COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1962/37

NOTES ON THE SURVEYING OF DRILL HOLES

by

J. Daly

RECORD No. 1962/37

NOTES ON THE SURVEYING OF DRILL HOLES

by

J. Daly

CONTENTS

ILLUSTRATIONS

SUMMARY

In drill hole surveying the azimuth and depression angles of the hole are measured at a series of points. To calculate the course of the hole from these measurements it is often assumed that the measurements are representative of the complete interval separating the half-way points between measurements.

This Record describes a method of calculation in which the continuous variation of the course of the hole is taken into account. It gives a practical example of the application of this method, and compares the results with those obtained by the simpler method. Notes are given on the accuracy of surveys.

INTRODUCTION

It is of the utmost importance to be able to determine the precise course of a drill hole aimed at a deep target. Various methods of survey are used to obtain the necessary information. The practical difficulties are considerable, and it cannot be claimed that there is yet any very accurate method, particularly in holes of small diameter. However, the purpose of the present Record is not to consider the reliability of the survey data, but to discuss methods of using these data to plot the course of the hole.

All survey methods involve the use of instruments that measure the azimuth and depression of the hole at various positions along its length. If these quantities are uniform over the course of the hole, it may be assumed that the hole is straight, and plotting its course involves no difficulties. However, this is in general not the case. The course of the hole is in general a twisted curve, and the measured azimuth and depression enable derivatives in various directions to be calculated. The mathematical problem involved is to plot the course of a twisted curve, given all derivatives at a series of points measured along the arc length. From the physical conditions, it may be assumed that the curve is continuous and differentiable to any order required.

In order to plot the course of the hole from the calculated values of the derivatives, an integration is necessary. A method in general use is to assume that the measured values of azimuth and depression at any point apply to the course of the hole for half the length to the next measuring point, so that the hole changes course sharply half way between measuring points. The accuracy of this method is discussed later in this Record; it is shown that the method involves replacing an integral by a sum of rectangular areas of finite width, and may thus be considered as an approximation of zero order.

It should be mentioned that there is no reason to suppose that the theory to be presented is original. Only elementary mathematics is involved, and it is certain that methods such as that proposed have long been used by organisations interested in deep drilling. However, so far as is known there has been no publication on the subject.

2. MATHEMATICAL THEORY

Suppose that the course of the hole is referred to a set of rectangular axes, with origin at the collar of the hole. It is most convenient to use axes in the direction of the survey grid. In what follows, it is assumed that the X-axis is parallel to the grid direction from which azimuth is most conveniently measured, the Y-axis at right angles to X, and the Z-axis vertically downwards. A suitable sign convention must also be chosen.

With the usual notation for arc length, the equation to the course of the hole is

$$s = f\,(x,y,z)$$

where f is a continuous function with derivatives of any order required.

Then

$$\left.\begin{aligned} ds^2 &= dx^2 + dy^2 + dz^2 \\ ds/dx &= \left[1 + (dy/dx)^2 + (dz/dx)^2\right]^{\frac{1}{2}} \\ dx/ds &= \left[1 + (dy/dx)^2 + (dz/dx)^2\right]^{-\frac{1}{2}} \\ \text{Similary} & \\ dy/ds &= \left[1 + (dx/dy)^2 + (dz/dy)^2\right]^{-\frac{1}{2}} \\ dz/ds &= \left[1 + (dx/dz)^2 + (dy/dz)^2\right]^{-\frac{1}{2}} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (1)$$

The quantities measured are azimuth (ϕ) and depression (θ). ϕ is measured from the magnetic meridian. For the purpose of the calculations, however, it is required that ϕ be given with reference to the X-axis. This value is obtained by adding to the measured azimuth the angle between the axis and the meridian, with due regard to sign. θ is measured from the horizontal plane. These values are used to calculate the derivatives (dy/dx etc.) from the following relations :

$$\left.\begin{aligned} dy/dx &= \tan\phi & \qquad dx/dy &= 1/(dy/dx) \\ (dx \sec\phi)/dz &= \tan(\pi/2 - \theta) & & \\ \text{Hence} & & & \\ dx/dz &= \cot\theta\cos\phi & \qquad dz/dx &= 1/(dx/dz) \\ dy/dz &= (dy/dx)(dx/dz) = \cot\theta\sin\phi & & \\ & & \qquad dz/dy &= 1/(dy/dz) \end{aligned}\right\} \ldots (2)$$

When dx/ds etc. are known, the coordinates (x, y, z) of the points are given by

$$\left.\begin{aligned} x &= \int_0^s (dx/ds)\,ds \\ y &= \int_0^s (dy/ds)\,ds \\ z &= \int_0^s (dz/ds)\,ds \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (3)$$

The process of plotting the course of the hole involves the following operations:

(a) From the measured values of θ and ϕ, calculate the six derivatives dy/dx etc. from Equations (2).

(b) From the calculated values of these derivatives, calculate the three derivatives dx/ds etc. from Equations (1)

(c) Plot dx/ds etc. against s.

(d) Evaluate x, y, z at the various measuring points by graphical integration of these curves.

It should be noted that Equations (1) give the values of dx/ds etc. with an ambiguity of sign. The appropriate signs are most easily worked out by examining the behaviour of the measured azimuth and depression as the depth increases. In general, this can be done without serious difficulty.

3. AN EXAMPLE OF THE PROCESS

As an example of the method of procedure and of the difference between the results and those obtained using the elementary method, the process has been applied to the West Peko drill hole 2A, at Tennant Creek. The survey data for this hole have been supplied by Peko Mines N.L.

The hole was collared at 6475W, 765N on the survey grid, the azimuth of which is 1 degree east of magnetic north. The azimuth of the hole is approximately 180 degrees. It is convenient to take the X-axis in the direction of the grid azimuth, positive to the south, and the Y-axis positive to the west. From an examination of the survey data, it appears that the depression of the hole varies almost continuously from 70 degrees to 36 degrees. It is apparent therefore that both x and z increase continuously with s, so that dx/ds and dz/ds are both positive. The azimuth varies from west to east of grid south, so that dy/ds has the same sign as dy/dx.

The calculations for this hole are shown on Tables 1 and 2 and Plate 1. Table 1 shows the first stage up to the calculation of the derivatives dx/ds etc. The second and third columns show the measured angles, and the next four the trigonometrical functions of these angles required for the calculations. The next columns contain the derivatives dy/dx etc., calculated to slide-rule accuracy using Equations (2). The last twelve columns show the calculation of the derivatives dx/ds etc., using Equations (1). All this calculation may be performed easily, using the early portions of Barlow's Tables which include a table of $n^{-\frac{1}{2}}$ against n.

Plate 1 shows the graphs dx/ds, dy/ds, dz/ds against s. Table 2 shows the remainder of the calculation, including the values of $\int_0^s (dx/ds)ds$ etc. obtained by graphical integration from Plate 1 and their reduction to grid coordinates, using the coordinates of the collar of the hole. The whole process is performed very expeditiously.

4. A NOTE ON SMOOTHING

The curves on Plate 1 show many small irregularities. The propriety of smoothing these out before integration is a matter of some theoretical interest, although in practice it is not likely to affect the accuracy of the final result. As mentioned earlier, the measurements are subject to considerable practical difficulties which limit the inherent accuracy of the final readings; therefore random errors may be expected. However, it cannot be assumed that all minor irregularities are due to instrumental errors. Conditions in the ground are also subject to sudden and irregular variations, which could cause minor irregularities in the curves. A more refined analysis might provide a basis for rejecting certain readings. Such analysis would lead to the conclusion that second derivatives of the type d^2x/ds^2 could not exceed a certain maximum, depending on the elastic properties of the drill rods. A reading that implied a value of any such second derivative exceeding this maximum could safely be rejected. Without such information there appears to be no valid basis for smoothing the curves.

5. THE ACCURACY OF THE METHODS

The results of the survey have been calculated by Peko Mines N.L., using the elementary method described earlier. It is not possible to compare these results with those shown on Table 2 in detail, as the elementary method gives coordinates at points half way between the survey points, while the more refined method gives coordinates at the survey points. A measure of the agreement of the two methods is provided by the calculated coordinates of the bottom of the hole. The results are as follows:

Table 2.	393.5 S	6438.7 W	Depth 1843.9
Peko Mines N.L.	397.95 S	6439.95 W	Depth 1845.17

It should be noted that the accuracy of these figures as shown is quite illusory. It is desirable to make the calculations to a greater degree of accuracy than is warranted, in order to avoid the possibility of the accumulation of rounding-off errors, which in an integration process such as this might be considerable. However, considering the overall accuracy of the measurements, an accuracy to the nearest foot is probably greater than can be expected, and the decimal places shown are meaningless.

The largest discrepancy is one of four feet in the N-S direction which in the present case is quite insignificant. Another possibility of comparison is in the Y-coordinate. The greatest excursion of the hole to the west is shown on Table 2 as 42.8ft at s=950, and by Peko Mines N.L. as 44.6 ft at about the same point. It appears, therefore, that in this hole the accuracy of the elementary method is satisfactory.

As compared with the method described, the elementary method has two possible sources of error:

(a) the derivative curves are replaced by series of horizontal lines, each centred at a measuring point, and the integral under the curve is replaced by the sum of the rectangular areas under these lines. As long as the curve is monotonically increasing or decreasing, the horizontal line will cross the curve at the measuring point, and the error in taking the rectangular area as the integral will balance out, to the first order. The only occasion on which this approximation to the integral will involve a completely uncompensated error, is when the measuring point coincides with a turning point of the curve.

(b) the derivatives in the various directions are considered independently, neglecting the fact that each derivative is affected by derivatives in other directions. This is unimportant in the present case, as variations in azimuth are much less than variations in depression. A more serious error would be involved in a hole in which variations in azimuth were about the same size as those in depression.

It appears that no advantage would be obtained by more refined methods of handling the observed results. What is required is a measure of the general accuracy of the whole surveying process. This would involve an investigation taking account of the accuracy of the surveying method and the elastic conditions of the drilling equipment; it would not lead to a more accurate method of calculation, but would make it possible to specify a region, around the calculated position of the survey point, in which the probability of the result exceeded some specified value.

6. ACKNOWLEDGEMENT

It is desired to acknowledge the assistance of Dr W.D. Parkinson with regard to some of the mathematical points discussed.

TABLE I

(1) S	(2) $\theta°$	(3) $\phi°$	(4) $\sin \phi$	(5) $\cos \phi$	(6) $\tan \phi = dy/dx$	(7) $\cot \theta$	(8) dx/dy $1 \div (6)$	(9) dx/dz $(7).(5)$	(10) dz/dx $1 \div (9)$	(11) dy/dz $(7).(4)$	(12) dz/dy $1 \div (11)$	(13) $(dy/dx)^2$	(14) $(dz/dx)^2$	(15) $\sum$ $1+(13)+(14)$	(16) dx/ds $(15)^{-\frac{1}{2}}$	(17) $(dx/dy)^2$	(18) $(dz/dy)^2$	(19) $\sum$ $1+(17)+(18)$	(20) dy/ds $(19)^{-\frac{1}{2}}$	(21) $(dx/dz)^2$	(22) $(dy/dz)^2$	(23) $\sum$ $1+(21)+(22)$	(24) dz/ds $(23)^{-\frac{1}{2}}$
0	70	8.5	0.148	0.989	0.149	0.364	6.69	0.360	2.78	0.054	18.5	0.022	7.72	8.74	0.338	44.77	343	389	0.051	0.130	0.003	1.133	0.940
66	70	8.5	0.148	0.989	0.149	0.364	6.69	0.360	2.78	0.054	18.5	0.022	7.72	8.74	0.338	44.77	343	389	0.051	0.130	0.003	1.133	0.940
100		10.5	0.182	0.983	0.185	0.369	5.40	0.363	2.76	0.067	14.9	0.034	7.59	8.62	0.341	29.12	223	253	0.063	0.132	0.004	1.136	0.938
160	70	8	0.139	0.990	0.141	0.364	7.12	0.360	2.78	0.051	19.6	0.020	7.72	8.74	0.338	50.62	384	436	0.048	0.130	0.003	1.133	0.939
200	69.5	10.25	0.178	0.984	0.181	0.374	5.53	0.368	2.72	0.067	14.9	0.033	7.38	8.41	0.345	30.50	223	255	0.063	0.135	0.004	1.139	0.936
280	70.25	13.5	0.233	0.972	0.240	0.359	4.16	0.349	2.87	0.083	12.1	0.058	8.21	9.27	0.331	17.35	145	163	0.078	0.122	0.007	1.129	0.940
340	69	11.25	0.195	0.981	0.199	0.384	5.03	0.377	2.65	0.075	13.3	0.040	7.04	8.08	0.352	25.27	177	203	0.070	0.142	0.006	1.148	0.933
400	70	9.67	0.169	0.986	0.172	0.364	5.87	0.359	2.79	0.062	16.1	0.030	7.76	8.79	0.337	34.08	260	295	0.058	0.129	0.004	1.133	0.939
500	69	10.5	0.182	0.983	0.185	0.384	5.40	0.378	2.65	0.070	14.3	0.034	7.00	8.03	0.353	29.12	204	234	0.065	0.143	0.005	1.148	0.933
540	67.5	7.25	0.126	0.992	0.127	0.414	7.87	0.411	2.43	0.052	19.2	0.016	5.92	6.94	0.380	62.0	370	433	0.048	0.169	0.003	1.172	0.924
560	67.5	8.5	0.148	0.989	0.149	0.414	6.69	0.409	2.45	0.061	16.4	0.022	5.98	7.00	0.378	44.77	268	313	0.056	0.167	0.004	1.171	0.924
580	67	9	0.156	0.988	0.158	0.424	6.31	0.419	2.39	0.066	15.2	0.025	5.70	6.72	0.386	39.87	229	270	0.061	0.176	0.004	1.181	0.920
600	67	8	0.139	0.990	0.140	0.424	7.12	0.420	2.38	0.059	17.0	0.020	5.67	6.69	0.386	50.61	287	339	0.054	0.176	0.003	1.179	0.921
619	66.5	5	0.087	0.996	0.087	0.435	11.43	0.433	2.31	0.038	26.3	0.008	5.33	6.34	0.397	130.6	692	823	0.034	0.187	0.001	1.180	0.917
640	65.5	6	0.105	0.995	0.105	0.456	9.51	0.454	2.20	0.047	21.3	0.011	4.85	5.86	0.413	90.51	453	544	0.043	0.206	0.002	1.208	0.909
660	65	3.5	0.061	0.998	0.061	0.466	16.35	0.465	2.15	0.028	35.7	0.004	4.63	5.63	0.421	268.92	1275	1545	0.025	0.216	0.001	1.217	0.904
680	66	5	0.087	0.996	0.087	0.445	11.43	0.443	2.26	0.039	25.6	0.008	5.09	6.10	0.405	130.64	657	789	0.036	0.196	0.002	1.198	0.913
700	65	5.5	0.096	0.995	0.096	0.466	10.39	0.464	2.16	0.045	22.2	0.009	4.64	5.65	0.421	107.84	494	603	0.041	0.215	0.002	1.217	0.904
750	65	4.5	0.078	0.997	0.079	0.466	12.71	0.465	2.15	0.036	27.8	0.006	4.63	5.63	0.421	161.44	772	934	0.032	0.216	0.001	1.217	0.904
800	64.5	-1	-0.017	1.000	0.017	0.477	-57.29	0.477	2.10	-0.008	-125.0	0.000	4.39	5.39	0.431	3.28×10^4	1.6×10^4	4.9×10^4	-0.007	0.227	-	1.227	0.902
845	63	-0.5	-0.009	1.000	-0.009	0.510	-114.59	0.510	1.96	-0.005	-200.0	0.000	3.85	4.85	0.454	1.3×10^4	4×10^4	5.3×10^4	-0.004	0.260	-	1.260	0.891
900	63.25	3	0.052	0.999	0.052	0.504	19.08	0.503	1.99	0.026	38.5	0.003	3.95	4.96	0.449	364	676	1041	0.030	0.253	0.001	1.254	0.893
950	62	1.75	0.031	1.000	0.031	0.532	32.73	0.532	1.88	0.016	62.5	0.001	3.53	4.54	0.470	1071.00	3906	4978	0.012	0.283	-	1.283	0.883
1000	61.25	-2.25	-0.039	0.999	-0.039	0.549	-25.45	0.548	1.83	-0.021	-47.6	0.002	3.33	4.33	0.480	647.8	2268	2917	-0.018	0.300	-	1.300	0.877
1050	60.25	-1	-0.017	1.000	-0.017	0.572	-57.29	0.572	1.75	-0.010	-100.0	0.000	3.06	4.06	0.497	3.28×10^3	10^4	1.35×10^4	-0.009	0.327	-	1.327	0.868
1070	61	(-0.013)				0.554	(-85)	(0.554)	1.81	-0.007	142.9	0.000	3.26	4.26	0.485	7225	2×10^4	2.7×10^4	-0.006	0.307	-	1.307	0.874
1090	60.5	-0.5	-0.009	1.000	-0.009	0.566	-114.59	0.566	1.77	-0.005	-200.0	0.000	3.12	4.12	0.492	1.3×10^4	4×10^4	5.3×10^4	-0.004	0.320	-	1.320	0.870
1120	60.5	-1.5	-0.026	1.000	-0.026	0.566	-38.19	0.566	1.77	-0.015	-66.7	0.001	3.12	4.12	0.492	1458	4441	5900	-0.011	0.320	-	1.320	0.879
1150	60	-2	-0.035	0.999	-0.035	0.577	-28.64	0.576	1.74	-0.020	-50.0	0.001	3.01	4.02	0.499	820	2.5×10^3	3316	-0.017	0.332	-	1.332	0.866
1200	60	-1	-0.017	1.000	-0.017	0.577	-57.29	0.577	1.73	-0.010	-100.0	0.000	3.00	4.00	0.500	3.28×10^3	1.0×10^4	1.35×10^4	-0.001	0.333	-	1.333	0.866
1272	58.3	-11.5	-0.199	0.980	-0.203	0.618	-4.91	0.606	1.67	-0.123	-8.1	0.041	2.78	3.82	0.512	24.13	66	91	-0.104	0.367	0.015	1.382	0.852
1310	59	-7.5	-0.131	0.991	-0.132	0.601	-7.60	0.596	1.68	-0.079	-12.7	0.017	2.82	3.83	0.511	57.7	160	219	-0.068	0.355	0.006	1.361	0.857
1355	58	(-0.148)				0.625	(-6.78)	0.620	1.61	-0.092	-10.9	0.022	2.60	3.62	0.525	44.6	116	162	-0.079	0.384	0.008	1.392	0.848
1400	56.25	-9.5	-0.165	0.986	-0.167	0.668	-5.98	0.660	1.52	-0.110	-9.1	0.028	2.30	3.32	0.548	35.7	83	118	-0.092	0.436	0.012	1.448	0.831
1450	57.5	(-0.165)				0.637	(-5.98)	0.628	1.59	-0.105	-9.5	0.028	2.53	3.56	0.530	35.7	91	126	-0.089	0.394	0.011	1.405	0.844
1460	56.25	-9.5	-0.165	0.986	-0.167	0.668	-5.98	0.660	1.52	-0.110	-9.1	0.028	2.30	3.32	0.548	35.7	83	118	-0.092	0.436	0.012	1.448	0.831
1470	57.25		(-0.151)			0.643	(-6.7)	0.635	1.58	-0.097	-10.3	0.024	2.48	3.51	0.534	44.9	106	152	-0.081	0.403	0.009	1.412	0.842
1505	57		(-0.136)			0.649	(-7.4)	0.642	1.56	-0.088	-11.4	0.019	2.43	3.45	0.539	54.8	129	185	-0.074	0.412	0.008	1.420	0.839
1540	55.5	-7	-0.122	0.993	-0.123	0.687	-8.14	0.682	1.47	-0.084	-11.9	0.015	2.16	3.18	0.561	66.3	142	308	-0.057	0.465	0.007	1.472	0.825
1600	51.25	-5	-0.087	0.996	-0.087	0.803	-11.43	0.800	1.25	-0.070	-14.3	0.008	1.56	2.57	0.624	131	204	336	-0.054	0.640	0.005	1.645	0.779
1620	51.5		(-0.092)			0.795	(-10.9)	0.791	1.26	-0.073	-13.7	0.008	1.60	2.61	0.619	119	188	308	-0.057	0.626	0.005	1.631	0.782
1680	46.5	-5.5	-0.096	0.995	-0.096	0.949	-10.39	0.944	1.06	-0.091	-11.0	0.009	1.12	2.13	0.685	108	121	230	-0.065	0.891	0.008	1.899	0.726
1710	46.75		(-0.096)			0.941	(-10.4)	0.936	1.07	-0.091	-11.0	0.009	1.14	2.15	0.682	108	121	230	-0.066	0.876	0.008	1.884	0.728
1800	42.25	-5.5	-0.096	0.995	-0.096	1.101	-10.39	1.096	0.99	-0.106	-9.4	0.009	0.99	2.00	0.707	108	89	198	-0.071	1.200	0.011	2.211	0.673
1890	41.5	-3	-0.052	0.999	-0.052	1.130	-19.08	1.129	0.89	-0.089	-17.0	0.003	0.79	1.79	0.748	364.0	287	652	-0.040	1.275	0.003	2.278	0.663
2000	39.5	-5	-0.087	0.996	-0.087	1.213	-11.43	1.208	0.83	-0.106	-9.4	0.008	0.69	1.69	0.768	131	89	221	-0.067	1.459	0.011	2.470	0.636
2100	37.75	-8.75	-0.152	0.988	-0.154	1.292	-6.49	1.276	0.78	-0.196	-5.1	0.024	0.61	1.63	0.782	42.1	26	69	-0.120	1.628	0.038	2.666	0.612
2198	35.25	-7.5	-0.131	0.991	-0.131	1.415	-7.60	1.400	0.71	-0.185	-5.4	0.017	0.51	1.53	0.809	57.5	29	88	-0.106	1.960	0.034	2.994	0.578
2227																							

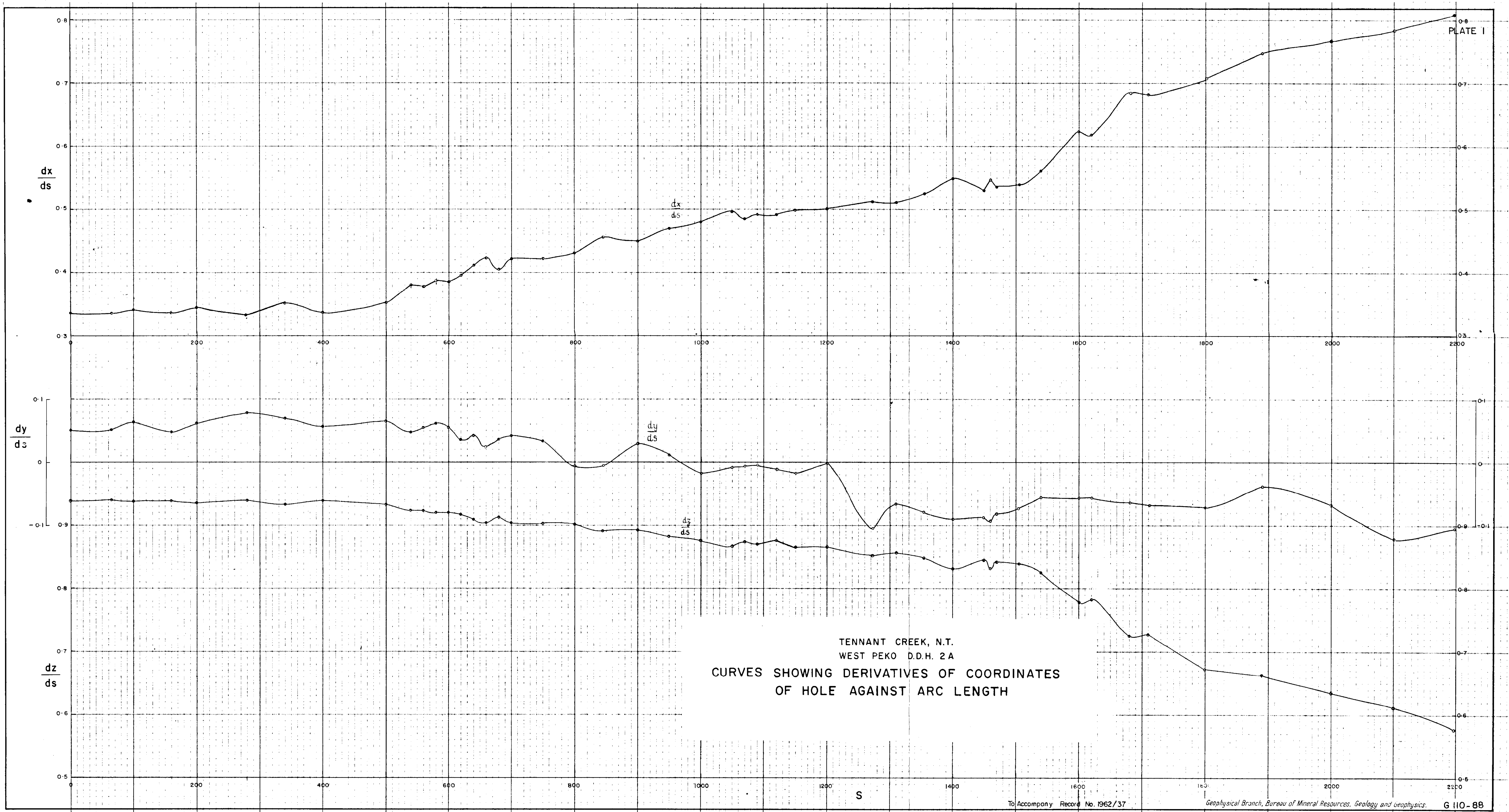
To Accompany Record No.1962/37

TABLE 2

S	$\int_0^s \frac{dx}{ds}\, ds$	$\int_0^s \frac{dy}{ds}\, ds$	$\int_0^s \frac{dz}{ds}\, ds$	N	W	Depth
0	0	0	0	765.0N	6475.0	0
66	22.3	3.4	62.0	742.7	6478.4	62.0
100	33.9	5.3	94.0	731.1	6480.3	94.0
160	54.3	8.7	150.2	710.7	6483.7	150.2
200	67.9	10.9	187.8	697.1	6485.9	187.8
280	95.0	16.5	262.8	670.0	6491.5	262.8
340	155.5	20.9	319.0	609.5	6495.9	319.0
400	136.1	24.8	375.1	628.9	6499.8	375.1
500	170.6	31.0	468.7	594.4	6506.0	468.7
540	185.2	33.2	505.8	579.8	6508.2	505.8
560	192.9	34.3	524.3	572.1	6509.3	524.3
580	200.5	35.4	542.8	564.5	6510.4	542.8
600	208.2	36.6	561.2	556.8	6511.6	561.2
619	215.7	37.4	578.6	549.3	6512.4	578.6
640	224.2	38.2	597.8	540.8	6513.2	597.8
660	232.5	38.9	615.9	532.5	6513.9	615.9
680	240.8	39.5	634.1	524.2	6514.5	634.1
700	249.0	40.3	652.2	516.0	6515.3	652.2
750	270.1	42.1	697.4	494.9	6517.1	697.4
800	291.4	41.1	742.6	473.6	6516.1	742.6
845	311.3	40.8	782.9	453.7	6515.8	782.9
900	336.1	41.8	832.0	428.9	6516.8	832.0
950	359.1	42.8	876.4	405.9	6517.8	876.4
1000	382.9	42.1	920.4	382.1	6517.1	920.4
1050	407.3	41.4	964.0	357.7	6516.4	964.0
1070	417.1	41.2	981.4	347.9	6516.2	981.4
1090	426.9	41.1	998.9	338.1	6516.1	998.9
1120	441.6	40.9	1025.1	323.4	6515.9	1025.1
1150	456.5	40.4	1051.3	308.5	6515.4	1051.3
1200	481.5	40.0	1094.6	283.5	6515.0	1094.6
1272	517.9	36.3	1156.4	247.1	6511.3	1156.4
1310	537.4	33.0	1188.9	227.6	6508.0	1188.9
1355	560.7	29.7	1227.2	204.3	6504.7	1227.2
1400	584.8	25.8	1265.0	180.2	6500.8	1265.0
1450	611.8	21.3	1306.9	153.2	6496.3	1306.9
1460	617.2	20.4	1315.3	147.8	6495.4	1315.3
1470	622.6	19.5	1323.6	142.4	6494.5	1323.6
1505	641.3	16.8	1353.0	123.7	6491.8	1353.0
1540	660.6	14.5	1382.2	104.4	6489.5	1382.2
1600	696.1	11.1	1430.3	68.9	6486.1	1430.3
1620	708.5	10.0	1445.9	56.5	6485.0	1445.9
1680	747.7	6.3	1491.1	17.3N	6481.3	1491.1
1710	768.1	4.4	1512.9	3.1S	6479.4	1512.9
1800	830.6	-1.8	1575.9	65.6S	6473.2	1575.9
1890	896.1	-6.8	1636.1	131.1S	6468.2	1636.1
2000	979.5	-12.7	1707.6	214.5S	6462.3	1707.6
2100	1057.0	-22.1	1770.0	292.0S	6452.9	1770.0
2198	1135.0	-33.2	1828.3	370.0S	6441.8	1828.3
2227	1158.5	-36.3	1843.9	393.5S	6438.7	1843.9

To Accompany Record No. 1962/37

PLATE I



TENNANT CREEK, N.T.
WEST PEKO D.D.H. 2A

CURVES SHOWING DERIVATIVES OF COORDINATES OF HOLE AGAINST ARC LENGTH

To Accompany Record No. 1962/37

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

G 110-88