

PS Regional Distribution of Hydraulic Properties of the Palaeozoic Wajid Sandstone Group Southwestern Saudi Arabia*

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Abstract

In the frame of aquifer studies in Saudi Arabia, we measured porosity and permeability of sandstones of the Palaeozoic Wajid Sandstone in order to get a database for a regional groundwater model. The Wajid sandstone is subdivided into five formations, which differ in their dominant depositional environment. From the base to the top these are: (i) Dibsiyah Formation representing a shallow-marine clastic shelf, (ii) Sanamah Formation containing glacial to proglacial sediments most of them deposited in tunnel valleys, (iii) Qusaibah Formation characterized by high-stand shales, (iv) Khusayyayn Formation showing large-scale tabular cross-bedded tidal sands, and the (v) Juwayl Formation again containing glacial to proglacial sediments mostly deposited in tunnel valleys and overlain by shallow-marine tidal beds.

Altogether 380 samples were taken in the outcrop area most of them along sedimentological logs to correlate poroperm properties with sedimentary facies and/or diagenetic features. From oriented samples, cylindric plugs were drilled. With a minipermeameter, all three directions were measured to analyse anisotropy. A column permeameter was used to measure intrinsic permeability under controlled conditions in a sealed cell. In general, both, porosity and permeability are high for all formations with values typically between 0.5 to 5 Darcy and 20-30%, respectively. Nevertheless, permeability varies about several orders of magnitude among samples or between vertical and horizontal permeability within one sample. This anisotropy can be well explained by varying sedimentary facies and cementation. To better predict poroperm properties in the subsurface, we measured gamma ray and analyzed selected samples with polarization and raster electron microscopy (REM). The data obtained enhance the quality of the hydraulic interpretations of this aquifer system.

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Introduction

The Sandstones of the Paleozoic Wajid Group are the most important groundwater reservoirs in the southern part of the Kingdom of Saudi Arabia. Although investigated by KELLOGG (1986), a detailed reservoir characterization was still missing.

The aim of this study is to deliver a reservoir characterization and a depositional basin model for the Wajid Group. This includes the interpretation of depositional processes and environments in terms of cyclo stratigraphy and sequence stratigraphy. The work is based on lithofacies classification and architectural elements analysis. We will discuss here the hydraulic parameters obtained from this study. For the first time, permeability and porosity of the Wajid Group were investigated. Furthermore, hydrogeological parameters were determined for each formation. Facies shifts and dimension of sedimentary features are the key to aquifer characterization of each formation.

The Wajid Group is of Middle/Late Cambrian to Middle Permian age and can be divided into three main parts (KELLOGG 1986, SHARLAND et al. 2001). These are:

Upper Wajid Sandstone Sequence (UWSS),
Qusaiba Member (QM), (Qalibah Fm.)
Lower Wajid Sandstone Sequence (LWSS).

These three subdivisions include four reservoirs:

Juwayl Formation,
Khusayyayn Formation, } UWSS
Sanamah Formation,
Dibsiyah Formation. } LWSS

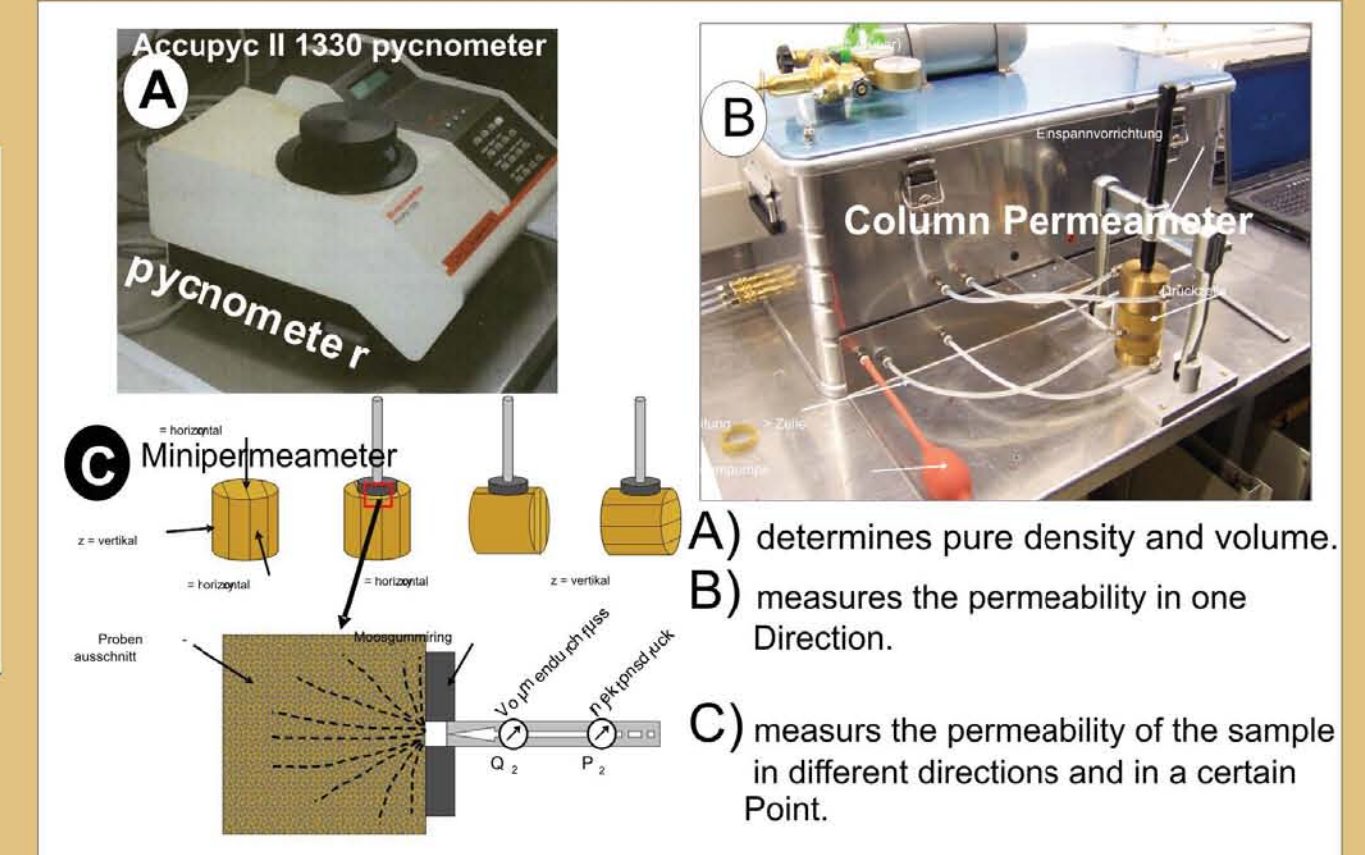
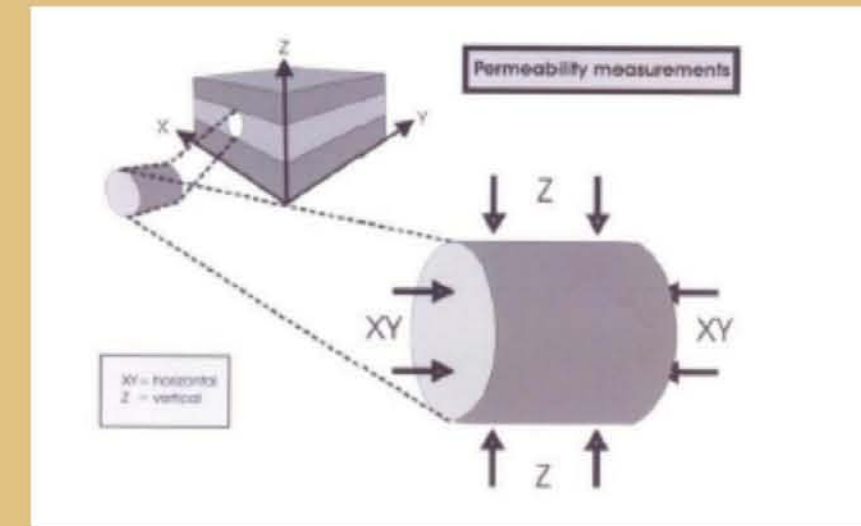
Qusaiba Member consists of shale and hydraulically separates the LWSS

Major unit	Hydro-geologic unit	Member	Stratigraphic Correlation	Age	TMS	Thickness (according to the Wajid Project wells)	Description
Upper Wajid Sandstone	UWSS	Juwayl Fm.	A	Unayyah Fm.	TMS 5	from 219 m up to 228 m	continental sandstone, subordinate clay and siltstone
		Barwah Fm.	B		TMS 4		
		Juwayl Fm.	C				
		Juwayl Fm.	D				
		Juwayl Fm.	E				
Qusaiba Member	QM	Qusaiba Fm.	F				
		Qusaiba Fm.	G				
		Qusaiba Fm.	H				
		Qusaiba Fm.	I				
		Qusaiba Fm.	J				
Lower Wajid Sandstone	LWSS	Sanamah Fm.	K				
		Sanamah Fm.	L				
		Sanamah Fm.	M				
		Sanamah Fm.	N				
		Sanamah Fm.	O				

Materials and methods

140 samples were oriented and collected along the sedimentological logs in the study area. The samples were drilled to get cylindrical plugs.

The hydraulic properties were measured in the lab, by a special method, to get a clear picture about the relation between the hydraulic properties and the different sedimentary facies of the aquifer.



Geology of the Study Area

The Wajid Group is Subdivided into five formations.

Hydrogeologically it consists of three main parts as mentioned above.

The Upper Wajid consists of two formations

The lower part consists of two Formations

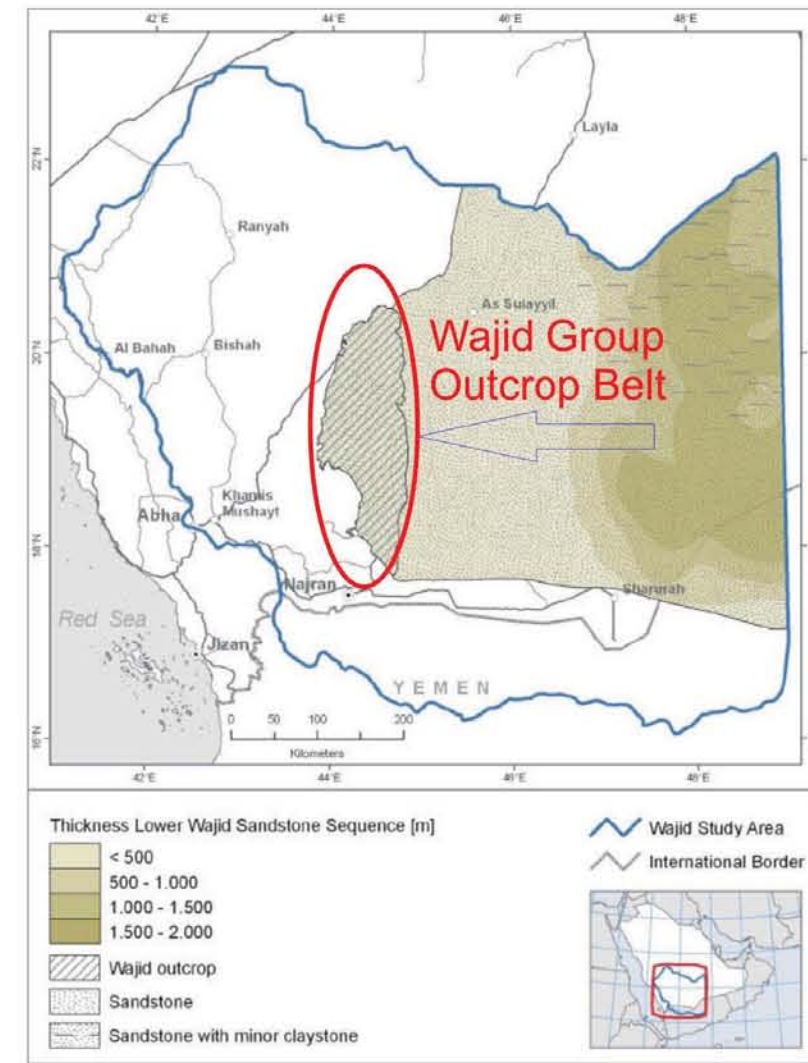
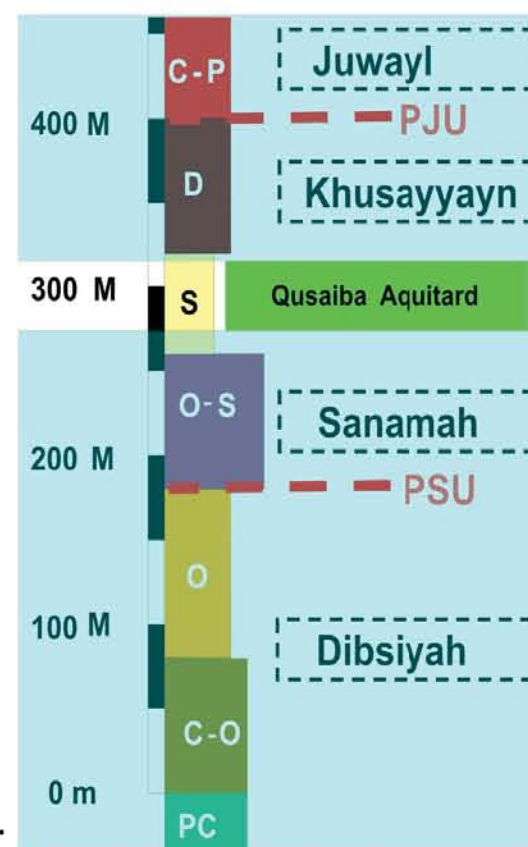
that span the Cambrian and Ordovician.

The Wajid Group starts in the Middle Cambrian (??) and extends to the middle Permian.

They form two hydraulic bodies

separated by an aquitard shaly formation.

Which is the Qusaiba Member of Qalibah Fm.



The sample need to be treated in a specific way to fit the measuring methods

- 1- cut in a certain dia.
- 2- dried by a special oven.
- 3- stored in a dry cans using some absorbent chemicals.
- 4- each sample is measured individually



Permeability of Khusayyayn Fm. as an example of the values of Wajid Sandstone Group

Direction	L.M/M.D	L.M/M.D
X	560	3194
Y	713	4210
Z	918	7250
Total	1009	4342

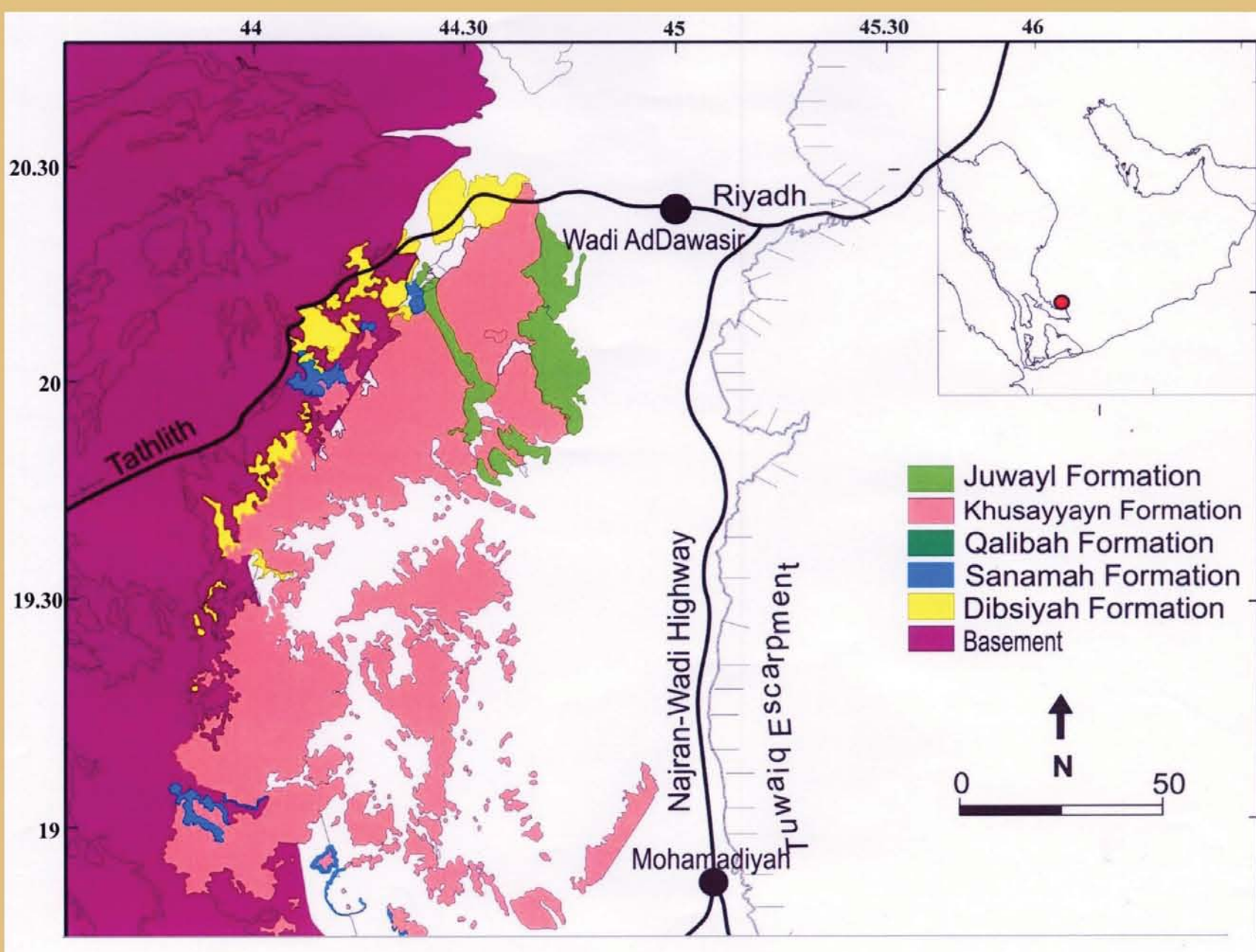
The porosity vary between 7.3 % and 31 % for all formations of this group

Motivation

Saudi Arabia does not have renewable water sources. But the country has fossil water bodies stored in large regional aquifers system.

The available water volume, and the yield of the aquifer depend on porosity and permeability of the formations, which were not known in details before this study. The aim of this study is therefore to determine these parameters for the Wajid Sandstone Group, which is one of the most important aquifer system in the country.

It is a thick sandstone succession, more than 1000 meters thick.



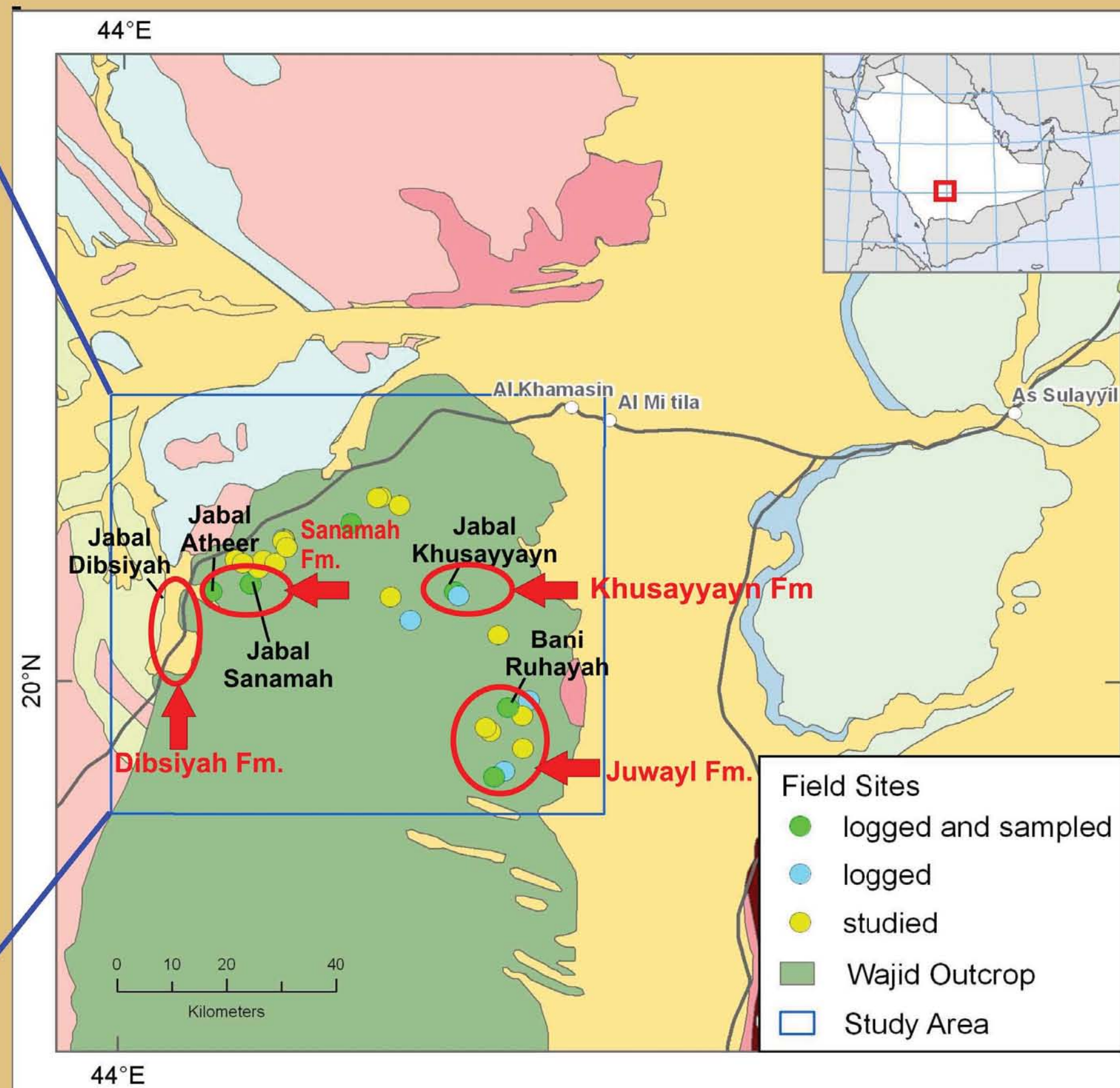
Field & Laboratory Work

The Wajid outcrops are located south of Wadi Ad Dawasir. During the field campaign, more than 16 sections (~ 600 m) have been logged on a cm-scale, covering all formations of Wajid Group in the study area. Samples for porosity and permeability measurements were taken at 6 locations. The

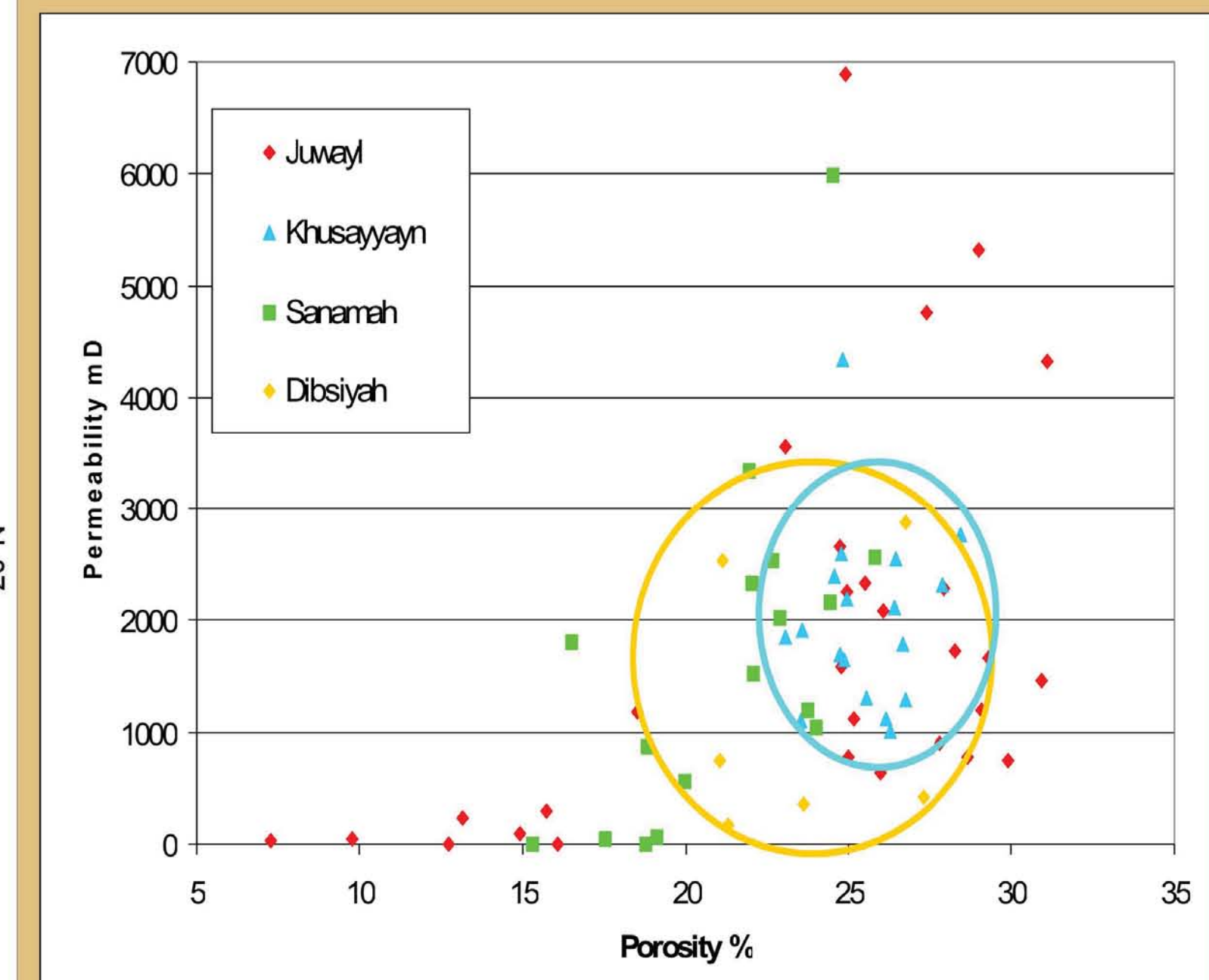
An extensive field work to collect samples from the main formations of Wajid Group.

A determination of the porosity and permeabilities in lab experiments.

Establishing correlations between the different formations and important parameters for water resources estimation.



- Porosity and permeability were measured.
- In general porosity and permeability are high.
- These properties vary between the formations.
- Low Diagenetic (secondary) influence in all Formations.



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Conclusions

- In general the Paleozoic Wajid sandstone shows very high porosities (20 - 31 %) and permeabilities (500 - 7000 mD).
- The effective volume is close to unconsolidated Quaternary deposits.
- Poro - Perm properties can be closely linked to sedimentary facies.
- Glacial sediments (Sanamah, Juwayl) show high heterogeneities, whereas shallow marine sediments are quite homogenous (dibsiyah, Khusayyayn).
- Better sorting in the Khusayyayn Fm. leads to higher permeabilities compared to Dibsiyah Fm.
- In glacial deposits permeabilities cannot be predicted without knowledge of sedimentary facies. They show highest (5000 - 7000 mD) as well as lowest permeabilities (5 - 500 mD).
- The high porosities provide large volumes for water storage in the Wajid sandstone. To account for permeabilities, sedimentary heterogeneities have to be

