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Calculation of Gravity and Magnetic Anomalies along Profiles with End Corrections and Inverse Solutions for Density and Magnetization

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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NOTE: The program described in this report is awaiting revision to permit plotting on the U.S. Geological Survey's Honeywell Multics Computer. At that time this report will be published as a U.S. Geological Survey Professional Paper.

A tape containing the interim Fortran code for the program, along with test data input, is available from a private vendor. For information about obtaining copies of this report and the tape, contact U.S. Geological Survey, Public Inquiries Office, 1961 Stout Street, Denver, Colorado 80202. The cost of the tape-copying service is presently $20.00 plus postage if the user supplies the tape. A vendor-supplied tape is $12.00 additional.

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Calculation of gravity and magnetic anomalies along profiles with end corrections and inverse solutions for density and magnetization

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ABSTRACT

An equation is derived for the vertical gravity field due to a body with polygonal cross section and finite strike length. The equations consists of the 2-dimensional equation of Talwani, Worzel, and Landisman (1959), with the addition of end corrections. Equations for the magnetic field due to a similar body were derived by Shuey and Pasquale (1973). They coined the term "2½-dimensional" to describe the geometry.

If the geometry of the causative body or bodies is specified, the 2½-dimensional equations can be combined with observation of the gravity and magnetic anomaly fields to make linear least squares solutions for density and susceptibility or remanent magnetization.

A computer program is presented which performs, for one or more bodies, along a profile perpendicular to strike, both forward calculations for the magnetic and gravity anomaly fields and independent gravity and magnetic inverse calculations for density and susceptibility or remanent magnetization.

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INTRODUCTION

In the quantitative interpretation of gravity and magnetic surveys, 2-dimensional calculations along profiles perpendicular to the axis of an infinitely long body have been popular (Talwani, Worzel, and Landisman, 1959; Talwani and Heirtzler, 1964). Reasons for this popularity are that structures which approach two-dimensionality are common in geology and data are often collected in profiles perpendicular to strike; polygonal cross sections of 2-dimensional bodies are conveniently represented on paper and input to the computer; and completely general 3-dimensional programs (e.g. Talwani, 1965) are slower and data input and display are more cumbersome. Shuey and Pasquale (1973) derived equations for the magnetic field of a compromise "2½-dimensional body", invariant in cross section but terminated a finite distance along strike. I have derived the equations for the gravity field of a 2½-dimensional body. The 2½-dimensional approach has the convenience and speed of the 2-dimensional approach with much of the generality of the 3-dimensional approach. For completeness, and to illustrate the difference between the magnetic and gravity cases, Shuey and Pasquale's derivation for the magnetic case is repeated in parallel with the derivation for the gravity case.

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In recent years much effort has been spent trying to find practical ways to invert potential field data to yield the geometry and physical properties of a causative body. The problem is difficult because the equations relating potential field to body geometry are nonlinear. Many useful solutions for special cases can be found in any recent volume of the journal Geophysics.

Fortunately, half of the potential field inverse problem is linear. For a given homogeneous body and profile geometry, the gravity field is a linear function of density and the magnetic field is a linear function of susceptibility or the x-, y-, and z-components of remanent magnetization. Once the geometry is specified, and nonlinear geometrical factors are calculated along the profile by a forward calculation, observed values of the gravity and magnetic field are used to calculate density and susceptibility or remanent magnetization by linear least squares. This method was used by Vacquier (1962) to calculate the direction and intensity of magnetization in a 3-dimensional seamount and by Bott (1967) to find the magnetization of numerous identical 2-dimensional rectangular blocks. Tanner (1967) used linear least squares to find the density of rectangular $2\frac{1}{2}$-dimensional blocks. I am aware, however, of no potential field inversion program, either linear or nonlinear, which is as general in application or as cheap and convenient to use as the Talwani or Shuey polygon programs.

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The rest of this paper describes an algorithm, programmed in Fortran IV, that calculates gravity and magnetic geometrical factors along a profile perpendicular to the strike of one or more "2½-dimensional" prisms of arbitrary polygonal cross section. The uniform density, susceptibility, and remanent magnetization of some or all of the prisms can be specified by the user, while the uniform density, susceptibility, and remanent magnetization of the remaining prisms (or all the prisms) is determined by linear least squares. Magnetic or gravity calculations can be done alone. Although documentation for general operation of the program is complicated, sample data sets for simple calculations are given in figure 7 and on pages 63 and 68.

An extended discussion beginning on p. 76 entitled "Hints for the effective use of the program", is not required for basic operations. It is intended to introduce selected aspects of modeling to the naive user, to suggest sophisticated applications of the program, and to explain at length certain topics treated briefly in the basic documentation.

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DERIVATION OF 2½-D FORMULAS

Parallel magnetic and gravity derivations

Separate magnetic and gravity calculations are made for two reasons. First, even though the gravity field could be calculated from the magnetic field, or vice versa, via the Poisson relationship (Grant and West, 1965 p. 213), calculations would not be saved because of the need to integrate the magnetic field or differentiate the gravity field. Second, in many applications, gravity alone or magnetics alone is required, or the gravity field is measured on the ground and the magnetic field from an aircraft, so separate calculations are required.

The gravity field at a point r external to a continuous mass distribution $\rho(\hat{r}_o)$ contained within a volume V (fig. 1) is given by the

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Figure 1.--NEAR HERE

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expression

$$\hat{F}(\hat{r}) = -\nabla U(\hat{r}), \qquad \text{(G1a)}$$

where the gravitational potential is given by

$$U(\hat{r}) = -G \int_V \rho(\hat{r}_o) \frac{d^3 r_o}{|\hat{r} - \hat{r}_o|} \qquad \text{(G1b)}$$

(Grant and West, 1965, p. 211). G is the universal gravitational constant.

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With similar geometry, the magnetic field is given by the expression

$$\hat{H}(\hat{r}) = - \nabla A(\hat{r}) \, , \tag{M1a}$$

where the magnetic scalar potential

$$A(\hat{r}) = - \int_V \hat{M}(\hat{r}_o) \cdot \nabla \frac{d^3 r_o}{|\hat{r} - \hat{r}_o|} \, . \tag{M1b}$$

(Grant and West, 1965, p. 212-213). $\hat{M}$ is the vector magnetization. Note the extra ∇ sign, indicating an extra order of spatial differentiation in the magnetic case. This difference makes the derivation shorter for magnetics than for gravity.

The derivations start in parallel. Figure 2 defines the

Figure 2.--NEAR HERE

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right-handed coordinate system and shows the body over which we integrate. The y-axis is parallel to the strike of the body, and observations lie along a profile contained within the x-z plane. The z-axis is positive downwards, in the derivation, for consistency with Shuey and Pasquale (1973) and for agreement with the paleomagnetic convention that normal inclinations are positive downward in the northern hemisphere. When inputting topography, flight line data, and body geometries, however, it is convenient to have z positive upwards. A conversion from z-positive-upwards to z-positive-downwards is effected in subroutines MAG and GRAV. The magnetic field derivation closely follows that of Shuey and Pasquale (1973). The Newtonian

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potential is defined as

$$U = \tfrac{1}{2}\int_V \frac{d^3 r_o}{|\hat{r} - \hat{r}_o|} \quad . \tag{1}$$

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Magnetic case: Equations (M1a) and (M1b) become

$$H_x = 2M_x P_x + 2M_z Q \,, \tag{M2a}$$

$$H_y = -2M_y R \,, \tag{M2b}$$

$$H_z = 2M_x Q - 2M_z P_z \,, \tag{M2c}$$

where

$$P_x = \partial^2 U/\partial x^2 \,, \tag{M3a}$$

$$P_z = -\partial^2 U/\partial z^2 \,, \tag{M3b}$$

$$R = -\partial^2 U/\partial y^2 \,, \tag{M3c}$$

$$Q = \partial^2 U/\partial x \partial z \quad . \tag{M3d}$$

To simplify the magnetic derivation, we specify equal strike length to either side of the x-z plane. Because of this symmetry about the x-z plane, the terms in $\partial^2 U/\partial x \partial y$ and $\partial^2 U/\partial y \partial z$ are zero, and from Laplace's equation

$$P_x - P_z - R = 0 \quad . \tag{M4}$$

Gravity case: Equations (G1a) and (G1b) become

$$F_x = -2G\rho\, \partial U/\partial x \,, \tag{G2a}$$

$$F_y = -2G\rho\, \partial U/\partial y \,, \tag{G2b}$$

$$F_z = -2G\rho\, \partial U/\partial z \quad . \tag{G2c}$$

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If we were to assume symmetry about the x-z plane,

$$F_y = -G\rho \partial U/\partial y = 0 \quad . \qquad \text{(G3)}$$

There is no advantage, however, to making this assumption for the gravity case, so we permit the gravity prism to have different y-lengths to either side of the x-z plane.

The equations for P_x, P_z, Q, R, and F_x, F_y, F_z have the form of second and first partial differentials of volume integrals. These volume integrals must be converted into line integrals around the polygonal cross sectional figure. Without loss of generality we place the coordinate origin at the observation point $\hat{r}$ and drop the subscript from the body point $\hat{r}_o$. Equation (M3a) becomes

$$P_z = \tfrac{1}{2}\iiint \frac{\partial^2}{\partial z^2} (x^2 + y^2 + z^2)^{-\frac{1}{2}} \, dxdydz \quad . \qquad \text{(M5)}$$

Equation (G2a) becomes

$$F_z = -G\rho \iiint \frac{\partial}{\partial z} (x^2 + y^2 + z^2)^{-\frac{1}{2}} \, dxdydz \quad . \qquad \text{(G4)}$$

F_z is chosen for detailed derivation because the total gravity field, which we measure, is very close to vertical.

In the magnetic case we integrate along strike between $Y_1=-Y$ and $Y_2=+Y$ and get

$$P_z = \tfrac{1}{2}\iint \frac{\partial^2}{\partial z^2} \ln \frac{r + Y}{r - Y} \, dxdz \, , \qquad \text{(M6)}$$

where

$$r^2 = x^2 + y^2 + z^2 \quad . \qquad \text{(M7)}$$

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In the gravity case we allow the body to have different partial strike lengths Y_1 and Y_2. In order to avoid ambiguities of sign, both Y_1 and Y_2 are defined, for the purposes of this derivation, as positive distances from the x-z plane: Y_1 positive in the -Y direction, Y_2 positive in the +Y direction. By symmetry the gravity contribution of identical bodies to either side of the x-z plane must be equal. Later, in the operational program, Y_1 and Y_2 will be input as signed algebraic quantities, positive in the +Y direction and negative in the -Y direction.

Integrating equation (G4) from 0 to Y_1 yields

$$-G\rho \frac{\partial}{\partial z}\iint\left(\ln\left(Y_1 + \sqrt{x^2 + Y_1{}^2 + z^2}\right) - \ln\sqrt{x^2 + z^2}\right)dxdz, \quad \text{(G5a)}$$

and integrating from 0 to Y_2 yields

$$-G\rho \frac{\partial}{\partial z}\iint\left(\ln\left(Y_2 + \sqrt{x^2 + Y_2{}^2 + z^2}\right) - \ln\sqrt{x^2 + z^2}\right)dxdz\ . \quad \text{(G5b)}$$

Summing these expressions we get

$$F_z = -G\rho \frac{\partial}{\partial z}\iint\left(-\ln(x^2 + z^2) + \ln\left(Y_1 + \sqrt{x^2 + Y_1{}^2 + z^2}\right) + \ln\left(Y_2 + \sqrt{x^2 + Y_2{}^2 + z^2}\right)\right)dxdz\ . \quad \text{(G5c)}$$

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In the magnetic case, integrating equation (M6) over z yields

$$P_z = \tfrac{1}{2} \int_{x_1}^{x_2} \left[\frac{\partial}{\partial z} \ln \frac{r + Y}{r - Y} \, dx \right]_{z_1}^{z_2} \qquad \text{(M8)}$$

$$= \tfrac{1}{2} \oint \frac{\partial}{\partial z} \ln \frac{r + Y}{r - Y} \, dx \ , \qquad \text{(M9)}$$

while in the gravity case, integration of equation (G5c) over z yields:

$$F_z = -G\rho \int_{x_1}^{x_2} \left[-\ln(x^2+z^2) + \ln(Y_1+\sqrt{x^2+Y_1{}^2+z^2}\,) + \ln(Y_2+\sqrt{x^2+Y_2{}^2+z^2}\,) \right]_{z_1}^{z_2} dx, \qquad \text{(G6)}$$

and

$$F_z = -G\rho \oint (-\ln(x^2+z^2) + \ln(Y_1+\sqrt{x^2+Y_1{}^2+z^2}\,) + \ln(Y_2+\sqrt{x^2+Y_2{}^2+z^2}\,)) \, dx \ . \qquad \text{(G7)}$$

Note the absence of the $\frac{\partial}{\partial z}$ term in equation (G7) when compared with equation (M9). From this point the derivations diverge.

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Magnetic derivation continued

In the magnetics case differentiation of the log term yields

$$P_z = -\oint \frac{Y}{r} \frac{z}{x^2 + z^2}\, dx \ . \qquad \text{(M10a)}$$

Similar manipulations on equations (M3a), (M3c), and (M3d) yield:

$$P_x = -\oint \frac{Y}{r} \frac{x}{x^2 + z^2}\, dz \ , \qquad \text{(M10b)}$$

$$Q = -\oint \frac{Y}{r} \frac{z}{x^2 + z^2}\, dz = \oint \frac{Y}{r} \frac{x}{x^2 + z^2}\, dx \ , \qquad \text{(M10c)}$$

and

$$R = -\oint \frac{Y}{r} \frac{x}{z^2 + Y^2}\, dz = -\oint \frac{Y}{r} \frac{z}{x^2 + Y^2}\, dx \ . \qquad \text{(M10d)}$$

Shuey and Pasquale (1973) cleverly introduced complex variables at this point and from equations (M10a) to (M10d) derived

$$\oint \frac{Y}{r} \frac{dx}{x + iz} = Q + iP_z \ , \qquad \text{(M11a)}$$

$$\oint \frac{Y}{r} \frac{idz}{x + iz} = -(Q + iP_x) \ , \qquad \text{(M11b)}$$

and

$$R = \mathrm{Im} \oint \frac{z}{r} \frac{dx}{x + iY} = -\mathrm{Im} \oint \frac{z}{r} \frac{dz}{z + iY} \ . \qquad \text{(M11c)}$$

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Supposing the polygonal cross section has N sides, a final integration is performed along each edge from the point (x_1, z_1) to (x_2, z_2) yielding the following easily programmable formulae:

$$Q + iP_z = \sum \frac{-\Delta x}{\Delta x + i\Delta z} \ln(F_2/F_1) \quad , \qquad \text{(M12a)}$$

and

$$Q + iP_x = \sum \frac{i\Delta z}{\Delta x + i\Delta z} \ln(F_2/F_1) \quad , \qquad \text{(M12b)}$$

where the sum is over the N sides of the polygon, and

$$\Delta z = z_2 - z_1 \quad , \qquad \text{(M13a)}$$

$$\Delta x = x_2 - x_1 \quad , \qquad \text{(M13b)}$$

and

$$F_n = \frac{\Delta x + i\Delta z}{x_n + iz_n} \left(1 + \frac{r_n}{Y}\right) \qquad \text{(M14)}$$

$$+ \frac{i}{Y^2} (x_n \Delta z - z_n \Delta x) \quad , \qquad \text{(M15)}$$

with n taking the values 1, 2. A modified version of Shuey and Pasquale's algorithm (R. T. Shuey, written communication, 1975) is presented as subroutine MAG on p. 36.

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Combining the geometrical factors of equations (M12) to (M15) with the components of magnetization according to equations (M2a) to (M2c) we obtain the components of the anomalous magnetic field H_x, H_y, and H_z, from which we calculate ΔT, the total field anomaly.

Let $\hat{T}_o$ be the total magnetic field measured at a point far from "anomalous" bodies. Then introduce an anomalous magnetic body into the vicinity which produces disturbing field components H_x, H_y, and H_z at the magnetometer head. The total field $\hat{T}$ measured by the magnetometer is now the vector sum of $\hat{T}_o$ and the disturbing field, and is given by:

$$\hat{T} = \left[(T_{o_x} + H_x)^2 + (T_{o_y} + H_y)^2 + (T_{o_z} + H_z)^2 \right]^{\frac{1}{2}} , \qquad \text{(M16a)}$$

where

$$T_{o_x} = T_o \cos I \cos A , \qquad \text{(M16b)}$$

$$T_{o_y} = T_o \cos I \sin A , \qquad \text{(M16c)}$$

$$T_{o_z} = T_o \sin I , \qquad \text{(M16d)}$$

and I is the inclination and A is the declination of $\hat{T}_o$. In general, the direction of $\hat{T}$ will differ from that of $\hat{T}_o$. The proton precession magnetometer is insensitive to field direction, however, and the anomalous field ΔT registered by the magnetometer is the scalar difference in magnitude between $\hat{T}$ and $\hat{T}_o$:

$$\Delta T = |\hat{T}| - |\hat{T}_o| = \left[(T_o \cos I \cos A + H_x)^2 + (T_o \cos I \sin A + H_y)^2 + (T_o \sin I + H_z)^2 \right]^{\frac{1}{2}} - |\hat{T}_o| . \qquad \text{(M17)}$$

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Although nature rarely allows us to remove an anomalous magnetic body in order to measure $|\hat{T}_o|$, A, and I, these quantities can usually be estimated from regional measurements distant from the anomalous body.

If $|H_x|$, $|H_y|$, and $|H_z| < |T_o|$, the first two terms of the binomial expansion of equation (M17) yield the following approximation for ΔT:

$$\Delta T \simeq H_z \sin I + H_x \cos I \cos A + H_y \cos I \sin A. \qquad \text{(M18)}$$

This approximation, which is the projection of the magnetic field of the anomalous body into the Earth's field direction, was used to calculate the total field anomaly by Talwani and Heirtzler (1964) and Shuey and Pasquale (1973). It is accurate only when the perturbing field is small compared to the Earth's field, so equation (M17) is preferred for strongly magnetized bodies. Equation (M18), which is linear in H_x, H_y, and H_z, must be used for linear least squares calculations. In subroutine FITMAG (p. 39), the approximate equation (M18) is normally used in both forward and inverse calculations, but an option is provided for forward calculations using exact equation (M17). No provision is made for an exact summation of the total field anomaly of multiple bodies. The approximate sum assumes that all total field anomalies are parallel. A user can modify the program to retain a running sum of H_x, H_y, and H_z and then compute the exact total field anomaly for all bodies together.

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Gravity derivation continued

To evaluate the line integral in the gravity case we rewrite z as a function of x along each side of the polygon (fig. 3).

Figure 3.--NEAR HERE

$$z = mx + z_o \qquad \text{(G8a)}$$

where

$$mx = \tan\Theta = \frac{z_2 - z_1}{x_2 - x_1} , \qquad \text{(G8b)}$$

and z_o is the z- intercept of the extension of the side. Equation (G7) becomes

$$F_z = -G\rho(-I_o + I_1 + I_2) , \qquad \text{(G9a)}$$

where

$$I_o = \oint \ln(x^2 + (mx + z_o)^2)dx \quad , \qquad \text{(G9b)}$$

$$I_1 = \oint \ln(Y_1 + \sqrt{Y_1{}^2 + x^2 + (mx + z_o)^2}\,)dx \quad , \qquad \text{(G9c)}$$

and

$$I_2 = \oint \ln(Y_2 + \sqrt{Y_2{}^2 + x^2 + (mx + z_o)^2}\,)dx \quad . \qquad \text{(G9d)}$$

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We define the new quantities:

$$c^2 = 1 + m^2 \quad \text{or} \quad c = \sqrt{1 + \tan^2\Theta} = \sec\Theta \quad , \qquad \text{(G10a)}$$

$$a = z_o\cos\Theta = z_o/c \quad \text{or} \quad z_o = a/\cos\Theta \quad , \qquad \text{(G10b)}$$

$$x_o = a\sin\Theta = z_o\sin\Theta\cos\Theta = mz_o/c^2 \quad , \qquad \text{(G10c)}$$

$$\xi = c(x + x_o), \quad d\xi = c\,dx, \quad \text{and } dx = \frac{1}{c}\,d\xi \quad . \qquad \text{(G10d)}$$

The expression for I_0, I_1, and I_2 all contain the form

$$x^2 + z^2 = x^2 + (mx + z_o)^2 \quad ,$$

which expands to

$$c^2(x^2 + 2\,\frac{mz_o}{c^2} + \frac{z_o^{\,2}}{c^2}\,).$$

Completing the square yields

$$c^2\left[x^2 + 2(\frac{mz_o}{c^2})x + (\frac{mz_o}{c^2})^2 + \frac{z_o^{\,2}}{c^2} - (\frac{mz_o}{c^2})^2\right]$$

$$= c^2\left[x^2 + 2x_o x + x_o^{\,2} + \frac{z_o c^2 - m^2 z_o^{\,2}}{c^4}\right] = c^2\left[(x + x_o)^2 + \frac{a^2}{c^2}\right];$$

or

$$x^2 + z^2 = x^2 + (mx + z_o)^2 = \xi^2 + a^2 \quad , \qquad \text{(G11)}$$

and we obtain

$$I_o = \frac{1}{c}\oint \ln(\xi^2 + a^2)d\xi \quad , \qquad \text{(G12a)}$$

$$I_1 = \frac{1}{c}\oint \ln(Y_1 + \sqrt{Y_1^{\,2} + \xi^2 + a^2}\,)d\xi \quad , \qquad \text{(G12b)}$$

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and

$$I_2 = \frac{1}{c} \int \ln(Y_2 + \sqrt{Y_2^2 + \xi^2 + a^2})\,d\xi \quad . \tag{G12c}$$

Integrating equation (G12a) using formula G23 of Dwight (1957) yields:

$$I_o = \frac{1}{c}\left[\xi \ln(\xi^2 + a^2) - 2\xi + 2a\tan^{-1}\frac{\xi}{a} \right]_{x_i}^{x_{i+1}} , \tag{G13a}$$

where x_i, and x_{i+1} are the endpoints of the ith line segment of the polygonal cross section.

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An integration formula for equations (G12a) and (G12b) is given by Nagy (1966). Incidentally, an erroneous solution is given by Kellogg (1929, p. 57). Using Nagy's integration formula yields

$$I_{1,2} = \frac{1}{c}\oint \ln(b + \sqrt{b^2+a^2+\xi^2}\, d\xi = \frac{1}{c}\left[\xi \ln(b+\sqrt{b^2+a^2+\xi^2} + b\ln(\xi+\sqrt{b^2+a^2+\xi^2} - \xi - a\sin^{-1}\left(\frac{a^2+b^2+b\sqrt{b^2+a^2+\xi^2}}{\sqrt{a^2+b^2}\,(b+\sqrt{b^2+a^2+\xi^2})}\right)\right]_{x_i}^{x_{i+1}}, \qquad \text{(G13b)}$$

where b represents Y_1 in integral I_1 and Y_2 in integral I_2.

To obtain x_i and z_i in the square root terms, we reverse the substitutions leading to equation (G11) and obtain

$$I_o = (x_i+x_o)\ln(x_i{}^2+z_i{}^2) - 2(x_i+x_o) + 2\frac{a}{c}\tan^{-1}\left(\frac{c(x_i+x_o)}{a}\right), \qquad \text{(G14a)}$$

$$I_{1,2} = \left[(x_i+x_o)\ln(b+\sqrt{b^2+x_i{}^2+z_i{}^2}\,) + \frac{b}{c}\ln(c(x+x_o)+\sqrt{b^2+x_i{}^2+z_i{}^2} - (x_i+x_o) - \frac{a}{c}\sin^{-1}\left(\frac{a^2+b^2+b\sqrt{b^2+x_i{}^2+z_i{}^2}}{\sqrt{a^2+b^2}\,(b+\sqrt{b^2+x_i{}^2+z_i{}^2})}\right)\right]_{x_i}^{x_{i+1}}. \qquad \text{(G14b)}$$

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Fortran subroutines commonly compute the arcsine from the arctangent. A simple trigonometric manipulation (fig. 4) permits

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Figure 4.--NEAR HERE

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conversion of the arcsine in formula (G14b) to the arctangent for direct computation. Let n be the numerator and d the denominator of the argument of the arcsine in formula (G15). If $\Theta=\sin^{-1}\frac{n}{d}$, then

$$\Theta = \tan^{-1}\frac{n}{\sqrt{d^2 - n^2}} \quad \text{(G15)}$$

Let

$$R_i = (b^2 + x_i{}^2 + z_i{}^2)^{\frac{1}{2}} \quad . \quad \text{(G16a)}$$

Then

$$n = a^2 + b^2 + bR_i \quad , \quad \text{(G16b)}$$

and

$$d = \sqrt{a^2 + b^2}\,(b + R_i) \quad , \quad \text{(G16c)}$$

and it follows that

$$(d^2-n^2)^{\frac{1}{2}} = a(R_i{}^2-b^2-a^2)^{\frac{1}{2}} = c(x_i{}^2+z_i{}^2-a^2)^{\frac{1}{2}} \quad . \quad \text{(G16d)}$$

From equation (G11) we have

$$x^2 + z^2 = c^2(x + x_o)^2 + a^2 \quad ,$$

so

$$a(x_i{}^2+z_i{}^2-a^2)^{\frac{1}{2}} = a(c^2(x_i+x_o)^2+a^2-a^2)^{\frac{1}{2}} = ac(x_i+x_o) = z_o(x_i+x_o) \quad . \quad \text{(G16e)}$$

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Equation (G14b) can now be re-expressed

$$I_{1,2} = \Bigg[(x_i+x_o)\ln(b+R_i) + \frac{b}{c}\ln(c(x_i+x_o)+R_i) - (x_i+x_o)$$

$$- \frac{a}{c}\tan^{-1}\left(\frac{a^2+b^2+bR_i}{z_o(x_i+x_o)}\right)\Bigg]_{x_i}^{x_{i+1}} \quad \text{(G17a)}$$

When evaluating I_1, b becomes y_1 and R_i becomes

$$R_{1,i} = \sqrt{(Y_1{}^2 + x_i{}^2 + z_i{}^2)} \quad . \quad \text{(G17b)}$$

When evaluating I_2, b becomes y_2 and R_i becomes

$$R_{2,i} = \sqrt{Y_2{}^2 + x_i{}^2 + z_i{}^2} \quad . \quad \text{(G17c)}$$

Evaluating at the endpoints yields:

$$I_o = (x_{i+1}+x_o)\ln(x_{i+1}{}^2+z_{i+1}{}^2) - 2(x_{i+1}+x_o) + 2\frac{a}{c}\tan^{-1}\left(\frac{c(x_{i+1}+x_o)}{a}\right)$$

$$-(x_i+x_o)\ln(x_i{}^2+z_i{}^2) + 2(x_i+x_o) - 2\frac{a}{c}\tan^{-1}\left(\frac{c(x_i+x_o)}{a}\right) \quad . \quad \text{(G18a)}$$

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$$
\begin{aligned}
I_1 = {} & (x_{i+1}+x_o)\ln(Y_1+R_{1,i+1}) \\
& -(x_i+x_o)\ln(Y_1+R_{1,i}) \\
& + \frac{Y_1}{c}\ln\left[c(x_{i+1}+x_o)+R_{1,i+1}\right] \\
& - \frac{Y_1}{c}\ln\left[c(x_i+x_o)+R_{1,i}\right] \\
& -(x_{i+1}+x_o)+(x_i+x_o) \\
& - \frac{a}{c}\tan^{-1}\left(\frac{a^2+Y_1^{\,2}+Y_1R_{1,i+1}}{z_o(x_{i+1}+x_o)}\right) \\
& + \frac{a}{c}\tan^{-1}\left(\frac{a^2+Y_1^{\,2}+Y_1R_{1,i}}{z_o(x_i+x_o)}\right) .
\end{aligned}
\tag{G18b}
$$

$$
\begin{aligned}
I_2 = {} & (x_{i+1}+x_o)\ln(Y_2+R_{2,i+1}) \\
& - (x_i+x_o)\ln(Y_2+R_{2,i+1}) \\
& + \frac{Y_2}{c}\ln\left[c(x_{i+1}+x_o)+R_{2,i+1}\right] \\
& - \frac{Y_2}{c}\ln\left[c(x_i+x_o)+R_{2,i}\right] \\
& - (x_{i+1}+x_o)+(x_i+x_o) \\
& - \frac{a}{c}\tan^{-1}\left(\frac{a^2+Y_2^{\,2}+Y_2R_{2,i+1}}{z_o(x_{i+1}+x_o)}\right) \\
& + \frac{a}{c}\tan^{-1}\left(\frac{a^2+Y_2^{\,2}+Y_2R_{2,i}}{z_o(x_i+x_o)}\right) .
\end{aligned}
\tag{G18c}
$$

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Recalling equation (G9a), $F_z = G_\rho(-I_o + I_1 + I_2)$, and letting

$$BI = x_i + x_o, \quad BX = x_{i+1} + x_o,$$

$$r_i = x_i^2 + z_i^2, \quad r_{i+1} = x_{i+1}^2 + z_{i+1}^2, \text{ and} \qquad \text{(G19)}$$

$$K = a/c,$$

we get $F_z = G_\rho \bullet$ **Terms:**

	Terms
$\left[BX \ln r_{i+1}^2 - BI \ln r_i^2 \right.$	1,2
$+ 2K \tan^{-1}(BX/K) - 2K \tan^{-1}(BI/K)$	3,4
$+ BI \ln((Y_1 + R_{1,i})(Y_2 + R_{2,i}))$	5
$- BX \ln((Y_1 + R_{1,i+1})(Y_2 + R_{2,i+1}))$	6
$+ \frac{Y_1}{C} \ln\left(\frac{C*BI + R_{1,i}}{C*BX + R_{1,i+1}}\right)$	7
$+ \frac{Y_2}{C} \ln\left(\frac{C*BI + R_{2,i}}{C*BX + R_{2,i+1}}\right)$	8
$+ K \tan^{-1}\left(\frac{a^2 + Y_1^2 + Y_1 R_{1,i+1}}{Z_o*BX}\right)$	9
$\left. + K \tan^{-1}\left(\frac{a^2 + Y_2^2 + Y_2 R_{x,i+1}^2}{Z_o*BX}\right) \right]$	10

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$$- K \tan^{-1}\left(\frac{a^2+Y_1^{\,2}+Y_1R_{1,i}}{Z_o*BI}\right) \qquad 11$$

$$- K \tan^{-1}\left(\frac{a^2+Y_2^{\,2}+Y_2R_{2,i+1}}{Z_o*BI}\right). \qquad 12$$

$$\text{(G20)}$$

Note that * is used to indicate multiplication involving the two-letter variables BI and BX.

The first four terms of equation (G20) give the gravity field of a standard 2-dimensional Talwani prism. In the 2-dimensional limit, terms 5 through 12 either equal zero for each segment of the polygon or sum to zero around the polygon. Equation (G20) is evaluated in subroutine GRAV on p. 35.

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The vertical gravity field g(J) at field point J due to body I is given by the linear equation

g(J)=G*RSUM(J,IBOD)*RHO(IBOD), (G21)

where G is the universal gravitation constant. RSUM(J,IBOD) is the geometrical factor computed in equation (G20) relating the field point J with body IBOD, and RHO(IBOD) is the density of body IBOD. (Multiple letter variables, * for multiplication, and parentheses for indexing are borrowed from FORTRAN to enable the reader to relate the text to the computer program.) The gravity fields of multiple bodies are additive, so the following system of linear equations applies for multiple bodies and multiple field points.

$$\begin{bmatrix} g(1) \\ g(2) \\ \cdot \\ \cdot \\ \cdot \\ g(NUMX) \end{bmatrix} = G \begin{bmatrix} RSUM(1,1) & RSUM(1,2)\ldots\ldots & RSUM(1,NBODS) \\ RSUM(2,1) & RSUM(2,2)\ldots\ldots & RSUM(2,NBODS) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ RSUM(NUMX,1) & RSUM(NUMX,2)\ldots & RSUM(NUMX,NBODS) \end{bmatrix} \begin{bmatrix} RHO(1) \\ RHO(2) \\ \cdot \\ \cdot \\ \cdot \\ RHO(NBODS) \end{bmatrix}$$

(G22)

For example, at field point 1,

g(1)=G[RSUM(1,1)*RHO(1)+RSUM(1,2)*RHO(2)+...+RSUM(1,NBODS)*RHO(NBODS)].

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In the forward mode RHO(1) through RHO(NBODS) are specified and GRV(1) through GRV(NUMX) are calculated directly. In the inverse mode observed values of GOBS(1) through GOBS(NUMX) are input to the subroutine FITG and the unknowns, RHO(1) through RHO(NBODS) are determined by the method of linear least squares (Subroutine LLSQ, International Business Machines, 1968, p. 160-163), provided that NUMX, the number of observations, is greater than or equal to the number of bodies with unknown density. A hybrid mode is also available, in which RHO is specified and forward calculations performed for the first IBOD-1 bodies. An inverse solution is subsequently performed for the remaining bodies IBOD through NBODS to fit the difference between the observed field and the field calculated for bodies 1 through IBOD-1.

The calculations for the magnetic case are similar to those for the gravity case but complicated by the vector nature of both induced and remanent magnetization. In the forward magnetic calculation the x, y, and z components of induced magnetization are added to the respective components of remanent magnetization in each body before calculation of the resultant fields. In the inverse magnetic calculation, two independent calculations are made assuming pure remanent magnetization and pure susceptibility. The combined effect of susceptibility and remanence can be examined by performing a forward calculation using an assumed susceptibility followed by a repeat, inverse calculation for the same body to determine the remanent magnetization required to fit the residual left after the forward calculation.

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In the case of pure induced magnetization, the approximate total magnetic field anomaly T(J) at field points J=1 through J=NUMX from bodies 1 through NBODS is given by

$$\begin{bmatrix} \Delta T(1) \\ \Delta T(2) \\ \cdot \\ \cdot \\ \cdot \\ \Delta T(3) \end{bmatrix} = \begin{bmatrix} a(1,1) & a(1,2) \ldots\ldots & a(1,NBODS) \\ a(2,1) & a(2,2) \ldots\ldots & a(2,NBODS) \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ a(NUMX,1) & a(NUMX,2) \ldots & a(NUMX,NBODS) \end{bmatrix} \begin{bmatrix} SUS(1) \\ SUS(2) \\ \cdot \\ \cdot \\ \cdot \\ SUS(NBODS) \end{bmatrix},$$

(M19)

where, from equations (M2a) to (M2c) and (M18),

a(J,I)=MX*(CHX*PXSUM(J,I)+CHZ*QSUM(J,I))
+MY*CHY*(PZSUM(J,I)-PXSUM(J,I))
+MZ*(CHX*QSUM(J,I)-CHZ*PZSUM(J,I)).

PXSUM(J,IBOD), PZSUM(J,IBOD), and QSUM(J,IBOD), are the geometrical factors computed by subroutine MAG following equations (M12) to (M15).

CHX=2cosIcosA, CHY=2cosIsinA, and CHZ=2sinI, (M20)

where I is the inclination, A the declination, MX the x-component, MY the y-component, and MZ the z-component of the Earth's magnetic field, SUS(IBOD) is the susceptibility of body IBOD. In the inverse mode observed values of TOBS(1) through TOBS(NUMX) are input to entry FITSUS of subroutine FITMAG and the unknowns, SUS(1) through SUS(NBODS), are determined by linear least squares. As in the gravity case, NUMX must be greater than NBODS.

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In the case of pure remanent magnetization, the number of linear equations is tripled by the need to solve independently for the x-, y-, and z- components of magnetization. Equation (M21) expresses the total field anomaly T(J) at fieldpoints J=1 through NUMX from bodies IBOD=1 through NBODS each with magnetization components MX(IBOD), MY(IBOD), and MZ(IBOD). CHX, CHY, CHZ, PXSUM, PYSUM, and PZSUM are the same as described above.

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$$
\begin{bmatrix} T(1) \\ T(2) \\ \cdot \\ \cdot \\ \cdot \\ T(3) \end{bmatrix}
=
\begin{bmatrix}
\alpha(1,1) & \alpha(1,2)\ldots\ldots\alpha(1,NBODS) & \beta(1,1) & \beta(1,2)\ldots\ldots\beta(1,NBODS) & \gamma(1,1) & \gamma(1,2)\ldots\ldots\gamma(1,NBODS) \\
\alpha(2,1) & \alpha(2,2)\ldots\ldots\alpha(2,NBODS) & \beta(2,1) & \beta(2,2)\ldots\ldots\beta(2,NBODS) & \gamma(2,1) & \gamma(2,2)\ldots\ldots\gamma(2,NBODS) \\
\vdots & \vdots \qquad \vdots & \vdots & \vdots \qquad \vdots & \vdots & \vdots \qquad \vdots \\
\alpha(NUMX,1) & \alpha(NUMX,2)\ldots\alpha(NUMX,NBODS) & \beta(NUMX,1) & \beta(NUMX,2)\ldots\beta(NUMX,NBODS) & \gamma(NUMX,1) & \gamma(NUMX,2)\ldots\gamma(NUMX,NBODS)
\end{bmatrix}
\cdot
\begin{bmatrix} MX(1) \\ MX(2) \\ \cdot \\ \cdot \\ \cdot \\ MX(NBODS) \\ MY(1) \\ MY(2) \\ \cdot \\ \cdot \\ \cdot \\ MY(NBODS) \\ MZ(1) \\ MZ(2) \\ \cdot \\ \cdot \\ \cdot \\ MZ(NBODS) \end{bmatrix}
\qquad (M21)
$$

where $\Delta T(J)$ is the observed total field anomaly at field point J,

$\alpha(J,IBOD) = CHX*PXSUM(J,IBOD)+CHZ*QSUM(J,IBOD)$,

$\beta(J,IBOD) = CHY*(PZSUM(J,IBOD)-PXSUM(J,IBOD))$, and

$\gamma(J,IBOD) = CHX*QSUM(J,IBOD)-CHZ*PZSUM(J,IBOD)$.

In some cases the system of equations (M21) is ill-conditioned. For example, if the y-axis is oriented towards magnetic north at the magnetic equator, $CHX=2\cos 0^{o}\cos 90^{o}=0$, and $CHZ=2\sin 0^{o}=0$. No solution is possible for MX or MZ, and the inverse solution is aborted. If the Earth's field is vertical, $CHY=2\cos 90^{o}\sin A=0$, or if the Earth's field is parallel to the x-axis, $CHY=2\cos I\sin 0^{o}=0$. If a body is very long in both Y directions (2-dimensional), PZSUM-PXSUM=0. In these three cases, the equations can be inverted for MX and MZ but not MY. Entry FITMVT of subroutine FITMAG automatically solves for MX, MY, and MZ if it can, or, in the case of CHY=0, solves for MX and MZ alone. The user should be aware that ill-conditioned equations, leading to inaccurate results, may occur for geometries approaching the pathologic cases described above. No warning will be given unless LLSQ actually fails. If LLSQ fails due to ill-conditioned equations when solving for MX, MY, and MZ, a second attempt is automatically made to solve for MX and MZ alone. To solve for two or three components of magnetization, NUMX must be equal to or greater than two or three times the number of bodies with unknown magnetization.

As in the gravity case, magnetic calculations can operate in a hybrid mode, in which forward calculations using remanent magnetization or susceptibility or both for bodies 1 through IBOD-1 are followed by inverse calculations to find the susceptibility of all the remaining bodies, the remanent magnetization of all the remaining bodies, or both.

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OPERATION OF THE PROGRAM

Figure 5 is a flow diagram for the main program 2HDPOT and

Figure 5.—NEAR HERE

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subroutine FIELD. The flow diagram is somewhat generalized. Most output operations have been omitted. The diagram has been drawn as if both magnetic and gravity calculations were always performed, whereas the program can branch to do gravity calculations or magnetic calculations alone. Flow diagrams are omitted for most subroutines on the assumption that their operations can be deciphered from the Fortran code.

Following is a listing of the program and all subroutines, including IBM subroutine LLSQ (International Business Machine, 1968, p. 160-163). The main program is divided into three parts. The first part, aided by subroutine SETUP, sets up the profile geometry and makes regional corrections to the observed magnetic and gravity profiles. The second part inputs the body geometries and computes geometrical factors in the subroutines GRAV and MAG. The third part calls subroutine FIELD, which computes magnetic and gravity fields in the forward mode, or calls subroutine FITGRV and FITMAG to compute them in the inverse mode, and subroutine PLOTER, which plots the results.

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Data may be input in either the formatted or the namelist mode. In most cases, it is easiest to create a formatted input file on card or disk. Modifications to the body subsequent to the first run can be made using the namelist facility or by modifying the formatted input file. Specifications for formatted data input are included along with sample data sets beginning on page 48. Specifications for namelist data input, and a sample of its use, begin on page 57. Tests of the program, with sample data sets for inverse solutions, begin on page 63.

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```
C...PROGRAM 2HDPOT. 2 1/2 DIMENSIONAL POTENTIAL FIELD CALCULATIONS...
C...CALCULATION OF GRAVITY AND MAGNETIC ANOMALIES ALONG PROFILES WITH
C...END CORRECTIONS AND INVERSE SOLUTION FOR DENSITY AND MAGNETIZATION.
C...BY JOHN W. CADY, U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225.
C...APRIL 23, 1976.
C...DIMENSIONED FOR 50 FIELD POINTS, 10 BODIES, 15 CORNERS PER BODY.
CT...CT'S COMMENT OUT STATEMENTS INTENDED FOR INTERACTIVE
C...SYSTEMS. JOHN CADY. 11/15/76
      DIMENSION GRV(50),TOT1(50),TOT2(50),GIN(50),TIN(50)
      DIMENSION GOUT(50),TOUT(50),VER(50)
      DIMENSION X(50),ELEV(50),TOPO(50),GOBS(50),TOBS(50)
      DIMENSION XCTOPO(99),ZCTOPO(99)
      DIMENSION PXSUM(50,10),PZSUM(50,10),QSUM(50,10),RSUM(50,10)
      DIMENSION Y1(10),Y2(10),YMAG(10),NEWBOD(10)
      DIMENSION XCORNR(15,10),ZCORNR(15,10),NCORNR(10)
      DIMENSION HEADER(20),XZUNIT(2)
      DIMENSION  COW(50),HORSE(50)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      NAMELIST/PROFIL/X,NUMX,HIMAG,XZUN,GCONS,TCONS,
     1 AZMUTH,FLDDEC,FLDINC,FLD,NLPLT,KSPL
      NAMELIST/BODS/KINDFP,NBODS,NEWBOD,Y1,Y2,YMAG,NCORNR,XCORNR,
     1 ZCORNR,IO
      DATA HIMAG/0./,XZUN/'  '/,AZMUTH/0./,FLDDEC/0./,FLDINC/0./,FLD/0./
      DATA (Y1(I),I=1,10),(Y2(I),I=1,10),(YMAG(I),I=1,10)/30*0.0/
      DATA (NEWBOD(I),I=1,10),(NCORNR(I),I=1,10)/20*0/
      DATA (HEADER(I),I=1,20)/20*'  '/,IO/6/,MODE/0/
      DATA (TOT2(I),I=1,50),(GIN(I),I=1,50),(TIN(I),I=1,50)/150*0./
      DATA (TOBS(I),I=1,50),(TOUT(I),I=1,50),(GOUT(I),I=1,50)/150*0./
      DATA (TOPO(I),I=1,50),(GRV(I),I=1,50),(TOT1(I),I=1,50)/150*0./
      DATA (VER(I),I=1,50)/50*0./,(GOBS(I),I=1,50)/50*0./
      DATA GERR/0./,T1ERR/0./,T2ERR/0./
      DATA ITI/5/,ITO/6/,IDI/7/,IDO/8/
7     CONTINUE
C                    *** PART ONE ***
C*****************SETUP PROFILE GEOMETRY***************************
C...TERMINAL INPUT ITI=5, TERMINAL OUTPUT ITO=6
C...DISK INPUT IDI=7, DISK OUTPUT IDO=8
       WRITE(ITO,700)IDO,ITO
700   FORMAT(" FOR BULK OUTPUT ON DSK TYPE ",I2,". ON TTY TYPE ",I2,":")
       READ(ITI,7000) IO
7000   FORMAT(I1)
       WRITE(ITO,701)
701   FORMAT(' FOR FORMATED INPUT,TYPE 0. NAMELIST INPUT,TYPE 5:')
       READ(ITI,7000) MODE
      IF(MODE.EQ.0) GO TO 9
      WRITE(ITO,702)
702   FORMAT('0NAMELIST ENTRY OF "PROFIL" LIST:'/
     1   X,NUMX,HIMAG,XZUN,AZMUTH,FLDDEC,FLDINC,FLD,GCONS,TCONS,
     1 NLPLT,KSPL')
      READ(ITI,PROFIL)
C...DUMMY STATEMENTS TO CIRCUMVENT BUG IN NAMELIST.
      DO 888 I=1,NUMX
888   DUMMY=DUMMY+X(I)
      DUMMY=DUMMY-(HIMAG+XZUN+AZMUTH+FLDDEC+FLDINC+FLD+GCONS+TCONS)
      WRITE(IO,PROFIL)
      WRITE(ITO,800)
800   FORMAT(' TYPE HEADER UP TO 80 CHAR.')
      READ(ITI,900) (HEADER(I),I=1,20)
      GO TO 12
C***   DATA UNIT 1   ***   MANDATORY   ***
9     READ(IDI,900) (HEADER(I),I=1,20)
900   FORMAT (20A4)
      IELEV=0
      NTOPO=0
      ISW=0
      WRITE(IO,900) (HEADER(I),I=1,20)
      IF(IO.EQ.IDO) WRITE(ITO,900) (HEADER(I),I=1,20)
C***   DATA UNITS 2 THRU 6 READ IN SETUP   ***   2 IS MANDATORY   ***
11    CALL SETUP(NUMX,X,ELEV,TOPO,XCTOPO,ZCTOPO,NTOPO,
     1 AZMUTH,FLDDEC,FLDINC,FLD)
C...INPUT VARIOUS PARAMETERS.
C***   DATA UNIT 7   ***   MANDATORY   ***
      READ(IDI,1100) KINDFP,NGIN,NTIN,NGOBS,NTOBS,INY,
     1 IREG,IRET,IWIDE,NLPLT,GCONS,TCONS,XZUN,KSPL,RHOBOU
1100  FORMAT(10I5,2F10.1,A2,I2,F6.2)
C...FROM DIST UNIT SYMBOL XZUN, CALCULATE GFAC, X-AXIS LABEL.
      WRITE(IO,1101)
1101  FORMAT(/,' KINDFP NGIN NTIN NGOBSNTOBS INY IREGIRET IWIDENLPLT',
     1 ' GCONS    TCONS   XZUN KSPL RHOBOU')
      WRITE(IO,1100) KINDFP,NGIN,NTIN,NGOBS,NTOBS,INY,IREG,IRET,
     1 IWIDE,NLPLT,GCONS,TCONS,XZUN,KSPL,RHOBOU
      WRITE (IO,1102)
1102  FORMAT('0  I',8X,'X',9X,'TOPO',6X,'GRAVTOPO',4X,'MAGELEV',8X,
     1'GIN',9X,'GOBS',7X,'TIN',7X,'TOBS'/'0')
C...INPUT OBSERVED OR REGIONAL FIELDS.
C***   DATA UNIT 8   ***   OPTIONAL   ***
      IF(NGIN.GT.0) CALL ELEVER(GIN,NUMX,X,NGIN,COW,HORSE,KSPL)
C***   DATA UNIT 9   ***   OPTIONAL   ***
      IF (NTIN.GT.0) CALL ELEVER(TIN,NUMX,X,NTIN,COW,HORSE,KSPL)
C***   DATA UNIT 10   ***   OPTIONAL   ***
      IF (NGOBS.GT.0) CALL ELEVER (GOBS,NUMX,X,NGOBS,COW,HORSE,KSPL)
C***   DATA UNIT 11   ***   OPTIONAL   ***
      IF (NTOBS.GT.0) CALL ELEVER (TOBS,NUMX,X,NTOBS,COW,HORSE,KSPL)
      NOBS=MAX0(NGOBS,NTOBS)
12    CALL UNITER(XZUN,GFAC,XZUNIT)
      IF(IWIDE.LT.60 .AND. IO.EQ.IDO) IWIDE=111
      IF(IWIDE.LT.60 .AND. IO.EQ.ITO) IWIDE=80
      IF (NLPLT.EQ.0) NLPLT=NUMX
      DO 13 I=1,NUMX
      COW(I)=TOPO(I)
      IF(TOPO(I).LT.0.) TOPO(I)=0.
13    WRITE(IO,1300) I,X(I),COW(I),TOPO(I),ELEV(I),GIN(I),GOBS(I),
     1 TIN(I),TOBS(I)
1300  FORMAT (I5,8F12.4)
C...REGIONAL CORRECTIONS FOR IREG OR IRET =0 (DEFAULT REGIONAL PROCEDURE)
      IF(KINDFP.EQ.3 .OR. IREG.NE.0) GO TO 16
C...REMOVE REGIONAL GIN+GCONS FROM GOBS. MODEL RESIDUAL.
      DO 15 I=1,NUMX
15    GOBS(I)=GOBS(I)-GIN(I)-GCONS
16    IF(KINDFP.EQ.2 .OR. IRET.NE.0) GO TO 21
C...REMOVE REGIONAL TIN+TCONS FROM TOBS. MODEL RESIDUAL.
      DO 17 I=1,NUMX
17    TOBS(I)=TOBS(I)-TIN(I)-TCONS
C...REGIONAL CORRECTION FOR IREG OR IRET =1 (SPECIAL)
21    IF(KINDFP.EQ.3 .OR. IREG.EQ.0) GO TO 23
C...GIN+GCONS ARE STARTING REGIONAL TO ADD TO COMPUTED GRAVITY.
      DO 22 I=1,NUMX
22    GRV(I)=GIN(I)+GCONS
23    IF(KINDFP.EQ.2 .OR. IRET.EQ.0) GO TO 31
C...TIN+TCONS ARE STARTING REGIONAL TO ADD TO COMPUTED MAGNETICS.
      DO 24 I=1,NUMX
      TOT1(I)=TIN(I)+TCONS
24    TOT2(I)=TOT1(I)
```

```
C                               *** PART TWO ***
C*****************COMPUTE GEOMETRICAL FACTORS*********************
C...INPUT NUMBER OF BODIES AND NUMBER OF CORNERS FOR EACH.
31      IF(MODE.LE.4) GO TO 37
33      WRITE(ITO,3300)
3300    FORMAT('0NAMELIST ENTRY OF "BODS" LIST TO ALTER BODY GEOMETRY:'/
       1 '    NEWBOD,Y1,Y2,YMAG,NCORNR,XCORNR,ZCORNR,KINDFP,NBODS,IO'/
       2 ' SET NEWBOD(I)=0 IF YOU WANT TO MODIFY GEOM OF BODY I.')
        READ(ITI,BODS)
C...DUMMY STATEMENTS TO CIRCUMVENT BUG IN NAMELIST.
        DUMMY=DUMMY+KINDFP+NBODS
        DO 333 I=1,NBODS
        DUMMY=DUMMY-NEWBOD(I)+Y1(I)-Y2(I)+YMAG(I)+NCORNR(I)
        DO 333 K=1,NCORNR(I)
333     DUMMY=DUMMY+XCORNR(K,I)-ZCORNR(K,I)
        WRITE(IO,BODS)
        GO TO 47
C***     DATA UNIT 12     ***     MANDATORY     ***
37      READ(IDI,3700) NBODS, (NCORNR(I),I=1,NBODS)
3700     FORMAT (16I5)
        WRITE(IO,3701)
3701    FORMAT(/' NBODS, NCORNR(I),I=1,NBODS')
        WRITE (IO,3700) NBODS, (NCORNR(I),I=1,NBODS)
        IF(INY.EQ.0) GO TO 47
C...INPUT STRIKE HALF-LENGTHS.
C***     DATA UNIT 13 (3 READ STATEMENTS)     ***     OPTIONAL     ***
3702    FORMAT(8G10.2)
        WRITE(IO,3703)
3703    FORMAT(' Y1(I),I=1,NBODS;Y2(I);YMAG(I)')
        READ(IDI,3702)  (Y1(I),I=1,NBODS)
        WRITE(IO,3702)  (Y1(I),I=1,NBODS)
        READ(IDI,3702)  (Y2(I),I=1,NBODS)
        WRITE(IO,3702)  (Y2(I),I=1,NBODS)
        READ(IDI,3702)  (YMAG(I),I=1,NBODS)
        WRITE(IO,3702)  (YMAG(I),I=1,NBODS)
47      DO 55 I=1,NBODS
        IF(MODE.LE.4) NEWBOD(I)=0
        IF(Y1(I).EQ.Y2(I)  .AND. Y1(I).NE.0.) WRITE(IO,4700)
4700    FORMAT (' GRAV BODY ',I3,' IS DEGENERATE. Y1=Y2.')
        NEWT=NCORNR(I)
        IF(MODE.GT.4) GO TO 51
C...INPUT X AND Z CORNERS FOR I'TH BODY.
C***     DATA UNIT 14 (2 READ STATEMENTS)     ***     MANDATORY     ***
        READ(IDI,3702)  (XCORNR(K,I),K=1,NEWT)
        READ(IDI,3702)  (ZCORNR(K,I),K=1,NEWT)
C...PLACE BODY CORNER AT TOPO SURFACE FOR CODE 777.
51      DO 53 K=1,NEWT
53      IF (ZCORNR(K,I).EQ.777.) CALL INTRPL(NTOPO,XCTOPO,ZCTOPO,
       1 XCORNR(K,I),ZCORNR(K,I))
        WRITE (IO,5300) I
5300    FORMAT ('0BODY',I5,   '-- COORDINATES OF CORNERS')
        WRITE (IO,5500)  (XCORNR(K,I),K=1,NEWT)
55      WRITE (IO,5500)  (ZCORNR(K,I),K=1,NEWT)
5500    FORMAT (1H ,8F10.4)
        IF(KINDFP.NE.3) CALL GRAV
       1 (NUMX,X,ELEV,NBODS,NCORNR,XCORNR,ZCORNR,Y1,Y2,RSUM,NEWBOD)
C      1 (NUMX,X,ELEV,NBODS,NCORNR,XCORNR,ZCORNR,Y1,Y2,RSUM,NEWBOD)
        IF(KINDFP.NE.2)
       1 CALL MAG(NUMX,X,ELEV,NBODS,NCORNR,XCORNR,ZCORNR,YMAG,
       2 PXSUM,PZSUM,QSUM,NEWBOD)
C...NEWBOD(I)=1 MEANS GEOM FACTORS HAVE BEEN COMPUTED FOR BODY I
C...AND WILL BE RECOMPUTED ON A SUBSQ PASS ONLY IF NEWBOD(I)=0.
        DO 57 I=1,NBODS
57      NEWBOD(I)=1
        X1=X(1)
```

```
C                               *** PART THREE ***
C**************COMPUTE FIELDS FORWARD AND/OR INVERSE******************
C***     DATA UNIT 15 READ IN FIELD     ***     MANDATORY     ***
61      CALL FIELD(NUMX,X,KINDFP,NBODS,MODE,PXSUM,PZSUM,QSUM,RSUM,
       1 AZMUTH,FLDDEC,FLDINC,FLD,NXTKFP,KPLOT,KOUT,IWIDE,
       2 TOPO,GRV,VER,TOT1,TOT2,GOBS,TOBS,GFAC,RHOBOU,YMAG)
        GMERR=0.
        GMSQ=0.
        T1MERR=0.
        T1MSQ=0.
        T2MERR=0.
        T2MSQ=0.
        WRITE (IO,6100)
6100    FORMAT('0        X         GOBS        GRV        GERR        TOBS        TOT1
       1     T1ERR        TOT2        T2ERR        GOUT        TOUT ')
C...COMPUTE RESIDUAL ERRORS
        DO 67 I=1,NUMX
        IF(KINDFP.EQ.3) GO TO 65
        GERR=GRV(I)-GOBS(I)
        IF(KOUT.EQ.0 .OR. KOUT.EQ.-2) GOUT(I)=GERR
        GMSQ=GMSQ+GERR*GERR
        GMERR=GMERR+GERR
        IF(KINDFP.EQ.2) GO TO 66
65      T1ERR=TOT1(I)-TOBS(I)
        IF(KOUT.EQ.0 .OR. KOUT.EQ.-2) TOUT(I)=T1ERR
        T1MSQ=T1MSQ+T1ERR*T1ERR
        T1MERR=T1MERR+T1ERR
        T2ERR=TOT2(I)-TOBS(I)
        T2MSQ=T2MSQ+T2ERR*T2ERR
        T2MERR=T2MERR+T2ERR
66      WRITE (IO,6500) X(I),GOBS(I),GRV(I),GERR,TOBS(I),TOT1(I),T1ERR,
       1 TOT2(I),T2ERR,GOUT(I),TOUT(I)
6500     FORMAT  (11(1PE10.2))
67      CONTINUE
        T1MSQ=SQRT(T1MSQ/NUMX)
        T2MSQ=SQRT(T2MSQ/NUMX)
        GMSQ=SQRT(GMSQ/NUMX)
        GMERR=GMERR/NUMX
        T1MERR=T1MERR/NUMX
        T2MERR=T2MERR/NUMX
        KO=IO
681     IF(KINDFP.NE.3) WRITE(KO,6700) GMERR,GMSQ
6700     FORMAT('0MEAN ERROR OF G=',1PE10.2,' ,RMS ERROR OF G= ',1PE10.2,
       1'MGAL.')
        IF(KINDFP.NE.2) WRITE(KO,6701) T1MERR,T1MSQ,T2MERR,T2MSQ
6701    FORMAT('0MEAN ERROR OF TOT1=',1PE10.2,' ,RMS ERROR OF TOT1=',
       1 1PE10.2,'GAMMAS.',/,'0MEAN ERROR OF TOT2=',1PE10.2,
       2 ' ,RMS ERROR OF TOT2=',1PE10.2,' GAMMAS.',//)
        IF(KO.EQ.ITO) GO TO 682
C...EXTRA OUTPUT ON TERMINAL IF BULK OUTPUT IS ON DISK.
        KO=ITO
        GO TO 681
682     IF(KOUT.EQ.0 .OR. KOUT.EQ.-2) GO TO 75
        IF(KINDFP.EQ.3 .OR. IREG.NE.0) GO TO 71
        DO 69 I=1,NUMX
69      GOUT(I)=GRV(I)+GIN(I)+GCONS
71      IF(KINDFP.EQ.2 .OR. IRET.NE.0) GO TO 75
        DO 73 I=1,NUMX
73      TOUT(I)=TOT1(I)+TIN(I)+TCONS
75      WRITE(IO,900)  (HEADER(I),I=1,20)
        IF(KPLOT.GE.0) CALL PLOTER (KINDFP,NUMX,X,ELEV,TOPO,GRV,GOBS,
       1GOUT,TOT1,TOT2,TOBS,TOUT,NGOBS,NTOBS,ISW,IWIDE,NLPLT,KPLOT,HEADER,
       2XZUNIT)
```

```
      IF(KOUT.GE.0) GO TO 77
      IF(KINDFP.EQ.3) GO TO 76
      WRITE(IDO,7600) (X(I),I=1,NUMX)
 7600 FORMAT(8F10.2)
      WRITE(IDO,7600) (GOUT(I),I=1,NUMX)
   76 IF(KINDFP.EQ.2) GO TO 77
      WRITE(IDO,7600) (X(I),I=1,NUMX)
      WRITE(IDO,7600) (TOUT(I),I=1,NUMX)
   77 IF(NXTKFP.NE.0) KINDFP=NXTKFP
      IF (MODE.GE.0) GO TO 81
      WRITE(IO,7700) MODE
 7700  FORMAT('0MODE= ',I3,'.  GRV AND VER, TOT1, TOT2 ARE RE-ZEROED.')
      MODESW=MODE
      MODE=-MODE
      DO 79 I=1,NUMX
      TOT1(I)=0.
      TOT2(I)=0.
      VER(I)=0.
   79 GRV(I)=0.
   81 GO TO (87,85,83,93,87,85,83),MODE
   83 WRITE(IO,8300)
 8300 FORMAT ('0THE COMPUTATION WILL RECOMMENCE WITH NEW MAG AND DENS,
     1BUT WITH THE SAME BODIES AND FIELD POINTS')
      GO TO 61
   85 WRITE(IO,8500)
 8500 FORMAT ('0  THE COMPUTATION WILL RECOMMENCE WITH NEW BODIES, DENSI
     1TIES, AND MAGNETIZATIONS BUT WITH THE SAME FIELD POINTS')
C...GOING TO 21 RE-ESTABLISHES ORIGINAL INPUT GRV,TOT1,TOT2.
      IF(MODESW.LT.0 .AND. (IREG.NE.0 .OR. IRET.NE.0))
     1 GO TO 21
      GO TO 31
   87 WRITE(IO,8700)
 8700 FORMAT ('0 THE COMPUTATION WILL RECOMMENCE AT THE VERY BEGINNING W
     1ITH THE COMPUTATION OF NEW FIELD POINTS')
      DO 89 I=1,NUMX
      ELEV(I)=0.
      TOPO(I)=0.
      GIN(I)=0.
      TIN(I)=0.
      GOBS(I)=0.
   89 TOBS(I)=0.
      DO 91 I=1,NBODS
      NEWBOD(I)=0.
      Y1(I)=0.
      Y2(I)=0.
   91 YMAG(I)=0.
      GO TO 7
   93 WRITE(IO,9300)
      IF(IO.EQ.IDO) WRITE(ITO,9300)
CCC9300  FORMAT('0THE COMPUTATION IS COMPLETE.')
 9300 FORMAT('0 THE COMPUTATION IS COMPLETE.TYPE(MODE)-OR+ 5,6,7 TO',
     1 ' ADJUST PARAMETERS',/,' BY NAMELIST: -7=PHYS',
     2 ' PROP, -6=BODY GEOM + PHYS PROP, -5=EVERYTHING;'/
     3 ' MODE NEG TO ZERO GRV,VER,TOT1,TOT2, ZERO TO STOP.',/
     4 ' POS TO RETAIN PRESENT VALUES AS INIT VALUES IN SUBSQ RUN.')
      READ(ITI,1100) MODE
      IF (MODE.EQ.0) STOP
      GO TO 77
      END
```

```
      SUBROUTINE SETUP(NUMX,X,ELEV,TOPO,XCTOPO,ZCTOPO,NTOPO,
     1 AZMUTH,FLDDEC,FLDINC,FLD)
C...SUBROUTINE SETS UP PROFILE GEOMETRY.
C...TOPO IS FLD PT Z FOR GRAV.  ELEV IS FLD PT Z FOR MAG.
      DIMENSION X(1),ELEV(1),TOPO(1),XCTOPO(1),ZCTOPO(1)
      DIMENSION COW(50),HORSE(50)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
C***  DATA UNIT 2    ***    MANDATORY    ***
   10 READ(IDI,100)XZERO,DELX,AZMUTH,FLDDEC,FLDINC,FLD,HIMAG,NUMX,NTOPO
     1,IELEV
      WRITE(IO,1001)
 1001 FORMAT('0 XZERO      DELX      AZMUTH     FLDDEC     FLDINC     FLD
     1      HIMAG  NUMX,NTOPO,IELEV')
  100 FORMAT (7F10.2,I4,2I3)
      WRITE(IO,100)XZERO,DELX,AZMUTH,FLDDEC,FLDINC,FLD,HIMAG,NUMX,NTOPO
     1,IELEV
      IF(NUMX.GT.0) GO TO 3
      NUMX=-NUMX
C...FLD PT X'S READ FROM CARDS
C***  DATA UNIT 3    ***    OPTIONAL    ***
      READ(IDI,101)  (X(I),I=1,NUMX)
      WRITE(IO,104)
  104 FORMAT (' DELX,XZERO DISREGARDED. X-ARRAY READ FROM CARDS.' )
      GO TO 7
C...CREATE EQUALLY SPACED FLD PT X'S.
    3 DO 5 I=1,NUMX
    5 X(I)=XZERO+(I-1)*DELX
C...INTERPOLATE TOPOGRAPHY
C***  DATA UNIT 4    ***    OPTIONAL    ***
    7 IF(NTOPO.GT.0) CALL ELEVER(TOPO,NUMX,X,NTOPO,XCTOPO,ZCTOPO,0)
      IF (IELEV) 11,13,12
C...READ EQUALLY SPACED ELEV (USUALLY AEROMAG).
C***  DATA UNIT 5    ***    OPTIONAL    ***
   11 READ(IDI,101)  (ELEV(I),I=1,NUMX)
      WRITE(IO,101)  (ELEV(I),I=1,NUMX)
  101 FORMAT (8G10.2)
C...ADD CONSTANT TO ELEV (USUALLY AEROMAG).
      DO 1101 I=1,NUMX
 1101 ELEV(I)=ELEV(I)+HIMAG
      RETURN
   12 IF(IELEV-2) 102,103,103
C...ELEV CREATED FROM TOPO+CONST (GROUND MAG OR DRAPED AEROMAG).
  102 DO 1201 I=1,NUMX
 1201 ELEV(I)=TOPO(I)+HIMAG
      RETURN
C...INTERPOLATE ELEV (USUALLY AEROMAG).
C***  DATA UNIT 6    ***    OPTIONAL    ***
  103 CALL ELEVER (ELEV,NUMX,X,IELEV,COW,HORSE,0)
      RETURN
C...ELEV=CONST (AERO OR GROUND MAG).
   13 DO 1301 I=1,NUMX
 1301 ELEV(I)=HIMAG
      RETURN
      END
```

```
      SUBROUTINE GRAV(NUMX,X,ELEV,NBODS,NCORNR,XCORNR,ZCORNR,
     1Y1,Y2,RSUM,NEWBOD)
C....COMPUTES GEOMETRICAL FACTORS FOR "2 1/2 DIMENSIONAL" GRAVITY
C.....PRISM. AFTER PROG 2DGRAV BY DAVE CAMPBELL (2/28/75).
C...MUST STEP CLOCKWISE AROUND BODY.
C       DIMENSIONED FOR 5Ø FLD PTS, 1Ø BODIES, 15 CORNERS PER BODY.
C...NUMX: NUMBER OF FIELDPOINTS.
C...X: ARRAY OF FIELD POINT X-VALUES.
C...ELEV: ARRAY OF FIELD POINT ELEVATIONS.
C...NBODS: NUMBER OF BODIES.
C...NCORNR: 1-DIM ARRAY CONTAINING NUMBER OF CORNERS IN EACH BODY,
C...   FIRST CORNER COUNTED AGAIN AS LAST CORNER.
C...XCORNR,ZCORNR: 2-DIM ARRAYS CONTAINING CORNERS OF BODIES.
C...   1ST INDEX IS CORNER NUMBER, 2ND. INDEX IS BODY NUMBER.
C...Y1,Y2: 1-DIM ARRAYS OF Y COORDINATES OF BODY ENDS.
C...   Y1 IS NEG, Y2 IS POS FOR A BODY CROSSING THE X-Z PLANE.
C...RSUM: 2-DIM OUTPUT ARRAY CONTAINING GEOMETRICAL FACTORS WHICH,
C...   WHEN MULTIPLIED BY DENSITY CONTRAST, GIVE GRAVITY ANOMALY.
C...   1ST INDEX IS FIELD POINT NUMBER, 2ND INDEX IS BODY NUMBER.
C...NEWBOD: 1-DIM ARRAY CONTROLLING CALCULATION OF RSUM.
C...   IF NEWBOD(I)=Ø, DELETE CALCULATION OF RSUM FOR ITH BODY.
      DIMENSION X(1),ELEV(1),RSUM(5Ø,1Ø),NEWBOD(1Ø)
      DIMENSION NCORNR(1),Y1(1),Y2(1),XCORNR(15,1Ø),ZCORNR(15,1Ø)
      DIMENSION VX(15),VZ(15),RSQ(15),R1(15),R2(15)
      PI=3.1415927
      TWOPI=2.*PI
C.....BEGIN BODY LOOP
      DO 5Ø I=1,NBODS
      IF(NEWBOD(I).NE.Ø) GO TO 5Ø
C.....INITIALIZE GEOMETRICAL FACTORS
      DO 3 J=1,NUMX
    3 RSUM(J,I)=Ø.
      NC=NCORNR(I)
      NS=NC-1
      JEND=1
C.....Y1 NORMALLY NEG(ALGEBRAIC Y-COORD) ON INPUT.
C......BECOMES NORMALLY POS(DIST FROM Y-AXIS) FOR CALCULATION.
      YY1=-Y1(I)
      YY2=Y2(I)
C.....INPUT CONVENTION: ZERO Y BECOMES INFINITY.
      IF(YY1.EQ.Ø..AND.YY2.EQ.Ø.) JEND=Ø
      Y1SQ=YY1*YY1
      Y2SQ=YY2*YY2
C.....BEGIN FIELD POINT LOOP
      DO 49 J=1,NUMX
      DO 2Ø I1=1,NC
C.....TRANSLATE ORIGIN TO FIELD POINT AND COMPUTE RADIUS VECTORS TO
C.....BODY CORNERS
      VX(I1)=XCORNR(I1,I)-X(J)
      VZ(I1)=-ZCORNR(I1,I)+ELEV(J)
C.....NOTE ELEV INPUT + UPWARD,ZCORNR INPUT - DOWNWARD,YET PHYSICAL
C.....COORDINATES ARE + DOWNWARD
C.....RSQ IS ARRAY OF SQUARED RADIUS VECTORS TO CORNERS OF POLYGON
C.....R1 AND R2 ARE ARRAYS OF RADIUS VECTORS TO Y1 AND Y2 CORNERS
      RSQ(I1)=VX(I1)*VX(I1)+VZ(I1)*VZ(I1)
      R1(I1)=SQRT(Y1SQ+RSQ(I1))
   2Ø R2(I1)=SQRT(Y2SQ+RSQ(I1))
C.....BEGIN BODY CORNER LOOP
      DO 49 I5=1,NS
      XI=VX(I5)
      XIP1=VX(I5+1)
      ZI=VZ(I5)
      ZIP1=VZ(I5+1)
C.....NO CONTRIBUTIONS FROM VERTICAL SIDES, DEL CALC FOR THEM
      IF(XI.EQ.XIP1) GO TO 49
C.....SET UP GEOMETRY FOR SLOPING SIDES
      DX=XIP1-XI
      DZ=ZIP1-ZI
      EM=DZ/DX
      CSQ=1.+EM*EM
      C=(SQRT(DZ*DZ+DX*DX))/DX
      ZØ=ZI-EM*XI
      A=ZØ/C
      ASQ=A*A
      AK=ZØ/CSQ
      XØ=EM*AK
      BX=XIP1+XØ
      BI=XI+XØ
      CBX=C*BX
      CBI=C*BI
C.....CALCULATION OF STANDARD 2D TERMS
      T1=Ø.
      T2=Ø.
      IF(RSQ(I5+1).GT.Ø.) T1=BX*ALOG(RSQ(I5+1))
      IF(RSQ(I5).GT.Ø.) T2=BI*ALOG(RSQ(I5))
      T3=ATAN2(BX,AK)
      IF(BX.GT.Ø.AND.AK.LT.Ø.) T3=T3-TWOPI
      T4=ATAN2(BI,AK)
      IF(BI.GT.Ø.AND.AK.LT.Ø.) T4=T4-TWOPI
C.....PROGRAM RETURNS ATAN2 IN (-PI,PI), BUT CALCULATION NEEDS.....
C.....T3,T4 IN (-3.*PI/2.,PI/2.)....APPROPRIATE FIXUP HERE.....
33    IF(JEND.EQ.Ø) GO TO 47
C.....TERMS DUE TO TRUNCATED ENDS OF PRISM
      R1I=R1(I5)
      R2I=R2(I5)
      R1IP1=R1(I5+1)
      R2IP1=R2(I5+1)
      T5=BI*ALOG((YY1+R1I)*(YY2+R2I))
      T6=BX*ALOG((YY1+R1IP1)*(YY2+R2IP1))
      T7=YY1/C*ALOG((CBI+R1I)/(CBX+R1IP1))
      T8=YY2/C*ALOG((CBI+R2I)/(CBX+R2IP1))
      FNUM=ASQ+Y1SQ+YY1*R1IP1
      DEN=ZØ*BX
C.....ADD 2.*PI TO ATAN2 VALUES FALLING IN THIRD QUADRANT.....
91    T9=ATAN2(FNUM,DEN)
      IF(FNUM.LT.Ø. .AND. DEN.LT.Ø.) T9=T9+TWOPI
      FNUM=ASQ+Y2SQ+YY2*R2IP1
1Ø1   T1Ø=ATAN2(FNUM,DEN)
      IF(FNUM.LT.Ø. .AND. DEN.LT.Ø.) T1Ø=T1Ø+TWOPI
      FNUM=ASQ+Y1SQ+YY1*R1I
      DEN=ZØ*BI
111   T11=ATAN2(FNUM,DEN)
      IF(FNUM.LT.Ø. .AND. DEN.LT.Ø.) T11=T11+TWOPI
      FNUM=ASQ+Y2SQ+YY2*R2I
121   T12=ATAN2(FNUM,DEN)
      IF(FNUM.LT.Ø. .AND. DEN.LT.Ø.) T12=T12+TWOPI
46    TERMS=T1-T2+2.*AK*(T3-T4)+T5-T6+T7+T8+AK*(T9+T1Ø-T11-T12)
      GO TO 48
47    TERMS=T1-T2+2.*AK*(T3-T4)
C.....MINUS SIGN BEFORE TERMS INDICATES CLOCKWISE INTEGRATION.
48    RSUM(J,I)=RSUM(J,I)-TERMS
49    CONTINUE
5Ø    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MAG(NUMX,X,ELEV,NBODS,NCORNR,XCORNR,ZCORNR,Y,PXSUM,
     1PZSUM,QSUM,NEWBOD)
C......COMPUTES GEOMETRICAL FACTORS FOR "2 1/2 DIMENSIONAL" MAGNETIC
C......PRISM. AFTER R.T. SHUEY AND A.S.PASQUALE(1973), END CORRECTIONS
C......IN MAGNETIC PROFILE INTERPRETATION, GEOPHYSICS, V 38, P.507-512.
C       MUST STEP CLOCKISE AROUND BODY.
C       DIMENSIONED FOR 50 FLD PTS, 10 BODIES, 15 CORNERS PER BODY.
C...NUMX: NUMBER OF FIELDPOINTS.
C...X: ARRAY OF FIELD POINT X-VALUES.
C...ELEV: ARRAY OF FIELD POINT ELEVATIONS.
C...NBODS: NUMBER OF BODIES.
C...NCORNR: 1-DIM ARRAY CONTAINING NUMBER OF CORNERS IN EACH BODY,
C...  FIRST CORNER COUNTED AGAIN AS LAST CORNER.
C...XCORNR,ZCORNR: 2-DIM ARRAYS CONTAINING CORNERS OF BODIES.
C... 1ST INDEX IS CORNER NUMBER, 2ND. INDEX IS BODY NUMBER.
C...Y: 1-DIM ARRAY OF BODY HALF STRIKE-LENGTHS.
C...PXSUM,PZSUM,QSUM: 2-DIM OUTPUT ARRAYS CONTAINING GEOMETRICAL
C...  FACTORS TO BE COMBINED WITH COMPONENTS OF MAGNETIZATION
C...  TO CALCULATE MAGNETIC ANOMALY. 1ST INDEX IS FIELD POINT NUMBER,
C...  2ND INDEX IS BODY NUMBER.
CCC   COMPLEX IM,F(2),FLN,DXIZ,ACLOG,CMPLX
      COMPLEX IM,F(2),FLN,DXIZ,CLOG,CMPLX
      DIMENSION X(1),ELEV(1),NCORNR(1),XCORNR(15,10),ZCORNR(15,10),Y(1)
      DIMENSION PXSUM(50,10),PZSUM(50,10),QSUM(50,10)
      DIMENSION VX(15),VZ(15),VR(15),NEWBOD(10)
      IM=CMPLX(0.0,1.0)
C.....BEGIN BODY LOOP
      DO 50 I=1,NBODS
      IF(NEWBOD(I).NE.0) GO TO 50
C.....INITIALIZE GEOMETRICAL FACTORS
      DO 3 J=1,NUMX
      PXSUM(J,I)=0.
      PZSUM(J,I)=0.
    3 QSUM(J,I)=0.
C.....INPUT CONVENTION: ZERO Y BECOMES 1.E15
      IF(Y(I).EQ.0.) Y(I)=1.E15
      YSQ=Y(I)*Y(I)
      NC=NCORNR(I)
      NS=NC-1
C.....FIELD POINT LOOP
      DO 49 J=1,NUMX
C.....TRANSLATE ORIGIN TO FIELD POINT AND COMPUTE RADII TO ALL BODY
C.....CORNERS
      DO 20 I1=1,NC
      VX(I1)=XCORNR(I1,I)-X(J)
      VZ(I1)=-ZCORNR(I1,I)+ELEV(J)
C.....NOTE ELEV INPUT +UPWARD,ZCORNR INPUT - DOWNWARD,YET PHYSICAL
C.....COORDINATES ARE + DOWNWARD
   20 VR(I1)=SQRT(VX(I1)*VX(I1)+YSQ+VZ(I1)*VZ(I1))
C.....BODY CORNER LOOP
      DO 49 I5=1,NS
      DX=VX(I5+1)-VX(I5)
      DZ=VZ(I5+1)-VZ(I5)
      DXIZ=DX+IM*DZ
      DO 30 I3=1,2
      IV=I5+I3-1
   30 F(I3)=(DXIZ*(1.+VR(IV)/Y(I)))/(VX(IV)+IM*VZ(IV))
     1 +(IM/YSQ)*(VX(IV)*DZ-VZ(IV)*DX)
C...NOTE COMPILER DEPENDENT ERRORS IN COMPLEX ARITHMETIC.
C...ON DEC-10 COMPUTER FUNCTION CLOG MUST BE REPLACED BY ACLOG.
C...ON WATFIV COMPILER CLOG MUST BE USED INSTEAD OF ACLOG.
C..ON OTHER SYSTEMS, TEST TO SEE WHICH COMPLEX LOG FUNCTION WORKS OK.
CCC   FLN=(ACLOG(F(2)/F(1)))/DXIZ
      FLN=(CLOG(F(2)/F(1)))/DXIZ
      Q1=-DX*REAL(FLN)
C     Q1=-DZ*AIMAG(FLN) ALTERNATIVE SOLN FOR Q1
      PX1=DZ*REAL(FLN)
      PZ1=-DX*AIMAG(FLN)
      PXSUM(J,I)=PXSUM(J,I)+PX1
      PZSUM(J,I)=PZSUM(J,I)+PZ1
      QSUM(J,I)=QSUM(J,I)+Q1
   49 CONTINUE
   50 CONTINUE
      RETURN
      END

      COMPLEX FUNCTION ACLOG(Z)
C....FUNCTION TO EVALUATE COMPLEX NATURAL LOG YIELDING
C....PHASE BETWEEN -PI AND PI USING SYSTEM FUNCTION CLOG
C....WHICH YIELDS PHASE BETWEEN 0 AND 2PI.
C...REQUIRED ON DEC-10 COMPILER TO REPLACE CLOG.
C...GIVES WRONG ANSWER ON WATFIV COMPILER.
      COMPLEX Z,CLOG
      ACLOG=CLOG(Z)
      IF(AIMAG(Z).GE.0) RETURN
      ACLOG=ACLOG+(0.,-6.2831853)
      RETURN
      END
```

```
      SUBROUTINE FIELD(NUMX,X,KINDFP,NBODS,MODE,PXSUM,PZSUM,QSUM,RSUM,
     1AZMUTH,FLDDEC,FLDINC,FLD,NXTKFP,KPLOT,KOUT,IWIDE,TOPO,GRV,VER,
     2 TOT1,TOT2,GOBS,TOBS,GFAC,RHOBOU,YMAG)
C...FIELD USES GEOM FACTORS FROM GRAV AND MAG TO COMPUTE FIELDS.
C...FIELD CALLS FITGRV AND FITMAG (WITH ENTRIES FITMVT AND FITSUS)
C...FOR INVERSE SOLUTIONS.  MOVEMENT WITHIN OR OUT OF FIELD IS
C...CONTROLLED BY ISKIP AND MODE READ IN DATA UNIT 15.
      DIMENSION X(1),PXSUM(50,10),PZSUM(50,10),QSUM(50,10),RSUM(50,10)
      DIMENSION TOPO(1),GRV(1),TOT1(1),GOBS(1),TOBS(1),TOT2(1),VER(1)
        DIMENSION COW(50),GOAT(50),ASS(50),YMAG(1),HORSE(50)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      REAL MX,MY,MZ,INC
      DOUBLE PRECISION DBLE,DSQRT
      NAMELIST/PROP/RHO,SUS,REMMAG,REMDEC,REMINC,ISKIP,
     1 NXMODE,NXKNFP,NXKPLT,NXKOUT,NXKFLD,IO
      DATA NXMODE/4/,NXKNFP/0/,NXKPLT/0/,NXKOUT/0/,NXKFLD/0/,ISKIP/0/
C...RADO CONVERTS FROM DEGREES TO RADIANS.
      RADO=0.0174533
C...INITIALIZE FITMAG WITH GEOMETRY OF EARTH'S MAG FIELD.
      INC=RADO*FLDINC
      CINC=COS(INC)
      SINC=SIN(INC)
C...DEC IS + ANGLE IF EARTH'S FIELD DIRECTION CLOCKWISE FROM X-AXIS.
      DEC=RADO*(FLDDEC-AZMUTH)
      CDEC=COS(DEC)
      SDEC=SIN(DEC)
      CX=FLD*CINC*CDEC
      CY=FLD*CINC*SDEC
      CZ=FLD*SINC
       CALL FITMAG(I,NUMX,NBODS,IWIDE,2.*CINC*CDEC,2.*CINC*SDEC,2.*SINC,
     1 DEC,YMAG,AZMUTH,X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
      DO 47 I=1,NBODS
C...ISKIP.GT.0 MEANS BODY PROPERTIES SAME AS BEFORE.
      IF(ISKIP.GT.0) GO TO 422
      MX=0.0
      MY=0.0
      MZ=0.0
C...READ PROPERTIES AND CONTROL PARAMETERS FOR I'TH BODY.
      IF(MODE.LE.4) GO TO 3001
1005  WRITE(ITO,1006) I
1006  FORMAT('0NAMELIST ENTRY OF "PROP" LIST FOR BODY',I3,':'/
     1 '   RHO,SUS,REMMAG,REMINC,ISKIP,NXMODE,NXKNFP,NXKPLT,',
     2 'NXKOUT,NXKFLD,IO')
      READ(ITI,PROP)
C...DUMMY STATEMENTS TO CIRCUMVENT BUG IN NAMELIST.
      DUMMY=RHO+SUS+REMMAG+REMINC+ISKIP+NXMODE+NXKNFP+NXKPLT+NXKOUT
     1 +NXKFLD
      WRITE(IO,PROP)
      MODE=NXMODE
      KPLOT=NXKPLT
      NXTKFP=NXKNFP
      KOUT=NXKOUT
      KFLD=NXKFLD
      GO TO 3002
C***   DATA UNIT 15    ***    MANDATORY    ***
3001  READ(IDI,105) RHO,SUS,REMMAG,REMDEC,REMINC,ISKIP,KPLOT,
     1 KOUT,KFLD,MODE,NXTKFP
3002  WRITE(IO,106)RHO,SUS,REMMAG,REMDEC,REMINC,ISKIP,KPLOT,
     1 KOUT,KFLD,MODE,NXTKFP
      ISW=0
105   FORMAT(5G10.2,6I5)
106   FORMAT(1X,5(1PE10.2),6I5)
      WRITE(IO,4010) I,RHO,SUS,REMMAG,REMDEC,REMINC,I
4010   FORMAT ('0BODY',I3,'--DENSITY CONTRAST RHO =',F7.4,
     1' GRAMS/CC, SUS=',1PE10.2,'       GAUSS/OE.'/
     2' REMANENT MAGNETIZATION=',1PE10.2,'  GAUSS WITH DECL=',
     3 0PF7.1,' DEG, INCL=',F7.1,' DEG'     /' FOLLOWING ',
     4'ARE THE FIELD COMPONENTS DUE TO BODY',I4,'.')
C...ISKIP.NE.-69 MEANS NO INVERSE CALCULATION.
      IF(ISKIP.NE.-69) GO TO 407
C...FIT DENSITY FOR BODIES I THRU NBODS.
      IF(KINDFP.NE.3) CALL FITGRV(NUMX,X,GOBS,GRV,I,NBODS,RSUM,IWIDE,
     1 GFAC,RHOBOU)
C...REMMAG.EQ.1 MEANS SOLN FOR VECTOR MAG OF BODIES I THRU NBODS.
      IF(KINDFP.NE.2 .AND. REMMAG.EQ.1)
     1 CALL FITMVT(I,NUMX,NBODS,IWIDE,2.*CINC*CDEC,2.*CINC*SDEC,2.*SINC,
     2 DEC,YMAG,AZMUTH,X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
C...SUS.EQ.1. MEANS SOLN FOR SUS OF BODIES I THRU NBODS.
C...FIT SUSCEPTIBILITY FOR BODIES I THRU NBODS.
42    IF(KINDFP.NE.2 .AND. SUS.EQ.1.)
     1 CALL FITSUS(I,NUMX,NBODS,IWIDE,2.*CINC*CDEC,2.*CINC*SDEC,2.*SINC,
     2 DEC,YMAG,AZMUTH,X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
      GO TO 48
407   IF(KINDFP.EQ.2) GO TO 421
      IF(REMMAG.EQ.0.) GO TO 41
C...CALC MX,MY,MZ (COMPONENTS OF REM. MAG.) FORWARD ONLY.
C...MULTIPLICATION BY 1.E5 CONVERTS FROM GAUSS TO 'GAMMAS'
      REMMAG=REMMAG*1.E5
C...RADO CONVERTS FROM DEGREES TO RADIANS.
      RINC=RADO*REMINC
      RDEC=RADO*(REMDEC-AZMUTH)
      DOG=REMMAG*COS(RINC)
      MX=DOG*COS(RDEC)
      MY=DOG*SIN(RDEC)
      MZ=REMMAG*SIN(RINC)
C...CALC X,Y,Z COMPONENTS OF INDUCED MAG. ADD TO MX,MY,MZ. FWD ONLY.
41    IF(SUS.EQ.0.) GO TO 421
C...NOTE FLD MUST BE IN GAMMAS.
      MX=MX+SUS*CX
      MY=MY+SUS*CY
      MZ=MZ+SUS*CZ
421   IF(ISKIP.LE.0) GO TO 423
422   IF(ISW.NE.0) WRITE(IO,4220) I,I
4220  FORMAT ('0BODY',I4,' HAS SAME MAG AND DENS PROPTS AS PREVIOUS BO'
     1,'DY.'/'  FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY',I4,'.')
C...DEC ISKIP EACH TIME THE OLD PROPERTIES ARE USED FOR A NEW BODY.
      ISKIP=ISKIP-1
      ISW=1
423   CONTINUE
C...FORWARD COMPUTATION OF MAG AND GRAV FOR ITH BODY.
      DO 46 J=1,NUMX
      IF(KINDFP.EQ.3) GO TO 444
      G=GFAC*RHO*RSUM(J,I)
      GRV(J)=GRV(J)+G
      COW(J)=G
      IF(KINDFP.EQ.2) GO TO 46
C...HX,HY,HZ ARE COMPONENTS OF MAG FLD VECTOR OF ITH BODY.
444   HX=2.*(MX*PXSUM(J,I)+MZ*QSUM(J,I))
      HY=2.*MY*(PZSUM(J,I)-PXSUM(J,I))
      HZ=2.*(MX*QSUM(J,I)-MZ*PZSUM(J,I))
      ASS(J)=HZ
      VER(J)=VER(J)+HZ
C...APPROXIMATE CALCULATION OF TOTAL FIELD ANOMALY.
      T=HZ*SINC+HX*CINC*CDEC+HY*CINC*SDEC
```

```
C...TOT1 IS RUNNING SUM FOR BODIES 1-I.  TOT1 AND TOT2 WILL BE USED
C...AS START IF INVERSE SOLN REQUIRED FOR BODIES I+1 THROUGH NBODS.
      TOT1(J)=TOT1(J)+T
      IF(KFLD.LT.2) TOT2(J)=TOT1(J)
      GOAT(J)=T
      IF(KFLD.LT.2) GO TO 46
C...MORE ACCURATE CALCULATION OF STRONG TOTAL FIELD ANOMALIES.
      TPRIME=DSQRT(DBLE((CX+HX)**2)+DBLE((CY+HY)**2)
     1 +DBLE((CZ+HZ)**2))-DBLE(FLD)
      TOT2(J)=TOT2(J)+TPRIME
      HORSE(J)=TPRIME
46    CONTINUE
      IF(KINDFP.NE.3)CALL PRINTR(X,COW,NUMX,IWIDE,'GRAV','(FWD',')  ')
      IF(KINDFP.NE.2)CALL PRINTR(X,GOAT,NUMX,IWIDE,'TOT1','(FWD',')   ')
      IF(KFLD.GE.2) CALL PRINTR(X,HORSE,
     1 NUMX,IWIDE,' ACC',' TOT','2 ')
      IF(KFLD.EQ.1 .OR. KFLD.EQ.3 .OR. KFLD.EQ.5)
     1 CALL PRINTR(X,ASS,NUMX,IWIDE,' VER','TICA','L ')
47    CONTINUE
      IF(KFLD.GE.4) GO TO 475
      DO 471 J=1,NUMX
471   TOT2(J)=TOT1(J)
      GO TO 48
475   DO 476 J=1,NUMX
476   TOT1(J)=TOT2(J)
48    IF(NBODS.EQ.1) RETURN
      WRITE(IO,4700)
4700  FORMAT('0FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY'
     1,' FIELDS'/'  DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE')
      GO TO (469,469,479),KINDFP
469   CALL PRINTR (X,GRV,NUMX,IWIDE,'  GR','AVIT','Y ')
      GO TO (479,611,479),KINDFP
479   IF(ISKIP.EQ.-69 .AND. REMMAG.EQ.1)
     1 CALL PRINTR(X,TOT1,NUMX,IWIDE,'TOT1','(MVT',') ')
      IF(ISKIP.EQ.-69 .AND. SUS.EQ.1)
     1 CALL PRINTR(X,TOT2,NUMX,IWIDE,'TOT2','(SUS',') ')
      IF(ISKIP.NE.-69)
     1 CALL PRINTR(X,TOT1,NUMX,IWIDE,'   T','OT1 ',' ')
      IF(ISKIP.NE.-69 .AND. KFLD.NE.0)
     1 CALL PRINTR(X,VER,NUMX,IWIDE,' VER','TICA','L ')
611   RETURN
      END
```

```
      SUBROUTINE FITGRV(NUMX,X,GOBS,GRV,I,NBODS,RSUM,IWIDE,GFAC,RHOBOU)
C...FITGRV FINDS THE DENSITY CONTRAST FOR BODIES I THRU NBODS.
C...NUMX,X,NBODS,RSUM SAME AS IN GRAV.
C...GOBS: ARRAY OF GRAVITY OBSERVED AT FIELDPOINTS.
C...GRV: ARRAY OF CALCULATED GRAVITY.  MAY BE NON-ZERO AT INPUT
C...   IF PARTIAL FORWARD CALCULATION PRECEEDED FITGRV CALL.
C...IWIDE: WIDTH OF PRINTER OUTPUT.
C...GFAC: NUMERICAL FACTOR CONTAINING UNIVERSAL GRAVITATIONAL CONSTANT.
C...   GFAC=6.673 IF DIMENSIONS ARE IN KM. GFAC CALC IN UNITER.
C...RHOBOU: BOUGUER RED. DENS. USED IN CALC DENS. FROM DENS. CONTRAST.
      DIMENSION GOBS(1),GRV(1),X(1),RSUM(50,10)
      DIMENSION A(500),B(50),FJ(20),IPIV(10),AUX(50),G(50)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      DATA FJ,IPIV,AUX/20*0.,10*0,50*0.1/
      DO 17 IBOD=I,NBODS
      K=(IBOD-I)*NUMX
      DO 17 J=1,NUMX
      A(J+K)=RSUM(J,IBOD)*GFAC
17    B(J)=GOBS(J)-GRV(J)
      EPS=.0001
      KK=NBODS-I+1
      CALL LLSQ(A,B,NUMX,KK,1,FJ,IPIV,EPS,IER,AUX)
      K=0
      DO 57 IBOD=I,NBODS
      K=K+1
      RHO=RHOBOU+FJ(K)
      WRITE(IO,101) IBOD,FJ(K),RHO
      IF(IO.EQ.IDO) WRITE(ITO,101) IBOD,FJ(K),RHO
101   FORMAT ('0LST SQRS SAYS BODY ',I3,' HAS DENSITY CONTRAST=',
     1 F10.3,' GM/CC, DENSITY=',F10.3,' GM/CC')
C...FWD CALC USING FJ OUTPUT BY LLSQ
      DO 37 J=1,NUMX
      G(J)=GFAC*FJ(K)*RSUM(J,IBOD)
37    GRV(J)=GRV(J)+G(J)
57    CALL PRINTR(X,G,NUMX,IWIDE,'   G','RAV ',' ')
      RETURN
      END
```

```
      SUBROUTINE FITMAG(I,NUMX,NBODS,IWIDE,CHX,CHY,CHZ,DEC,YMAG,AZMUTH,
     1 X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
C...NOTE THAT THIS MULTIPLE-ENTRY SUBROUTINE IS NON-STANDARD FORTRAN.
C...IT IS EASILY CONVERTED TO STANDARD FORTRAN IF YOUR SYSTEM REQUIRES.
C...ENTRY TO INITIALIZE MAG-FITTING SUBROUTINE.
C...PXSUM,PZSUM,QSUM,NUMX,X,NBODS ARE SAME AS IN MAG.
C...CHX,CHY,CHZ,DEC: DEF. IN CALL FITMAG. FIELD, PROFILE GEOM.
C...   DEC IS THE ANGLE FROM X-AXIS TO EARTH FLD DECL., + CLOCKWISE.
C...MX,MY,MZ: XYZ COMPONENTS OF MAGNETIZATION IN BODY IBOD
C...   COMPUTED IN FITMVT OR FITSUS BY LEAST SQUARES.
C...IWIDE: WIDTH OF PRINTER OUTPUT.
C...YMAG: 1-DIM ARRAY OF HALF-STRIKE LENGTHS. SAME AS Y IN MAG.
C...AZMUTH: AZIMUTH OF+X AXIS, IN DEG + CLOCKWISE FROM TRUE NORTH.
C...TOBS:  ARRAY OF OBSERVED TOTAL MAGNETIC FIELD AT FIELDPOINTS.
C...TOT1: ARRAY OF TOTAL MAG FIELD CALC. BY FITMVT.
C...TOT2: ARRAY OF TOTAL MAG FIELD CALC. BY FITSUS.
C...   TOT1 AND TOT2 MAY BE NON-ZERO ON INPUT IF PARTIAL FORWARD
C...   CALCULATION PRECEEDED FITMVT OR FITSUS CALL.
      DIMENSION X(1),TOBS(1),TOT1(1),TOT2(1),YMAG(1)
      DIMENSION PXSUM(50,10),PZSUM(50,10),QSUM(50,10)
      DIMENSION A( 500),B(50),FJ(20),IPIV(10),AUX(50),T(50)
      REAL MX,MY,MZ,MXSQ,MYSQ,MZSQ
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
C...GEOMX,Y,Z ARE COMPLETE GEOM FACTORS TO MULTIPLY BY MX,MY,MZ.
      GEOMX(PX,Q)=CHX*PX+CHZ*Q
      GEOMY(PZ,PX)=CHY*(PZ-PX)
      GEOMZ(Q,PZ)=CHX*Q-CHZ*PZ
      DATA FJ,IPIV,AUX/20*0.,10*0,50*0./
      CDEC=COS(DEC)
C...SMCDEC PREVENTS DIVISION BY CDEC=0.
      SMCDEC=SIGN(AMAX1(ABS(CDEC),1.E-10),CDEC)
      RAD=57.29578
      MX=0.
      MY=0.
      MZ=0.
      EPS=0.001
      RETURN
C.....................................................................
C...FITMVT FINDS THE VECTOR MAGNETIZATION CONTRAST OF BODIES I TO NBODS
      ENTRY FITMVT(I,NUMX,NBODS,IWIDE,CHX,CHY,CHZ,DEC,YMAG,AZMUTH,
     1 X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
C...TEST FOR DEGENERATE GEOMETRIES WHERE INVERSION FOR ALL THREE
C...COMPONENTS OF MAGNETIZATION IS IMPOSSIBLE.  NOTE THAT THERE IS
C...NO TEST FOR SMALL NON-ZERO CHX,CHY,CHZ.  GEOMETRIES WHICH
C...RESULT IN VERY SMALL CHX, CHY, OR CHZ MAY CAUSE LLSQ TO FAIL.
      IF(CHX.NE.0.  .AND.  CHZ.NE.0.) GO TO 12
      WRITE(IO,110)
       IF(IO.EQ.IDO) WRITE(ITO,110)
110   FORMAT(/' CHX=0. AND CHZ=0. EARTHS FLD HORIZONTAL AND PARALLEL',
     1 ' TO Y-AXIS.',/,'CANNOT INVERT FOR MX, MZ.')
      RETURN
12    KY=1
      IF(CHY.NE.0.) GO TO 13
      WRITE(IO,120)
      IF(IO.EQ.IDO) WRITE(ITO,120)
120   FORMAT(/' CHY=0. EARTHS FIELD VERTICAL OR PARALLEL TO X-AXIS.',/,
     1 ' INVERT FOR MX AND MZ BUT NOT MY.')
      KY=0
      GO TO 16
C...TEST FOR 2-DIMENSIONALITY (YMAG VERY LARGE).
13    DO 14 IBOD=I,NBODS
      IF(YMAG(IBOD).GE.1.E15) GO TO 15
14    CONTINUE
      GO TO 16
15    WRITE(IO,150)
      IF(IO.EQ.IDO) WRITE(ITO,150)
C...FOLLOWING CONDITION MEANS YOU CAN'T SOLVE FOR MY IF THE BODY
C...IS VERY LONG OR TWO-DIMENSIONAL BECAUSE THE CONTRIBUTION FROM
C...THE ENDS IS INSIGNIFICANT.  THE BODY MAY PASS THIS TEST BUT
C...STILL BE TOO LONG FOR LLSQ TO WORK (STATEMENT 170).
150   FORMAT(/' INVERSION REQUESTED FOR AT LEAST ONE BODY WITH YMAG',
     1 ' .GE. 1.E15.',/,' INVERT FOR MX AND MZ BUT NOT MY.')
      KY=0
16    DO 17 IBOD=I,NBODS
C...K-INDEXING IMITATES 2-DIM ARRAY WITH 1-DIM ARRAY A.
      K=(IBOD-I)*NUMX*(KY+2)
      DO 17 J=1,NUMX
      PX=PXSUM(J,IBOD)
      PZ=PZSUM(J,IBOD)
      Q=QSUM(J,IBOD)
      A(J+K)=GEOMX(PX,Q)
C...KY(SET=1 IN STATEMENT 12) PERMITS SOLUTION FOR MY.
      IF(KY.EQ.1) A(J+K+NUMX)=GEOMY(PZ,PX)
      A(J+K+(KY+1)*NUMX)=GEOMZ(Q,PZ)
17    B(J)=TOBS(J)-TOT1(J)
      KK=(NBODS-I+1)*(KY+2)
      CALL LLSQ(A,B,NUMX,KK,1,FJ,IPIV,EPS,IER,AUX)
      IF(IER.NE.0) CALL LSQERR(IER,'VECTOR MAG',NUMX,KK)
      IF(IER.LE.0 .OR. KY.EQ.0) GO TO 21
      WRITE(IO,170)
      IF(IO.EQ.IDO) WRITE(ITO,170)
C...SEE IF FAILURE OF LLSQ IS DUE TO AN INSIGNIFICANT CONTRIBUTION
C...FROM THE ENDS.  IF THIS IS THE CASE THE INVERSION WILL
C...PROCEED BY DISREGARDING MY.
170   FORMAT(' TRY SOLUTION DISREGARDING MY.')
      KY=0
      GO TO 16
21    K=0
C...FWD CALCULATION USING FJ OUTPUT BY LLSQ.
      DO 57 IBOD=I,NBODS
      K=K+1
      MX=FJ(K)
      IF(KY.EQ.0) GO TO 35
      K=K+1
      MY=FJ(K)
35    K=K+1
      MZ=FJ(K)
      DO 37 J=1,NUMX
      PX=PXSUM(J,IBOD)
      PZ=PZSUM(J,IBOD)
      Q=QSUM(J,IBOD)
      T(J)=MX*GEOMX(PX,Q)+MZ*GEOMZ(Q,PZ)
      IF(KY.EQ.1) T(J)=T(J)+MY*GEOMY(PZ,PX)
37    TOT1(J)=TOT1(J)+T(J)
C...COMPUTE COMPONENTS, AZIMUTH, DECLINATION OF MAGNETIZATION.
C...B IS IN GAMMAS SO MULT MX,MZ BY 1.E-5 TO GET GAUSS
      MX=MX*1.E-5
      MY=MY*1.E-5
      MZ=MZ*1.E-5
      REMDEC=RAD*ATAN2(MY,MX)+AZMUTH
      MXSQ=MX*MX
      MYSQ=MY*MY
      MZSQ=MZ*MZ
      AMP=SQRT(MXSQ+MYSQ+MZSQ)
      REMINC=RAD*ATAN(MZ/SQRT(MXSQ+MYSQ))
      IF(REMINC.GE.0) GO TO 375
C...INCL EXPRESSED IN RANGE 0-180 DEG. AZIMUTH SIGNED ACCORDINGLY.
      REMINC=REMINC+180.
      AMP=-AMP
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375   WRITE(IO,101) IBOD,MX,MY,MZ,REMDEC,REMINC,AMP
      IF(IO.EQ.IDO) WRITE(ITO,101) IBOD,MX,MY,MZ,REMDEC,REMINC,AMP
101   FORMAT('0LST SQRS SAYS BODY ',I3,' HAS MAGNETIZATION COMPONENTS',/
     1 ' MX= ',1PE10.2,', MY= ',1PE10.2,', MZ= ',1PE10.2,/
     2 ' DEC= ',0PF7.1,', INC= ',F7.1,', AMP= ',1PE10.2)
C...PREVENT DIVISION BY MX=0.
      MX=SIGN(AMAX1(ABS(MX),1.E-10),MX)
C...IF MY.EQ.0, VECTOR ALREADY LIES IN X-Z PLANE.
      IF(MY.EQ.0.) GO TO 376
      EFFINC=RAD*ATAN(MZ/ABS(MX))
      IF(EFFINC.LT.0.) EFFINC=EFFINC+180.
      WRITE(IO,102) AZMUTH,EFFINC
102   FORMAT(' IN THE X-Z PLANE(AZ= ',F7.1,'),EFF INC= ',F7.1)
C...IF CDEC.EQ.1., VECTOR ALREADY LIES IN PLANE OF EARTH'S FIELD.
376   IF(CDEC.EQ.1.) GO TO 57
      HYPINC=RAD*ATAN(MZ/ABS(MX/SMCDEC))
      IF(HYPINC.LT.0) HYPINC=HYPINC+180.
38    WRITE(IO,103) HYPINC
      IF(IO.EQ.IDO) WRITE(ITO,103) HYPINC
103   FORMAT(' HYP EARTH FIELD TO PRODUCE 2-D EFF INC HAS INC= ',F7.1)
57    CALL PRINTR(X,T,NUMX,IWIDE,' TOT','1(MV','T)')
      RETURN
C.......................................................................
C...FITSUS FINDS THE SUSCEPTIBILITY CONTRAST FOR BODIES I THRU NBODS
      ENTRY FITSUS(I,NUMX,NBODS,IWIDE,CHX,CHY,CHZ,DEC,YMAG,AZMUTH,
     1 X,TOBS,TOT1,TOT2,MX,MY,MZ,PXSUM,PZSUM,QSUM)
      DO 27 IBOD=I,NBODS
C...K-INDEXING IMITATES 2-DIM ARRAY WITH 1-DIM ARRAY A.
      K=(IBOD-I)*NUMX
      DO 27 J=1,NUMX
C...NOTE MX AND MZ MUST BE IN UNITS OF 1.E-5 GAUSS ("GAMMAS")
C...B ALSO IS GAMMAS, SO FJ IS A PURE RATIO, SUS.
      PX=PXSUM(J,IBOD)
      PZ=PZSUM(J,IBOD)
      Q=QSUM(J,IBOD)
      A(J+K)=MX*GEOMX(PX,Q)+MY*GEOMY(PZ,PX)+MZ*GEOMZ(Q,PZ)
27    B(J)=TOBS(J)-TOT2(J)
      KK=NBODS-I+1
2     CALL LLSQ(A,B,NUMX,KK,1,FJ,IPIV,EPS,IER,AUX)
      IF(IER.NE.0) CALL LSQERR(IER,'SUSCEPTIBILITY',NUMX,KK)
      K=0
      DO 77 IBOD=I,NBODS
      K=K+1
      WRITE(IO,104) IBOD,FJ(K)
      IF(IO.EQ.IDO) WRITE(ITO,104) IBOD,FJ(K)
104   FORMAT ('0LST SQRS SAYS BODY',I3,' HAS SUS= ',
     1 1PE10.2,' GAUSS/OE.')
C...FWD CALC USING FJ OUTPUT BY LLSQ
      DO 67 J=1,NUMX
      PX=PXSUM(J,IBOD)
      PZ=PZSUM(J,IBOD)
      Q=QSUM(J,IBOD)
      T(J)=FJ(K)*(MX*GEOMX(PX,Q)+MY*GEOMY(PZ,PX)+MZ*GEOMZ(Q,PZ))
67    TOT2(J)=TOT2(J)+T(J)
77    CALL PRINTR(X,T,NUMX,IWIDE,' TOT','2(SU','S)')
      RETURN
      END
```



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      SUBROUTINE LSQERR(IER,TIT,NUMX,KK)
C...GIVES ERROR MESSAGES FOR SUBROUTINE LLSQ.
      COMMON IO
      DIMENSION TIT(3)
      WRITE(IO,100) (TIT(I),I=1,3),IER
100   FORMAT(/,' ERROR IN LLSQ ROUTINE FOR ',3A5,'. IER= ',I3)
      IF(IER.EQ.-2) WRITE(IO,101) NUMX,KK
101   FORMAT(' NUMX= ',I3,'. MUST BE GE ',I3)
      IF(IER.EQ.-1) WRITE(IO,102)
102   FORMAT(' ZERO-MATRIX A')
      IF(IER.GE.1) WRITE(IO,103)
103   FORMAT(' MATRIX A ILL-CONDITIONED. MAY BE DUE TO VERY DEEP',
     1 'BOTTOMS OF BODIES, YMAG BIG BUT LT 1.E15',/,
     2 'OR NEAR-DEGENERATE GEOMETRIES DESC. IN ENTRY FITMVT.')
      RETURN
      END

      SUBROUTINE UNITER(XZUN,GFAC,XZUNIT)
C...GIVEN CODE FOR DISTANCE UNITS (KM OR BLANK, MI, KF, ME, FT, OR NM),
C...UNITER COMPUTES GRAVITATIONAL CONSTANT GFAC AND X-AXIS LABEL.
      DIMENSION XZUNIT(2)
      REAL KM,MI,MILE,KF,KILO,ME,METR,NM,NAUT
      DATA BL/' '/,KM/'KM'/,MI/'MI'/,KF/'KF'/,ME/'ME'/,FT/'FT'/,
     1 NM/'NM'/,MILE/'MILE'/,S/'S'/,KILO/'KILO'/,FEET/'FEET'/,
     2 METR/'METR'/,ES/'ES'/,NAUT/'NAUT'/,PARS/'PARS'/,ECS/'ECS'/
      GFAC=6.673
      XZUNIT(1)=KM
      XZUNIT(2)=BL
      IF(XZUN.EQ.BL.OR.XZUN.EQ.KM) RETURN
      IF(XZUN.NE.MI) GO TO 3
      GFAC=GFAC*1.609
      XZUNIT(1)=MILE
      XZUNIT(2)=S
      RETURN
3     IF(XZUN.NE.KF) GO TO 5
      GFAC=GFAC*1.609
      GFAC=GFAC*0.3048
      XZUNIT(1)=KILO
      XZUNIT(2)=FEET
      RETURN
5     IF(XZUN.NE.ME) GO TO 7
      GFAC=GFAC*0.001
      XZUNIT(1)=METR
      XZUNIT(2)=ES
      RETURN
7     IF(XZUN.NE.FT) GO TO 9
      GFAC=GFAC*0.0003048
      XZUNIT(1)=FEET
      RETURN
9     IF(XZUN.NE.NM) GO TO 11
      GFAC=GFAC*1.852
      XZUNIT(1)=NAUT
      XZUNIT(2)=MILE
      RETURN
C...ERROR OUTPUT: XZUN NOT RECOGNIZED.
11    GFAC=GFAC*3.08E13
      XZUNIT(1)=PARS
      XZUNIT(2)=ECS
      RETURN
      END
```

```
      SUBROUTINE ELEVER(ELEV,NUMX,XARY,NEWT,XCORNR,ZCORNR,KSPL)
C...CREATeS Z-ARRAY ELEV CORRESPONDING TO XARY OF LENGTH NUMX BY
C...LINEAR INTERPOLATION OF INPUT ARRAYS XCORNR AND ZCORNR OF LNTH NEWT.
C...XARY NORMALLY EQUALLY SPACED, XCORNR UNEQUALLY SPACED.
C...ALTERNATIVELY, FOR KSPL=1, DOES SPLINE INTERPOLATION.
C...IN SPLINE INTERPOLATION 2ND DERIVATIVE ASSUMED 0 AT ENDPOINTS.
      DIMENSION XCORNR(1),ZCORNR(1),ELEV(1),XARY(1)
      DIMENSION A(50),B(50),C(50),D(2),P(50),S(50)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      DATA D(1),D(2)/2*0.0/
100   FORMAT (8G10.2)
      READ (IDI,100) (XCORNR(K),K=1,NEWT)
      READ (IDI,100) (ZCORNR(K),K=1,NEWT)
      IF(KSPL.NE.1) GO TO 99
      M=NEWT
      CALL SPLIN1(M,0.0,XCORNR,ZCORNR,A,B,C,0,D,P,S)
      IF(M.GT.0) GO TO 23
      WRITE(IO,2100)
2100  FORMAT(' PARM OUT OF RANGE IN SPLINE. TRY LINEAR INTERPOLATION.')
      GO TO 99
C...SPLINE INTERPOLATION FROM W.L. ANDERSON, USGS, DENVER.
23    DO 29 I=1,NUMX
      XX=XARY(I)
      IF(XX.LT.XCORNR(1) .OR. XX.GT.XCORNR(NEWT)) GO TO 28
      M1=NEWT-1
      DO 25 J=1,M1
      K=J
      IF(XX.LE.XCORNR(J+1)) GO TO 27
25    CONTINUE
27    Z=XX-XCORNR(K)
      ELEV(I)=ZCORNR(K)+((C(K)*Z+B(K))*Z+A(K))*Z
      GO TO 29
28    ELEV(I)=0.
29    CONTINUE
      RETURN
C...LINEAR INTERPOLATION.
99    I=1
      K=1
      XLAST=-99.
      SLOPE=-99.
1     IF (I-NUMX) 2,2,18
2      XLAST=XCORNR(K)
      DOG=XARY(I)-XLAST
      IF(DOG) 11,12,12
11    ELEV(I)=0
      I=I+1
      GO TO 1
12    ZLAST=ZCORNR(K)
      K=K+1
      IF(K-NEWT) 13,13,16
13    XNEXT=XCORNR(K)
      SLOPE=(ZCORNR(K)-ZLAST)/(XCORNR(K)-XLAST)
14    CAT=XARY(I)-XNEXT
      IF(CAT) 15,15,2
15    ELEV(I)=ZLAST+DOG*SLOPE
      I=I+1
      IF (I.GT.NUMX) GO TO 18
      DOG=XARY(I)-XLAST
      GO TO 14
16    IF(I.GT.NUMX) GO TO 18
      DO 17 J=I,NUMX
17    ELEV(J)=0
18    RETURN
      END
```

```
      SUBROUTINE INTRPL (N,XARRY,ZARRY,X,Z)
C...FINDS A SINGLE Z CORRESPONDING TO X BY LINEAR INTERPOLATION
C...OF ARRAYS XARRY AND ZARRY OF LENGTH N.
      DIMENSION XARRY(N),ZARRY(N)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      I=1
      IF(X-XARRY(1)) 5,3,1
1     I=I+1
      IF(I-N) 2,2,5
2     IF(X-XARRY(I)) 4,3,1
3     Z=ZARRY(I)
      RETURN
4     Z=ZARRY(I-1)+(ZARRY(I)-ZARRY(I-1))*
     1 (X-XARRY(I-1))/(XARRY(I)-XARRY(I-1))
      RETURN
5     WRITE(IO,50) I
50    FORMAT ('0INTRPL FAILED. X OUTSIDE RANGE OF XARRY. I=',I3)
      Z=0.
      RETURN
      END
```

```
      SUBROUTINE PRINTR(X,A,NUMX,IWIDE,F1,F2,F3)
C...PRINTS VECTORS X AND A OF LENGTH NUMX IN NCOL COLUMNS.
C...NCOL DEPENDS UPON PRINTER WIDTH IWIDE.  PURPOSE IS TO SAVE PAPER.
      DIMENSION ALABEL(3,5)
      DIMENSION CAT(5),PIG(5),X(NUMX),A(NUMX),XLABEL(5)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      DATA (XLABEL(I),I=1,5)/5*'     '/,EX/'X    '/
      NCOL=MIN0(IWIDE/24,NUMX)
C...COMPUTE NUMBER OF ROWS REQUIRED.
      DOG=1.*NUMX/NCOL*1.
      NROW=DOG
      IF(DOG.EQ.NROW)  GO TO 3
      NROW=NROW+1
3     IF(NROW*(NCOL-1).LT.NUMX) GO TO 5
C...REDUCE COLUMNS FOR COMPACT PRINTOUT.
      NCOL=NCOL-1
      GO TO 3
5     DO 13 I=1,NCOL
      XLABEL(I)=EX
      ALABEL(1,I)=F1
      ALABEL(2,I)=F2
13    ALABEL(3,I)=F3
      WRITE(IO,130) (XLABEL(I),(ALABEL(K,I),K=1,3),I=1,NCOL)
130   FORMAT('0',5(6X,A1,5X,2A4,A2,2X))
C...PRINT X AND A IN NCOL ASCENDING COLUMNS.
      DO 25 I=1,NROW
      DO 23 J=1,NCOL
      K=I+(J-1)*NROW
      IF(K.LE.NUMX) GO TO 21
      GO TO 24
21    PIG(J)=X(K)
23    CAT(J)=A(K)
      GO TO 25
24    NCOL=J-1
25    WRITE(IO,250) (PIG(J),CAT(J),J=1,NCOL)
250   FORMAT('X',5(2G12.4))
      RETURN
      END
```

```
      SUBROUTINE PLOTER(KINDFP,NUMX,X,ELEV,TOPO,GRV,GOBS,GOUT,
     1 TOT1,TOT2,TOBS,TOUT,NGOBS,NTOBS,ISW,IWIDE,NLPLT,KPLOT,HEADER,
     2 XZUNIT)
      DIMENSION X(1),ELEV(1),TOPO(1),GRV(1),GOBS(1),GOUT(1),TOUT(1)
      DIMENSION TOT1(1),TOT2(1),TOBS(1),Y(5Ø,9),HEADER(1),S(9),XZUNIT(2)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      IF(ISW.LT.Ø) GO TO 2
      ELMIN=1.E15
      ELMAX=-1.E15
      GMIN=1.E15
      GMAX=-1.E15
      TMIN=1.E15
      TMAX=-1.E15
      CALL MNMX(ELEV,NUMX,ELMIN,ELMAX)
      CALL MNMX(TOPO,NUMX,ELMIN,ELMAX)
      IF(NGOBS.GT.Ø) CALL MNMX(GOBS,NUMX,GMIN,GMAX)
      IF(NTOBS.GT.Ø) CALL MNMX(TOBS,NUMX,TMIN,TMAX)
2     IF(KINDFP.NE.3) CALL MNMX(GRV,NUMX,GMIN,GMAX)
      IF(KINDFP.NE.3) CALL MNMX(GOUT,NUMX,GMIN,GMAX)
      IF(KINDFP.NE.2) CALL MNMX(TOT1,NUMX,TMIN,TMAX)
      IF(KINDFP.NE.2) CALL MNMX(TOT2,NUMX,TMIN,TMAX)
      IF(KINDFP.NE.2) CALL MNMX(TOUT,NUMX,TMIN,TMAX)
C...EXPAND RANGES FOR NEAT GRAPH AND
C...SCALE ALL VARIABLES TO GRAV IF POSSIBLE, OTHERWISE TO MAG.
      IF(KINDFP.EQ.3) GO TO 5
      DELG=DEL(GMAX-GMIN)
4Ø1   CALL EXPAND(GMIN,GMAX,DELG)
      YMIN=GMIN
      YMAX=GMAX
      DELY=DELG
      IF(KINDFP.NE.2) GO TO 5
      TMIN=Ø.
      TMAX=Ø.
      GO TO 7
5     DELT=DEL(TMAX-TMIN)
      CALL EXPAND(TMIN,TMAX,DELT)
5Ø1    IF(KINDFP.NE.3) GO TO 7
      YMIN=TMIN
      GMIN=Ø.
      YMAX=TMAX
      GMAX=Ø.
      DELY=DELT
C...SCALE ELEV AND TOPO TO 1/5 OF FULL VERTICAL SCALE.
7     CALL SCALEY(ELEV,NUMX,ELMIN,ELMAX,YMIN,YMAX*.1,Y,1)
      CALL SCALEY(TOPO,NUMX,ELMIN,ELMAX,YMIN,YMAX*.1,Y,2)
      CALL SCALEY(GOBS,NUMX,GMIN,GMAX,YMIN,YMAX,Y,3)
      CALL SCALEY(TOBS,NUMX,TMIN,TMAX,YMIN,YMAX,Y,4)
      CALL SCALEY(GRV,NUMX,GMIN,GMAX,YMIN,YMAX,Y,5)
      CALL SCALEY(TOT1,NUMX,TMIN,TMAX,YMIN,YMAX,Y,6)
      CALL SCALEY(TOT2,NUMX,TMIN,TMAX,YMIN,YMAX,Y,7)
      CALL SCALEY(TOUT,NUMX,TMIN,TMAX,YMIN,YMAX,Y,8)
      CALL SCALEY(GOUT,NUMX,GMIN,GMAX,YMIN,YMAX,Y,9)
      ISW=-1
      IF(KPLOT.EQ.1) GO TO 9
      DATA S(1)/'1'/,S(2)/':'/,S(3)/'G'/,S(4)/'T'/,
     1 S(5)/'*'/,S(6)/'+'/,S(7)/'#'/,S(8)/'@'/,S(9)/'$'/
      WRITE(IO,2Ø) (S(I),I=1,9)
2Ø    FORMAT('ØPLOT SYMBOLS: ELEV=',A1,' TOPO=',A1,' GOBS=',A1,
     1 ' TOBS=',A1,' GRV=',A1,' TOT1=',A1,' TOT2=',A1,
     2 ' TOUT=',A1,' GOUT=',A1)
      CALL PRLPLT(X,Y,X(NUMX),X(1),YMAX,YMIN,TMAX,TMIN,
     1 9,5Ø,NLPLT,NUMX,S,IWIDE,XZUNIT)
      IF(KPLOT.EQ.Ø) RETURN
9     XMIN=X(1)
      XMAX=X(NUMX)
      DELX=DEL(XMAX-XMIN)
C     CALL DECPLT(X,Y,XMAX,XMIN,YMAX,YMIN,TMAX,TMIN,
C    1 9,5Ø,NUMX,HEADER,KINDFP,DELX,DELY,XZUNIT)
      RETURN
      END

      SUBROUTINE MNMX(A,N,AMIN,AMAX)
C...MNMX FINDS THE MIN AND MAX AMIN AND AMAX OF VECTOR A WITH
C...LENGTH N IF THEY ARE LT AND GT INPUT AMIN AND AMAX RESP.
      DIMENSION A(N)
      DO 5 I=1,N
      TEM=A(I)
      IF(TEM.GT.AMAX) AMAX=TEM
5     IF(TEM.LT.AMIN) AMIN=TEM
      RETURN
      END

      FUNCTION DEL(SPREAD)
C...DEL IS A CONVENIENT TENFOLD DIVISION OF SPREAD.
      FI=1.
      DEL=SPREAD/1Ø.
      IF(DEL.LT.FI) GO TO 1Ø
2     IF(DEL.GT.FI*2.) GO TO 3
      DEL=FI*2.
      RETURN
3     IF(DEL.GT.FI*5.) GO TO 4
      DEL=FI*5.
      RETURN
4     IF(DEL.GT.FI*1Ø.) GO TO 5
      DEL=FI*1Ø.
      RETURN
5     FI=FI*1Ø.
      GO TO 2
1Ø    IF(DEL.LT.FI*.5) GO TO 13
      DEL=FI*.5
      RETURN
13    IF(DEL.LT.FI*.2) GO TO 14
      DEL=FI*.2
      RETURN
14    IF (DEL.LT.FI*.1) GO TO 15
      DEL=FI*.1
      RETURN
15    FI=FI*.1
      GO TO 1Ø
      END

      SUBROUTINE EXPAND(AMIN,AMAX,DEL)
C...GIVEN OLD AMIN AND AMAX DEFINING A RANGE, CREATE NEW
C...AMIN AND AMAX DEFINING A RANGE EQUALLY DIVISIBLE BY DEL.
      AMIN=DEL*(AINT(AMIN/DEL)-1)
      AMAX=DEL*(AINT(AMAX/DEL)+1)
1      RETURN
      END
```

```
      SUBROUTINE SCALEY(A,NUMX,AMIN,AMAX,BMIN,BMAX,Y,N)
C...SCALEY TAKES A VECTOR A WITH RANGE AMIN-AMAX, SCALES IT TO FIT THE
C...RANGE BMIN-BMAX, AND INSERTS IT AS THE N'TH ROW OF 2-D PLOT ARRAY Y.
      DIMENSION A(1),Y(50,9)
      RATIO=0.
      IF(AMAX.GT.AMIN) RATIO=(BMAX-BMIN)/(AMAX-AMIN)
      DO 10 I=1,NUMX
10    Y(I,N)=BMIN+(A(I)-AMIN)*RATIO
      RETURN
      END


      SUBROUTINE PRLPLT(X,Y,XMAX,XMIN,YMAX,YMIN,TMAX,TMIN,NY,IYDM,
     1       LINES,LAST,SYM,IW,XZUNIT)
C
C     LONG PRINTER PLOT, ONE X, SEVERAL Y VALUES
C     ARGUMENTS
C...MODIFIED TO LABEL GRAV,MAG AND TO ALLOW VARIABLE PLOT WIDTH.
C      X     THE ARRAY OF X COORDINATES
C      Y     THE ARRAY OF Y COORDINATES
C     XMAX   THE LARGEST VALUE OF X
C     XMIN   THE SMALLEST VALUE OF X
C     YMAX   THE LARGEST VALUE OF Y
C     YMIN   THE SMALLEST VALUE OF Y
C     TMAX   THE MAX OF AUXILIARY VARIABLE T (FOR AXIS LABEL)
C     TMIN   THE MIN OF AUXILIARY VARIABLE T
C     NY     THE NUMBER OF Y VARIABLES
C     IYDM   THE ACTUAL DIMENSION OF THE FIRST SUBSCRIPT OF Y
C     LINES  THE NUMBER OF LINES TO BE USED FOR THE X AXIS
C     LAST   THE NUMBER OF DATA POINTS
C     SYM    THE SYMBOLS TO PLOT, ONE FOR EACH Y
C     IW     THE WIDTH OF PLOT (EG 80 FOR TELETYPE, 126 FOR PRINTER)
C
      DIMENSION X(LAST),Y(IYDM,NY),SYM(NY),ZY(11),TZY(11),GRAPH(112)
      DIMENSION TICK(22),TICKY(22),XZUNIT(2)
      COMMON/INOUT/IO,ITI,ITO,IDI,IDO
      DATA BLANK/' '/,CR/'-'/,PL/'<'/
      DATA (TICK(I),I=1,22)/22*'....'/,(TICKY(I),I=1,22)/22*'+'/
      XSCALE=(XMAX-XMIN)/(LINES-1.)
      IR=MIN0(IW-15,111)
      ICOL=IR/10+1
      ICOL2=ICOL*2-1
      IRP1=IR+1
      TYSCAL=(TMAX-TMIN)/IR
      YSCALE=(YMAX-YMIN)/IR
      DO 10 K=1,ICOL
   10 ZY(K)=10.*(K-1)*YSCALE+YMIN
      WRITE(IO,15) (ZY(K),K=1,ICOL)
   15 FORMAT(/,'   GRAV    ',1P12E10.2)
      DO 11 K=1,ICOL
11    TZY(K)=10.*(K-1)*TYSCAL+TMIN
      WRITE(IO,16) (TZY(K),K=1,ICOL)
16    FORMAT('    MAG    ',1P12E10.2,/)
169   WRITE(IO,20) XZUNIT(1),XZUNIT(2),TICKY(1),
     1 (TICK(K),TICKY(K),K=1,ICOL2)
   20 FORMAT('    ',2A4,3X,A1,22(A4,A1))
      INDEX=1
   30 IF(X(INDEX).GE.XMIN) GO TO 40
      INDEX=INDEX+1
      IF(INDEX.LE.LAST) GO TO 30
      WRITE(IO,35)
   35 FORMAT(1H0,'NO X IS GREATER THAN XMIN')
      RETURN
   40 X1=XMIN
      DO 80 I=1,LINES
      IF(MOD(I,5).EQ.1) GO TO 45
      GRAPH(1)=CR
      GRAPH(IRP1)=CR
      GO TO 50
   45 GRAPH(1)=PL
      GRAPH(IRP1)=PL
   50 DO 55 J=2,IR
   55 GRAPH(J)=BLANK
      X2=((I-.5)*(XMAX-XMIN))/(LINES-1.)+XMIN
   57 IF(INDEX.GT.LAST) GO TO 70
      IF(X(INDEX).GE.X2) GO TO 70
      IF(X(INDEX).LT.X1) GO TO 65
      DO 60 J=1,NY
      IF(Y(INDEX,J).LT.YMIN.OR.Y(INDEX,J).GT.YMAX) GO TO 60
      IY=(Y(INDEX,J)-YMIN)/YSCALE+1.5
      GRAPH(IY)=SYM(J)
   60 CONTINUE
      INDEX=INDEX+1
      GO TO 70
   65 INDEX=INDEX+1
      GO TO 57
   70 XES=(I-1)*XSCALE+XMIN
      WRITE(IO,75) XES,(GRAPH(J),J=1,IRP1)
   75 FORMAT(1H ,2X,1PE9.2,2X,101A1)
      X1=X2
   80 CONTINUE
      WRITE(IO,20) XZUNIT(1),XZUNIT(2),TICKY(1),
     1 (TICK(K),TICKY(K),K=1,ICOL2)
      WRITE(IO,85) (ZY(K),K=1,ICOL)
   85 FORMAT(/,'   GRAV    ',1P12E10.2)
      WRITE(IO,86) (TZY(K),K=1,ICOL)
86    FORMAT('    MAG    ',1P12E10.2)
      RETURN
      END
```

```
      SUBROUTINE SPLIN1(M,H,X,Y,A,B,C,T,D,P,S)
C--ONE DIMENSIONAL CUBIC SPLINE INTERPOLATION
C
C  BY W.L.ANDERSON, U.S. GEOLOGICAL SURVEY, DENVER, COLORADO.
C
C  PARMS--- M= NUMBER OF DATA POINTS .GT. 2
C           H= EQUAL INTERVAL OPTION WHEN H.GT.0.0 (USE DUMMY X HERE),
C              UNEQUAL INTERVALS IF H=0.0 (X REQUIRED STORAGE)
C           X= INDEP.VAR WHEN H=0.0 (DIM .GE. M).
C           Y= DEPENDENT VARIABLE  (DIM .GE. M).
C           A,B,C=COEFF.ARRAYS (EACH DIM .GE. M)
C                RESULTS ARE RETURNED IN 1ST(M-1) ELEMENTS OF A,B,&C.
C                ALSO USED AS WORK ARRAYS DURING EXECUTION.
C           T= TYPE OF BOUNDARY CONDITION SUPPLIED IN D ARRAY. USE
C              T=1 IF 1ST DERIVATIVES GIVEN AT END POINTS, OR
C              T=0 IF 2ND DERIVATIVES GIVEN AT END POINTS.
C           D= BOUNDARY ARRAY (DIM 2) AT POINT 1 AND M RESPECTIVELY.
C           P,S= WORK ARRAYS (EACH DIM=M).
C--ERROR RETURN WITH M=-(ABS(M)) IF ANY PARM OUT OF RANGE.
C  THE RESULTING CUBIC SPLINE IS OF THE FORM:
C      Y=Y(I)+A(I)*(X-X(I))+B(I)*(X-X(I))**2+C(I)*(X-X(I))**3
C        FOR I=1,2,...,M-1
C
      IMPLICIT REAL*4 (A-H,O-Z)
      REAL*4  X(1),Y(1),A(1),B(1),C(1),D(2),P(1),S(1),MUL
      INTEGER*4 T
      IF(T.LT.0.OR.T.GT.1.OR.H.LT.0..OR.M.LT.3) GO TO 999
      N=M-1
      IF(T.EQ.0) GO TO 20
C--1ST DERIVATIVE BOUNDARIES GIVEN
      NE=N-1
      IF(H) 999,11,1
C--EQUAL SPACING H .GT. 0. AND T=1
    1 HH=3.0/H
      DO 2 I=1,NE
      B(I)=4.0
      C(I)=1.0
      A(I)=1.0
    2 P(I)=HH*(Y(I+2)-Y(I))
      P(1)=P(1)-D(1)
      P(NE)=P(NE)-D(2)
C--SOLUTION OF TRIDIAGONAL MATRIX EQ. OF ORDER NE
    3 C(1)=C(1)/B(1)
      P(1)=P(1)/B(1)
      DO 4 I=2,NE
      MUL=1.0/(B(I)-A(I)*C(I-1))
      C(I)=MUL*C(I)
    4 P(I)=MUL*(P(I)-A(I)*P(I-1))
C--OBTAIN SPLINE COEFFICIENTS
      A(NE+T)=P(NE)
      I=NE-1
    5 A(I+T)=P(I)-C(I)*A(I+T+1)
      I=I-1
       IF(I.GE.1) GO TO 5
      IF(T.EQ.0) GO TO 6
      A(1)=D(1)
      A(M)=D(2)
    6 IF(H.EQ.0.0) GO TO 14
      HH=1.0/H
      DO 7 I=1,N
      MUL=HH*(Y(I+1)-Y(I))
      B(I)=HH*(3.0*MUL-(A(I+1)+2.0*A(I)))
    7 C(I)=HH*HH*(-2.0*MUL+A(I+1)+A(I))
      RETURN
C--UNEQUAL SPACING H=0.. AND T=1
   11 DO 12 I=1,N
   12 S(I+1)=X(I+1)-X(I)
      DO 13 I=1,NE
      B(I)=2.0*(S(I+1)+S(I+2))
      C(I)=S(I+1)
      A(I)=S(I+2)
   13 P(I)=3.0*(S(I+1)**2*(Y(I+2)-Y(I+1))+S(I+2)**2*(Y(I+1)-Y(I)))/
     *     (S(I+1)*S(I+2))
      P(1)=P(1)-S(3)*D(1)
      P(NE)=P(NE)-S(N)*D(2)
      GO TO 3
   14 DO 15 I=1,N
      HH=1.0/S(I+1)
      MUL=(Y(I+1)-Y(I))*HH**2
      B(I)=3.0*MUL-(A(I+1)+2.0*A(I))*HH
   15 C(I)=-2.0*MUL*HH+(A(I+1)+A(I))*HH**2
      RETURN
C--2ND DERIVATIVE BOUNDARIES GIVEN
   20 NE=N+1
      IF(H) 999,31,21
C--EQUAL SPACING H .GT. 0 AND T=0
   21 HH=3.0/H
      DO 22 I=2,N
      B(I)=4.0
      C(I)=1.0
      A(I)=1.0
   22 P(I)=HH*(Y(I+1)-Y(I-1))
      B(1)=2.0
      B(NE)=2.0
      C(1)=1.0
      C(NE)=1.0
      A(NE)=1.0
      P(1)=HH*(Y(2)-Y(1))-0.5*H*D(1)
      P(NE)=HH*(Y(M)-Y(N))+0.5*H*D(2)
      GO TO 3
C--UNEQUAL SPACING H=0 AND T=0
   31 DO 32 I=1,N
   32 S(I+1)=X(I+1)-X(I)
      N1=N-1
      DO 33 I=1,N1
      B(I+1)=2.0*(S(I+1)+S(I+2))
      C(I+1)=S(I+1)
      A(I+1)=S(I+2)
   33 P(I+1)=3.0*(S(I+1)**2*(Y(I+2)-Y(I+1))+S(I+2)**2*(Y(I+1)-Y(I)))/
     *     (S(I+1)*S(I+2))
      B(1)=2.0
      B(NE)=2.0
      C(1)=1.0
      C(NE)=1.0
      A(NE)=1.0
      P(1)=3.0*(Y(2)-Y(1))/S(2)-0.5*S(2)*D(1)
      P(NE)=3.0*(Y(M)-Y(N))/S(M)+0.5*S(M)*D(2)
      GO TO 3
  999 M=-IABS(M)
      RETURN
      END
```

```
      SUBROUTINE LLSQ(A,B,M,N,L,X,IPIV,EPS,IER,AUX)
C
C     ..................................................................
C
C        SUBROUTINE LLSQ
C
C        PURPOSE
C           TO SOLVE LINEAR LEAST SQUARES PROBLEMS, I.E. TO MINIMIZE
C           THE EUCLIDEAN NORM OF B-A*X, WHERE A IS A M BY N MATRIX
C           WITH M NOT LESS THAN N. IN THE SPECIAL CASE M=N SYSTEMS OF
C           LINEAR EQUATIONS MAY BE SOLVED.
C
C        USAGE
C           CALL LLSQ (A,B,M,N,L,X,IPIV,EPS,IER,AUX)
C
C        DESCRIPTION OF PARAMETERS
C           A      - M BY N COEFFICIENT MATRIX (DESTROYED).
C           B      - M BY L RIGHT HAND SIDE MATRIX (DESTROYED).
C           M      - ROW NUMBER OF MATRICES A AND B.
C           N      - COLUMN NUMBER OF MATRIX A, ROW NUMBER OF MATRIX X.
C           L      - COLUMN NUMBER OF MATRICES B AND X.
C           X      - N BY L SOLUTION MATRIX.
C           IPIV   - INTEGER OUTPUT VECTOR OF DIMENSION N WHICH
C                    CONTAINS INFORMATIONS ON COLUMN INTERCHANGES
C                    IN MATRIX A. (SEE REMARK NO.3).
C           EPS    - INPUT PARAMETER WHICH SPECIFIES A RELATIVE
C                    TOLERANCE FOR DETERMINATION OF RANK OF MATRIX A.
C           IER    - A RESULTING ERROR PARAMETER.
C           AUX    - AUXILIARY STORAGE ARRAY OF DIMENSION MAX(2*N,L).
C                    ON RETURN FIRST L LOCATIONS OF AUX CONTAIN THE
C                    RESULTING LEAST SQUARES.
C
C        REMARKS
C           (1) NO ACTION BESIDES ERROR MESSAGE IER=-2 IN CASE
C               M LESS THAN N.
C           (2) NO ACTION BESIDES ERROR MESSAGE IER=-1 IN CASE
C               OF A ZERO-MATRIX A.
C           (3) IF RANK K OF MATRIX A IS FOUND TO BE LESS THAN N BUT
C               GREATER THAN 0, THE PROCEDURE RETURNS WITH ERROR CODE
C               IER=K INTO CALLING PROGRAM. THE LAST N-K ELEMENTS OF
C               VECTOR IPIV DENOTE THE USELESS COLUMNS IN MATRIX A.
C               THE REMAINING USEFUL COLUMNS FORM A BASE OF MATRIX A.
C           (4) IF THE PROCEDURE WAS SUCCESSFUL, ERROR PARAMETER IER
C               IS SET TO 0.
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           HOUSEHOLDER TRANSFORMATIONS ARE USED TO TRANSFORM MATRIX A
C           TO UPPER TRIANGULAR FORM. AFTER HAVING APPLIED THE SAME
C           TRANSFORMATION TO THE RIGHT HAND SIDE MATRIX B, AN
C           APPROXIMATE SOLUTION OF THE PROBLEM IS COMPUTED BY
C           BACK SUBSTITUTION. FOR REFERENCE, SEE
C           G. GOLUB, NUMERICAL METHODS FOR SOLVING LINEAR LEAST
C           SQUARES PROBLEMS, NUMERISCHE MATHEMATIK, VOL.7,
C           ISS.3 (1965), PP.206-216.
C
C     ..................................................................
C
      DIMENSION A(1),B(1),X(1),IPIV(1),AUX(1)
C
C     ERROR TEST
      IF(M-N)30,1,1
C
C     GENERATION OF INITIAL VECTOR S(K) (K=1,2,...,N) IN STORAGE
C     LOCATIONS AUX(K) (K=1,2,...,N)
    1 PIV=0.
      IEND=0
      DO 4 K=1,N
      IPIV(K)=K
      H=0.
      IST=IEND+1
      IEND=IEND+M
      DO 2 I=IST,IEND
    2 H=H+A(I)*A(I)
      AUX(K)=H
      IF(H-PIV)4,4,3
    3 PIV=H
      KPIV=K
    4 CONTINUE
C
C     ERROR TEST
      IF(PIV)31,31,5
C
C     DEFINE TOLERANCE FOR CHECKING RANK OF A
    5 SIG=SQRT(PIV)
      TOL=SIG*ABS(EPS)
C
C
C     DECOMPOSITION LOOP
      LM=L*M
      IST=-M
      DO 21 K=1,N
      IST=IST+M+1
      IEND=IST+M-K
      I=KPIV-K
      IF(I)8,8,6
C
C     INTERCHANGE K-TH COLUMN OF A WITH KPIV-TH IN CASE KPIV.GT.K
    6 H=AUX(K)
      AUX(K)=AUX(KPIV)
      AUX(KPIV)=H
      ID=I*M
      DO 7 I=IST,IEND
      J=I+ID
      H=A(I)
      A(I)=A(J)
    7 A(J)=H
C
C     COMPUTATION OF PARAMETER SIG
    8 IF(K-1)11,11,9
    9 SIG=0.
      DO 10 I=IST,IEND
   10 SIG=SIG+A(I)*A(I)
      SIG=SQRT(SIG)
C
C     TEST ON SINGULARITY
      IF(SIG-TOL)32,32,11
C
C     GENERATE CORRECT SIGN OF PARAMETER SIG
   11 H=A(IST)
      IF(H)12,13,13
   12 SIG=-SIG
```

```
C
C      SAVE INTERCHANGE INFORMATION
   13 IPIV(KPIV)=IPIV(K)
      IPIV(K)=KPIV
C
C      GENERATION OF VECTOR UK IN K-TH COLUMN OF MATRIX A AND OF
C      PARAMETER BETA
      BETA=H+SIG
      A(IST)=BETA
      BETA=1./(SIG*BETA)
      J=N+K
      AUX(J)=-SIG
      IF(K-N)14,19,19
C
C      TRANSFORMATION OF MATRIX A
   14 PIV=0.
      ID=0
      JST=K+1
      KPIV=JST
      DO 18 J=JST,N
      ID=ID+M
      H=0.
      DO 15 I=IST,IEND
      II=I+ID
   15 H=H+A(I)*A(II)
      H=BETA*H
      DO 16 I=IST,IEND
      II=I+ID
   16 A(II)=A(II)-A(I)*H
C
C      UPDATING OF ELEMENT S(J) STORED IN LOCATION AUX(J)
      II=IST+ID
      H=AUX(J)-A(II)*A(II)
      AUX(J)=H
      IF(H-PIV)18,18,17
   17 PIV=H
      KPIV=J
   18 CONTINUE
C
C      TRANSFORMATION OF RIGHT HAND SIDE MATRIX B
   19 DO 21 J=K,LM,M
      H=0.
      IEND=J+M-K
      II=IST
      DO 20 I=J,IEND
      H=H+A(II)*B(I)
   20 II=II+1
      H=BETA*H
      II=IST
      DO 21 I=J,IEND
      B(I)=B(I)-A(II)*H
   21 II=II+1
C      END OF DECOMPOSITION LOOP
C
C
C      BACK SUBSTITUTION AND BACK INTERCHANGE
      IER=0
      I=N
      LN=L*N
      PIV=1./AUX(2*N)
      DO 22 K=N,LN,N
      X(K)=PIV*B(I)
   22 I=I+M
      IF(N-1)26,26,23
   23 JST=(N-1)*M+N
      DO 25 J=2,N
      JST=JST-M-1
      K=N+N+1-J
      PIV=1./AUX(K)
      KST=K-N
      ID=IPIV(KST)-KST
      IST=2-J
      DO 25 K=1,L
      H=B(KST)
      IST=IST+N
      IEND=IST+J-2
      II=JST
      DO 24 I=IST,IEND
      II=II+M
   24 H=H-A(II)*X(I)
      I=IST-1
      II=I+ID
      X(I)=X(II)
      X(II)=PIV*H
   25 KST=KST+M
C
C
C      COMPUTATION OF LEAST SQUARES
   26 IST=N+1
      IEND=0
      DO 29 J=1,L
      IEND=IEND+M
      H=0.
      IF(M-N)29,29,27
   27 DO 28 I=IST,IEND
   28 H=H+B(I)*B(I)
      IST=IST+M
   29 AUX(J)=H
      RETURN
C
C      ERROR RETURN IN CASE M LESS THAN N
   30 IER=-2
      RETURN
C
C      ERROR RETURN IN CASE OF ZERO-MATRIX A
   31 IER=-1
      RETURN
C
C      ERROR RETURN IN CASE OF RANK OF MATRIX A LESS THAN N
   32 IER=K-1
      RETURN
      END
C
```

FORMATTED DATA INPUT

The program is designed for formatted entry of data, with a namelist option provided for interactive modification of model parameters. Figure 6 is an operational flow chart to aid the user in

---

Figure 6.--NEAR HERE

---

preparing formatted data on card, disk, or other input devices.

Following are the specifications for formatted data input. To allow flexibility in the use of the program, the specifications are rather complicated. An examination of Figure 7, however, shows that

---

Figure 7.—NEAR HERE

---

data entry can be very simple. For simple forward calculations, the user can modify to suit his own purposes one of the data sets shown in Figure 7. For simple inverse calculations the user can modify one of the input data sets labeled FOR05.DAT under FIRST TEST and SECOND TEST on pages 63 and 68.

Input of formatted data occurs on logical unit 5, nominally a disk drive. Interactive prompts and user input occur on logical unit 7, nominally the user's terminal. In response to prompting from the program, the user may receive all output on his terminal (nominally unit 7) or send the bulk output to a printer file (nominally unit 6).

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In the latter case, selected output, including density and magnetization determined by least squares, are output on the terminal as well.

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Specifications for formatted input data

Data Unit	Format	Columns	Variable name, comments, etc.
1	(16A5)		Title card, mandatory.
		1	Number 1 for page throw at beginning of output. Otherwise blank.
		2-80	Arbitrary title.
2	(7F10.2,I4,2I3)		Parameters for profile line, mandatory.
	F10.2	1-10	XZERO: Initial X-value.
	F10.2	11-20	DELX: Increment of X.
	F10.2	21-30	AZMUTH: Azimuth of +X axis, in degrees + clockwise from true north.
	F10.2	31-40	FLDDEC: Declination of earth's field in degrees, + clockwise from true north.
	F10.2	41-50	FLDINC: Inclination of earth's field in degrees.
	F10.2	51-60	FLD: Strength of earth's total magnetic field in gammas. Needed only for calculations involving susceptibility.
	F10.2	61-70	HIMAG: Height of magnetometer above or, if -, below elevation ELEV, determined later.
	I4	71-74	NUMX: Number of field points at which calculations will be made. Usually + but - value acts as switch to cause |NUMX| X-values to be read as data unit 3.
	I3	75-77	NTOPO: Number of X-TOPO pairs defining topography, input to ELEVER as data unit 4.

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Data Unit	Format	Columns	Variable name, comments, etc.
2 (cont.)	I3	78-80	IELEV (Switch to determine input mode for ELEV, the elevation of magnetic fieldpoint.) = -1: Read ELEV(J),J=1,NUMX as data unit 5. 0: ELEV(J)=HIMAG,J=1,NUMX (constant elevation). +1: ELEV(J)=TOPO(J)+HIMAG (ground magnetometer or draped aeromag). >2: Interpolate ELEV(J),J=1,NUMX from IELEV X-ELEV pairs input to ELEVER as data unit 6.
3	(8G10.2)		X-values of fieldpoints. May be unequally spaced. Optional card string, used if NUMX negative. Input X(I),I=1,|NUMX|, 8 per card.
4	(8G10.2)		X-Z pairs for interpolation to form TOPO. Optional, used if NTOPO>0. String of X-values 8 per card followed, on separate card or cards, by Z-values, I=1,NTOPO.
5	(8G10.2) (Don't use both data units 5 and 6.)		Z-values, corresponding to X(I),I=1, NUMX, defining ELEV. Optional, required if IELEV=-1 ELEV(I),I=1,NUMX, 8 per card.
6	(8G10.2)		X-Z pairs for interpolation to form ELEV. Optional, used if IELEV>2. String of X-values 8 per card followed, on separate card or cards, by Z-values, I=1,IELEV.

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Data Unit	Format	Columns	Variable name, comments, etc.
7	(10I5,2G10.2,A2,I2)		Miscellaneous parameters, <u>mandatory</u>.
	I5	1-5	KINDFP = 1: grav. and mag. = 2: grav. only. = 3: mag. only.
	I5	6-10	NGIN: Number of input (e.g. regional) grav. values. This and next three variables define the number of X-Z pairs to be interpolated.
	I5	11-15	NTIN: Number of input (eg. regional) mag. values.
	I5	16-20	NGOBS: Number of observed grav. values.
	I5	21-25	NTOBS: Number of observed mag. values.
	I5	26-30	INY = 0: Standard 2-dimensional bodies, unlimited in Y. = 1: 2½-dimensional. Read Y's in data unit 13.
	I5	31-35	IREG (Switch for regional gravity procedure. See below for explanation.)
	I5	36-40	IRET (Switch for regional magnetic procedure.) = 0: Normal mode. Remove regional GIN+GCONS from GOBS or TIN+TCONS from TOBS, model residual. = 1: GIN+CONS or TIN+TCONS are starting regional to add to computed gravity or magnetic fields respectively. Model GOBS or TOBS with regional retained.
	I5	41-45	IWIDE: Columnar width of output device eg. 80 for teletype, 110 for line printer. Use IWIDE=0 for these default values.
	I5	46-50	NLPLT: Number of lines in X-axis of printer plot. Use NLPLT=0 for default NLPLT=NUMX.
	G10.2	51-60	GCONS: Constant regional or base level gravity value.

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Data Unit	Format	Columns	Variable name, comments, etc.
7 (cont.)	G10.2	61-70	TCONS: Constant regional or base level magnetic value.
	A2	71-72	XZUN: Unit for distances. Required for gravity, optional for magnetics. = KM or blank, kilometers; MI, miles; KF, kilofeet; ME, meters; FT, feet; NM, nautical miles.
	I2	73-74	KSPL (Switch for interpolation mode of GIN, TIN, GOBS and TOBS.) = 0: Linear interpolation. = 1: Spline interpolation. 2nd derivative at endpoints = 0.
	FG.2	75-80	RHOBOU in the Bouguer reduced density used only in output by FITGRV. Normally 2.67, may take other values including 0, used in modeling free air gravity profiles.
8	(8G10.2)		X-Z pairs for interpolation to create GIN. Optional, used if NGIN>0.
9	(8G10.2)		X-Z pairs for interpolation to create TIN. Optional, used if NTIN>0.
10	(8G10.2)		X-Z pairs for interpolation to create GOBS. Optional, used if NGOBS>0.
11	(8G10.2)		X-Z pairs for interpolation to create TOBS. Optional, used if NTOBS>0.

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Data Unit	Format	Columns	Variable name, comments, etc.
12	(16I5)		Number of bodies, number of corners in each.
	I5	1-5	NBODS: number of bodies.
	I5	6-10	NCORNR(1): number of corners in body 1, last corner counted twice.
	I5	11-15	NCORNR(2): number of corners in body 2,...
	I5	16-20	etc.
13	(8G10.2)		Half strike-lengths of bodies. Optional, 3 card-strings required if INY=1 even if calculation is for mag. or grav. alone. Cards may be blank. In grav. case, strike lengths may be different to either side of X-Z plane, so Y1 and Y2 needed. Mag. symmetrical, so only YMAG needed.
	1st card string		Y1(I),I=1,NBODS, 8 per card. +Y dimension of grav. body from X-Z plane, + "out of paper". Normally +.
	2nd card string		Y2(I),I=1,NBODS, 8 per card. -Y dimension of grav. body from X-Z plane, - "into paper". Normally -.
	3rd card string		YMAG(I),I=1,NBODS, 8 per card. Half strike-length of mag. body, always +.
14	(8G10.2)		X and Z corners for Ith body, mandatory.
	1st card string		XCORNR(K),K=1,NCORNR(I).
	2nd card string		ZCORNR(K),K=1,NCORNR(I).
			Repeat for each body. Use ZCORNR(K)=777. only as a code which places the body corner at the topographic surface by interpolation.

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Data Unit	Format	Columns	Variable name, comments, etc.
15	(5G10.2,6I5)		Physical properties for Ith body and control parameters for continuing run, mandatory.
	G10.2	1-10	RHO: Density contrast in gm/cm^3.
	G10.2	11-20	SUS: Susceptibility contrast in gauss/oersted. SUS=1. is required for inverse soln. for SUS.
	G10.2	21-30	REMMAG: Remanent magnetization contrast in gauss. REMMAG=1. is required for inverse soln. for REMMAG.
	G10.2	31-40	REMDEC: Declination of remanent magnetization, + clockwise from true north. Ignored in inverse soln.
	G10.2	41-50	REMINC: Inclination of remanent magnetization. Ignored in inverse soln.
	I5	51-55	ISKIP (Switch for next body or inverse soln.) = 0 or 1: Read another card like this one for next body if one exists. $\geq$2: Use physical properties from this card for (ISKIP-1) bodies to follow, then read another card like this one for next body if one exists. -69: Inverse soln. for this and all remaining bodies. Must also have REMMAG and/or SUS=1.
	I5	56-60	KPLOT (Plot switch. 0 default.) = 0: Printer plot output. = 1: Plot on DEC10 hardware plotter. Device requested on teletype. = 2: Both of above. =-1: Delete plot.

Data Unit	Format	Columns	Variable name, comments, etc.
	I5	61-65	KOUT (Output option switch. 0 default.) = 0 or −2: GOUT is residual between GRV and GOBS. TOUT is residual between TOT1 and TOBS. = ±1 and IREG=0: GOUT(I)=GRV(I)+GIN(I)+GCONS = ±1 and IRET=0: TOUT(I)=TOT1(I)+TIN(I)+TCONS If IREG≠0, revert to GOUT(I)=GRV(I)−GOBS(I). If IRET≠0, revert to TOUT(I)=TOT1(I)−TOBS(I). < 0 X and GOUT and/or X and TOUT are output to unit 6 in 8F10.2 format for subsequent use to create GIN and TIN.

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Data Unit	Format	Columns	Variable name, comments, etc.
15	I5	66-70	KFLD (Switch for printing of vertical field and choosing approximate or exact equation for calculating total field anomaly.) = 0: Default. Use approximate equation (M18). Omit vertical field. TOT2 set equal to TOT1 before proceeding with further calculations. = 1: Same as 0 but print vertical field. = 2: Use approximate equation (M18) to calculate TOT1 and exact equation (M17) to calculate TOT2. Omit vertical field. TOT2 set equal to TOT1 before proceeding with further calculations. = 3: Same as 2, but also print vertical field. = 4: Same as 2, but set TOT1=TOT2 before proceeding with further calculations. = 5: Same as 4, but print vertical field.

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Data Unit	Format	Columns	Variable name, comments, etc.
15 (cont.)	I5	71-75	MODE (Switch to control program flow following calculations for all bodies. Required only on final card in data unit 15 sequence.) = ± 1: Go back to beginning and read new data unit 1. = ± 2: Go back and read new body geometries (data unit 12). = ± 3: Go back and read new physical properties (data unit 15) = ± 4: End computation. = - : Rezero computed fields GRV, TOT1, TOT2, and VER before continuing. = + : Keep present field values as input to new calculation.
	I5	76-80	NXKNFP: 0 Default means no change. Switch used to set new value (1, 2, or 3) of KINDFP prior to beginning new calculations. Required only on final card in data unit 15 sequence. Irrelevant for MODE=±1. Often useful for MODE=±2 to delete mag. or grav. calculations. Take care with MODE=±3, for if KINDFP was 2, switch to KINDFP=1 or 3 will find missing mag. geometrical factors, or if KINDFP was 3, switch to KINDFP=1 or 2 will find missing grav. geometrical factors.

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NAMELIST DATA INPUT

In simple cases the program can be executed using namelist data input exclusively (for example, the calculation of the gravity field of an infinite slab shown below, but it is intended as a means of modifying a few parameters following a run using formatted input.) The namelist data input mode is entered via a program prompt on the user's terminal (logical unit 7), and namelist input occurs on the terminal as well. The output options are the same as for formatted data input. The program prompts the user when namelist data input is required. To input namelist parameters, type a space, a $, the namelist name, another space, the list of variables to be changed, and end with a $ and a carriage return. For example:

```
$PROFIL YZERO=-5.,HIMAG=10.,XZUN='ME'$CR.
```


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The four namelist names and the associated variable are:

PROFIL: X, NUMX, HIMAG, XZUN, GCONS, TCONS, AZMUTH, FLDDEC, FLDINC, FLD, NLPLT, KSPL

BODS: NEWBOD, Y1, Y2, YMAG, NCORNR, XCORNR, ZCORNR, KINDFP, NBODS, IO. (NEWBOD(I) is a switch set equal to 1 when any geometrical factor has been computed for body I. To recompute geometrical factors for body I, NEWBOD(I) must be reset to 0.)

PROP: RHO, SUS, REMMAG, REMDEC, REMINC, ISKIP, IO, NXMODE, NXKNFP, NXKPLT, NXROUT, NXKFLD. (The last five variables are the same as MODE, NXTKFP, KPLOT, KOUT, AND KFLD used in formatted input.)

PLOT: (Used only for USGS hardware plotting routine DECPLT. Ignore except for fancy plots.) Default values in parentheses.

IPX, IPY: Interval between labeled ticks on x- and y-axes. (Default value 1 means each tick labeled.)

SIZEL, SIZET, SIZES, SIZEH: Height in cm for: axis numbering (.2), axis labels (.3), plot symbols (.2), header (.2).

HIGH, WIDE: Height and width of plot in cm. (Default values of 20.32 and 25.4 are dimensions of Tectronix 4010 scope display.)

XAX, YAX: x- and y-axis labels. (XAX default: x in KM, or MILES, KILOFEET, METRES, FEET, NAUT MILES. YAX default: MILLIGALS and/or GAMMAS.)

NXAX, NYAX: Number of characters in XAX and YAX. (Max.=20, default value.)

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Following is a sample run using namelist input exclusively. The lines of type enclosed by boxes were input by the user.

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```
TTY50 assigned

.RU 2HDPOT

FOR BULK OUTPUT ON DSK TYPE "6". ON TTY TYPE "7".
7
FOR FORMATED INPUT,TYPE "0". NAMELIST INPUT,TYPE "5".
5

NAMELIST ENTRY OF "PROFIL" LIST:
  X,NUMX,HIMAG,XZUN,AZMUTH,FLDDEC,FLDINC,FLD,GCONS,TCONS, NLPLT,KLIN
 $PROFIL X=-5,0,5,NUMX=3$
$PROFIL
 X=  -5.000000    ,  0.0000000    ,  5.000000    , 47*  0.0000000
 NUMX=            3,  HIMAG=  0.0000000    ,  XZUN=  0.1574802E-01,
 GCONS=  0.0000000    ,  TCONS=  0.0000000    ,  AZMUTH=  0.0000000    ,
 FLDDEC=  0.0000000    ,  FLDINC=  0.0000000    ,  FLD=  0.0000000
 NLPLT=           0,  KLIN=            0, $
TYPE HEADER UP TO 80 CHAR.
 GRAVITY OF 1KM THICK INFINITE SLAB.

KINDFP NGIN NTIN NGOBSNTOBS INY IPROC1,2 IWIDENLPLT GCONS     TCONS   XZUN KLIN
   1    0    0    0    0    0    0    0   80    3  0.00       0.00          0

  I        X          TOPO        GRAVTOPO      MAGELEV          GIN           GOBS           TIN          TOBS

  1    -5.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
  2     0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
  3     5.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000

NAMELIST ENTRY OF "BODS" LIST TO ALTER BODY GEOMETRY:
  NEWBOD,Y1,Y2,YMAG,NCORNR,XCORNR,ZCORNR,KINDFP,NBODS
 $BODS NCORNR=5,XCORNR=-9999,9999,9999,-9999,-9999,ZCORNR=0,0,-1,-1,0,KINDFP=2$
$BODS
 KINDFP=            2,  NBODS=            1,  NEWBOD=10*            0,
 Y1=10*  0.0000000    ,  Y2=10*  0.0000000    ,  YMAG=10*  0.0000000    ,
 NCORNR=            5, 9*            0,  XCORNR=  -9999.000    ,
2*   9999.000    , 2*  -9999.000    , 145*  0.0000000    ,
 ZCORNR=2*  0.0000000    , 2*  -1.000000    , 146*  0.0000000    ,
$

BODY  1-- COORDINATES OF CORNERS
 -0.10E+05  0.10E+05  0.10E+05 -0.10E+05 -0.10E+05
  0.00      0.00     -1.0      -1.0       0.00

NAMELIST ENTRY OF "PROP" LIST FOR BODY  1:
  RHO,SUS,REMMAG,REMINC,ISKIP,NXMODE,NXKNFP,NXKPLT,NXKOUT,NXKFLD
 $PROP RHO=1$
$PROP
 RHO=   1.000000    ,  SUS=  0.0000000    ,  REMMAG=  0.0000000    ,
 REMDEC=  0.0000000    ,  REMINC=  0.0000000    ,  ISKIP=            0,
 NXMODE=            4,  NXKNFP=            0,  NXKPLT=            0,
 NXKOUT=            0,  NXKFLD=            0, $
  1.00E+00  0.00E-01  0.00E-01  0.00E-01  0.00E-01    0    0    0    0    4
  0.00E-01

BODY  1--DENSITY CONTRAST RHO = 1.0000 GRAMS/CC, SUS=  0.00E-01     GAUSS/OE.
REMANENT MAGNETIZATION=  0.00E-01  GAUSS WITH DECL=     0.0 DEG, INCL=     0.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY  1.

     X         GRAVITY         X         GRAVITY          X         GRAVITY
  -5.000        41.94       0.0000       41.91         5.000        41.94

     X        GOBS       GRV       GERR       TOBS       TOT1      T1ERR      TOT2      T2ERR      GOUT      TOUT
GRAVITY OF 1KM THICK INFINITE SLAB.

PLOT SYMBOLS: ELEV=1 TOPO=: GOBS=G TOBS=T GRV=* TOT1=+ TOT2=# TOUT=@ GOUT=%

  GRAV    -5.00E+00  2.69E+00  1.04E+01  1.81E+01  2.58E+01  3.35E+01  4.12E+01
   MAG     0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01
 KM        +....+....+....+....+....+....+....+....+....+....+....+....+
  -5.00E+00  @      G                                                 %    <
   0.00E-01  @      %                                                 *    -
   5.00E+00  @      %                                                 *    -
 KM        +....+....+....+....+....+....+....+....+....+....+....+....+

  GRAV    -5.00E+00  2.69E+00  1.04E+01  1.81E+01  2.58E+01  3.35E+01  4.12E+01
   MAG     0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01

   YSCALE = 7.6923E-01    XSCALE = 5.0000E+00    TYSCAL= 0.0000E-01

 THE COMPUTATION IS COMPLETE. TYPE (MODE) +OR- 5,6,7 TO ADJUST PARAMETERS
BY NAMELIST: 7-PHYS PROP, 6-BODY GEOM + PHYS PROP, 5-EVERYTHING;
MODE NEG TO ZERO GRV,VER,TOT1,TOT2, ZERO TO STOP.
0
STOP

END OF EXECUTION
CPU TIME: 1.75  ELAPSED TIME: 7:4.85
```

TESTS OF THE PROGRAM

The first test uses a 8x8x3 prism from a book of magnetic type curves by Aero Service (undated, p. 259). TOBS was measured from the total magnetic field curve on p. 259, and GOBS was calculated using the formula for the gravity field of a right rectangular prism (Nagy, 1966, eq. 9, p. 365). The rectangular prism was divided into two bodies by a diagonal in order to test the program on a sloping side. The forward calculation shows measured (not-interpolated) values of GOBS and GRV to agree within 0.1%. TOBS AND TOTl agree within 2% of the anomaly magnitude, the error resulting from measurement on the plotted curves. Following the forward calculations are successful inverse calculations resulting in density contrast, susceptibility, and remanent magnetization very close to the nominal values. Observed and computed anomaly values at x=-10. are marked with a box to aid the reader in making comparisons. The Earth's magnetic field declination and inclination are underlined for comparison with computed declination and inclination of magnetization. Input values of RHO and SUS in the forward case are underlined for comparison with values of RHO, SUS, and AMP (amplitude) of remanent magnetization computed in the inverse case which follows.

The second test is a magnetic test only using an 8x1x∞ prism of Aero Service (undated, p. 235). The azimuth of the x-axis is 60°, compared to 0° in the first test. A bottom depth of -9999 was used to approximate minus infinity. Again the prism was divided into two bodies in order to test the program on sloping sides. The division was not made along a simple diagonal for the following reason. With a near-infinite bottom depth, and division of the rectangular cross section into two congruent triangles, the triangle with its base near the surface has a much greater magnetic effect at the observation points than does the triangle with its base at depth. The results are accurate in the forward calculation, but the equations are ill-conditioned in the inverse calculation.

The third and fourth tests use half of the prism of the first test and compute its gravity and magnetic fields in each of four quadrants to ensure that computed anomalies have the proper sign both above and below the observation point. The gravity effect of a body is reversed when it is moved from below to a point the same distance above an observation point.

In the magnetic case, however, the lines of force of a vertically polarized body enter through the top and emerge through the bottom. The vertical component of magnetization, and hence the total field anomaly if the Earth's field is vertical, is the same a given distance above a rectangular prism as it is the same distance below. The horizontal component of magnetization, and hence the total field anomaly if the Earth's field is horizontal, is opposite in sign at points equally disposed above and below the body.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
842-171

FIRST TEST

```
.TYPE FOR05.DAT
 TEST 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.
-10.      1.        0.        0.        60.       100000.   0.        21 00 00
  1    0    0   11   15    1    0    0  110      00.       0.        KM 0
-10.      -8.       -6.       -4.       -2.       0.        2.        4.
6.        8.        10.
3.4188    6.7024    15.2465   38.4065   60.7750   66.2300   60.7750   38.4065
15.2465   6.7024    3.4188
-10.      -8.       -6.       -5.       -4.       -3.55     -2.       0.
2.        3.        4.        4.65      6.        8.        10.
0.094     0.281     0.906     1.781     2.938     3.078     2.453     1.750
0.875     0.06      -1.250    -1.406    -0.875    -0.388    -0.169
  2    4    4
-4.       -4.
4.        4.
4.        4.
-4.       4.        -4.       -4.
-1.       -1.       -4.       -1.
-4.       4.        4.        -4.
-4.       -1.       -4.       -4.
1.        .00001    0.        0.        0.             2    2    0    3   -3    0
0.        1.        1.        0.        0.           -69    2    0    2    4    0

.RU 2HDPOT

FOR BULK OUTPUT ON DSK TYPE "6". ON TTY TYPE "7".
7
FOR FORMATED INPUT,TYPE "0". NAMELIST INPUT,TYPE "5".
0
TEST 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.

 XZERO      DELX      AZMUTH     FLDDEC     FLDINC     FLD         HIMAG  NUMX,NTOPO,IELEV
  -10.00       1.00       0.00       0.00      60.00 100000.00       0.00  21  0  0

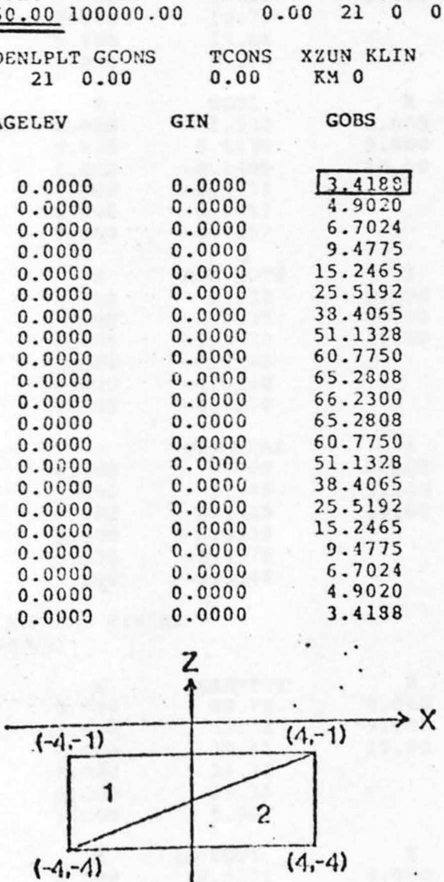
KINDFP NGIN NTIN NGOBSNTOBS INY IPROC1,2 IWIDENLPLT GCONS     TCONS   XZUN KLIN
   1    0    0   11   15    1    0    0  110   21  0.00       0.00    KM 0
```

I	X	TOPO	GRAVTOPO	MAGELEV	GIN	GOBS	TIN	TOBS
1	-10.0000	0.0000	0.0000	0.0000	0.0000	3.4188	0.0000	0.0940
2	-9.0000	0.0000	0.0000	0.0000	0.0000	4.9020	0.0000	0.1721
3	-8.0000	0.0000	0.0000	0.0000	0.0000	6.7024	0.0000	0.2810
4	-7.0000	0.0000	0.0000	0.0000	0.0000	9.4775	0.0000	0.4754
5	-6.0000	0.0000	0.0000	0.0000	0.0000	15.2465	0.0000	0.9060
6	-5.0000	0.0000	0.0000	0.0000	0.0000	25.5192	0.0000	1.7810
7	-4.0000	0.0000	0.0000	0.0000	0.0000	38.4065	0.0000	2.9380
8	-3.0000	0.0000	0.0000	0.0000	0.0000	51.1328	0.0000	2.9674
9	-2.0000	0.0000	0.0000	0.0000	0.0000	60.7750	0.0000	2.4530
10	-1.0000	0.0000	0.0000	0.0000	0.0000	65.2808	0.0000	2.0559
11	0.0000	0.0000	0.0000	0.0000	0.0000	66.2300	0.0000	1.7500
12	1.0000	0.0000	0.0000	0.0000	0.0000	65.2808	0.0000	1.3715
13	2.0000	0.0000	0.0000	0.0000	0.0000	60.7750	0.0000	0.8750
14	3.0000	0.0000	0.0000	0.0000	0.0000	51.1328	0.0000	0.0600
15	4.0000	0.0000	0.0000	0.0000	0.0000	38.4065	0.0000	-1.2500
16	5.0000	0.0000	0.0000	0.0000	0.0000	25.5192	0.0000	-1.3184
17	6.0000	0.0000	0.0000	0.0000	0.0000	15.2465	0.0000	-0.8750
18	7.0000	0.0000	0.0000	0.0000	0.0000	9.4775	0.0000	-0.5574
19	8.0000	0.0000	0.0000	0.0000	0.0000	6.7024	0.0000	-0.3880
20	9.0000	0.0000	0.0000	0.0000	0.0000	4.9020	0.0000	-0.2697
21	10.0000	0.0000	0.0000	0.0000	0.0000	3.4188	0.0000	-0.1690

```
NBODS, NCORNR(I),I=1,NBODS
  2    4    4
Y1(I),I=1,NBODS;Y2(I);YMAG(I)
 -4.0       -4.0
  4.0        4.0
  4.0        4.0

BODY    1-- COORDINATES OF CORNERS
 -4.0        4.0       -4.0       -4.0
 -1.0       -1.0       -4.0       -1.0

BODY    2-- COORDINATES OF CORNERS
 -4.0        4.0        4.0       -4.0
 -4.0       -1.0       -4.0       -4.0
 1.00E+00   1.00E-05   0.00E-01   0.00E-01   0.00E-01    2    2    0    0   -3
 0.00E-01
```



BODY 1--DENSITY CONTRAST RHO = 1.0000 GRAMS/CC, SUS= 1.00E-05 GAUSS/OE.
REMANENT MAGNETIZATION= 0.00E-01 GAUSS WITH DECL= 0.0 DEG, INCL= 0.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 1.

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	2.069	-4.000	29.59	2.000	26.27	8.000	1.556
-9.000	2.944	-3.000	40.09	3.000	17.90	9.000	1.133
-8.000	4.348	-2.000	44.34	4.000	10.21	10.00	0.8531
-7.000	6.699	-1.000	43.68	5.000	5.586		
-6.000	10.79	0.0000	39.82	6.000	3.384		
-5.000	18.06	1.000	33.79	7.000	2.229		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.6294E-01	-4.000	2.393	2.000	-0.4202	8.000	-0.1002
-9.000	0.1071	-3.000	2.272	3.000	-0.7788	9.000	-0.6731E-01
-8.000	0.1900	-2.000	1.578	4.000	-0.8391	10.00	-0.4727E-01
-7.000	0.3529	-1.000	0.9602	5.000	-0.4943		
-6.000	0.6886	0.0000	0.4457	6.000	-0.2681		
-5.000	1.389	1.000	-0.5390E-02	7.000	-0.1580		

X	ACC TOT2	X	ACC TOT2	X	ACC TOT2	X	ACC TOT2
-10.00	0.6250E-01	-4.000	2.393	2.000	-0.4209	8.000	-0.1016
-9.000	0.1064	-3.000	2.271	3.000	-0.7803	9.000	-0.6836E-01
-8.000	0.1885	-2.000	1.577	4.000	-0.8398	10.00	-0.4883E-01
-7.000	0.3516	-1.000	0.9590	5.000	-0.4951		
-6.000	0.6885	0.0000	0.4443	6.000	-0.2695		
-5.000	1.388	1.000	-0.5859E-02	7.000	-0.1592		

X	VERTICAL	X	VERTICAL	X	VERTICAL	X	VERTICAL
-10.00	-0.4563E-01	-4.000	1.962	2.000	0.2217	8.000	-0.1409
-9.000	-0.4568E-01	-3.000	2.485	3.000	-0.2926	9.000	-0.1004
-8.000	-0.3054E-01	-2.000	2.146	4.000	-0.6517	10.00	-0.7409E-01
-7.000	0.2867E-01	-1.000	1.661	5.000	-0.5077		
-6.000	0.2139	0.0000	1.180	6.000	-0.3181		
-5.000	0.7589	1.000	0.7076	7.000	-0.2064		

BODY 2 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 2.

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	1.350	-4.000	8.814	2.000	34.51	8.000	5.147
-9.000	1.765	-3.000	12.22	3.000	34.40	9.000	3.575
-8.000	2.355	-2.000	16.44	4.000	23.20	10.00	2.566
-7.000	3.208	-1.000	21.29	5.000	18.74		
-6.000	4.455	0.0000	26.41	6.000	11.86		
-5.000	6.264	1.000	31.18	7.000	7.678		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.3652E-01	-4.000	0.4768	2.000	1.332	8.000	-0.2722
-9.000	0.5462E-01	-3.000	0.6775	3.000	0.8139	9.000	-0.1812
-8.000	0.8347E-01	-2.000	0.9007	4.000	-0.3409	10.00	-0.1238
-7.000	0.1299	-1.000	1.122	5.000	-0.8133		
-6.000	0.2038	0.0000	1.311	6.000	-0.6251		
-5.000	0.3171	1.000	1.417	7.000	-0.4157		

X	ACC TOT2	X	ACC TOT2	X	ACC TOT2	X	ACC TOT2
-10.00	0.3613E-01	-4.000	0.4756	2.000	1.332	8.000	-0.2734
-9.000	0.5371E-01	-3.000	0.6768	3.000	0.8135	9.000	-0.1816
-8.000	0.8301E-01	-2.000	0.8994	4.000	-0.3428	10.00	-0.1240
-7.000	0.1289	-1.000	1.121	5.000	-0.8145		
-6.000	0.2031	0.0000	1.311	6.000	-0.6250		
-5.000	0.3164	1.000	1.416	7.000	-0.4170		

X	VERTICAL	X	VERTICAL	X	VERTICAL	X	VERTICAL
-10.00	-0.1317E-01	-4.000	0.2674	2.000	1.709	8.000	-0.2628
-9.000	-0.9575E-02	-3.000	0.4533	3.000	1.549	9.000	-0.1917
-8.000	-0.2931E-03	-2.000	0.6903	4.000	0.5425	10.00	-0.1409
-7.000	0.2026E-01	-1.000	0.9633	5.000	-0.3339		
-6.000	0.6190E-01	0.0000	1.254	6.000	-0.4370		
-5.000	0.1392	1.000	1.529	7.000	-0.3546		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	3.419	-4.000	38.41	2.000	60.78	8.000	6.703
-9.000	4.709	-3.000	52.30	3.000	52.30	9.000	4.709
-8.000	6.703	-2.000	60.78	4.000	38.41	10.00	3.420
-7.000	9.907	-1.000	64.97	5.000	24.32		
-6.000	15.25	0.0000	66.23	6.000	15.25		
-5.000	24.32	1.000	64.97	7.000	9.907		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.9945E-01	-4.000	2.870	2.000	0.9121	8.000	-0.3724
-9.000	0.1617	-3.000	2.949	3.000	0.3513E-01	9.000	-0.2486
-8.000	0.2734	-2.000	2.479	4.000	-1.180	10.00	-0.1711
-7.000	0.4828	-1.000	2.082	5.000	-1.308		
-6.000	0.8924	0.0000	1.756	6.000	-0.8931		
-5.000	1.706	1.000	1.411	7.000	-0.5736		

X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	3.42E+00	3.42E+00	6.94E-04	9.40E-02	9.95E-02	5.45E-03	9.95E-02	5.45E-03	6.94E-04	5.45E-03
-9.00E+00	4.90E+00	4.71E+00	-1.93E-01	1.72E-01	1.62E-01	-1.04E-02	1.62E-01	-1.04E-02	-1.93E-01	-1.04E-02
-8.00E+00	6.70E+00	6.70E+00	1.08E-04	2.81E-01	2.73E-01	-7.56E-03	2.73E-01	-7.56E-03	1.08E-04	-7.56E-03
-7.00E+00	9.48E+00	9.91E+00	4.30E-01	4.75E-01	4.83E-01	7.35E-03	4.83E-01	7.35E-03	4.30E-01	7.35E-03
-6.00E+00	1.52E+01	1.52E+01	1.71E-03	9.06E-01	8.92E-01	-1.36E-02	8.92E-01	-1.36E-02	1.71E-03	-1.36E-02
-5.00E+00	2.55E+01	2.43E+01	-1.20E+00	1.78E+00	1.71E+00	-7.53E-02	1.71E+00	-7.53E-02	-1.20E+00	-7.53E-02
-4.00E+00	3.84E+01	3.84E+01	5.88E-04	2.94E+00	2.87E+00	-6.81E-02	2.87E+00	-6.81E-02	5.88E-04	-6.81E-02
-3.00E+00	5.11E+01	5.23E+01	1.17E+00	2.97E+00	2.95E+00	-1.82E-02	2.95E+00	-1.82E-02	1.17E+00	-1.82E-02
-2.00E+00	6.08E+01	6.08E+01	4.27E-04	2.45E+00	2.48E+00	2.60E-02	2.48E+00	2.60E-02	4.27E-04	2.60E-02
-1.00E+00	6.53E+01	6.50E+01	-3.08E-01	2.06E+00	2.08E+00	2.60E-02	2.08E+00	2.60E-02	-3.08E-01	2.60E-02
0.00E-01	6.62E+01	6.62E+01	6.08E-04	1.75E+00	1.76E+00	6.24E-03	1.76E+00	6.24E-03	6.08E-04	6.24E-03
1.00E+00	6.53E+01	6.50E+01	-3.08E-01	1.37E+00	1.41E+00	3.97E-02	1.41E+00	3.97E-02	-3.08E-01	3.97E-02
2.00E+00	6.08E+01	6.08E+01	4.26E-04	8.75E-01	9.12E-01	3.71E-02	9.12E-01	3.71E-02	4.26E-04	3.71E-02
3.00E+00	5.11E+01	5.23E+01	1.17E+00	6.00E-02	3.51E-02	-2.49E-02	3.51E-02	-2.49E-02	1.17E+00	-2.49E-02
4.00E+00	3.84E+01	3.84E+01	5.88E-04	-1.25E+00	-1.18E+00	7.00E-02	-1.18E+00	7.00E-02	5.88E-04	7.00E-02
5.00E+00	2.55E+01	2.43E+01	-1.20E+00	-1.32E+00	-1.31E+00	1.08E-02	-1.31E+00	1.08E-02	-1.20E+00	1.08E-02
6.00E+00	1.52E+01	1.52E+01	1.71E-03	-8.75E-01	-8.93E-01	-1.81E-02	-8.93E-01	-1.81E-02	1.71E-03	-1.81E-02
7.00E+00	9.48E+00	9.91E+00	4.30E-01	-5.57E-01	-5.74E-01	-1.62E-02	-5.74E-01	-1.62E-02	4.30E-01	-1.62E-02
8.00E+00	6.70E+00	6.70E+00	1.11E-04	-3.88E-01	-3.72E-01	1.56E-02	-3.72E-01	1.56E-02	1.11E-04	1.56E-02
9.00E+00	4.90E+00	4.71E+00	-1.93E-01	-2.70E-01	-2.49E-01	2.11E-02	-2.49E-01	2.11E-02	-1.93E-01	2.11E-02
1.00E+01	3.42E+00	3.42E+00	7.08E-04	-1.69E-01	-1.71E-01	-2.10E-03	-1.71E-01	-2.10E-03	7.08E-04	-2.10E-03

```
MEAN ERROR OF G = -8.92E-03 ,RMS ERROR OF G=   5.45E-01
MEAN ERROR OF TOT1=  5.25E-04 ,RMS ERROR OF TOT1=  3.26E-02
MEAN ERROR OF TOT2=  5.25E-04 ,RMS ERROR OF TOT2=  3.26E-02

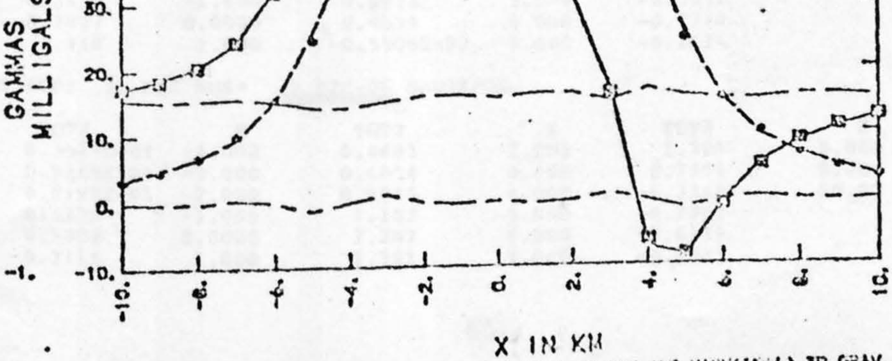
TEST 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.

PLOT SYMBOLS: ELEV=1 TOPO=: GOBS=G TOBS=T GRV=* TOT1=+ TOT2=# TOUT=@ GOUT=%

 GRAV   -1.00E+01 -1.58E+00  6.84E+00  1.53E+01  2.37E+01  3.21E+01  4.05E+01  4.89E+01  5.74E+01  6.58E+01
 MAG    -1.40E+00 -9.37E-01 -4.74E-01 -1.05E-02  4.53E-01  9.16E-01  1.38E+00  1.84E+00  2.31E+00  2.77E+00
KM          +....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+
 -1.00E+01  :            %  *                @ #                                                          <
 -9.00E+00  :            %  *G               @     #                                                      -
 -8.00E+00  :            %         *         @        #                                                   -
 -7.00E+00  :            %            G*     @           T#                                               -
 -6.00E+00  :            %                   @                          #T                                -
 -5.00E+00  :           %                    @            *G                            # T               <
 -4.00E+00  :            %                   @                                *                          # T-
 -3.00E+00  :            %                   @                                             G*             #-
 -2.00E+00  :            %                   @                                                     T#     -
 -1.00E+00  :            %                   @                                             #           *  -
  0.00E-01  :            %                   @                                         #                * <
  1.00E+00  :            %                   @                               T#                        *  -
  2.00E+00  :            %                   @                      T#                        *           -
  3.00E+00  :            %                   @#T                                           G*             -
  4.00E+00  :  T #       %                    @                       *                                   -
  5.00E+00  : #     %                        @.           *G                                              <
  6.00E+00  :           #%                   @                                                            -
  7.00E+00  :            %    #     G*       @                                                            -
  8.00E+00  :            %       * #         @                                                            -
  9.00E+00  :            %  *G        T#     @                                                            -
  1.00E+01  :            %  *              # @                                                            <
KM          +....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+....+

 GRAV   -1.00E+01 -1.58E+00  6.84E+00  1.53E+01  2.37E+01  3.21E+01  4.05E+01  4.89E+01  5.74E+01  6.58E+01
 MAG    -1.40E+00 -9.37E-01 -4.74E-01 -1.05E-02  4.53E-01  9.16E-01  1.38E+00  1.84E+00  2.31E+00  2.77E+00

  YSCALE = 8.4211E-01     XSCALE = 1.0000E+00     TYSCAL= 4.6316E-02
ENTER PLOTTER NO.=1
```



TEST 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.

<<TK4010[X/Y:17.6/12.6-CM[CH I/O:129/129[LN I/O:126/126
<< DEV:TTY1[BLKS:323
TO EXIT TYPE "0". TO ADJUST PLOT ON SAME DEV TYPE "1". TO CHNG DEV AND ADJ PLOT TYPE "2". TO CHNG DEV TYPE "3"
0

MODE= -3. GRV AND VER, TOT1, TOT2 ARE RE-ZEROED.

THE COMPUTATION WILL RECOMMENCE WITH NEW MAG AND DENS,BUT WITH THE SAME BODIES AND FIELD POINTS
0.00E-01 1.00E+00 1.00E+00 0.00E-01 0.00E-01 -69 2 0 0 4
0.00E-01

BODY 1--DENSITY CONTRAST RHO = 0.0000 GRAMS/CC, SUS= 1.00E+00 GAUSS/OE.
REMANENT MAGNETIZATION= 1.00E+00 GAUSS WITH DECL= 0.0 DEG, INCL= 0.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 1.

LST SQRS SAYS BODY 1 HAS DENSITY CONTRAST= 0.998 GM/CC, DENSITY= 3.668 GM/CC

X	GRAV	X	GRAV	X	GRAV	X	GRAV
-10.00	2.066	-4.000	29.55	2.000	26.23	8.000	1.553
-9.000	2.939	-3.000	40.02	3.000	17.87	9.000	1.131
-8.000	4.341	-2.000	44.26	4.000	10.19	10.00	0.8517
-7.000	6.688	-1.000	43.61	5.000	5.577		
-6.000	10.78	0.0000	39.75	6.000	3.379		
-5.000	18.03	1.000	33.74	7.000	2.225		

LST SQRS SAYS BODY 2 HAS DENSITY CONTRAST= 1.000 GM/CC, DENSITY= 3.670 GM/CC

X	GRAV	X	GRAV	X	GRAV	X	GRAV
-10.00	1.350	-4.000	8.812	2.000	34.50	8.000	5.146
-9.000	1.765	-3.000	12.21	3.000	34.39	9.000	3.574
-8.000	2.354	-2.000	16.44	4.000	28.19	10.00	2.566
-7.000	3.208	-1.000	21.29	5.000	18.73		
-6.000	4.454	0.0000	26.41	6.000	11.86		
-5.000	6.263	1.000	31.17	7.000	7.676		

CHY=0. EARTHS FIELD VERTICAL OR PARALLEL TO X-AXIS.
INVERT FOR MX AND MZ BUT NOT MY.

LST SQRS SAYS BODY 1 HAS MAGNETIZATION COMPONENTS
MX= 5.35E-06, MY= 0.00E-01, MZ= 8.66E-06
DEC= 0.0, INC= 58.3, AMP= 1.02E-05
PROJECTED INTO EARTHS FIELD AZIMUTH, INC= 58.3

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.7018E-01	-4.000	2.443	2.000	-0.4635	8.000	-0.9872E-01
-9.000	0.1175	-3.000	2.281	3.000	-0.8161	9.000	-0.6595E-01
-8.000	0.2053	-2.000	1.559	4.000	-0.8588	10.00	-0.4609E-01
-7.000	0.3762	-1.000	0.9269	5.000	-0.4983		
-6.000	0.7243	0.0000	0.4052	6.000	-0.2677		
-5.000	1.441	1.000	-0.4896E-01	7.000	-0.1566		

LST SQRS SAYS BODY 2 HAS MAGNETIZATION COMPONENTS
MX= 5.05E-06, MY= 0.00E-01, MZ= 8.78E-06
DEC= 0.0, INC= 60.1, AMP= 1.01E-05
PROJECTED INTO EARTHS FIELD AZIMUTH, INC= 60.1

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.3684E-01	-4.000	0.4824	2.000	1.351	8.000	-0.2758
-9.000	0.5514E-01	-3.000	0.6857	3.000	0.8269	9.000	-0.1837
-8.000	0.8431E-01	-2.000	0.9118	4.000	-0.3425	10.00	-0.1255
-7.000	0.1312	-1.000	1.136	5.000	-0.8225		
-6.000	0.2061	0.0000	1.328	6.000	-0.6327		
-5.000	0.3207	1.000	1.436	7.000	-0.4209		

LST SQRS SAYS BODY 1 HAS SUS= 1.02E-05 GAUSS/OE.

X	TOT2	X	TOT2	X	TOT2	X	TOT2
-10.00	0.6432E-01	-4.000	2.446	2.000	-0.4294	8.000	-0.1024
-9.000	0.1095	-3.000	2.322	3.000	-0.7959	9.000	-0.6879E-01
-8.000	0.1941	-2.000	1.613	4.000	-0.8575	10.00	-0.4830E-01
-7.000	0.3607	-1.000	0.9813	5.000	-0.5051		
-6.000	0.7037	0.0000	0.4554	6.000	-0.2740		
-5.000	1.419	1.000	-0.5508E-02	7.000	-0.1614		

LST SQRS SAYS BODY 2 HAS SUS= 9.82E-06 GAUSS/OE.

X	TOT2	X	TOT2	X	TOT2	X	TOT2
-10.00	0.3586E-01	-4.000	0.4683	2.000	1.309	8.000	-0.2674
-9.000	0.5365E-01	-3.000	0.6654	3.000	0.7994	9.000	-0.1780
-8.000	0.8198E-01	-2.000	0.8846	4.000	-0.3348	10.00	-0.1216
-7.000	0.1276	-1.000	1.102	5.000	-0.7989		
-6.000	0.2002	0.0000	1.287	6.000	-0.6139		
-5.000	0.3115	1.000	1.391	7.000	-0.4083		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	3.416	-4.000	38.36	2.000	60.73	8.000	6.699
-9.000	4.703	-3.000	52.24	3.000	52.27	9.000	4.706
-8.000	6.695	-2.000	60.70	4.000	38.38	10.00	3.418
-7.000	9.896	-1.000	64.90	5.000	24.31		
-6.000	15.23	0.0000	66.16	6.000	15.24		
-5.000	24.29	1.000	64.91	7.000	9.902		

X	TOT1 (MVT)	X	TOT1 (MVT)	X	TOT1 (MVT)	X	TOT1 (MVT)
-10.00	0.1070	-4.000	2.925	2.000	0.8875	8.000	-0.3745
-9.000	0.1726	-3.000	2.967	3.000	0.1080E-01	9.000	-0.2496
-8.000	0.2896	-2.000	2.471	4.000	-1.201	10.00	-0.1716
-7.000	0.5074	-1.000	2.063	5.000	-1.321		
-6.000	0.9304	0.0000	1.733	6.000	-0.9004		
-5.000	1.761	1.000	1.387	7.000	-0.5775		

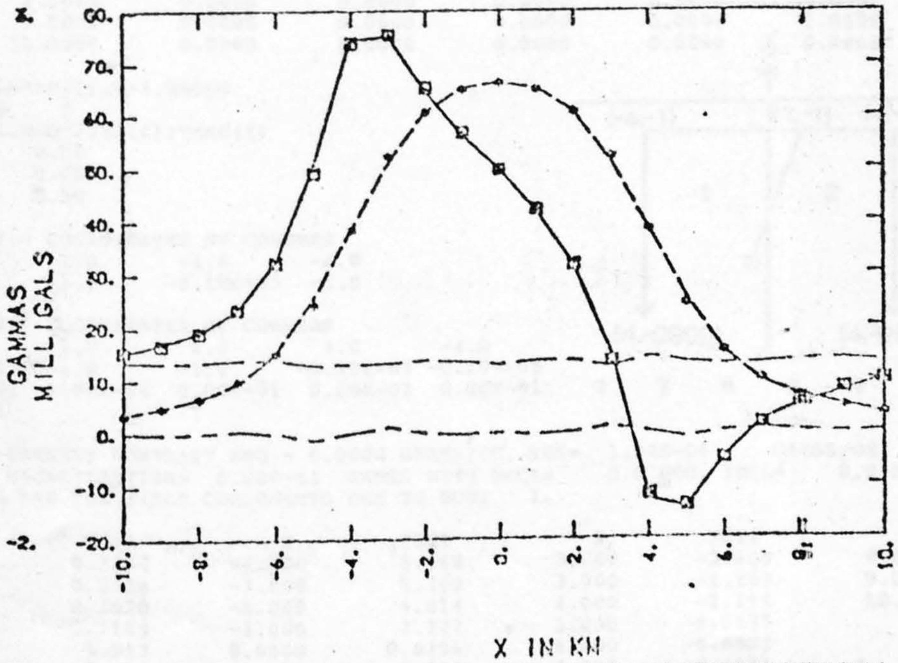
X	TOT2 (SUS)	X	TOT2 (SUS)	X	TOT2 (SUS)	X	TOT2 (SUS)
-10.00	0.1002	-4.000	2.914	2.000	0.8792	8.000	-0.3698
-9.000	0.1631	-3.000	2.987	3.000	0.3544E-02	9.000	-0.2468
-8.000	0.2761	-2.000	2.498	4.000	-1.192	10.00	-0.1699
-7.000	0.4882	-1.000	2.083	5.000	-1.304		
-6.000	0.9039	0.0000	1.743	6.000	-0.8879		
-5.000	1.731	1.000	1.386	7.000	-0.5697		

X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	3.42E+00	3.42E+00	-2.95E-03	9.40E-02	1.07E-01	1.30E-02	1.00E-01	6.18E-03	-2.95E-03	1.30E-02
-9.00E+00	4.90E+00	4.70E+00	-1.99E-01	1.72E-01	1.73E-01	5.33E-04	1.63E-01	-8.99E-03	-1.99E-01	5.33E-04
-8.00E+00	6.70E+00	6.69E+00	-7.45E-03	2.81E-01	2.90E-01	8.60E-03	2.76E-01	-4.88E-03	-7.45E-03	8.60E-03
-7.00E+00	9.48E+00	9.90E+00	4.18E-01	4.75E-01	5.07E-01	3.20E-02	4.88E-01	1.28E-02	4.18E-01	3.20E-02
-6.00E+00	1.52E+01	1.52E+01	-1.68E-02	9.06E-01	9.30E-01	2.44E-02	9.04E-01	-2.11E-03	-1.68E-02	2.44E-02
-5.00E+00	2.55E+01	2.43E+01	-1.23E+00	1.78E+00	1.76E+00	-1.96E-02	1.73E+00	-5.05E-02	-1.23E+00	-1.96E-02
-4.00E+00	3.84E+01	3.84E+01	-4.94E-02	2.94E+00	2.93E+00	-1.27E-02	2.91E+00	-2.41E-02	-4.94E-02	-1.27E-02
-3.00E+00	5.11E+01	5.22E+01	1.10E+00	2.97E+00	2.97E+00	-6.45E-04	2.99E+00	1.96E-02	1.10E+00	-6.45E-04
-2.00E+00	6.08E+01	6.07E+01	-7.51E-02	2.45E+00	2.47E+00	1.81E-02	2.50E+00	4.46E-02	-7.51E-02	1.81E-02
-1.00E+00	6.53E+01	6.49E+01	-3.83E-01	2.06E+00	2.06E+00	6.94E-03	2.08E+00	2.71E-02	-3.83E-01	6.94E-03
0.00E-01	6.62E+01	6.62E+01	-6.96E-02	1.75E+00	1.73E+00	-1.71E-02	1.74E+00	-7.33E-03	-6.96E-02	-1.71E-02
1.00E+00	6.53E+01	6.49E+01	-3.69E-01	1.37E+00	1.39E+00	1.52E-02	1.39E+00	1.44E-02	-3.69E-01	1.52E-02
2.00E+00	6.08E+01	6.07E+01	-4.94E-02	8.75E-01	8.88E-01	1.25E-02	3.79E-01	4.18E-03	-4.94E-02	1.25E-02
3.00E+00	5.11E+01	5.23E+01	1.13E+00	6.00E-02	1.08E-02	-4.92E-02	3.54E-03	-5.65E-02	1.13E+00	-4.92E-02
4.00E+00	3.84E+01	3.84E+01	-2.18E-02	-1.25E+00	-1.20E+00	4.86E-02	-1.19E+00	5.77E-02	-2.18E-02	4.86E-02
5.00E+00	2.55E+01	2.43E+01	-1.21E+00	-1.32E+00	-1.32E+00	-2.44E-03	-1.30E+00	1.44E-02	-1.21E+00	-2.44E-03
6.00E+00	1.52E+01	1.52E+01	-6.25E-03	-8.75E-01	-9.00E-01	-2.54E-02	-8.88E-01	-1.29E-02	-6.25E-03	-2.54E-02
7.00E+00	9.48E+00	9.90E+00	4.24E-01	-5.57E-01	-5.77E-01	-2.01E-02	-5.70E-01	-1.23E-02	4.24E-01	-2.01E-02
8.00E+00	6.70E+00	6.70E+00	-3.48E-03	-3.88E-01	-3.74E-01	1.35E-02	-3.70E-01	1.82E-02	-3.48E-03	1.35E-02
9.00E+00	4.90E+00	4.71E+00	-1.96E-01	-2.70E-01	-2.50E-01	2.01E-02	-2.47E-01	2.29E-02	-1.96E-01	2.01E-02
1.00E+01	3.42E+00	3.42E+00	-1.21E-03	-1.69E-01	-1.72E-01	-2.60E-03	-1.70E-01	-9.26E-04	-1.21E-03	-2.60E-03

MEAN ERROR OF G = -3.85E-02 ,RMS ERROR OF G= 5.44E-01
MEAN ERROR OF TOT1= 3.04E-03 ,RMS ERROR OF TOT1= 2.17E-02
MEAN ERROR OF TOT2= 2.93E-03 ,RMS ERROR OF TOT2= 2.65E-02

TEST, 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.

ENTER PLOTTER NO.=1



TEST 2HDPOT VS AERO SERVICE(UNDATED,P.259) 3D MAG AND NAGY(1966) 3D GRAV.

SECOND TEST

```
TYPE FOROS.DAT
TEST 2HDPOT VS AERO SERVICE(UNDATED, P. 235) 3D MAG.
-10.    1.       60.        0.         45.        100000.    0.         21 00 00
   3    0    0    0   15    1    0    0 110     00.        0.         ME
-10.    -8.      -6.        -5.        -4.        -3.6       -2.        0.
2.      3.       4.         4.5        6.         8.         10.
.2907   .5443    1.4536     2.9814     5.8144     6.0680     4.5155     3.1175
1.7629  -0.0309  -3.0000    -3.3402    -2.0041    -1.0515    -0.6247
   2    4    5-
                 BLANK CARD
                 BLANK CARD
.5      .5
-4.     1.       -4.        -4.
-1.     -1.      -9999.     -1.
-4.     1.       4.         4.         -4.
-9999.  -1.      -1.        -9999.     -9999.
0.      .0001    0.         0.         0.           2    2    0    0   -3    0
0.      1.       1.         0.         0.         -69    2    0    0    4    0

.RU 2HDPOT

FOR BULK OUTPUT ON DSK TYPE "6". ON TTY TYPE "7".
7
FOR FORMATED INPUT,TYPE "0". NAMELIST INPUT,TYPE "5".
0
TEST 2HDPOT VS AERO SERVICE(UNDATED, P. 235) 3D MAG.

 XZERO        DELX      AZMUTH      FLDDEC      FLDINC       FLD         HIMAG   NUMX,NTOPO,IELEV
  -10.00       1.00      60.00        0.00       45.00  100000.00         0.00   21  0  0

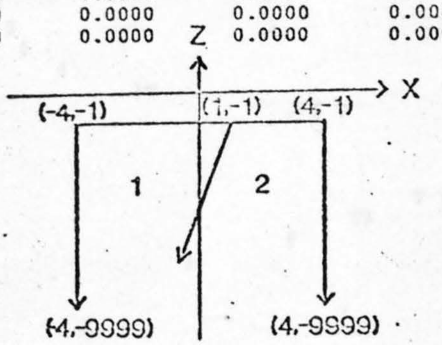
KINDFP NGIN NTIN NGOBSNTOBS INY IPROC1,2 IWIDENLPLT GCONS      TCONS   XZUN KLIN
   3    0    0    0    15    1    0    0  110   21  0.00        0.00    ME 0
```

I	X	TOPO	GRAVTOPO	MAGELEV	GIN	GOBS	TIN	TOBS
1	-10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2907
2	-9.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3870
3	-8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5443
4	-7.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8446
5	-6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4536
6	-5.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.9814
7	-4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.8144
8	-3.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	5.7358
9	-2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	4.5155
10	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.6418
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.1175
12	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.5983
13	2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.7629
14	3.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0309
15	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-3.0000
16	5.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-3.0854
17	6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-2.0041
18	7.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.3317
19	8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.0515
20	9.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.8378
21	10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.6247

```
NBODS, NCORNR(I),I=1,NBODS
  2    4    5
Y1(I),I=1,NBODS;Y2(I);YMAG(I)
 0.00       0.00
 0.00       0.00
 0.50       0.50

BODY   1-- COORDINATES OF CORNERS
 -4.0       1.0       -4.0       -4.0
 -1.0      -1.0      -0.10E+05   -1.0

BODY   2-- COORDINATES OF CORNERS
 -4.0       1.0        4.0        4.0       -4.0
 -0.10E+05 -1.0       -1.0       -0.10E+05  -0.10E+05
  0.00E-01  1.00E-04   0.00E-01   0.00E-01   0.00E-01     2    2    0    0   -3
  0.00E-01
```




```
BODY  1--DENSITY CONTRAST RHO = 0.0000 GRAMS/CC, SUS=  1.00E-04     GAUSS/OE.
REMANENT MAGNETIZATION=  0.00E-01  GAUSS WITH DECL=     0.0 DEG, INCL=     0.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY   1.
```

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.2392	-4.000	5.368	2.000	-2.669	8.000	-0.3982
-9.000	0.3236	-3.000	5.362	3.000	-1.769	9.000	-0.3262
-8.000	0.4626	-2.000	4.014	4.000	-1.193	10.00	-0.2722
-7.000	0.7163	-1.000	2.727	5.000	-0.8525		
-6.000	1.253	0.0000	0.8496	6.000	-0.6393		
-5.000	2.620	1.000	-2.299	7.000	-0.4974		

BODY 2 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 2.

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.5781E-01	-4.000	0.2470	2.000	4.472	8.000	-0.6439
-9.000	0.6927E-01	-3.000	0.3633	3.000	1.976	9.000	-0.4722
-8.000	0.8448E-01	-2.000	0.5829	4.000	-1.577	10.00	-0.3606
-7.000	0.1053	-1.000	1.065	5.000	-2.177		
-6.000	0.1348	0.0000	2.337	6.000	-1.414		
-5.000	0.1784	1.000	4.900	7.000	-0.9252		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.2971	-4.000	5.615	2.000	1.803	8.000	-1.042
-9.000	0.3929	-3.000	5.726	3.000	0.2074	9.000	-0.7984
-8.000	0.5471	-2.000	4.597	4.000	-2.769	10.00	-0.6328
-7.000	0.8216	-1.000	3.792	5.000	-3.029		
-6.000	1.388	0.0000	3.187	6.000	-2.053		
-5.000	2.798	1.000	2.601	7.000	-1.423		

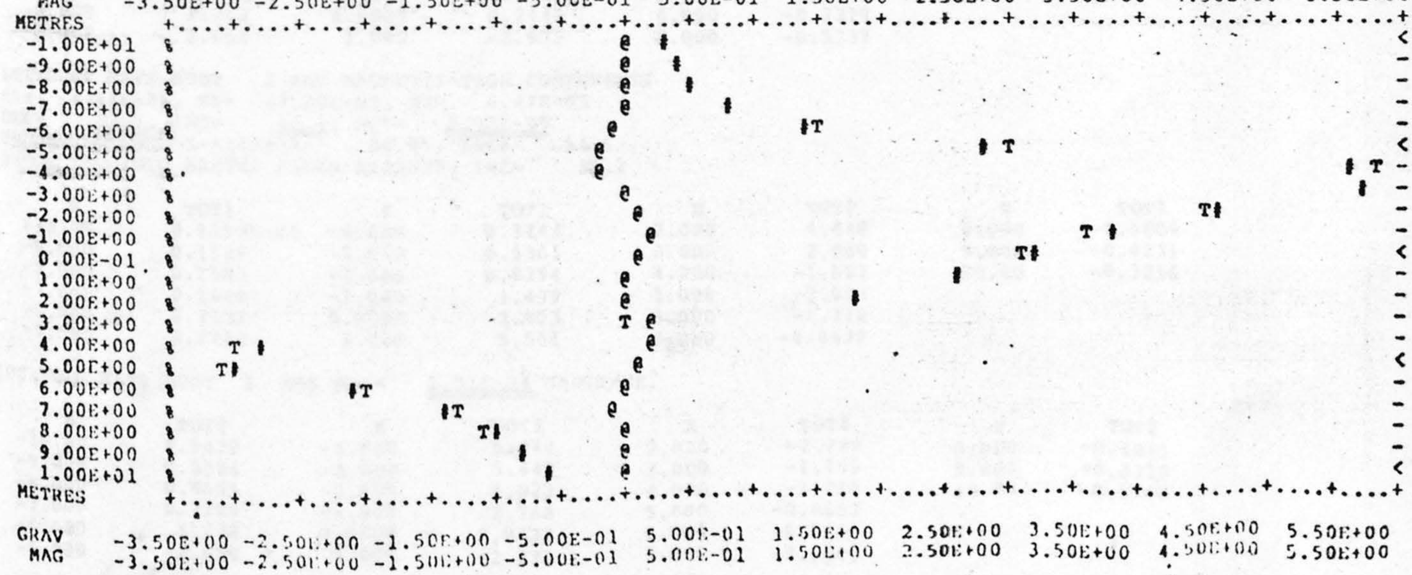
X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	0.00E-01	0.00E-01	0.00E-01	2.91E-01	2.97E-01	6.35E-03	2.97E-01	6.35E-03	0.00E-01	6.35E-03
-9.00E+00	0.00E-01	0.00E-01	0.00E-01	3.87E-01	3.93E-01	5.90E-03	3.93E-01	5.90E-03	0.00E-01	5.90E-03
-8.00E+00	0.00E-01	0.00E-01	0.00E-01	5.44E-01	5.47E-01	2.77E-03	5.47E-01	2.77E-03	0.00E-01	2.77E-03
-7.00E+00	0.00E-01	0.00E-01	0.00E-01	8.45E-01	8.22E-01	-2.31E-02	8.22E-01	-2.31E-02	0.00E-01	-2.31E-02
-6.00E+00	0.00E-01	0.00E-01	0.00E-01	1.45E+00	1.39E+00	-6.55E-02	1.39E+00	-6.55E-02	0.00E-01	-6.55E-02
-5.00E+00	0.00E-01	0.00E-01	0.00E-01	2.98E+00	2.80E+00	-1.83E-01	2.80E+00	-1.83E-01	0.00E-01	-1.83E-01
-4.00E+00	0.00E-01	0.00E-01	0.00E-01	5.81E+00	5.62E+00	-1.99E-01	5.62E+00	-1.99E-01	0.00E-01	-1.99E-01
-3.00E+00	0.00E-01	0.00E-01	0.00E-01	5.74E+00	5.73E+00	-9.98E-03	5.73E+00	-9.98E-03	0.00E-01	-9.98E-03
-2.00E+00	0.00E-01	0.00E-01	0.00E-01	4.52E+00	4.60E+00	8.11E-02	4.60E+00	8.11E-02	0.00E-01	8.11E-02
-1.00E+00	0.00E-01	0.00E-01	0.00E-01	3.64E+00	3.79E+00	1.51E-01	3.79E+00	1.51E-01	0.00E-01	1.51E-01
0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.12E+00	3.19E+00	6.91E-02	3.19E+00	6.91E-02	0.00E-01	6.91E-02
1.00E+00	0.00E-01	0.00E-01	0.00E-01	2.60E+00	2.60E+00	2.86E-03	2.60E+00	2.86E-03	0.00E-01	2.86E-03
2.00E+00	0.00E-01	0.00E-01	0.00E-01	1.76E+00	1.80E+00	4.02E-02	1.80E+00	4.02E-02	0.00E-01	4.02E-02
3.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.09E-02	2.07E-01	2.38E-01	2.07E-01	2.38E-01	0.00E-01	2.38E-01
4.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.00E+00	-2.77E+00	2.31E-01	-2.77E+00	2.31E-01	0.00E-01	2.31E-01
5.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.09E+00	-3.03E+00	5.60E-02	-3.03E+00	5.60E-02	0.00E-01	5.60E-02
6.00E+00	0.00E-01	0.00E-01	0.00E-01	-2.00E+00	-2.05E+00	-4.89E-02	-2.05E+00	-4.89E-02	0.00E-01	-4.89E-02
7.00E+00	0.00E-01	0.00E-01	0.00E-01	-1.33E+00	-1.42E+00	-9.09E-02	-1.42E+00	-9.09E-02	0.00E-01	-9.09E-02
8.00E+00	0.00E-01	0.00E-01	0.00E-01	-1.05E+00	-1.04E+00	9.34E-03	-1.04E+00	9.34E-03	0.00E-01	9.34E-03
9.00E+00	0.00E-01	0.00E-01	0.00E-01	-8.38E-01	-7.98E-01	3.94E-02	-7.98E-01	3.94E-02	0.00E-01	3.94E-02
1.00E+01	0.00E-01	0.00E-01	0.00E-01	-6.25E-01	-6.33E-01	-8.07E-03	-6.33E-01	-8.07E-03	0.00E-01	-8.07E-03

MEAN ERROR OF G = 0.00E-01 ,RMS ERROR OF G= 0.00E-01
MEAN ERROR OF TOT1= 1.45E-02 ,RMS ERROR OF TOT1= 1.07E-01
MEAN ERROR OF TOT2= 1.45E-02 ,RMS ERROR OF TOT2= 1.07E-01

TEST 2HDPOT VS AERO SERVICE(UNDATED, P. 235) 3D MAG.

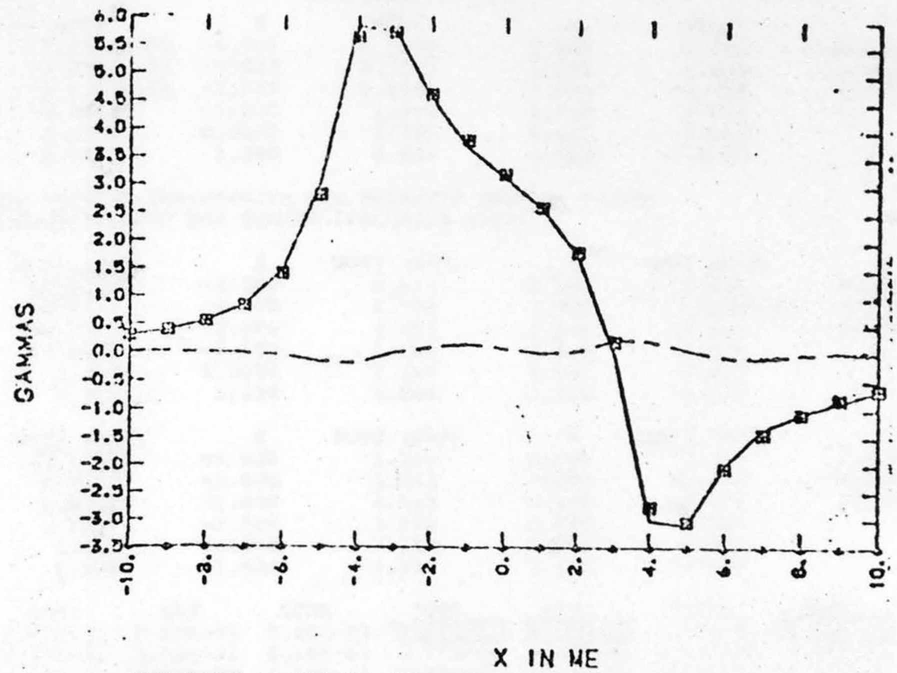
PLOT SYMBOLS: ELEV=1 TOPO=: GOBS=G TOBS=T GRV=* TOT1=+ TOT2=# TOUT=@ GOUT=%

GRAV -3.50E+00 -2.50E+00 -1.50E+00 -5.00E-01 5.00E-01 1.50E+00 2.50E+00 3.50E+00 4.50E+00 5.50E+00
MAG -3.50E+00 -2.50E+00 -1.50E+00 -5.00E-01 5.00E-01 1.50E+00 2.50E+00 3.50E+00 4.50E+00 5.50E+00



GRAV -3.50E+00 -2.50E+00 -1.50E+00 -5.00E-01 5.00E-01 1.50E+00 2.50E+00 3.50E+00 4.50E+00 5.50E+00
MAG -3.50E+00 -2.50E+00 -1.50E+00 -5.00E-01 5.00E-01 1.50E+00 2.50E+00 3.50E+00 4.50E+00 5.50E+00

YSCALE = 1.0000E-01 XSCALE = 1.0000E+00 TYSCAL= 1.0000E-01
ENTER PLOTTER NO.=1



TEST ZHOPOT VS AERO SERVICE(UPDATED, P. 236) 20 KILO.

<<TK4010[X/Y:17.6/12.6-CM[CH I/O:159/159[LN I/O:126/126
<< DEV:TTY1[BLKS:342
TO EXIT TYPE "0". TO ADJUST PLOT ON SAME DEV TYPE "1". TO CHNG DEV AND ADJ PLOT TYPE "2". TO CHNG DEV TYPE "3".
0

MODE= -3. GRV AND VER, TOT1, TOT2 ARE RE-ZEROED.

THE COMPUTATION WILL RECOMMENCE WITH NEW MAG AND DENS,BUT WITH THE SAME BODIES AND FIELD POINTS
0.00E-01 1.00E+00 1.00E+00 0.00E-01 0.00E-01 -69 2 0 0 4
0.00E-01

BODY 1--DENSITY CONTRAST RHO = 0.0000 GRAMS/CC, SUS= 1.00E+00 GAUSS/OE.
REMANENT MAGNETIZATION= 1.00E+00 GAUSS WITH DECL= 0.0 DEG, INCL= 0.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 1.

LST SQRS SAYS BODY 1 HAS MAGNETIZATION COMPONENTS
MX= 3.98E-05, MY= -7.43E-05, MZ= 7.57E-05
DEC= -1.8, INC= 41.9, AMP= 1.13E-04
PROJECTED INTO X-AXIS(AZ= 60.0), INC= 62.3
PROJECTED INTO EARTHS FIELD AZIMUTH, INC= 43.6

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.2347	-4.000	5.439	2.000	-3.141	8.000	-0.4592
-9.000	0.3189	-3.000	5.197	3.000	-2.055	9.000	-0.3760
-8.000	0.4584	-2.000	3.637	4.000	-1.380	10.00	-0.3137
-7.000	0.7148	-1.000	2.225	5.000	-0.9849		
-6.000	1.262	0.0000	0.2442	6.000	-0.7379		
-5.000	2.664	1.000	-2.975	7.000	-0.5737		

LST SQRS SAYS BODY 2 HAS MAGNETIZATION COMPONENTS
MX= 4.61E-05, MY= -4.20E-05, MZ= 6.47E-05
DEC= 17.7, INC= 46.1, AMP= 8.98E-05
PROJECTED INTO X-AXIS(AZ= 60.0), INC= 54.6
PROJECTED INTO EARTHS FIELD AZIMUTH, INC= 35.1

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.9496E-01	-4.000	0.3744	2.000	4.848	8.000	-0.5809
-9.000	0.1128	-3.000	0.5361	3.000	2.080	9.000	-0.4231
-8.000	0.1363	-2.000	0.8294	4.000	-1.621	10.00	-0.3216
-7.000	0.1680	-1.000	1.439	5.000	-2.082		
-6.000	0.2121	0.0000	2.923	6.000	-1.310		
-5.000	0.2762	1.000	5.561	7.000	-0.8430		

LST SQRS SAYS BODY 1 HAS SUS= 1.01E-04 GAUSS/OE.

X	TOT2	X	TOT2	X	TOT2	X	TOT2
-10.00	0.2428	-4.000	5.448	2.000	-2.709	8.000	-0.4041
-9.000	0.3284	-3.000	5.442	3.000	-1.795	9.000	-0.3310
-8.000	0.4695	-2.000	4.073	4.000	-1.210	10.00	-0.2762
-7.000	0.7269	-1.000	2.768	5.000	-0.8652		
-6.000	1.272	0.0000	0.8622	6.000	-0.6480		
-5.000	2.659	1.000	-2.333	7.000	-0.5048		

LST SQRS SAYS BODY 2 HAS SUS= 9.93E-05 GAUSS/OE.

X	TOT2	X	TOT2	X	TOT2	X	TOT2
-10.00	0.5743E-01	-4.000	0.2454	2.000	4.442	8.000	-0.6397
-9.000	0.6881E-01	-3.000	0.3609	3.000	1.963	9.000	-0.4691
-8.000	0.8392E-01	-2.000	0.5791	4.000	-1.566	10.00	-0.3582
-7.000	0.1046	-1.000	1.058	5.000	-2.162		
-6.000	0.1339	0.0000	2.321	6.000	-1.404		
-5.000	0.1772	1.000	4.867	7.000	-0.9191		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

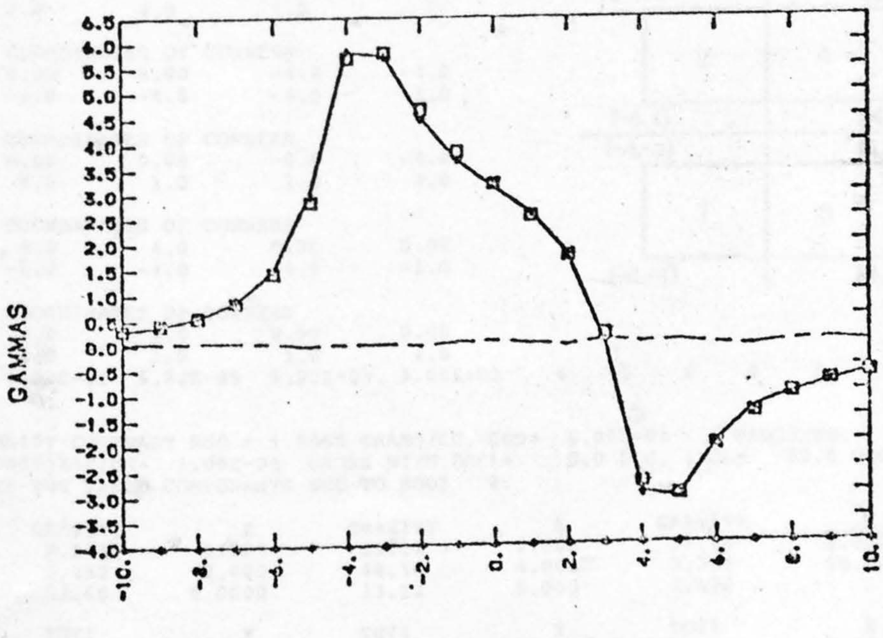
X	TOT1 (MVT)	X	TOT1 (MVT)	X	TOT1 (MVT)	X	TOT1 (MVT)
-10.00	0.3296	-4.000	5.813	2.000	1.707	8.000	-1.040
-9.000	0.4317	-3.000	5.733	3.000	0.2529E-01	9.000	-0.7991
-8.000	0.5947	-2.000	4.467	4.000	-3.001	10.00	-0.6353
-7.000	0.8828	-1.000	3.665	5.000	-3.067		
-6.000	1.474	0.0000	3.167	6.000	-2.047		
-5.000	2.940	1.000	2.586	7.000	-1.417		

X	TOT2 (SUS)	X	TOT2 (SUS)	X	TOT2 (SUS)	X	TOT2 (SUS)
-10.00	0.3002	-4.000	5.693	2.000	1.734	8.000	-1.044
-9.000	0.3972	-3.000	5.803	3.000	0.1680	9.000	-0.8001
-8.000	0.5534	-2.000	4.652	4.000	-2.777	10.00	-0.6344
-7.000	0.8315	-1.000	3.826	5.000	-3.028		
-6.000	1.406	0.0000	3.184	6.000	-2.053		
-5.000	2.836	1.000	2.534	7.000	-1.424		

X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	0.00E-01	0.00E-01	0.00E-01	2.91E-01	3.30E-01	3.89E-02	3.00E-01	9.52E-03	0.00E-01	3.89E-02
-9.00E+00	0.00E-01	0.00E-01	0.00E-01	3.87E-01	4.32E-01	4.47E-02	3.97E-01	1.02E-02	0.00E-01	4.47E-02
-8.00E+00	0.00E-01	0.00E-01	0.00E-01	5.44E-01	5.95E-01	5.04E-02	5.53E-01	9.09E-03	0.00E-01	5.04E-02
-7.00E+00	0.00E-01	0.00E-01	0.00E-01	8.45E-01	8.83E-01	3.81E-02	8.32E-01	-1.31E-02	0.00E-01	3.81E-02
-6.00E+00	0.00E-01	0.00E-01	0.00E-01	1.45E+00	1.47E+00	2.04E-02	1.41E+00	-4.78E-02	0.00E-01	2.04E-02
-5.00E+00	0.00E-01	0.00E-01	0.00E-01	2.98E+00	2.94E+00	-4.15E-02	2.84E+00	-1.45E-01	0.00E-01	-4.15E-02
-4.00E+00	0.00E-01	0.00E-01	0.00E-01	5.81E+00	5.81E+00	-9.85E-04	5.69E+00	-1.21E-01	0.00E-01	-9.85E-04
-3.00E+00	0.00E-01	0.00E-01	0.00E-01	5.74E+00	5.73E+00	-2.67E-03	5.80E+00	6.73E-02	0.00E-01	-2.67E-03
-2.00E+00	0.00E-01	0.00E-01	0.00E-01	4.52E+00	4.47E+00	-4.88E-02	4.65E+00	1.37E-01	0.00E-01	-4.88E-02
-1.00E+00	0.00E-01	0.00E-01	0.00E-01	3.64E+00	3.66E+00	2.28E-02	3.83E+00	1.84E-01	0.00E-01	2.28E-02
0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.12E+00	3.17E+00	4.96E-02	3.18E+00	6.61E-02	0.00E-01	4.96E-02
1.00E+00	0.00E-01	0.00E-01	0.00E-01	2.60E+00	2.59E+00	-1.24E-02	2.53E+00	-6.39E-02	0.00E-01	-1.24E-02
2.00E+00	0.00E-01	0.00E-01	0.00E-01	1.76E+00	1.71E+00	-5.59E-02	1.73E+00	-2.92E-02	0.00E-01	-5.59E-02
3.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.09E-02	2.53E-02	5.62E-02	1.68E-01	1.99E-01	0.00E-01	5.62E-02
4.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.00E+00	-3.00E+00	-8.77E-04	-2.78E+00	2.23E-01	0.00E-01	-8.77E-04
5.00E+00	0.00E-01	0.00E-01	0.00E-01	-3.09E+00	-3.07E+00	1.81E-02	-3.03E+00	5.78E-02	0.00E-01	1.81E-02
6.00E+00	0.00E-01	0.00E-01	0.00E-01	-2.00E+00	-2.05E+00	-4.33E-02	-2.05E+00	-4.90E-02	0.00E-01	-4.33E-02
7.00E+00	0.00E-01	0.00E-01	0.00E-01	-1.33E+00	-1.42E+00	-9.51E-02	-1.42E+00	-9.22E-02	0.00E-01	-8.51E-02
8.00E+00	0.00E-01	0.00E-01	0.00E-01	-1.05E+00	-1.04E+00	1.14E-02	-1.04E+00	7.71E-03	0.00E-01	1.14E-02
9.00E+00	0.00E-01	0.00E-01	0.00E-01	-8.38E-01	-7.99E-01	3.36E-02	-8.00E-01	3.77E-02	0.00E-01	3.36E-02
1.00E+01	0.00E-01	0.00E-01	0.00E-01	-6.25E-01	-6.35E-01	-1.06E-02	-6.34E-01	-9.72E-03	0.00E-01	-1.06E-02

MEAN ERROR OF G = 0.00E-01 ,RMS ERROR OF G= 0.00E-01
MEAN ERROR OF TOT1= 4.16E-03 ,RMS ERROR OF TOT1= 3.94E-02
MEAN ERROR OF TOT2= 2.08E-02 ,RMS ERROR OF TOT2= 1.00E-01

ENTER PLOTTER NO.=1



TEST 2HOPOT VD AERO SERVICE(UPDATED, P. 255) TO MAG.

THIRD TEST

```
.TYPE FOR05.DAT
 FOUR QUADRANT SYMMETRY TEST. VERTICAL FIELD.
-10.      2.      0.       0.       90.        50000.    0.          11  0  0
   1   0    0    0    0    1    0    0 110      00.0      0.0
   4   5    5    5    5
-4.       -4.     -4.      -4.
4.        4.      4.       4.
4.        4.      4.       4.
-4.       0.      0.       -4.      -4.
-1.       -1.     -4.      -4.      -1.
-4.       0.      0.       -4.      -4.
4.        4.      1.       1.       4.
0.        4.      4.       0.       0.
-1.       -1.     -4.      -4.      -1.
0.        4.      4.       0.       0.
4.        4.      1.       1.       4.
1.        0.      .00001   0.       90.          4   -1   0   0   4   0

RU 2HDPOT

FOR BULK OUTPUT ON DSK TYPE "6". ON TTY TYPE "7".
7
FOR FORMATED INPUT,TYPE "0". NAMELIST INPUT,TYPE "5".
0
FOUR QUADRANT SYMMETRY TEST. VERTICAL FIELD.

XZERO      DELX    AZMUTH    FLDDEC      FLDINC     FLD          HIMAG  NUMX,NTOPO,IELEV
 -10.00     2.00     0.00       0.00      90.00   50000.00        0.00  11  0  0

KINDFP NGIN NTIN NGOBSNTOBS INY IPROC1,2 IWIDENLPLT GCONS        TCONS  XZUN KLIN
  1     0    0     0    0    1    0    0  110   11  0.00          0.00     0
```

I	X	TOPO	GRAVTOPO	MAGELEV	GIN	GOBS	TIN	TOBS
1	-10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	-8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	-6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	-4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	-2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

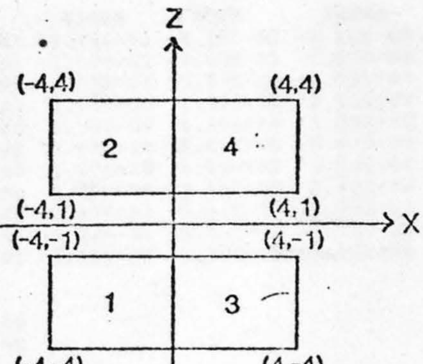
```
NBODS, NCORNR(I),I=1,NBODS
  4     5     5     5     5
Y1(I),I=1,NBODS;Y2(I);YMAG(I)
 -4.0     -4.0     -4.0     -4.0
  4.0      4.0      4.0      4.0
  4.0      4.0      4.0      4.0

BODY     1-- COORDINATES OF CORNERS
 -4.0      0.00      0.00     -4.0      -4.0
 -1.0     -1.0      -4.0      -4.0      -1.0

BODY     2-- COORDINATES OF CORNERS
 -4.0      0.00      0.00     -4.0      -4.0
  4.0      4.0       1.0       1.0       4.0

BODY     3-- COORDINATES OF CORNERS
  0.00     4.0       4.0       0.00      0.00
 -1.0     -1.0      -4.0      -4.0      -1.0

BODY     4-- COORDINATES OF CORNERS
  0.00     4.0       4.0       0.00      0.00
  4.0      4.0       1.0       1.0       4.0
 1.00E+00  0.00E-01  1.00E-05  0.00E-01  9.00E+01    4   -1   0   0   4
 0.00E-01
```




```
BODY  1--DENSITY CONTRAST RHO = 1.0000 GRAMS/CC, SUS=   0.00E-01       GAUSS/OE.
REMANENT MAGNETIZATION=   1.00E-05   GAUSS WITH DECL=   0.0 DEG, INCL=   90.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY    1.

   X       GRAVITY        X        GRAVITY        X        GRAVITY        X        GRAVITY
-10.00      2.571      -4.000      33.12        2.000      12.68        8.000      1.411
-8.000      5.292      -2.000      48.10        4.000      5.292        10.00      0.8484
-6.000      12.68      0.0000      33.12        6.000      2.571

   X        TOT1          X         TOT1          X         TOT1          X         TOT1
-10.00     -0.1136     -4.000      1.405        2.000     -0.1632       8.000     -0.6972E-01
-8.000     -0.1812     -2.000      2.915        4.000     -0.1812       10.00     -0.4452E-01
-6.000     -0.1632     0.0000      1.405        6.000     -0.1136
```

BODY 2 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 2.

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	-2.571	-4.000	-33.12	2.000	-12.68	8.000	-1.411
-8.000	-5.292	-2.000	-48.10	4.000	-5.292	10.00	-0.8483
-6.000	-12.68	0.0000	-33.12	6.000	-2.571		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.1136	-4.000	1.405	2.000	-0.1632	8.000	-0.6972E-01
-8.000	-0.1812	-2.000	2.915	4.000	-0.1812	10.00	-0.4452E-01
-6.000	-0.1632	0.0000	1.405	6.000	-0.1136		

BODY 3 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 3.

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	0.8483	-4.000	5.292	2.000	48.10	8.000	5.292
-8.000	1.411	-2.000	12.68	4.000	33.12	10.00	2.571
-6.000	2.571	0.0000	33.12	6.000	12.68		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.4452E-01	-4.000	-0.1812	2.000	2.915	8.000	-0.1812
-8.000	-0.6972E-01	-2.000	-0.1632	4.000	1.405	10.00	-0.1136
-6.000	-0.1136	0.0000	1.405	6.000	-0.1632		

BODY 4 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 4.

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	-0.8484	-4.000	-5.292	2.000	-48.10	8.000	-5.292
-8.000	-1.411	-2.000	-12.68	4.000	-33.12	10.00	-2.571
-6.000	-2.571	0.0000	-33.12	6.000	-12.68		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.4452E-01	-4.000	-0.1812	2.000	2.915	8.000	-0.1812
-8.000	-0.6972E-01	-2.000	-0.1632	4.000	1.405	10.00	-0.1136
-6.000	-0.1136	0.0000	1.405	6.000	-0.1632		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

X	GRAVITY	X	GRAVITY	X	GRAVITY	X	GRAVITY
-10.00	-0.7957E-05	-4.000	-0.6974E-05	2.000	-0.5245E-05	8.000	0.7153E-05
-8.000	-0.7138E-05	-2.000	-0.2145E-05	4.000	0.2384E-05	10.00	0.7957E-05
-6.000	0.4053E-05	0.0000	-0.4768E-05	6.000	0.8345E-06		

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.3162	-4.000	2.448	2.000	5.504	8.000	-0.5018
-8.000	-0.5018	-2.000	5.504	4.000	2.448	10.00	-0.3162
-6.000	-0.5535	0.0000	5.620	6.000	-0.5535		

X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	0.00E-01	-7.96E-06	-7.96E-06	0.00E-01	-3.16E-01	-3.16E-01	-3.16E-01	-3.16E-01	-7.96E-06	-3.16E-01
-8.00E+00	0.00E-01	-7.14E-06	-7.14E-06	0.00E-01	-5.02E-01	-5.02E-01	-5.02E-01	-5.02E-01	-7.14E-06	-5.02E-01
-6.00E+00	0.00E-01	4.05E-06	4.05E-06	0.00E-01	-5.53E-01	-5.53E-01	-5.53E-01	-5.53E-01	4.05E-06	-5.53E-01
-4.00E+00	0.00E-01	-6.97E-06	-6.97E-06	0.00E-01	2.45E+00	2.45E+00	2.45E+00	2.45E+00	-6.97E-06	2.45E+00
-2.00E+00	0.00E-01	-2.15E-06	-2.15E-06	0.00E-01	5.50E+00	5.50E+00	5.50E+00	5.50E+00	-2.15E-06	5.50E+00
0.00E-01	0.00E-01	-4.77E-06	-4.77E-06	0.00E-01	5.62E+00	5.62E+00	5.62E+00	5.62E+00	-4.77E-06	5.62E+00
2.00E+00	0.00E-01	-5.25E-06	-5.25E-06	0.00E-01	5.50E+00	5.50E+00	5.50E+00	5.50E+00	-5.25E-06	5.50E+00
4.00E+00	0.00E-01	2.33E-06	2.38E-06	0.00E-01	2.45E+00	2.45E+00	2.45E+00	2.45E+00	2.38E-06	2.45E+00
6.00E+00	0.00E-01	8.34E-07	8.34E-07	0.00E-01	-5.53E-01	-5.53E-01	-5.53E-01	-5.53E-01	8.34E-07	-5.53E-01
8.00E+00	0.00E-01	7.15E-06	7.15E-06	0.00E-01	-5.02E-01	-5.02E-01	-5.02E-01	-5.02E-01	7.15E-06	-5.02E-01
1.00E+01	0.00E-01	7.96E-06	7.96E-06	0.00E-01	-3.16E-01	-3.16E-01	-3.16E-01	-3.16E-01	7.96E-06	-3.16E-01

MEAN ERROR OF G = -1.08E-06 ,RMS ERROR OF G= 5.68E-06
MEAN ERROR OF TOT1= 1.71E+00 ,RMS ERROR OF TOT1= 3.10E+00
MEAN ERROR OF TOT2= 1.71E+00 ,RMS ERROR OF TOT2= 3.10E+00

FOUR QUADRANT SYMMETRY TEST. VERTICAL FIELD.

THE COMPUTATION IS COMPLETE. TYPE (MODE) +OR- 5,6,7 TO ADJUST PARAMETERS
BY NAMELIST: 7-PHYS PROP, 6-BODY GEOM + PHYS PROP, 5-EVERYTHING;
MODE NEG TO ZERO GRV,VER,TOT1,TOT2, ZERO TO STOP.
0
STOP

END OF EXECUTION
CPU TIME: 3.85 ELAPSED TIME: 8:29.88
EXIT

FOURTH TEST

```
.TYPE FOR05.DAT
FOUR QUADRANT SYMMETRY TEST. HORIZONTAL FIELD.
-10.   2.     0.      0.     0.      50000.   0.       11 0 0
  3    0   0  0    1  0    0 110   00.0     0.0
  4    5   5  5    5
-4.   -4.    -4.     -4.
4.     4.     4.      4.
4.     4.     4.      4.
-4.    0.     0.     -4.     -4.
-1.   -1.    -4.     -4.     -1.
-4.    0.     0.     -4.     -4.
4.     4.     1.      1.      4.
0.     4.     4.      0.      0.
-1.   -1.    -4.     -4.     -1.
0.     4.     4.      0.      0.
4.     4.     1.      1.      4.
1.     0.    .00001   0.     90.      4   -1   0   0   4   0

.RU 2HDPOT

FOR BULK OUTPUT ON DSK TYPE "6". ON TTY TYPE "7".
7
FOR FORMATED INPUT,TYPE "0". NAMELIST INPUT,TYPE "5".
0
FOUR QUADRANT SYMMETRY TEST. HORIZONTAL FIELD.

XZERO      DELX     AZMUTH     FLDDEC      FLDINC      FLD         HIMAG  NUMX,NTOPO,IELEV
 -10.00     2.00      0.00       0.00        0.00   50000.00        0.00  11   0   0

KINDFP NGIN NTIN NGOBSNTOBS INY IPROC1,2 IWIDENLPLT CCONS         TCONS   XZUN KLIN
  3     0    0     0    0    1     0    0  110    11  0.00          0.00      0
```

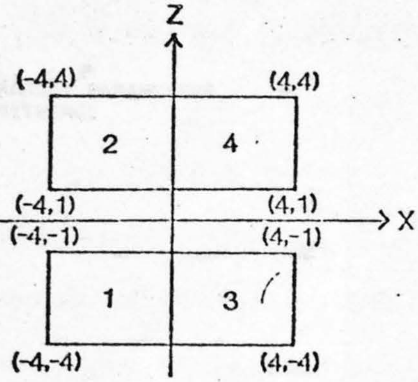
I	X	TOPO	GRAVTOPO	MAGELEV	GIN	GOBS	TIN	TOBS
1	-10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	-8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	-6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	-4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	-2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	2.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	4.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	6.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	8.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	10.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

```
NBODS, NCORNR(I),I=1,NBODS
  4    5    5    5    5
Y1(I),I=1,NBODS;Y2(I);YMAG(I)
 -4.0     -4.0      -4.0      -4.0
  4.0      4.0       4.0       4.0
  4.0      4.0       4.0       4.0
BODY    1-- COORDINATES OF CORNERS
 -4.0     0.00      0.00      -4.0      -4.0
 -1.0    -1.0      -4.0       -4.0      -1.0

BODY    2-- COORDINATES OF CORNERS
 -4.0     0.00      0.00      -4.0      -4.0
  4.0     4.0       1.0        1.0       4.0

BODY    3-- COORDINATES OF CORNERS
  0.00    4.0       4.0        0.00      0.00
 -1.0    -1.0      -4.0       -4.0      -1.0

BODY    4-- COORDINATES OF CORNERS
  0.00    4.0       4.0        0.00      0.00
  4.0     4.0       1.0        1.0       4.0
 1.00E+00  0.00E-01  1.00E-05  0.00E-01  9.00E+01    4   -1   0   0   4
 0.00E-01
```




```
BODY  1--DENSITY CONTRAST RHO = 1.0000 GRAMS/CC, SUS=  0.00E-01     GAUSS/OE.
REMANENT MAGNETIZATION=  1.00E-05  GAUSS WITH DECL=    0.0 DEG, INCL=   90.0 DEG
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY   1.
```

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.1263	-4.000	2.023	2.000	-0.9046	8.000	-0.5814E-01
-8.000	0.3148	-2.000	0.1352E-05	4.000	-0.3148	10.00	-0.2992E-01
-6.000	0.9046	0.0000	-2.023	6.000	-0.1263		

BODY 2 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 2.

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.1263	-4.000	-2.023	2.000	0.9046	8.000	0.5814E-01
-8.000	-0.3148	-2.000	0.1352E-05	4.000	0.3148	10.00	0.2992E-01
-6.000	-0.9046	0.0000	2.023	6.000	0.1263		

BODY 3 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 3.

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	0.2992E-01	-4.000	0.3148	2.000	0.1352E-05	8.000	-0.3148
-8.000	0.5814E-01	-2.000	0.9046	4.000	-2.023	10.00	-0.1263
-6.000	0.1263	0.0000	2.023	6.000	-0.9046		

BODY 4 HAS SAME MAG AND DENS PROPTS AS PREVIOUS BODY.
FOLLOWING ARE THE FIELD COMPONENTS DUE TO BODY 4.

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.2992E-01	-4.000	-0.3148	2.000	0.1352E-05	8.000	0.3148
-8.000	-0.5814E-01	-2.000	-0.9046	4.000	2.023	10.00	0.1263
-6.000	-0.1263	0.0000	-2.023	6.000	0.9046		

FOLLOWING ARE PRINTED THE GRAVITY AND MAGNETIC ANOMALY FIELDS
DUE TO THE SUMMATION OF THE BODIES TABULATED ABOVE

X	TOT1	X	TOT1	X	TOT1	X	TOT1
-10.00	-0.2850E-06	-4.000	0.3502E-06	2.000	0.1982E-05	8.000	-0.7451E-06
-8.000	-0.7441E-06	-2.000	0.1982E-05	4.000	0.3576E-06	10.00	-0.2850E-06
-6.000	-0.9649E-06	0.0000	0.1907E-05	6.000	-0.9686E-06		

X	GOBS	GRV	GERR	TOBS	TOT1	T1ERR	TOT2	T2ERR	GOUT	TOUT
-1.00E+01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-2.85E-07	-2.85E-07	-2.85E-07	-2.85E-07	0.00E-01	-2.85E-07
-8.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-7.44E-07	-7.44E-07	-7.44E-07	-7.44E-07	0.00E-01	-7.44E-07
-6.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-9.65E-07	-9.65E-07	-9.65E-07	-9.65E-07	0.00E-01	-9.65E-07
-4.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.50E-07	3.50E-07	3.50E-07	3.50E-07	0.00E-01	3.50E-07
-2.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.98E-06	1.98E-06	1.98E-06	1.98E-06	0.00E-01	1.98E-06
0.00E-01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.91E-06	1.91E-06	1.91E-06	1.91E-06	0.00E-01	1.91E-06
2.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	1.98E-06	1.98E-06	1.98E-06	1.98E-06	0.00E-01	1.98E-06
4.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.58E-07	3.58E-07	3.58E-07	3.58E-07	0.00E-01	3.58E-07
6.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-9.69E-07	-9.69E-07	-9.69E-07	-9.69E-07	0.00E-01	-9.69E-07
8.00E+00	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-7.45E-07	-7.45E-07	-7.45E-07	-7.45E-07	0.00E-01	-7.45E-07
1.00E+01	0.00E-01	0.00E-01	0.00E-01	0.00E-01	-2.85E-07	-2.85E-07	-2.85E-07	-2.85E-07	0.00E-01	-2.85E-07

MEAN ERROR OF G = 0.00E-01 ,RMS ERROR OF G= 0.00E-01
MEAN ERROR OF TOT1= 2.35E-07 ,RMS ERROR OF TOT1= 1.16E-06
MEAN ERROR OF TOT2= 2.35E-07 ,RMS ERROR OF TOT2= 1.16E-06

FOUR QUADRANT SYMMETRY TEST. HORIZONTAL FIELD.

THE COMPUTATION IS COMPLETE. TYPE (MODE) +OR- 5,6,7 TO ADJUST PARAMETERS
BY NAMELIST: 7-PHYS PROP, 6-BODY GEOM + PHYS PROP, 5-EVERYTHING;
MODE NEG TO ZERO GRV,VER,TOT1,TOT2, ZERO TO STOP.
0
STOP

END OF EXECUTION
CPU TIME: 3.09 ELAPSED TIME: 6:12.68
EXIT

HINTS FOR EFFECTIVE USE OF THE PROGRAM

Program 2HDPOT is a general purpose tool. The following suggestions are intended to help the user to discover powerful or novel ways in which he can use the tool. This section is in no way an introduction to geophysics, but hopefully it will suggest, to the naive reader, an approach to modeling which he can master through his own reasoning and study. It is the responsibility of the user to understand and defend his use of the tool in a given situation.

Modeling residual anomalies

In the simplest kind of modeling a regional trend is removed from the data. Calculations are made for one or more bodies in an attempt to match the residual anomalies. The physical properties of the bodies, usually stated as contrasts between each body and the surrounding country rock, can be specified initially or determined by least squares, or both. In program 2HDPOT, GCONS and TCONS allow for the removal of constant "regionals" from the observed data, and GIN and TIN permit the removal of regional trends defined by one or more straight line segments or a splined curve. In regional crustal modeling, regional gravity trends are accounted for in the model, aside from a constant (GCONS), the use of which is described below. Long magnetic profiles, however, usually have a regional trend, often an artifact of an inaccurate geomagnetic field model, which is not caused by sources in the crust and must be removed using TIN.

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842-171

Regional crustal modeling

This section deals mainly with gravity modeling, such as that described by Talwani, Sutton, and Worzel (1959), where combined gravimetric and seismic refraction data permit modeling of a section through the crust and upper mantle. Magnetic data is often used together with gravity data in crustal modeling (Cady, 1975), but it lacks the power of gravity modeling to define crustal structure because there is no direct relationship between magnetization and seismic velocity; because there is no requirement comparable to isostasy to demand approximately equal amounts of magnetization in every crustal section; and because geomagnetic field models leave regional trends which cannot be explained by sources in the crust.

Free air and Bouguer gravity anomaly profiles are commonly used in crustal modeling. Isostatic anomalies are not generally used because assumptions about the crust-mantle boundary are incorporated in the isostatic correction.

The free air correction can be looked at as either an adjustment of observed gravity to the reference spheroid taken as mean sea level, or an adjustment of theoretical gravity to the observation point. The latter interpretation is preferred because it preserves the exact geometrical relationship between observation points and anomaly-causing bodies. Theoretical gravity and the free air correction are calculated on the assumption that there are no lateral variations in density along any equipotential surface. Free air anomalies result from such lateral variations in density. We must include, in a crustal model

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derived from free air anomalies, all bodies which give rise to lateral density variations along equipotential surfaces, approximated by surfaces of equal distance above or below sea level. Above sea level we must include all rocks up to the highest mountains, for a sloping topographic surface is a very abrupt lateral density variation. Below sea level we must include, explicitly, both water and rock. For modeling of the continental crust and margins we assume no lateral density variation below the upper mantle and place the bottom of the model at a depth of 50 to 75 km; but if our model were concerned with mantle convection or included oceanic trench areas, the bottom would need to be deeper.

The complete Bouguer correction can be viewed either as the removal of the gravity effect of mass above sea level to adjust the observation to sea level; or as an initial step in modeling intended to remove, once and for all, the effect of all topographic relief if the rocks making up that relief have a density equal to the chosen Bouguer reduction density. The latter interpretation is preferred because it preserves the exact geometrical relationship between observation points and anomaly sources, some of which may be above sea level. In calculating Bouguer anomalies from a model, it is convenient to use the density contrast between each body and the Bouguer reduction density. Bodies with density equal to the Bouguer reduction density have a density contrast of zero and can be omitted from the calculation. Thus, if the chosen Bouguer reduction density is equal to that of the near surface rocks, gravity calculations involving a complicated topographic surface are elminated.

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For sea-surface gravity stations, a positive Bouguer correction is made for the difference between the density of sea water (1.03 gm/cm^3) and the Bouguer reduction density, effectively replacing the water with material of density equal to the Bouguer reduction density. Hence, when modeling to fit a Bouguer anomaly profile, sea water is assigned a density contrast of zero, eliminating it from the calculation.

Aside from the elimination from the calculation of sea water and bodies having a density equal to the Bouguer reduction density, and the use of density contrasts instead of absolute density, modeling Bouguer anomalies is the same as modeling free air anomalies. Lateral density contrasts are the only source of anomalies, and the same considerations apply when deciding how deep to terminate the model.

Theoretical gravity calculated from a reference spheroid contains no information about the variation of density with depth in the earth. Hence, calculations of the gravity effect of a crustal model will differ from observed free air or Bouguer gravity anomalies by a constant which depends upon the thickness of the section included in the model and the average density within the section, (Talwani, Sutton, and Worzel, 1959, p. 1548). For example, at San Francisco, the average density of a 50 km thick section of the crust and upper mantle is 3.08 gm/cm^3, and the free air and Bouguer anomalies are both about 20 mgal (Cady, 1975, fig. 5-7). The gravity effect of an infinite slab of density 3.08 gm/cm^3 is $2\pi G\rho h$=(41.93)(3.08)(50)=6457 mgal. The difference between this slab effect and the observed free air

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anomaly, or 6457-20=6437 mgal, is a constant which must be input to program 2HDPOT as GCONS, to be subtracted from the gravity effect computed for the model. For calculating Bouguer anomalies, we use the density contrast of the slab, or 3.08-2.67=0.41 gm/cm^3, yielding a slab effect of (41.93)(0.41)(50)=860 mgal. The slab effect less the observed Bouguer anomaly, or 860-20=840 mgal, is the calculated value of GCONS for modeling the Bouguer anomaly profile at San Francisco.

Due to uncertainties in seismically determined sections and inferred densities, and to lateral variations in gravity and geologic structure which make the slab model inappropriate, GCONS is a roughly determined constant that varies between seismic sections. When he has arrived at a final model using a given GCONS, the user is advised to try several computer runs with different values of GCONS, comparing the root mean square errors of each run, to see how critical this constant is to his model. The final value of GCONS used in a 50 km thick model passing through San Francisco (Cady, 1975) was 808 mgal.

Dividing a model into its regional and local parts

It is often convenient to make widely spaced calculations along a regional profile in order to define regional structure before making more detailed calculations to define local structure of a selected portion of the profile. As the last step before commencing the detail calculation, the user can make a run which includes the regional bodies which will not change in the detail modeling but excludes the bodies which will change. The parameter KOUT permits the output of X, TOUT,

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and GOUT for later input, using subroutine ELEVER, as TIN and GIN in a subsequent detail run of the program.

In the subsequent run, if IREG and IRET equal 0, the plot will have high resolutions, because its abscissa will only span the range of the residual left after the regional modeling. If IREG and IRET equal 1, the plot abscissa will span the whole range of GOBS and TOBS, but will have lower resolutions.

Effective inclination calculated by subroutine FITMVT

In two-dimensional magnetic modeling, the magnetic poles due to the y-component of magnetization are so far away that the y-component can be ignored. In general, the inclination of the magnetization vector is given by REMINC=ATAN(MZ/SQRT(MX**2+MY**2)). If, however, we ignore the y-component MY, we can define the effective inclination in the x-z plane as EFFINC=ATAN(MZ/ABS(MX)). Subroutine FITMVT calculates the effective inclination in the three-dimensional case as a means of assessing the importance of MY. IF EFFINC is significantly larger than REMINC, the user should ascertain whether there is justification in the data for the large value of MY returned by the least squares routine.

A second diagnostic parameter is the hypothetical inclination of the Earth's magnetic field, assuming that its declination remains unchanged, which would be required to produce, by induction alone, the calculated effective inclination in the x-z plane. As a limiting example, if the Earth's field declination were perpendicular to the

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x-axis, it would be impossible to produce, by induction alone, an x-component of magnetization. In general, a horizontal component of magnetization FX along the azimuth of the Earth's field will have an x-component MX=FX*CDEC, where CDEC is the cosine of the angle between the x-axis and the azimuth of the Earth's field. Hence, from MX and MZ, ignoring MY, we calculate the desired hypothetical inclination HYPINC=ATAN(MZ/ABS(FX)), where FX=MX/CDEC. If the geometry is close to two-dimensional (meaning that the contribution due to MY is small), and if remanent magnetization is unimportant or parallel to the induced magnetization, then HYPINC should be close to the inclination of the Earth's field.

Tricky uses of the least squares option

Suppose that the user knows what the density contrast or magnetization is of a body, and he simply wants to determine its geometry. Should he forego the least squares option? Not necessarily. The least squares option will always produce the best fit possible for a given geometry, making it easy to compare the wavelengths of the observed and calculated anomalies and decide whether the depth to source is correct. Once the depth has been determined, the size of the body can be changed to produce acceptable magnitudes for density and magnetization.

Even if it is known that remanent magnetization is not present, it is often useful to request least squares solutions for both susceptibility and remanent magnetization. The latter solution will

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always be better than the former, and can give indications of desired changes in body geometry.

One powerful use of the least squares routine is to divide a single body up into many sub-bodies. If, for example, one is trying to model a gravity high with a homogeneous gabbro body, and least squares assigns a negative density contrast to part of the body, that part may be eliminated in subsequent runs. Suppose that the gabbro body were also the source of a magnetic high. In early runs, there might be a large dispersion between magnetization directions determined for the sub-bodies. Portions of the body with reverse magnetization might be eliminated, especially if they also showed negative density contrasts. If the gabbro body is truly homogeneous, then refinements in its geometry should lead to convergence between the sub-bodies in calculated values of density and intensity and direction of magnetization.

Curvature correction

Program 2HDPOT uses a Cartesian coordinate system and thus is intended for general application on a planar surface or portions of a planetary surface small enough that curvature can be ignored. A user wishing to make calculations where curvature must be considered may input body corners and observation points which reflect this curvature. If the curvature is small (as in the case of a 2000 km long profile on the Earth), he may write subroutines which will calculate curvature-corrected x and z coordinates for body corners

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from input distance and elevation along the Earth's surface. If the curvature is large (as in the case of an orbital probe), he may write subroutines which will convert from a convenient polar coordinate system to a Cartesian coordinate system.

Changing total field directions

The total field calculations assume that the direction of the total field vector is constant along the profile. These conditions cannot be met if the profile is very long relative to the dominant wavelength of the planetary field or if the anomaly field is strong compared to the planetary field. In the first case, the total field can be reduced to the pole before modeling begins, or the profile can be modeled in segments, assuming constant field direction within each segment. In the second case, a magnetometer which measures one or more separate components of the magnetic field would be preferred to a total field magnetometer, and the program could be modified to calculate individual components in place of the total field.

Miscellaneous suggestions

By using an unequal spacing of field points along the x-axis, the user may emphasize the effect upon the least squares solution of selected portions of the profile.

Linear interpolation is the default interpolation scheme for input of GIN, TIN, GOBS, and TOBS, because spline interpolation can be unpredictable. If you use spline interpolation, check to make sure it does what you want to the data.

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Note that strike length can be different for each body. Hence, a true three-dimensional body can be approximated, although in the magnetic case it must be symmetrical about the x-z plane.

In most cases, MODE should be negative, so that GRV, TOT1, TOT2, and VER are rezeroed before beginning a new computation. Positive values of MODE permit a calculation to be divided into two parts, with the results of the first part used as a starting point in the second part. For example, if in the first part a model is fit to GOBS, producing a calculated model anomaly field GRV, in the second part a different model can be used to model the residual between GOBS and GRV. The user is advised to study the program listing before trying such advanced maneuvers.

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ACKNOWLEDGMENTS

Program 2HDPOT derives from contributions by several people. The justification for the present paper is to pull these contributions together into a useful package.

In 1970, Allan Cox suggested combining Talwani's 2-dimensional magnetic and gravity modeling programs with a least squares solution for physical properties. Following that suggestion, I wrote the 2-dimensional prototype for program 2HDPOT.

The 2½-dimensional approach was inspired by a paper by Shuey and Pasquale (1973), and subroutine MAG is a modification of their subroutine MAG2H.

David L. Campbell provided invaluable assistance with the derivation of the 2½-dimensional gravity equations and wrote a prototype for subroutine GRAV which solved the sticky problem of choosing quadrants when evaluating arctangents.

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FIGURE CAPTIONS

Figure 1. Density or magnetization distribution $\rho(\hat{r}_o)$ within volume V as seen from field point $\hat{r}$.

Figure 2. Geometry of 2½-D body. Z-axis is positive down, y-axis is along strike, and traverse is along x-axis. Note that data is input as if z-axis were positive upward. AZMUTH is the angle between the x-axis and true north and FLDDEC is the declination of the Earth's magnetic field, both positive clockwise. FLDINC is the inclination of the Earth's magnetic field.

Figure 3. x-z relationship along one side of the polygonal cross section.

Figure 4. Geometry for converting the arcsine to the arctangent.

Figure 5. Generalized flow diagram for program 2HDPOT and subroutine FIELD.

Figure 6. Operational flow chart to assist user preparation of formatted input data.

Figure 7. Three simple examples of formatted input data. For simple examples of data input in the inverse mode, see FIRST TEST and SECOND TEST on pages 63 and 68.

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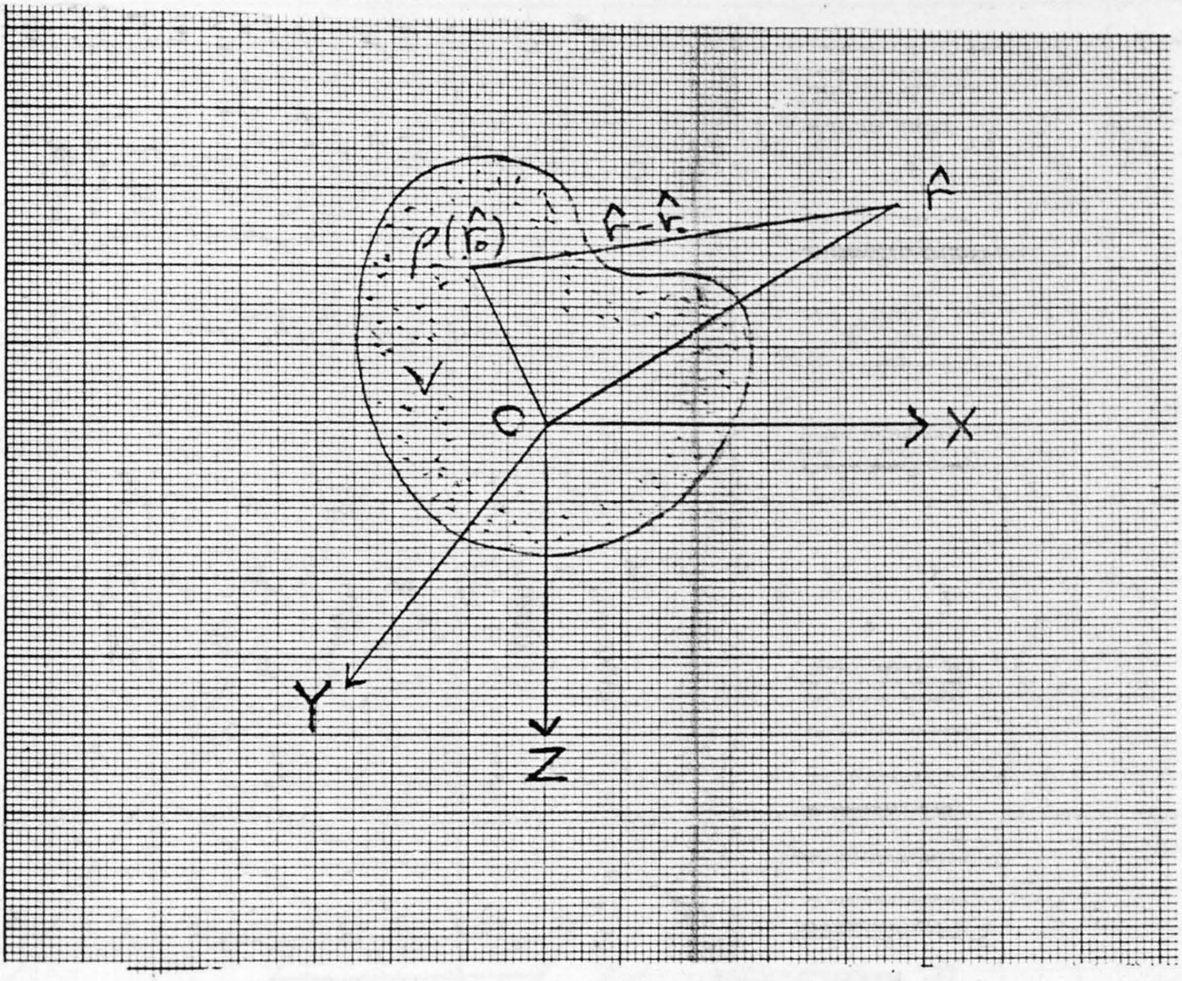

Figure 1. Density or magnetization distribution $\rho(\hat{r}_o)$ within volume V as seen from field point $\hat{r}$.

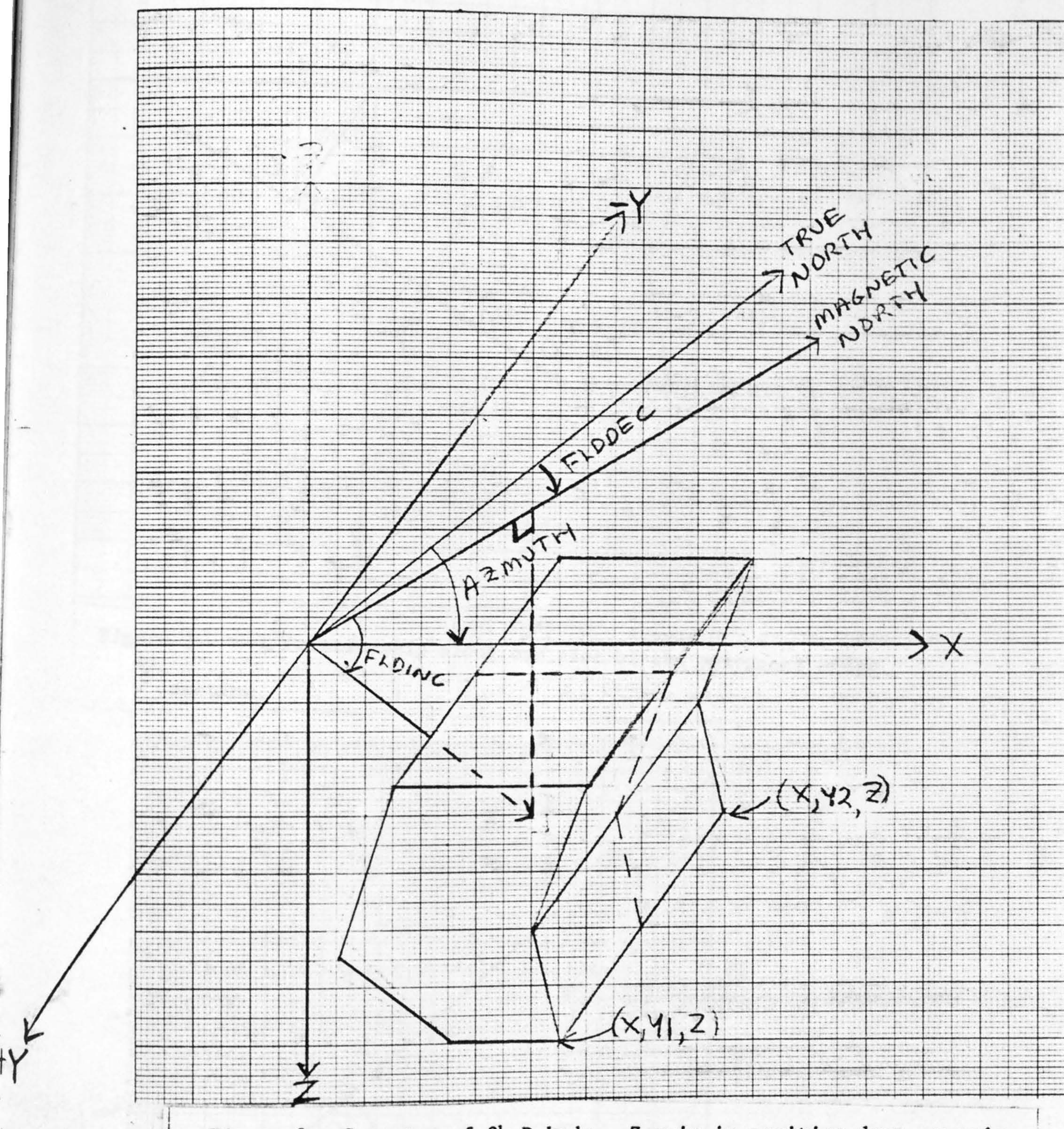

Figure 2. Geometry of 2½-D body. Z-axis is positive down, y-axis is along strike, and traverse is along x-axis. Note that data is input as if z-axis were positive upward. AZMUTH is the angle between the x-axis and true north and FLDDEC is the declination of the Earth's magnetic field, both positive clockwise. FLDINC is the inclination of the Earth's magnetic field.

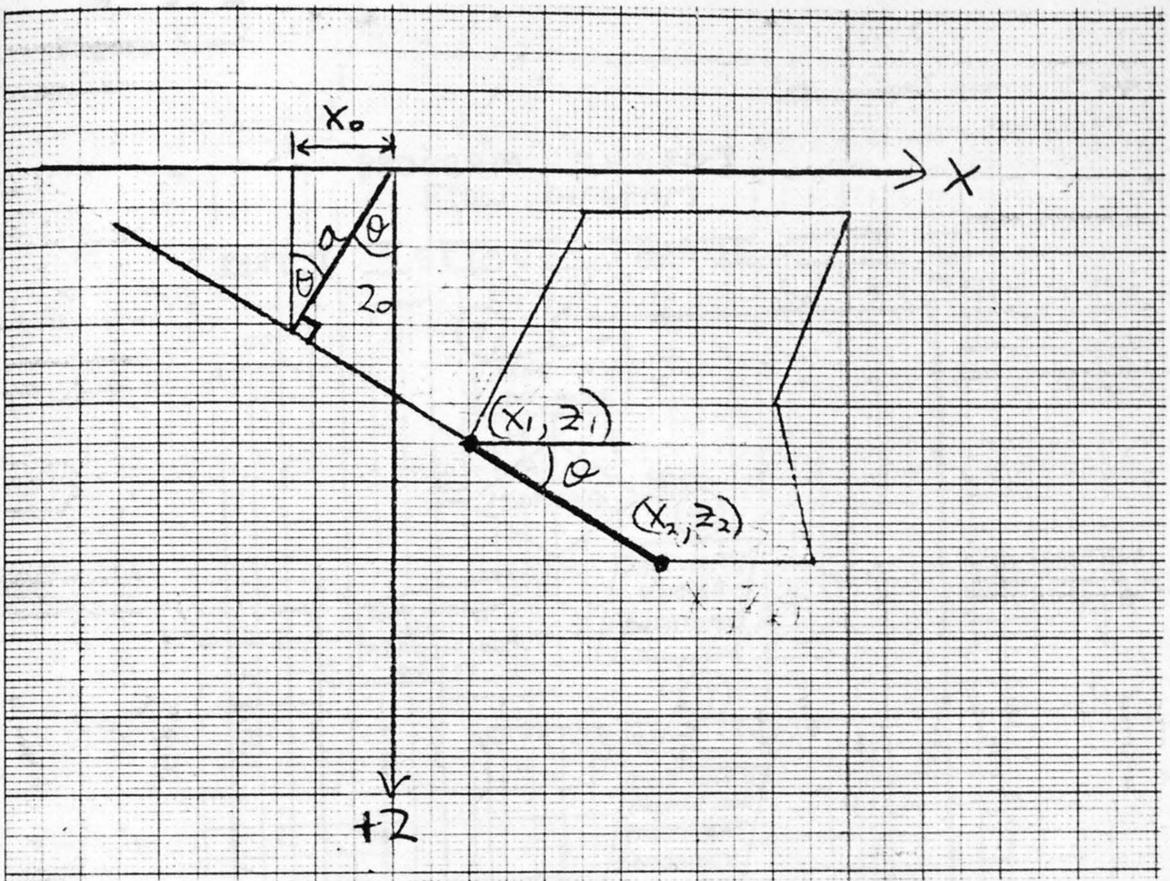

Figure 3. x-z relationship along one side of the polygonal cross section.

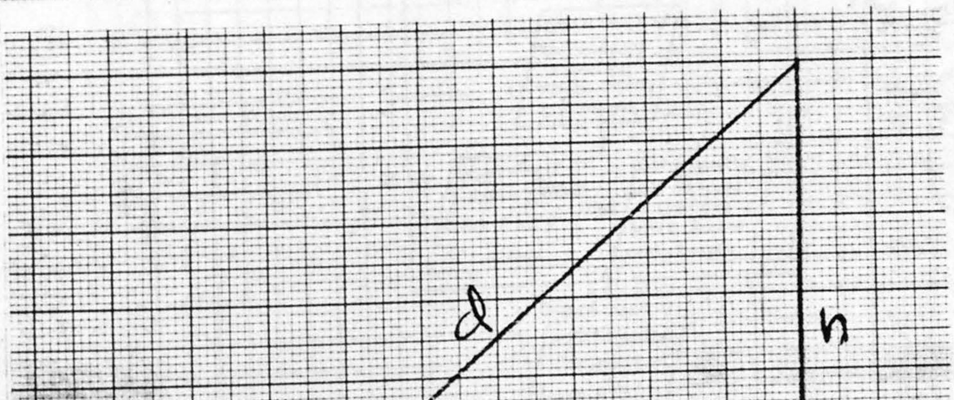

Figure 4. Geometry for converting the arcsine to the arctangent.

Figure 5.--

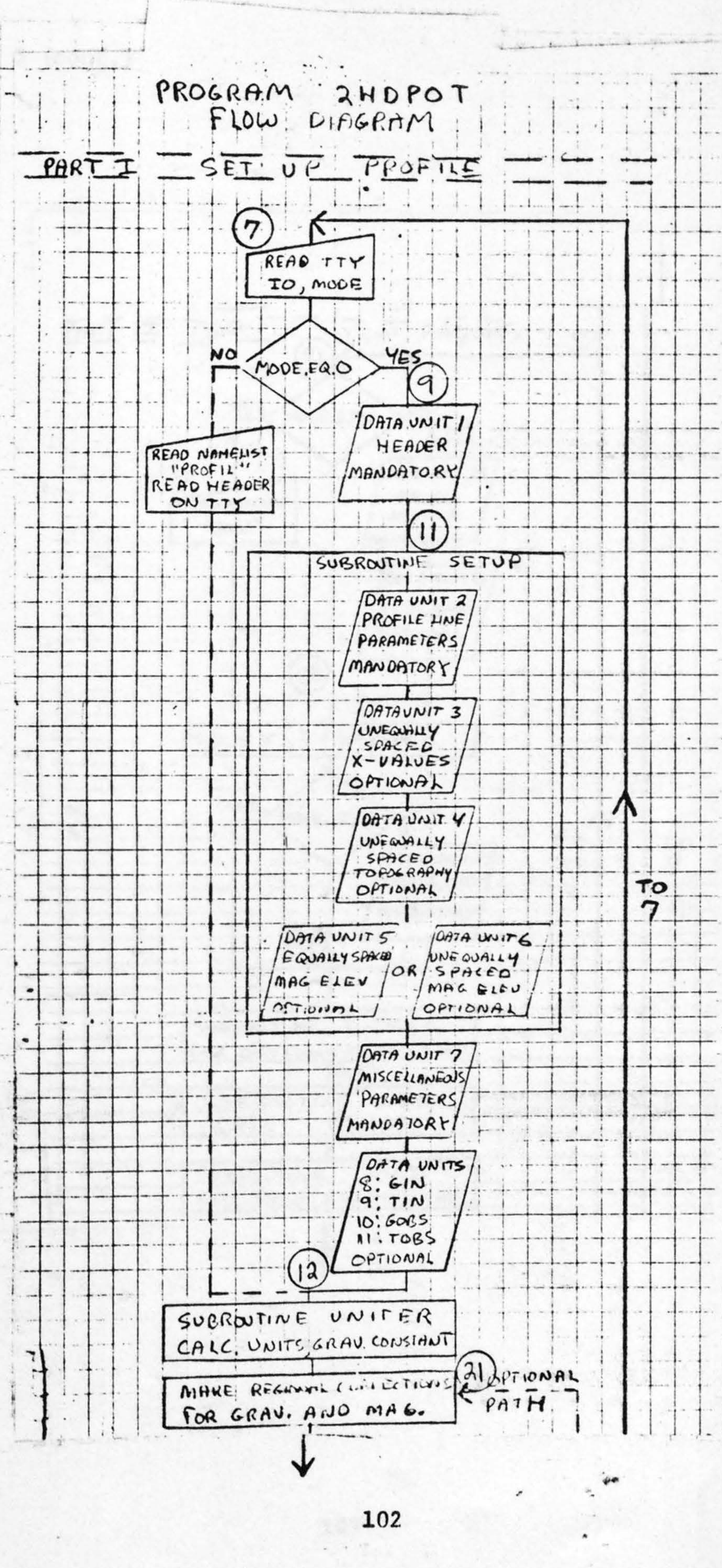
PROGRAM 2HDPOT
FLOW DIAGRAM
PART I SET UP PROFILE
7
READ TTY
TO, MODE
MODE.EQ.0
NO
YES
9
READ NAMELIST
"PROFIL"
READ HEADER
ON TTY
DATA UNIT 1
HEADER
MANDATORY
11
SUBROUTINE SETUP
DATA UNIT 2
PROFILE LINE
PARAMETERS
MANDATORY
DATA UNIT 3
UNEQUALLY
SPACED
X-VALUES
OPTIONAL
DATA UNIT 4
UNEQUALLY
SPACED
TOPOGRAPHY
OPTIONAL
DATA UNIT 5
EQUALLY SPACED
MAG ELEV
OPTIONAL
OR
DATA UNIT 6
UNEQUALLY
SPACED
MAG ELEV
OPTIONAL
TO
7
DATA UNIT 7
MISCELLANEOUS
PARAMETERS
MANDATORY
DATA UNITS
8: GIN
9: TIN
10: GOBS
11: TOBS
OPTIONAL
12
SUBROUTINE UNITER
CALC. UNITS GRAV. CONSTANT
MAKE REGIONAL CORRECTIONS
FOR GRAV. AND MAG.
21
OPTIONAL
PATH

Figure 5 (cont.)

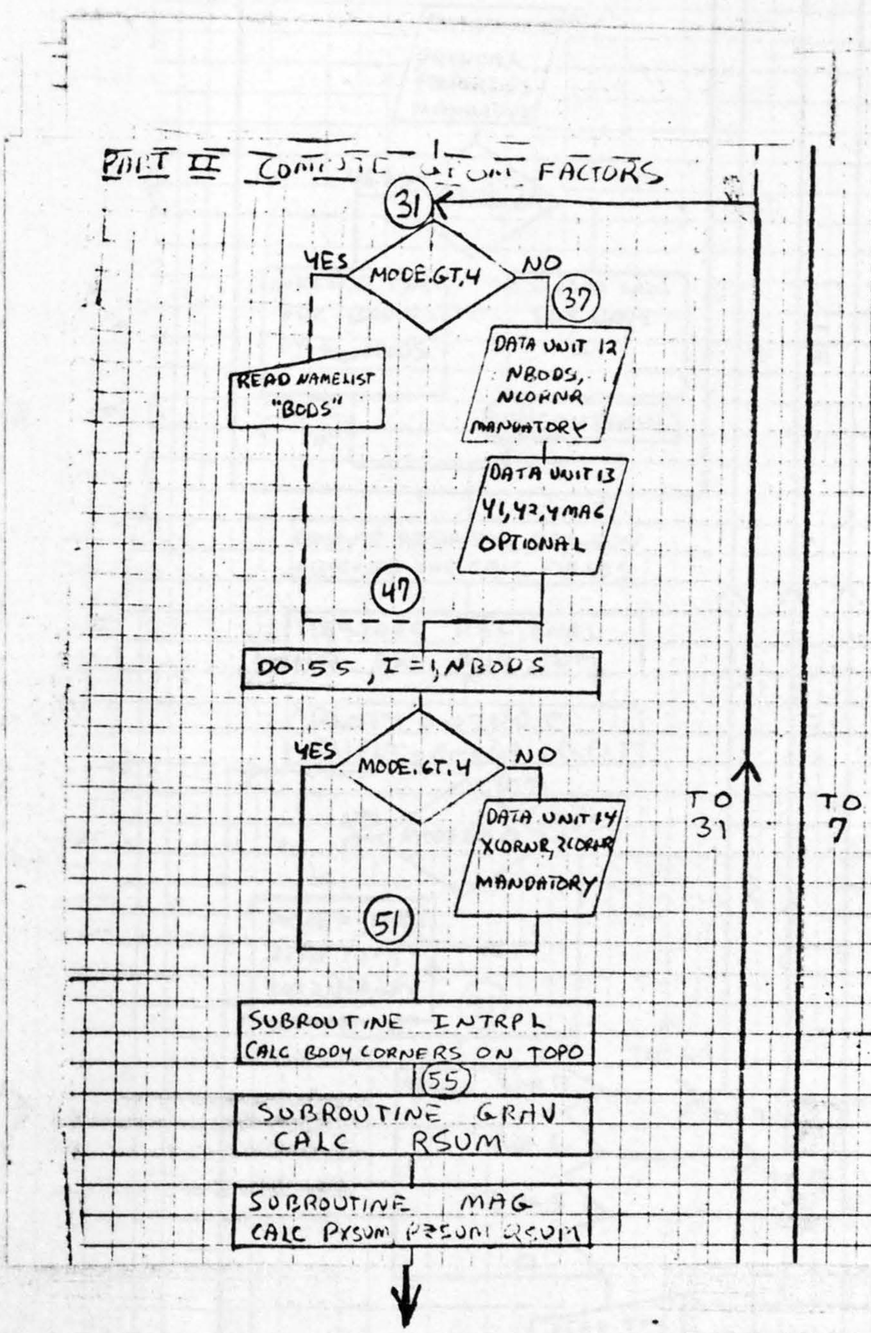

Figure 5 (cont.)

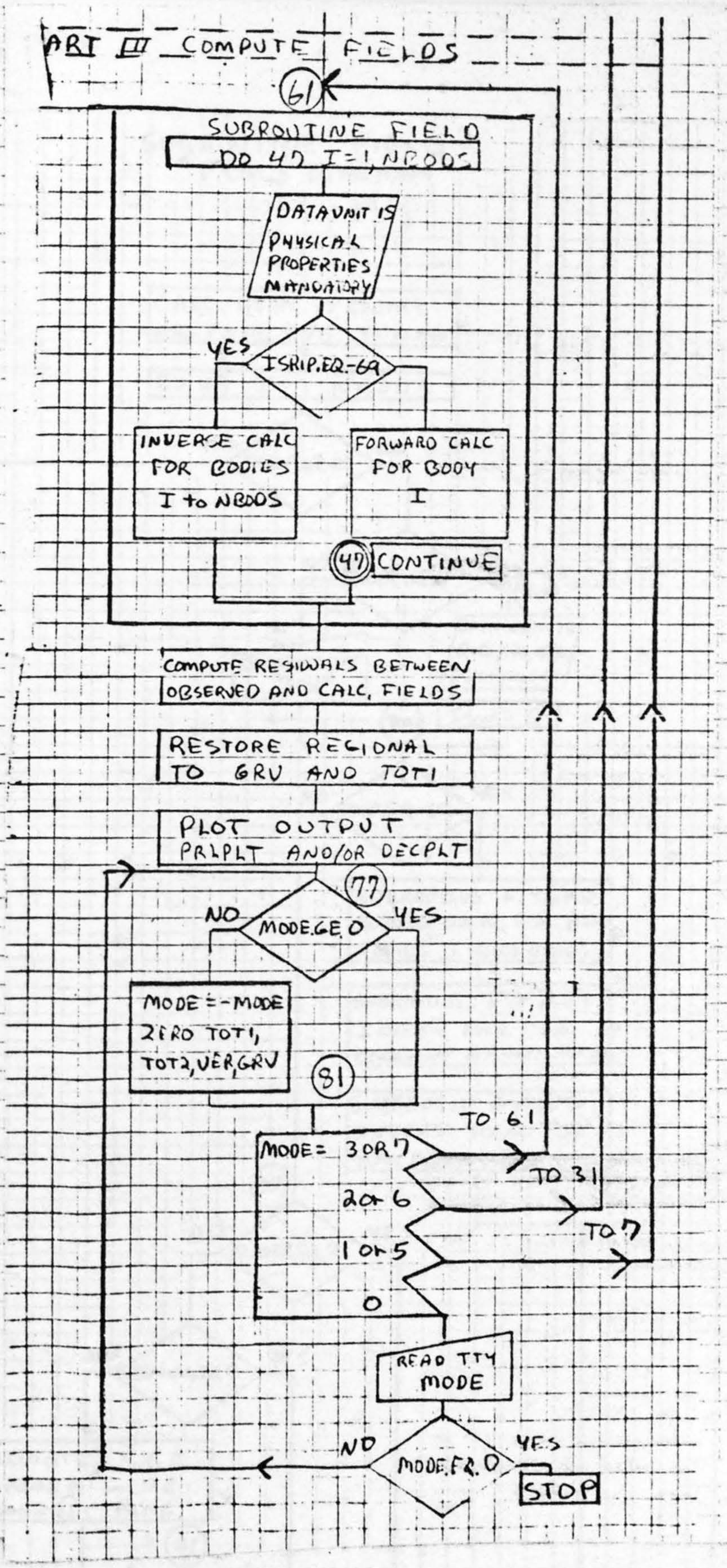

Figure 5 (cont.)

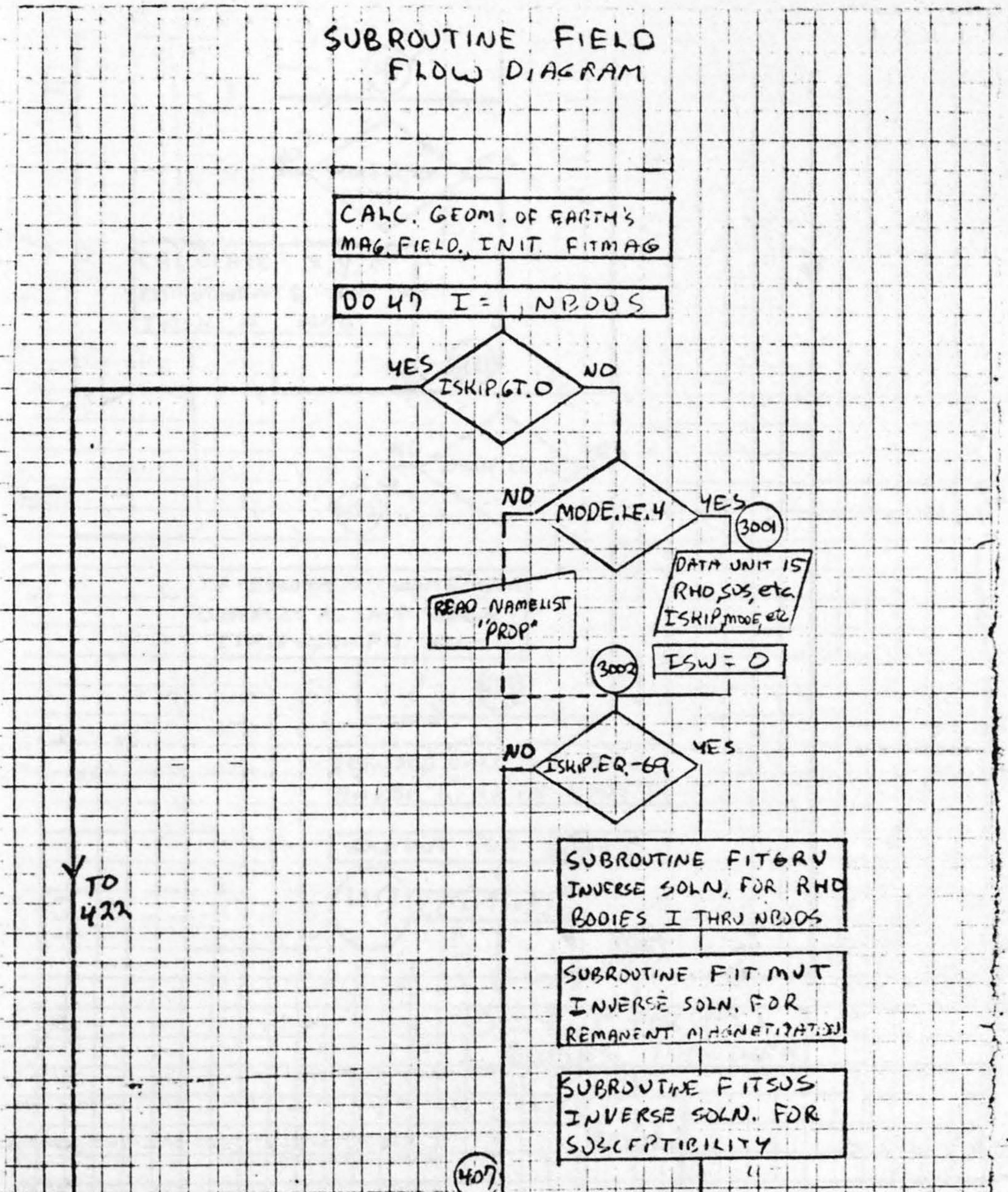

Figure 5 (cont.)

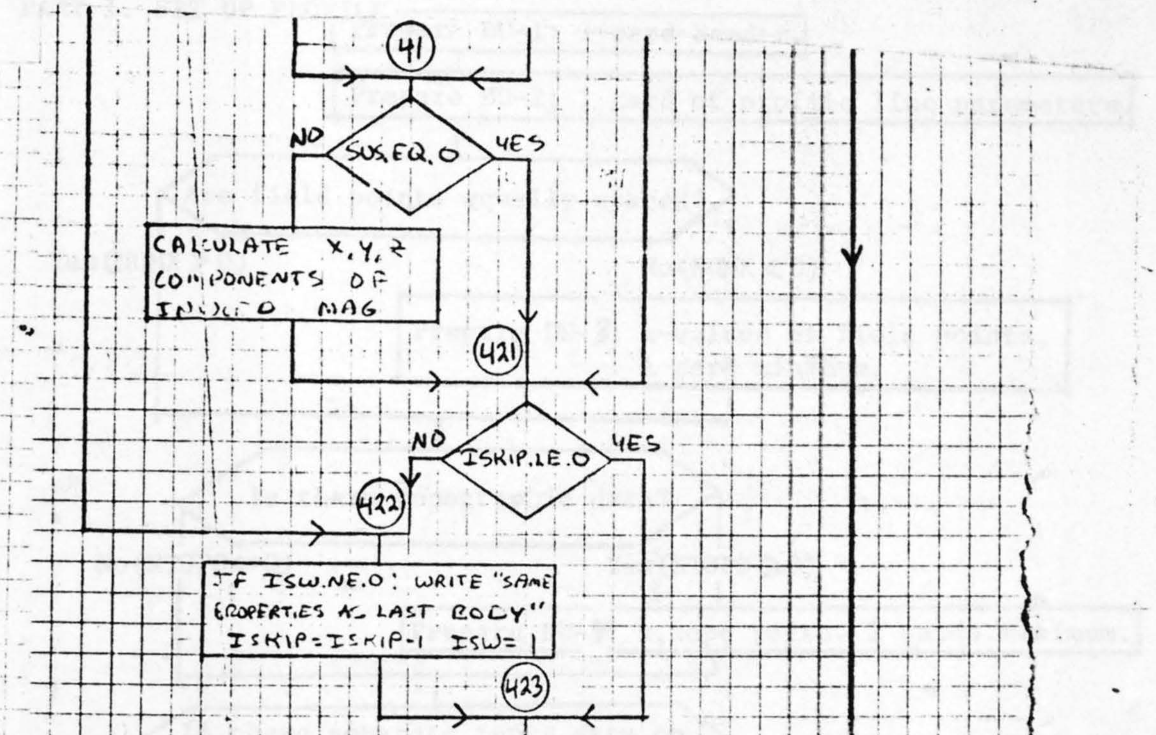

Figure 6.-- FORMATTED DATA INPUT TO ASSIST USER IN

OPERATIONAL FLOW CHART /PREPARATION OF FORMATTED INPUT DATA

Prepare following data units (DU's) as cards or lines in disk file.

PART I. SET UP PROFILE

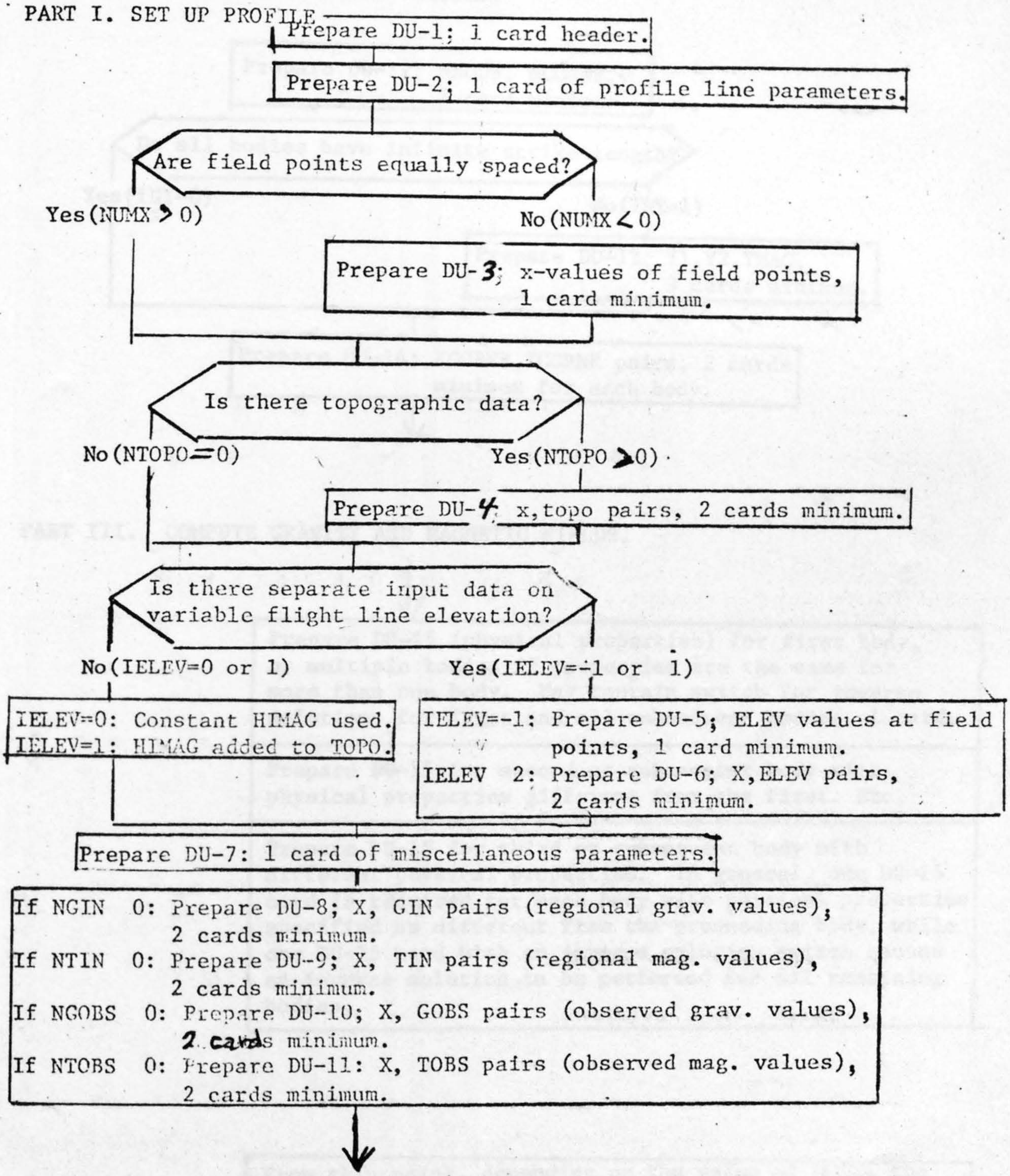

Figure 6 (cont.)

PART II. COMPUTE GEOMETRICAL FACTORS.

Prepare DU-12; NBODS, NCORNR, 1 card minimum.

Do all bodies have infinite strike length?

Yes(INY=0)

No(INY=1)

Prepare DU-13; Y1,Y2,YMAG, 3 cards minimum.

Prepare DU-14; XCORNR,ZCORNR pairs, 2 cards minimum for each body.

PART III. COMPUTE GRAVITY AND MAGNETIC FIELDS.

Prepare DU-15 (physical properties) for first body, or multiple bodies if properties are the same for more than one body. May contain switch for inverse solutions for first and all subsequent bodies. 1 card.

Prepare DU-15 for second or subsequent body with physical properties different from the first. Etc.

Prepare DU-15 for third or subsequent body with different physical properties. In general, one DU-15 card is required for each body with physical properties specified as different from the preceeding body, while one DU-15 card with an inverse solution switch causes an inverse solution to be performed for all remaining bodies.

From this point, depending on the value of MODE, the user can recompute fields using a new DU-15; recompute body geometries using a new DU-12 through DU-15; or begin all over with a new DU-1 through DU-15.

Figure 7. Three simple examples of formatted data input. For simple examples of data input in the inverse mode, see FIRST TEST and SECOND TEST on pages 63 and 68.

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```
                      1         2         3         4         5         6         7         8
Columns    12345678901234567890123456789012345678901234567890123456789012345678901234567890

DATA UNIT

1           SIMPLEST DATA INPUT 2D GRAV, FORWARD CALCULATION.
2          -10.       2.                                                           11
7              2
12             1    5
14         -4.       4.        4.        -4.       -4.
           -1.       -1.       -4.       -4.       -1.
15         1.                                                                        4


1           SIMPLEST DATA INPUT 2.5D GRAV, FORWARD CALCULATION.
2          -10.       2.                                                           11
7              2    0    0    0    0    1
12             1    5
13         -4.
           4.
                     BLANK CARD
14         -4.       4.        4.        -4.       -4.
           -1.       -1.       -4.       -4.       -1.
15         1.                                                                        4

1           SIMPLEST DATA INPUT 2.5D MAG AND GRAV, FORWARD CALCULATION.
2          -10.      2.        0.        0.        60.       100000.               11
7              1    0    0    0    0    1
12             1    5
13         -4.
           4.
           4.
14         -4.       4.        4.        -4.       -4.
           -1.       -1.       -4.       -4.       -1.
15         1.        .00001                                                          4

           12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure 7