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SIEVE ANALYSIS FOR THE PURPOSE OF SELECTING SAND PRODUCTION CONTROL DEVICES

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Abstract

Sand production for the sandstone reservoirs is a major difficulty that needs to be remedied early in the life of the reservoir. Sieve analysis of the core samples is an effective and straight forward methodology to tackle the problem. The work presented here was for a prolific thick sandstone reservoir in an off-shore field in Iran. Core samples were crushed to the grain size and standard sieve analysis was performed. Characterization of grain size distribution was achieved by sieve analysis based on statistical parameters. Four statistical measurements for the sieved samples were performed. The strategy produced the most probable grain size of 200 microns and 150 microns for the upper and lower layer, respectively. This helped in selecting the appropriate wire wrapped screen or slotted liner for preventing sand production. This proved to be effective and no sand production is presently observed with this design of completion. In addition, statistical analysis revealed some correlation between sorting of grain size and permeability of the cores but no correlation with sand grains mean size. However, as expected the porosity increased directly with sorting and it had no correlation with the sand grains mean size.

1. Introduction

The main purpose of the project was estimation of the mean size of sands and the size of sand which had the maximum population for a prolific off-shore sandstone formation in the south of Iran. This was achieved by sieve analysis. The off-shore oil reservoir from Burgan formation has the same geologic characteristics of well-studied formation in the Persian gulf region common with Kuwait, Saudi Arabia and some other oil-rich countries of the region (Al-Ajmi and Azim, 2003, Stromenger, et al, 2002, Ahlbrandt, et al, 2000). The reservoir of interest consisted of two layers: Burgan A and Burgan B.

The Burgan sands are believed to have been deposited as delta sediments. The Burgan source area began rising during the later Upper Shuaiba time, silt and shale with some occasional thin carbonate beds are inter-bedded over the field and surrounding areas. Due to the rise of the source area at the beginning of Burgan B deposition, a thick layer of sand was deposited, probably as a delta of numerous streams.

During Burgan A sand deposition no regression of the sea had happened, but further transgression occurred which resulted in the deposition of silts and clay particles. Even traces of carbonates were deposited during Burgan A sand depositional period. An interbedded sequence of sand, silt and clay particles was the product of rises and falls of the sea during Burgan A time. Some of the beds cover a wide area but some others are very limited in their lateral extent over the field. The deposition of Burgan A was ended with a major transgression of the sea and with the deposition of limestone beds on top of the Burgan A sand known as Dair Limestone. The Dair Limestone member covers the entire area in the field and surrounding areas and it indicates the end of Burgan deposition.

The Burgan is further defined as a sequence of fairly well sorted, medium to coarse-grained sands, usually loosely packed, and with interbeds of shale and silt shale and abundant amber and bituminous matter. The Burgan sandstone is cemented by carbonate and clay. The upper sand stringers in Burgan A are very fine grained sand (silt

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size) and generally have poorer rock characteristics. The sand grain size generally becomes coarser and exhibits better porosity and permeability towards the base of Burgan A. The basal portion of the Burgan (Burgan B) consists of medium to coarse, unconsolidated sandstone. Since the Burgan B sand is generally clean and has very coarse grains (it resembles beach sand in most cases), it has on the average higher porosity and permeability than the Burgan A.

Geological study of Burgan reservoirs shows that there are several unconsolidated sand layers in these reservoirs. In unconsolidated sand reservoirs, cementation between sands does not exist and the sands can slip and move over each other and migrate from sand body to the well and then to the production tubing. The visual observation of cores also confirms this point and it should be considered in well completion design. Slotted liner and Screener are two type of bottom hole well completion as sand control devices, which restrict the sand migration and settle them beyond the tubing but inside the well.

The well completion design specifically for Screener or Slotted liner requires some information about texture and mean size of sands. The mesh size of openings on sand control device must be less than the mean size of sands so that the accumulation of sands beyond them could occur. Accumulation of sands over the sand controller device makes considerable pressure drop across the production conduit due to occupying the flowing area. Reduction in production rate causes reduction in income and profits of production, so the design of sand controller mesh sizes should be optimized to compensate the economic and hydraulic considerations.

2. Sieve Analysis

Sandgrain sizes are most generally measured by sieving. The basic principle of this technique is as follows. A sand sample of known weight is passed through a set of sieves of known mesh sizes. The sieves are arranged in downward decreasing mesh diameters. The sieves are mechanically vibrated for a fixed period. The weight of sediment retained on each sieve is measured and converted into a percentage of the total sediment sample. This method is quick and sufficiently accurate for most purposes.

Both graphic and statistical methods of data presentation have been developed for the interpretation of sieve data. The percentage of the samples in each class can be shown graphically in bar charts or histogram. Another method of graphic display is the cumulative curve or cumulative arithmetic curve. Cumulative curves are extremely useful because many sample curves can be plotted on the same graph and differences in sorting are at once apparent. The closer a curve approaches the vertical the better sorted it is, as a major percentage of sediment occurs in one class. Significant percentages of coarse and fine end-members show up as horizontal limbs at the ends of the curve.

Sorting can be expressed by various statistical methods. The simplest of these is the measurement of the central tendency of which there are three commonly used parameters: median, mode, and mean. The median grain size is that which separates 50% of the sample from the other; the median is the 50 percentile. The mode is the largest class interval. The mean is variously defined, but a common formula is the average of the 25 and 75 percentile.

A second aspect of sieve analysis is its sorting or the measure of degree of scatter. Sorting is the tendency for the grains to fall in one class of grain size. Several formulas have been used to define this parameter for a sample.

A third property of a grain size frequency curve is termed "kurtosis" or the degree of "peakedness". Curves, which are more peaked than the normal distribution curve, are termed "leptokurtic"; those, which are saggier than the normal, are said to be "platykurtic".

The fourth property of a sieve analysis is its skewness, or degree of lop-sidedness. Samples weighted towards the coarse end-members are said to be positively skewed (lop-sided toward the negative phi values), samples weighted towards the fine end are said to be negatively skewed (lop-sided toward the positive phi values).

In summary, the four statistical measurements for sieved samples consist of a measure of central tendency (including median, mode, and mean); a measure of the degree of scatter or sorting; kurtosis, the degree of peakedness; and skewness, the lop-sidedness of the curve. Various formulae have been defined for these parameters. Sieve analysis presented here follows the approach and definitions presented by Folk and Ward (1957).

3. Results and Discussion of Results

As mentioned earlier, the purpose of sieve analysis in this project was to estimate the mean size of the sand grains in Burgan formation. Two important parameters for this purpose are Percentage of the Total Sediment (PTS) and Cumulative Percentage of the Total Sediment (CPTS) retained. The cumulative percentage of retained is calculated by adding percentage of the total sediment of sample in every stage with the percentage of the total sediment of previous stage. The benefit of working with cumulative percentage of retained is reliability of estimation of mean and to observe distribution of the data as well. Fortunately, the sieve test results of each sample have been reported (Nemati, et al., 2003) in both Percentage of Total Sedimentation (PTS) and Cumulative Percentage of the Total Sediment (CPTS).

Figures 1 and 2 are examples of PTS histogram and CPTS graph of one core sample from Burgan formation. The complete set of the histograms for all the core samples studied is reported elswhere (Khadivi and Vossoughi, 2005).

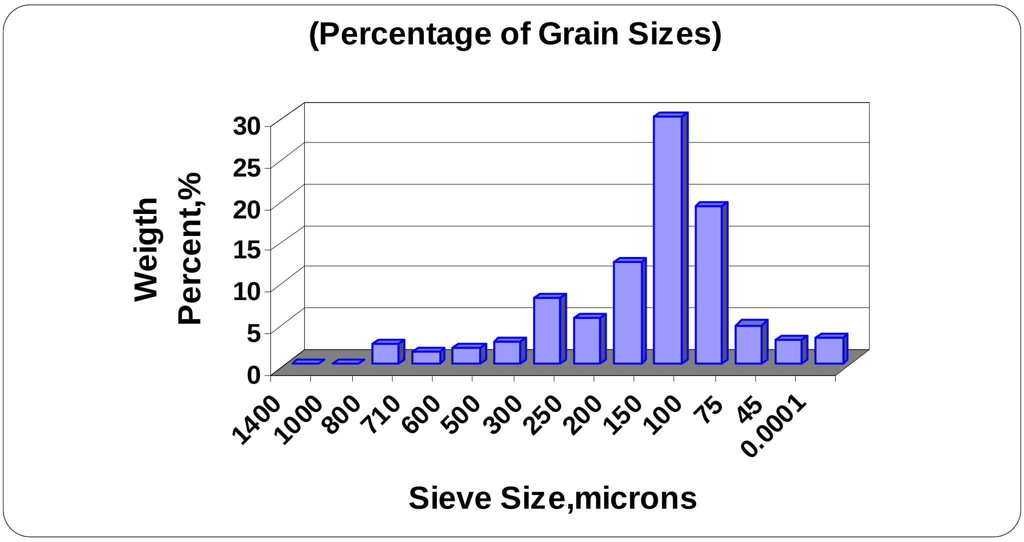

Figure 1. Percentage of retained for core no. C1B28

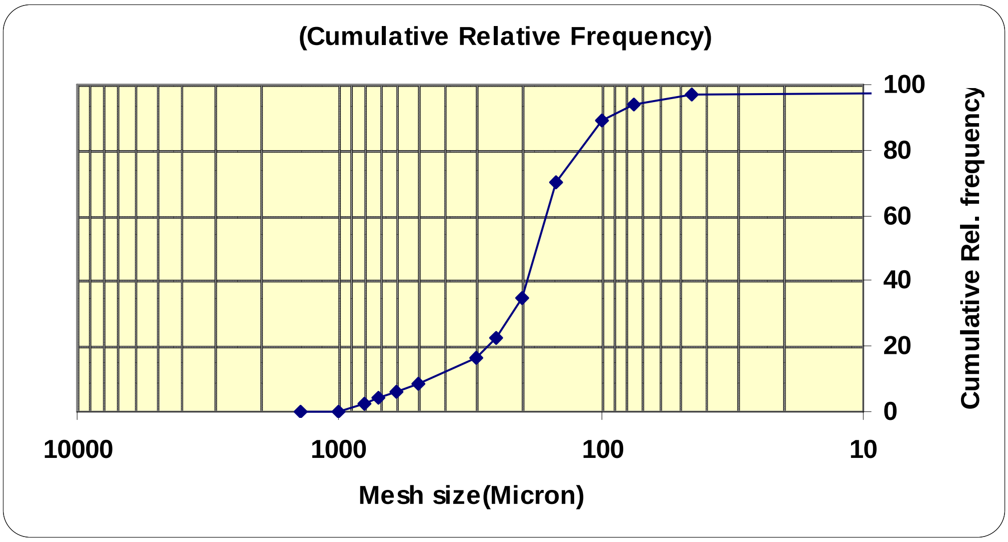

Figure 2. Cumulative percentage of retained for core no C1B28

Figure 3 is an exhibition of values of sorting and mean for all of the cores from Burgan A and Burgan B formations. No significant dependency seems to exist between these two parameters; however, an important conclusion over this graph is that both parameters exhibit similar behavior over the depth intervals in both reservoirs. Despite the fact that Burgan A seems to be heterogeneous (sand/shale sequence), the sorting is uniform in Burgan A. On the other hand, Burgan B, which seems to be more homogeneous, shows varying sorting values with high fluctuation in the top and lower variability at the bottom. Figure 3 compares the mean size and sorting of grain sizes in both reservoirs. As this figure shows, these trends track each other in Burgan A and top of the Burgan B. In the lower part of Burgan B, "sorting" remains almost constant while the "mean" decreases in stepwise fashion. It means, in spite of variation of grain sizes ("mean" decreasing), the relative amount of different sizes (sorting) remains constant. The value of "sorting" is quite high (0.9) in this zone, which means Burgan B is substantially a homogeneous media and consequently is a high porous and permeable zone.

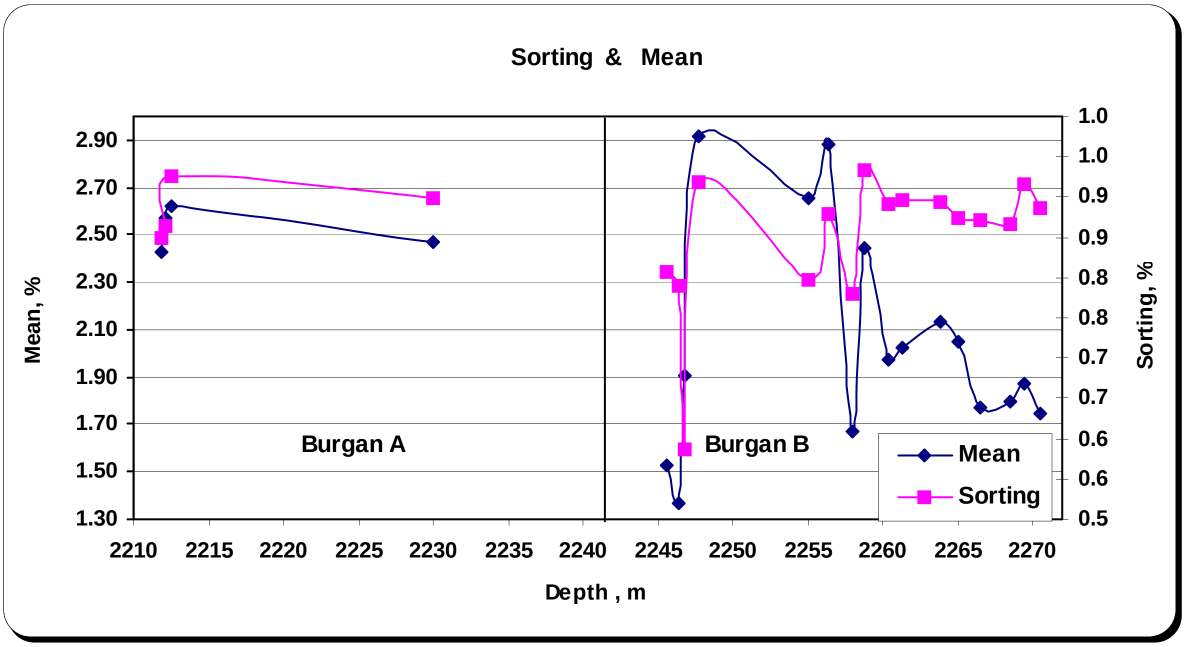

Figure 3. Sorting and “mean” variation with depth

In order to investigate the relationship of “sorting” and “mean” parameters with permeability, permeability and “sorting”, and permeability and “mean” have been plotted versus depth in Figures 4 and 5, respectively. Permeability and “sorting” seem to have better correlation than permeability and “mean”. Comparison of porosity with “sorting” and “mean” is presented in Figures 6 and 7, respectively. Correlation between porosity and “sorting” is evident from Figure 6 (especially for Burgan B region); however, no correlation exists between porosity and “mean” values.

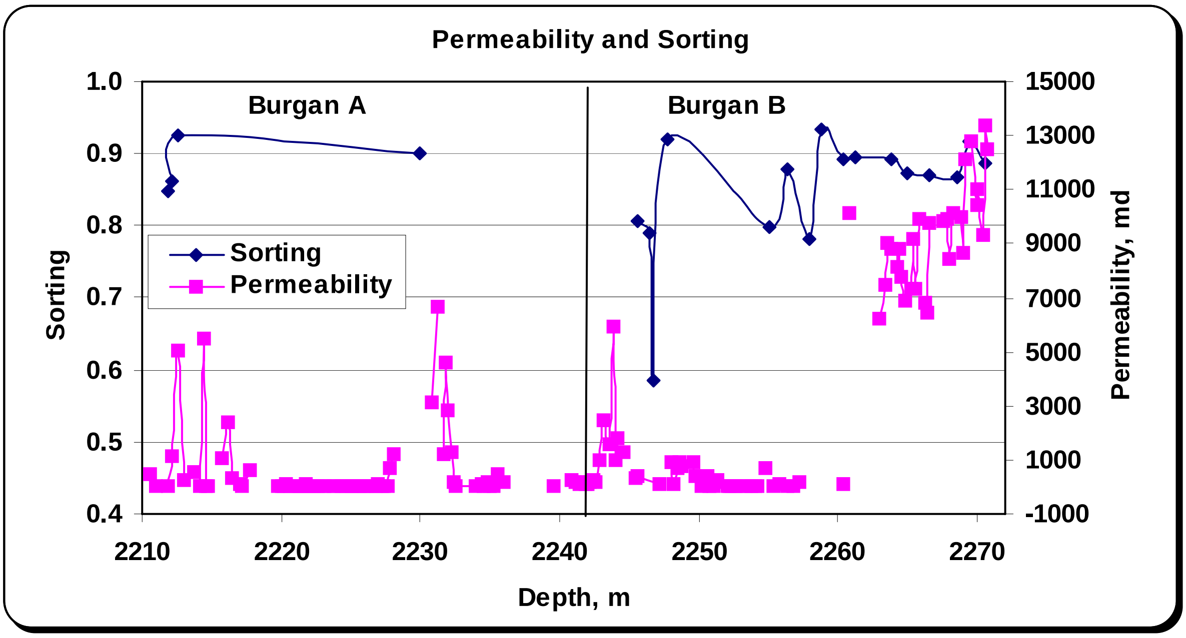

Figure 4. Permeability and sorting variation with depth

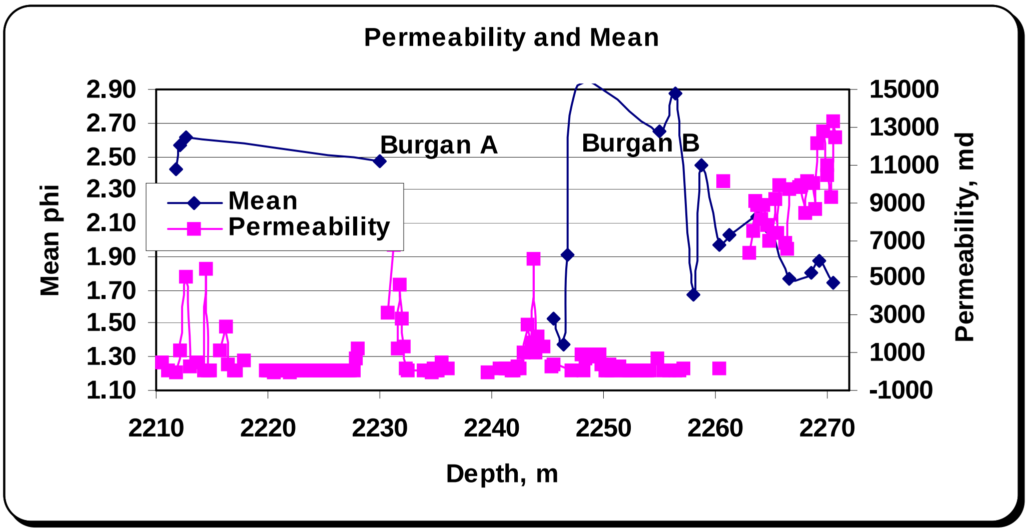

Figure 5. Permeability and "mean" variation with depth

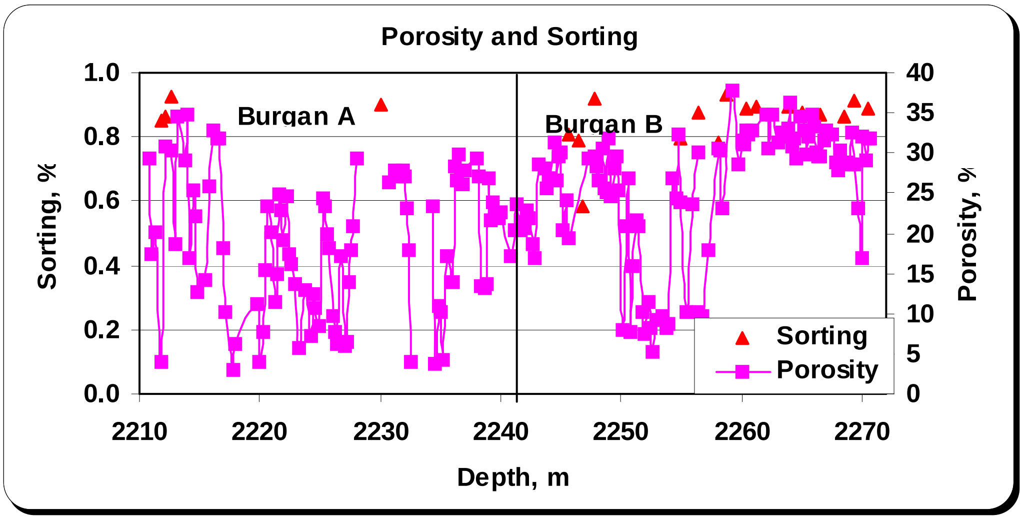

Figure 6, Porosity and sorting variation with depth

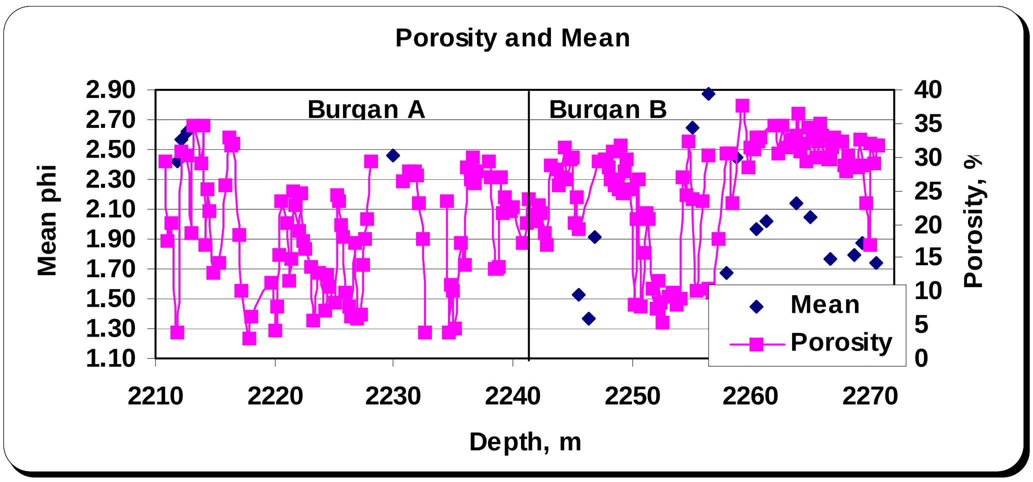

Figure 7. Porosity and "mean" variation with depth

Variation of porosity and permeability with depths is compared for Burgan A and B in Figures 8 and 9, respectively. As observed, there is good correlation between porosity and permeability in Burgan A and especially in Burgan B, where the permeability curve follows the porosity curve very closely. The permeability-porosity cross plot (not shown here) also confirms this correlation. Hence, based on porosity and permeability data and confirmation from sorting and mean trends (Figure 3), existence of very well sorted and high permeable sand layer at the base of Burgan B is detected.

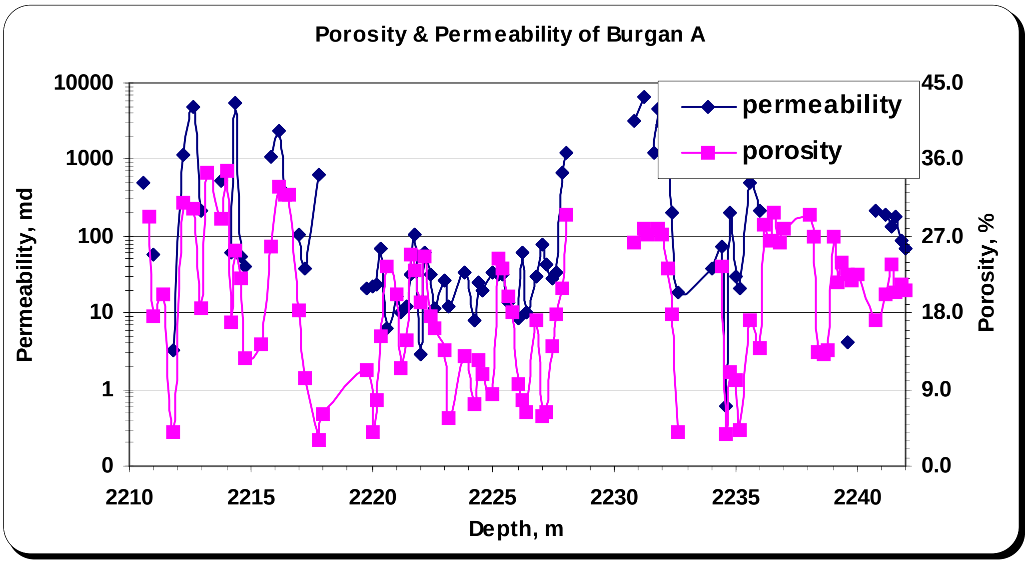

Figure 8. Porosity and Permeability variation with depth in Burgan A

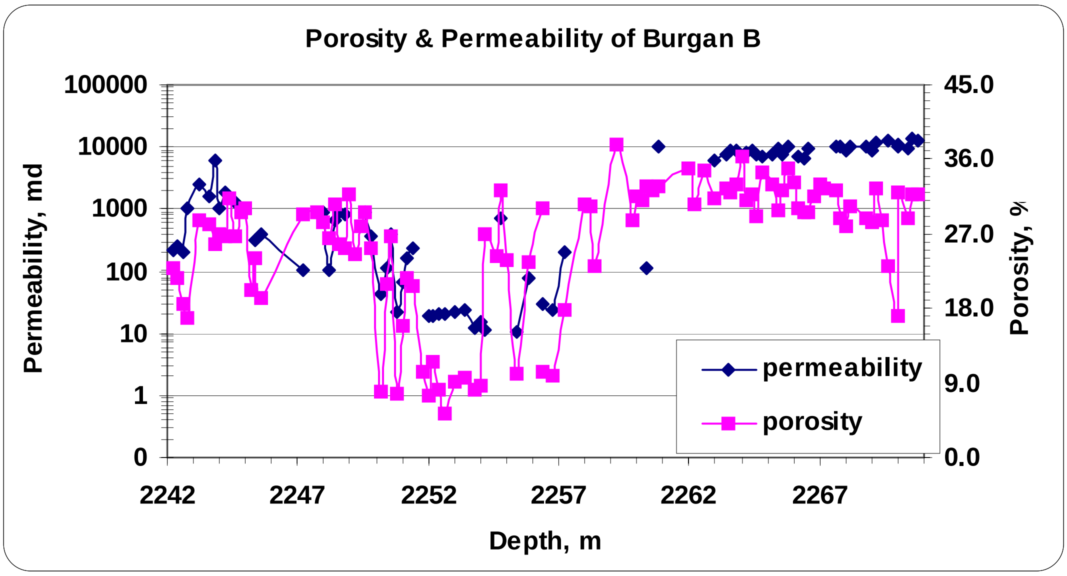

Figure 9. Porosity and Permeability variation with depth in Burgan B

The main purpose of sieve analysis presented here was estimation of the most probable size of sand grains in each reservoir. After computing the “mean”, “sorting” and other statistical parameters, it became clear that the calculated mean value based on the mean values of the cores does not represent the true mean value for the entire reservoir intervals. The existence of heterogeneity in Burgan reservoirs and uncertainties in Burgan A resulted doubtful conclusions. Therefore, a different methodology was devised to estimate the mean sandgrain size over the entire samples of each formation. In effect, all the cores taken from a given formation were considered to have been grinded together for the sieving purposes. In the former case, statistical values such as minimum, maximum, and average size of sediment grains were determined for each core. Further, distribution of these values for the entire depth of the formation was determined and the statistical values for the entire formation were generated. In the latter case, statistical values were generated not for the individual core but for the entire depth of the formation. The physical significance of this approach will be simply mixing all the sand grains generated for the entire formation for sieving purposes. It is believed that the latter approach is more suitable for the purpose of this study being to select a suitable wire wrapped screen or slotted liner for preventing sand production.

Based on this approach an appropriate variable would be total weight of sediments (TWS) retained on each sieve. Curves of "minimum", "average" and "maximum" based on Total Weight of Sediments (TWS) distributions are plotted in Figures 10 and 11 for Burgan A and B, respectively. The x-axis of Figures 10 and 11 is based on "Phi" scale which is defined as following,

$$\Phi(phi) = -Log_2[Mesh\ Size\ (microns)] \tag{1}$$

That is, the mesh sizes are decreasing from left to right on the x-axes in these figures.

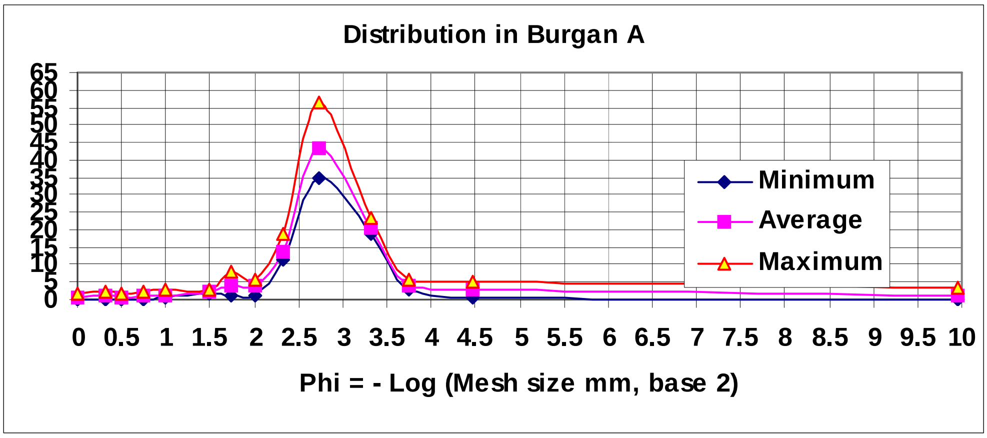

Figure 10. Curves of maximum, average and minimum of TWS retained for Burgan A

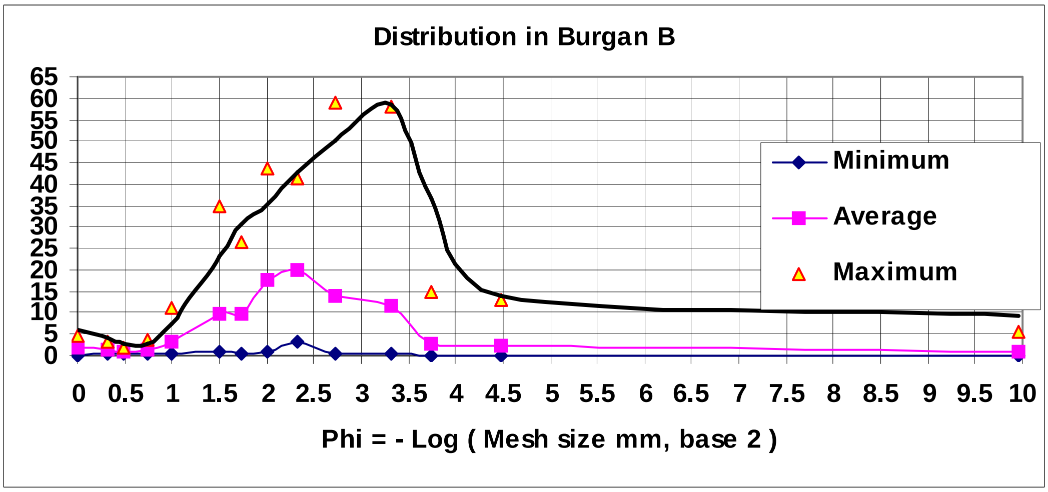

Figure 11. Curves of maximum, average and minimum of TWS retained for Burgan B

Figure 10 is a strong leptokurtic histogram of distribution of very well sorted sand grain sizes in Burgan A. The most probable size based on this histogram is 150 microns (2.737 unit phi). Figure 11 presents histograms of distribution of sand grain sizes in Burgan B. The shapes of "minimum" and "average" histograms are more or less leptokurtic to very leptokurtic and histograms are almost unimodal. The most probable size based on "minimum" and "average" histograms is 200 microns (2.32 unit phi). In Burgan B the "maximum" histogram, is negatively skewed, while "average" and "minimum" histograms are normal. Estimation based on "maximum" histogram would be pessimistic and that based on "minimum" is optimistic. The most likely case would be based on "average" histogram.

In the optimistic and in the most likely cases, the most probable size is 200 microns and in pessimistic case, the most probable size is 150 microns. If we look more carefully into the “maximum” histogram of PTS, it would be clear that there are too much differences between “maximum” percentages and “minimum” percentages, so it would be safer to focus on “maximum” histogram because this can be more representative than “minimum” histogram due to higher population. Hence, decision making in Burgan B should be based on “maximum” histogram and mesh sizes of 150 microns are the most probable sizes to migrate. Either 200 or 150 values can be applied for designing of slotted liner or wire wrapped screener for Burgan B. However, from point of view of economic consideration, 150 microns result more pressure drop and less production.

4. Conclusions

Sieve analysis of individual cores is a useful and simple tool to characterize sandstone formations from “sorting” point of view and to infer homogeneity of sedimentation. The study presented here indicates that permeability and porosity exhibit some correlation with “sorting” but not with “mean” values of sand grain sizes. Designing of slotted liner or wire wrapped screener for the purpose of controlling sand production must be based on sieve analysis of the entire formation interval not on the individual cores. Following conclusions can be drawn from the study presented here:

- Sieve analysis predicts existence of very well sorted and high permeable sand layer at the base of Burgan B formation.
- Burgan A formation exhibited more uniform “sorting” in spite of its geological nature of sand/shale sequence of deposition. Burgan B revealed varying sorting values with high fluctuation in the top and lower variability at the bottom.
- Permeability and porosity exhibited strong correlation with “sorting” but no correlation with the “mean” values as expected.
- There is good correlation between porosity and permeability in Burgan A and better in Burgan B, where the permeability curve with depth follows the porosity curve very closely. This was further confirmed with permeability-porosity cross plots not shown here.
- Sieve analysis of the entire formation interval produced the most probable sand grain size of 150 mictons for Burgan A and 200 microns for Burgan B.

5. Acknowledgements

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8. References

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