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CONTENTS

Geohorizons is published by the Society of Petroleum Geophysicists (SPG), India. **Geohorizons** welcomes your contribution and articles on latest researches and investigations in the field of petroleum geophysics, related geoscientific and engineering disciplines. News items about the Society, announcements and other features containing information of interest to the members of the Society are also welcome.

Editorial

This is the first issue after new editorial team took over the office. The April, July and October issues are being combined as the new team took longer time than expected to settle. We shall put our sincere efforts to bring the coming issues in time.

The first paper in this issue "Some significant contributions of Roy on depth determination from observed Potential data" makes use of determination of spot-depth from gravity data. The numerically effective technique developed by the author for finding depth to causative mass by downward continuation of observed potential data along a vertical passing through the causative mass is discussed.

The second paper "Stratigraphic inversion for enhancing vertical resolution'' describes a complete methodology incorporating all the steps of post stack inversion. To demostrate the efficacies, synthetics as well as real data examples have been illustrated.

The third paper on "Structural play and Hydrocarbon distribution in Olpad-Dandi area, Cambay basin, India makes use of fence diagram for correlating log data. On the same log data sesimic inversion was also carried out which corroborates the studies of fence diagram.

The fourth paper on "Estimation of frequency degradation due to random static errors in seismic data" analyse the contribution of static errors to frequency degradation during stacking of seismic data.

Contribution in the form of research articles, discussion notes, and individual experiences are solicited from the members. Support provided by the advertisers is highly appreciated without which such endeavor of knowledge dissemination cannot sustain.

G.Sarvesam

President's Page

I take this opportunity to express my sincere gratitude to all the SPG members for giving me the responsibility of leading the Society. I shall try my best in fulfilling the cherished dreams of our predecessors of taking SPG to new heights.

[illegible] scenario when chances of making discovery of large hydrocarbon reserves or new hydrocarbon provinces are diminishing, development geophysics can play a major role in augmenting the hydrocarbon resources in the already proven hydrocarbon provinces.

Two virtual reality centres, at Mumbai in ONGC, are going to give geoscientists an opportunity to exploit the geophysical technology and their expertise. SPG has an onerous responsibility of propagating such new technologies among the geoscientists.

Newer paradigms through the use of 3D visualisation technology need to be developed and its dissemination among the fellow geoscientists is the need of the hour. This requires frequent interaction with the geoscientists abroad where such technologies are used more frequently. SPG's continuing education programme will have to be strengthened in this direction.

To widen the reach of the SPG, two new Regional Sections, were inaugurated at Delhi and Hyderabad this year. Besides, three new Student Sections at Andhra University, Waltair, Indian Institute of Technology (IIT), Kharagpur and NGRI, Hyderabad were also formed in the past 2-3 months.

Students Section of SPG are organising various educational and developmental programmes in their respective fields of activity. The Student Section of Kurukshetra University participated in Science Day exhibition and displayed models depicting Plate Tectonics, earthquake Hazards and Geostationary Satellite which were highly appreciated. Their stall has bagged the second prize in the competition.

To make the geoscientist familiar with the subsurface geological problems, Geological Excursions were also organised by SPG North-East Chapter along Shillong-Jowai-Badarpur section. SPG Dehradun in the same vein organised a day long tour to Saketi Fossil Park and Nahan-Renuka section. Such practical experiences are felt more worth than years of classroom teaching.

SPG is trying to organise more educational programmes in ensuing months and is committed to serve its members more efficiently.

Kharak Singh

Some Significant Contributions of Roy on Depth Determination from Observed Potential Data : A review

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Abstract

On carrying out modelling of gravity data Skeels (1947) concluded that depth determination from observed potential field data is ambiguous. This conclusion adversely affected the importance of Gravity-Magnetic (GM) survey in oil and mining industries. To examine the possibility of depth determination from survey data, Roy (1962) carried out a theoretical analysis of gravity response of a subsurface mass and concluded that a unique depth to the causative mass can be determined if the geometry of the mass is known and its density (contrast) is assumed constant. This information laid the ground for Hammer to put forward a technique for determination of spot-depth in a basin from observed gravity data (Hammer 1977). Determination of spot-depth from gravity data is still being used as a routine job in oil and mining industries all over the world.

Subsequently, to determine depth to a buried mass, Roy conceived that continuation of the observed potential response would exhibit wide oscillation on reaching the target (Roy 1966). For downward continuation of a two dimensional field, Roy (1966) derived a 4-point formula and applied it to observed electromagnetic field, with selective spacing of data, and determined the depth to the causative mass. Though his numerical approach did not work well, his concept that the continued field will exhibit a wild behaviour on reaching the target, stood as a beckoning light to researchers to deliver a reasonable technique to achieve it. This was finally achieved in the first part of nineties.

1. Works carried out by Roy : A short summary

1.1 The back ground

Information about depth to the basement is the first requirement in exploration of hydrocarbons in a basin. The first attempt on depth determination from observed gravity data is due to Skeels (1947). On carrying out a numerical modelling of gravity data, Skeels concluded that depth determination from observed gravity data is ambiguous in the sense that many finite masses, shallower than the causative mass, approximately reproduce the given gravity response at the ground level.

1.2 Determination of spot-depth

The conclusion of Skeels (1947) adversely affected importance of gravity magnetic (GM) surveys in oil and mining industries. To re-examine the situation, Roy (1962) carried out a theoretical analysis of the gravity response

$$\Delta g(a, b, 0) = G \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{0}^{\infty} \frac{z\rho(x, y, z)\, dx\, dy\, dz}{[(x-a)^2 + (y-b)^2 + z^2]^{3/2}} \qquad (1)$$

of the subsurface mass and came to the conclusion that a unique depth to the causative mass can be determined if the geometry of the bounding surface of the mass is known and its density (contrast) is treated as constant. Subsequently, Hammer (1977) classified the basement features of interest to oil industry in three broad classes: a sphere, a horizontal cylinder and a thin plate approximation to a fault and determined their depths from the observed gravity data. Following the same concept, Gupta (1983) obtained the depth to the causative mass as solution of a non-linear algebraic equation resulting from minimization of the sum of squared differences of the observed and the calculated gravity response of an assumed mass with respect to depth in least squares sense.

1.3 Determination of point to point depth

The work of Roy (1962) paved the way for finding the depth to the basement at isolated points in a basin where the observed gravity data indicated existence of a subsurface feature of known geometry. To determine point to point depth to the top of a causative mass with a general bounding surface, Roy (1966) derived a 4-point formula for downward continuation of two-dimensional potential data from the level of observation and showed, under a selective spacing of data, that the continued field exhibits a discontinuity on reaching the target.

For downward continuation of a two-dimensional potential field H specified over datum level $\bar{S}$, Roy (1966) used Taylor's series extrapolation, an approach also suggested by Peters (1949), and derived the 4-point formula

$$H(q_4) = 4H(q_0) - \sum_{j=1}^{3} H(q_j), \qquad (2)$$

to find the unknown H at q_4, lying at a level S_1 at depth h below $\bar{S}$ for H known on and above $\bar{S}$. The points q_1, q_2, q_3 and q_4 in (2) lie on a circle of radius h, q_0 defining its centre, q_3, q_0, q_1 lying over $\bar{S}$ and q_2 and q_4 lying on a vertical through q_0 ; q_2 lying above $\bar{S}$ and q_4 below it. For H given over $\bar{S}$, $H(q_3)$, $H(q_0)$, $H(q_1)$ are known, $H(q_2)$ can be obtained on upward continuation of H specified over $\bar{S}$ (if not known otherwise) and subsequently, $H(q_4)$ is given by (2). On finding the H-values over S_1 at equdistant points h apart, the H-values at the next deeper level S_2 at depth 2h below $\bar{S}$ are computed by use of formula (2) for H-values known on and above S_1. Subsequently, the H-values at deeper levels S_3, S_4..... S_m located at depths $d_m = mh$, m= 3,4, ...m below $\bar{S}$ are computed. The computed $H(q_4)$ is excepted to exhibit a wide discontinuity when the continuation point q_4 lies in the causative mass. This depth of discontinuity defines the depth to the causative mass.

2. A discussion on Roy's work

2.1 Choice of Boundary Source

For a potential field H given on the level $\bar{S}$, Roy (1962. p.90) states that "following extension of Green's theorem of equivalent layer, the field can be exactly reproduced by each of infinite number of surface distributions (or double distributions in magnetic case) shallower than the one which orginally produced the anomaly". In a cartesian reference frame with z-axis downward the above statement can be expressed as cartesian reference frame with z-axis downward, the above statement can be expressed as :

$$H(a,b,0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \frac{h\,\sigma(x,y,h)\,dx\,dy}{[(x-a)^2+(y-b)^2+(0-h)^2]^{3/2}}, \quad h \le D, \qquad (3a)$$

For H representing the gravity field over the ground level $\bar{S}$ defined by z=0, σ defining the simple layer density over S defined by z=h, and

$$H(a,b,0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \left\{\frac{3h^2-[(x-a)^2+(y-b)^2+h^2]}{[(x-a)^2+(y-b)^2+h^2]^{5/2}}\right\} \mu(x,y,z)\,dx\,dy, \quad h \le D, \qquad (3b)$$

for H defining the downward vertical component magnetostatic field over $\bar{S}$, μ defining the double layer density of downward doublets normal to S; and D defining the depth to the shallowest point of the causative mass below $\bar{S}$. The choice of the boundary densities advised in Roy (1962), particularly in the case of the gravimetric field, was followed in geophysics till the end of the seventies (Bhattacharyya and Chan 1977).

It may be noted here that the Green's formula, a harmonic function $\phi = O(r^{-n})$, $n \ge 1$, $r \to \infty$, defined in the upper half-space domain B_e bounded below by a general half-space boundary S (may be horizontal surface as a particular case), the φ at any point $P \in B_e$ can be expressed as a combination of simple and double layer boundary densities belonging to S. For a horizontal S, it has been shown by Roy (1962) that φ in B_e can be obtained as a potential due to a simple density σ alone over S as

$$\phi(a,b,0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \frac{\sigma(x,y,h)}{[(x-a)^2+(y-b)^2+h^2]^{1/2}}\,dx\,dy, \quad h \ge D, \qquad (4)$$

D defining the depth to the shallowest point of the causative mass.

Since Green's formula is valid for a φ with asymptotic behaviour $O(r^{-n})$, $n \ge 1$, $r \to \infty$, the boundary density σ can reproduce a φ in B_e with asymptotic behaviour $O(r^{-2})$, $r \to \infty$. This means, the σ can also reproduce the magnetic potential a φ in B_e such that the magnetostatic field ΔT can also be obtained as derivative of simple layer potential given in (4). Hence, the statement "or double layer distributions in magnetic case" appears as an unnecessary restriction on use of simple source density in reproduction of gravity- magnetic fields by boundary sources.

2.2 Nature of solution and its interpretation

It has been stated in Roy (1962) that if both positive and negative densities are accepted as solution of the equation (3a) for Δg prescribed over $\bar{S}$, then there is no end to the depth of the causative mass (Roy 1962, p. 90).

(i) That the solution may be a combination of both positive and negative densities is neither discussed nor a reference on, it is cited in his work. Further, (ii) Roy (1962) probably took the cue from Skeels (1947) to interpret every depth of S containing an equivalent layer of S at depth as a depth to the causative mass. The question arises, can we define these depths of S as depth to the causative mass ?

We know, for a subsurface mass m placed at a depth D below the datum plane $\bar{S}$, the gravity response Δg is positive all over $\bar{S}$. If this Δg is reproduced by a simple layer density σ belonging to a horizontal surface S placed at a depth d below $\bar{S}$. then for $h \le D$, $\sigma(q) \ge 0$, $q \in S$ and this σ is unique. For h>D, this σ oscillates about zero over S indicating that S lies wholly or partially below the causative mass m (Laskar 1980, 1994, 2000). Hence, we find that the intuition about the nature of the solution is right though a formal proof was not supplied or referred to a past work in his paper.

2.3 Cause of oscillation of solution at target

On depth determination by downward continuation of potential data, Roy (1966) states that the field on downward continuation exhibits a wild oscillation on reaching the target (Roy 1966, p. 168)

The cause of the oscillation of the solution on reaching the target is neither stated nor explained in his paper. It may be bacause of the singularity of the field lying at the causative mass or it may be for some other reasons involved in formulation of the problem. It may not be out of point to mention that the gravity response of a sphere is defined every where, including its interior. As such, if singularity of the field is the cause of oscillation in solution, the depth to the sphere is expected to remain untraced in downward continuation of the gravity response of it. This is not true. Oscillation in the continued field must occur on reaching the target irrespective of the field having a singularity at the causative mass (Laskar 2000).

2.4 A critical study of 4-point formula

Roy (1966) has derived a 4-point formula for downward continuation of two-dimensional potential fields. The weakness of the formula does not reveal itself clearly in its derivation, except the doubt in convergence of the extrapolated series and the derivation of the formula on use of a truncated series. The weakness of the formula however becomes evidently clear when it is derived from the Arithmetic Mean Value Theorem of potential theory (Kellogg 1929, P. 223).

For a two-dimensional harmonic function φ