KING FAHD UNIVERSITY OF PETROLEUM & MINREALS

Application of GIS Software in Handling Geological Data

City and Regional Planning (514)

Introduction to GIS

A Term Project

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Abstract

The tight gas Sand stone reservoir i.e. Sarah Formation of Ordovician age is one of the hottest topic in the Saudi Arabia. The Sarah Formation contains glacio-fluvio deposits. One of the greatest challenges faced by the exploration companies is it fracturing and ultimately production of hydrocarbon i.e. gas. The aim of this paper is to prepare a geological map that shows the best location for sampling and collection data from the outcrop. The targeted area lies in central province of Saudi Arabia. The sand stone is outcropping in several areas which is scattered widely. To find the best location, this is accessible from the main road. The goal of this paper is to apply the Geographic Information System in to petroleum geology. The expected results of the project will be basically organized and summarized by GIS data and tabular data together in the digital format. The GIS data will help in selecting and then arranging the geologic data intelligently.

1. Introduction

The outcrop studies are very important analogs for subsurface. It predicts the subsurface behavior of certain parameters. The rapid improvement in the field of geographic information system (GIS) software, 3D geologic modeling technique and other relevant software enhanced the outcrop studies. This project dealt for outcrops study of Sarah Formation that is exposed in the Hail, Al – Baq'a Saudi Arabia (Figure 1). The formation is made up of glaciofluvial deposits. Since the glacial was melted in early Ordovician age and the outcome or outwash was deposited in several areas (Khalil 2011).

The geographic information system (GIS) software is used to digitize the Sarah formation in Hail area i.e. Al Baqa quadrangle. The formation is scattered in different areas but one main outcrop i.e. AL IIB is about 25 sq. km is exposed prominently. And this section is selected for the study. The whole outcrop is covered by selecting 38 samples. These samples cover the outcrop from top to bottom and from left to right. ArcView 9.3 is used to analyzed the data and save the data as attributes for each sample. The attributes cover the all the possible information that cover the all the need of geologist. The different GIS tools of Arc View are used for handling the data for example digitization tool, geo referencing tools, graphical analysis of the data and as well as very important is the spatial analysis tool. The spatial analysis tool covers the very important part of geologic model and analysis data in several ways to convey the sense of explanation.

Figure 1: Location of the study area, Hail Saudi Arabia (Google Map).

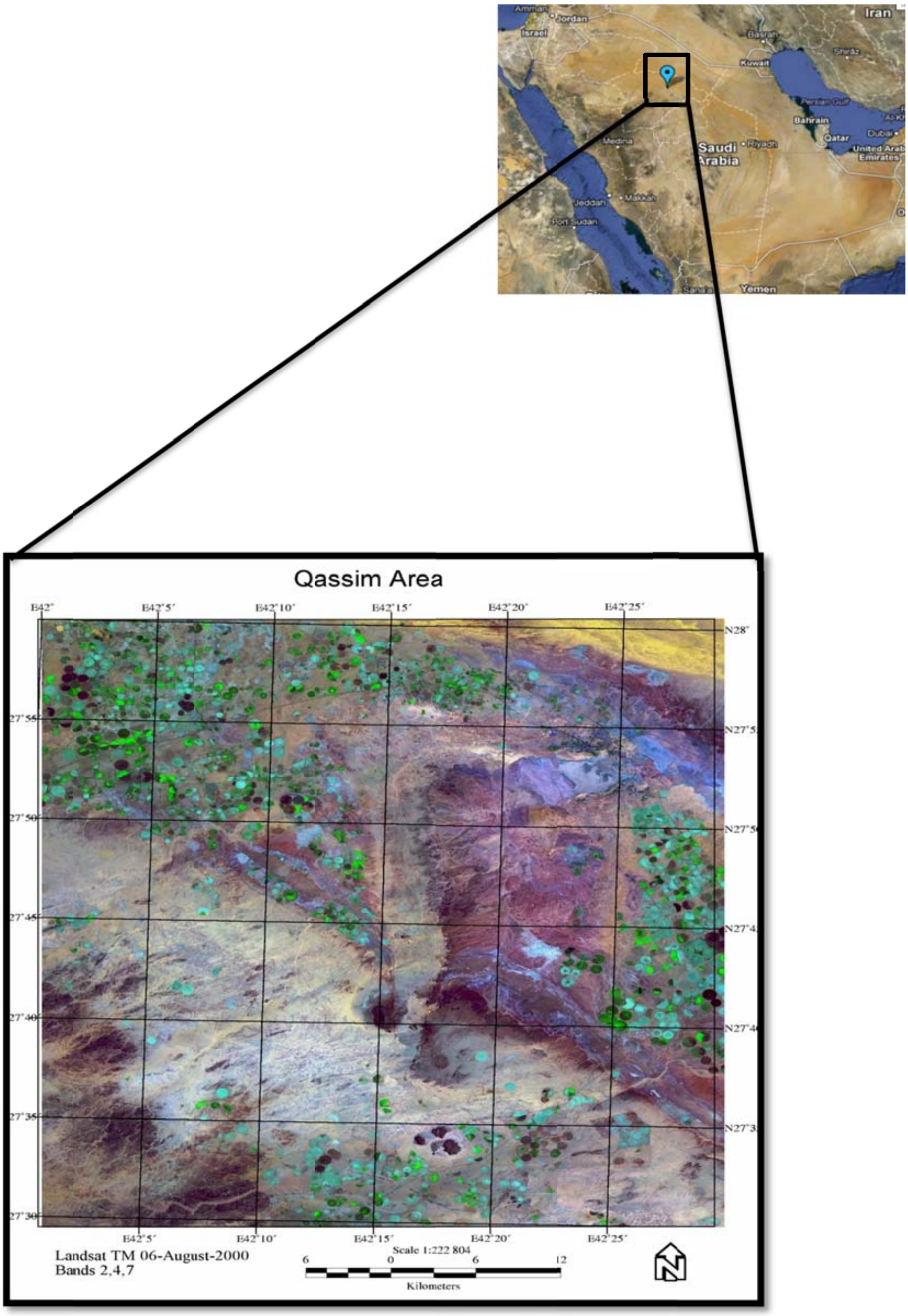

Figure 2: The Sarah Formation outcropping in Al IIb, Hail Saudi Arabia

2. Problem statement

The Sarah formation is considered as the tight gas reservoir especially for natural gas. And recently this topic gained enormous fame in this region because maximum recovery from oil and gas has been increased by leaps and bound (Al Mahmound and Al-Ghamdi 2010). The data collected from the subsurface give limited information because of horizontal extant. So that's y the outcrop analog is use to predict the lateral variation of the useful parameters. The handling of data and production of model is quite difficult job. The outcrop model is not fully designed yet to know the subsurface behavior.

3. Motivation statement

The limitation of techniques and difficulties to determine the detailed reservoir heterogeneity in the subsurface encourage the use of surface outcrop analog. The out crop analog gives information about rocks body dimension, size and orientation which is unavailable from the subsurface. The cross plot between porosity and permeability and its models give a sufficient knowledge about the understanding of the reservoir behavior. The direct benefit of such input is to improve reservoir characterization and fluid simulation model(s). The key role of GIS in this aspect is to provide the best way of selecting the outcrops. In term of better viewing and exploring geologic data, arc scene is used. The main application is the production of intelligent maps that links the tabular information to graphical data. Ultimately this results in the sound and concrete decisions.

4. Methodology

This part contains three steps that are related to each other, the first one is the selection of the out crop i.e. study area this is done with the help of GIS software. The second is the collection of the samples and other useful information from the field. The third one is to arrange and handle that data and prepare the outcome results.

8.1 Site Selection

The site selection is a tricky job, because this steps is done is at office before going to field. For this purpose the Arc Map is used. Several different formations are exposed in Al Baq'a but Sarah formation is needed to be digitized. Point, line and polygon is used in the Arc Map to explain the sample location, stratigraphic section and exposed Sarah Formation respectively. More than sixty locations were digitized for Sarah formation as polygon. But due to best exposure only one outcrop is selected i.e. is Al IIb (Figure 2.). Its area is about more than 25 sq. km and considered as best location for study.

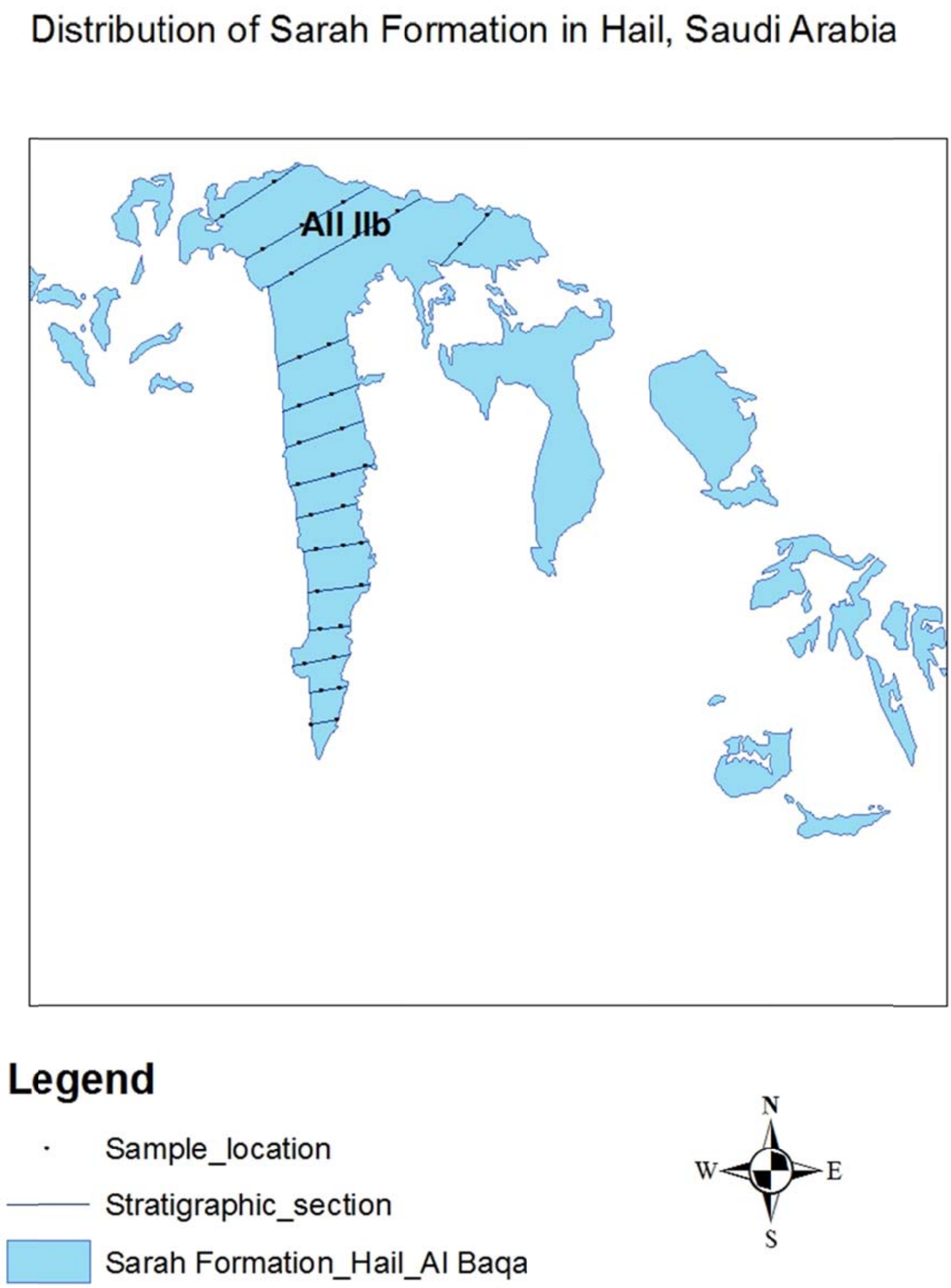

Figure 3: Selected out crop of Sarah formation Hail, Saudi Arabia

8.2 Sample Collection and Data Acquisition

The sample is collected from outcrop for laboratory studies. The pattern of collection is to cover the whole outcrop from bottom to top and from left to right. About thirty eight samples are collected to cover the outcrop from all sides. The samples are then analyzed under microscope to get useful information. Several other data is acquired for example sedimentary structure, thin section analysis, facies analysis, sand stone classification and porosity and permeability reading.

8.3 Handling of data in Arc Map

All the data collected is handled well in the software, and for each sample location the attributes are assigned. These attributes contains sample no, sedimentary structure, thin section description, porosity and permeability readings and etc. Moreover, the beauty of the arc map is that its hyperlink property helps in assigning the thin section to relevant sample.

5. Application of Arc Map Tools

The important Arc map tools used are:

1. standard Tool bar
2. Layout Tool bar
3. Spatial analyst
4. Editor Tool
5. Geo referencing Tool
6. Layout
7. Layer and attribute data management
8. Graphical representation of result
9. Topology
10. Data frame properties

And other useful tools are used in handling data and manipulating the data for creation of models and graph for example arc catalog and arc tool box (Figure 3).

The standard tool bar contains several useful functions. With the help of add data button, when data in the form of image or scanned copy is added. The next step is to add the shape file which is also added from standard tool bar (Figure 3). The shape file is prepared in the arc catalog and drags it in the arc map. For the current project, the scanned image of Al Baqa quadrangle is uploaded in the arc map, the next step is the creation of shape file in the form of point line and polygon. After that the several helpful tools are added from arc tool box window. The very important steps are the geo referencing of the map. So with the help of "Geo referencing tool" the map is geo referenced. The map is now ready for digitization. So with the help of "Editing tool" the map selected for editing and target layer is selected. First of all the polygon layer is selected to digitize the Sarah formation in the Al Baqa quadrangle (Figure 3). Majority of the Sarah Formation out crop is located in the central of the map.

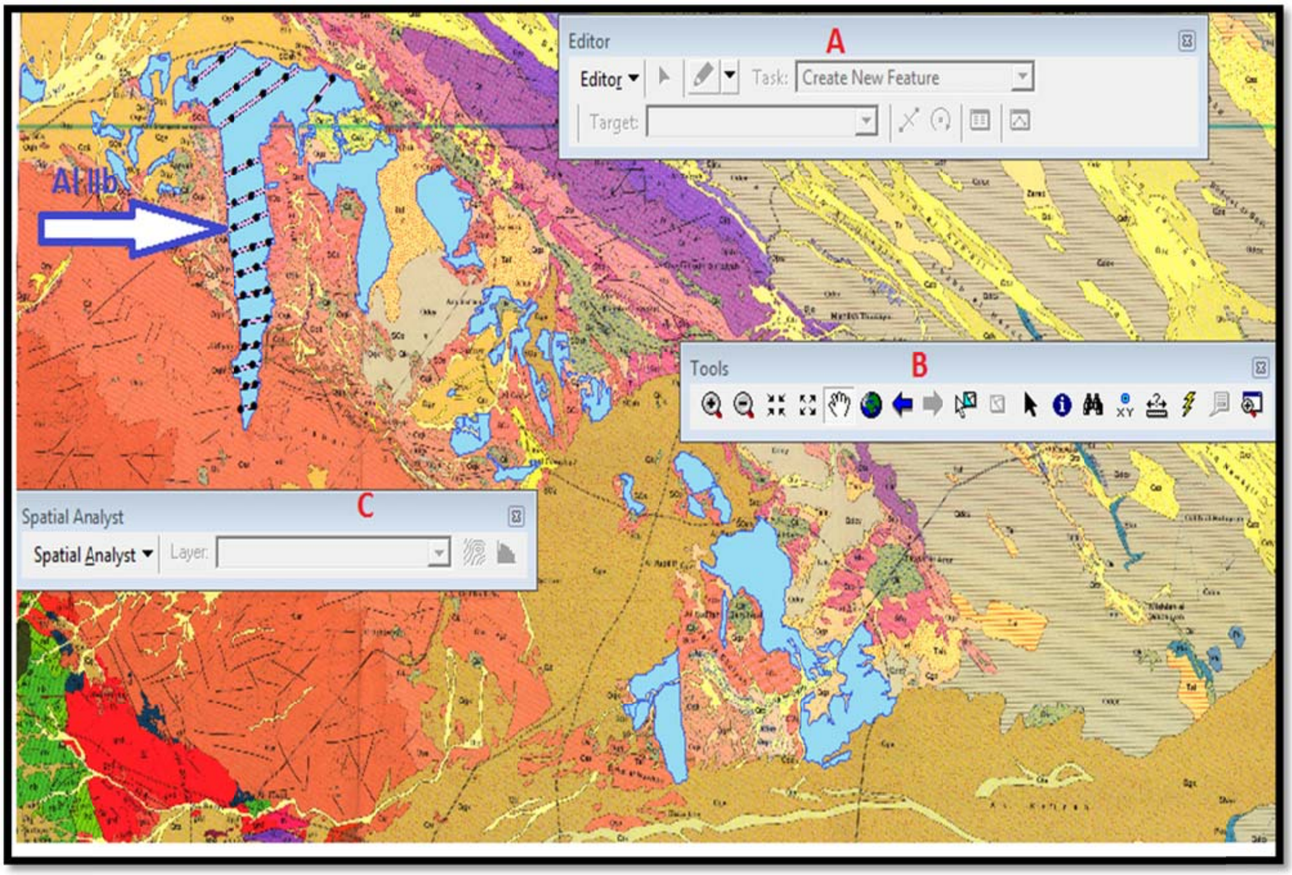

Figure 4: Map shows the selected outcrop i.e. (al llB) and Editor tool (A), Tools bar (B), and Spatial Analyst (C). The sky blue color shows the Sarah Formation outcropping in area

The very important steps are the geo referencing of the map. So with the help of “Geo referencing tool” the map is geo referenced. The map is now ready for digitization. So with the

Attributes of Olddata

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0	3	Point	0			0	0		Quartz Arenite
1	0	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	low angle cross srtatifi	10	0.5	Detrital quartz grains (D), ov	Quartz Arenite
2	1	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Hummockey cross strat	12	0.2	quartz grains (D), overgrow	Quartz Arenite
3	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Glacial striation	15	0.5	sutured contacts between	Quartz Arenite
4	3	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Sole Marks	14	0.6	Compaction of detrital clay g	Quartz Arenite
5	4	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Flute Marks	13	0.1	Multiple twins in feldspar (F)	Quartz Arenite
6	5	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Trough cross stratificati	12	0.4	Detrital quartz grains (D) an	Quartz Arenite
7	6	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	planner cross stratificai	11	0.4	Detrital quartz grains (D), fe	Quartz Arenite
8	7	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Flute Marks	10	0.8	Quartz grains (D) in glassy	Quartz Arenite
9	8	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	low angle cross srtatifi	15	0.4	Quartz grains (D), and Feld	Quartz Arenite
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17	1	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Flute Marks	15	0.1	Compacted detrital quartz gr	Quartz Arenite
18	1	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Trough cross stratificati	13	0.2	Duartz grains (D) with authi	Quartz Arenite
19	1	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Glacial striation	16	0.7	Single detrital quartz grain	Quartz Arenite
20	1	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	planner cross stratificai	14	0.4	Quartzgrains (D) with authi	Quartz Arenite
21	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Flute Marks	12	0.3	Quartzgrains (D) with authi	Quartz Arenite
22	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Trough cross stratificati	20	0.4	Duartz grains (D) with minor	Quartz Arenite
23	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	planner cross stratificai	18	0.5	Detrital Quartzgrains (D) wit	Quartz Arenite
24	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Glacial striation	18	0.5	Quartzgrains (D) with minor	Quartz Arenite
25	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Flute Marks	16	0.6	Quartzgrains (D) with mino	Quartz Arenite
26	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	Trough cross stratificati	18	0.4	Quartzgrains (D) with minor	Quartz Arenite
27	2	Point	0	E:\Kfupm\3rd semester\CRP 514\Term project\Scaned map\	planner cross stratificai	17	0.5	Quartz grains (D) quartz ov	Quartz Arenite

Record: 12 Show: All Selected Records (0 out of 39 Selected) Options

Figure 5: Attributes table showing the detail information of each sample

Help of “Editing tool” the map selected for editing and target layer is selected. First of all the polygon layer is selected to digitize the Sarah formation in the Al Baqa quadrangle. Majority of the Sarah Formation out crop is located in the central of the map (Figure 3).

But the main out crop is exposed in the northwest of the map (Figure 3). The second target is the selection of the stratigraphic section. So for this purpose the polylines are selected. These lines cover the whole outcrop from top to bottom and contain useful information in the form of attribute table. The third important part is the selection of sample location. From each polylines two to three points are selected, and each point location contain all the required information. Each point contains a series of informing like sedimentary structure, thin selection analysis and as well as images, facies analysis, sand stone classification, porosity and permeability reading. The mentioned information is collected from the fields and as well lab work. The data is then analyzed in the graphical and as well as in the spatial analyst tool. The two parameter i.e. porosity and permeability are examined well, because it is very important tool for predicting the formation, and helps in predicting the behavior in kriging, spline function and inverse density weighted (Figure4).

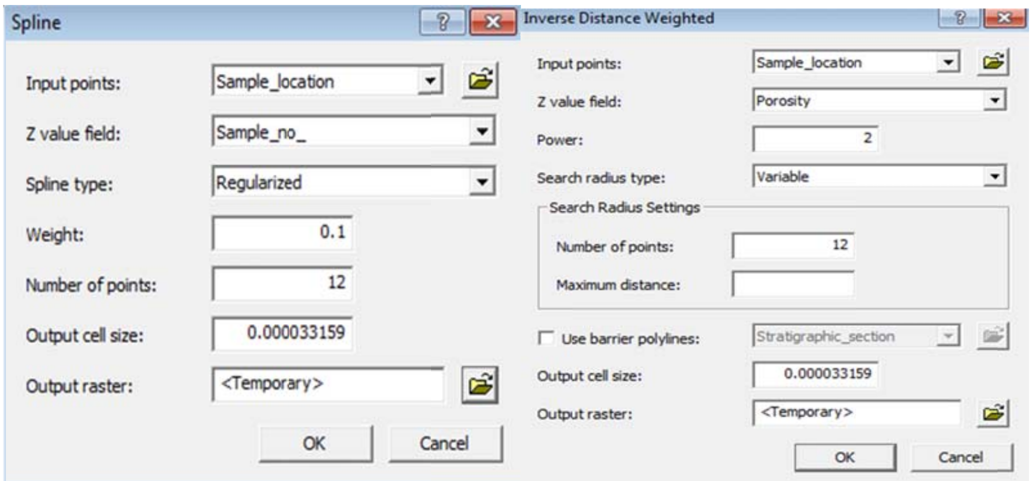


Figure 6: The figure showing the spline and inverse density weighted tool of Arc map.

6. Results and Discussion

It is generally agreed upon the complexity of the Sarah Formation, its distribution behavior is irregular and unpredictable. Some of the important results of porosity and permeability are shown in Graphical form but its tight nature is still a debate.

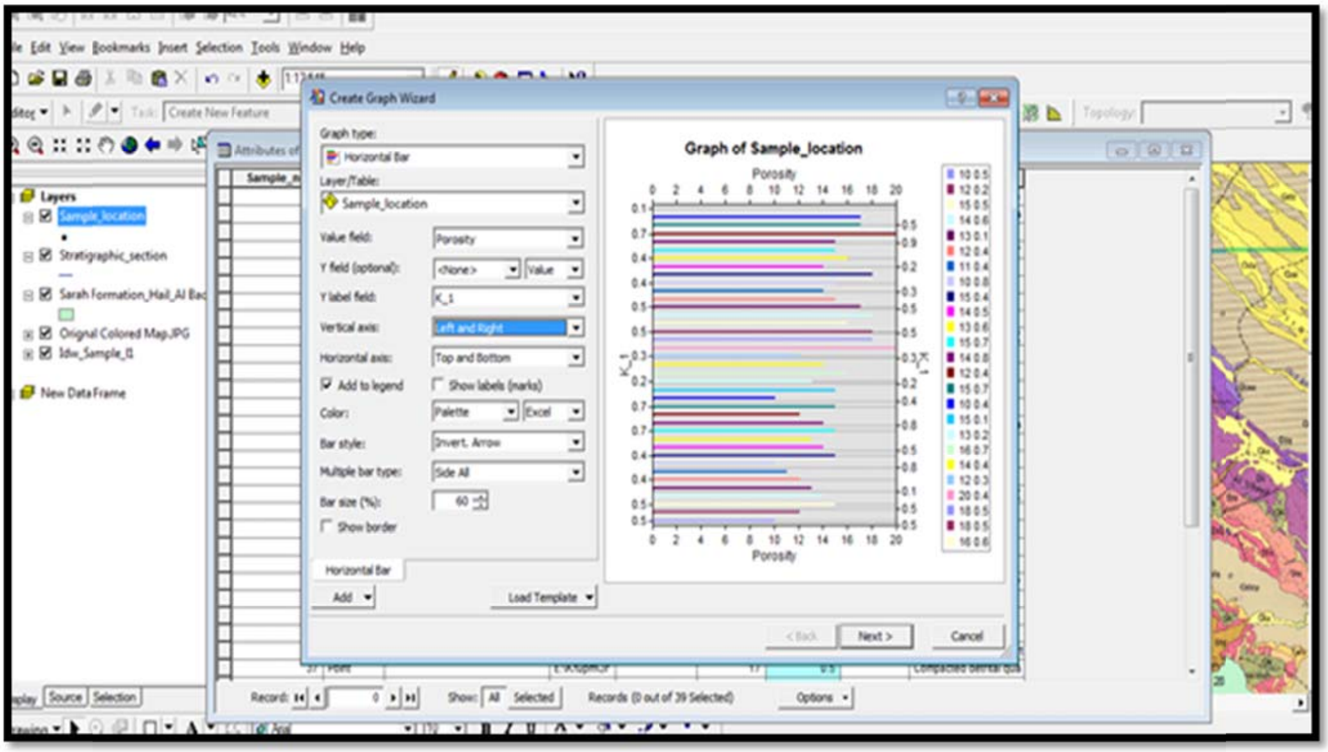


Figure 7: Shows the procedure of graph and its steps

The three main parameters needs to be drawn aginst each other. All these three parameter are usfull in knowing the behavior of the reservoir. The thirty eight samples and fifteen stratigraphic section are distrubtued intelligently to cover the whole outcrop (Figure 6).

Distribution of Sample Location in Hail, Saudi Arabia

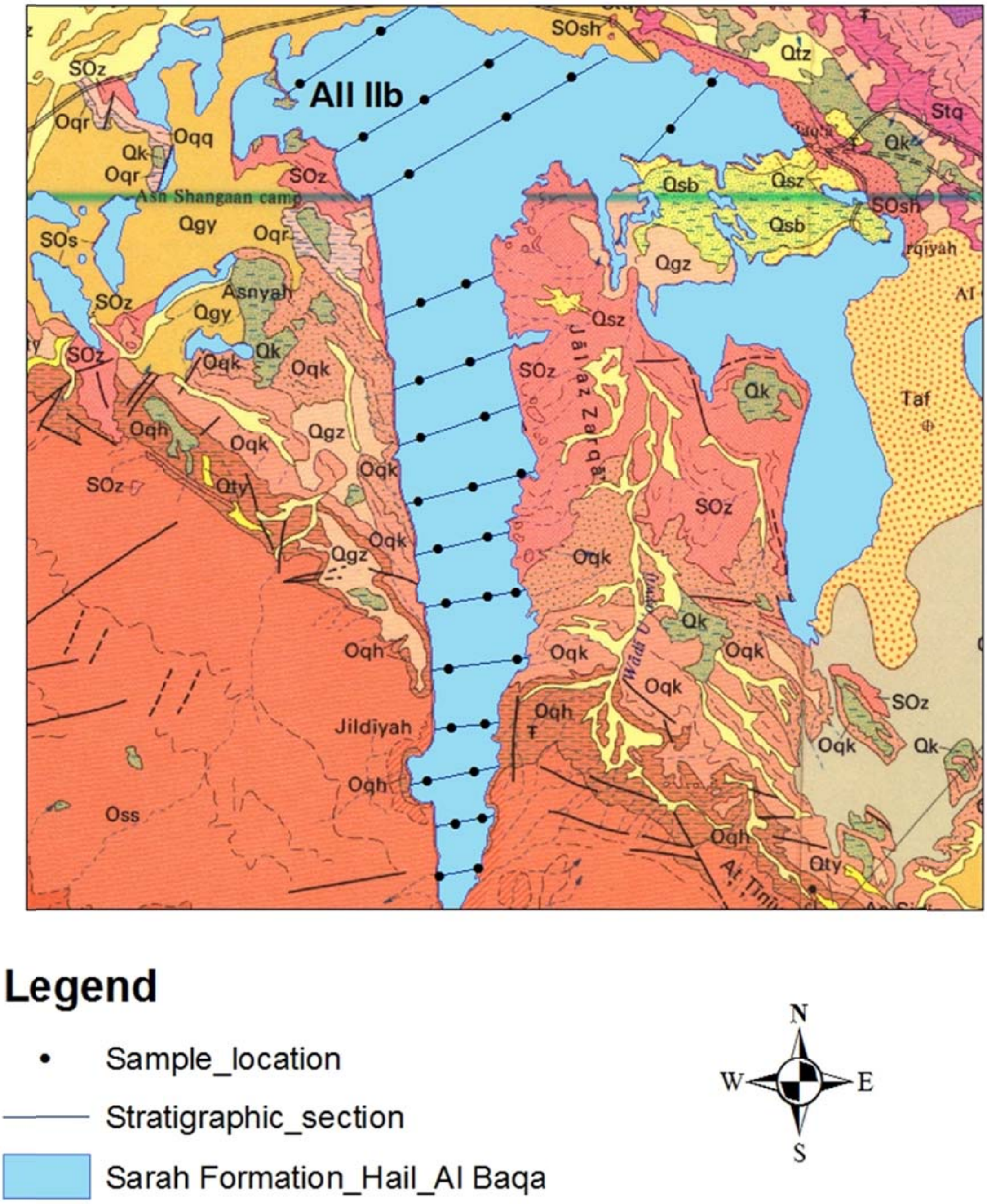
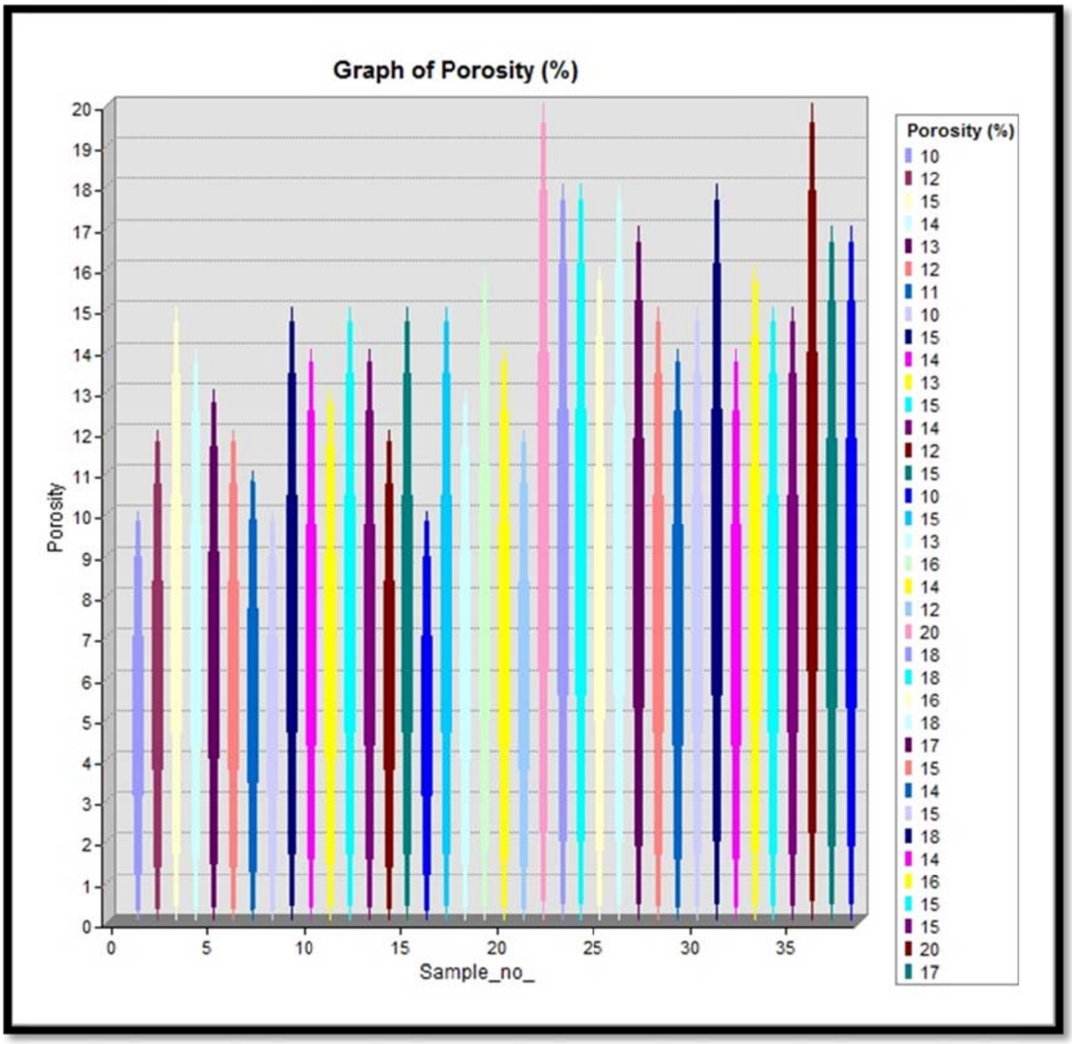


Figure 8: Distribution of Sample location and Stratigraphic section

10.1 Porosity Graph

The porosity graph is plotted against the sample number (X-axis) and shows some interesting result. The sample no. 24 and 22 shows remarkable highest values while on other hand sample no. 1 and 28 shows lowest values (Graph 1).

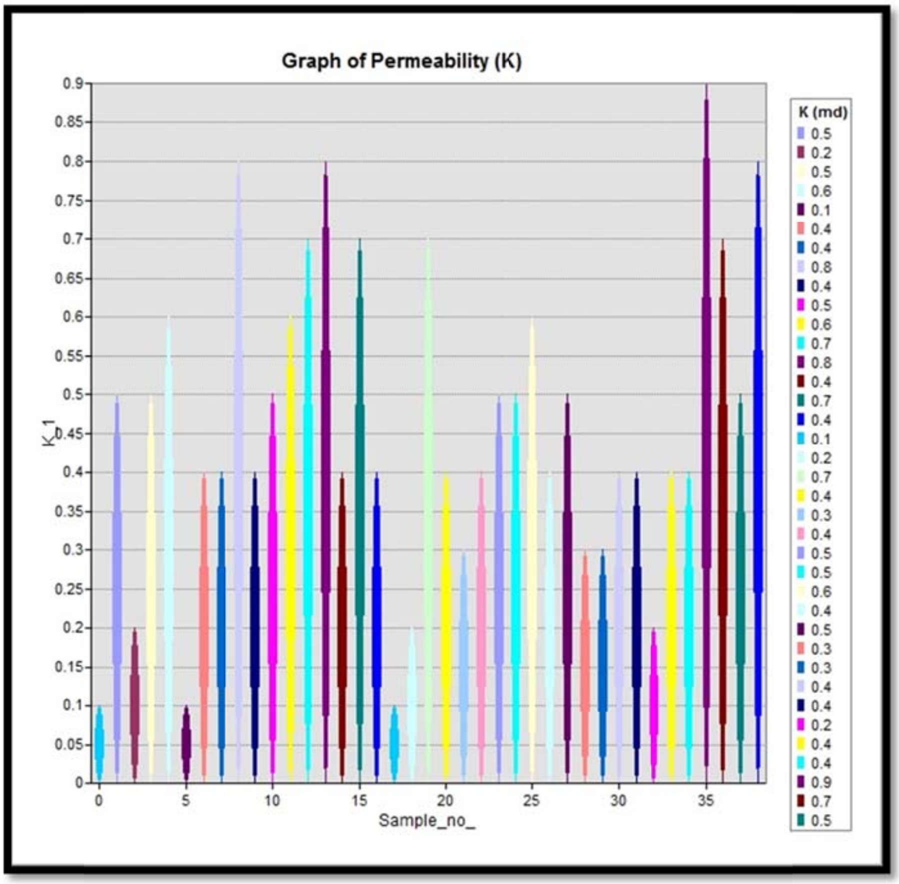


Graph 1: The cross plot between porosity and sample number

The reading shows that the formation is poros at the surface but its values is limited between 20 % and just above 10 %. The irregular behavior shows that the each bed is badly effected by weathering. But on the other hand the porosity reding for subsurface tight gas is less then 8%.

10.2 Permeability Graph

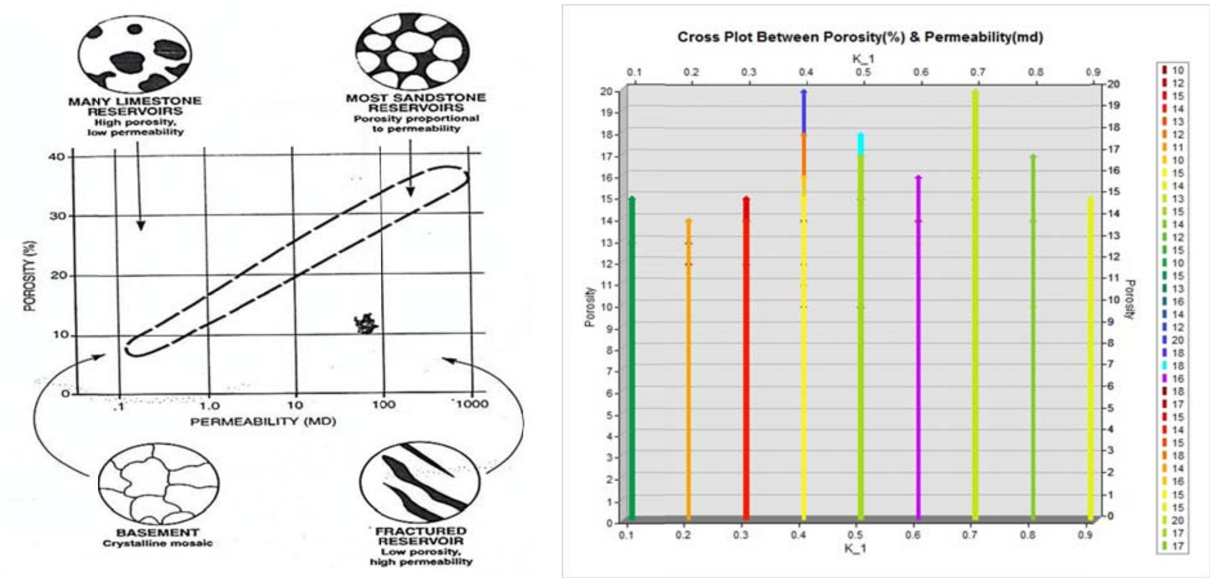
The permeability factor is very important in petroleum industry and its role is very important in term of fluid flow and pore pattern. The permeability is the network of pore that is connected to each other. The permeability reading of thirty eight samples is above 0.5 md and below 0.9 md. The graph shows some irregular behavior, but readings limit the graph. For tight gas, the permeability reading is 0.1md and it is then considered as tight gas. But in this case some values fall above that margin. The reason for this behavior is the climatic effect that causes the pore to widen and on other hand the reason for low permeability of tight sandstone under the surface is the digenetic and over burden effect. These two effect i.e. digenetic and over burden effect enhance the cementing phenomenon, this process results in the low permeability reading.



Graph 2: Permeability reading of the selected sample

10.3 Cross plot between Porosity and Permeability

Although the porosity and permeability shows the straight line (graph 3), this is true for sub surface data but the real surface data it shows some abnormal behavior. The reason for this is the presence of clay and other mineral which block the pore throat. But most of the samples having higher porosity reading but on other hand they contain low reading of permeability (Graph).

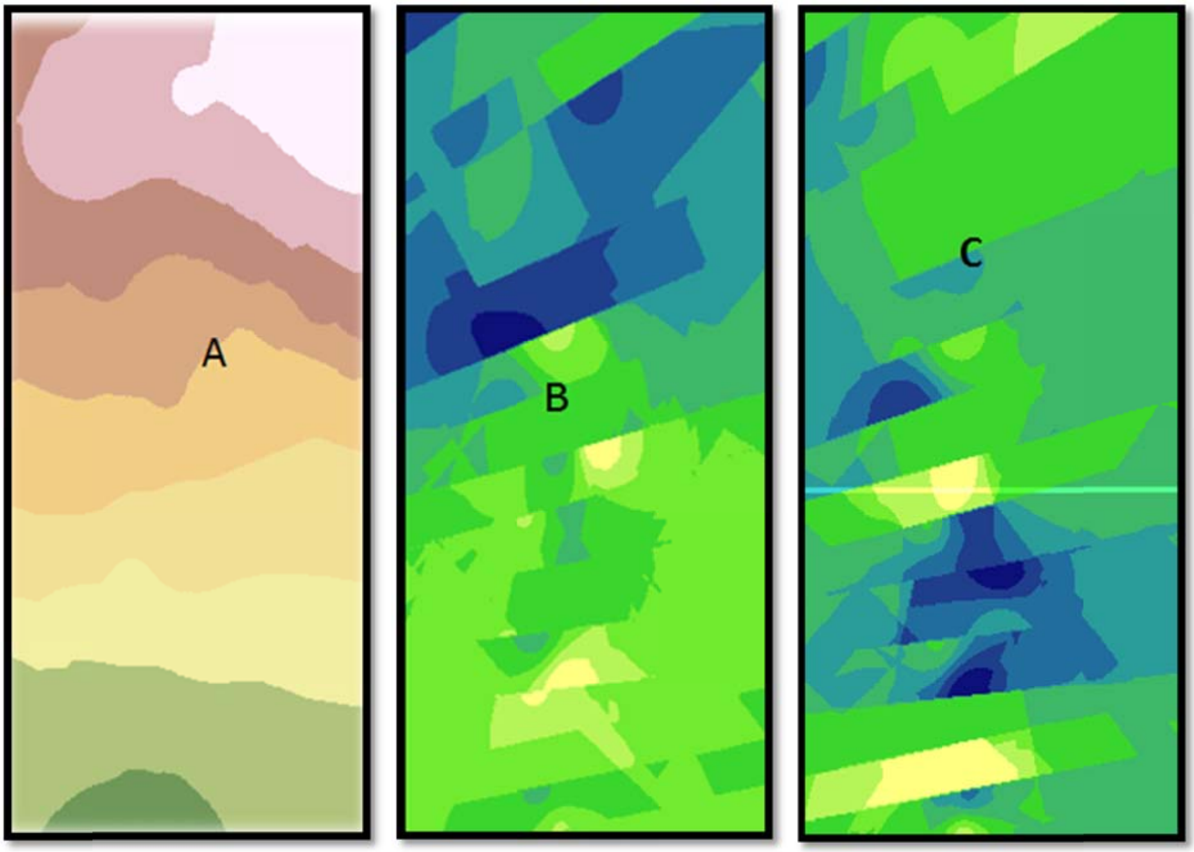


Graph 3: Porosity-permeability different of reservoirs and the cross plot of porosity-permeability

10.4 Inverse density weight Model

The inverse density model is the great application of GIS software. It gives values per unit mass. These values contain a lot of information in describing the trend of sample location that cover the whole out crop. The values are shown in different colors (Model 1A). The values are gradually increases as moving form bottom to top of the model, but the lateral extent is same. The inverse density model shows two prominent behavior, one is the sharp boundaries which shows the boundaries of stratigraphic section and second is the color scheme, which define the distribution of porosity reading is uniform and closely related to one another. The same color scheme is found in the porosity model at several localities, which shows the rock units at that location contain the same bed of porosity (Model 1B).

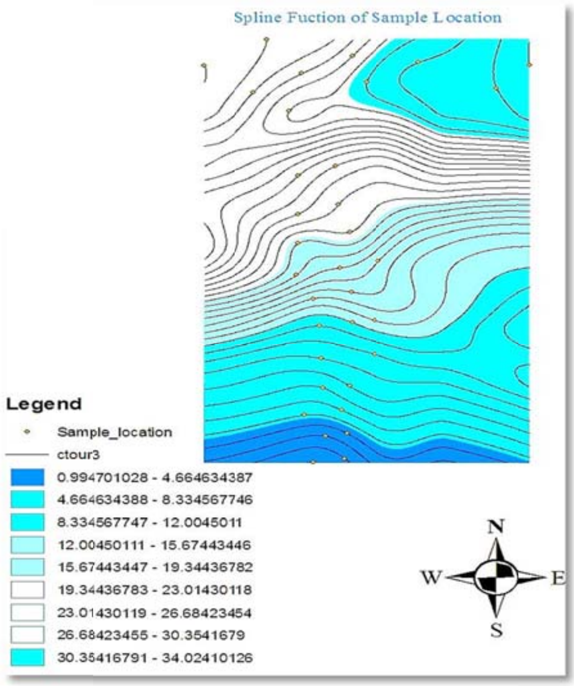
The permeability model is quite clear and shows the same behavior as porosity does but in case of permeability model the more permeable bed is located at the bottom the outcrop. This results in less exposure to the climate.

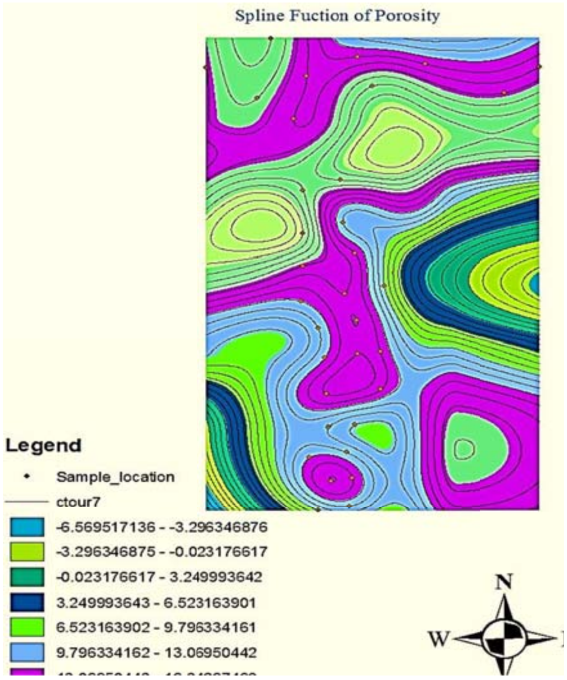


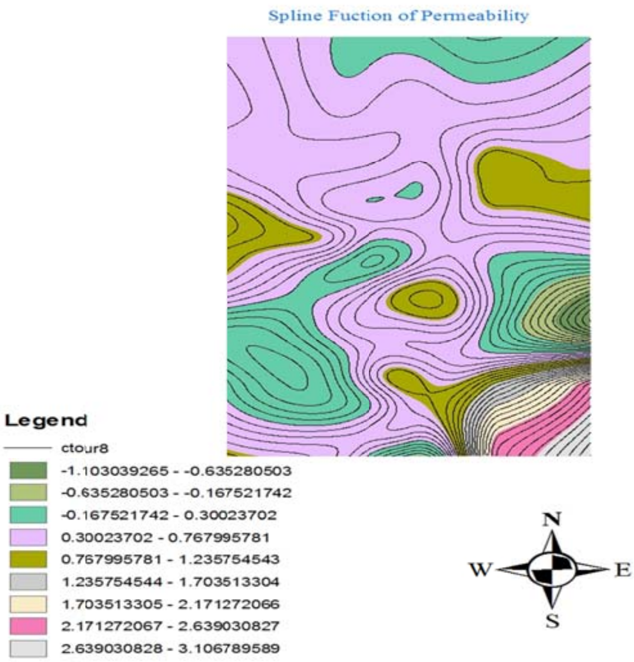
Model 1: Inverse density model of: (A) Sample Location, (B) Porosity, (C) Permeability

10.5 Spline Model

Spline function use mathematical function that resolves the overall surface curvature effect. The outcome the spline function is the smooth surface with no sharp edges. It connects all the input points located on the surface and minimizes the total curvature of the surface. The spline function helps in predicting the smoothly varying values like the porosity and permeability, and come up with the surface model that shows distribution pattern of this model (Model 2). The sample location distribution in model 2 is quite clear and increases upward.



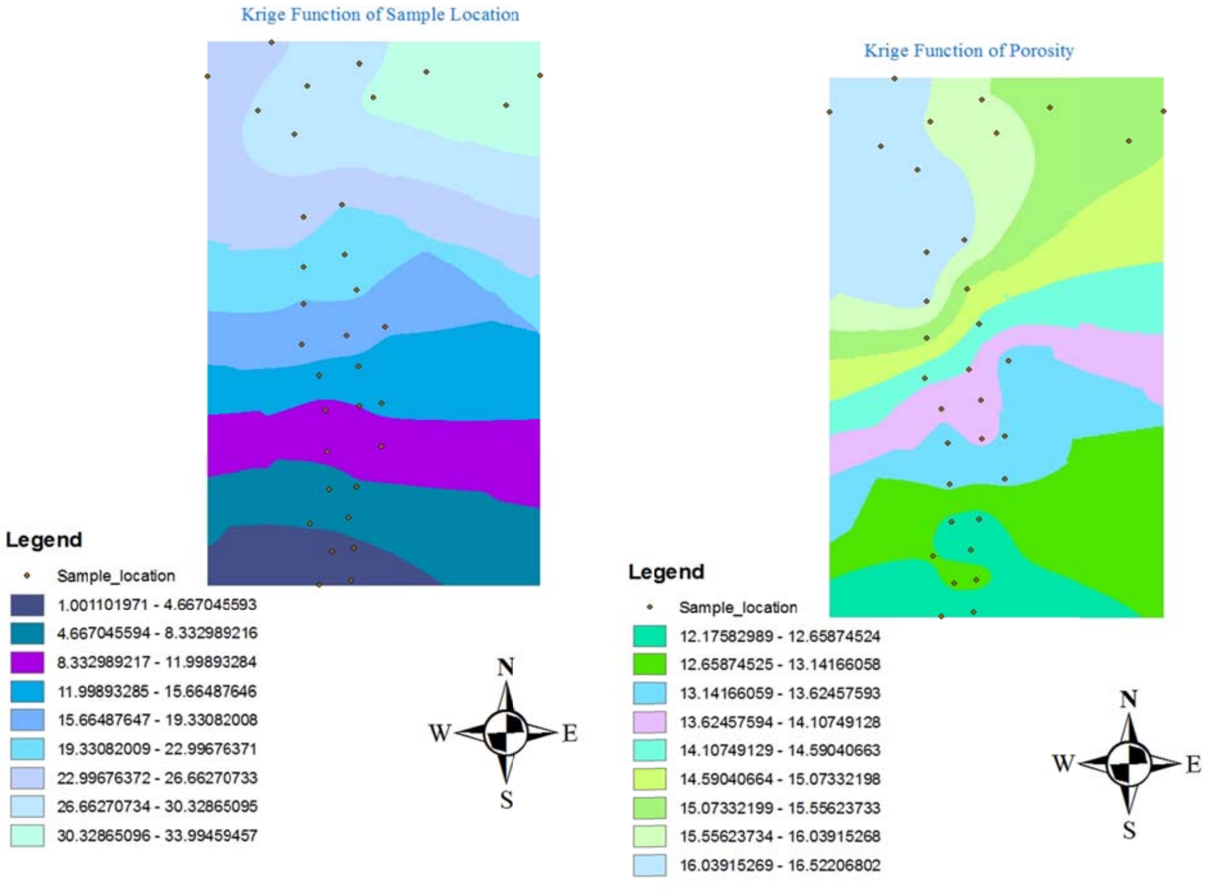




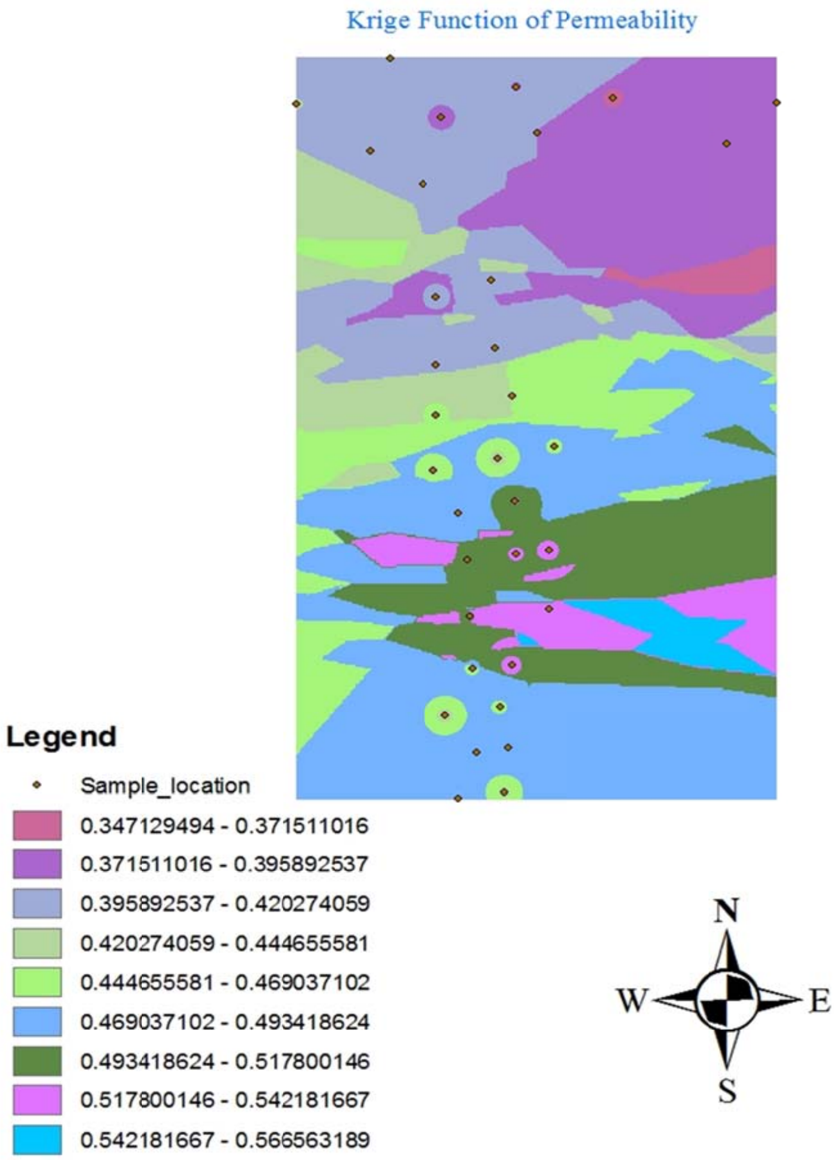
Model 2: Spline of Sample Location, Porosity and Permeability

10.6 Kriging Model

Kriging is the strong statistical tool used for distribution and interpolation of complicated values. The main function of the tool is that it assumes the distance or direction between samples and reflects a spatial correlation and explains the variation in the surface. In other word it fits a function to a specified number of values within given radiuses to get the output value function. The outcome results are derived from the measures of relation samples using sophisticated weight average technique.



Model 3: Kriging Function of Sample Location and Porosity



Model 4: Kriging Function of Permeability

7. Conclusion

The sand stone is considered as tight because of its low porosity and permeability values. The composition of the sand stone is glacial-fluvial deposits. And the best suitable outcrop is exposed in the Al IIb, Hail. This paleo valley incised in to other formation and cross cut it. Models and graph describe the porosity and permeability very clearly and helps in analyzing data. The trend of the porosity is not gradual but it increases and decreases according to the type facise. To handle the data with the Arc map is quite easy and its application in the field of geology is very wide. The area of about twenty five sq. km is intelligently cover form all side and the data collected form field and even form the lab work is handled easily. The models shown are best fit out crop and helps in knowing the heterogeneity trend in the beds. Some beds are higher in porosity reading but at the same time they show poor reading for permeability and vice versa. The inverse density weighted, spline and kriging models are quite clearly define the surface trend of the readings. The attribute tables contain the huge amount of information and give the result in limited time.

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