Chapter 89
Application of Empirical Model Decomposition and Independent Component Analysis to Magnetic Anomalies Separation: A Case Study for Gobi Desert Coverage in Eastern Tianshan, China

Chengbin Wang, Jianguo Chen, and Fan Xiao

Abstract Traditional mineral resources prospecting and information extraction method cannot satisfy the complexity of geological and multi-stages of ore-forming processes. In this paper, empirical model decomposition (EMD) and independent component analysis (ICA) are applied to separate and reconstruct magnetic data so as to extract the signals from different sources. Firstly, original magnetic data is sifted to get intrinsic mode functions (IMFs) from high to low frequency. Secondly, ICA is utilized to reconstruct the former IMFs which obtained by removing background and get independent components (ICs). Finally, nine IMFs and three ICs are obtained by the combining method that is used to process magnetic data of Gobi desert coverage in Eastern Tianshan. IC1 discriminates igneous rocks, and may be related to magmatic intrusion, IC2 tracks the distribution of plates and may be related to plate subduction, IC3 indicates the basite-ultrabasic rocks which are distributed in the middle of area and may be related to crustal thickening.

Keywords Empirical model decomposition (EMD) • Independent component analysis (ICA) • Magnetic data • Gobi desert coverage • Eastern Tianshan

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N.J. Raju (ed.), *Geostatistical and Geospatial Approaches for the Characterization of Natural Resources in the Environment*, DOI 10.1007/978-3-319-18663-4_89

89.1 INTRODUCTION

Because of the complexity of geological processes and multi-stages of ore-forming processes, original magnetic anomalies are composed of a mixture of various geological factors including background and local anomalies which may be caused by ore deposits or other geological anomalies. Separating magnetic anomalies is one of most difficult and important issues in mineral prospecting and potential resource assessment. In recent years, the means to predict mineral resources is using interaction information such as geology, mineral products, remote sensing, physical geography, exploration geochemistry and so on. Moreover, exacting the valid information is the pivotal and the most difficult step in mineral resources prediction and assessment [1]. Lots of new methods such as wavelet, fractal, and non-negative matrix factorization, Empirical Model Decomposition and independent component analysis have been introduced into the mathematical geology field. This paper mainly introduces an application of EMD and ICA combining method to magnetic anomalies separation.

89.2 PRINCIPLES AND METHODS

89.2.1 Empirical Model Decomposition

Empirical Model Decomposition, which was recently proposed by E. Huang, is nonlinear and unstable signal processing method which introduced the concept of intrinsic model function (IMF). Compared with Fourier transform and wavelet, EMD completely gets rid of the shackles of linearity and stability. So it has many successfully applications in meteorology, biomedical, structural mechanics, finance, communication, signal processing, image processing and others.Any complex time (space) signals (data) are composed by IMFs from high to low frequency. An IMF is a function that satisfies two conditions: (1) in the whole data set, the number of extreme and the number of zero crossings must either equal or differ at most by one; and (2) at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero [2]. Nunes et al. proposed a modifiedbidimensional empirical mode decomposition (BEMD) on the basis of one-dimensional empirical model decomposition [3].

89.2.2 Independent Component Analysis

Independent component analysis is a multicenter signal processing method and it tries to transform an observed multidimensional vector into components that are statistically independent from each other as possible [4]. ICA is widely applied in signal processing, sound signal separation, communication, face identification, remote-sensing information processing etc. ICA model is a basic generative model, and it describes how the observed data is generated by a mixing process. To guarantee that ICA model is solvable, the following assumption and limitations must be made: (1) statistical independence, (2) non-Gaussian distribution, (3) the unknown mixing matrix is square [5]. Assume n mutually independent random variables $s_1, s_2 \ldots s_n$, whose linear combination generates n random variables $x_1, x_2 \ldots, x_n$, i.e.

$$xi = a_{i1}s_i + a_{i2}s_2 + \ldots + a_{in}s_n \quad i = 1, 2, 3 \ldots, n \tag{89.1}$$

where a_{ij}, $i, j = 1, 2, \ldots, n$ are real coefficients. For convenience, define $\boldsymbol{x} = [x_1, x_2, \ldots, x_n]^{\mathrm{T}}$, $s = [s_1, s_2, \ldots, s_n]^{\mathrm{T}}$, and $\boldsymbol{A}$ as the matrix with elements a_{ij}, the composite model can be written as

$$\boldsymbol{x} = \boldsymbol{As} \tag{89.2}$$

The independent components $\boldsymbol{s}$ can be solved by computing the inverse matric $\boldsymbol{B}$ of matrix $\boldsymbol{A}$, i.e.

$$\boldsymbol{s} = \boldsymbol{Bx} \tag{89.3}$$

In conclusion, EMD and ICA separate signals according to scale features and independence of data instead of pre-set base functions.

89.2.3 Technique Process

The process of combining method includes following three steps:

1:200,000 magnetic data are decomposed into IMFs by BEMD. Algorithm employs enveloping surface method and biharmonic spline interpolation.

ICA is utilized to reconstruct the former IMFs which obtained by removing background and get ICs.

Geological interpretation of ICs combined with geological information.

89.3 CASE STUDY

Eastern Tianshan contains a number of Paleozoic terrains that amalgamated between the Tarim and Siberian blocks, and experienced a series of complex tectonic evolution events mainly during Paleozoic accretion and collision, Mesozoic thermal subsidence and Cenozoic trusting and uplift. The study area is composed of three tectonic zones consisting of the late Paleozoic Ha'erlike–Dananhu

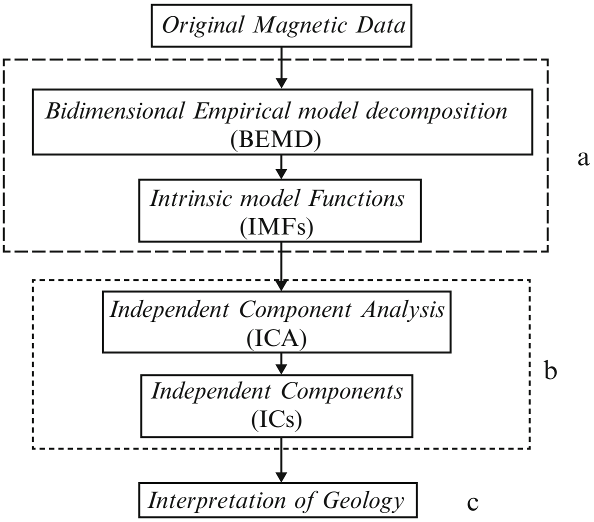

Fig. 89.1 Flow chart of EMD and ICA combining method

island arc, late Paleozoic Jueluotage rift and central Tianshan terrine systems, which are separated by the regional-scale deep Dacaotan–Dananhu and Aqikkuduk–Shaquanzi faults, respectively. This paper applies EMD and ICA (Fig. 89.1) to analyze magnetic data which was collected in Gobi desert coverage in Eastern Tianshan, China. Firstly, using BEMD to sift magnetic data so as to get IMFs. Secondly, Fast ICA method [6] is applied to reconstruct the IMFs to obtain useful information.The magnetic separation results display the change from high frequency to low frequency. IMF1 indicates the high frequency maybe caused by noises while Res represents the low frequency maybe caused by background. Nonetheless, it is difficult to explain IMFs's geological significance because of too many IMFs. So we utilize the Fast ICA to reconstruct the local IMFs which obtained by removing background, then, three independent components (ICs) are obtained (Fig. 89.2).

We find that results of ICA are concise and easy to geological interpretation. IC1 discriminates igneous rocks from stratum, and may be related to magmatic intrusion, IC2 tracks the distribution of plates and may be related to plate subduction, IC3 indicates the basite-ultrabasic rocks which are distributed in the middle of area and may be related to crustal thickening.

89.4 CONCLUSION

This paper proposed a new method combining EMD and ICA to separate and reconstruct magnetic data. It is obviously that the combining method is effective to extract signals from different sources which may be related to geological events. Furthermore, it is necessary to deepen the geological interpretation in the further.

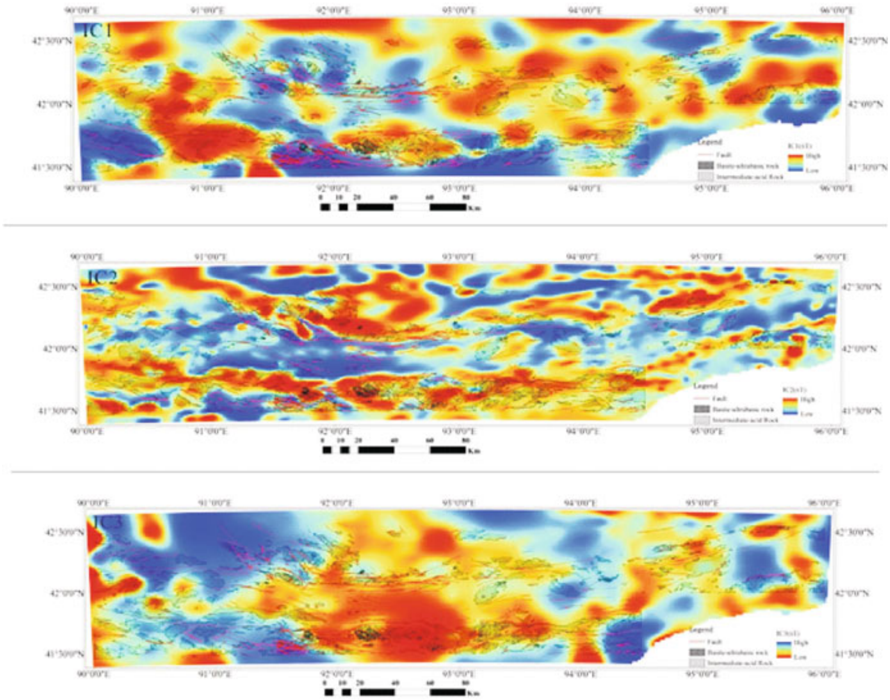

Fig. 89.2 Results of ICA

ACKNOWLEDGEMENTS This research has been financially supported by Chinese Geological Survey Program (1212011120986), National Key Technology R&D Program (No. 2011-BAB06B08-2) and Special fund program of Institute of Geophysical and Geochemical Exploration CAGS (WHS201205).

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