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USE OF PERCEPTRON NEURAL NETWORKS AS A TOOL FOR MINERAL POTENTIAL MAPPING IN EGYPT

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استخدام الإدراك الحسي لشبكات الخلايا العصبية كأداة لرسم الخرائط المعدنية المحتملة في مصر

الخلاصة: ويقترح المدرك الحسى لشبكات الخلايا العصبية الاصطناعية (PNN) نموذج لتمييز لمناطق عالية الإمكانيات المعدنية في الصحراء الشرقية لمصر باستخدام بيانات الاستشعار عن بعد والبيانات الإشعاعية ألجويةً المخزنة في قاعدة بيانات نظم المعلومات الجغرافية. وقد تم اختيار نموذج الشبكة العصبية والذي يتضمن وحدة واحدة مخفية عن طريق المدرك الحسي لشبكات الخلايا العصبية والذي يستخدم معادلة حد النقل الصعب. وقد قدرت الشبكة المستخدمة خارطة الذهب المحتملة بكفاءة والتي تشير إلى انه امكن الكشف عن كل من المناطق المعدنية للذهب المعروفة سابقا وكذا أشارت الي مناطق تمعدن جديدة محتمله لنفس المعدن. وتشير هذه النتائج الأولية إلى أن الإدراك الحسي لشبكات الخلايا العصبية يمكن أن تكون أداة فعالة لنمذجة البيانات الموزعة مكانيا لاستكشاف المعادن

ABSTRACT: *A perceptron artificial neural network (PNN) model is proposed to discriminate zones of high mineral potential in the Eastern Desert of Egypt using remote sensing and airborne spectral gamma-ray data stored in a GIS database. A neural network model with one hidden unit was selected by means of a perceptron neuron, which uses the hard-limit transfer function. The trained network delineated a gold potential map efficiently, detected a previously known area as well as a suggested potentially mineralized one. These initial results suggest that PNN can be an effective tool for mineral exploration using spatial data modeling.*

1. INTRODUCTION

Mineral exploration is a complex task which often requires the use of remote sensing, geophysical and geological data to achieve satisfactory results. This demands a multithematic approach, and has made geographical information systems (GIS) a popular tool among exploration geologists because they allow for more effective integration and analysis of large numbers of spatial data with different attributes and formats (Burrough and McDonnell 1998). Data integration methods in GIS may be divided into two main groups based on knowledge-driven and data driven models.

The first group is the band ratios of Landsat ETM+ data were used to enhance the spectral differences between bands and to reduce the topographic effects. Dividing one spectral band by the other produces an image that provides relative band intensities. A thorough description of the selection of sensitive bands for minerals can be found in relevant publications such as Sabin's Ratio (3/1, 5/7 and 3/5 in RGB) (Sabins, 1997) and Abram's ratio (3/1, 5/7 and 4/5 in RGB) (Abrams, 1983) for candidate band ratios. ETM+ 5/7 and 3/1 band ratios were selected as input variables to the model because of their ability to discriminate clay minerals, ore-related hydroxyl and iron-oxide alteration respectively. The band ratios 3/5 or 4/5 have shown great influence on the discrimination of lithologies.

The second group is the airborne geophysical survey data for the study area, carried out in 1984, of which the designated as area - II is used. This survey involves aero-spectrometric data such as Potassium (K in %), equivalent Uranium (eU in ppm), and equivalent Thorium (eTh in ppm) and their ratios. The potassium composite image K with the ratios K/eU and K/eTh highlights areas where hydrothermal alterations associated with potassium enrichment (zones of potash alteration) might have occurred.

The perceptron network is a single-layer network whose weights and biases can be trained to produce a correct target vector when presented with the corresponding input vector. This perceptron rule was the first training algorithm developed for neural networks. The Principles of neurodynamics, first developed by Rosenblatt (1961) is the pioneering work in this respect. In the present study, a perceptron neural network model was developed using a comprehensive exploration GIS database for mineral potential mapping in the Eastern Desert gold mining province, Egypt (Fig. 1). A gold potential map was generated with the model.

2. STUDY AREA AND DATASETS

The study area is located in the Eastern Desert of Egypt (Fig. 1) which is a part of the Arabian Nubian Shield which was formed by accretion of island arcs, accretionary prisms- back arc basins, and continental microplates during the Pan-African orogeny about 600 Ma ago (Stern. 1994; Kusky et al. 2003). The Eastern Desert of Egypt (Fig. 2) is almost exclusively built up of ophiolitic melange and associated rocks, accreted arcs together with subordinate molasse-type sediments and late-tectonic volcanics and granitoid intrusives (El Ramly et al., 1993).

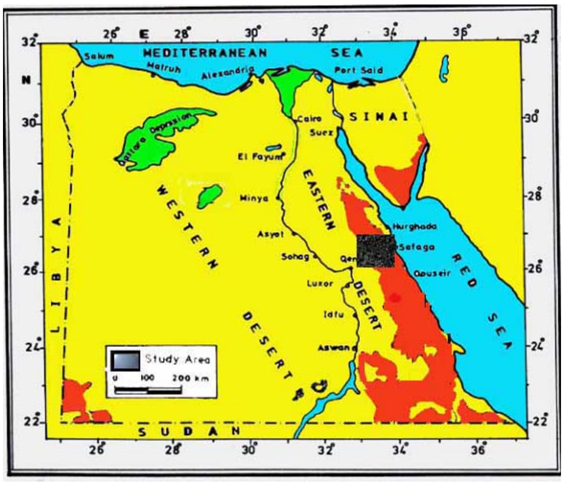

Fig (1): Location map of the study area.

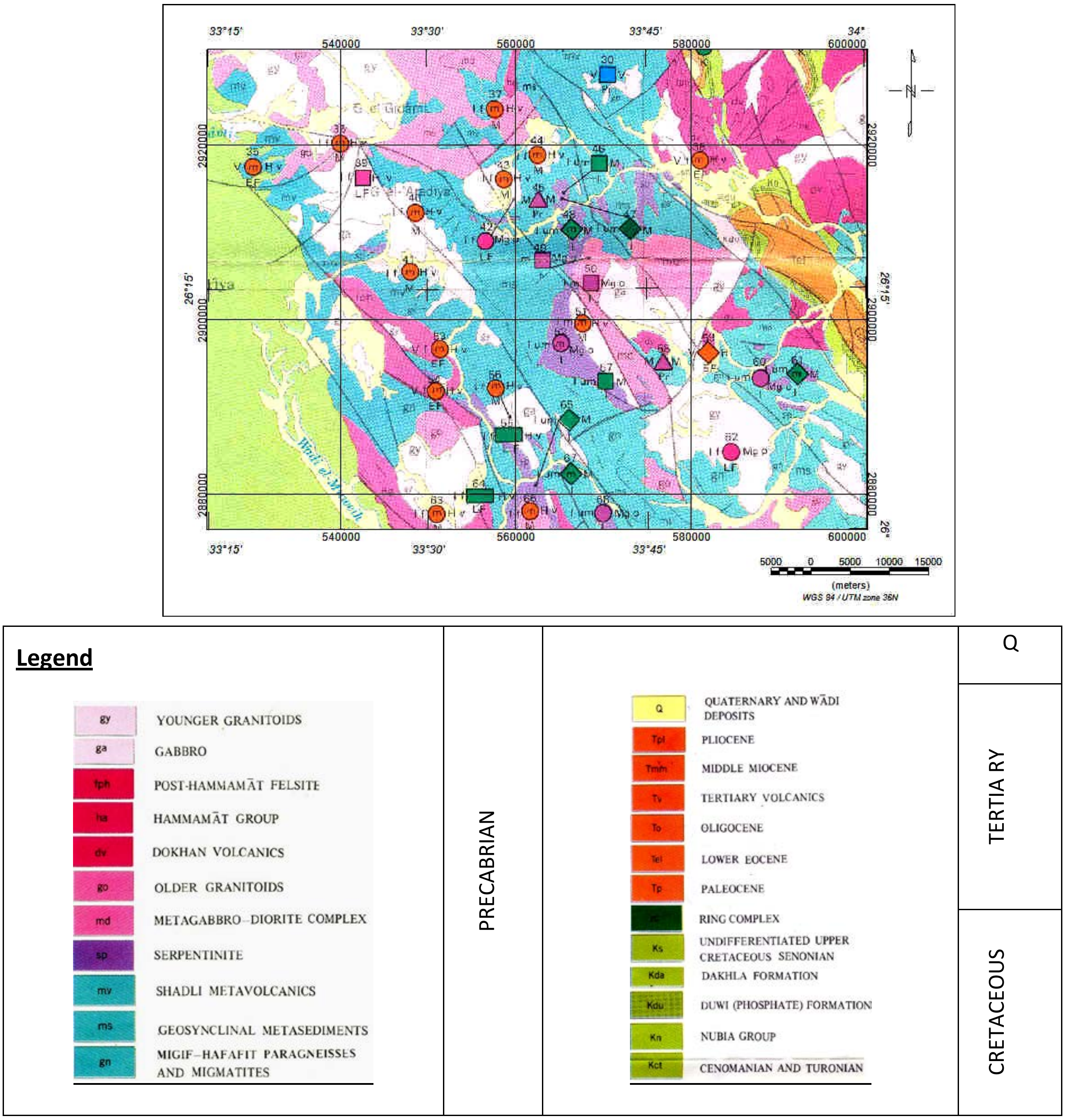

Fig. (2): Metallogenic map of the Qena Quadrangle, Egypt. (E.G.S.M., 1984).

Precambrian plutonic, volcanic, metavolcanic and metasedimentary rocks cover the majority of the study area. The study area comprises fourteen of old gold mines in the Eastern Desert of Egypt that have been exploited since Pharaonic and Roman times. The revolution of exploration and exploitation techniques as well as the high prices of gold in the last few decades lead to the development at the old gold mines and explore new sites of gold mineralization.

Enhanced Thematic Mapper Plus (ETM+) data processing was focused on identifying hydrothermally altered areas. The band ratios have been shown to be very useful in delineating rock alteration in the area. ETM+ 3/1, 5/7 and 3/5 or 4/5 band ratios were selected as input variables to the model because of their ability to discriminate ore-related hydroxyl and iron-oxide alterations respectively (Figs 3, 4, 5 and 6).

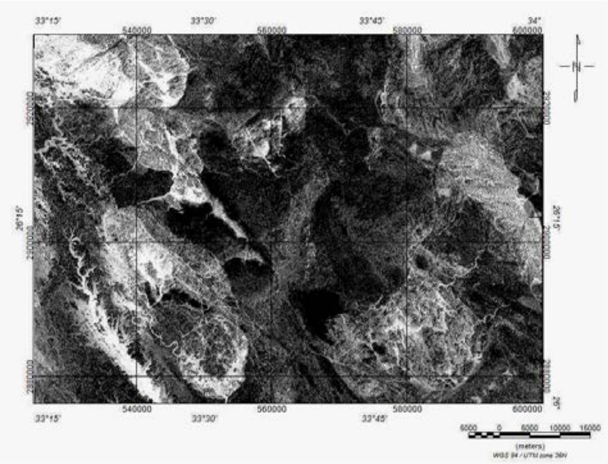

Fig. (3): Band ratio ETM+ 3/1 of the study area.

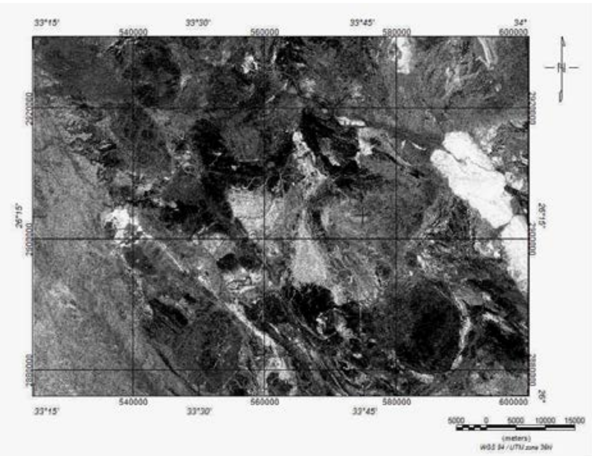

Fig. (4): Band ratio ETM+ 5/7 of the study area.

The airborne gamma spectrometric data used here contain maps which show the apparent surface concentrations of radioelement Potassium (K in %), equivalent Uranium (eU in ppm), and equivalent Thorium (eTh in ppm). The potassium composite image K with the ratios K/eU and K/eTh highlights areas where hydrothermal alterations associated with potassium enrichment (zones of potash alteration) might have occurred (Figs 7, 8, 9 and 10). These alteration zones are frequently associated with the formation of various types of non-radioactive mineral deposits such as gold (Au) deposits.

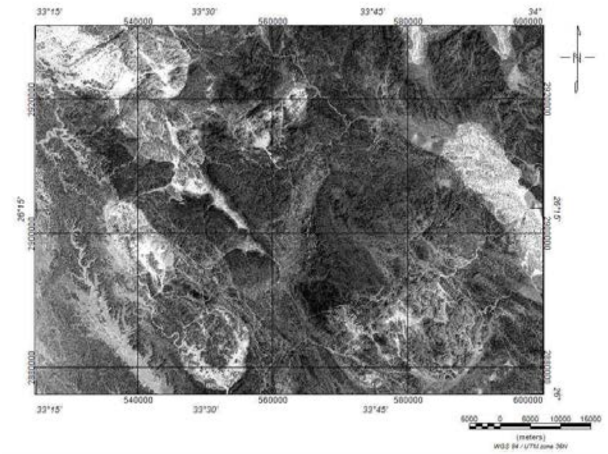

Fig. (5): Band ratio ETM+ 3/5 of the study area.

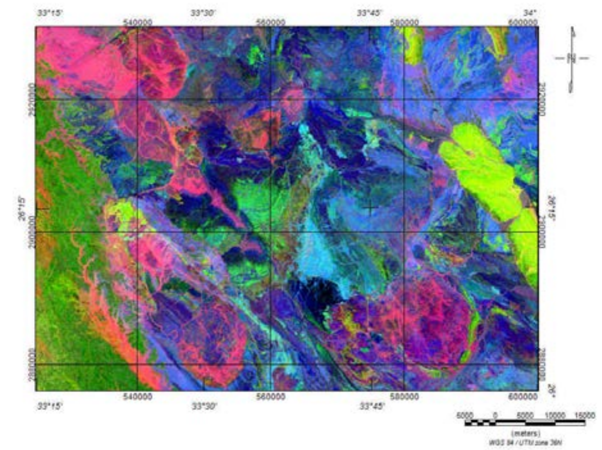

Fig. (6): False color composite image of the three ratios (3/1, 5/7 and 3/5) in RGB of the study area.

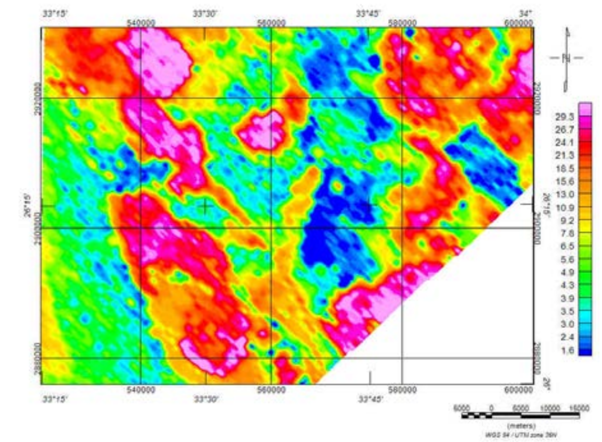

Fig. (7): Potassium map of the study area.

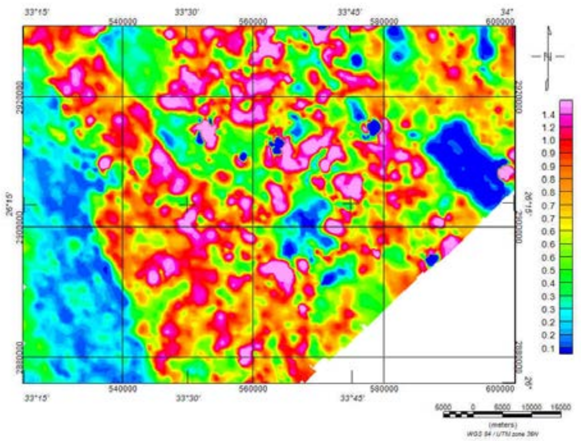

Fig. (8): Ratio map K/eU of the study area.

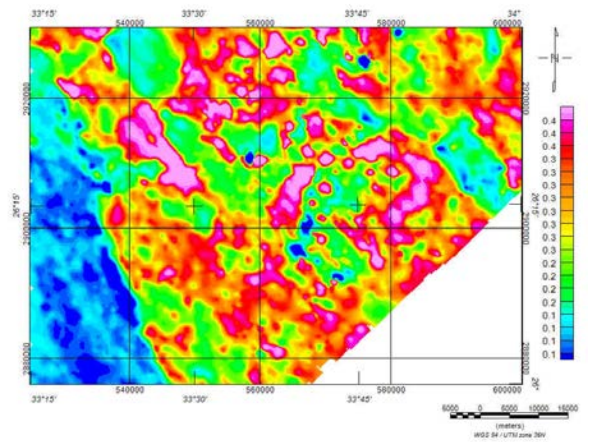

Fig. (9): Ratio map K/eTh of the study area.

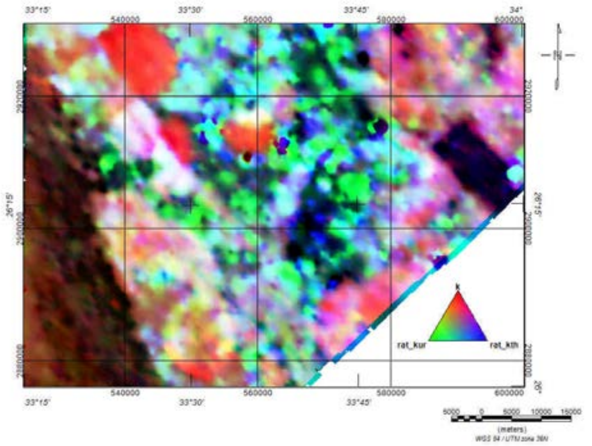

Fig. (10): Linearly/Stretched False Color Potassium Composite Image of the study area.

Resampling has been made to project the produced data from ETM (Egyptian Traverse Mercator - Red Belt) system to UTM (Universal Traverse Mercator) system. This process was necessary to achieve compatibility with ETM+ Landsat images, and to ensure the coincidence between the different layers that could be extracted from both types of data. All six input maps were stored as raster layers with 15 m spatial resolution in the exploration GIS. The GIS database is viewed as a collection of maps of a particular data type (such as solid geology).

3. METHODOLOGY

In this paper a class of neural network architecture called the perceptron neural network (PNN) is used to predict deposit and barren cells. The perceptron network (Fig. 11) is single-layer network whose weights and biases can be trained to produce a correct target vector when presented with the corresponding input vector. In recent years, many papers have reported using PNN architecture for a variety of applications with good results. But few of them are in the mineral exploration research. Perceptrons are especially suited for simple problems in pattern classification. They are fast and reliable networks for the problems they can solve. In addition, an understanding of the operations of the perceptron provides a good basis for understanding more complex networks. The hard-limit transfer function gives a perceptron the ability to classify input vectors by dividing the input space into two regions. Specifically, outputs will be 0 if the net input n is less than 0, or 1 if the net input n is 0 or greater. Perceptron networks have several limitations. First, the output values of a perceptron can take on only one of two values (0 or 1) because of the hard-limit transfer function. Second, perceptrons can only classify linearly separable sets of vectors.

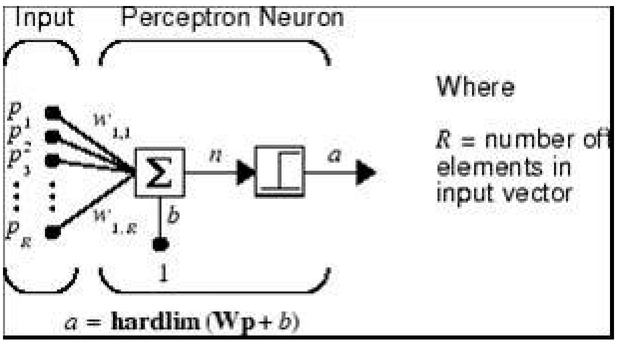

Fig. (11): The perceptron neuron, which uses the hard-limit transfer function.

For this study, GIS data set (Fig. 12) is used to examine the prospectvity of gold deposits in an approximately 75 x 57 km area in the Eastern Desert gold mining province in Egypt. The GIS layers correspond to information such as the solid geology, remote sensing and airborne spectral gamma-ray data are shown in Figure12. In addition to, fourteen (14) of old gold mines in the Eastern Desert of Egypt are used as target data. The thematic layers are divided into a grid of square cells of 15 m side. Each cell is represented by the cell position and set of attributes within the two dimensional matrix of cells.

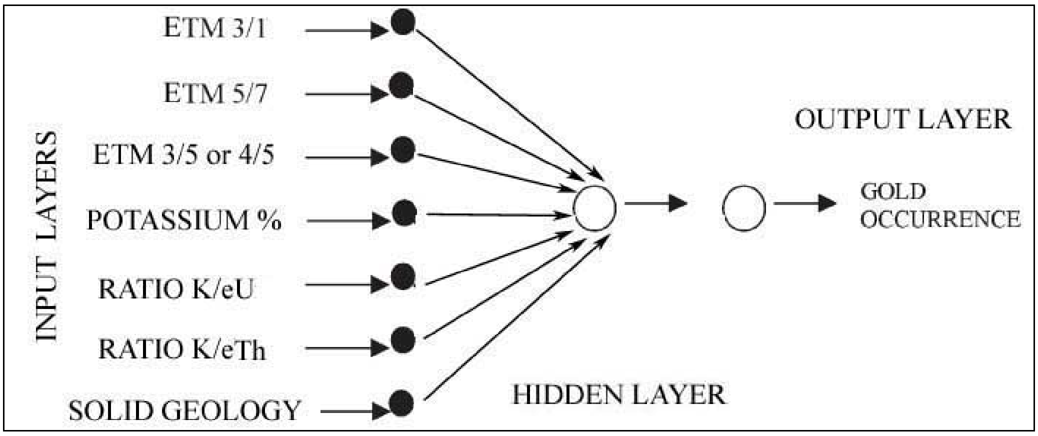

Fig. (12): Structure of the network model used for gold potential mapping.

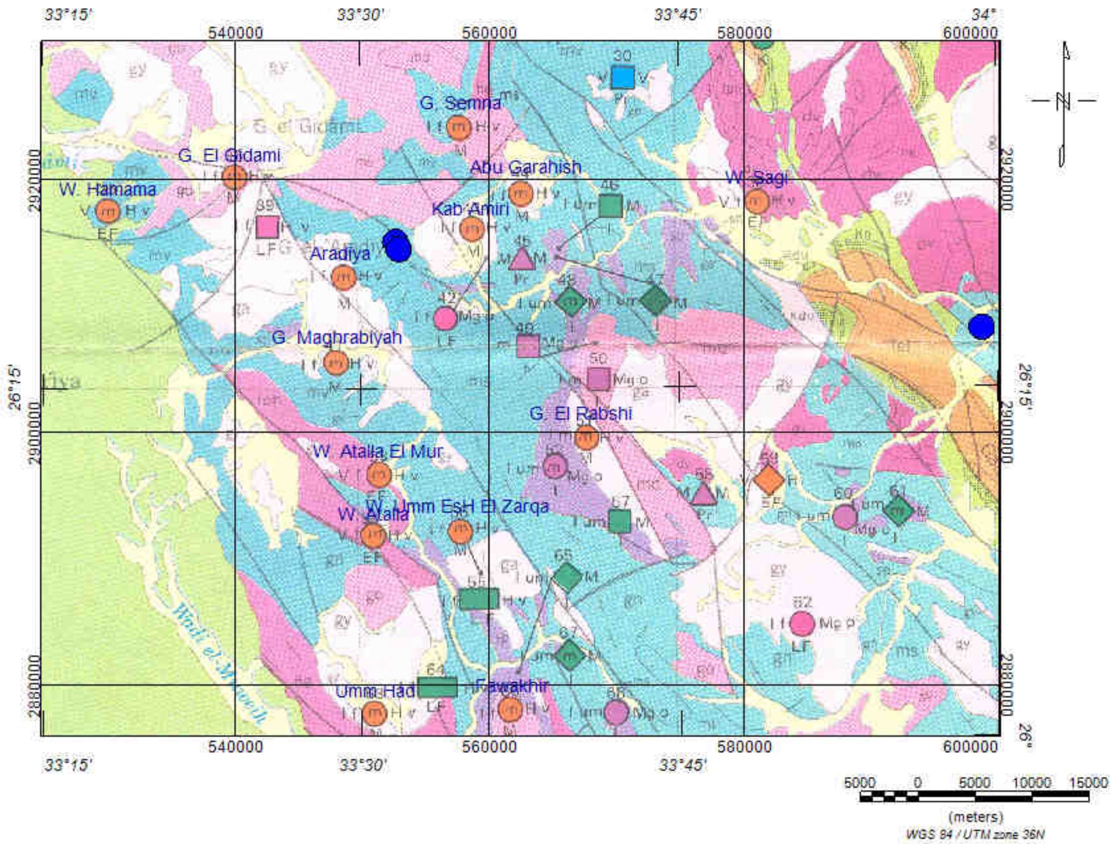

Fig. (13): Metallogenic map of the study area with the previously known (orange color) and the favorable (blue colors) gold mines.

4. RESULTS

A mineral potential surface map (Fig. 13) was generated by presenting the trained network with an input pattern set from the entire district. During this phase the output unit generated a value of 0 (barren) or 1, which can be interpreted as the favorability (probability) to the presence of gold occurrence at a given location.

The gold potential map for the Eastern Desert gold mining province generated by the network model suggested three (3) potentially mineralized previously unknown areas (blue colors) such as the two zones located between El Aradiya and Kab Amiri gold mines. The third one is clearly delineated on the eastern edge of the study area, suggesting additional potential targets for further exploration. The accuracy assessment illustrates excellent correlation between the favorable (probability) map and the alteration maps (Figs. 6 and 10), which were sensitive to detect hydrothermal alteration mineral assemblages associated with epithermal gold and hydrothermal porphyry copper mineralization (Sabins, 1997). These results suggest that the model could be used to estimate the presence/absence of occurrence patterns, bearing in mind the complexity of the phenomenon being modeled.

CONCLUSIONS

The paper proposes the use of perceptron neural network (PNN) model to discriminate zones of high mineral potential in the Eastern Desert of Egypt. This model uses the Geographic Information Systems (GIS) data of the location. Training patterns were created by recording the values shown by input GIS variables. In addition to fourteen (14) locations of the gold occurrence database is used as target data. The training dataset was completed adding three (3) locations scattered over the study area. Further investigation is currently undertaken to explore other alternate neural networks for the purpose of prospectivity analysis.

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