Exploring and Evaluation of Paleozoic Saudi Arabian Sand for Proppant Applications*

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Abstract

Hydraulic fracturing that was started in 1949 has been dramatically increased over the past few years which has been resulted in a huge demand of quality sand to be used as proppant. The increasing demand has created a supply and demand gap. This study presents results on experimental work on Saudi Arabian sandstone for possible use as proppant, especially local sand of northern and central Saudi Arabia, as well as the comparison in characteristics of equivalent sandstone from south Saudi Arabia. This work includes the characteristics of Paleozoic sandstone in the light of characteristics of proppants and research on the laboratory experiments.

A total 27 represented sandstone samples from 8 different locations were collected for this analysis, which includes the Paleozoic Siq, Quweira and Qasim formations as well as their members Sajir and Kahfah. Samples preparations included disaggregation and washing. For grain size analysis, an X-ray particle size analyzer was used after that the selected samples were sieved using API ISO 19C stack to make them representative. Clean sand was graded to sieve size distributions of 20/40, 30/50 and 50/70 for detailed qualitative and quantitative analysis. Bulk density was measured for every sample, microscopic analysis was done to determine the sphericity and roundness of the sands using the Krumbein and Sloss chart. A crush test was performed on 18 selective sand samples following API recommended practice 56 and ANSI/API 19C, applying 2000 and 3000 psi pressure. Finally, Scanning Electron Microscope (SEM) and EDS analysis were done to understand morphology and mineralogy. Sieve analysis revealed that the Siq Formation in two locations is 20/40 and 40/70, and representative samples have bulk densities of 1.395 gm/cc and 1.397 gm/cc. Crush tests at 2000 and 3000 psi pressure respectively, resulted in first 18.34% fine, then the second one produced 5.76% of fine at 2000 psi whereas the 40/70 representative sample produced 12.37% of fine at 3000 psi. Most of the samples of other formations were 30/50 representative and produced more than 10% of fine at 2000 psi. Only five samples produced less than 10% fine at 2000 psi but more than 10% at 3000 psi. Bulk density of most sand samples is 1.38 to 1.41 gm/cc, which is lower than the equivalent sand from south Saudi Arabia (Wajid Group, Bulk density 1.68 gm/cc). SEM analysis reveals enormous fracture and dissolution features on the sand surface which may be due to the oxidation and longtime chemical reaction from surface exposure that reduces their bulk density.

The analyzed sand samples of the Siq, Quweira and Qasim formations are fine- to medium-grained and moderately sorted. Different depositional environments are responsible for their variation in texture (grain size, sorting and shape). The Siq Formation was deposited directly on the basement as braided stream deposits, the Quweira is fluvial to intertidal deposits, the Sijir Member is fluvio-marine and the Kahfah Member was deposited in a shallow marine to near shoreface environment. Other controls such as origin of detrital sources, tectonics, climate, weathering and transport history played a role as well on these variations.

In conclusion, the Paleozoic sand in south Saudi Arabia of the Wajid Group (fluvial, shallow marine and glacial deposits) is better than the sand of central and northern Saudi Arabian in terms of strength. But these sands can be used as low-grade sand for hydraulic fracturing. Certain exploratory and evaluation measures might be needed and introduced for selection of suitable sand resources; by identifying sand from certain detrital sources that have optimum recycling and weathering history. This is in addition to some necessary processing and treatment to improve the Saudi natural sands quality.

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Outline

- Introduction
- Methodology
- Results and Discussion
- Conclusions
- References

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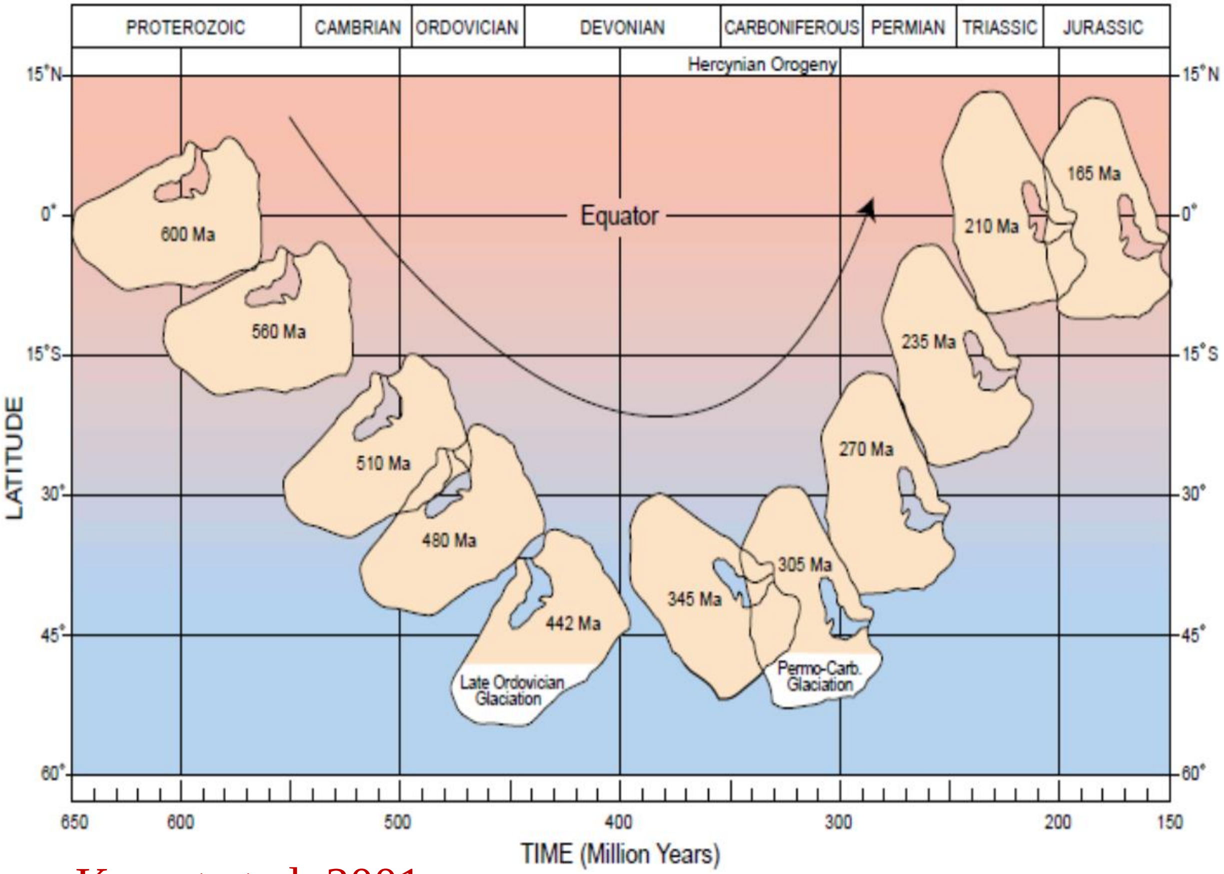
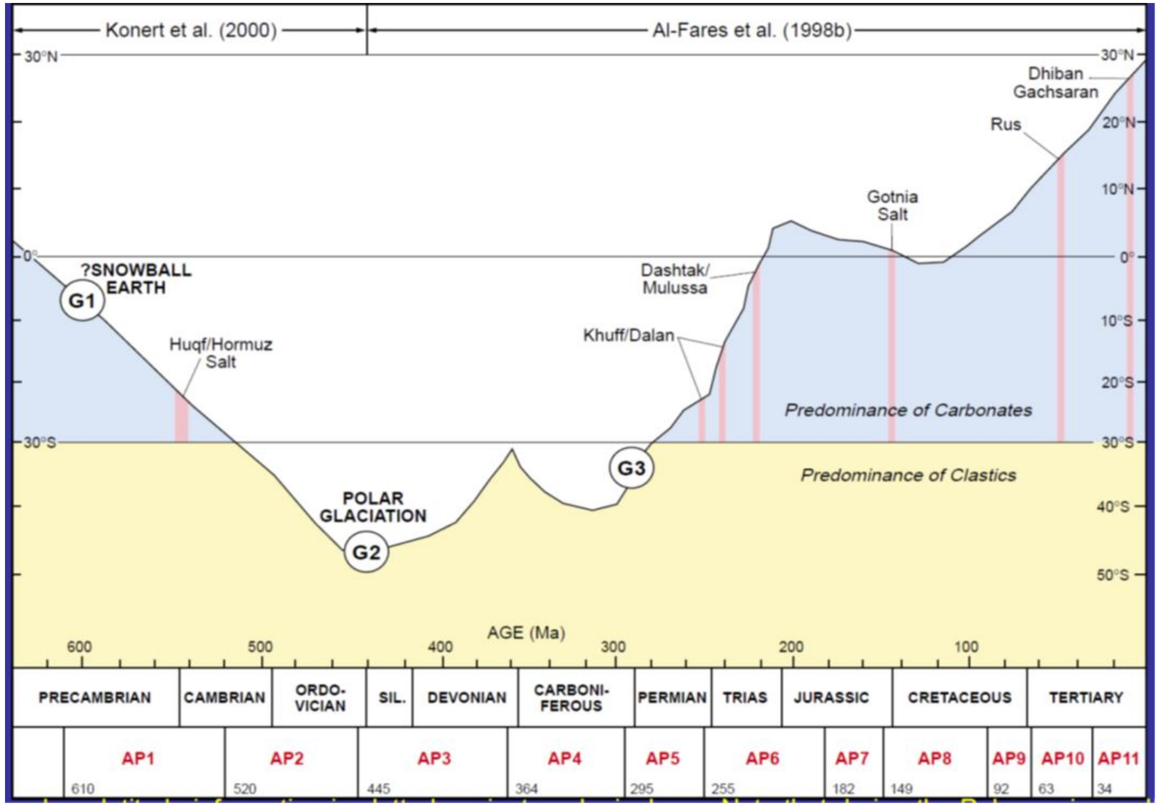
Introduction

- Paleozoic formations are mostly clastic sediments and rich in sandstone & shale because of paleo depositional environment.
- They are distributed covering 600000 square km area across Saudi Arabia, Oman, Yemen and UAE (Garzanti et al. 2003).
- Saudi Arabia has a large reserve of unconsolidated sand and sandstone reserve.

Geological Setting in Paleozoic



Konert et al. 2001



Al Fares et al. 1998b; Konert et al. 2000

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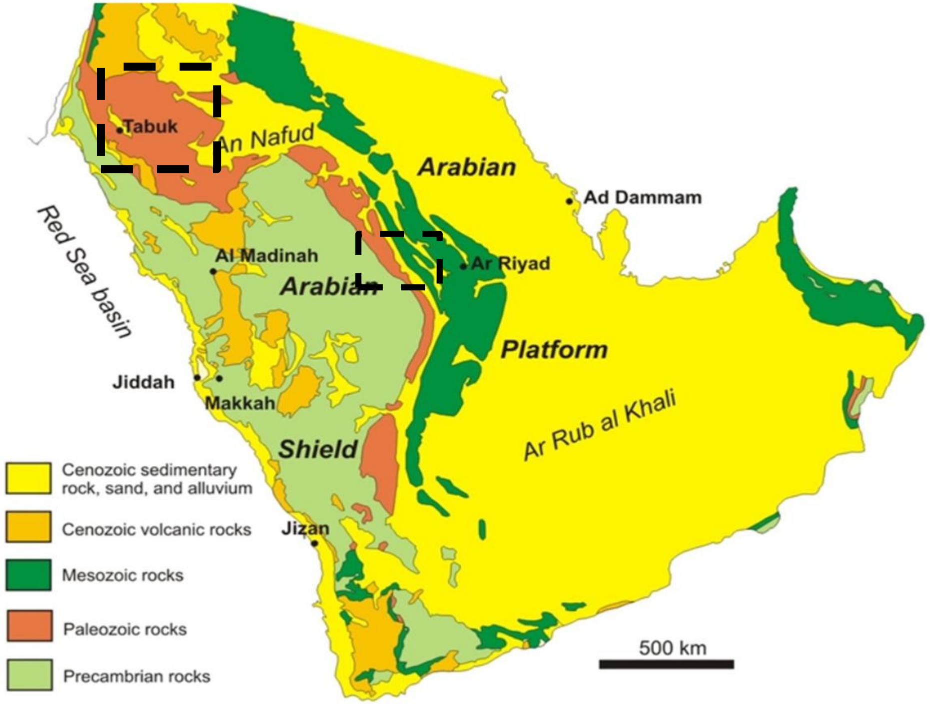
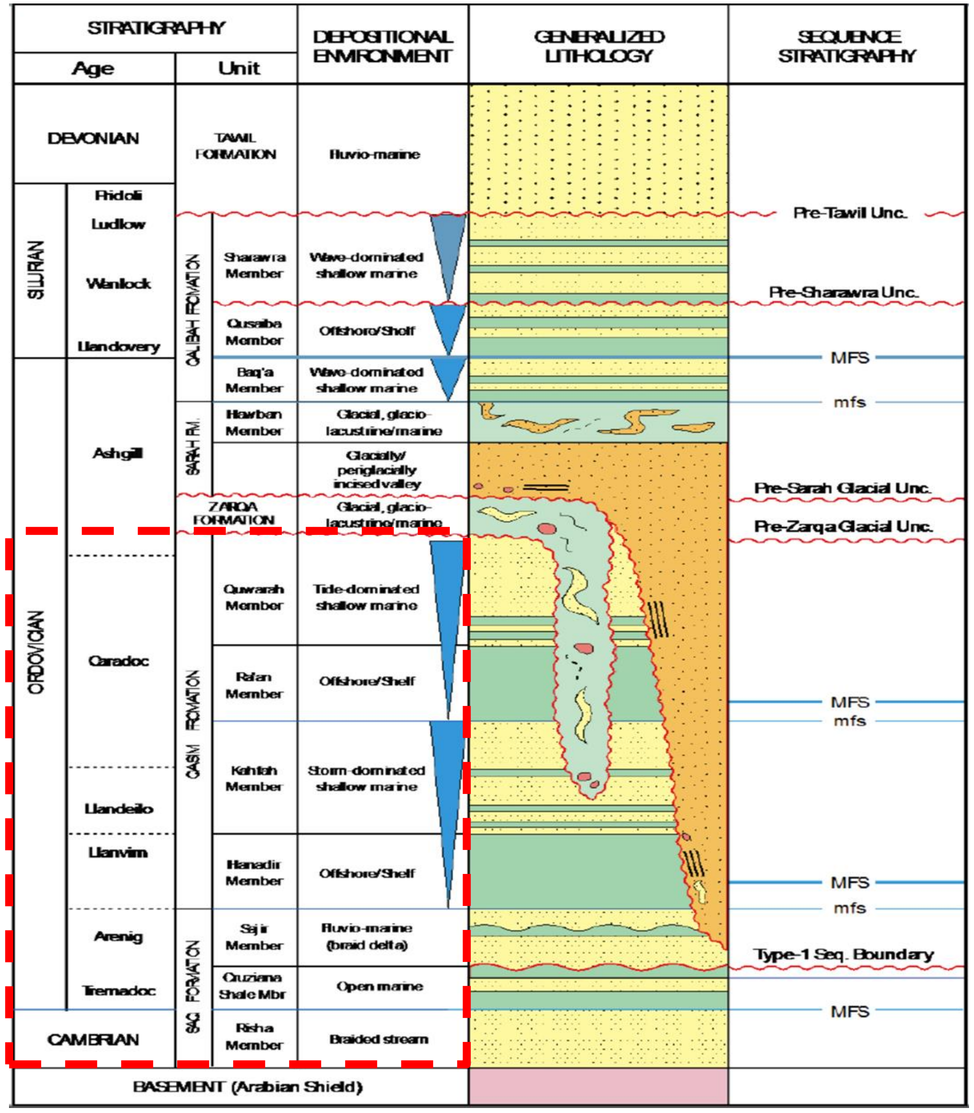
Study Area

- Total 27 sand samples
- 15 Selected for analysis



Courtesy: Saudi Geological Survey

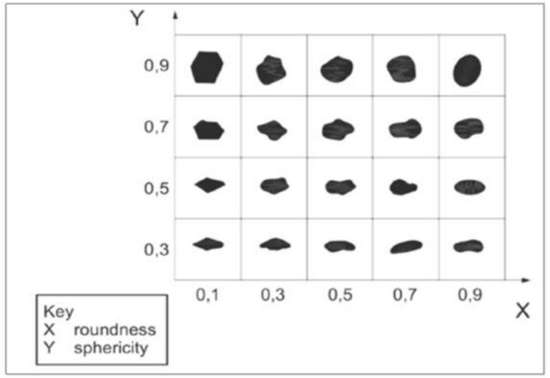


Paleozoic Stratigraphy of Central Saudi Arabia (after GeoArabia)

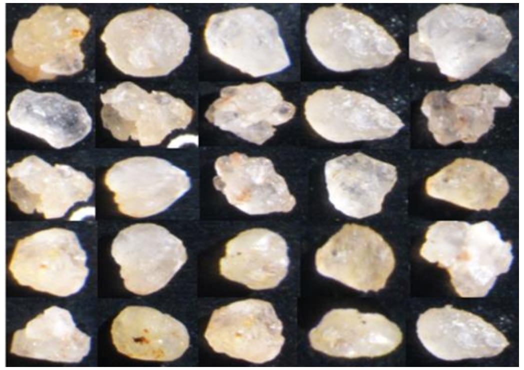
Laboratory Methodology

Washing

X-ray particle size analysis



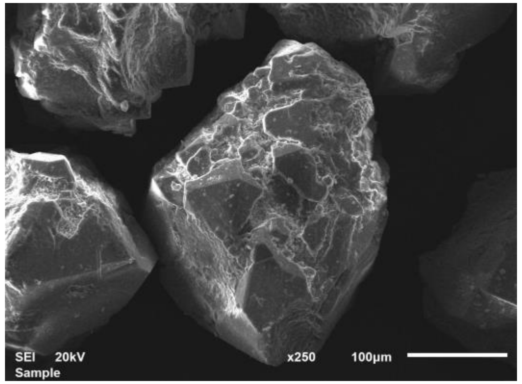
Krumbin and Sloss chart



Sand Morphology

Sieving

Crush Resistance Test



SEM analysis

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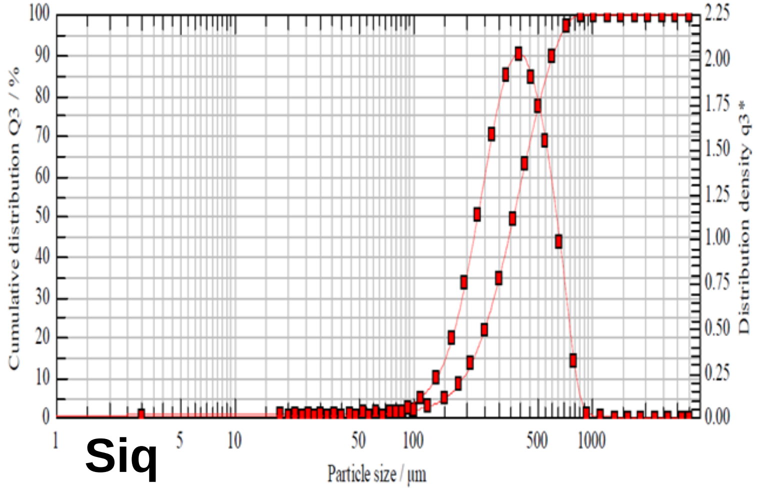
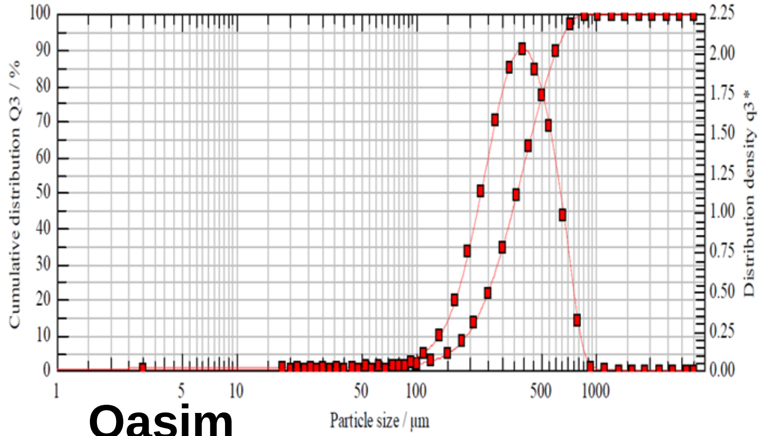
Results and Discussion

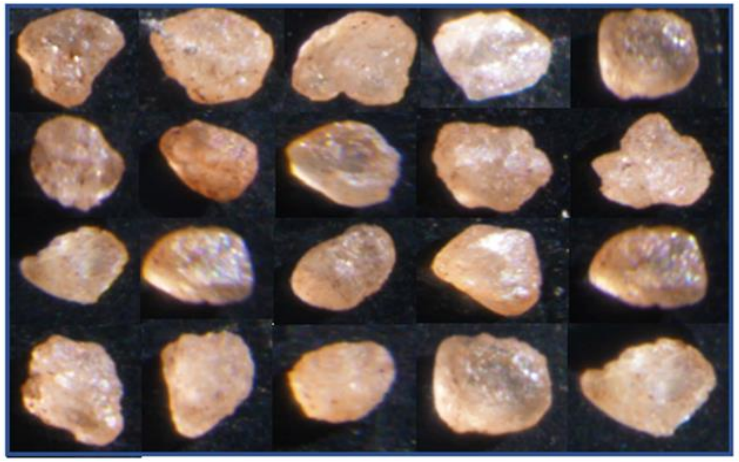


Siq

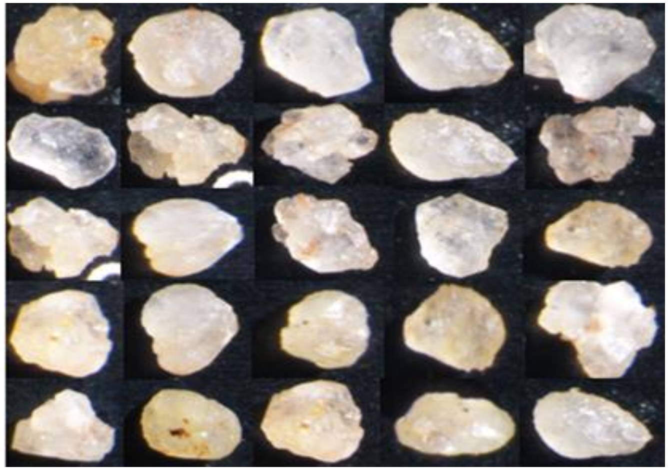


Qasim

X-ray particle size analysis



Siq

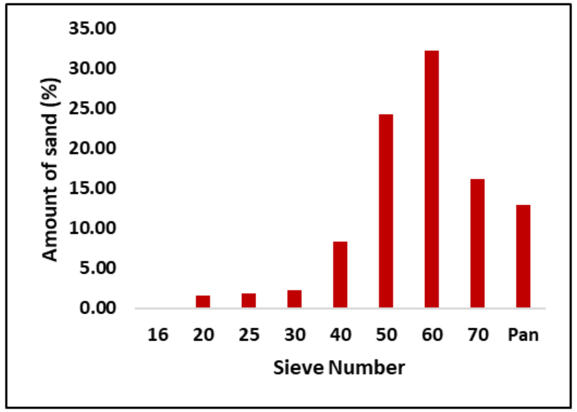


Qasim

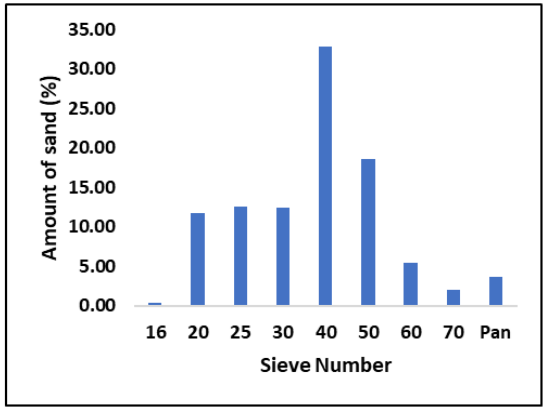
Sand morphology

Formation/Member	Sphericity/Roundness
Siq	0.877 / 0.688
Quweira	0.90 / 0.80
Sajir	0.80 / 0.70
Kahfah	0.84 / 0.68

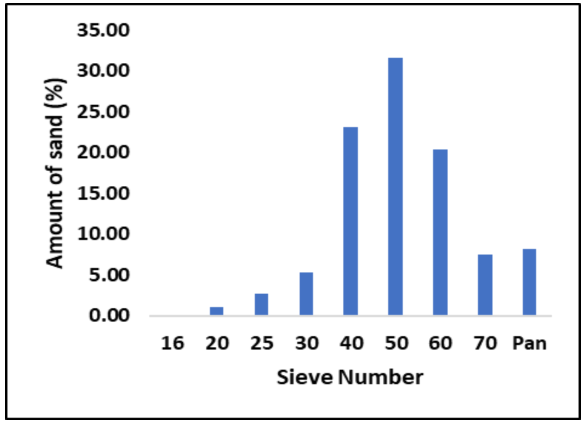
Results and Discussion



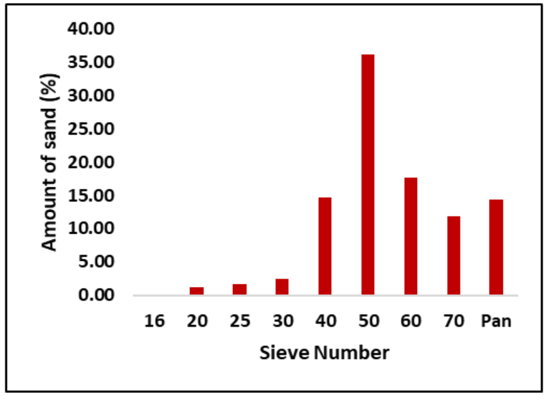
Siq 40/70



Siq 20/40



Quweira 30/50



Sajir 40/70

Sample Id	Representative
L-19-U5-Quweira	40/70
L-19-S4-Quweira	30/50
L-43-U1-S2-Quweira	30/50
L-42-S-4-U4-54-Quweira	30/50
L-73-S2-Quweira	Fine
L-73-S1-Quweira	Fine
L-6-S-6	40/70
SS-5	30/50
15-Qasim	Fine
Ce-6	Fine
S-14 (Kahfah)	40/70
L-7-Sajir-S3	30/50
L-7-Sajir-S1	30/50
L-2-U6-A Siq	40/70
L-2-U2-Siq	20/40

Sieve results according to API ISO 19C practice

Results and Discussion

Sample Id	Representative	Bulk Density (gm/cc)	%Fine @2000 psi	% Fine @ 3000 psi
L-19-U5-Quweira	40/70	1.403	9.82	18.25
L-19-S4-Quweira	30/50	1.477	10.57	42.94
L-43-U1-S2-Quweira	30/50	1.452	19.6	-
L-42-S-4-U4-54-Quweira	30/50	1.384	29.27	-
L-6-S-6 Sajir	40/70	1.409	9.22	15.03
SS-5	30/50	1.388	23.33	-
S-14 Kahfah	40/70	1.468	7.17	10.23
L-7-Sajir-S1	30/50	1.434	24.06	-
L-2-U6-A Siq	40/70	1.397	5.76	12.37
L-2-U2-Siq	20/40	1.395	18.34	-

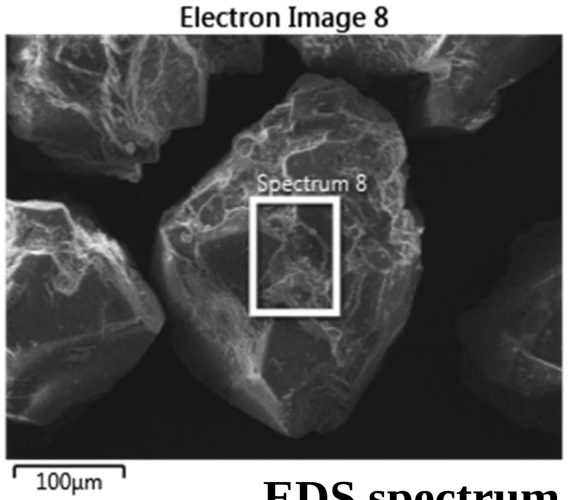
Crush resistance test results according ANSI/API 19C, Practice 56

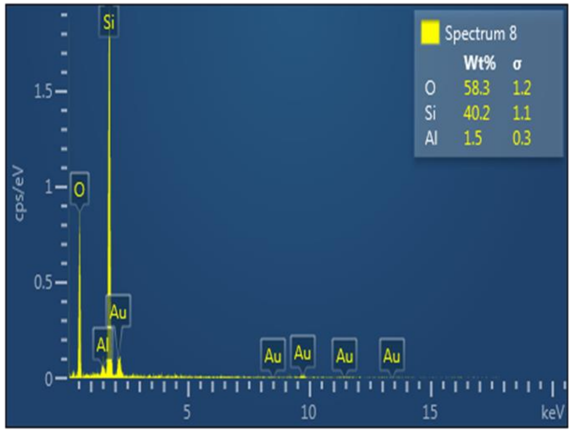
Area	Avg. Sphericity/ Roundness	Bulk Density (gm/cc)	Crush Resistance Test Result
Northern Saudi Arabian	0.857 / 0.717	1.395	5-10% fine at 2000 psi but more than 10% at 3000 psi
Southern Saudi Arabia	0.79 / 0.64	1.680	Avg. 6% fine at 2000 psi but more than 9 % at 3000 psi

Comparison between Northern and Southern Saudi Arabian sand.

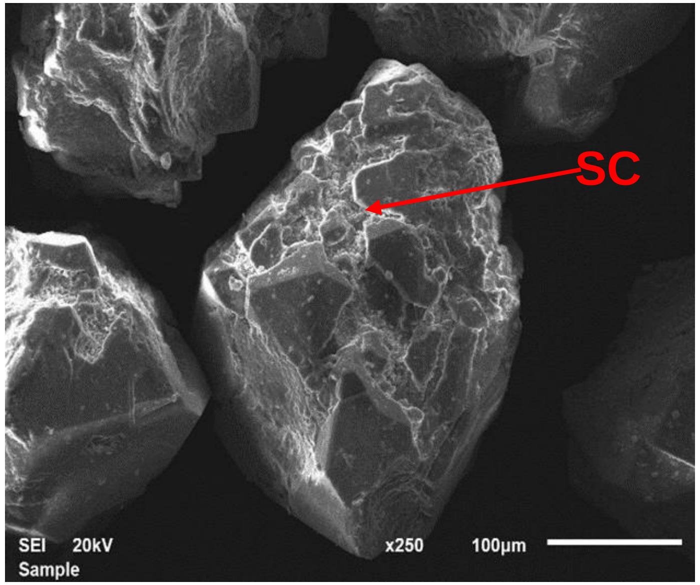
(Data of Southern Saudi Arabia after Benaafi M. et al,.2016)

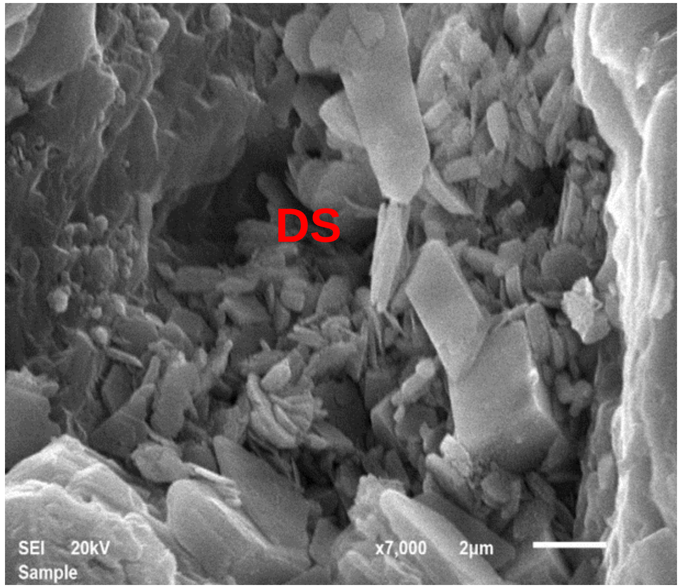
Results and Discussion



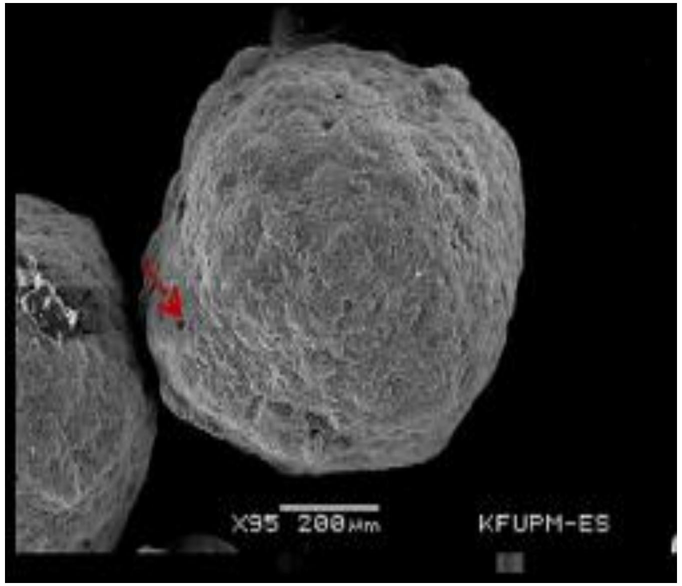


EDS spectrum of Siq sandstone shows SiO_2





SEM image of Siq formation with Surface Crack (SC) and Dissolution Surface (DS)



High Strength Proppants
Ibrahim et al. 2018

Conclusions

- Different depositional environments are responsible for the variation of their grain size which is braided stream, fluvio-marine to nearshore face setting.
- Paleozoic natural sands of central and northern Saudi Arabia can be used as low graded frack sand for hydraulic fracturing.
- Certain exploratory and evaluation measures might be needed and introduced for selection of suitable sand resources.
- This can be done by identifying sand from certain detrital sources that having optimum recycling and weathering history.
- Paleozoic sand of South Saudi Arabia of Wajid group is better than the sand of Central and Northern Saudi Arabian in terms of strength.
- Quality of natural sands could be improved by certain measures, such as selection of collection sites, processing and applying some treatments.

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