Geology, Geomorphology and Genesis of Andarokh Karstic Cave, North-East Iran

Mojtaba Heydarizad

Abstract—Andarokh basin is one of the main karstic regions in Khorasan Razavi province NE Iran. This basin is part of Kopeh-Dagh mega zone extending from Caspian Sea in the east to northern Afghanistan in the west. This basin is covered by Mozdooran Formation, Ngr evaporative formation and quaternary alluvium deposits in descending order of age. Mozdooran carbonate formation is notably karstified. The main surface karstic features in Mozdooran formation are Groove karren, Cleft karren, Rain pit, Rill karren, Tritt karren, Kamintza, Domes, and Table karren. In addition to surface features, deep karstic feature Andarokh Cave also exists in the region. Studying Ca, Mg, Mn, Sr, Fe concentration and Sr/Mn ratio in Mozdooran formation samples with distance to main faults and joints system using PCA analyses demonstrates intense meteoric digenesis role in controlling carbonate rock geochemistry. The karst evaluation in Andarokh basin varies from early stages ‘deep seated karst’ in Mesozoic to mature karstic system 'Exhumed karst' in quaternary period. Andarokh cave (the main cave in Andarokh basin) is rudimentary branch work consists of three passages of A, B and C and two entrances Andarokh and Sky.

Keywords—Andarokh basin, Andarokh cave, geochemical analyses and karst evaluation.

I. INTRODUCTION

Iran is a vast country with large carbonate rock outcrops which cover 11 percentage of Iran’s land surface, and a large number of caves have been formed by the simultaneous effect of tectonic and chemical weathering in these karstified areas. In early 1970’s, foreign speleologist groups started modern and scientific surveys in Iran, and their investigation leads to discover of Parou cave with 1364-m length west of Andarokh basin, Andarokh cave (the main cave in Andarokh basin) which classified as Rudimentary branch work consists of three passages of A, B and C and two entrances Andarokh and Sky.

The Andarokh-Kardeh basin is located 40 km north of Mashhad, with elevation ranging from 1150 to 1710 masl. The climate of this region is semi-arid with average annual precipitation of 260 mm.

II. GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

The study area is covered by Mozdooran Formation consists of three units (Jmz1, Jmz2 & Jmz3). This formation is composed of Limestone, Limestone with Shale and Gypsum inter beds. The Mozdoorna Formation is covered by Neogene Red Formation (early Neogen). The Neogene Red Formation mainly contains Marl, Marly Sandstone and Gypsum evaporative minerals. The Ngr Formation contains paragenetic assemblage including Halite (NaCl), Gypsum (CaSO4.2H2O), Anhydrite (CaSO4) Sylvite (KCl) and Iangbeinite (2MgSO4·K2SO4) [2], and Quaternary sediments contain Conglomerate, Sandy Conglomerate and Sandstone.

The main structural features which exist in the region are Kardeh thrust fault (Ktf) with north-west-south-east direction (Fig. 2). In addition to (Ktf), six main joints series have also been identified in the study region (Table I).

The geomorphological features in karstic environment have great role in studying karst systems which have been classified to surface and deep karstic features. The main surface geomorphological karstic features in Andarokh region are Groove karren (Fig. 3 (a)), Cleft karren (Fig. 3 (b)), Rain pit (Fig. 3 (c)), Rill karren (Fig. 3 (d)), Tritt karren (Fig. 3 (e)), Kamintza (Fig. 3 (f)), Dome (Fig. 3 (g)) and Table karren (Fig. 3 (h)) [3].

In addition to surface karstic feature, deep karstic features (caves) also exist in the region. Andarokh cave is the main cave in the Andarokh basin which classified as Rudimentary branch work caves [4] (Fig. 4).
Fig. 1 Andarokh basin geological map, geological profile in A-B direction and Andarokh cave plan

Fig. 2 (a) Kardeh trust fault (Ktf), (b) Kardeh polish fault, (c) and (d) main extension joints in the study area
Fig. 3 Geomorphological features in the study area: Groove karren (a), Cleft Karren (b), Rain pit (c), Rill karren(d), Tritt karren(e), Kamintza(f), Dome (g) and Table karren (h).

Fig. 4 Classification of cave system based on the recharge types [4]

III. GEOCHEMICAL CHARACTERISTICS OF THE STUDY AREA

The concentrations of Fe, Sr, Mg, Mn, Ca and Mg in Mozdooran carbonate karstic Formation samples have been analyzed using spectrometry technique in Ferdowsi University of Mashhad, Iran. The concentration of Sr varies between 824 to 4500 ppm, Mn varies between 50.6 to 368.3 ppm, Ca varies between 867.6 to 338000 ppm, Fe varies between 468.8 to 12500 ppm and Mg varies between 2000 to 8400 ppm.

The correlation between these ions concentration with the distance between sampling points to the main faults and joints system has been studied by PCA technique using SPSS software.

Two main factors have been identified during PCA analyses. In the first component, Mn, Mg and Fe have inverse correlation, and Ca has direct correlation with distance to faults and the main joints system. In the second component, Sr and Sr/Mn have strong direct correlation with distance to faults and joints system. The PCA results demonstrate that
meteoric diagenesis has great role in controlling carbonate rock geochemistry. In meteoric diagenesis, the circulation of meteoric water in faults and joints system results in the increase of Sr and Sr/Mn ratio in samples, while farther sampling points to faults and joints system face lower meteoric diagenesis and contain higher Mn, Mg and Fe [5] (Table II). The graphical display of the loadings of the seven variables on the two components is shown in Fig. 5. Fe, Mn, Mg, Ca are associated with the horizontal axis (Factor1), while Sr, Sr/Mn and distance to faults are associated with the vertical axis (Factor2) which confirms meteoric digenesis.

### Table II

**Principle Component Analyses in Geochemical Data and Distance to Faults and Joints System**

<table>
<thead>
<tr>
<th>Joint Set</th>
<th>PCA First Component</th>
<th>PCA Second Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>0.980</td>
<td>-0.119</td>
</tr>
<tr>
<td>Mn</td>
<td>0.982</td>
<td>-0.094</td>
</tr>
<tr>
<td>Ca</td>
<td>-0.966</td>
<td>0.21</td>
</tr>
<tr>
<td>Sr</td>
<td>-0.07</td>
<td>0.891</td>
</tr>
<tr>
<td>Sr/Mn</td>
<td>0.1</td>
<td>0.78</td>
</tr>
<tr>
<td>Mg</td>
<td>0.973</td>
<td>-0.126</td>
</tr>
<tr>
<td>Distance to Faults</td>
<td>-0.17</td>
<td>0.849</td>
</tr>
</tbody>
</table>

In caves survey, karstic features in walls and ceiling of the caves can also give valuable information regarding to ancient hydraulic condition [6]. The main karstic features which exist in the Andarokh cave is Etchipts and Ceiling pockets (Fig. 7). Existence of ceiling pocket in A passage demonstrates tropical weather during the formation of this passage which happened at the same time as Ngr evaporative Formation deposition.

**Fig. 6 Andarokh cave plan: A (a), B (b) and C (c) passages and two main Andarokh valley (d and e) and Sky (f) entrances**

**Fig. 7 Ceiling pockets (a) and Etchipts (b) in the Andarokh cave**

The Andarokh cave is one of the main karstic caves in Khorasan Razavi located in Jmz2 member of Mozdooran Formation in Andarokh valley, NE Iran. This Cave has 18-meter length and has three main passages A (Fig. 6 (a)), B (Fig. 6 (b)) and C (Fig. 6 (c)), and two main Andarokh valley (Figs. 6 (d) and (e)) and Sky (Fig. 6 (f)) entrances.

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The Andarokh cave genesis is complicated and started by Mozdooran Formation deposition in deep Bajocian sea and then during Cambriidian time shorijeh sandstone containing evaporative mineral precipitate over Mozdooran Formation. These layers uplifted from sea by Simerian orogeny, and the first stage of karstification was commenced by the infiltration of meteoric water which caused the formation of B passage and Sky entrances. B passage has 12-m length, more than 2-m width and 3-m height, while Sky entrance has 1-m height and 0.5-m width. The karstification evaluates from deep seated karst whenever Mozdooran Formation is completely covered by shorijeh Formation to Denuded karst when shorijeh was totally removed by erosion. In the second stage of Andarokh cave formation in Pasadenaian, A and C passages and Andarokh valley entrance formed. Passage A has 3-m length, 2-m height and 1-m width, while A passage has 6-m length, 2-m height and 1-m width. The Andarokh valley entrance is
main entrance with 3-m width and 2.5-m height. The final stage of evaluation occurred by Ngr Formation deposition over karstified Mozdooran Formation. In this case, Mozdooran karstic system evaluated to mantled karst and by the erosion of Ngr Formation evaluated toward Exhumed karst [7] (Fig. 8).

Fig. 8 Schematic model of karst evaluation from syngenetic karst (early diagenetic evolution) to exhumed karst [7]

V. CONCLUSION

The Andarokh basin is one of the main karstified regions in Khorasan Razavi province NE Iran with notable surface karstic features including Groove karren, Cleft karren, Rain pit, Rill karren, Trutt karren, Dome, Table karren and Kamintza and deep karstic features such as Andarokh cave. This cave is Rudimentary branch work cave which consists of three passages of A, B and C and also Sky and Andarokh valley entrances. Geochemical analyses Fe, Mg, Mn, Ca, Sr and Sr/Mn ratio in samples from Mozdooran Formation with distance to main fault and joints system using PCA analyses demonstrate that Meteoric digenesis is dominantly controlled carbonate rock geochemistry. Karst evaluation in the region varies from deep seated karst in early stages to Exhumed karst in the last stage of karstification.

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Mojtaba Heydarizad is also a member of several associations including Iranian Association of Water Resources (IAWR) 2013-Present and Iran young geologists’ campaign.