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GEOSTATISTICAL STUDY OF SULFUR VARIATIONS IN THE HAT CREEK DEPOSIT

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GEOSTATISTICAL STUDY OF SULFUR VARIATIONS IN THE HAT CREEK DEPOSIT

Respectfully submitted

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Montreal, June 27, 1978

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FOREWORD

This report is the continuation of the geostatistical study of the HAT CREEK DEPOSIT. In the first report, B.T.U. variations were studied. In this one, sulfur variations are analysed in three different layers. It contains conclusions, variograms and maps of kriging results.

CONCLUSIONS

1. The purpose of this study is to analyze the fluctuations of the sulfur content in the layers of the Hat Creek deposit and to estimate its average value in regular blocks.

   The layers are horizontally projected and no tonnage calculations have been made.

2. Only three layers have been selected. They are A1-1, B1-2 and D1-3. They have different economic values and they have been studied only in the western part of the deposit. (PART 1 of Figure 1 of the previous report). The data considered are the coordinates and average sulfur content of the intersections in the three layers (no cut-off made on BTU). They have been read on a tape sent by MINTEC on May 27, and they are listed in Appendix 1.

3. Statistics of the sulfur content values in the three layers are presented in Table 1. The apparent relationship between sulfur and BTU means has been examined. Correlation coefficients and additional sulfur and BTU means (layers A2-1, C2-1, D1-1) show that no simple direct relationship can be found between sulfur and BTU (nor between sulfur and ash percentage or specific gravity, since these variables are very well correlated with BTU).

4. It can also be noticed that no simple relationship exists between sulfur values and depth.

5. However, a good proportional effect can be observed between the layers. The standard deviation of sulfur contents in each of them clearly decreases with the mean.

6. As a consequence of this effect, the relative standard deviation keeps almost the same value. This allows to expect similar precisions in the estimation of the three layers, despite their different average values.

7. <u>Variograms</u>

   All the experimental data have been used in the computation of the variograms since their distributions do not show outliers. Furthermore, because of the good regularity of thickness, it is possible to compute the variograms on the sulfur contents of the intersections. Different directions of the horizontal plane have been investigated and the experimental curves are shown in Appendix 2.

Layer	Number of intersections analysed	Mean (sulfur) (%)	Standard deviation (%)	Relative standard deviation	Minimum (%)	Maximum (%)	B.T.U.	Correlation Coefficient with B.T.U.
A1-1	17	0.664	.18	27%	0.43	1.06	5589	0.53
B1-2	40	0.673	.24	36%	0.17	1.42	5730	0.13
D1-3	74	0.300	.10	34%	0.15	0.62	9570	- 0.08
A2-1		0.270	.12				1387	
C2-1		0.427	.18				2982	
D1-1		0.274	.11				5888	

Table 1 Statistics of the distributions of three layers under study and three additional layers.

8. Unlike B.T.U., sulfur contents do not show any trend or any well defined anisotropy. The poor definition of the variograms for the A1-1 and B1-2 layers can be partly accounted for by the low number of intersections available in these layers.

9. By selecting only well defined points, and concentrating on the average variograms, it is possible to adjust a spherical model in each case. The parameters of models are shown in Table 2.

10. The D1-3 layer definitely presents a better continuity than the two other layers: the nugget effect is only one sixth of the total variability (sill) and the zone of influence extends as far as 1000 m from each sample points. The amplitude of the discontinuity at small distances (nugget effect) for the other layers is much more important.

11. The average sulfur content of 75 x 75 m blocks has been estimated by kriging. Blocks are the same as those estimated for BTU in the first study. Maps of the estimated blocks have been produced on the plotter at the scale 1" = 300 m and on the printer at the scale 1" = 75 m (Appendix 3). On both sets of maps, only blocks which are within the outline of the layers are shown. In each block, the estimated average sulfur content and the standard error of estimation are given. As already noticed the average relative standard error or precision keeps the same in the three layers (Table 2).

Layer	Nugget Effect $(\%)^2$	Sill $(\%)^2$	Range (m)	Average Standard error (%)	Relative Standard error
A1-1	0.0110	0.0240	550	0.077	12%
B1-2	0.0225	0.0375	1000	0.085	13%
D1-3	0.0015	0.0093	1000	0.038	12.5%

Table 2 Parameters of the models adjusted to the variograms of sulfur content in the three layers studied and corresponding average error in the estimation of the average sulfur content of 75 x 75 m blocks. In all cases, the models are the sum of a nugget effect and an isotropic spherical component (sill + range). The average standard error is the mean of the standard errors for all the 75 x 75 m blocks estimated by kriging in the layer. The relative standard error is the precision for a 68% precision level.

APPENDIX 1

For each layer, the intercept of an hole with the layer is characterized by :

- the hole number,
- the three coordinates of the top of the intercept (in the order: longitude, latitude and elevation),
- the average ash content (in percent),
- the average BTU,
- the average sulfur content (in percent),
- the average specific gravity,
- the true length of the intercept (in meters).

A zero for the sulfur content indicates that the value is not available or no measurement has been made.

25	6120.5	23786.4	921.1	54.24	4859.	0.43	1.60	33.66
37	6036.2	23469.1	733.7	48.71	5543.	0.60	1.56	42.75
44	5833.3	23469.1	815.7	45.04	6078.	0.68	1.54	37.02
106	5867.4	23782.1	852.5	37.26	7132.	0.72	1.48	32.89
135	5032.1	23658.7	822.8	42.60	6249.	0.64	1.52	33.58
136	5956.6	23946.3	861.4	44.72	6120.	0.94	1.53	33.48
139	6106.6	23171.9	691.6	46.76	5962.	0.69	1.55	60.33
141	5689.5	23491.2	913.3	48.34	5456.	0.43	1.57	20.29
144	6258.8	23487.9	907.3	37.24	7969.	0.64	1.47	44.23
145	5951.3	23487.3	793.4	43.47	6021.	0.71	1.52	41.31
149	5806.4	23197.8	811.4	55.97	4233.	0.35	1.62	57.10
155	5951.0	23792.7	834.5	46.28	6000.	0.51	1.55	33.79
203	6258.8	23606.3	914.5	38.53	7001.	0.69	1.49	40.46
236	5642.2	23184.5	957.1	61.78	3208.	0.53	1.67	63.88
242	5785.9	23643.3	943.8	41.33	6524.	1.06	1.51	35.80
247	5944.4	24110.8	901.6	48.68	5141.	0.82	1.57	23.87
250	5796.1	23346.2	812.0	49.77	5246.	0.00	1.57	46.03
251	6205.0	23353.7	790.6	56.82	4069.	0.00	1.62	40.01
255	5913.0	23207.9	733.5	52.18	4616.	0.00	1.59	51.51
262	6106.3	23639.6	853.0	48.30	5242.	0.00	1.55	34.56
267	6056.4	24092.4	966.7	41.42	6744.	0.85	1.50	31.31

Layer A1-1

12	5911.3	24443.8	721.2	37.81	7274.	0.66	1.54	14.14
14	6280.4	23770.2	732.7	46.52	6309.	0.70	1.62	24.04
17	6203.7	24108.0	847.1	35.50	6719.	0.36	1.52	22.82
18	5759.8	24444.1	883.7	58.55	3647.	0.42	1.73	10.05
25	6231.3	23736.4	728.1	34.06	7713.	0.63	1.50	22.70
37	6185.6	23469.1	525.1	44.11	6101.	0.88	1.60	18.15
38	6051.6	24393.2	740.0	33.12	7659.	0.56	1.50	28.91
44	5715.9	23469.1	612.5	57.17	4393.	0.61	1.72	16.91
46	5582.4	24131.4	963.8	48.85	5483.	1.06	1.65	6.46
106	5867.4	23782.1	630.1	41.68	6032.	0.76	1.57	37.08
120	5658.9	23787.5	753.1	55.45	4598.	0.69	1.70	31.69
124	5494.7	23793.3	977.5	73.03	1327.	0.17	1.88	25.73
128	6718.3	24403.8	891.6	29.31	8362.	0.91	1.46	43.21
134	5492.5	23177.3	825.4	64.37	3282.	0.68	1.79	28.89
135	5921.2	23664.8	545.4	38.40	7164.	0.80	1.54	28.32
136	5952.8	23948.0	645.1	37.62	7130.	0.84	1.53	31.49
138	5941.8	24700.8	854.7	32.49	7959.	0.75	1.49	19.43
141	5637.9	23493.2	698.7	56.35	4640.	0.81	1.72	19.14
147	6414.4	23638.9	439.8	36.43	7427.	0.70	1.52	59.09
153	6567.8	24712.0	858.5	22.50	9496.	0.54	1.40	15.57
157	6566.9	24856.7	846.8	22.28	9325.	0.46	1.40	7.95
161	5655.4	24408.2	939.4	53.05	4448.	0.99	1.69	7.48
168	6551.5	24404.5	848.9	28.58	8481.	0.47	1.45	46.31
172	6408.5	24250.5	860.1	29.95	7527.	0.33	1.47	9.32
181	6564.1	24556.3	854.4	31.51	7836.	0.41	1.48	23.01
183	6250.0	23943.6	835.2	52.99	4764.	0.47	1.68	54.90
190	5655.2	24254.8	954.7	37.43	6956.	1.42	1.53	26.96
191	5942.3	24233.4	716.4	35.25	7481.	0.68	1.52	22.27
193	5802.5	24558.2	946.8	37.65	7084.	0.71	1.53	24.06
196	5950.4	24563.7	810.8	32.71	7918.	0.56	1.49	21.99
199	6114.1	24258.4	720.5	30.71	8260.	0.69	1.47	26.61
200	5636.5	23938.5	933.6	55.29	4399.	0.65	1.69	31.38
201	6559.4	24256.1	819.3	24.06	9136.	0.51	1.41	39.00
205	5811.3	24245.4	808.2	37.19	7195.	0.69	1.53	22.96
227	6709.4	24558.5	814.6	25.21	8901.	0.73	1.42	35.89
233	6779.2	24556.2	794.4	26.72	8637.	0.41	1.44	18.90
235	6529.0	24096.6	858.6	21.12	9389.	0.98	1.38	29.91
240	5490.3	23651.0	918.1	77.61	1051.	0.23	1.92	12.13
242	5764.0	23633.0	622.9	52.34	5041.	0.67	1.67	35.01
247	5930.7	24106.1	699.1	33.03	7964.	0.00	1.50	25.93
250	5781.4	23363.8	544.6	59.02	4256.	0.00	1.74	23.23
257	5574.5	23228.7	757.2	68.18	2506.	0.00	1.82	10.00
259	5557.5	23483.1	760.6	53.95	4699.	0.00	1.69	13.90
261	5799.2	23959.4	714.1	41.90	6539.	0.00	1.57	38.80
262	6107.9	23634.0	546.2	39.02	7202.	0.00	1.55	33.73
263	6208.5	23943.0	751.3	34.90	7633.	0.00	1.51	30.05
266	5697.5	24096.6	874.5	46.83	5726.	0.84	1.62	19.87
267	6153.5	24092.4	704.9	39.03	7453.	0.00	1.55	22.80

Layer B1-2

17	6297.3	24104.8	753.5	14.93	9587.	0.24	1.33	11.28
18	5759.8	23444.1	718.5	19.51	9995.	0.16	1.37	35.54
19	6187.7	24505.6	816.9	21.60	9201.	0.21	1.39	33.80
21	5866.6	24867.2	824.3	23.10	9373.	0.24	1.40	13.16
22	6319.4	24553.0	840.2	16.56	10302.	0.15	1.34	13.89
23	5576.6	24131.4	767.1	18.28	9936.	0.20	1.36	9.06
25	6301.4	23786.4	606.7	16.84	10327.	0.28	1.35	23.00
37	6243.5	23469.1	424.8	15.53	10895.	0.32	1.34	9.11
38	6121.2	24393.2	619.4	13.90	11017.	0.23	1.32	12.03
39	6181.3	24877.8	791.6	16.69	10453.	0.32	1.35	12.94
43	5313.2	24076.5	907.8	26.71	8794.	0.15	1.44	25.26
44	5632.1	23469.1	467.3	22.38	9677.	0.23	1.40	18.07
46	5781.7	24131.4	618.5	17.51	10298.	0.44	1.35	17.43
4	6370.3	24401.4	772.0	17.87	10332.	0.30	1.36	21.21
50	5505.3	24376.1	844.9	19.10	9695.	0.18	1.37	18.30
51	5485.4	23461.1	635.2	24.17	9261.	0.24	1.41	13.61
53	5366.0	23797.9	853.4	29.98	8224.	0.20	1.47	20.23
106	5867.4	23782.1	448.0	15.45	10606.	0.34	1.33	11.84
107	6463.9	23958.6	620.1	21.61	9645.	0.49	1.39	17.40
120	5670.3	23786.4	542.8	37.65	7303.	0.41	1.54	13.14
124	5497.0	23704.2	769.3	22.09	9521.	0.16	1.40	8.26
127	5193.2	23798.9	921.2	21.64	9750.	0.26	1.39	16.32
132	5199.3	23492.8	922.4	23.87	9093.	0.39	1.41	12.20
133	6300.5	24096.3	749.8	18.87	10200.	0.37	1.37	27.97
135	5913.5	23669.1	416.5	19.10	10316.	0.22	1.37	20.01
136	5950.2	23949.2	497.4	15.40	10687.	0.30	1.33	19.50
137	5340.3	23493.9	840.8	21.85	9622.	0.27	1.39	12.15
138	5944.5	24697.2	729.8	16.20	10197.	0.54	1.34	16.58
142	6414.2	24711.3	792.8	18.65	10143.	0.33	1.37	16.48
151	6407.6	23942.7	879.1	18.20	10048.	0.37	1.36	38.60
152	6021.9	25020.5	899.5	17.00	10188.	0.55	1.35	18.30
153	6567.8	24712.0	732.4	17.06	10495.	0.38	1.35	17.85
156	6418.4	24857.1	837.1	21.87	9609.	0.37	1.39	10.43
157	6564.4	24855.8	743.2	23.28	9510.	0.46	1.41	23.80
158	5463.6	24091.3	831.9	24.11	9170.	0.20	1.42	10.85
160	6416.3	25014.1	822.1	18.45	9965.	0.27	1.36	23.07
161	5654.6	24404.9	738.8	19.44	9596.	0.21	1.37	10.87
162	6703.4	24708.1	752.8	33.35	7778.	0.46	1.50	29.76
163	6420.3	25167.1	829.4	19.96	9881.	0.46	1.38	23.33
105	6726.1	25009.7	797.0	23.76	9186.	0.34	1.41	23.76

Layer D1-3 (beginning)

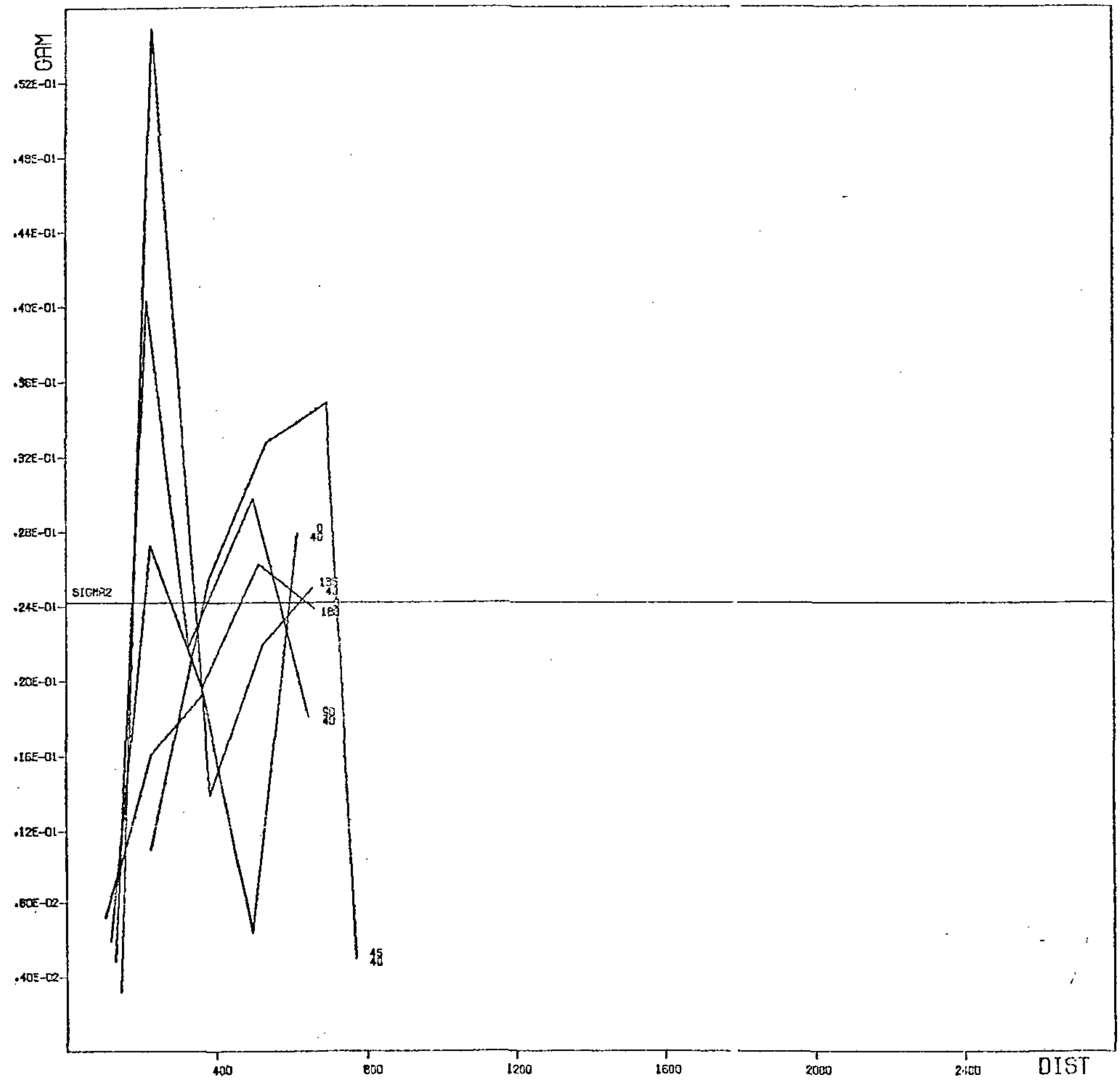
166	5349.8	24407.8	914.1	46.30	5875.	0.27	1.02	13.26
168	6548.0	24409.1	697.5	21.86	9725.	0.59	1.39	10.88
169	5186.4	23961.0	941.5	27.48	8590.	0.22	1.45	16.10
171	5186.7	23636.0	931.8	24.17	8910.	0.29	1.41	16.82
172	6404.3	24252.1	743.2	21.59	9739.	0.34	1.39	22.30
176	5191.1	23339.6	949.3	34.29	7438.	0.26	1.51	3.69
179	5334.9	23176.8	795.7	36.23	7499.	0.34	1.53	11.40
180	6411.1	23790.3	760.5	23.43	9227.	0.39	1.40	19.93
181	6560.1	24556.3	710.7	21.00	9797.	0.31	1.39	16.88
187	6254.8	24249.0	729.7	17.28	10366.	0.29	1.35	18.84
188	5343.2	24249.2	910.7	23.35	9070.	0.21	1.41	17.14
190	5655.2	24254.8	734.3	16.15	10204.	0.26	1.34	14.47
191	5937.3	24223.3	576.5	15.75	10615.	0.23	1.34	11.60
192	6284.3	24715.7	852.8	20.69	9699.	0.62	1.38	12.12
193	5797.1	24560.9	750.5	13.79	10836.	0.21	1.32	16.96
194	5994.5	25120.8	851.7	15.69	10438.	0.32	1.34	18.60
196	5947.4	24565.9	585.0	15.25	10653.	0.21	1.33	17.12
197	6114.2	25020.2	812.3	37.66	7076.	0.40	1.53	6.81
198	6121.4	24560.9	673.8	14.52	10744.	0.29	1.33	21.33
199	6111.2	24255.6	574.6	15.99	10482.	0.22	1.34	11.10
200	5640.5	23929.3	682.1	19.03	9623.	0.21	1.37	11.90
201	6554.9	24273.3	649.6	23.29	9688.	0.46	1.40	24.40
202	5488.1	24254.6	839.8	21.64	9563.	0.16	1.39	11.25
204	5660.2	24554.2	843.9	15.65	10430.	0.25	1.34	17.02
205	5808.6	24240.8	629.2	18.77	10110.	0.27	1.36	10.95
208	5487.5	23939.7	765.9	19.60	9781.	0.16	1.37	16.41
817	6100.2	24860.8	769.9	16.70	10276.	0.32	1.35	16.72
219	6870.6	24861.1	775.1	31.30	8278.	0.39	1.47	17.79
222	6558.8	25176.0	829.1	18.42	10120.	0.27	1.36	36.25
227	6708.5	24560.1	650.7	19.45	9949.	0.22	1.37	16.79
235	6527.5	24096.4	696.1	20.77	9756.	0.30	1.38	25.56
240	5490.3	23651.0	770.8	19.03	9850.	0.20	1.37	9.43
247	5921.4	24103.0	562.8	17.31	10396.	0.00	1.35	11.75
248	5335.7	23629.1	839.6	21.41	9004.	0.00	1.39	11.34
259	5499.1	23484.9	637.2	24.54	9104.	0.00	1.42	12.62
263	6272.0	23943.9	629.3	17.42	10364.	0.00	1.35	27.81
265	6210.4	24405.1	716.6	16.22	10366.	0.23	1.34	15.27
266	5634.9	24096.6	702.6	17.89	9971.	0.20	1.36	16.69
267	6214.7	24092.4	577.7	15.87	10763.	0.00	1.34	17.84

Layer D1-3 (end)

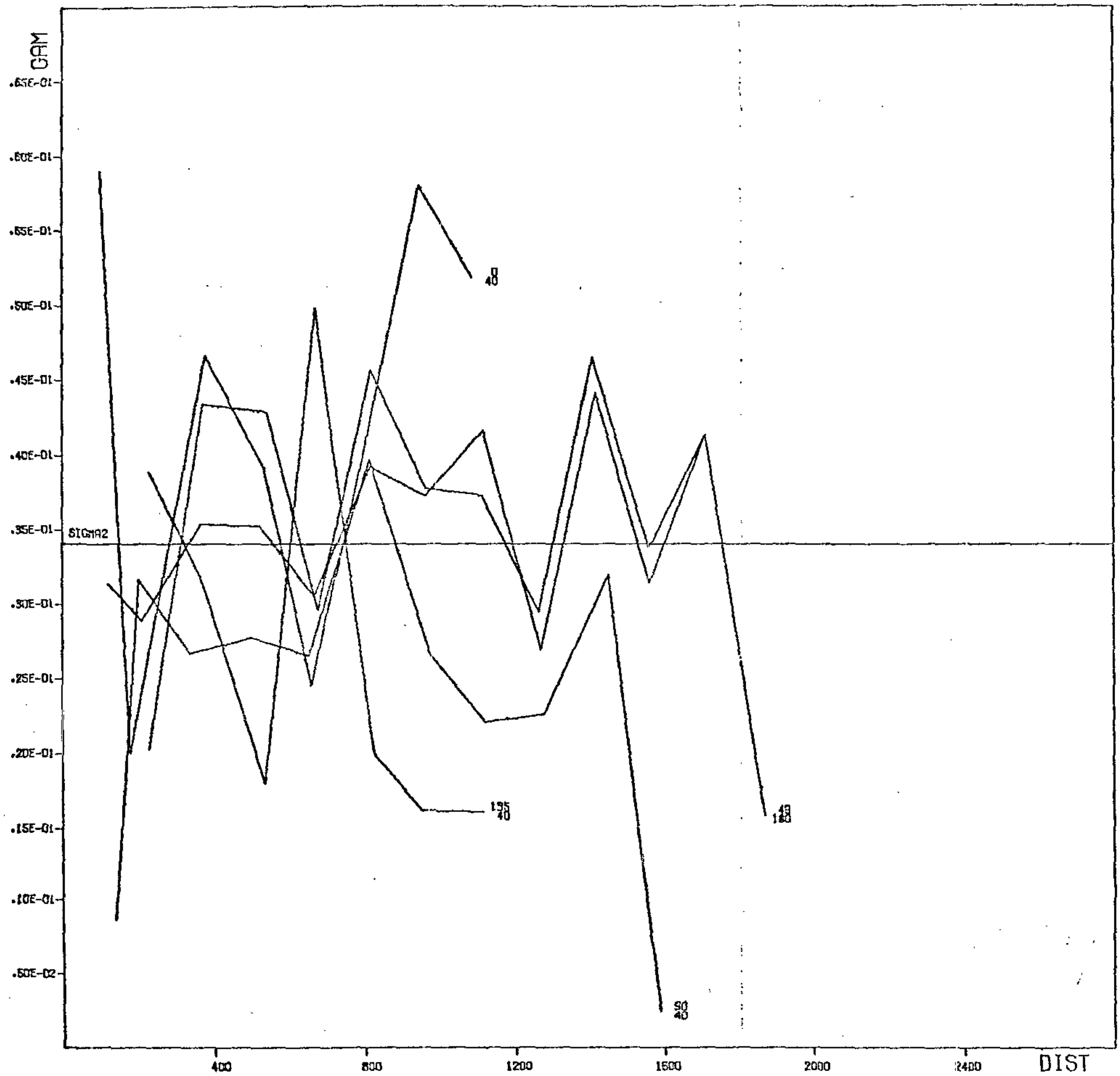
APPENDIX 2

Experimental variograms of BTU in the layers

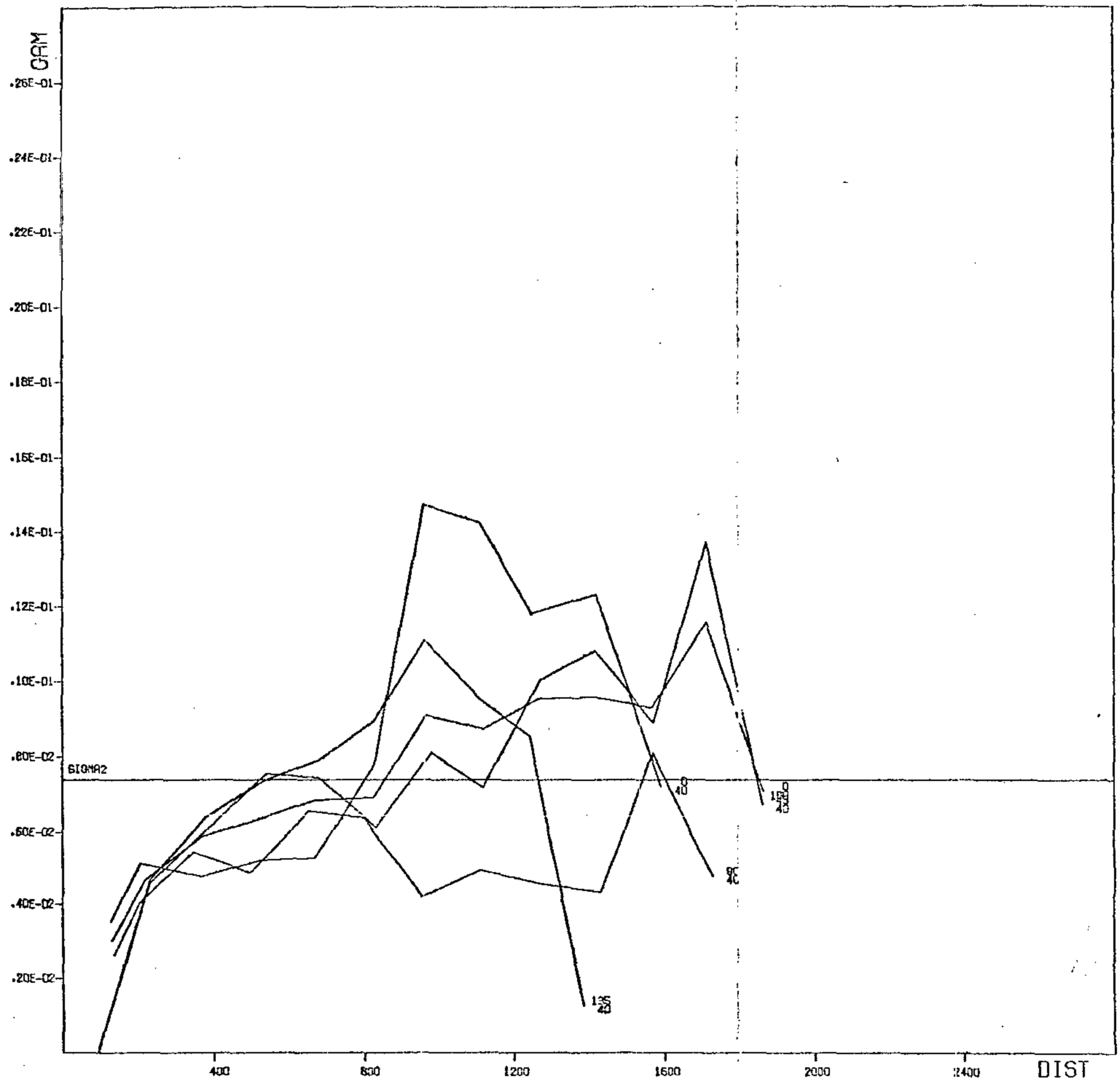
The variograms have been computed along the four principal directions of the horizontal plane : N-S or 90, NE-SW or 45, E-W or 0, NW-SW or -45. The MAREC2 program (See David, p. 149) has been used with an angular regularization PSI=45^{o} and an interval for distances STEP=150m. The average variogram (PSI=180^{o} same STEP) has also been determined (noted 0-180 on the diagrams). In the computation, the intercepts are localized by the three coordinates of their top. Thus the distance is the true distance between the intercepts and not the projected distance in the horizontal plane. On the diagram, the horizontal line with SIGMA2 indicates the amplitude of the experimental variance of the sample values.



VARIOGRAMS OF SULFUR IN ZONE A11



VARIOGRAMS OF SULFUR IN ZONE B12

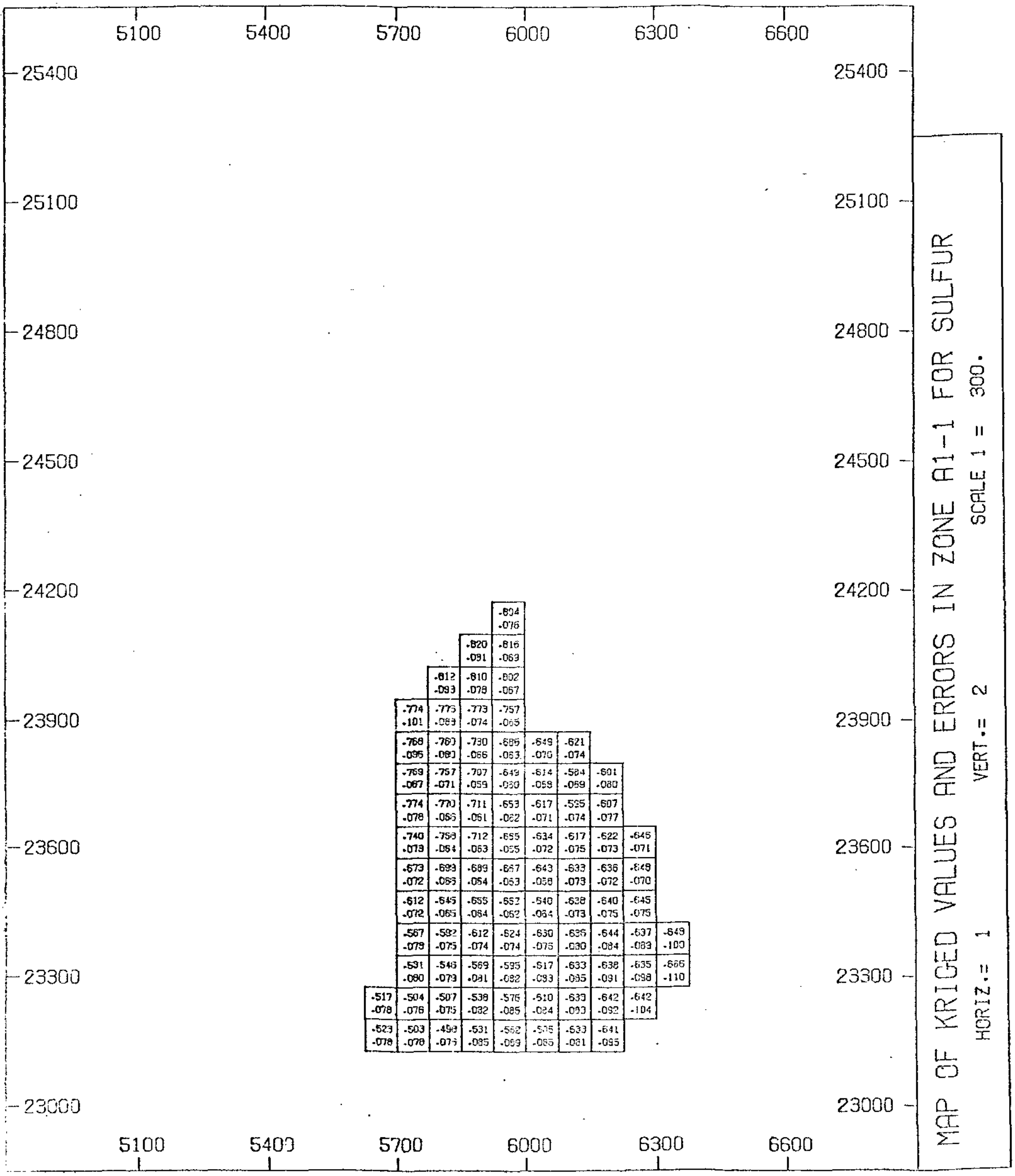


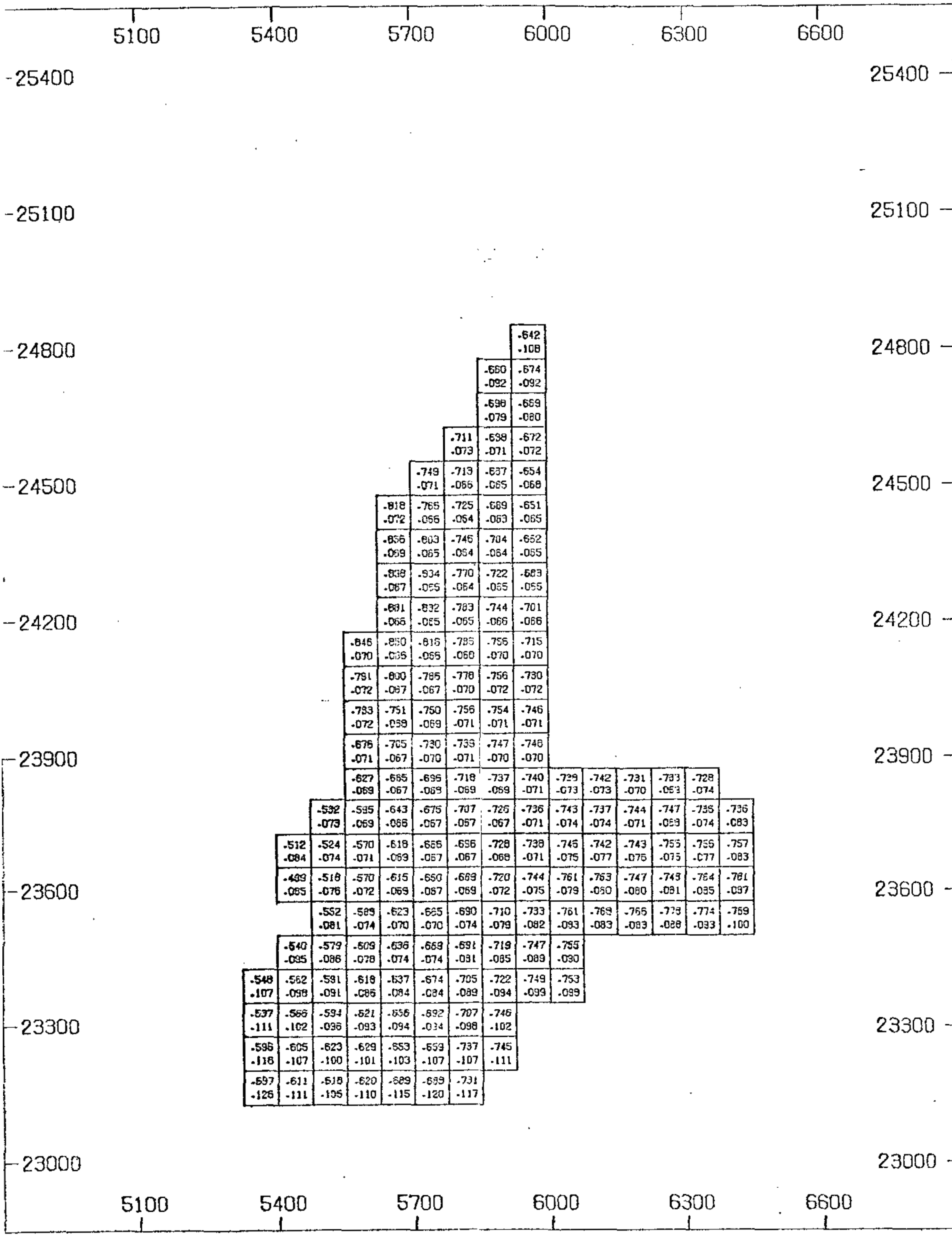
VARIOGRAMS OF SULFUR IN ZONE D13

APPENDIX 3

Maps of the estimated 75 x 75 blocks in the three layers

All the following maps have been obtained automatically, but only blocks within the limits of the layers are shown. In each block the estimated sulfur content and the standard error of estimation are shown (both in percent).

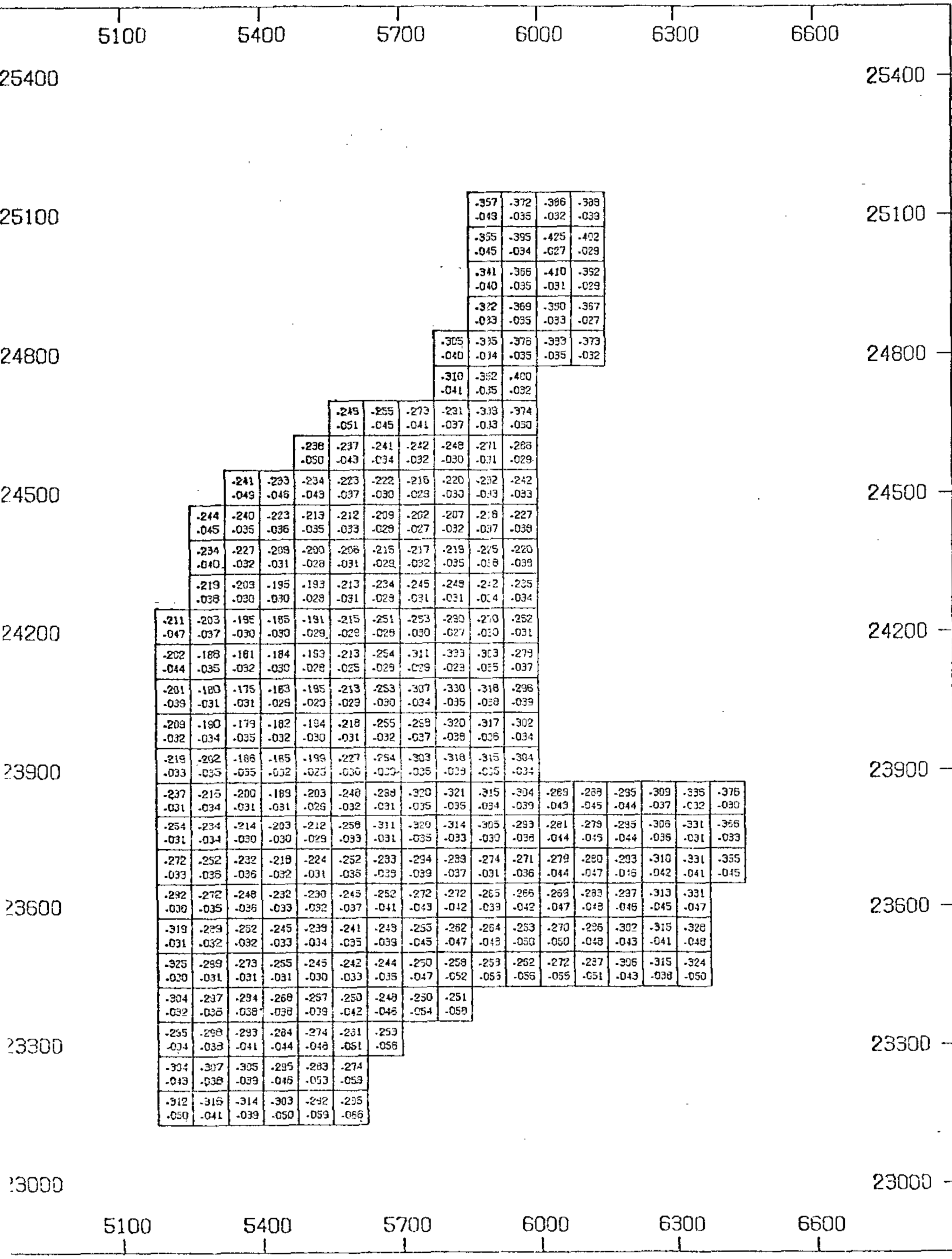

MAP OF KRIGED VALUES AND ERRORS IN ZONE A1-1 FOR SULFUR
HORIZ.= 1 VERT.= 2 SCALE 1 = 300.
5100 5400 5700 6000 6300 6600
25400
25100
24800
24500
24200
23900
23600
23300
23000
.804 .076
.820 .091 .816 .069
.812 .093 .810 .078 .802 .067
.774 .101 .775 .089 .773 .074 .757 .065
.768 .096 .760 .080 .730 .066 .686 .063 .649 .070 .621 .074
.769 .067 .757 .071 .707 .059 .649 .060 .614 .059 .584 .059 .601 .080
.774 .078 .770 .066 .711 .061 .653 .062 .617 .071 .595 .074 .607 .077
.740 .079 .758 .064 .712 .063 .655 .055 .634 .072 .617 .075 .622 .073 .645 .071
.673 .072 .699 .066 .689 .054 .657 .053 .643 .058 .633 .073 .636 .072 .649 .070
.612 .072 .645 .065 .655 .064 .652 .062 .540 .064 .638 .073 .640 .075 .645 .075
.567 .079 .592 .075 .612 .074 .624 .074 .630 .076 .636 .080 .644 .084 .637 .083 .649 .100
.591 .080 .546 .079 .569 .081 .595 .082 .617 .093 .633 .095 .638 .091 .635 .098 .666 .110
.517 .078 .504 .076 .507 .075 .538 .082 .576 .085 .610 .084 .633 .093 .642 .092 .642 .104
.523 .078 .503 .078 .458 .076 .531 .085 .562 .069 .575 .065 .633 .081 .641 .095



MAP OF KRIGED VALUES AND ERRORS IN ZONE B1-2 FOR SULFUR

SCALE 1" = 300. m

HORIZ.= 1 VERT.= 2



MAP OF KRIGED VALUES AND ERRORS IN ZONE D1-3 FOR SULFUR

HORIZ.= 1 VERT.= 2 SCALE 1" = 300.m