

## Application of Inversion Techniques on Marine Magnetic Data - Andaman Shelf

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**Abstract:** Analysis of the total intensity magnetic data over the western Andaman shelf has been carried out for determination of depth to magnetic basement using the Analytical signal and Werner Deconvolution methods. The basement depths are refined with optimisation procedure of iteration modelling. The depths Derived from these methods match well with the acoustic basement mapped by the seismic reflection survey across the Andaman shelf. The interpretation by these methods demonstrates the rapid utility in virgin areas for deriving the first order basement configuration quickly. The gradual slope of the basement from west to east on the western Andaman shelf may be attributed to the ongoing process of the subduction of the older crust in the Sunda Trough.

**Keywords:** Marine Geophysics, Andaman Sea.

### INTRODUCTION

The Bengal Deep Sea Fan is considered to be one of the largest and thickest sedimentary fans of the world. The Andaman arc in the northeastern Indian Ocean together with the Burmese arc further north define nearly 2100 km along margin of the underthrusting Indian plate with the Burma plate (Fitch 1970, Curray *et al.*, 1979). The tectonic map of the Andaman arc (Curray 1990) and adjoining areas is shown in Figure 1. The Andaman arc is of particular interest for its Neogene back arc spreading. This activity is presumably related to leaky transform tectonics (Uyeda and Kanamori, 1979). Curray *et al* (1979) described a set of north-south faults slicing the seafloor along the eastern edge of the Andaman Nicobar Ridge in the Nicobar deep and under the western part of Andaman Sea. Some of these faults are seismically active (Mukhopadhyay, 1988). The Sunda arc is a model for plate convergence (Curray 1989). Most of the sediment accumulations are relatively undeformed, but the eastern margin is passing obliquely into Sunda subduction zone, where some of the sediment and oceanic crust have formed the accretionary

prism of the Indo - Burma ranges, the Andaman Nicobar Ridge, and the outer arc ridge off Sumatra and Java. Venkateswarlu and Chatterjea (1988) inferred a fault like structure using total intensity magnetic data in the Andaman Sea. Considering the geological importance of this area, and as it was the least studied (except Rodolfo K.S, 1969), a few magnetic profiles were run across the study area (Fig.1). We have used the total magnetic intensity data to derive a first order basement configuration of the western shelf of Andaman arc with the Analytical signal and Werner Deconvolution methods. These methods are fast and do not require prior knowledge of the basement rock level or its evolutionary history and magnetic parameters like susceptibility and dip. The depths obtained are further refined using Marquardt's (1963) iteration modelling and the final results have been compared with the known seismic results at places.

### DATA

Total magnetic intensity data were collected along four E-W profiles spaced at one

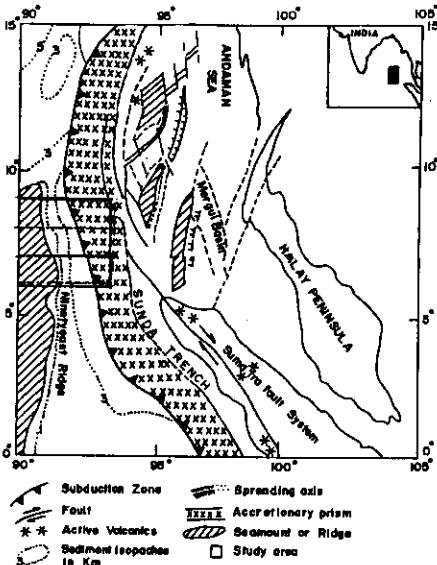


Fig.1 : Tectonic map of Western Andaman shelf (after J.R. Curray, 1989).

degree interval over the Andaman shelf (Fig.2) onboard DSV Nandarachit during 1989-90 field season. Satellite navigation system

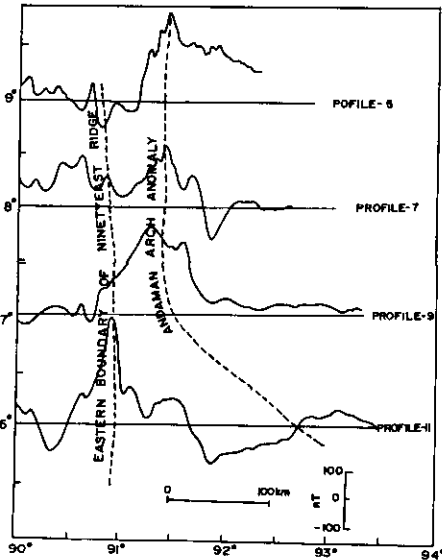


Fig.2 : Total field magnetic anomalies plotted perpendicular to the ship's tracks.

(Magnavox 1107) was used for obtaining the continuous positions. Deep sea Raytheon Echosounder (12 kHz) was used for recording the continuous depth to the seabed whereas Geometrics Proton Precession magnetometer was used for measuring the total magnetic intensity field. The magnetic data were reduced by subtracting the International Geomagnetic Reference Field (IGRF) of 1990.0 epoch, computed at each observation point. The magnetic anomalies thus obtained were plotted and shown as stacked anomaly profiles (Fig.2).

RESULTS AND DISCUSSION

The magnetic anomalies observed over the western Andaman shelf between 90°E and 93°E are well pronounced and distinct. The peak to peak amplitudes of these anomalies are of the order of 300 to 350 nT and showed congruence from one profile to the other (Fig.2).

The interpretations of magnetic anomalies in general can be carried out using a) graphical methods (Vacquier *et al*, 1951, Bean 1966, Koulamzine *et al*, 1970), b) Forward modelling (Talwani and Heirtzler 1964) c) spectral and statistical methods (Spector and Grant 1970, Bhattacharya and Liu 1975) and d) inversion methods (Ku and Sharp 1983). Some of the methods mentioned above have limitations. However, the methods suggested by Nabighian (1972) and Ku and Sharp (1983) can be judiciously used in this virgin area without much ambiguity. In the present study the Analytical signal method proposed by Nabighian (1972) and the Werner Deconvolution method refined by Ku and Sharp (1983) are employed for interpreting the observed magnetic anomalies over the Andaman shelf that covers Sunda Trough. This is due to the fact that 1) the parameters of the causative source rock are possible to deduce directly from the observed magnetic data, and 2) these methods do not require any prior assumption regarding the shape, size of the causative source rock and geological structural configuration.

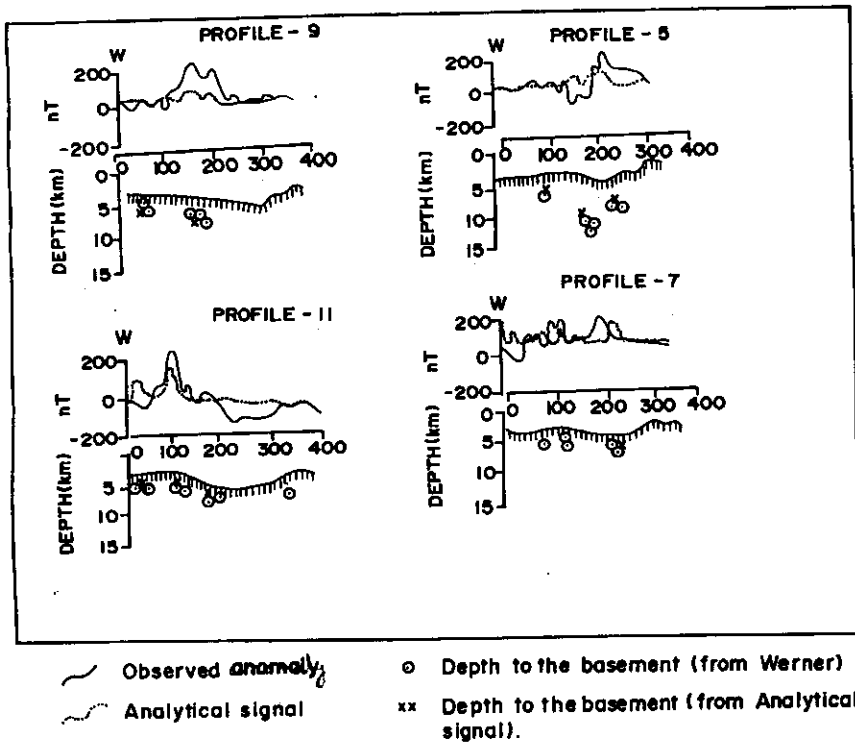


Fig.3 : Basement depths derived using the Werner Deconvolution and Analytical signal methods.

Approximately symmetrical analytical signals (Fig.3) are computed from the horizontal derivatives of the observed magnetic anomalies (Fig.2) and good analytical functions (Fig.3) have been obtained for the observed magnetic data. If the analytical functions obtained are not symmetrical, then additional controls can be exercised by splitting these functions into symmetric and asymmetric following the method of Koulamzine *et al* (1970). Symmetrical bell shaped function is observed wherever the total field magnetic anomalies are distinct. The depth to the top of the source has been obtained by the location of half - maximum and half - width of the analytical bell shaped function.

The Werner Deconvolution method can also be employed either for the total intensity magnetic field data or to its horizontal derivative for computing the depths to the magnetic

basement and its configuration. In this method the determination of the depths and other parameters like horizontal distance, dip and susceptibility are achieved by the proper selection of decimation operator (Ku and Sharp 1983) for that particular anomaly. The susceptibilities 0.002-0.004 computed for the magnetic profiles in the present study are close to the values reported to the oceanic basalts. The depth to the basement obtained from Werner method coincides with that of analytical signal method (Fig.4) and is shown as a continuous basement surface. The present study area with all probabilities appears to be formed in Cretaceous quiet period (Ramana *et al*, 1993). Thereby, a definite magnetic polarity direction is difficult to assign. Further the study area covers the Sunda Trough, a subduction zone with more thickness of basement rocks. We have used the two dimensional subroutine of

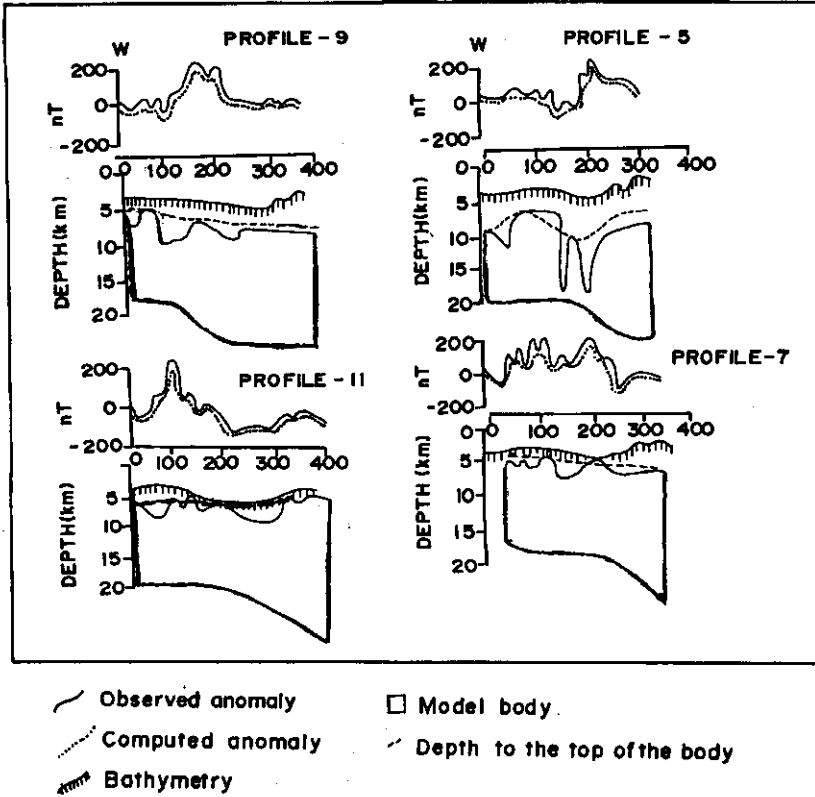


Fig.4 : Comparison of basement configuration derived from Inversion techniques and two dimensional model studies derived using Talwani and Heirtzler method (1964).

Talwani and Heirtzler (1964) and computed theoretical magnetic anomaly. Then Marquardt's (Ku and Sharp 1983, Malleswara Rao *et al*, 1993) iteration is applied with the initial model derived from Werner and analytical signal methods. In each iteration the procedure is continued till the object function reduces to pre-assigned tolerance limit. This tolerance limit has been attained after completion of nearly 150 iterations for obtaining the body parameters more accurately. For the sake of comparison we considered the basement configuration derived from forward modelling under seismic constraints and superposed over the computed basement surface obtained with inversion techniques and found negligible de-

viation (Fig.4). Over the subduction zone the depth to the top of the basement on profile 5 is about 10 km which gradually decreases to 7.5 km on profile 11. The seismic reflection and refraction results of Curray *et al* (1982), Gopala Rao, *et al* (1993) show similar basement depths in the study area. Thus the utility of these techniques for deriving the basement depths over the virgin areas like Andaman shelf has been demonstrated. The continuous basement shown in figure 4 in general shows an eastward dipping. This dipping of the basement layer is attributed to the onward continuing phenomenon of subduction in the Sunda Trough. The real mosaic of the ocean floor undergoing subduction can be determined ac-

curately with more closely spaced geophysical data in the Andaman shelf.

### CONCLUSIONS

1. The Andaman shelf is characterised by well pronounced and consistent magnetic anomalies with peak to peak amplitudes of 300 to 350 nT.
2. The application of Analytical signal and Werner Deconvolution methods are more suitable to the Andaman shelf area and the results derived are further refined with Marquardt's iteration modelling under seismic constraints.
3. The depth to the top of magnetic basement

varies from 7.5 km in the south to more than 10 km in north below the sea level.

4. In the unknown geological environment these inversion techniques seem to be more suitable for obtaining first order information about basement.

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### References

- BEAN, R.J., (1966) A rapid graphical solution for the aeromagnetic anomaly of two dimensional Tabular body. *Geophysics*, v. 31, pp 963-970.
- BHATTACHARYA, B.K. and LIU, L., (1975) Spectral analysis of gravity and magnetic anomalies due to two dimensional structures. *Geophysics*, v.40, pp 993-1013.
- CURRAY, J.R., MOORE, D.G., LAWYER, L.A., EMMEL, F.J., RAITT, R.W., HENRY, M and KIEKHEFER, R., (1979) Tectonics of the Andaman Sea and Burma. *Am. Ass. Petro. Geol. Mem.* 29, pp. 189-198.
- CURRAY, J.R., (1989) The Sunda Arc: A model for oblique plate convergence. *Netherlands Journal of Sea Research*, v.24(2/3), pp. 131-140.
- CURRAY, J.R., (1990) Geological history of the Bengal geosyncline, Proc. of 16th Convention and seminar on exploration geophysics "Seismotectonics of the Indian Sub-continent" 5-7, Dec., Dehradun, India.
- CURRAY, J.R., EMMEL, F.J., MOORE, D.G. and RAITT, R.W., (1982) Structure and tectonics and geological history of the North-eastern Indian Ocean. *In: The Ocean basins and margins* (Eds.) E.M. Naim and F.G. Stehli, Plenum Press, New York, pp. 339-450.
- FITCH, T.J., (1970) Earthquake mechanism in the Himalayan, Burmese and Andaman regions and continental tectonics in central Asia. *J. Geophy. Res.*, v.75, pp. 2699-2709.
- GOPALA RAO, D., *et al.* (1993) Analysis of multichannel seismic reflection and magnetic data along 13°N latitude across the Bay of Bengal. *Marine Geophysical Research* v.15 (In press).
- KOULOMZINE, T.H., LAMONTAGUE, Y and NADEAN, A., (1970) New methods for the direct interpretation of magnetic anomalies caused by inclined dykes of infinite length. *Geophysics*, v.35, pp. 812-830.
- KU, C.C. and SHARP, J.A., (1983) Werner Deconvolution for automated magnetic interpretation and its refinement using Marquardt's inversion modelling. *Geophysics*, v.48, pp. 754-774.
- MARQUARDT, D.W., (1963). An algorithm for least-squares estimation of non linear parameters. *J. Soc. Indust. Appl. Maths.* v.11, pp. 431-441.
- MUKHOPADHYAY, M. (1988) Gravity anomalies and deep structure of the Andaman arc. *Mar. Geophy. Res.* v.9, pp. 197-210.
- MALLESWARA RAO, M.M., LAKSHMINARAYANA, S., MURTY, K.S.R. and SUBRAHMANYAM, A.S. (1993) Two computer programs for the analysis of Marine magnetic data. *Computers and GeoSciences*, vol 19, No 5, pp. 657-672.
- NABHGHIAN, M.N. (1972) The Analytical signal of two-dimensional magnetic bodies with polygonal cross section, its properties and use for automated anomaly interpretation. *Geophysics*, v.37, pp. 507-517.
- RODOLFO, K.S. (1969) Bathymetry and marine geology of the Andaman basin and tectonic implications for southeast Asia. *Geol. Soc. Amer. Bull.*, v.80, pp. 1203-1230.
- RAMANA, M.V., SUBRAHMANYAM, V., KRISHNA, K.S., CHAUBEY, A.K., SARMA, K.V.L.N.S., MURTY, G.P.S., GOPALA RAO, D., MITTAL, G.S. and R.K. DROLIA, (1993) Marine Geophysical Studies in Northern Bay of Bengal, v.15 *Mar Geophy. Res.* (In press).
- SPECTOR, A and GRANT, F.S. (1970) Statistical models for interpreting aeromagnetic data. *Geophysics*. v.35, pp. 293-302.
- TALWANI, M. and HEIRTZLER, J.R. (1964) Computation of magnetic anomalies caused by two dimensional structures of arbitrary shape. (Ed.) J. Parks, *Computers in mineral Industry. The School of Earth Science, Stanford University*, pp. 464-480.
- VACQUIER, V., STEENLAND, R.C., HENDERSON and ZIETZ.

- (1951) Interpretation of aeromagnetic maps, GSA Memoir 47, pp. 151.
- UYEDA, S. and KANAMORI, H. (1979) Back arc opening and the mode of subduction. *J. Geophy. Res.* v.84, pp. 1049-1061.
- VENKATESWARLU, P.D. and CHATTERJEA, P. (1988) Magnetic (total field) and Bathymetry studies in the Andaman Sea. A qualitative Appraisal. *J. Asso. Explo. Geophy.* 9, pp. 191-197.

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