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RESEARCH ARTICLE

THE KARSTIC GEOMORPHOLOGY IN THE DOLOMITE OF DRINJAL FORMATION IN CENTRAL IRAN (CASE STUDY SADDAT SIRIZE IRON MINE)

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ABSTRACT

In the present work, we deal with the geomorphological features formed by karstification in the dolomite of the Drinjal Formation. The study area is located on the southeast wall of the Saddat Sirize iron mine, which is mostly covered by the sedimentary sequence of the Drinjal Formation. The geomorphological features have a direct effect on the slope stability, extraction of the orebody, etc., in a mining project. The aim of this study is to determine the effect of karst geomorphology on the mining project. For this purpose, fields methods were used to examine the dolomite of Drinjal formation. Dolomite in the study area has a variety of developed karstic geomorphological features such needle shape karrens, solution runnel karrens and cryclastic karrens, conical shape doline and Collapse dolines, Karstic cavity and Karst windows. karst geomorphology makes it highly susceptible to a variety of different geological hazards. These karstic geomorphologies can cause the instability of the Saddat Sirize iron mine wall.

KEYWORDS

Drinjal Formation, karst, Dolomite, Saddat Sirize mine

1. Introduction

Saddat Sirize iron mine is located in the center of Iran in the southeast zone of Kerman Province. The general appearance of the Drinjal Formation Dolomite is a light brown in color and from the late Cambrian geological time period (Darvishzadeh, 2003; Ghorbani, 2013). In central Iran, very limited research has been accomplished in the field of karstification. karst engineering is one of the modern and important fields. Dolomite is one of the most commonly occurred sedimentary rocks and its contains a high percentage of the mineral dolomite, $CaMg(CO_3)_2$ (Mattox et al., 2008; Yasin et al., 2017; Yasin and Ibrahim, 2017). The term "Karst" was used first to describe the region of Carso in northeastern Italy and western Slovenia, where the landform was first noticed and studied in the 19th century (Burger and Dubertret, 1975).

Karst can be defined as any terrain or landscape where the dissolving of soluble bedrock such as limestone, dolomite, gypsum, marble and salt by both groundwater and surface water has played a dominant role in the development of the area (Ford and Williams, 2013; Goldscheider et al., 2020; Wang et al., 2019). Geomorphologically, karst occurs primarily on limestones (and dolomites), and ground cavities and dissolution landforms develop best on competent, fractured rocks (Ford, 2020; Li et al., 2019). Karst terrain occurs in temperate, tropical, alpine, and polar environments. Karst features range in scale from microscopic (chemical precipitates) to entire drainage systems and ecosystems which cover hundreds of square miles and broad karst plateaus (Goldscheider et al., 2020; Zhu et al., 2019).

Typical karst terrain is dominated by the presence of caves, sinkholes, losing/disappearing streams and springs. These features are known to have caused structural and infrastructural problems such as road and highway subsidence, building-foundation collapse, dam leakage and groundwater contamination and pollution (Wang et al., 2020). Karst problems worldwide cause huge annual costs as a result of insufficient understanding of karst processes (Williams, 2019). The family of carbonate rocks containing a more or less significant proportion of dolomite, a calcium and magnesium carbonate (Ca, Mg) CO_3. In outcrops, these rocks often look like elephant skin. They do not fizz in the presence of 10% HCl. While carbonate rocks are insoluble in distilled water, groundwater will contain dissolved carbon dioxide that forms a weak carbonic acid (H_2CO_3) in which these rocks are slightly soluble. Some carbon dioxide is derived from the atmosphere during rainfall resulting in a weak carbonic acid, most of the carbon dioxide is derived from organics within the soil and by decaying organic material (El-Aal and Masoud, 2017).

Dolomitization can be primary, when carbonate rocks form in an evaporitic environment, or secondary, during diagenesis, due to the circulation of magnesium rich fluids. Dolomites may comprise only one part of a limestone unit. The family of dolomitic rocks includes everything between pure limestone and pure dolostone, depending on the percentage of mineral dolomite. Since dolomitization is only rarely complete, the dissolution of CaCO3 in a dolomitic rock results in voids that may give the rock a very high porosity (Gilli, 2015). The geology of the

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central Iran is very complicated. The occurrences of karst in central Iran is limited so therefore this research domain was not studied. The purpose of the present study is to describe the karstic geomorphology in the dolomite of Drinjal Formation. The effect of karstification has been determined on the engineering project. The first time in central Iran detailed research work was carried out on karstification.

2. Geology of The Study Area

The Geology of Iran is divided into five major zones which including the Zagros, Sanandaj-Sirjan, Central Iran, the East and Southeast, and the Alborz. About 10.5% of the country is underlain by the carbonate rock formation (Vardanjani et al., 2017). Karstification is less in central Iran zone is compared with Zagros zone. The Drinjal formation is located in Shergasht mountain range. The lithology of Drinjal composed of dolomite and sandstone and from Cambrian age (Darvishzadeh, 2003). Dolomite in the study area is dissected by many structural elements (faults and/or joints) affected by kartification. Thinly bedded sandstone has eliminated from the surface by the process of denudation (Figure 2). The general appearance of Dolomite is a light brown in color. Sadat Sirize iron mine is located in southeast zone of Kerman Province and the geological map of study area is shown in (Figure 1).

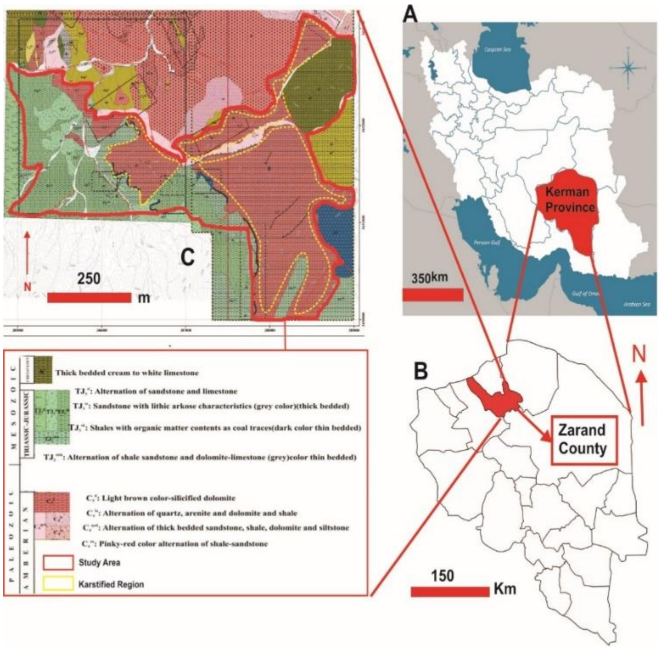

Figure 1: A the location of Kerman province in Iran, B The location of Zarand county in Kerman province, C the geological map of the study area.

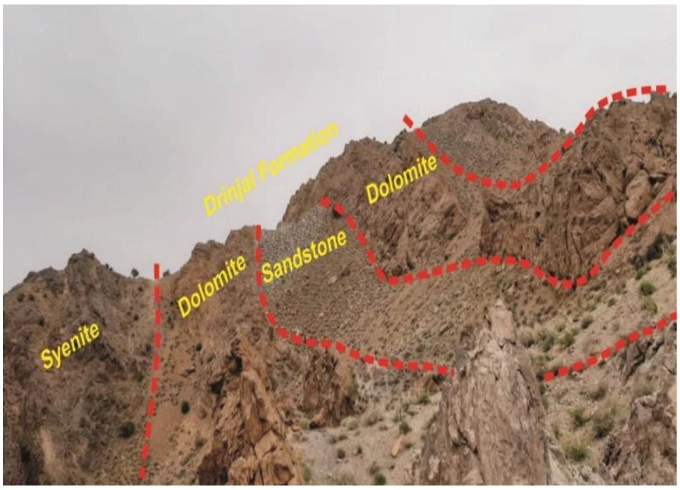

Figure 2: The Stratigraphy of the Drinjal Formation in Saddat Sirize iron mine.

3. Data Collection and Methodology

It is very important to get complete information about geological and morphological settings, characteristics of rocky outcrops, condition of surface and groundwater, karst development process, and the role of human impact over time. Therefore, for the Saddat Sirize mine, geologic and morphological were studied using traditional methods (Figure 1). Several field visits were made to the site to investigate and examine the karstification process. Field data were collected in the following ways: (1) Traverses were made along and across the bedding and Photographs were taken in the field by smart phone. (2) Types of rock and material types (the key rock and material types have been collected, identified, and investigated at each site). (3) The characteristics of the weather were identified by observing the degree of change in the color and texture of the rock. (4) The compressive strength was measured using the geological hammer for the strength of the rock.

4. Results and Discussions

4.1 Petrographic study of Dolomite

Based on the shape and size of the crystals, and method of formation, the Dolomites in the study area are divided into four types. Different types of dolomite can be a reflection of the time of formation, source, or composition of the original limestone.

4.1.1 Dolomite type D-1

This type of dolomite is composed of almost the same size and amorphous crystals with irregular crystal surfaces. The size of these crystals varies from 1 to 20 microns (Figure 4-B) These dolomitizes are dense, dark, free of fossils, and with detrital quartz grains and evaporative crystals, which often have effects from primary sedimentary textures (such as lamination and intraclasts) (Figure 3 A & B).

4.1.2 Dolomite type D2 & D3

These dolomites are composed of shaped crystals, in small to medium sizes and dense with (e) planar crystal boundaries. The size of dolomite crystals type D2 is between 1.5 to 20 microns and the size of dolomite crystals type D3 is between 50 to 300 microns Is) (Figure 4 A & B). This type of dolomite often fills the empty spaces between the allocums as a substitute in the allocums or as dolomitic cement (Figure 3 D & C). Dolomites Type 2 and 3 are the most abundant type of dolomite in Drinjal Formation. Dolomites Type D3 is morphologically destructive, therefore the original sedimentary texture is destroyed (Figure 3-C & 3-B).

4.1.3 Dolomites Type D-4

These dolomites are composed of semi-shaped to shaped crystals of 100 to more than 500 microns in the form of dolomite cement filling cavities and fractures (Figure 3 E & F). Typically, the size of the crystals depends on the size of the empty space, which increases from the wall to the center of the cavities and fractures. These dolomites sometimes show a wave of extinction Which indicates that they are formed under conditions of high pressure and temperature, but the heat and pressure have not been high enough to form the saddle dolomite.

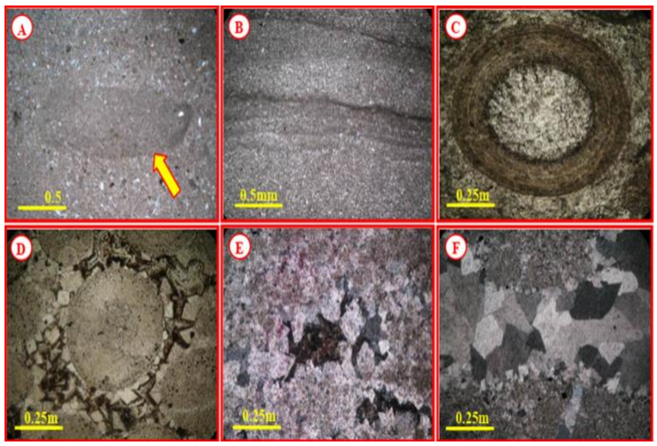

Figure 3: Microscopic images of dolomites of Drinjal Formation based on fabric (size and shape). A) Dolomite type, D1 crystals of the same size with uneven borders containing intraclasts. B) Traces of fine stromatolitic lamination remaining in dolomite type D1. C) Dolomite Type D3 morphologically destructive, and original sedimentary texture is destroyed. D) dolomites Type D3 fill the space between the allocums. E) Dolomites type D4 formation and cavity filling. F) Large semi-shaped crystals filling the dissolving veins (Bavi, et al 2013).

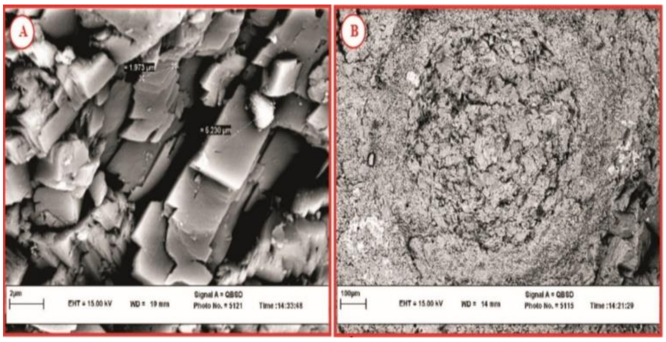

Figure 4: SEM image of dolomites of Drinjal Formation based on fabric (Size and shape). A) Dolomite Tpye D2 Fine and self-forming dolomite crystals. B) Dolomite Type D1 has been confirmed in the outer cortex. Two types of Dolomites D3 in the form of destructive tissue have destroyed the core (Bavi et al., 2013).

4.2 Origin and Classification of Karstic Geomorphology Along the Wall of Saddat Sirize Iron Mine

4.2.1 Karrens or lapies

Karrens develop slowly on dolomite rocks than on gypsum and limestone. The needle shape karrens, solution runnel karrens and cryclastic karrens can be observed in dolomite of Drinjal Formation in Saddat Sirize iron mine (Figure 5). Lapies or karren, are small-scale (millimeter to several-meter) weathering formations found at the surface or beneath the soil cover. The resulting shapes vary greatly, and include acorn cups, bowls, flutes, clints and grikes, perforations, needles, blades, etc. Karrens caused by runoff over solid rock, these consolidate runoff channels, which then develop in different ways based on the steepness of the slope, forming sinuous meanders called runnels in low-relief area, and verticals flutes.

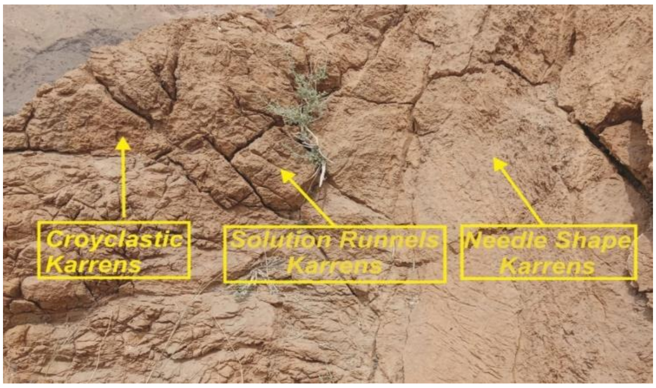

Figure 5: Karrens in the dolomite of Drinjal Formation.

4.2.2 Dolines or Sinkhole

The sinkhole is a very common term that includes cenote, sink, swallet, swallow hole, or doline used in engineering and environmental issues for "the depression or hole in the ground mostly caused by karst process -the chemical dissolution of carbonate rocks". Sinkholes vary in size from 1 to 600 m (3.3 to 2,000 ft) both in diameter and depth. Sinkholes can be distinguished in different shapes, such as cylindrical, conical, bowl- or pan-shaped (Gunn and Parise, 2007; Youssef et al., 2016). The genetic classifications of sinkholes proposed by Gutiérrez et al. and by Gutiérrez and Cooper into two main groups solution sinkholes and subsidence sinkholes (Gutiérrez and Cooper, 2013; Gutiérrez et al., 2014). In these classifications, two terms are used, the first term referring to material type including cover (unconsolidated deposits or residual soil material), bedrock (karst rocks), and caprock (non-karst rocks). The second term represents the subsidence mechanisms including collapse (brittle deformation of soil or rock material), sagging (ductile bending of sediments and rocks due to the absence of basal support), and suffusion (downward migration of cover deposits through voids). In the current research work, different types of sinkholes were detected in the study area, which plays a strong role in the formation of a geo-hazard. The Dolomite of Drinjal Formation along the slope of the mine wall is highly fractured and weathered, which is characterized by the presence of sinkhole or doline. They have a significant impact on slope stability in the study area. The conical shape doline can be observed in dolomite of Drinjal Formation in Saddat Sirize iron mine (Figure 6). Collapse dolines Caused by the inward collapse of the roof of an underground cavity (Figure 7).

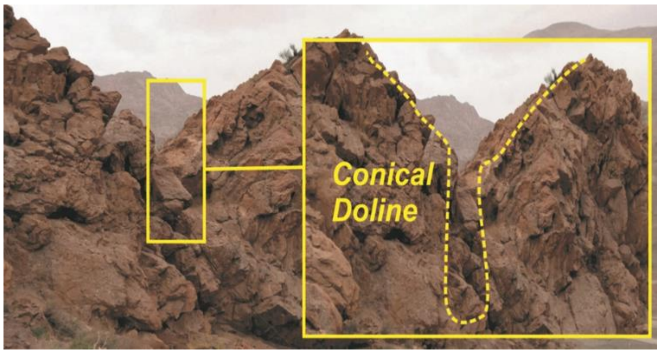

Figure 6: Conical doline in the dolomite of Drinjal Formation along the wall of Saddat Sirize iron mine

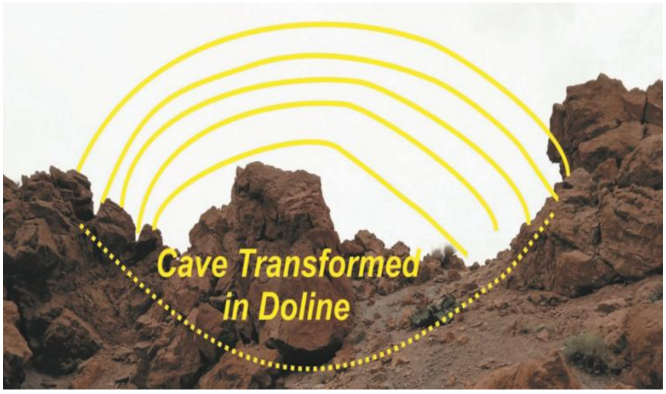

Figure 7: Dolomite unit has been uncovered for long periods of time, base level variations in the rock record as the traces left by different phases of karstification. A large stalagmite, a vestige from an older cave that was unroofed by erosion.as result Collapse dolines formed by the inward collapse of the roof of an underground cavity.

4.2.3 Karstic cavity

Karstic cavities are spaces created by dissolution, overlaid onto the fracture network. The formation of most cavities begins with a tectonic phase, since the opening of joints is a necessary prelude to the infiltration of water. At depth, circulation is determined by hydromechanical linkages, high pressures causing joints to open. Karstic cavity can be observed in dolomite of Drinjal Formation in Saddat Sirize iron mine (Figure 8). When carbonate sediments are originally deposited, they contain abundant void space within the sediment mass. Over time, this sediment may undergo diagenesis (physical and chemical changes that lead to conversion of sediment to rock) that result in development of additional porosity as solutions modify the sediment particles. When particles dissolve away, the resulting molds and other dissolution-related openings begin to touch each other, further enhancing porosity and permeability. The distinction between diagenesis and karst-related dissolution is often unclear, but the result is the same, a geologically young, carbonate-sediment deposit with enhanced porosity and permeability.

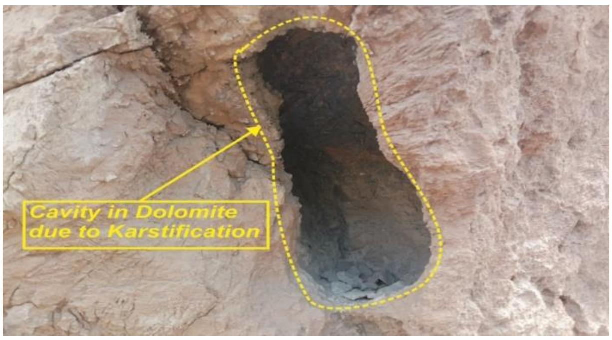

Figure 8: Karstic cavity in dolomite of Drinjal Formation.

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4.2.3.1 Karst Window

Streams and rivers can be found running across the surface of karst regions, where they are connected to varying degrees with the subterranean drainage network. This results in a variety of landforms. Pocket valleys originate in carbonates rocks cirques with springs emerging at their bases. A blind valley is a gorge that terminates abruptly at a point where the stream sinks. Karst windows (Figure 9) are essentially the combination of a pocket valley and a blind valley. In thin carbonates rocks units, where water flows close to the impermeable substratum, sections of active river valley alternate with stretches where the water flows below ground.

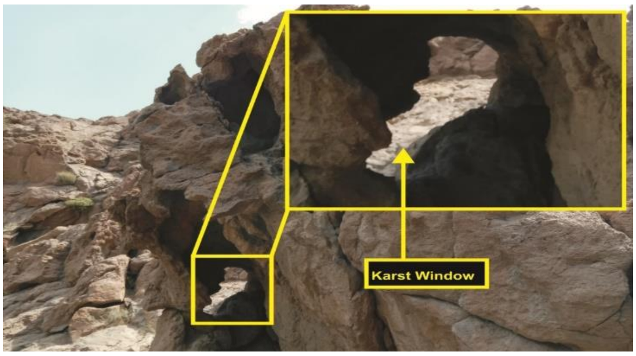

Figure 9: Karst Window in the dolomite of Drinjal Formation along the wall of Saddat Sirize iron mine.

5. Conclusion

Karstic features are a common and well-developed phenomenon that can be seen in the dolomite of Cambrian age in central Iran. In the study area, Drinjal Formation is composed of brown color dolomite. Most of the karstic features such as needle shape karrens, solution runnel karrens and cryclastic karrens, conical shape doline and Collapse dolines, Karstic cavity and Karst windows are formed in dolomite of the Drinjal Formation. But karstification is less in central geological of Iran than Zagros region. These karstic geomorphology as result of solution process and tectonic activities. In such of highly karstic zone much more chances for the instability of Saddat Sirize iron mine wall. It was found that different karst features contribute the slope stability problems such as differential erosion, empty cavities, filled sinkholes, and weathering effect along discontinuities. It was found that mitigation methods are most effective to increase rock stability. Further research requires advanced engineering modeling for the effect of the karst zone. And detailed hydrological studies will be required on the formation of the aquifer's system by the karstification process and its impact on an engineering project.

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