67	2.09	0.44	2.78	0.13	1.23
5 (16)	HL246	2.20	66.07	0.43	10.33	5.13	0.04	2.39	4.33	0.20	2.47	0.08	2.17
6 (20)	HL246	222.60	66.15	0.52	10.42	5.36	0.04	2.74	4.09	0.31	2.29	0.11	1.84
9 (37)	HL469	524.90	65.56	0.58	12.49	5.15	0.05	2.57	2.16	0.66	2.78	0.14	1.36
10 (52)	HL469B	564.80	36.30	0.58	11.96	7.11	0.05	2.60	2.36	0.13	2.80	0.14	2.17
11 (58)	HL469B	625.70	65.65	0.60	11.95	4.86	0.05	2.65	2.90	0.60	2.69	0.12	1.12
12 (63)	HL469B	675.80	66.47	0.54	11.02	5.11	0.03	2.27	2.76	0.14	2.82	0.11	1.89
22/133	MAC15	15.60	68.41	0.70	13.01	4.79	0.02	1.91	0.04	0.07	3.14	0.09	1.76
23/136	MAC15	44.50	67.92	0.74	12.17	6.39	0.02	2.56	0.04	0.03	2.82	0.04	1.83
24/138	MAC15	67.30	66.23	0.76	13.18	5.90	0.02	1.84	0.05	0.06	3.23	0.05	2.62
25/141	MAC10	17.80	68.81	0.54	10.64	6.90	0.05	3.00	1.24	0.54	1.87	0.14	0.53
26/144	MAC10	57.00	67.43	0.56	11.60	4.67	0.06	2.44	1.82	0.39	2.87	0.12	1.23
27/147	MAC10	87.70	67.40	0.54	12.22	5.11	0.03	2.39	1.34	0.26	3.09	0.13	1.71
28/150	MAC10	114.90	65.23	0.66	11.36	8.13	0.05	3.29	2.48	0.38	1.84	0.25	0.41
32/161	MAC11	243.40	65.59	0.47	10.70	4.28	0.12	2.01	3.89	0.12	3.14	0.18	1.23
35/210	HL345	52.60	67.05	0.52	12.01	3.81	0.07	2.02	2.53	0.24	3.32	0.12	1.11
36/215	HL345	93.90	65.48	0.53	12.11	5.26	0.04	2.46	1.95	0.10	3.13	0.11	1.83
38/223	HL345	167.30	68.17	0.60	11.97	4.62	0.05	2.36	1.69	0.20	2.94	0.11	1.18
39/226	HL345	196.30	66.71	0.61	11.81	5.24	0.05	2.53	2.03	0.35	2.80	0.14	1.36
40/229	HL345	223.90	68.61	0.54	11.42	4.77	0.04	2.03	1.60	0.11	2.91	0.14	1.79
41/236	HL026	40.90	68.68	0.50	11.62	4.46	0.04	2.13	1.65	0.31	2.98	0.11	1.37
42/238	HL026	61.50	66.14	0.55	12.62	5.13	0.05	2.73	1.56	0.25	3.09	0.12	1.48
43/241	HL026	81.70	63.26	0.54	11.63	8.29	0.05	3.11	2.74	0.22	2.15	0.26	1.66
44/243	HL026	100.90	66.44	0.60	13.63	4.84	0.03	2.81	1.15	0.36	3.24	0.12	1.12
45/245	HL026	121.80	68.03	0.63	12.41	5.10	0.03	2.35	1.13	0.08	2.87	0.14	1.26
46/247	HL026	141.30	66.44	0.55	11.47	4.87	0.06	2.50	3.33	0.09	2.74	0.13	1.34
47/249	HL026	159.80	71.37	0.31	12.73	2.94	0.04	1.75	1.78	0.25	3.31	0.08	0.76
49/253	HL040	110.30	66.78	0.52	12.14	5.31	0.03	2.21	1.53	0.21	3.06	0.12	1.87
50/255	HL040	130.90	66.95	0.54	12.25	4.75	0.03	2.41	1.54	0.66	2.94	0.13	1.67
51/257	HL040	153.40	66.14	0.60	12.27	5.17	0.04	2.69	1.95	0.61	2.73	0.13	1.36
52/259	HL040	170.00	66.27	0.60	11.91	4.98	0.05	2.50	2.60	0.37	2.73	0.12	1.24
53/261	HL040	190.10	67.25	0.60	11.93	5.03	0.14	2.48	1.98	0.20	2.78	0.14	1.15
54/263	HL040	212.00	68.45	0.44	14.29	3.02	0.03	1.77	2.12	0.38	3.72	0.11	0.77
	Mean		66.06	0.56	12.00	5.16	0.05	2.43	2.03	0.30	2.86	0.13	1.43
	Mode		66.14	0.60	12.22	5.13	0.04	2.53	1.95	0.20	2.78	0.12	1.23
Lower Shale Facies													
14/95	HL469B	735.50	66.17	0.64	11.92	5.17	0.03	2.47	2.10	0.28	2.91	0.13	1.56
15/100	HL469B	784.90	64.46	0.62	12.24	6.38	0.04	2.92	2.25	0.40	2.64	0.13	2.07
16/105	HL469B	855.70	64.17	0.80	13.43	5.97	0.04	3.14	1.89	0.07	3.26	0.14	1.25
17/114	HL469C	984.30	66.86	0.71	12.14	6.08	0.03	2.87	1.68	0.34	2.77	0.17	1.48
18/119	HL469C	1038.50	66.69	0.75	12.19	5.66	0.04	3.27	1.62	0.63	2.60	0.14	1.24
19/124	HL469C	1085.60	63.96	0.80	12.80	6.02	0.04	3.25	2.48	0.77	2.69	0.16	1.17
20/128	HL469C	1125.10	64.10	0.77	12.83	5.96	0.04	3.16	2.27	0.84	2.87	0.16	1.28
21/131	HL469C	1155.60	63.47	0.60	14.73	6.97	0.09	3.56	1.07	0.58	3.28	0.15	0.67
29/151	MAC10	187.60	60.81	0.50	10.26	6.05	0.15	3.65	5.67	1.10	3.31	0.14	0.88
	Mean		64.52	0.69	12.50	6.03	0.06	3.14	2.34	0.56	2.93	0.15	1.29
Upper Rhyolitic Sequence shales													
7 (27)	HL469	424.00	63.82	0.52	15.17	4.07	0.19	1.97	2.45	0.10	4.19	0.11	0.54
8 (31)	HL469	462.20	64.14	0.50	11.87	6.87	0.04	1.92	2.17	0.09	3.06	0.15	3.08
31/158	MAC11	161.20	68.10	0.72	11.98	8.30	0.04	2.48	0.07	0.02	2.13	0.15	0.85
33/190	MAC19	17.70	56.37	0.73	12.99	6.41	0.18	4.35	5.00	0.43	3.40	0.17	0.05
34/194	MAC19	452.80	63.21	0.81	12.75	7.49	0.10	2.79	2.72	0.24	2.40	0.15	0.32
	Mean		63.13	0.66	12.95	6.63	0.11	2.70	2.48	0.18	3.04	0.15	0.9

Table 1: continued

TRACE ELEMENTS																			
Locality*	Ni	Cr	V	Sc	Zr	Y	Sr	Rb	Ba	Cu	Pb	Zn	As	Tl	Se	Sb	Cd	La	Mo
Que River Shale Formation																			
1 (3)	64	148	127	17	149	28	75	126	664	41	46	87	19	<1.5	1.4	3.6	<1	25	8.4
2 (5)	67	144	180	18	147	27	65	115	644	44	39	44	20	<1.5	1.85	<2	<1	30	6.6
3 (8)	67	139	223	18	140	28	51	120	667	44	37	98	14	1.6	2.35	3.6	<1	31	5.9
4 (12)	43	93	180	13	142	25	78	112	621	37	47	160	18	<1.5	1.55	4.5	<1	42	4.6
5 (16)	62	146	186	15	114	24	64	89	591	41	34	121	77	2.6	1.85	17.9	<1	35	7.8
6 (20)	57	113	137	15	130	19	74	85	575	35	44	45	45	1.8	1.1	9.6	<1	34	4.8
9 (37)																			
10 (52)																			
11 (58)	64	131	254	18	134	27	115	115	749	66	37	139	14	<1.5	3.25	2.9	<1	32	5.2
12 (63)	67	120	113	16	125	26	60	113	672	35	45	59	60	1.5	1.5	3.5	<1	23	7.9
22/133																			
23/136																			
24/138	316	143	152	21	154	30	23	125	558	73	83	507	41	1.7	2.1	9.7	<1	38	9.5
25/141	54	125	105	15	134	28	57	81	575	83	11	74	10	<1.5		<2	<1	30	<1
26/144	64	136	190	17	141	26	50	118	849	64	41	114	19	<1.5	1.85	4.1	<1	27	7.2
27/147	56	115	113	15	138	26	36	128	862	42	68	107	29	<1.5	0.75	4.5	<1	34	8.3
28/150	66	151	131	18	122	28	50	84	646	70	13	99	24	<1.5	<1	<2	<1	28	<1
32/161																			
35/210																			
36/215	68	139	123	17	144	27	39	117	587	36	79	83	31	<1.5	1.2	4.5	<1	29	10.1
38/223	71	139	210	18	134	24	28	109	553	64	79	110	21	<1.5	3.25	4.2	<1	26	6.3
39/226	65	140	217	18	132	26	34	105	514	53	46	110	15	<1.5	2.5	6	1.5	26	4
40/229	52	125	116	17	130	24	46	106	606	40	70	30	25	<1.5	1	13.6	<1	22	9.6
41/236																			
42/238	68	142	172	18	150	28	32	122	618	45	62	110	29	<1.5	1.85	8.3	<1	31	8.1
43/241	69	157	325	19	156	29	32	136	659	75	34	115	13	2	3.7	3.5	<1	32	6.6
44/243	63	153	153	17	123	29	95	87	452	61	58	115	23	<1.5	3.11	5.4	<1	26	1.2
45/245	71	141	227	19	148	25	41	120	584	51	323	938	31	2	2.05	9.4	3.2	30	5.6
46/247	67	140	152	16	134	26	81	105	579	48	54	126	32	1.5	1.75	10.2	<1	28	6.9
47/249	21	67	69	8	160	26	47	114	974	15	31	74	16	3.4	<1	6.2	<1	47	2.2
49/253	61	127	119	18	144	28	52	123	655	44	79	171	28	1.8	1.25	6.4	1.5	28	8.3
50/255	66	148	126	17	147	28	49	123	723	36	49	150	21	2.3	1.45	5.1	<1	30	8.2
51/257	66	137	193	19	143	27	67	112	677	55	47	97	17	<1.5	1.7	3.1	<1	30	6.1
52/259	74	140	309	18	143	28	74	117	576	49	400	656	29	1.7	3.05	7.4	1.6	27	7
53/261	67	141	407	17	146	27	46	111	580	54	57	134	17	<1.5	4.4	5.5	<1	26	4.8
54/263	26	57	98	11	211	35	64	130	825	20	37	81	13	3.3	1.5	5.1	1	48	2.6
	69.72	130.93	176.10	16.66	141.90	26.86	56.03	112.00	649.48	49.00	70.69	163.93	25.90	2.09	2.05	6.45	1.76	30.86	6.44
	67	139	180	18	134	28	64	115	575	44	37	110	29	1.8	1.85	4.5	1.5	30	6.6
Lower Shale Facies																			
14/95	62	137	141	18	138	27	57	119	779	49	45	98	19	2.6		2.8	<1	23	6.5
15/100	70	146	222	19	130	28	70	109	660	78	33	207	17	<1.5	7.85	3.1	2.8	28	2.6
16/105																			
17/114																			
18/119	75	140	211	20	136	25	52	107	725	61	54	172	16	1.6		3.3	<1	27	4
19/124	89	151	345	21	146	28	90	114	859	57	26	163	11	<1.5		2.4	<1	27	2.2
20/128																			
21/131	89	193	109	20	219	32	40	135	771	46	179	463	40	<1.5	<1	2.6	1.8	49	2.1
29/151																			
	77	153.4	205.6	19.6	153.8	28	61.8	116.8	758.8	58.2	67.4	220.6	20.6	2.1		2.84	2.3	30.8	3.48
Upper Rhyolitic Sequence shales																			
7 (27)	35	69	130	15	173	36	69	156	610	55	17	21	12	1.6		<2	<1	52	2.1
8 (31)	48	137	106	16	141	27	77	116	520	67	62	57	23	<1.5		6.1	<1	40	1.3
31/158																			
33/190																			
34/194																			

Table 2: Specification for each element.

Element	Line	Tube	kV	mA	Collimator	Crystal	Angle	Detector	Overlapping lines
Al	KA	ScMo	40	70	Coarse	PE	145.07	FL	
As	KB	ScMo	100	30	Fine	LiF200	30.445	SC	U, Br, Bi, W
Ba	LA	Au	40	70	Fine	LiF200	87.225	FL	Sc, Ti
Ca	KA	ScMo	40	70	Fine	LiF200	113.2	FL	
Cd	KA	Au	80	35	Fine	LiF200	15.285	SC	
Cr	KA	Au	40	70	Fine	LiF200	69.39	FL	V, Ba, La
Cu	KA	ScMo	90	30	Fine	LiF200	45.045	FS	Zn
Fe	KA	ScMo	90	30	Fine	LiF200	57.56	FL	
K	KA	ScMo	40	70	Fine	LiF200	136.765	FL	
La	LA	Au	40	70	Coarse	LiF220	138.91	FL	Ba, Ti
Mg	KA	ScMo	40	70	Coarse	PX1	23.155	FL	
Mn	KA	ScMo	90	30	Fine	LiF200	63.025	FL	
Mo	KA	Rh	90	30	Fine	LiF220	28.865	SC	
Na	KA	ScMo	40	70	Coarse	PX1	27.965	FL	Zn
Ni	KA	ScMo	90	30	Fine	LiF200	48.69	FL	Zn
P	KA	ScMo	40	70	Coarse	GE	141.06	FL	
Pb	LB	ScMo	90	30	Fine	LiF200	28.26	SC	Rb, Bi, Br, Ti
Rb	KA	ScMo	90	30	Fine	LiF200	26.6	SC	Pb, U, Bi
Rh	Compton	Rh	90	30	Fine	LiF200	18.31	SC	
S	KA	ScMo	40	70	Coarse	GE	110.715	FL	
Sb	KA	Au	80	35	Fine	LiF200	13.43	SC	Cd, Sn
Sc	KA	Au	40	70	Fine	LiF200	97.76	FL	Ca
Si	KA	ScMo	40	70	Coarse	PE	109.16	FL	
Sr	KA	Au	80	35	Fine	LiF200	25.135	SC	Pb
Ti	KA	ScMo	40	70	Fine	LiF200	86.215	FL	
Tl	LB	ScMo	100	30	Fine	LiF200	29.18	SC	Se, Ba, Bi, Br, W
V	KA	Au	40	70	Fine	LiF220	123.26	FL	Ti, Ba
Y	KA	ScMo	90	30	Fine	LiF200	23.77	SC	Rb, Pb, Bi, Th
Zn	KA	ScMo	90	30	Fine	LiF200	41.805	FS	
Zr	KA	Au	80	35	Fine	LiF200	22.53	SC	Sr

Line : KA K-alpha line, KB K-beta line, LA L-alpha line, LB L-beta line. Tube ScMo- Scandium - Molybdenum tube, Au Gold tube. kV ?, mA ?, Detector FL Flow counter, SC Scintillation counter, FS Flow counter and Scintillation counter..

Table 2.3 Centred Covariance matrix, calculated using average values for suite one andesites to dacites of Crawford et al., 1992. See Chapter 5 for details

	SiO ₂	TiO ₂	Al ₂ O ₃	FeO*	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂	0.029	0.020	0.026	0.014	-0.007	0.005	-0.054	-0.059	0.034	-0.008
TiO ₂	0.020	0.044	0.023	0.028	-0.018	0.015	-0.098	-0.038	0.024	0.001
Al ₂ O ₃	0.026	0.023	0.031	0.013	0.005	0.004	-0.075	-0.059	0.042	-0.010
FeO*	0.014	0.028	0.013	0.045	-0.016	0.016	-0.074	-0.051	0.006	0.018
MnO	-0.007	-0.018	0.005	-0.016	0.107	-0.015	0.017	-0.074	0.011	-0.010
MgO	0.005	0.015	0.004	0.016	-0.015	0.013	-0.041	0.002	-0.002	0.003
CaO	-0.054	-0.098	-0.075	-0.074	0.017	-0.041	0.385	0.007	-0.075	0.008
Na ₂ O	-0.059	-0.038	-0.059	-0.051	-0.074	0.002	0.007	0.381	-0.087	-0.023
K ₂ O	0.034	0.024	0.042	0.006	0.011	-0.002	-0.075	-0.087	0.065	-0.021
P ₂ O ₅	-0.008	0.001	-0.010	0.018	-0.010	0.003	0.008	-0.023	-0.021	0.042