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

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***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 Iran, salt cave with 5010-m length (the second largest salt cave in the world) in Hormuz island south of Iran, Alisadr cave (Hamadan) west of Iran with 11440-m mapped passage and Kataleh khor cave (Zanjan) north of Iran with 12860-m length and so many other caves. Although so many speleologist groups work, but this science is in its beginning steps in Iran.

Iran is located in Alpine-Himalayian orogenic belt extending from western Pacific in the east to the Atlantic Ocean in the west which is considered as the remains of great ancient Tethys existed between "Eurasian and Gondwana" during Paleozoic-Mezosoic era. Andarokh-Kardeh basin has been located in Kopeh-Dagh mega zone north of Iran. The Kopeh-Dagh sedimentary-structural zone in north-east of Iran has north-west south-east trend extends from east Caspian region to the north of Afghanistan. The Kopeh-Dagh south boundary is limited to Paleo-Tethys, while its north boundary is limited to Eshgabad fault in Touran plate [1].

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 (J_{mz1}, J_{mz2} & J_{mz3}). 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 ($CaSO_4.2H_2O$), Anhydrite ($CaSO_4$) Sylvite (KCl) and Iangbeinite ($2MgSO_4K_2SO_4$) [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).

TABLE I
Dip Degree and Dip Direction Degree in the Main Sets of Joints in the Study Area

Joint Set	Dip degree	Dip direction degree
J1	75	325
J2	70	330
J3	60	35
J4	65	310
J5	70	0
J6	60	93

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).

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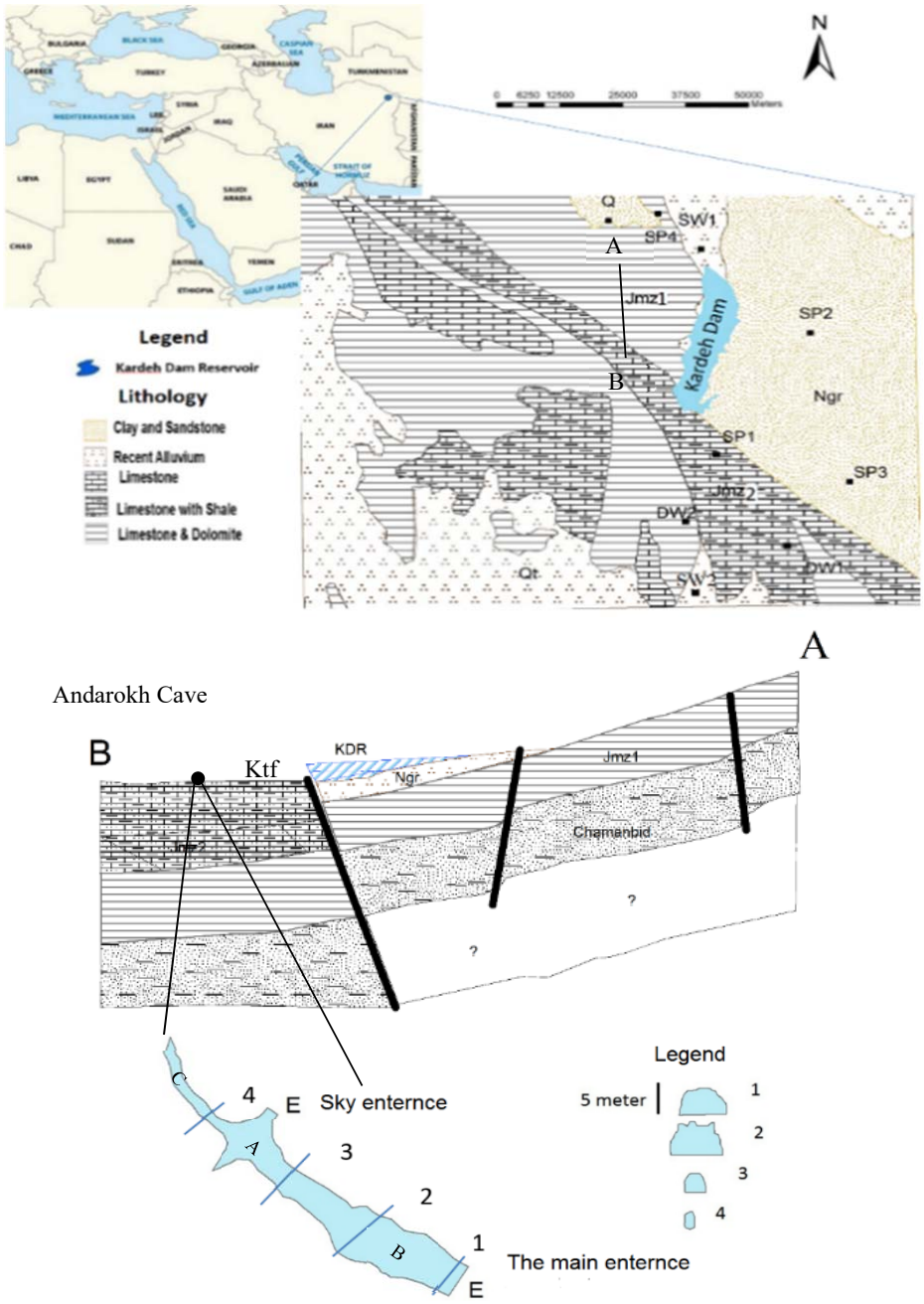

Fig. 1 Andarokh basin geological map, geological profile in A-B direction and Andarokh cave plan

Fig. 2 (a) Kardeh trust fault (Ktf), (b) Kardeh polish fault, (c) and (d) main extension joints in the study area

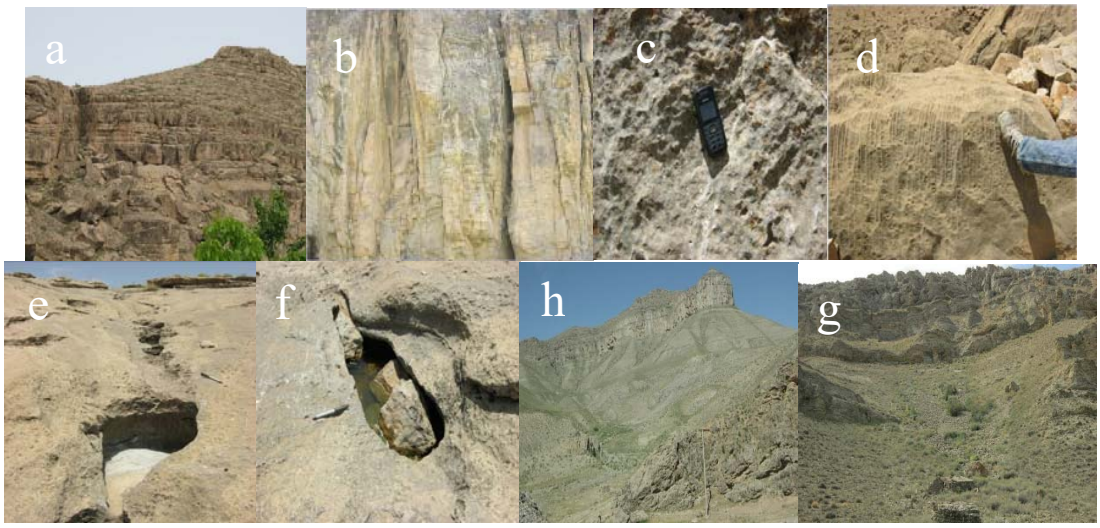

Fig. 3 Geomorphological features in the study area Groove karren (a), Cleft Karren (b), Rain pit (c), Rill karren(d), Tritt karren(e), Kamintza(f), Dome (g) and Table karren (h)

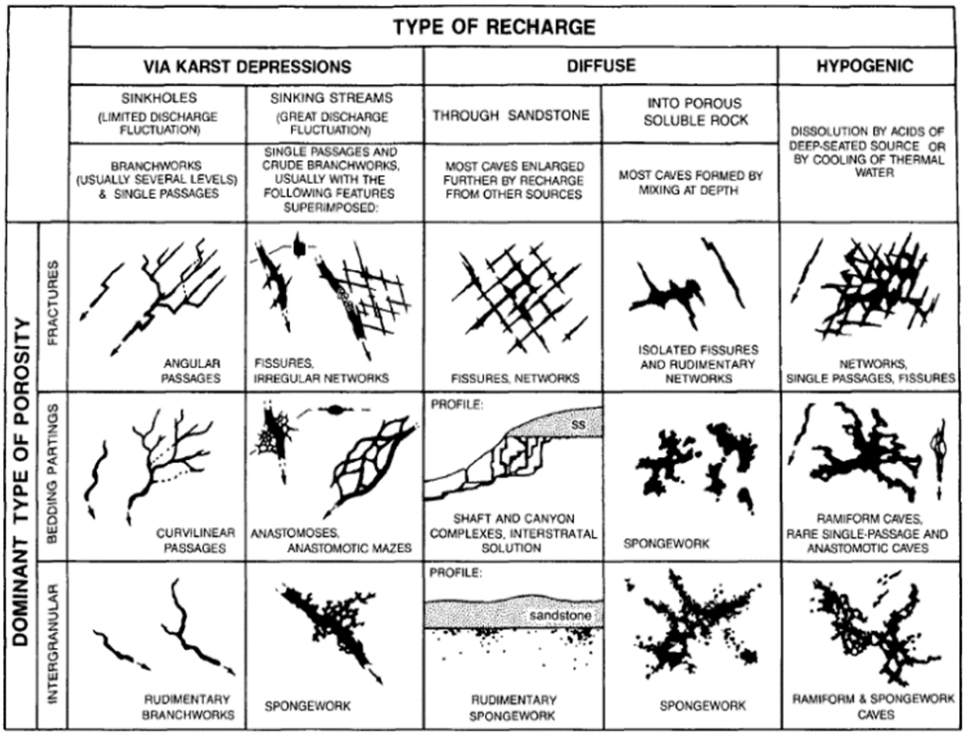

Fig. 4 Classification of cave system based on the recharge types [4]

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

Joint Set	PCA First Component	PCA Second Component
Fe	0.980	-0.119
Mn	0.982	-0.094
Ca	-0.966	0.21
Sr	-0.07	0.891
Sr/Mn	0.1	0.78
Mg	0.973	-0.126
Distance to Faults	-0.17	0.849

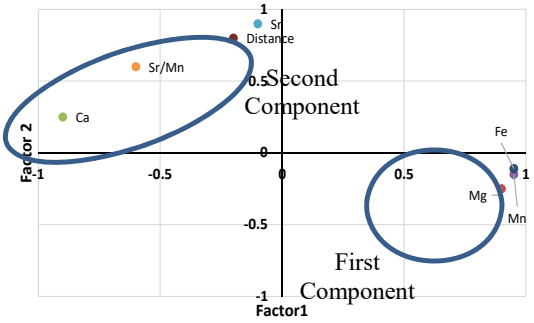

Fig. 5 Plotting the component 1 scores against the component 2 scores

IV. GENESIS OF THE ANDAROKH CAVE SYSTEM

The Andarokh cave is one of the main karstic caves in Khorasan Razavi located in Jmz_2 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.

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

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.

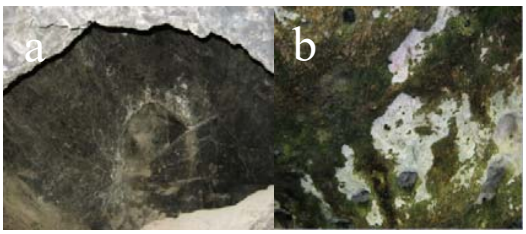

Fig. 7 Ceiling pockets (a) and Etchipts (b) in the Andarokh cave

The Andarokh cave genesis is complicated and started by Mozdooran Formation deposition in deep Bajocian sea and then during Cambridjian 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 Pasadenian, A and C passages and Andarokh valley entrance formed. Passage A has 3-m length, 2-m height and 1-mwidth, 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 kasrtified 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).

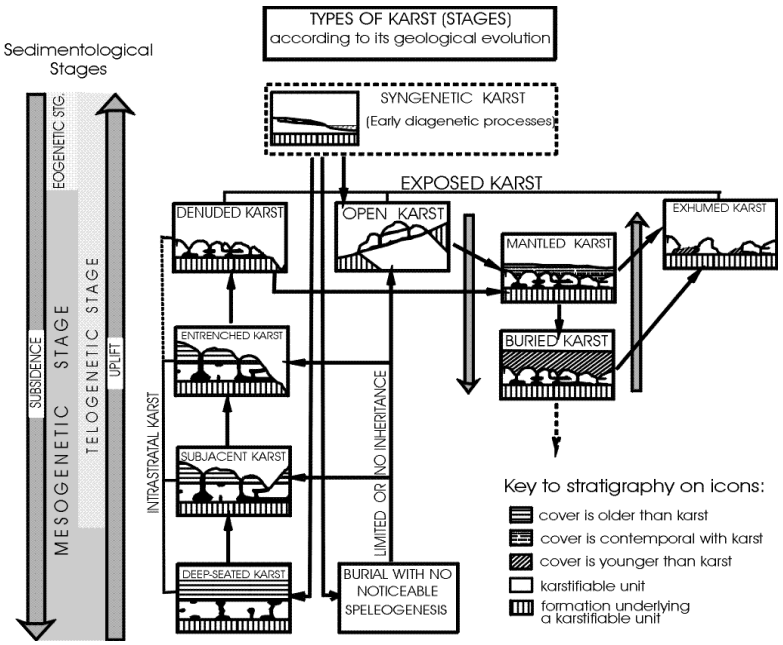

Fig. 8 Schematic model of karst evaluation from syngenetic karst (early diagenetic evolution) to exhumed karst [7]

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, Tritt 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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