Reservoir Potential of Marwat and Khisor Trans Indus Ranges, Northwest Pakistan*

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Abstract

The Marwat-Khisor ranges constitute the central part of the Trans Indus ranges. These northeast trending fold-thrust belts represent the leading deformational front of the Kohat fold and thrust belt and form the southeastern border of Bannu Basin. Marwat Anticline constitutes the main topographic expression of the area along with frontal Khisor thrust. The Marwat Range hosts Siwalik rocks throughout its map trace, whereas exposed stratigraphy of the Khisor Range comprises Cambrian to Jurassic platform sediments, which are unconformably overlain by fluvial sediments of Siwalik Group. Exploratory wells drilled in the area along with surface geology provide information about the regional stratigraphic record. The sedimentary rock assemblages outcropping along the Trans Indus Range indicate a fairly quiet period of continuous sedimentation in a shallow sea with the down sagging of the Kohat-Potwar Basin, occasionally interrupted by localized uplifts, resulting in unconformities. Multiple potential reservoirs are present throughout the stratigraphic sequence in the Trans Indus ranges ranging in age from Cambrian to Cretaceous. These mainly include shallow marine / deltaic clastics of Mesozoic and Paleozoic. This paper attempts to share our updated understanding about the potential of different reservoirs within the region in terms of their depositional settings, thickness, depth and more importantly their overall hydrocarbon potential. This would help evaluate the risks involved in exploration, based on our recent experience of exploration work and making use of available well data, field observations, petrographic analysis, source rock analysis, and basin modeling. Recognition of continuity in facies along with approximation of depths to different reservoirs are some of the challenges faced in carrying out a successful exploration program, a task which is made more difficult due to the limited data available in the area. Different formations show wide range of thickness and facies variation and at times truncations of the entire formation towards east makes this area also attractive for stratigraphic cum structural plays.

Introduction

The Himalayan foreland fold and thrust belt of Pakistan includes Kohat foreland fold-thrust belt along with its associated frontal Trans-Indus Ranges to the west of the Indus River. The study area defines an east-west to northeast-southwest trending fold-thrust belt system, located in central part of Trans Indus Ranges. The stratigraphic and structural architecture of these ranges depicts that the external most and latest thrusting has occurred along their fronts. The stratigraphic fabric comprises Cambrian to Eocene platform succession unconformably overlain by a thick pile of fluviatile molasse deposits. A number of potential reservoirs exist throughout the stratigraphic succession. It is therefore worthwhile to examine their reservoir potential in terms of their depositional settings, thickness, depth etc. to appraise hydrocarbon potential of different reservoirs. A study has been made based on integration of all the information including surface geology, field observations, available well data, available rock samples and petrographic analysis.

Geological Setting and Stratigraphy

The study area possesses northwestern boundary of the Indian lithospheric plate (Figure 1). Under thrusting of Indo-Pakistani Plate beneath the Eurasian Plate resulted in compressional tectonic features since Eocene until present on the northern and northwestern fringes of the Indo-Pakistani Plate. This continued under-thrusting produced the spectacular mountain ranges of Himalayas and a chain of foreland fold-and-thrust belts as thick sheets of sediments thrust over the Indian Craton. The Trans Indus Ranges and the Salt Ranges of the outer Himalayas constitutes the active deformational front of Kohat and Potwar Plateau. The Marwat-Khisor ranges are characterized by east-west to east-northeast structural trends. The Marwat Range is an anticlinal feature largely covered by the Pliocene-Pleistocene Siwalik Group rocks. The Khisor Range that lies south of the Marwat Range exposes Cambrian to Jurassic platform sediments, which are unconformably overlain by fluvial sediments of Siwalik Group (Figure 2). The platform sediments become thicker and more complete from east to west.

Reservoir Potential

Data of wells drilled in and around the study area, field observations and petrographic analysis shows that several potential reservoirs are present throughout the stratigraphic sequence in the study area. Details of various formations having reservoir potential are discussed below.

Cambrian

The Khewra Formation, classified as sublitharenite, only outcrops in core of Saiyiduwali anticline in southwestern part of Khisor Range (Figure 2). Its exposed thickness is over 137m as its base is not exposed (Figure 3a). Maximum thickness of over 325m is encountered in Isakhel-1 well. Based on plug data, measured porosity is 21.6% and permeability is 57.8 ka mD (Figure 3b). Wireline log data of surrounding wells also suggest the presence of good quality porous sandstone (Figure 3c). It is a proven reservoir in eastern Potwar area and produces hydrocarbons from Adhi, Missa Keswal, Rajian and Kal fields. The overall textural and compositional maturity and presence of glauconite indicate marginal marine setting where sediment input was from sandy river systems.

Permian

The Chiddru Formation, classified as lithic greywacke, is exposed in south and middle part of the Khisor Range where it is about 65m thick (Figure 2 and Figure 4a). A maximum thickness of 86m is encountered in the Marwat-01 well. Good porosity with wide-open fractures was observed in the formation (Figure 4b). Wireline log data of surrounding wells also confirm the presence of good porosity sands (Figure 4c). Based on grains, bioclasts, and cement, the formation represents siliciclastic shoreface to shallow marine environment.

Triassic

The Tredian Formation, classified as sublitharenite, is exposed in the Sheikh Budin area of the Marwat Range and the southern and northern part of the Khisor Range where it is 65m thick (Figure 2 and Figure 5a). A maximum thickness of 91m was encountered in the Chonai-1 well. Based on plug data, the measured porosity is 26% and permeability is 105.5 ka mD (Figure 5b). Wireline logs of surrounding wells also indicate presence of good porosity sands (Figure 5c). We interpret this as deposited in a high-velocity flow fluvial environment.

The Kingrialli Formation is classified as peloidal-bioclastic grainstone. It is exposed in the Khisor Range where it is 195m thick (Figure 2 and Figure 6a). Based on plug data, the measured porosity is 0.6% (Figure 6b). Wireline logs of surrounding well suggest the presence of 5-8% porosity (Figure 6c). Secondary porosity most likely developed by leaching and solution activity. The Kingrialli dolomite is a proven reservoir in the Chanda Deep well. We interpret this as deposited in a wave-dominated, shelf environment near platform interior like bars, sand shoals and carbonate beach.

Jurassic

The Datta Formation, classified as sublitharenite, is exposed in the extreme western part of the Khisor Range, it is over 350m thick (Figure 2 and Figure 7a). A maximum thickness of 357m was encountered in the Chonai-1 well. Based on plug data, the measured porosity and permeability is in range of 18-30% and 31-515 ka mD, respectively (Figure 7b). Wireline logs of surrounding wells suggest the presence of thick sands with an average porosity of 20% (Figure 7c). It is a proven reservoir and producing oil and gas at Dhulian, Toot, Meyal and Ratana fields in the western Potwar area. We interpret this to be deposited in a fluvio-deltaic transitional environment.

The Samanasuk Formation is classified as a bioclastic peloidal grainstone, exposed on the northeastern plunging end of the Sheikh Budin anticline (Figure 2 and Figure 8a). A maximum thickness of 306m was encountered in the Pezu-1 well. Based on plug data, the measured porosity is 0.7% (Figure 8b). Wireline logs indicate the presence of 2-3% porosity (Figure 8c). The formation is reported to have produced oil and gas in the Kohat area. The formation was deposited on a shallow shelf with open and restricted marine conditions as carbonate platform depositional product.

Cretaceous

The Lumshiwal Formation consists of sandstone with interbeds of shale, exposed on the northeastern plunging end of the Sheikh Budin Anticline where it is 56m thick (Figure 9a). The formation is well developed in the western part of the Trans Indus ranges but thins towards the east and pinches out in the central part of the Marwat Range. A maximum thickness of 405m was encountered in the Pezu-1 well. The average porosity is 20% and permeability in Chonai-1 well is around 500mD. Wireline logs indicate the presence of thick sands with an average of 25% porosity (Figure 9b).

Conclusion

Shallow marine/deltaic clastics of the Mesozoic and Paleozoic show potential reservoirs in the study area with a good range of porosity and permeability values. Carbonate sequences also have good potential where enough fracture density exists. Great potential for economic reservoirs exist within the clastic sequence Khewra (Cambrian), Warcha and Chiddru (Permian), Tredian (Triassic), Datta (Jurassic) and Lumshiwal (Cretaceous) as well as the carbonate sequences Kingrialli (Triassic) and Samanasuk (Jurassic). Surface geology along with drilling activity shows ample thicknesses of the reservoir formations to be economical. Due to limited availability of data, recognition of continuity in facies along with approximation of depths to different reservoirs is a challenge faced in carrying out a successful exploration program. Nevertheless, with additional seismic a better understanding of the facies distribution and reservoir characteristics of different formations would develop, thereby reducing the exploration risk.

Acknowledgements

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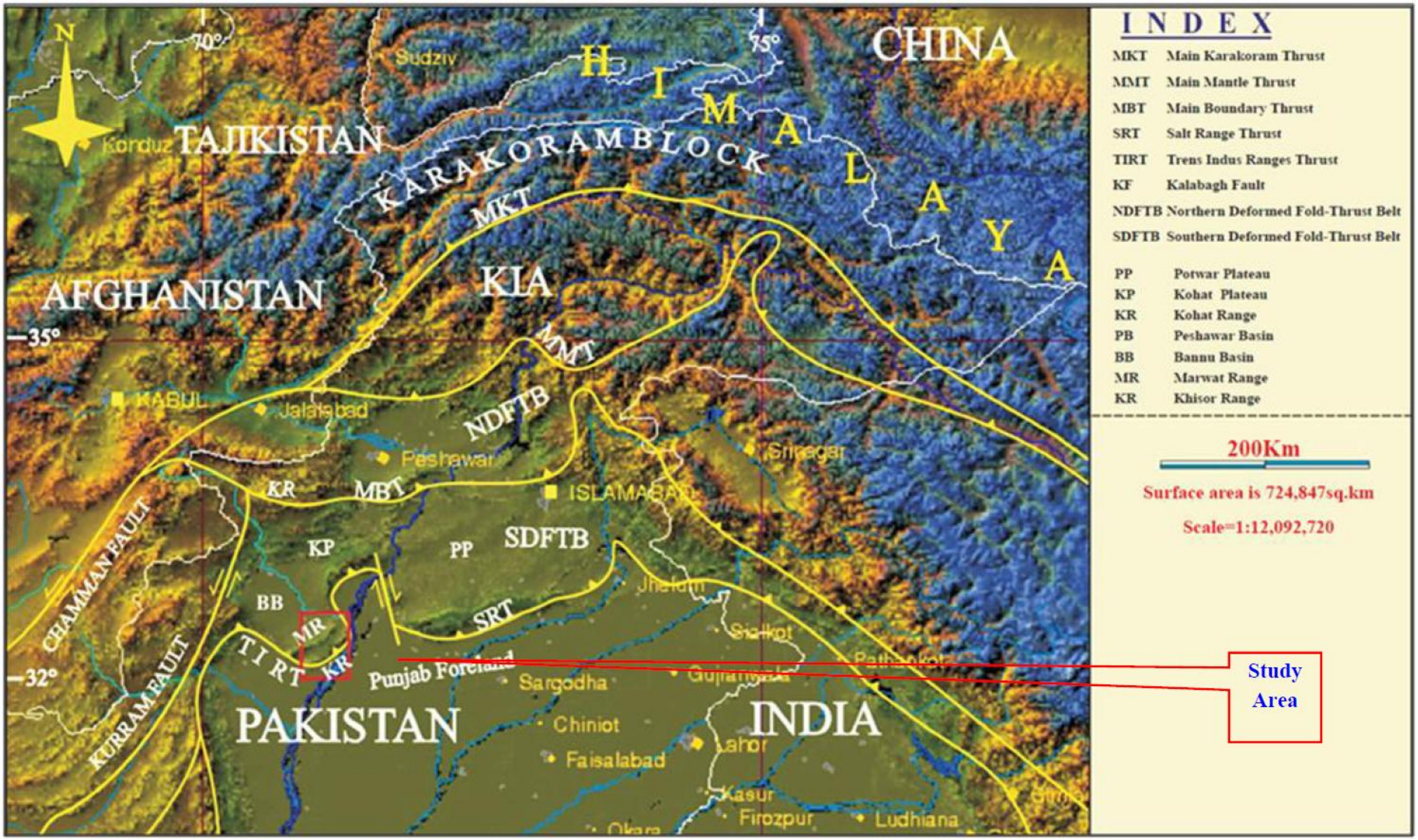

Figure 1. Regional tectonic framework.

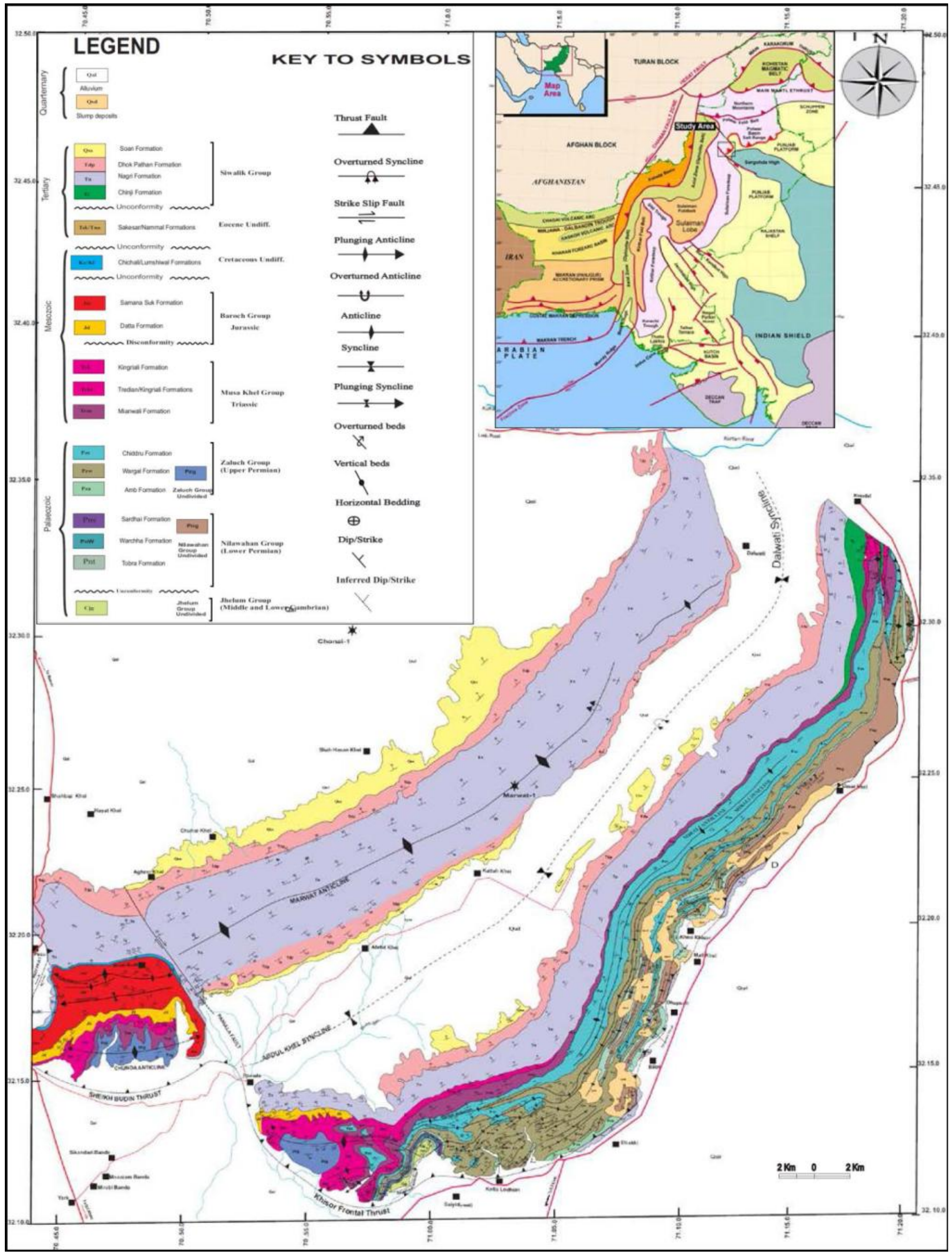

Figure 2. Geological map of the study area.

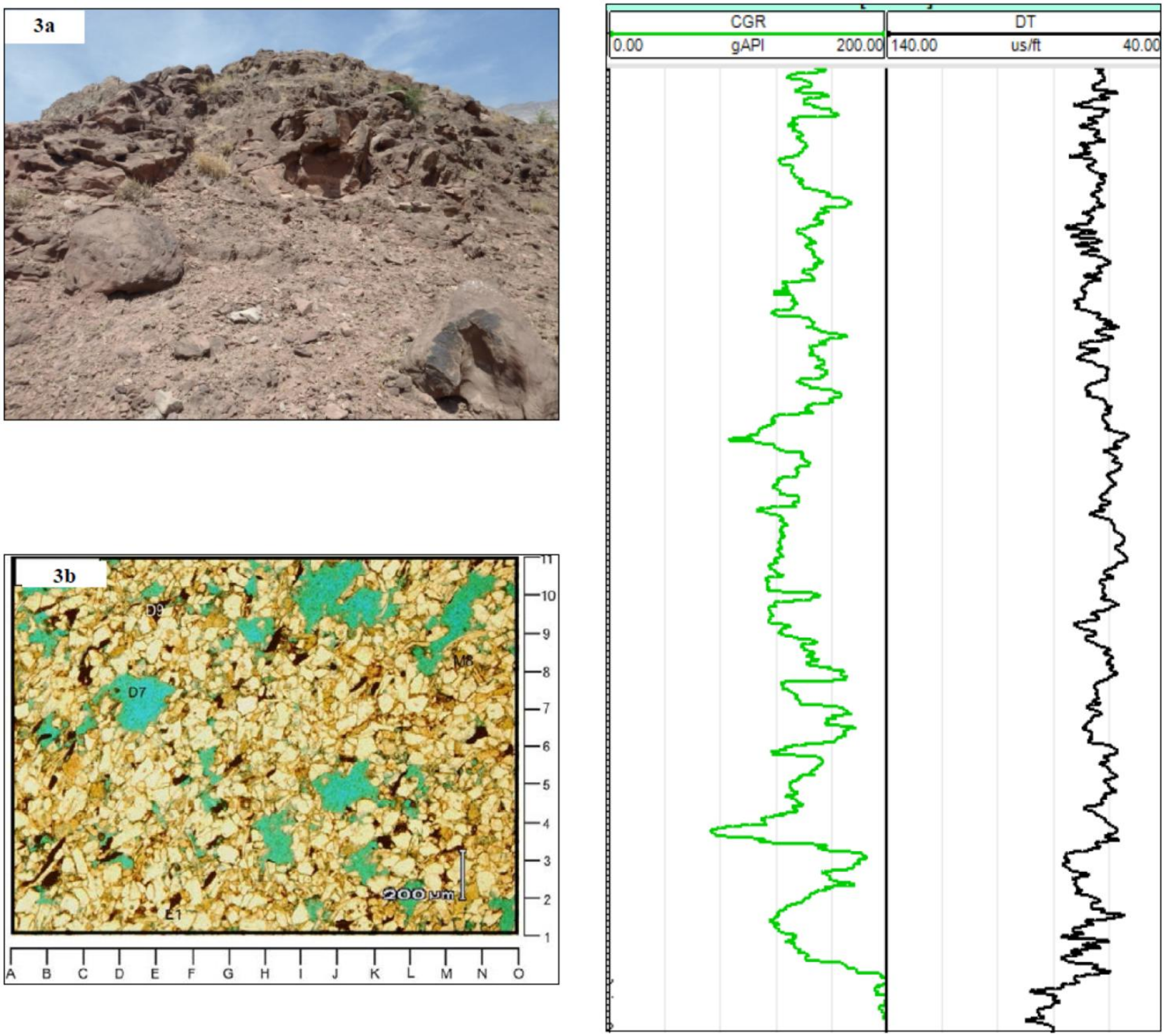

Figure 3. a) Khewra Sandstone; b) showing opaque mineral (D9), mica (E1), glauconite (M8) and porosity (D7). Grains are closely packed and mostly long to pointed contact (Mag X04); c) wireline log response of nearby well for Khewra Formation (151m).

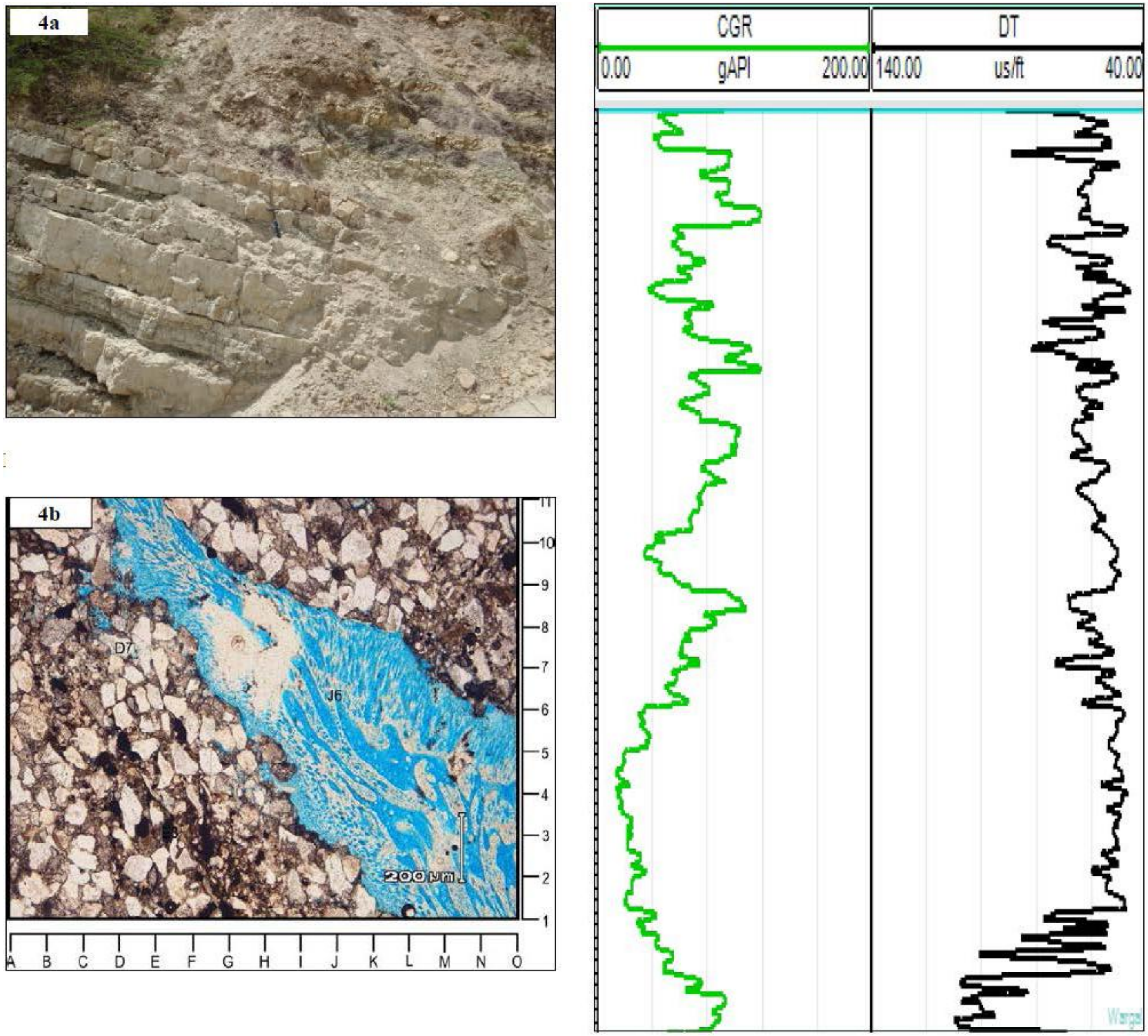

Figure 4. a) Chiddru Sandstone; b) showing open stylolite fracture (J6) represents fractured porosity, opaque mineral (E3) and monocrystalline quartz (D7) (Mag X04); c) wireline log response of nearby well for Chiddru Formation (74m).

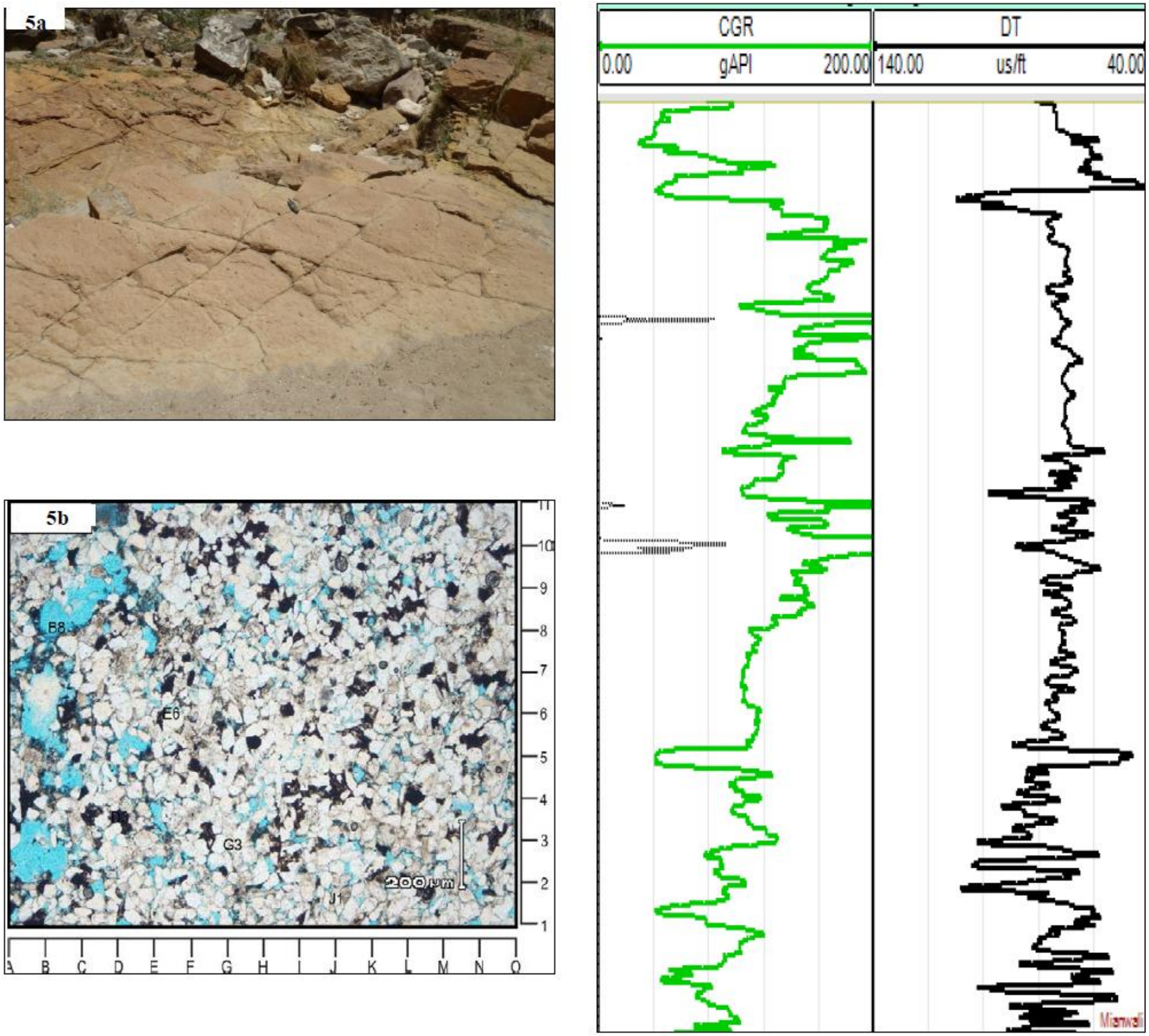

Figure 5. a) Two set fractures in Tredian Sandstone; b) showing monocrystalline quartz (F6), mica (G3), intergranular porosity (B8) and plagioclase (JI) embedded in oxidized matrix (D3) (Mag X04); c) wireline log response of nearby well for Tredian Formation (91m).

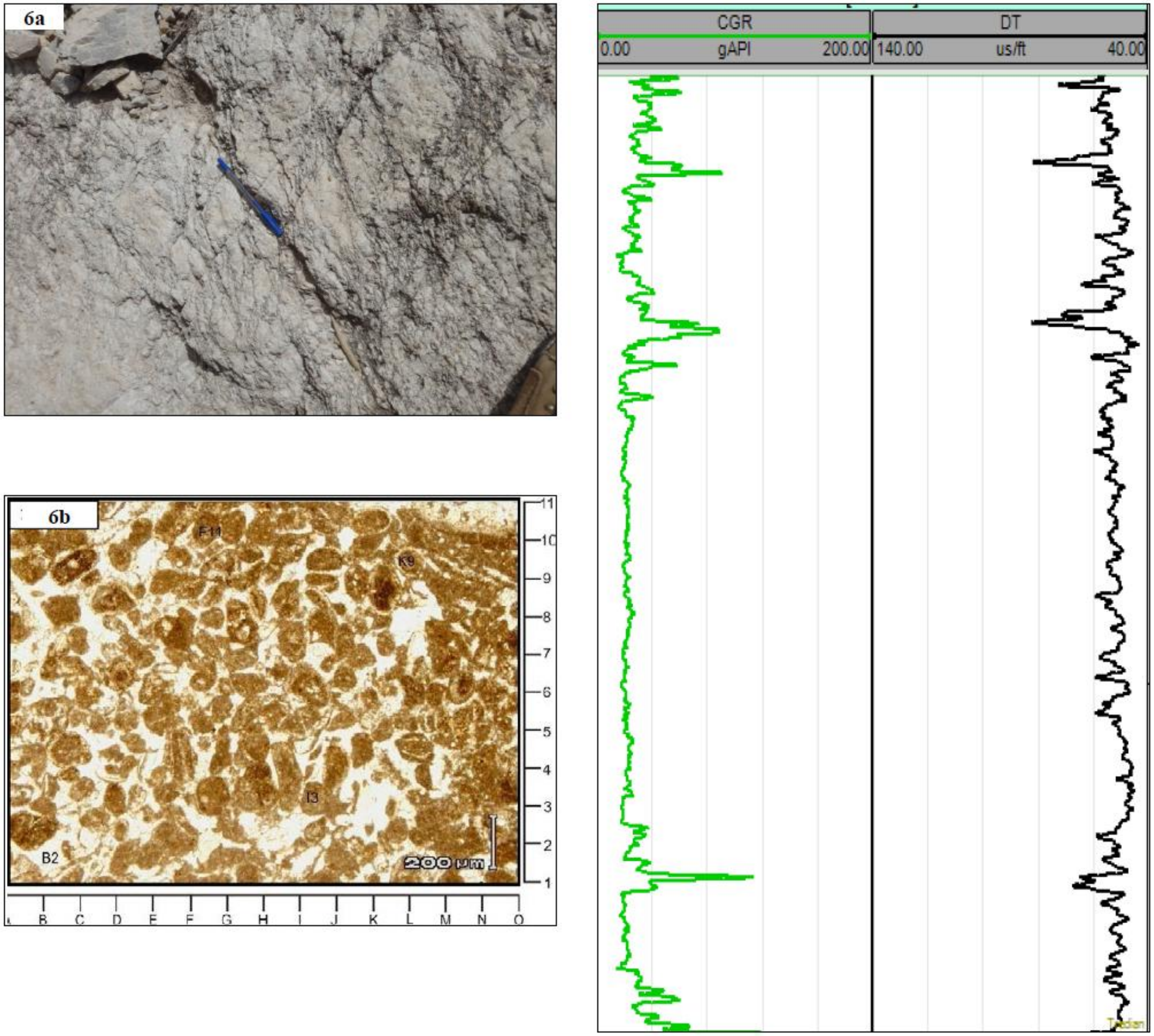

Figure 6. a) Two set fractures in Kingrialli Dolomite; b) showing peloidal-bioclastic grainstone displaying peloid (IB), micritized biserisal foram (F11) and ooid (K9) embedded in granular mosaic cement (B2) (Mag X04); c) wireline log response of nearby well for Kingrialli Formation (124m).

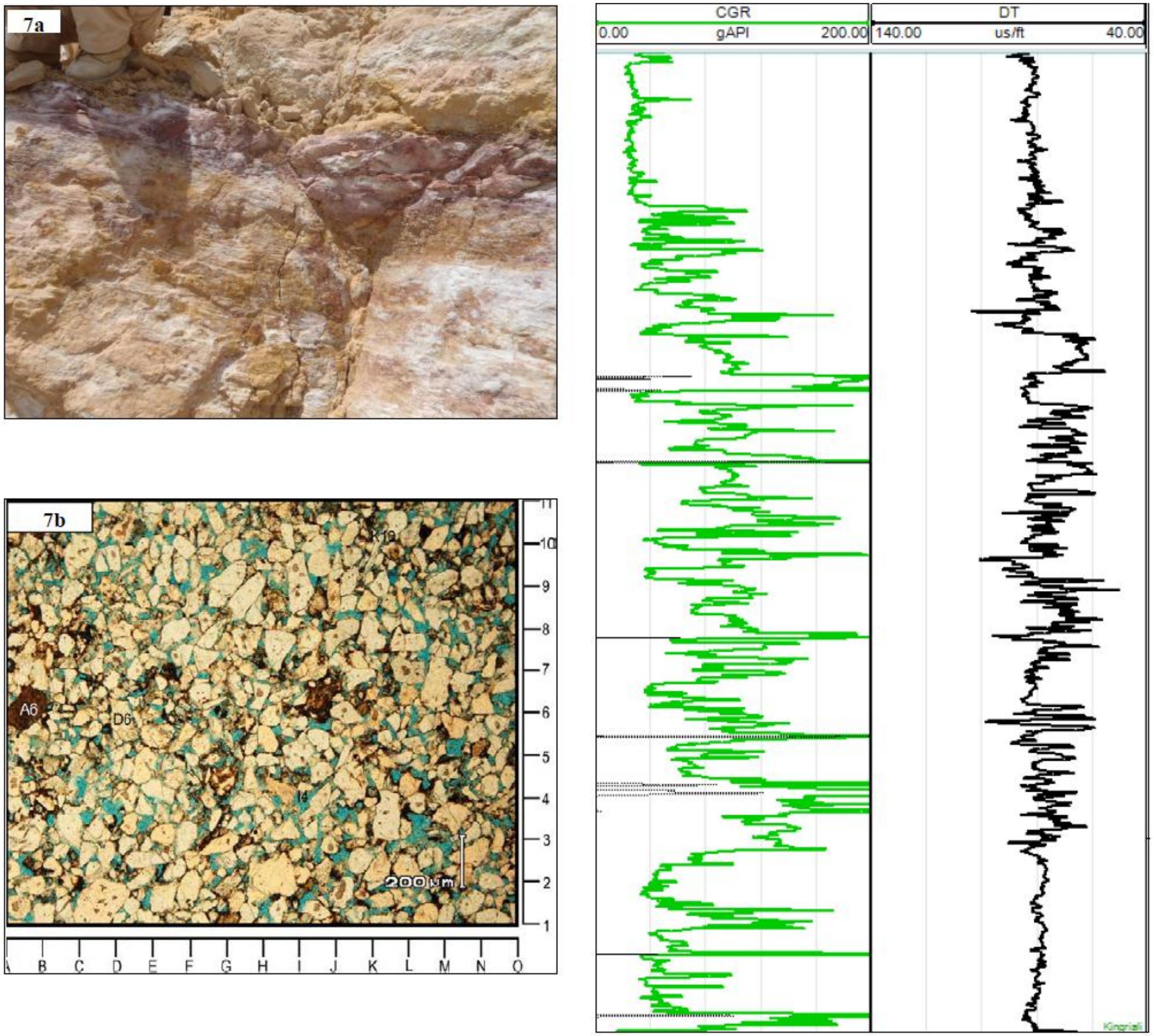

Figure 7. a) Datta Sandstone; b) showing zoned plagioclase (D6), mica (KIO), fractured quartz (D5), rock fragment-siltstone (A6), intergranular effective porosity and high permeability (I4). Grains are loosely packed and mostly pointed contact (Mag X04); c) wireline log response of nearby well for Datta Formation (350m).

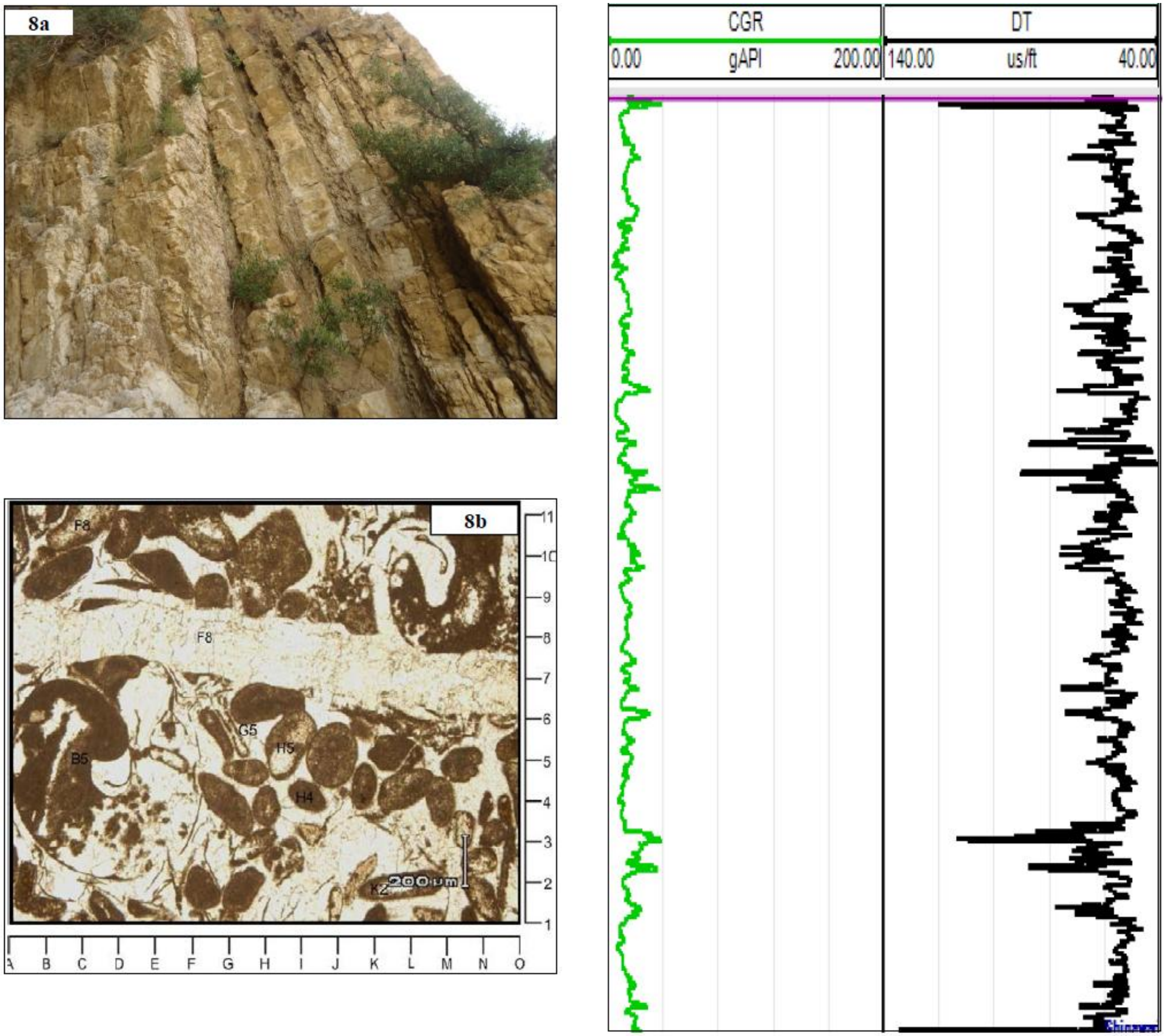

Figure 8. a) Samanasuk Limestone; 8) showing peloidal-bioclastic grainstone displaying peloid (H4), lumpy micritized ooid (H5), gastropod (B5), fracture (F8) and micritized algae (K2) embedded in sparry cement (G5) (Mag X04); c) wireline log response of nearby well for Samanasuk Formation (190m).

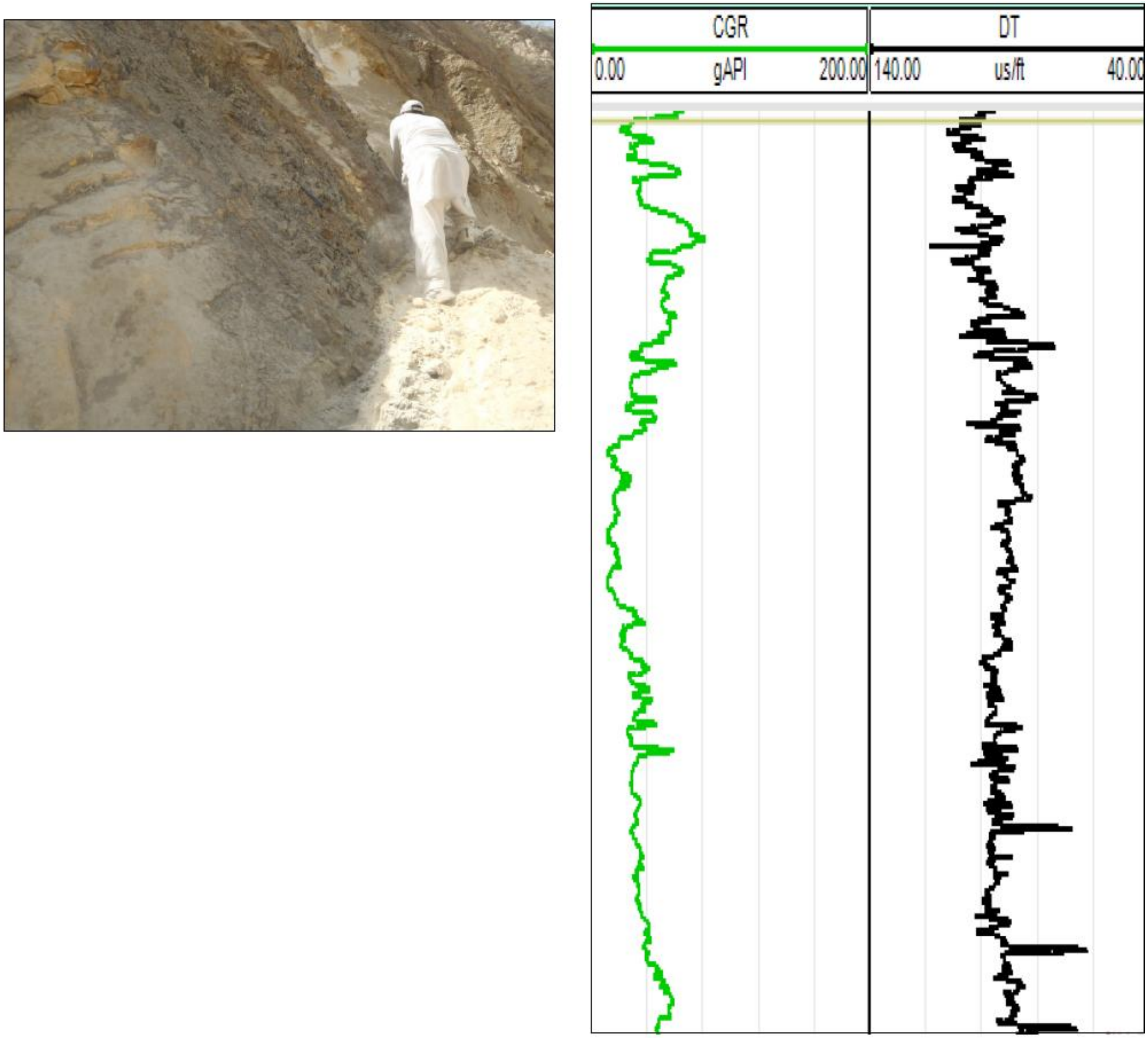

Figure 9. a) Very friable Lumshiwal Sandstone; b) wireline log response of nearby well for Lumshiwal Formation (165m).