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The Occurrences and Formation of Ladderback Ripples on Barchans Dunes of Najaf Dunes Field, Iraq, in Aeolian Environments

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Abstract

This paper concerns the study of ripples that occur on the windward of Barchan dunes from the dunes field of Najaf governorate, Iraq. These dunes consist mainly of sand sediments with variable sizes, including medium, fine, and very fine sands. Quartz represents the major light mineral in the Najaf Dunes sand. The prevailing wind direction in the study area is NW-SE. The major ripple crest series of every pattern are oriented perpendicular to the NW-SE wind direction, whereas imbricated ripple groups within the troughs of the preexisting ripples are created by the WSW-ENE wind trend. These ripples tend to be formed by shortened ripples that occupy the troughs of the prolonged series. All crests of the ladderback ripples are oriented at right angles to asymmetry ripples. The ladderback ripples were noticed from fine to very fine- grained sediments, which consist mainly of quartz. The wavelength of the ladderback ripples ranges from 2 – 4 cm, while they are 0.1 – 0.2 cm in height. The occurrence of ladderback ripples within an aeolian environment indicates a variety of wind directions, which influenced the arrangements of the crest ripples.

Keyword: Ladderback ripples, interference ripples, Sand Dunes, Dunes Field.

تكوين وظهور علامات النيم السلمي على كثبان البرخان من حقل كثبان النجف في البيئة الهوائية, العراق

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الخلاصة

يهتم هذا البحث بدراسة علامات النيم التي تحدث على جهة اتجاه الرياح للكثبان الرملية من حقل الكثبان في محافظة النجف – العراق. تتكون رواسب الكثبان الرملية من مجموعة متنوعة من الرمال ذات الحجم المتوسط و الناعم و الناعم جدًا. يمثل الكوارتز المكون الرئيسي للمعادن الخفيفة في رمال كثبان النجف .أن اتجاه الرياح السائد في منطقة الدراسة هو شمال غرب –جنوب شرق . القمم لعلامات النيم الرئيسي في كل حالة يتم توجيهه بشكل عمودي على اتجاه الرياح NW–SE ، في حين يتم تشكيل مجموعات التموج المتراكبة في أحواض علامات النيم الموجودة سابقا باتجاه الرياح WSW–ENE المسببة لها. تميل هذه العلامات النيم إلى أن تتكون من تموجات

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أقصر تشغل أحواض المجموعة الأطول وجميع قمم التموجات ذات السلم موجهة عموديا على التموجات الغير متناظرة . تم ملاحظة علامات النيم نوع السلمي انها تتكون من حبيبات ناعمة إلى ناعمة جدا واغلبها من معدن الكوارتز و يتراوح الطول الموجي لها من 2 – 4 سم وايضا يتراوح ارتفاع التموجات من 0.1 – 0.2 سم. إن وجود علامات النيم ظهر السلم في بيئة هوائية دليل على مجموعة متنوعة من اتجاه الرياح مما أثر على ترتيبات قمم التموجات ايضا .

Introduction

Ripple marks are uniform ridge-like frameworks oriented cross to the current flow. They are grown and preserved at the interface across the space separating a fluid medium and a moveable sand sediment, by the interaction between these two environments [1]. The imbricated ripples are oriented at perpendicular straight lines to the existing crests, where major bed forms are oftentimes created on the wave-sheltered beds, when the level of water falls during the ebb period in intertidal environments. The consequent built structures have been described as ladder-back ripples [2]. The ladderback ripples are an interference form of ripple marks which have two groups of overlapped ripples that are especially oriented perpendicular to each other [3]. In intertidal environments, the ladderback ripples were described to reflect diagnostic features of the late-phase development of the run-off. [4]. Reddering, 1987, [5] provided an evidence that ladder-back ripples may also occur in sub-tidal environments. Ladderback and supercritically climbing ripples are typically interpreted to be formed in tidal conditions by bidirectional currents, either via tide or wave activity [6].

Ladderback ripples are widespread within the recent intertidal flat environments [7- 13]. They are described as a form of deposition in intertidal environments that are often preserved in the rock lists in the literature [2, 14, 15, 22]. However, studies related to Ladderback ripples in aeolian environments are seldom.

The present study aims to investigate the appearance and forming of ladderback ripples in aeolian conditions. The Najaf dunes field is sited in the west and southwest of Najaf City, Iraq. These dune fields extend parallel to the prevailing NW-SE wind orientation (Figure-1). The study area is located about 20 km west of Najaf City center, near the village of Al-Rahimiya, at latitude of (31º57′42″N) and longitude of (44º08′16″ E) (Figure-2). Barchan dunes type is present in the Najaf dunes field together with several morphological types of dunes, including the Barchanoid, Nabkha, and sand sheet. Fine sand size represents the main size of the fractions of Barchan dunes. Thier sorting average of 0.62 Ø reflects that they are moderately well sorted, where quartz represents the major light mineral of these dunes [24, 25]

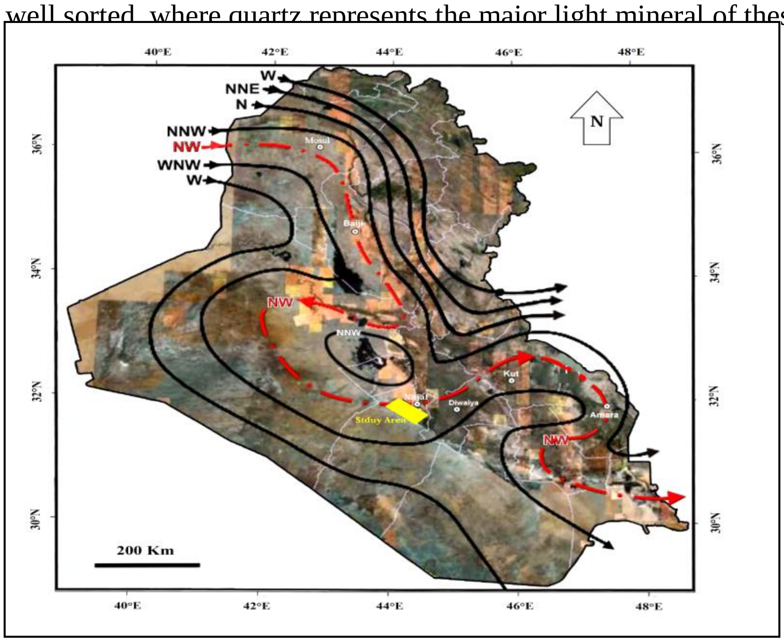

Figure 1- Contour map of wind direction in Iraq showing the study area at NW contour direction [23].

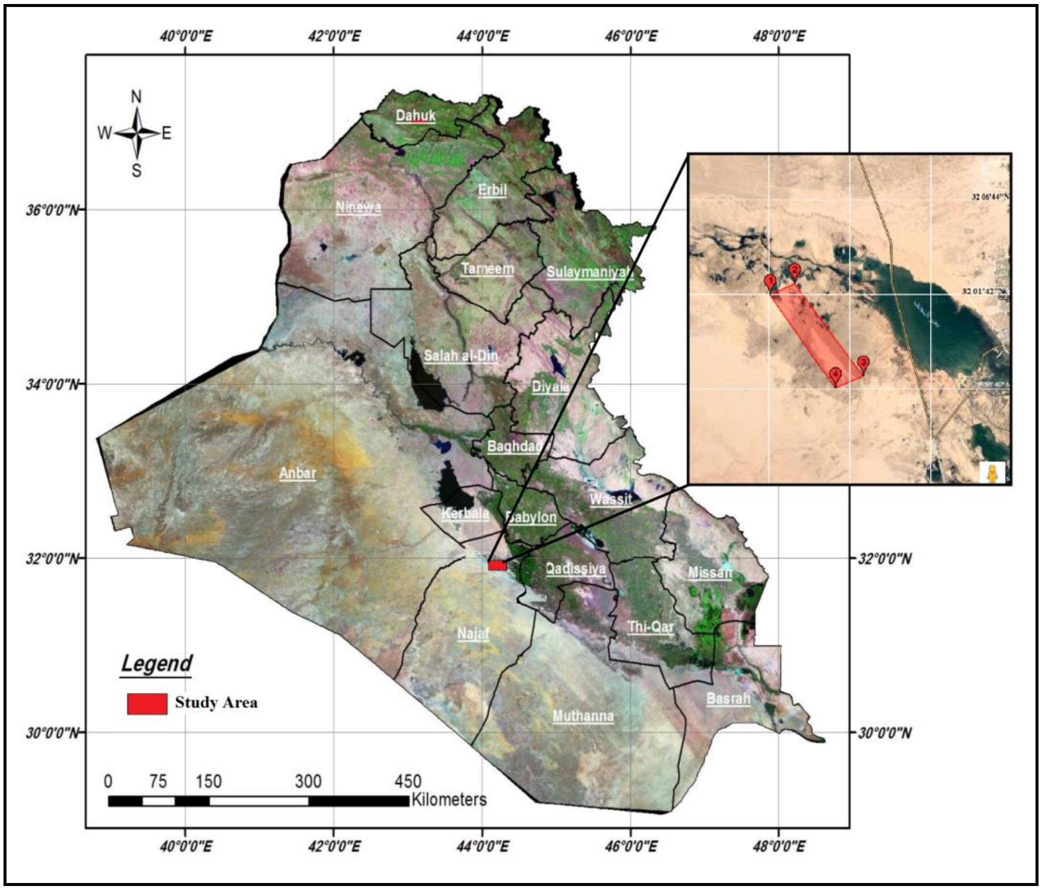

Figure 2- Satellite image of Iraq showing the study area

Methodology

The methods applied in this study involve a basically detailed fieldwork to study the ladderback ripples. The orientation was measured by a Brunton compass, the wavelength and height were measured by a tape measure and ruler, and a GPS device was utilized to indicate the exact points. The readings were conducted in September and October 2019, with sampling of sand ripples from many positions on Barchans dunes. The grain size analysis was performed by a Ritsch Shaker in the laboratory of the geology department of the University of Baghdad.

Ladderback ripples occurrence on sand dunes

Ladderback ripples are observed on the windward side of Barchan dunes at Najaf Dune Field. The orientations of these ripples are WSW-ENE, while the main ripples orientation is perpendicular to the prevailing wind direction, i.e. NW-SE. The asymmetrical ripple marks are observed in the study area because of the effects of wind direction. The ladder-back ripples of the present dunes field consist of superimposed asymmetrical ripples that are extended at 90º to the original crested line ripple series. Ladderback ripples were characterized to have medium to very fine-grained size (Figure-3). The wavelength of the ladderback ripples ranges from 2 - 4 cm and their height ranges from 0.1 – 0.2 cm (Table- 1). The evidence of a late stage of wind action is provided throughout the ladderback ripples. The minimal ripple series was perhaps created by wind influx laterally over the troughs basin of the main ripples, possibly due to local wind action as well as short periods of wind current impacts (Figure-5).

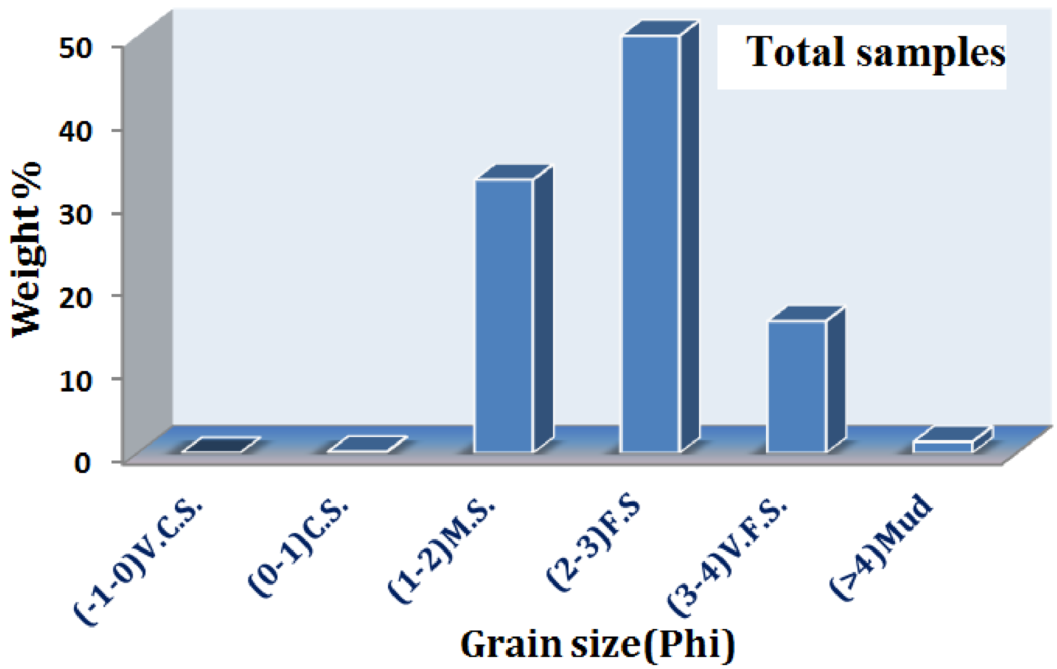

Figure 3- Histogram of the average grain size of ladderback ripples sand. .

Table 1- Wave length (L) and height (H) of the ladderback ripples

No. Read	L.	H.	No. Read	L.	H.
R1	2	0.1	R11	4	0.2
R2	2.8	0.18	R12	2.9	0.19
R3	3.3	0.2	R13	1.9	0.1
R4	2.9	0.21	R14	1.8	0.1
R5	1.9	0.14	R15	2.2	0.15
R6	3.5	0.2	R16	3.1	0.2
R7	2.1	0.1	R17	2.4	0.14
R8	2	0.11	R18	2.7	0.2
R9	4	0.2	R19	3.1	0.19
R10	3.9	0.2	R20	2	0.11

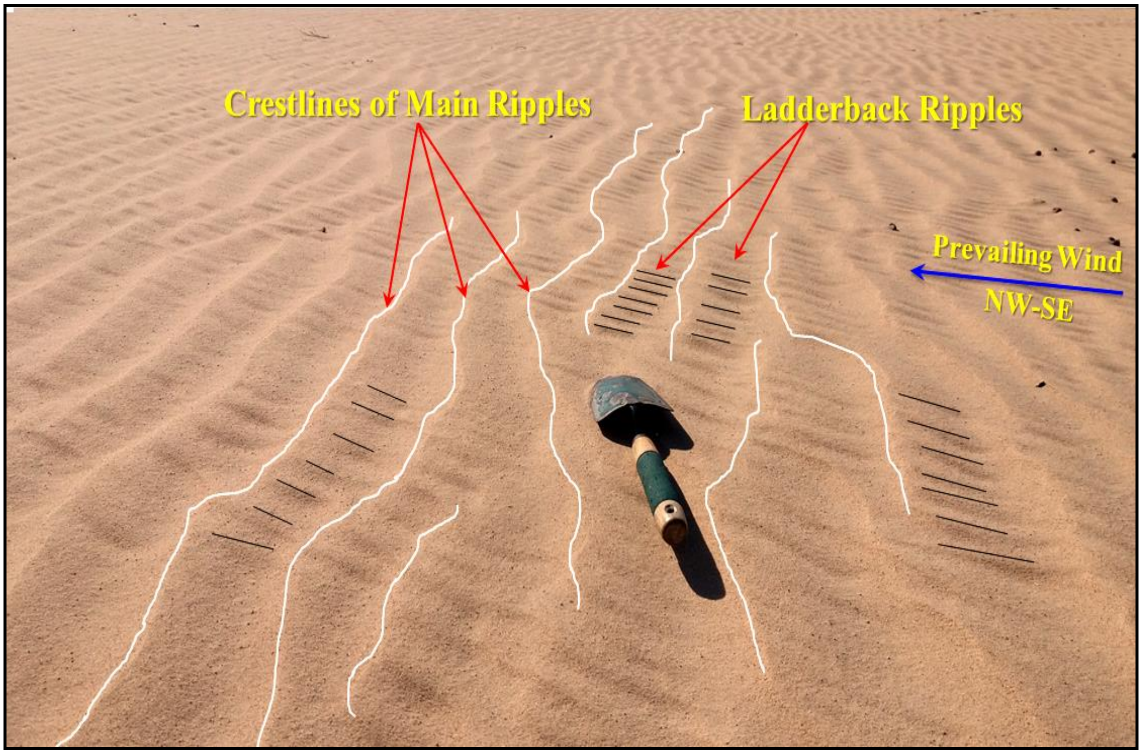

Figure 4- Aeolian ladderback ripples between the main ripples on the windward side of Barchan dune in Najaf dunes field.

Discussion

The ripple marks might represent one of the most frequent phenomena described in the sedimentology records. Based on modern methodologies; ripples are recognized readily via their measurement, setting, and morphology [26]. Ripple marks are divided into two broad portions: water formed and aeolian ripples [27]. Wind ripples are widespread on the entire sand flats, unless these afford highly fast sedimentation and provide a good model of itself-predominant of aeolian regime [28].

The ripple marks are perfect indicators of wind current orientations [29]. The prevailing wind direction in the study area is northwest-southeast (Fig.1). Thus, any change in local wind direction and velocity are reflected in the ripples marks. The parallel crests are orientated vertically to the wind direction that affects the formation of superimposed ladderback ripples in the troughs of older asymmetrical ripples. Ladderback ripples have low wavelengths, which is a function of wind velocity, grain size of sand, and separation and sorting processes. Thus, ripples of coarse sands have a greater interval than those of fine sands [30]. Ladderback ripples can occur in other depositional environments, created by various techniques and diverse scales, such as the intertidal and subtidal ones [5]. Ripples and ladderback ripples in aeolian environments have a low preservation probability because the sand grains do not contain cement materials between them. They also lack the moisture required for the consolidated sample. Thus, they are intractable during geological recording.

Conclusions

1. This study re-assessed the occurrence and formation mechanisms of ladderback ripples in aeolian environments. We observed that these sedimentary structures are associated with asymmetrical ripples on the windward side of Barchans dunes in Najaf dunes field.
2. The formation mechanisms of the ladderback ripples involve late-stage wind action on the sand surface between the main ripples. The minimal ripple series was perhaps created by wind influx laterally over the troughs basin of the main ripples, maybe due to local wind action and current impacts of short periods of wind.

3. The preventing occurs of adhesion and consolidated sediment due to the lack of cement between the grains of ladderback ripples in aeolian environments. Thus, this feature is difficult to recognize during rock recording with stratigraphy formation.
4. The observed ladderback ripples type is an indicator of a change in wind direction and velocity in the study area, where the trend is WSW-ENE which is different from the prevailing NW-SE wind direction.

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