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Facies and Depositional Environments of Khewra Sandstone, Eastern Salt Range, Pakistan

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Abstract

The Early Cambrian Khewra Sandstone is well exposed in the southern part of the eastern Salt Range in its type section, the Khewra Gorge. The 130 m thick succession has unconformable upper and lower contacts and is dominantly sandstone with subordinate claystone. In the lower part of the succession, fine grained sandstone alternates with units of silty mudstone and a minor amount of shale. Flaser bedding is the dominant sedimentary structure in the sandstones beds; asymmetrical ripples are abundant and burrows are moderately common, indicating a marine environment with rapidly changing current speeds. Most of the unit is interpreted as tidal flat sands, although there are lenticular-shaped beds that are interpreted as tidal channels. Parallel laminated fine sandstones with subordinate low angle cross-bedding overlie the tidal deposits and are interpreted as shoreface deposits. The middle and upper middle part of the Khewra Sandstone is fine-grained sandstone that is extensively cross-bedded. The beds are wedge shaped and lenticular, suggesting small channels that are interpreted as stacked tidal channels. The uppermost part of the succession comprises medium-grained, well sorted sandstone. Cross-bedding is less common than in the middle part of the succession but parallel lamination is common and low angle cross bedding occurs in some beds. Most beds are tabular beds; the bed geometry and sedimentary structures suggest that it was deposited in a wave-dominant environment.

Keywords: Khewra Sandstone, Tide and wave dominated, Shallow marine

1. Introduction

The Early Cambrian Khewra Sandstone is the lower most formation of the Cambrian succession, exposed in the Salt Range Pakistan. At its type locality (Khewra Gorge lat. 32° 39’ 57’’.6 N and long. 073° 00’15’’.7 E) (Figure 1) Khwera Sandstone dominantly consists of sandstone with minor amount of clay. The formation is generally devoid of fossils except rare trace fossils (Schindewolf and Seilacher 1955), and due to its stratigraphic position (overlying the Late Proterozoic Salt Range Formation and disconformably underlying the lower to middle Cambrian Kussak Formation), the age assigned is as Early Cambrian (Kazmi and Abbasi2008).

Details of the paleoenvironment of the Khewra Sandstone are not well understood. Baqri and Baloch (1991) interpreted a deltaic environment of deposition on the basis of grain size analysis. The main objective of this study is to evaluate the paleodepositional environments of the facies of the Early Cambrian Khewra Sandstone. The focus is the Khewra Gorge outcrop to synthesize the detailed sedimentology including various sedimentary structures and lithologies.

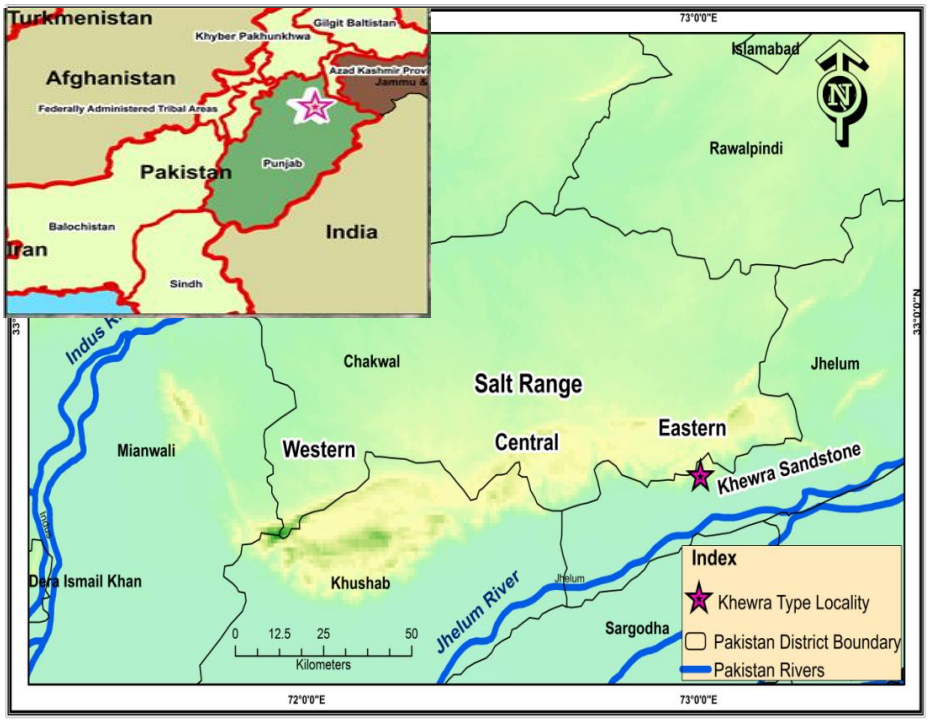

Figure 1: Location map of Khewra Sandstone

The lithostratigraphic units of Salt Range are from Neoproterozoic to Cenozoic and consist of sedimentary successions that are punctuated by important diastems, hiatuses and unconformities of both local and regional extent. The oldest is a mid-Cambrian unconformity between the Khewra Sandstone and the Kussak Formation.

The Cambrian succession in the Salt Range and Potwar Basin is collectively known as the "Jehlum Group" and is comprised of four main lithostratigraphic units. The Cambrian succession is thickest and best developed in the eastern Salt Range and sharply thins and wedges out towards the west. It is extensively exposed along the southern boundaries of the Salt and Khisore Ranges.

2. Results

2.1 Sedimentolgy of Khewra Sandstone

The Khewra Sandstone dominantly consists of sandstone. The outcrop is comprised of the following units that are also subdivided into separate parts.

Unit Kh-1:

The Kh-1 unit is 24 m thick lower part of the formation. The unit consists of beds of sandstone alternating with silty mudstone and thin maroon shale at the base. Bed thickness ranges from 1 to 5 m. Generally, the beds are parallel laminated with some high angle cross bedding. Flasers (Figure 2) are prominent

and widespread structure of this unit. Other features are asymmetrical ripples and symmetrical ripples. Sand beds have burrows (Figure 3). A thin section of this unit has lenticular shape beds with wedge geometry. The sand of these beds is fine and parallel laminated with a thickness of 10 to 45 cm. Most of the sand is interpreted as tidal sand flat while lenticular wedge shape beds are interpreted as tidal channel sand.

Unit Kh-2:

The unit Kh-2 is interpreted as shorface sand and comprises of 21 m thick lower middle part of the formation. The sand of this unit sub angular, moderate to well sorted, purple to red fine grain sandstone. Sandstone beds are thickly bedded and massive in appearance Sand bed thickness varies from 2 to 6 m. Most sand beds are parallel laminated and massive at the base although some beds have low angle cross lamination at the base that passes upward into parallel lamination. The top parts of sand beds have high angle cross bedding.

Unit Kh-3:

The Unit Kh-3 is 23 m thick and comprises thick to thin bedded, purple to brick red fine grain sandstone with thinly interbedded siltstone and minor shale. Sand grains are sub angular to round and moderately well sorted. The Kh-3 Sandstone occurs in the middle part of the succession. Bed thickness is variable from 1 to 4 m. The basal beds are thickly bedded and straight with parallel lamination that passes upward into high angle cross bedding and parallel lamination. The middle to top of the unit has lenticular wedge shape beds that pinch out and are stacked (Figure 4). These beds are thin and parallel laminated and only 5 to 40 cm thick. The lenticular shape, thin sand beds are interpreted as tidal channels and stacked tidal channels. Consequently, the unit is interpreted as tidal channel sand deposits.

Unit Kh-4

The unit Kh-4 is interpreted as tidal sand flat which is 36 m in thickness and comprises of thick bedded coarsening upward fine to medium grain sandstone. Basal fine grain sand beds are mostly separated by thin siltstones. In appearance, the sand is purple to brick red that becomes dusty red with weathering. Sand grains are sub angular to rounded and well sorted. Sand beds become gradually thicker and massive upward ranging from 2 to 6 m. Most beds are massive and pass upward into, high angle cross bedding and planar cross bedding that passes upward to parallel lamination at the top of this unit.

Unit Kh-5:

The 26 meter thick Kh-5 is the top most unit of the outcrop and consists of beds of medium grain sub angular to sub rounded, well sorted sandstone that generally look porous and uncemented. As compared with lower units, the top most part is lacking in sedimentary structures. In appearance, the sands are greyish which is due to weathering while fresh surfaces are yellowish white in color. Sandstone beds are thick and massive and have small fractures; they typically range from 2 to 7 m thick although there are small lenticular shaped beds whose thickness is only 3 cm. The top most sand bed has a contact with the conglomerate bed that marks the top of the succession. Most of the beds are parallel laminated and some are structureless at the base and pass upward into planar tabular bedding. The sand beds are mostly parallel laminated and tabular that suggesting the sand was deposited by wave action. Lenticular thin sand beds are interpreted as thin tidal channels. Therefore, the unit is interpreted as wave dominated shoreface deposits

3. Depositional History

The detailed field study of this succession reveals that tides were dominantly active at the time of deposition, but the current energy was variable. The geometry of Kh-1 to the

lower part of Kh-4 is variable in terms of thickness and type of cross bedding. It suggests that the water current was not constant and sediment supply was also variable. Generally, narrow tidal channels are common in this succession. The abundance of flasers, burrows and other primary structures like ripple marks within Kh-1 indicate a shallow marine tide-dominated environment prevailing in the early stages of the deposition of this formation.

In upper part of Kh-4 to the top of Kh-5 the outcrop has a gradual change in the frequency of cross bedding and beds become planar, tabular and gradually increase in thickness. The grain size also increases from fine to medium at the top. Moreover, this succession rarely has tidal channels which also indicate a change of environment during deposition of Kh-5. The geometry of the top most part indicates that deposition occurred under a wave dominated environment. The stratigraphic succession indicates that there was not much change in sea level during the deposition of the Khewra Sandstone and it was deposited in a shallow marine tide dominated to wave dominated environment.

In general, the succession has a progradational stacking pattern with a lowstand marked by the conglomerates at the top of the Khewra Sandstone, which separates it from the overlaying shale succession.

4. Discussion

Generally, it is recognized that most thick red sequences are non-marine (Lindholm, R., 1987) and most previous researchers have interpreted the Khewra Sandstone as non-marine deposits. Iqbal B. Kadri (1995) interpreted the Khewra sandstone as the product of an arid to the marginal marine environment.

The present study of the type locality of Khewra Sandstone reveals that it was deposited in a shallow marine tide to wave dominated environment. The color of sand throughout the succession is not consistent. The red color may be caused by leaching of lower evaporite deposits, which oxidizes and stains various compounds of iron such as hematite and limonite. The formation is mainly composed of Quartz with very minor quantities of feldspar with common silica and hematite (Jehangiri.et al 2014) which is probably responsible for the color of the formation.

The Khewra Sandstone is known as barren out crop because there are no fossils preserved. Schindewolf and Seilacher (1955) reported “trilobites trails” and did not assign an exact age. The present study reported burrows at the basal part of the formation which must be marine in the Cambrian.

In terms of reservoir potential, the outcrop has an almost uniform grain size of sand and sorting favorable for reservoir potential. The Khewra Sandstone is poorly cemented with intergranular porosity but the porosity may be variable and the top most wave dominated unit probably the better reservoir quality compared with the tide dominated units that contain more fine sand and clay and probably are more heterogeneous in terms of porosity and permeability. The reservoir potential may be diminished by heterogeneity in the lower tidal deposits.

5. Conclusions

The Khewra Sandstone was deposited in a tide to wave dominated shallow marine environment.

The presence of burrows in Kh-1 suggests a shallow marine environment and Kh-1 is a mix of mostly tidal flat and tidal channels deposits.

The planar laminated sandstone of Unit Kh-2 is shoreface sand.

Unit Kh-3 mostly comprises tidal channels.

The unit Kh-4 cross bedded sand assemblage suggests tidal sand flat.

The top most part is characterized by wave dominated shoreface deposits.

The depositional history of the Khewra Sandstone suggests a prograding succession.

6. Acknowledgements

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7. References

Baqri S. R. H. and Baloch M. Q., (1991), Sedimentological Studies and Paleoenvironments of Khewra Sandstone with reference to its hydrocarbon potential, PJPT No.1

Iqbal B . Kadri (1995) Petroleum Geology Of Pakistan published by Pakistan Petroleum Limited, Karachi, Pakistan.

Jehangiri et al. 2014 The Early Cambrian Khewra Sandstone,Salt Range,Pakistan: Endorsing southern Indian provenance, Arabian General of Geosciences.

Kazmi, A.H. nd Abbasi, I. A., (2008) Stratigraphy and Historical Geology of Pakistan, Graphic Publishers, Nazimabad, Karachi, Pakistan pp. 1-100

Lindholm, R., (1987), "A Practical Approach to Sedimentology", Allen & Unwin, Inc., London, UK p. 1-276

Schindewolf, D.H. & Seilacher, A. (1955) Bulrage Zur Kenntris dis Kambriams in der Salt Range (Pakistan),Abh, Akd. Wiss. Litt., Mainz, 10, p.466

Figure 2. Sand beds showing flasers, pencil as a scale.

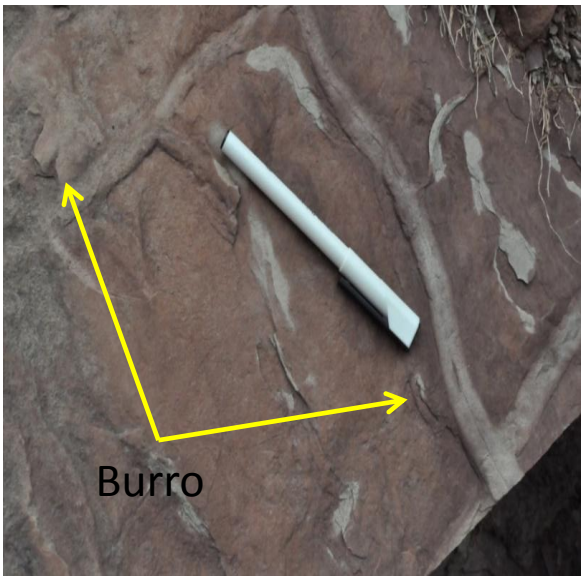

Figure 3. Sand bed showing the presence of burrows

Figure 4. Lenticular wedge shaped thin sand beds, pinching out at the top of unit Kh-3