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CONTENTS

APPLICATION OF AHP WITH GIS FOR PREDICTIVE COPPER POTENTIAL MAPPING: A CASE STUDY IN LUNG PO - HOP THANH AREA, LAO CAI PROVINCE, VIET NAM

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Abstract: *In recent years, applications of geographical information systems (GIS) combining with geomathematical methods on earth sciences and especially on potential mineral mapping have been used widely. Aim of this article is to introduce the effective methodology of combining the analytic hierarchy process (AHP) method with GIS for studies of mineral. Application of this methodology for copper potential mapping in Lung Po - Hop Thanh area also was presented on the main criteria of stratigraphic, structural, geochemical maps and known copper deposits. Each criterion was evaluated with the aid of AHP and the result mapped by GIS. Final potential map for copper in the study area is mapped using the obtained weights of all sub-criteria under supporting of ArcGIS software. Three zones with different levels of high potential, potential and low potential were identified. The results of application in this article provide acceptable outcomes for copper exploration in the study area.*

Key words: *AHP, GIS, Copper potential, Lung Po copper, copper of Lao Cai.*

1. INTRODUCTION

In recent years, applications of geographical information systems (GIS) combining with geomathematical methods on earth sciences and especially on potential mineral mapping have been used widely. Many typical studies on generating favorable maps for mineral deposits were published such as the papers of Carranza et al., 1999; Hariri, 2003; Porwal et al., 2003 and Partington, 2010.

Data integration methods in GIS may be divided into two main groups based on knowledge-driven and data-driven models. The knowledge driven model means that evidential weights are estimated subjectively based on one's expert opinion about spatial association of target deposits with certain geologic features, whereas the data driven model means that evidential weights are quantified objectively with respect to locations of known target deposits. The data-driven approaches recently have been used commonly such as regression logistics, weights of evidence, artificial neural networks. Several knowledge-driven approaches include Boolean logic, index overlays, analytic hierarchy process (AHP), and fuzzy logic. The integration of GIS and AHP is a powerful tool to solve the site selection and potential mapping problem. AHP is a systematic decision approach first developed by Saaty (1980). AHP is a decision analysis method that considers both qualitative and quantitative information and combines them into systematic hierarchies to rank alternatives based on a number of criteria.

Previous studies indicated that Lung Po-Hop Thanh area has a potential of copper with typical deoposits such as Lung Po, Vi Kem, Sinh Quyen, Ta Phoi... Besides studying results from those deposits, it still has not had any systematically research about copper potential mapping for Lung Po-Hop Thanh area. Therefore, mapping copper potential areas for the study area is important for prospecting, explorating and exploting in near future.

The aim of this article is to introduce the application of the GIS modeling combining with the powerful AHP method for prospecting mineral and initial results for copper potential mapping in Lung Po - Hop Thanh Area, Lao Cai Province, Viet Nam.

2. ANALYTIC HIERARCHY PROCESS (AHP) METHODS

The AHP is an approach for facilitating decision-making by organizing perceptions, feelings, judgments, and memories into a multi-level hierarchic structure that exhibits the forces that influence a decision (Saaty 1994). The AHP method breaks down a complex multi-criteria decision problem into a hierarchy and is based on a pairwise comparison of the importance of different criteria and sub criteria. The AHP process is developed into three principal steps. The first step establishes a hierarchic structure. The first hierarchy of a structure is the goal. The final hierarchy involves identifying alternatives, while the middle hierarchy levels appraise certain factors or conditions. The second step computes the element weights of various hierarchies by means of three sub-steps. The first sub-step establishes the pairwise comparison matrix. The second sub-step computes the eigenvalue and eigenvector of the pairwise comparison matrix. The third sub-step performs the consistency. Let C_1, ..., C_m be m performance factors and W = (w_1, ..., w_m) be their normalized relative importance weight vector which is to be determined by using pairwise comparisons and satisfies the normalization condition:

$$\sum_{j=1}^{m} W_j = 1 \text{ với } Wj \geq 0 \; (j = 1,2,...,m) \qquad (1)$$

The pairwise comparisons between the m decision factors can be conducted by asking questions to experts, which criterion is more important with regard to the decision goal. The answers to these questions form an m *x* m pairwise comparison matrix as follows :

$$A = (a_{ij})_{mxm} = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{m1} & \dots & a_{mm} \end{bmatrix}, \qquad (2)$$

Where a_{ij} represents a quantified judgment on w_i/w_j with $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$ for i, j = 1, ..., m.

If the pairwise comparison matrix A = $(a_{ij})_{mxm}$ satisfies $a_{ij} = a_{ik}a_{kj}$ for any i, j, k = 1, ..., m, then A is said to be perfectly consistent; otherwise, it is said to be inconsistent. Form the pairwise comparison matrix A, the weight vector W can be determined by solving the following characteristic equation:

$$AW = \lambda_{max} W, \qquad (3)$$

Where λ_{max} is the maximum eigenvalue of A. Such a method for determining the weight vector of a pairwise comparison matrix is referred to as the principal right eigenvector method. The pairwise comparison matrix A should have an acceptable consistency, which can be checked by the following consistency ratio (CR):

$$CR = \frac{(\lambda_{max} - n)/(n-1)}{RI}$$

Where RI is the average of the resulting consistency index depending on the order of the matrix. If CR ≤ 0.1, the pairwise comparison matrix is considered to have an acceptable consistency; otherwise, it is required to be revised. Finally, the third step of the AHP method computes the entire hierarchic weight. The alternative with the highest eigenvector value is considered to be the first choice (Saaty 1996).

3. APPLICATION OF AHP WITH GIS FOR PREDICTIVE COPPER POTENTIAL MAPPING: A CASE STUDY IN LUNG PO - HOP THANH AREA, LAOCAI PROVINCE, VIET NAM

3.1. Study area and GIS database

The Lung Po - Hop Thanh area (about 1245 km^2) located in Bat Xat district and Lao Cai city, NW Viet Nam. It is about 330 km from Ha Noi Capital. Based on collected documents, GIS database concering to copper mineral in the study area include stratigraphic maps (scale of 1:50.000), structural maps, geochemical maps and known copper deposits.

Following previous studies, 16 known copper deposits are defined in the area (Fig. 2). Stratigraphic data are drived and compiled from several geological maps of 1:50,000 scale. Linear structural features interpreted from DEM were combined with faults available in geological maps to generate a structural evidence map. The resutls indicate that there are two major fault systems of NW-SE, NE-SW. To define the favorable zone for copper mineral, the faults are buffered to 100 m in different classes of <100; 100-200; 200-300; 300-400; 400-500m. The geochemical map with sixteen anomalies of Cu, Co, Ni was constructed based on geochemical data of previous studies in the area. The GIS data are shown in the Fig. 1.

3.2. Factor weights in Analytical Hierarchy Process (AHP)

In this study, to get factor weights in AHP, pair-wise comparision matrixes of main criteria (Stratigraphic, structural, geochemical) and their sub-criteria are built with scores given in Table 1. These scores are defined by experts' opinions on geology. Table 2 to 5 are pairwise comparison matrixes of main and sub- criteria and their weight values. Results indicated that the CR values of all the camparisons are lower than 0.1, which indicated that the use of the weights is suitable.

Table 1: Various states for pairwise comparison and their numerical rates (Saaty 1980)

Intensity of Importance	Definition
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Stronly to very strongly preferred
7	Very strongly preferred
8	Very strongly to extremely preferred
9	Extremely preferred

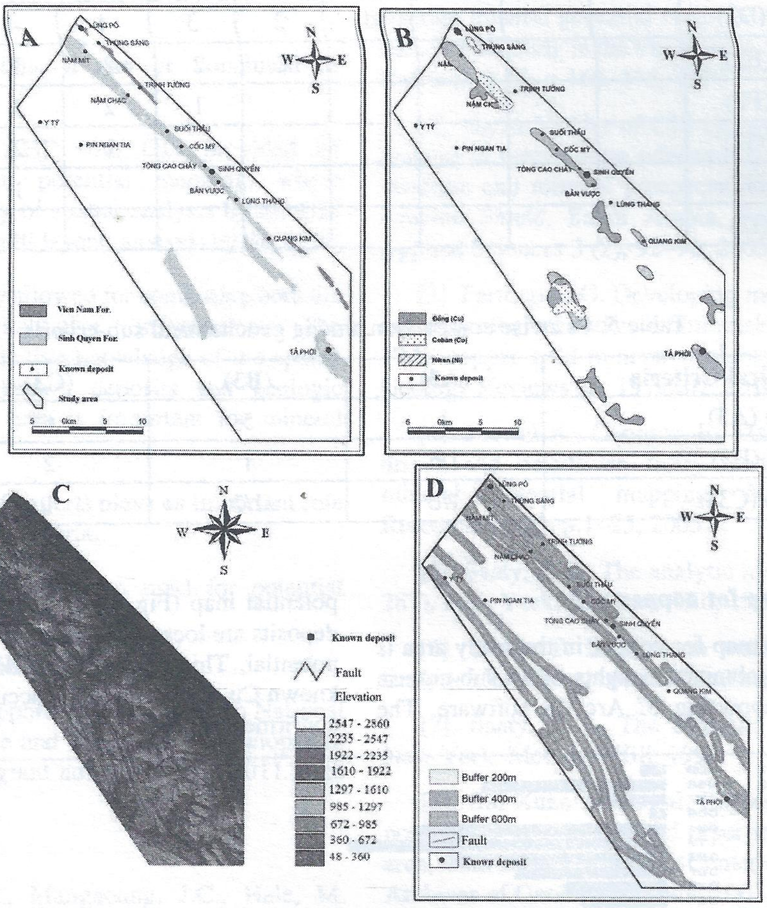

Fig. 1. A. Simplified geological map; B. Geochemical map; C. Digital elevationmodel; D. Typical buffered fault map in the study area

Table 2: Pairwise comparison among main criteria

Main Criteria	(A)	(B)	(C)	Weight (W)
Stratigraphic (A)	1	1/2	1/4	0.238
Structural (B)	2	1	1/3	0.136
Geochemical (C)	4	3	1	0.625

CR = 0,02

Table 3: Pairwise comparison among stratigraphic sub-criteria

Stratigraphic Criteria	(A1)	(B1)	(C1)	(D1)	Weight (W)
Sinh Quyen 1 (A1)	1	1/7	1/4	2	0.080
Sinh Quyen 2 (B1)	7	1	4	8	0.622
Vien Nam (C1)	4	1/4	1	6	0.248
Muong Hum (D1)	1/2	1/8	1/6	1	0.051

CR = 0,05

Table 4: Pairwise comparison among structural sub-criteria

Structural Criteria	(A2)	(B2)	(C2)	(D2)	(E2)	(F2)	(G2)	(H2)	(I2)	Weight (W)
Buffer 100m (A2)	1	1	2	2	2	3	4	5	7	0,204
Buffer 200m (B2)		1	2	3	4	5	6	6	6	0,257
Buffer 300m (C2)			1	2	3	4	5	5	6	0,177

Buffer 400m (D2)				1	2	3	4	4	5	0.124
Buffer 500m (E2)					1	2	2	3	4	0.082
Buffer 600m (F2)						1	2	3	3	0.060
Buffer 700m (G2)							1	2	2	0.041
Buffer 800m (H2)								1	1	0.029
Buffer 900m (I2)									1	0.026

CR = 0,03

Table 5: Pairwise comparison among geochemical sub-criteria

Geochemical Criteria	(A3)	(B3)	(C3)	Weight (W)
Cu (A3)	1	5	6	0,726
Ni (B3)	1/5	1	2	0,172
Co (C3)	1/6	1/2	1	0,102

CR = 0,03

3.3. Potential map for copper

Final potential map for copper in the study area is mapped using the obtained weights of all sub-criteria (Fig. 2) under supporting of ArcGIS software. The potential map (Fig. 3) indicated that 10 know copper deposits are located in the areas with high and medium potential. This means that model predict 80% of the known Cu deposits and the accuracy of the method are confirmed.

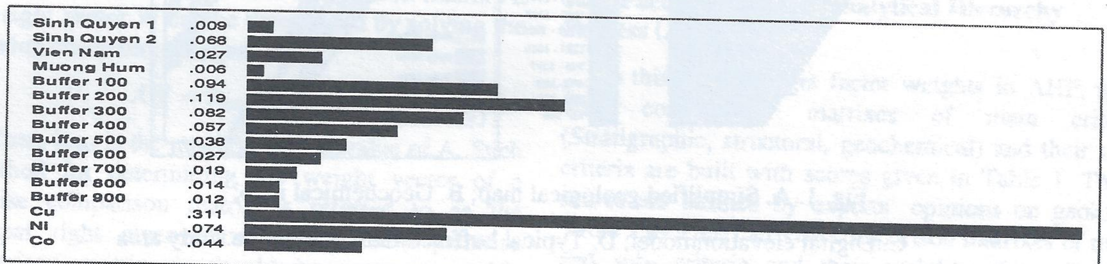

Fig.2. Final weight values of all sub-criteria

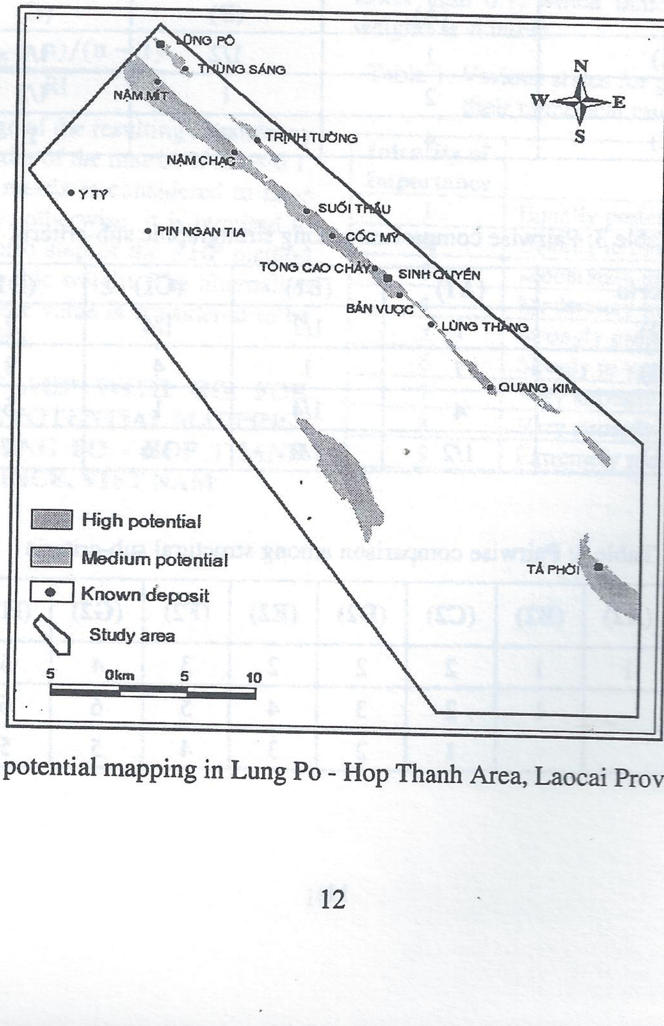

Fig. 3. Copper potential mapping in Lung Po - Hop Thanh Area, Laocai Province, Viet Nam

4. CONCLUSIONS

From obtained reults, it can be conclused as follows:

- Combining the AHP with GIS provided an improved method for potential mapping, which enhanced the capability of spatial analysis by the GIS and the capability of multi layers' analysis by the AHP.

- This methodology allowed for combining both the quantitative and qualitative information. The quanlitative and quantitative knowledge of the spatial association between known deposits and geologic features in the study area is important for mineral potential mapping.

- The knowledge of experts plays an important role to define the weights of criteria.

- This methodology can also used for potential mapping of other metals.

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