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M. Pilkington and P. Keating

Geophysics Division
Geological Survey of Canada
1 Observatory Crescent, Ottawa, Ont., Canada K1A 0Y3

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INTRODUCTION

CONTAC and DYKE are two FORTRAN subroutines for the automatic interpretation of vertical gradient anomalies. They are designed to produce estimates of body parameters for two interpretational models, the dipping geological contact and the dipping (thick) dyke. Input is assumed to be line data consisting of horizontal position (metres) and gradient value (nT/m). [Note that we are using the convention: gradient = $-\partial T/\partial z$ which means that a gradient high is observed over a positively magnetized body.] Results from CONTAC and DYKE can be used in a preliminary interpretation or for determining good starting models that can be used in more sophisticated approaches such as inversion routines for single/multiple bodies.

The theoretical basis for the subroutines is not discussed here but is detailed in the paper: "An Automated Method for the Interpretation of Magnetic Vertical Gradient Anomalies" by P. Keating and M. Pilkington (Geophysics, v.55, 336-343, 1990). References to this paper will be referred to as [Ref]. In the following, we restrict our discussion to practical use of the programs with emphasis on input variables and interpretation of the output.

CONTAC and DYKE

On the accompanying diskette are CONTAC.FOR and DYKE.FOR which contain the subroutines CONTAC and DYKE respectively. Also included in each is an example calling program and the subroutines LUDCMP and LUBKSB, which solve a linear system of equations. The calling programs for CONTAC and DYKE are essentially the same, the only differences being in the number of data points used in the window (6 for CONTAC, 10 for DYKE) and the types of body parameters solved for (DYKE estimates the dyke thickness).

Input variables

H = total field magnitude (nT)

AINC = " " inclination (degrees) in plane of profile

STR = angle (clockwise) between magnetic north and profile strike (degrees)

TOL = tolerance distance (metres)

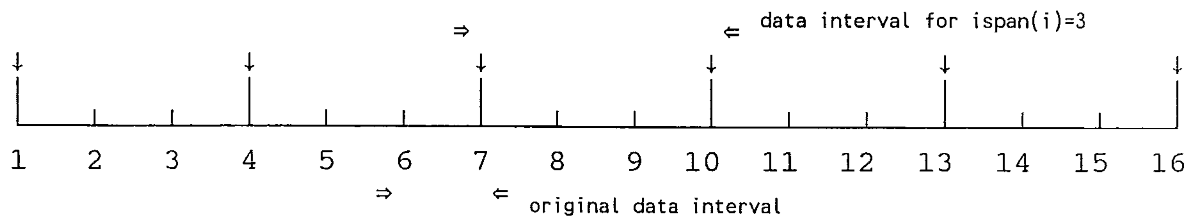
ISPAN(I) = span used for run i

ISP = number of spans used

Note that induced magnetization is assumed in the calling program. Hence $\psi = \lambda$ and b = c (See [Ref] for meaning of symbols). If remanent magnetization is included, then ψ must be input and the value of c changed accordingly.

TOL controls the number of solutions that are accepted. As the window or operator is passed along the profile data, the distance in x (horizontal) and z (depth) between successive solutions is found. If both are less than TOL, both solutions are accepted. If not, the former solution is rejected and the latter compared with the next computed solution. If TOL is set to a large number, e.g. 10^6, all solutions will be accepted resulting in poor clustering of body parameter estimates and an output that is difficult to interpret. As TOL is decreased, fewer solutions are accepted and spurious estimates resulting from noise or closely spaced anomalies will be excluded. Setting TOL equal to the average data spacing usually gives good results. Figures 1 and 2 show the effects of varying TOL. In Figure 1, TOL = 50 m (equal to the data spacing) which results in a fairly good clustering of solutions around the theoretical bodies. See [Ref] Figure 4 for an explanation of the symbols used in Figures 1 and 2. Reducing TOL to 5 m (Figure 2) causes a reduction in the total number of acceptable solutions, with those remaining providing more accurate information on the body parameters. Note that this is synthetic data, so a TOL as low of 5 m could be used. This value would unlikely be useful for real data.

ISPAN(I) and ISP are used to specify the window length used. Since the depth to which the window responds to best is dependent on the window length and the number of points to be used in each estimate is constant (6 for CONTAC, 10 for DYKE), the window length is increased by increasing the span between the data values. If ISPAN(I) = 3, then every third data value is used in the data window. The window length is given by (NPT-1)*ISPAN(I). So for CONTAC, (NPT=6) with ISPAN(I)=3 the window length is 15 original data intervals:



Window length for a value of ISPAN = 3. Numbered scale indicates the original data value positions. Vertical arrows show the data values used with ISPAN = 3.

No matter what the value of ISPAN is, the window is moved along the profile at the original data interval. What value of span to use is dependent on the dominant depth to sources along a profile. If sources are near-surface, smaller spans give the best results. If sources are deep, larger spans are the most useful. The best approach is to try a large number of spans, e.g., ISP=10 and ISPAN(I)=1,2....10 and determine those span values providing the most solutions. As an example, Figure 3 has two dykes, one at 120 m depth and the other at 800 m. Solutions are plotted for TOL = 50 m. ISP = 10 and ISPAN(I) = 1,2,....9,10. Listed in Table 1 below are the number of acceptable solutions as a function of the span value [ISPAN(I)].

	DYKE		CONTAC	
ISPAN(I)	*deep*	*shallow*	*deep*	*shallow*
1	0	10	10	19
2	0	14	44	29
3	13	13	44	18
4	19	4	43	3
5	18	2	39	0
6	10	0	35	0
7	3	0	32	0
8	0	0	28	0
9	0	0	24	0
10	0	0	20	0

Number of acceptable solutions as a function of span for deep and shallow bodies.

For program DYKE, we see that the maximum number of solutions for the deep body are for ISPAN=4,5 while for the shallow body ISPAN=2,3. For program CONTAC, the shallow dyke gives a maximum response at ISPAN=1-3, while the deeper dyke produces results for spans up to 10.

Output data

With input parameters specified as above, output from DYKE is in the following form:

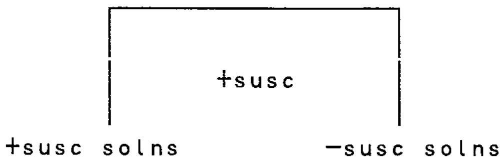
	totf	inc	str	tol
	60000.000	90.000	.000	5.000
	# of solutions	8 for span 1		
3154.392	122.204	142.737	44.266	.154E-02
3150.760	119.679	138.544	51.027	.258E-02
3150.101	120.185	139.499	49.952	.241E-02
3149.907	120.044	140.019	49.941	.239E-02
3150.048	119.959	140.251	49.990	.240E-02
3150.067	120.049	140.224	49.993	.241E-02
3149.933	120.033	139.938	50.050	.240E-02
3149.894	120.156	140.884	49.994	.244E-02
	# of solutions	12 for span 2		
3151.985	119.141	140.748	53.635	.309E-02
3152.381	119.382	139.485	48.410	.298E-02
3150.404	120.984	138.672	46.340	.263E-02
3148.579	121.396	138.997	48.762	.231E-02
3148.590	119.830	140.259	51.187	.222E-02
3149.964	118.685	141.266	51.368	.230E-02
3151.125	119.350	141.572	50.208	.243E-02
3150.929	120.821	141.267	49.027	.251E-02
3149.570	121.161	140.519	48.685	.252E-02
3148.296	119.791	138.779	50.099	.238E-02

The columns contain, horizontal location (m), depth (m), dip (degrees), dyke thickness (m) and susceptibility (cgs). Note that the dip is measured counterclockwise from the horizontal. For CONTAC, the output is the same except there is no thickness value. To convert susceptibility into SI units, multiply by 4π.

PROGRAM USAGE

Contac

Figures 1-3 show that contact solutions occur over dyke-like bodies. This is to be expected since we can regard a dyke as the juxtaposition of two contacts. In this case, the susceptibilities determined over such a feature will not be of the same sign:



This is because the same anomaly would be observed over a contact between, say, formation A (+ve susceptibility) and formation B (0 susc) as between A (0 susc) and B (-ve susc). Essentially, all that is detected is the contrast in magnetization. The original gradient data is needed to differentiate which case we are dealing with. NEGATIVE SUSCEPTIBILITY DOES NOT NECESSARILY MEAN REVERSED MAGNETIZATION.

Experiences with model studies suggests that for deeper sources (>500 m), CONTAC solutions for small span values give good resolution of features, but the depth may be underestimated. As the span value is increased, resolution deteriorates (e.g. solutions no longer cluster at the edges of dyke-like bodies but migrate towards the centre) but the depth estimate approaches the true value.

Dyke

Since DYKE also detects only magnetization contrasts, when positively magnetized bodies are separated by non-magnetic formations, the intervening formation can be interpreted as a negatively magnetized body surrounded by a non-magnetic medium. Hence, the negative flanks of closely spaced sources may show up as reversely magnetized dykes when using DYKE. This effect can be seen in Figure 1 at a horizontal distance of 6 km, where two dyke solutions appear between the theoretical bodies. Also in Figure 3, we see the same effect. The negative flank between the two positive gradient anomalies is modelled as a thick dyke with a thickness comparable to the separation of the two bodies. Examination of the original profile data and knowledge of local rock magnetizations will determine whether such solutions are artifacts or reversely magnetized bodies.

DISKETTE CONTENTS:

DYKE.FOR - Source code for program DYKE

DYKE.EXE - Executable file for DYKE

CONTAC.FOR - Source code for program CONTAC

CONTAC.EXE - Executable file for CONTAC

M1 - Example data set (Generated from the models in Figure 1,2)

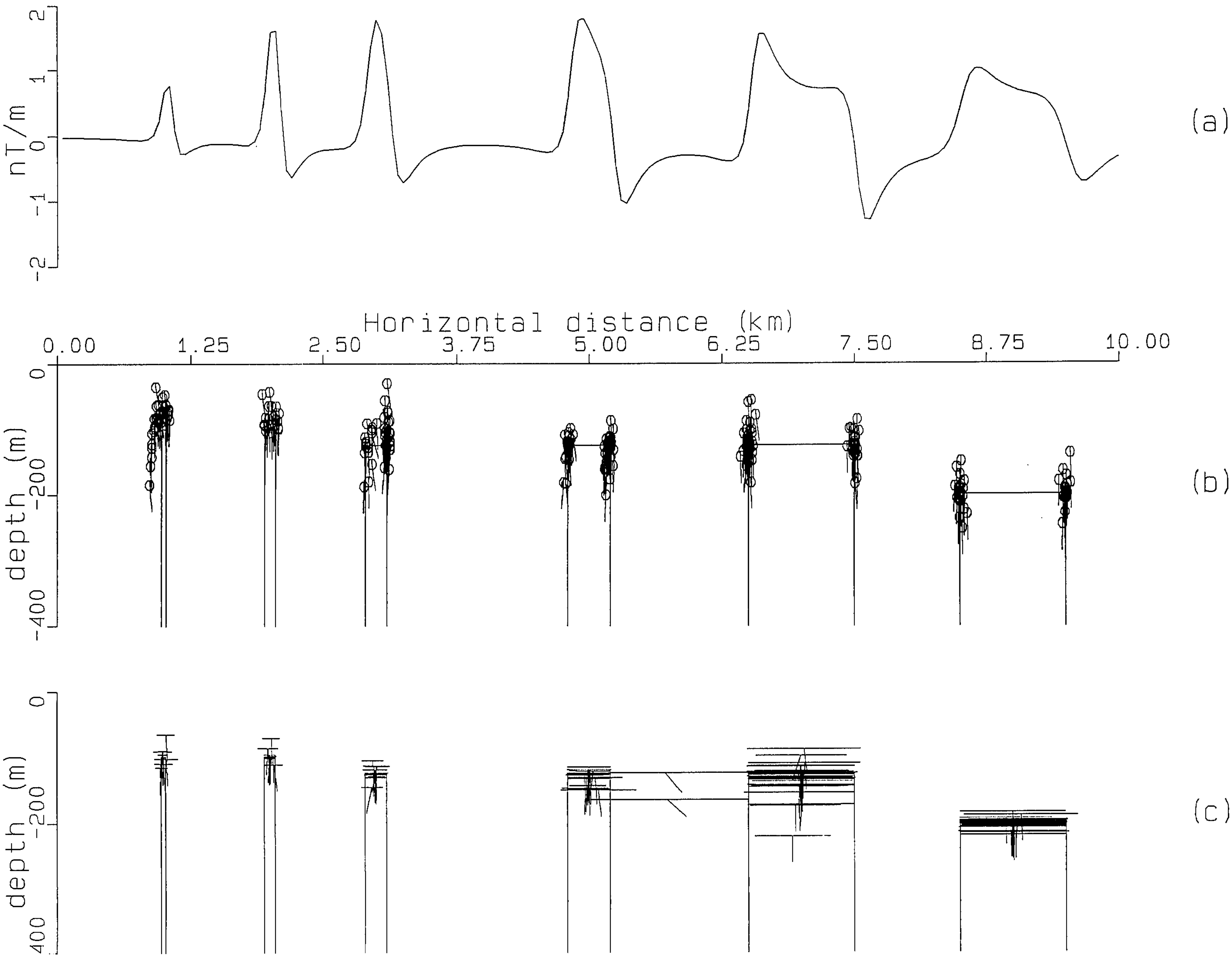
M1.D - Output from DYKE using M1 data

M1.C - Output from CONTAC using M1 data

M2 - Example data set (Generated from the models in Figure 3)

M2.D - Output from DYKE using M2 data

M2.C - Output from CONTAC using M2 data



nT/m
2
1
0
-1
-2
(a)
Horizontal distance (km)
0.00
1.25
2.50
3.75
5.00
6.25
7.50
8.75
10.00
depth (m)
0
-200
-400
(b)
depth (m)
0
-200
-400
(c)

FIG. 1

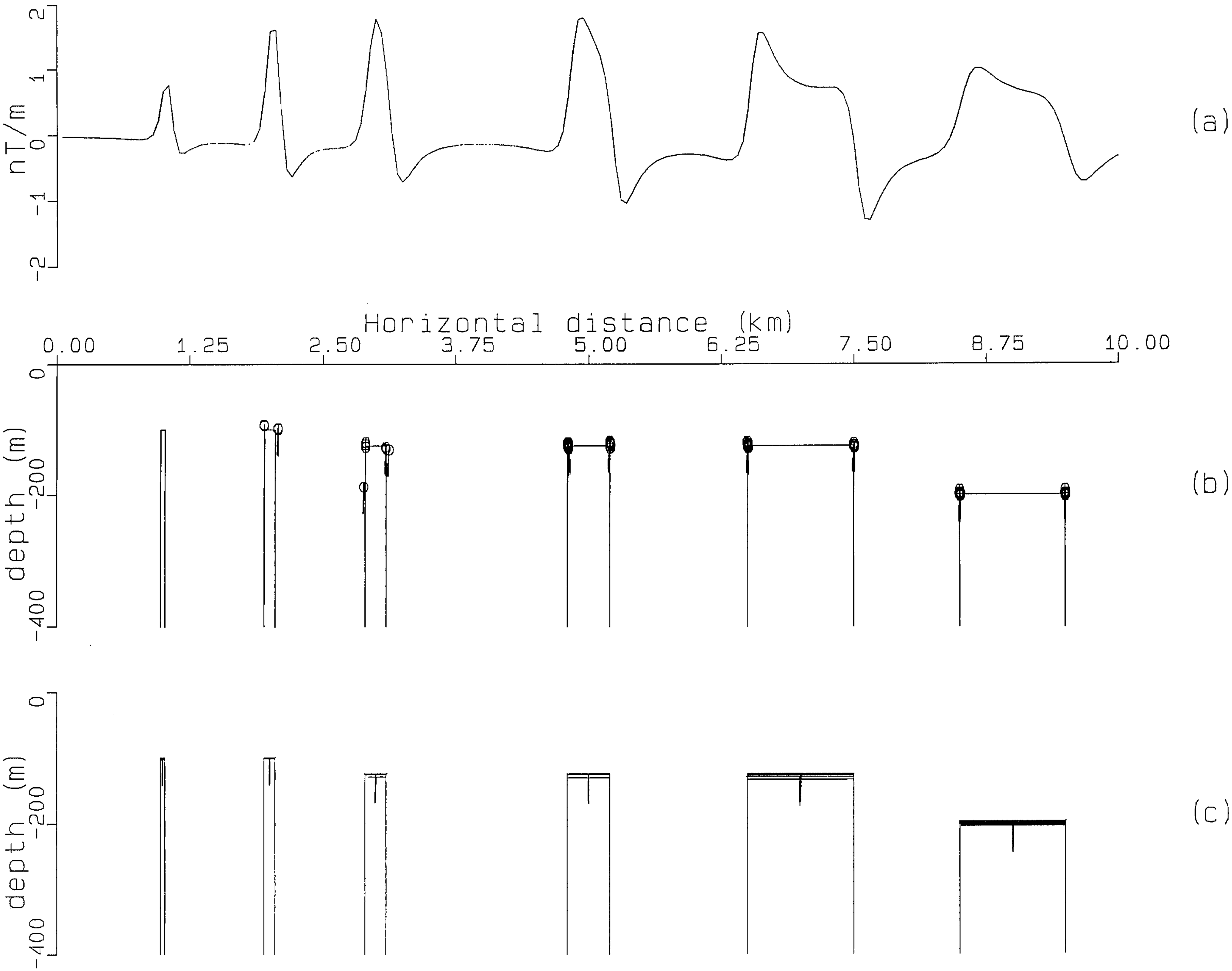

nT/m
2
1
0
-1
-2
(a)
Horizontal distance (km)
0.00
1.25
2.50
3.75
5.00
6.25
7.50
8.75
10.00
depth (m)
0
-200
-400
(b)
depth (m)
0
-200
-400
(c)

FIG. 2

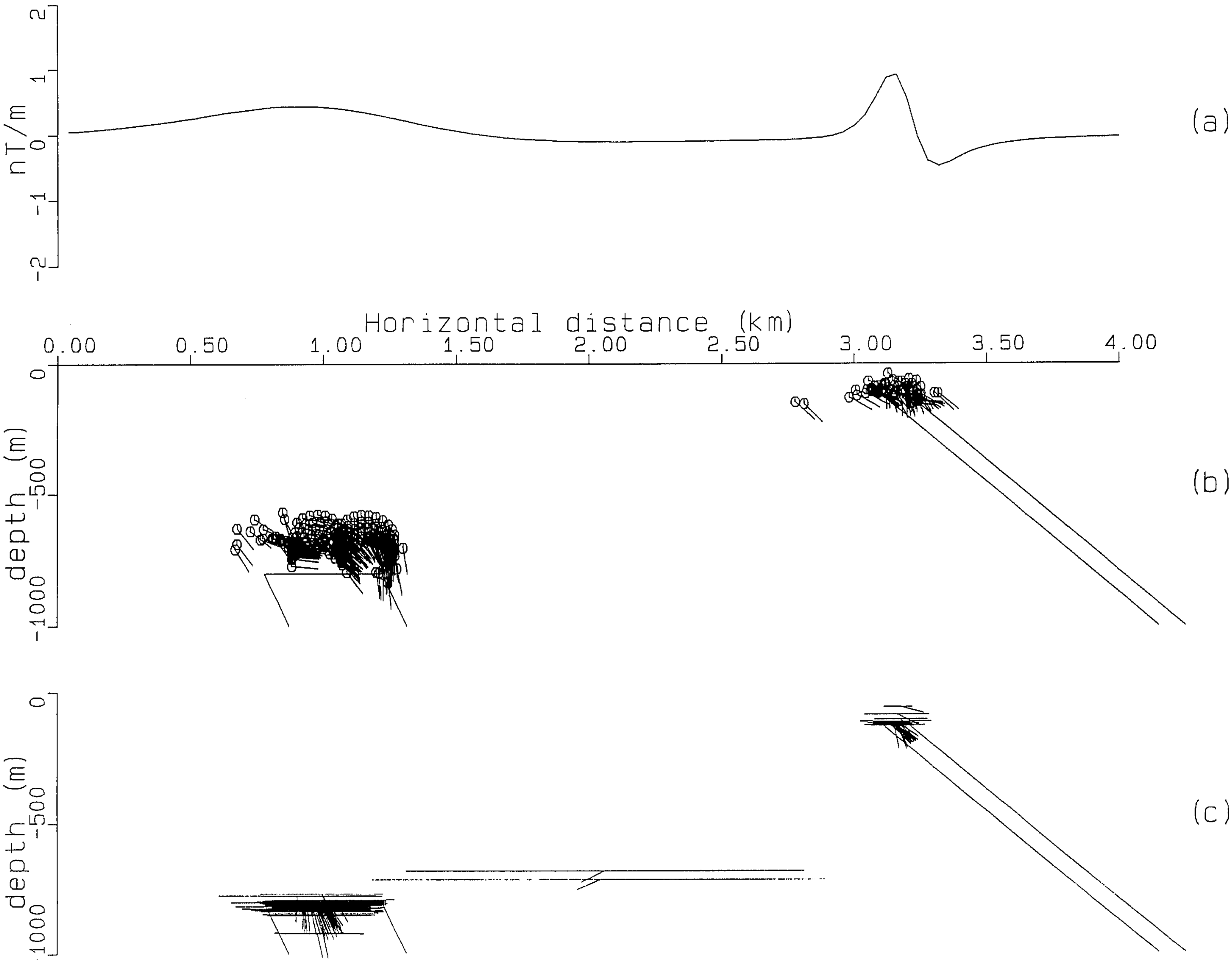

nT/m
2
1
0
-1
-2
(a)
Horizontal distance (km)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
depth (m)
0
-500
-1000
(b)
depth (m)
0
-500
-1000
(c)

FIG. 3