International Journal of Applied Earth Observation and Geoinformation 46 (2016) 31–44

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

A general framework of TOPSIS method for integration of airborne geophysics, satellite imagery, geochemical and geological data

Maysam Abedi*, Gholam-Hossain Norouzi

Department of Mining Engineering, College of Engineering, University of Tehran, Iran

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form
14 November 2015
Accepted 24 November 2015
Available online 3 December 2015

Keywords:
TOPSIS method
Mineral potential/prospectivity mapping
Porphyry type deposit

ABSTRACT

This work presents the promising application of three variants of TOPSIS method (namely the conventional, adjusted and modified versions) as a straightforward knowledge-driven technique in multi criteria decision making processes for data fusion of a broad exploratory geo-dataset in mineral potential/prospectivity mapping. The method is implemented to airborne geophysical data (e.g. potassium radiometry, aeromagnetic and frequency domain electromagnetic data), surface geological layers (fault and host rock zones), extracted alteration layers from remote sensing satellite imagery data, and five evidential attributes from stream sediment geochemical data. The central Iranian volcanic-sedimentary belt in Kerman province at the SE of Iran that is embedded in the Urumieh–Dokhtar Magmatic Assemblage arc (UDMA) is chosen to integrate broad evidential layers in the region of prospect. The studied area has high potential of ore mineral occurrences especially porphyry copper/molybdenum and the generated mineral potential maps aim to outline new prospect zones for further investigation in future. Two evidential layers of the downward continued aeromagnetic data and its analytic signal filter are prepared to be incorporated in fusion process as geophysical plausible footprints of the porphyry type mineralization. The low values of the apparent resistivity layer calculated from the airborne frequency domain electromagnetic data are also used as an electrical criterion in this investigation. Four remote sensing evidential layers of argillic, phyllic, propylitic and hydroxyl alterations were extracted from ASTER images in order to map the altered areas associated with porphyry type deposits, whilst the ETM+ satellite imagery data were used as well to map iron oxide layer. Since potassium alteration is generally the mainstay of porphyry ore mineralization, the airborne potassium radiometry data was used. The geochemical layers of Cu/B/Pb/Zn elements and the first component of PCA analysis were considered as powerful traces to prepare final maps. The conventional, adjusted and modified variants of the TOPSIS method produced three mineral potential maps, in which the outputs indicate adequately matching of high potential zones with previous working and active mines in the region.

1. Introduction

Airborne geophysical surveys are widespread attempts in the reconnaissance stage of exploration programs that benefits natural resources industries such as mining, oil and environment because the data acquired provide broad pieces of information concerning the geological setting of a region, as well as measures geophysical variations arising from different physical characteristics of subsurface rocks. Such surveys support those industries by covering large prospected areas with multi-sensor geophysical equipment consisting of magnetic, radiometric and electromagnetic devices, which subsequently reduce cost in airborne geophysical data acquisition. The information extracted from airborne geophysical datasets can be incorporated with other regional exploration datasets for Mineral Potential/Prospectivity Mapping (MPM) (Carranza and Sadeghi, 2010; Abedi et al., 2015) or geothermal prospectivity mapping (Carranza et al., 2008a).

The significant purpose of MPM is to either delineate new ore-bearing mineralization in a region or to enhance potential zones of ore occurrences for further exploratory investigations. MPM is a Multi Criteria Decision Making (MCDM) operation that integrates multiple exploratory criteria/attributes and subsequently produces a predictive map that outlines new prospective zones. Various MPM approaches have been developed which can be categorized into data- and knowledge-driven techniques (Agterberg et al., 1990; Bonham-Carter, 1994; Pan and Harris, 2000; Carranza, 2008). In data-driven techniques, the known mineral deposits are used as training points to establish relationships between the known ore

* Corresponding author.
E-mail addresses: MaysamAbedi@ut.ac.ir (M. Abedi), norouzih@ut.ac.ir (G.-H. Norouzi).

http://dx.doi.org/10.1016/j.jag.2015.11.016

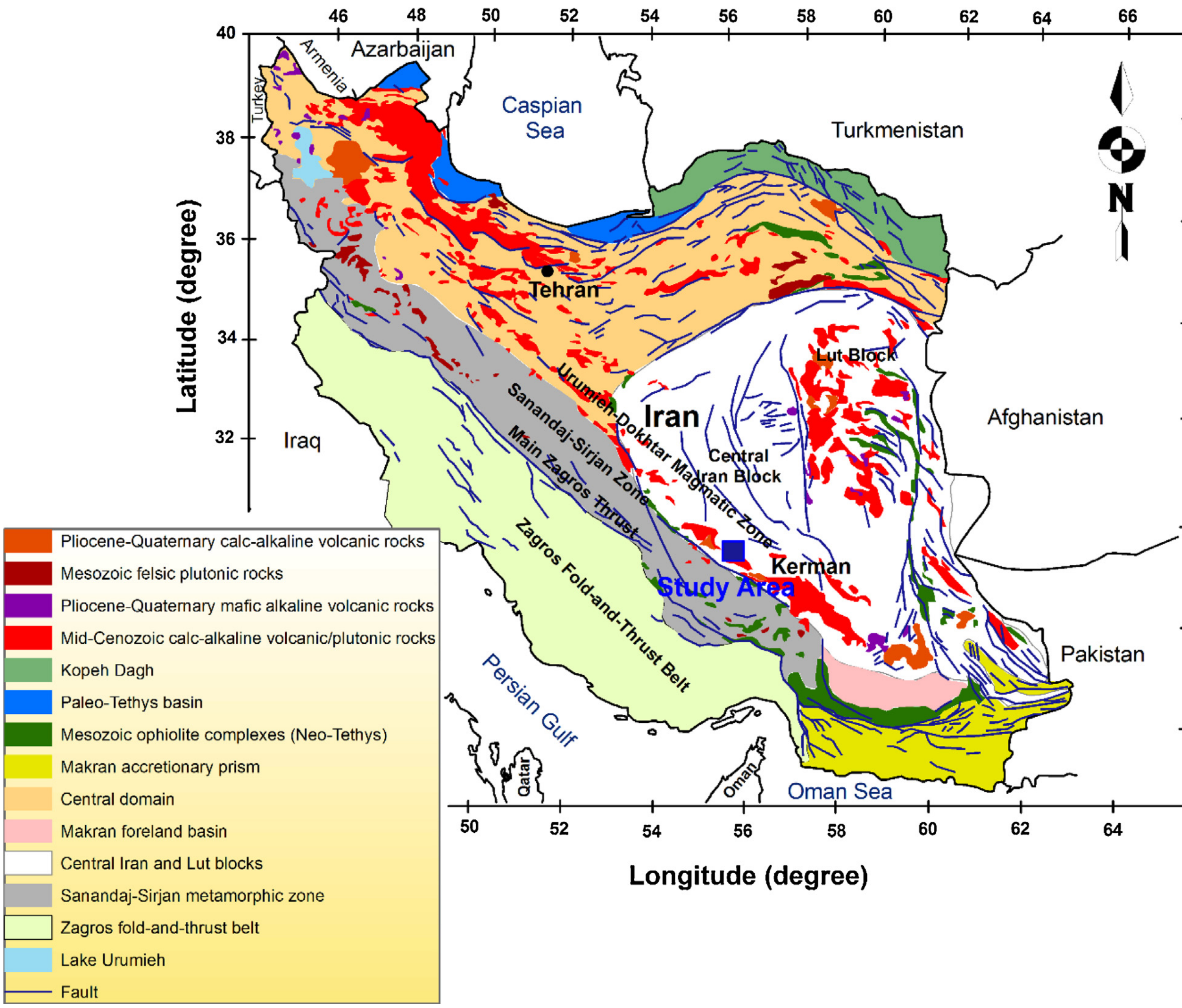

Fig. 1. Location of the studied area in the general geological map of Iran (reproduced from the National Geoscience Database of Iran, http://www.ngdir.ir).

deposits and extracted evidential layers from geo-exploratory criteria based upon numerous statistical/mathematical algorithms (Carranza, 2008). These relationships yield the importance and relative weight of each layer (Carranza and Hale, 2002a) and are finally integrated into a single MPM by assigning the obtained weights (Nykänen and Salmirinne, 2007). The popular data-driven methods applied to MPM in the last two decades are weights of evidence (Pan and Portefield, 1995; Carranza and Hale, 2002b; Agterberg and Bonham-Carter, 2005; Ford et al., 2015), logistic regression (Agterberg and Bonham-Carter, 1999; Carranza and Hale, 2001; Mejía-Herrera et al., 2014), neural networks (Harris et al., 2003; Nykänen, 2008; Abedi and Norouzi, 2012), evidential belief functions (Carranza and Hale, 2002c; Carranza and Hale, 2003; Carranza et al., 2005, 2008a), Bayesian classifiers (Porwal et al., 2006; Abedi and Norouzi, 2012), support vector machines (Zuo and Carranza, 2011; Abedi et al., 2012a), clustering methods (Paasche and Eberle, 2009; Eberle and Paasche, 2012; Abedi et al., 2013a) and random forest method (Rodriguez-Galiano et al., 2014; Carranza and Laborte, 2015a,b,c). The other techniques in MPM use a geoscientist's knowledge for weighting of evidence that are known the knowledge-driven approaches. They include various methods such as Boolean logic (Bonham-Carter et al., 1989), index overlay (Carranza et al., 1999; Mirzaei et al., 2014), the Dempster–Shafer belief theory (Moon, 1990; Carranza et al., 2008b), fuzzy logic operators (Abedi et al., 2013b; Moradi et al., 2015), wildcat mapping (Carranza and Hale, 2002d), and lots of outranking methods (Abedi et al., 2015; Abedi, 2015; Hossaini and Abedi, 2015; Abedi et al., 2013c, 2012b,c).

The work presented here attempts to outline new prospective zones for further investigation of porphyry type ore mineralization mostly copper and molybdenum, pertaining to the central Iranian volcanic-sedimentary belt in the Kerman province of Iran. The outputs of a powerful MCDM method, i.e. TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) technique, are evaluated in data fusion of numerous evidential layers extracted from the airborne geophysical survey, satellite imagery, geology and geochemical data sets in the desired area. Three variants of the TOPSIS method namely the conventional, adjusted and modified ones are applied to the multi-disciplinary exploration datasets to integrate diverse evidential layers in the study area. The conventional TOPSIS method has been used previously by Pazand et al. (2012) and Pazand and Hezarkhani (2015) for copper potential mapping in Iran, but here the adjusted and modified formulations of the TOPSIS method are presented and applied to a real case study in porphyry type ore mineralization and new MPM outputs are compared to the conventional prospectivity map generated by the TOPSIS algorithm. We have used our previous exploration datasets comprising of sixteen evidential layers extracted from airborne geophysical data, satellite imagery, geological data and stream sediment geochemical data (Abedi et al., 2015, 2013c,d). The validation of the TOPSIS