http://dx.doi.org/10.5455/sf.XXXXX

Science Forum (Journal of Pure and Applied Sciences)

journal homepage: www.atbuscienceforum.com

Applications of Slide Scan Images of Thin-Sections in Sedimentological Studies

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ABSTRACT

Several conventional and unconventional digitization tools have been used to improve viewing and acquisition of information in the field of sedimentology and sedimentary petrology, in geology and in science and technology in general. Slide scan images of sedimentary rock thin-sections provide inexpensive, very good, whole thin-section views at magnifications similar to those of the conventional microscope. This paper demonstrates how slide scan images can be obtained and how they can quickly be used to gather detailed textural, structural and compositional information of sandstones at microscopic scale. The method has been used in studying features such as grain size, grain shape, fabric, contact between grains, graded bedding, cross lamination and porosity without the need for polarizing microscope and photomicrograph. This unpopular, unconventional method is not known by most researchers even though it can provide alternative means of obtaining vital geological information relevant to both the academia and the industry. This method is also recommended to teachers in low-equipment universities and research centers where research petrological microscopes are either absent or inadequate or during periods of lock-down. This is because it utilizes simple

ARTICLE INFO

Received 23 May 2023
Received in Revised Form 31 May 2023
Accepted 01 June 2023
Published xxxxxxxx
Available Online xxxxxxxx

KEYWORDS

thin-section,
slide-scan image,
sedimentology, texture

1.0 Introduction

Digitization is one of the various ways to improve viewing and maximize data acquisition in the field of science and technology. In this light, various tools have been used to digitize rock thin sections in an attempt to gather geological information at microscopic scale. Examples include petrologic microscopes, scanning electron microscopy and cathodoluminescence. These tools are very expensive, they require special conditions to work and are only able to view very small portions of the thin sections. As a result, the identification and description of features such as macro-structures are usually accomplished by obtaining multiple photomicrographs. Attempts have been ongoing since the 1960s to get this information through digitization of entire thin sections for better geological information gathering especially for quantification purposes. In the last few decades, conventional photography using films were used for the digitization. More recently, researchers such as De Keyser (1999), Hansen (2000) and Tarquini and Armienti(2003) have used high resolution scanners to

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obtain full thinsections of rocks with high resolution pixels.

Different ways of quantifying textural parameters of sandstones based on thinsection have beenalso been developed bysedimentologists over the years. For slide scan images, the visual estimation and manual counting methods can easily be applied. This method has the advantage of being relatively fast and it involves the visual estimation of such parameters as grain size, shape, sorting, percentages of components, and fabric using comparison charts devised by researchers in this field (e.g.Pettijohn, 1975; Mathew et al., 1991).

The present paper attempts to demonstrate how slide scan images of thin sections can be used to provide vital textural and macro-structural information from sandstone samples. Specifically, attempts have been made to demonstrate how slide scan image can be obtained, how to quantify grain size parameters, how macro-structures can be deciphered from slide scan images and how porosity can be estimated. This method can be used to quickly provide these vital information for exploration and exploitation of mineral resources though many researchers do not know about it. Ill-equipped research centres in especially developing and third world countries can take advantage of this method because it requires only basic office equipment and laptops (or tablets/notebooks or even smartphones) for analysis. It can also be used when access to laboratories are difficult due to events such as lock-down periods.

2.0 Methods

The method for obtaining slide scan images of rock thin sections is simple. First the thin sections are produced perpendicular to the bedding of the rock samples. Four ways in which 35mm slide scan images are commonly obtained include the use of flatbed scanners, dedicated film scanners, slide duplicators and professional Photoshop. For flatbed scanner to be used, it must be the type that is able to scan negatives, slides, traditional paper photos and documents. The recommended scanner must also have optical resolution of at least 2400 dpi. The scanner is connected to the computer directly and the slides are inserted on the scanner for the image which can be directly viewed in the computer via the scanner software. The image is either stored on the computer or another device for preservation or further processing. In the present work, the slide scan images of the sandstones (eolian) were obtained using Polaroid Sprint Scan 35LE scanner.

Textural features of the rock such as grain size, morphology and fabric can easily be examined on the slide scan image by comparing with charts such as shown in Figure 1., below.

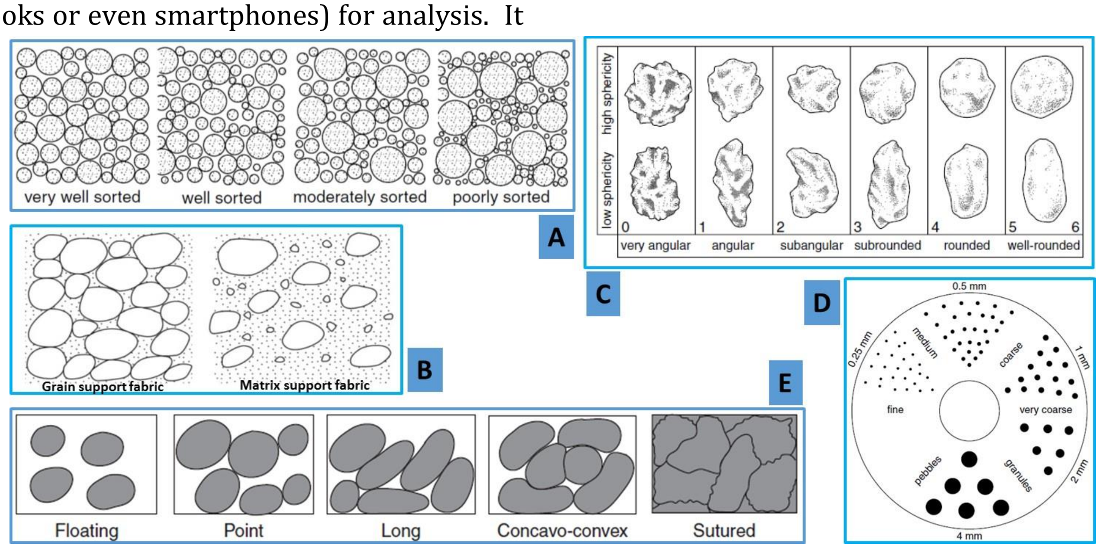

Figure 1. Charts for visual estimation of sedimentological features. **A**: Charts for visual estimation of sorting; **B**:chart illustrating fabric of sandstones; **C**: Categories of roundness for sediment grains, for each category a grain of low and high sphericity is shown; **D**: Chart for estimating grain-size of sands;**E**: Chart illustrating nature of grain contacts.

Answers to two aspects of porosity can also be obtained from slide scan images; the type and amount of porosity. Figure 2A is a sketch showing the types of porosity while Figure 2B demonstrates how porosity amount can simply be computed through gridding method. In this method, which is similar to point counting, sections of the slide scan image is enlarged and gridded. Each of the cell is now point counted for either grain or pore space. Here the grain is represented by any component that is not a pore space. At least 100 counts can be achieved for a grid of 10 by 10 cells. A table of tallies is formed from the counts which can easily be converted to frequency table from which percentages of the total pore space can be computed. In Figure 2B a total of 800 counts can be made.

3.0 Applications of thin-section slide scan images in sedimentology

In this study, the application of slide scan images in textural and macro-structural studies of sandstones will be demonstrated using slide scan images of eolian sandstones. Attempts will be made to decipher compositional attributes from the images. These will be illustrated using the examples below

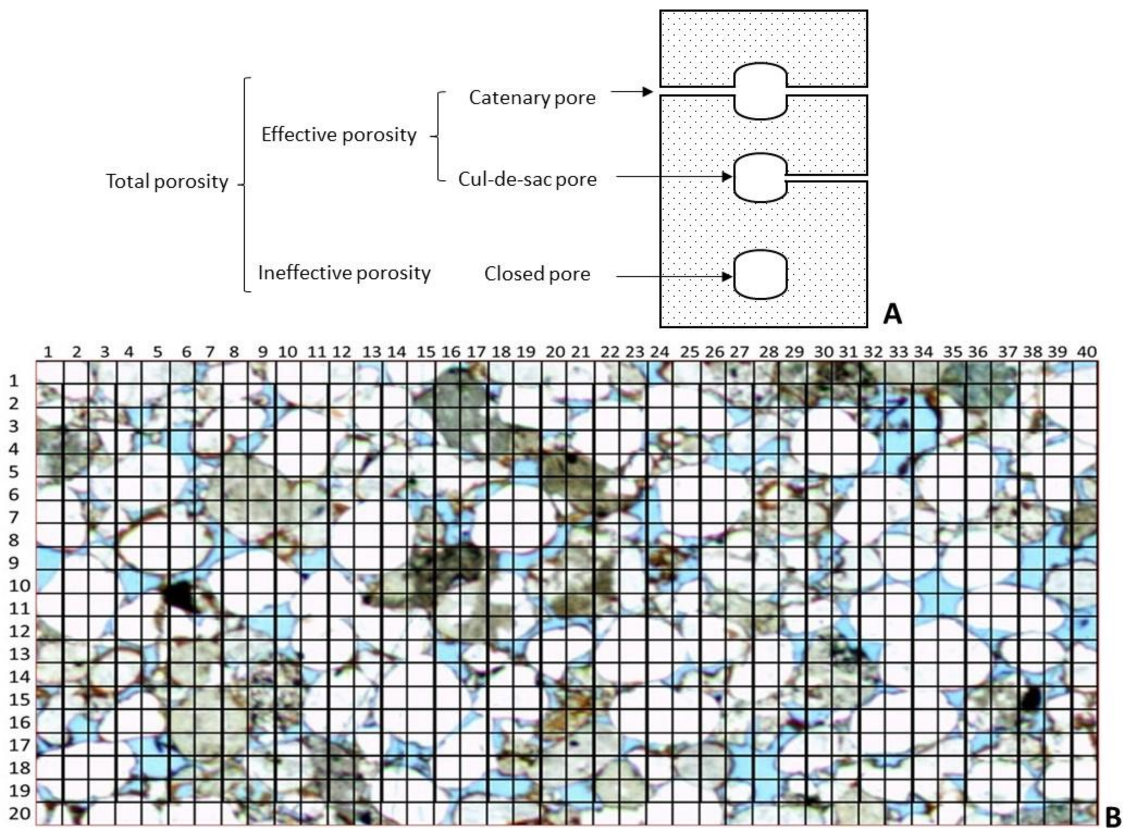

Figure 2.A: Three basic types of pores (Selley, 2000); **B**: Grid for porosity estimation using 800 counts.

3.1 Studies of textural characteristics of sandstones

Simple description of sedimentological attributes of sandstones can easily be done with a slide scan image. Example is shown below for the features displayed by the sample in Figure 3. The textural attributes of the sample include: 1) bimodal grain size distribution with the coarser and finer grains having good sorting individually; 2) grains are predominantly rounded with generally high sphericity; 3) grain contacts are predominantly touching with few long and concavo-convex contacts; 4) the fabric is grain-supported. Sedimentary structures observable in the sample are: 1) graded laminae showing normal grading (Fig. 3A); B: cross lamination displayed by inclined laminae (Fig. 3A). Apart from the grain contacts that indicate diagenetic phase, the observation of grain dissolution (Fig. 3B) especially at the upper left side of the sample is also indicative of diagenetic effect. Bothprimary and secondary (dissolution) porosity are observed (Fig. 3B). The pore spaces are better interconnected at the upper part of the slide where better permeabilities are

expected. Permeability is better within the laminae formed by the larger grains and lowerin laminae formed by the finer grains and generally increases upwards
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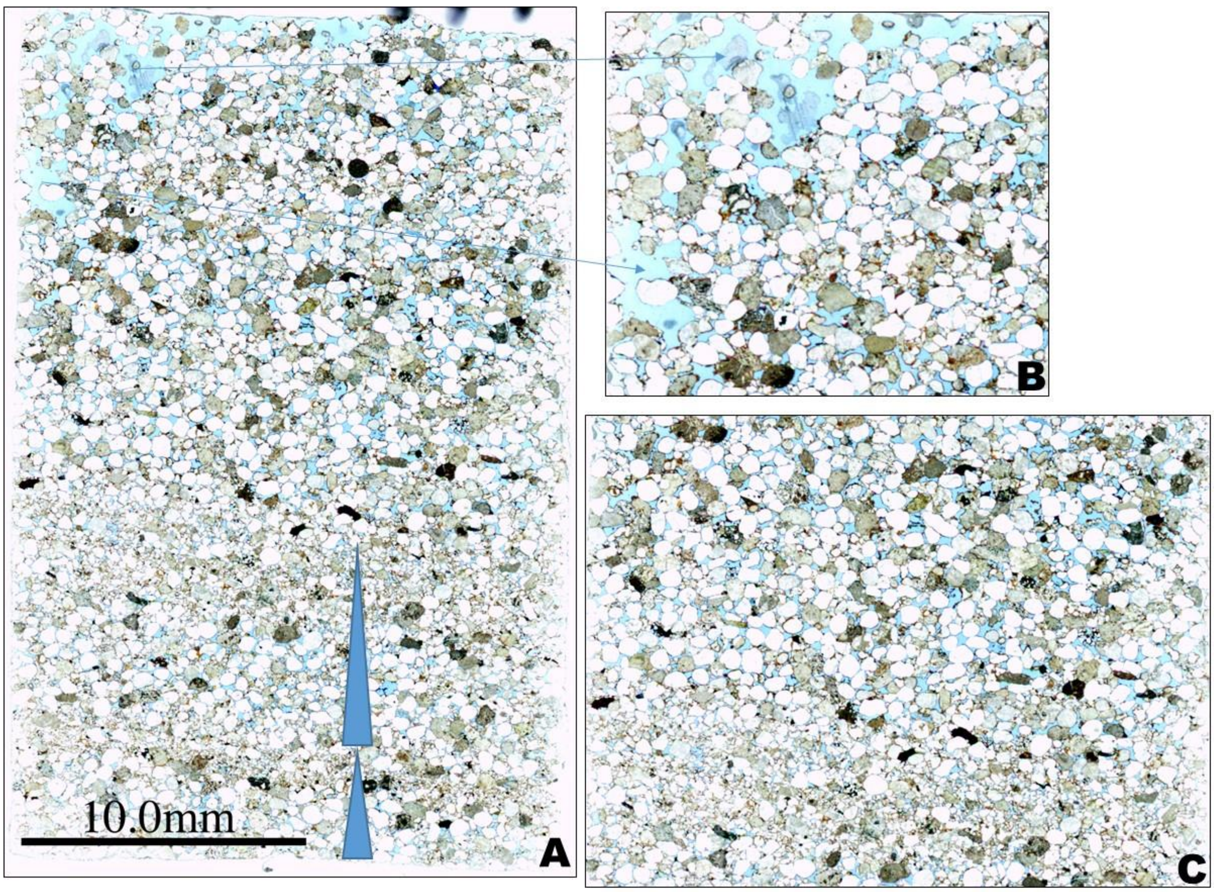

Figure 3. Slide scan image showing whole thin section view of eolian sandstone; **A:** normal grading at the lower part of the slide; **B:** closer view of upper left side of the image showing secondary pore due to grain dissolution (arrows); **C:** alternation of fine grained lamina and coarse grained lamina indicating bimodal grain distribution.

Figure 4 displays a closer view of the sample indicating the nature of the grain contacts. Majority of the grains do not touch each other (floating) or may just touch each other at a point (point contact). Long and concavo-convex contacts are displayed by few grains. This indicates the extent of compaction or burial.

3.2 Identification of some compositional features

Compositional features may not be well defined by slide scan images but grains such as rock fragments can be indicated when enlarged. For example, Figure 5 shows sandstone rock fragments as brown grains while the black deformed grains represent fine grained rock fragments. Grain dissolution porosities are also indicated.

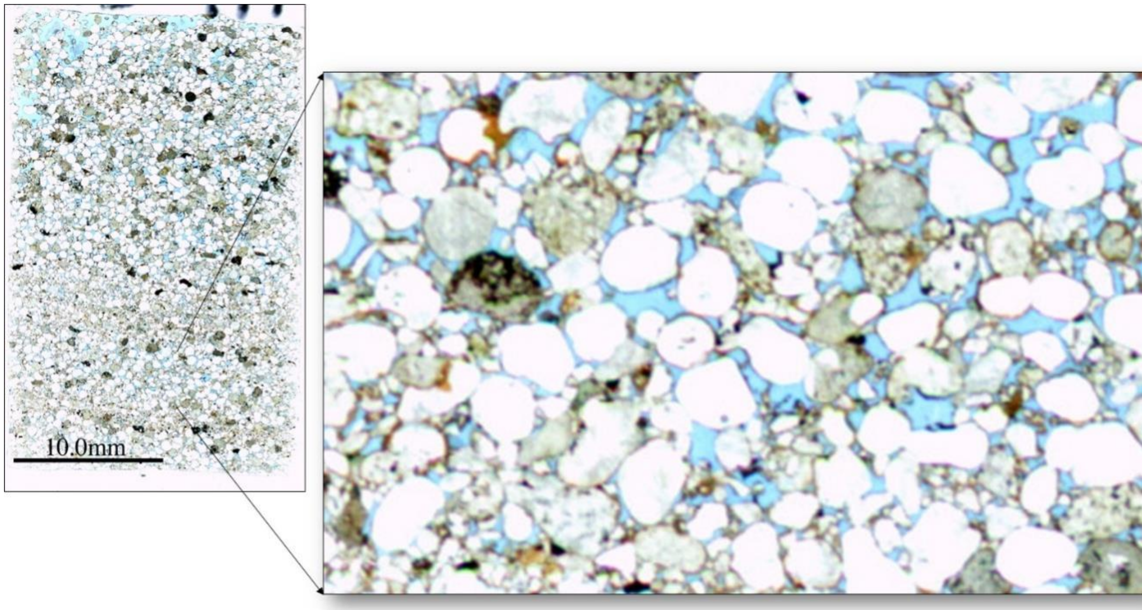

Figure 4. Close-up view to display nature of grain contacts in the sandstone

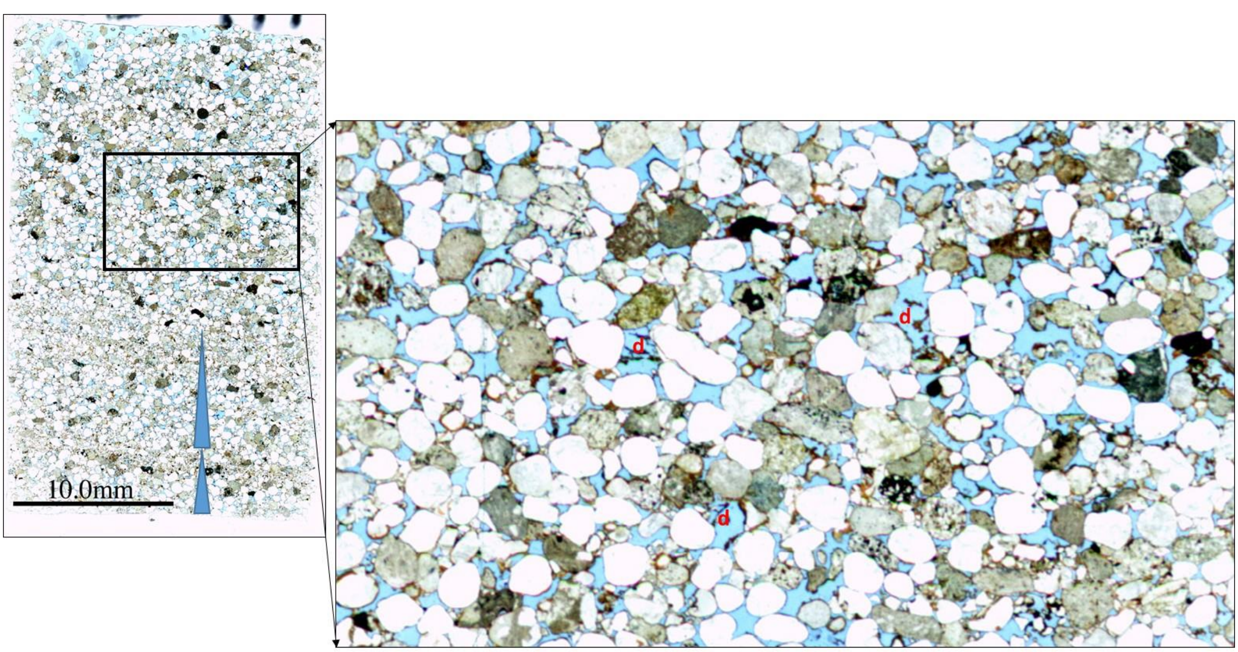

Figure 5. Close-up view showing sandstone rock fragments (brown) and fine grained rock fragments (black) as well as dissolution porosity (d).

3.3 Deciphering sedimentary structures

Deciphering macrostructures easily is one of the advantages that the slide scan images have over conventional petrologic microscopes because acquisition of several photomicrographs in order to show only one features can be avoided. Such structures include graded laminae and cross lamination. Figure 6 illustrates how these features can be discerned from slide scan images. A closer view of alternating fine and coarse grained laminae shows that pore spaces are occluded in the finer grained laminae. This may affect vertical fluid flow in the sandstone.

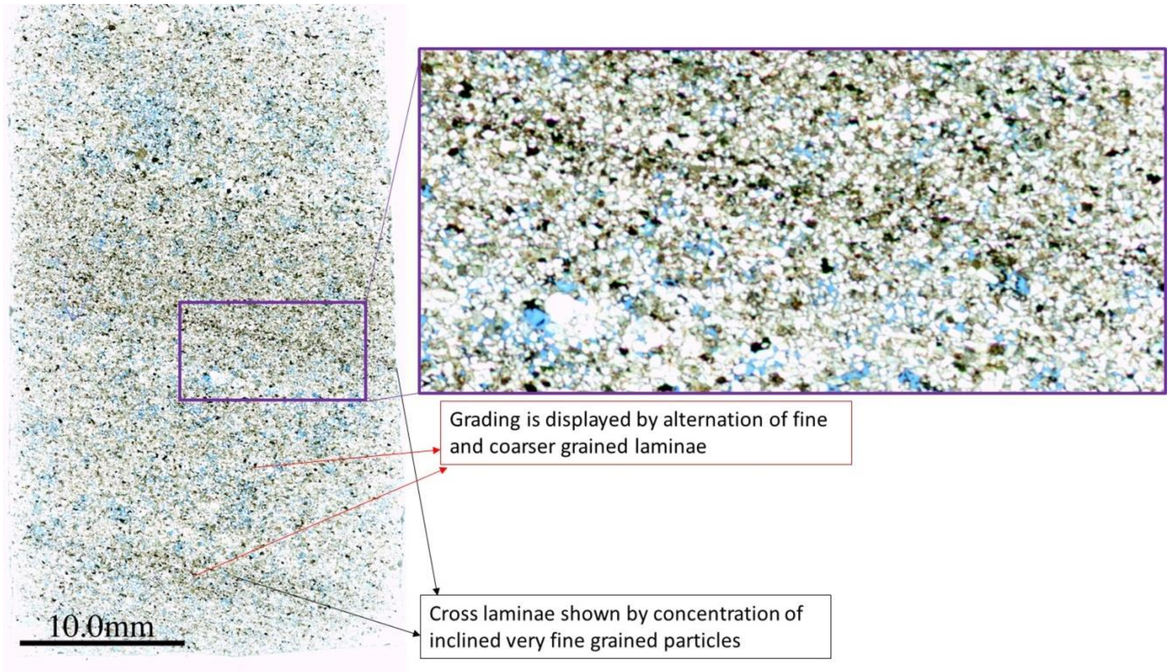

Figure 6. Grading of grain size and cross lamination.

3.4 Porosity measurement

Porosity plays relevant role in aquifers, reservoirs as well as in engineering projects that deal with rocks. The total porosity consists of the volume of voids given by all types of pore spaces either connected or not that are present in the rock and may be filled with water, air or hydrocarbon (oil or gas). Figure 7 demonstrates how quick porosity estimation can be made. Different parts of the slide scan image may be enlarged and their porosities estimated after which the average is taken. The number of cells present on Figure 7is 800 and a total of approximately 94 cells were counted as pore spaces which gives a porosity of about 12% for the enlarged part.

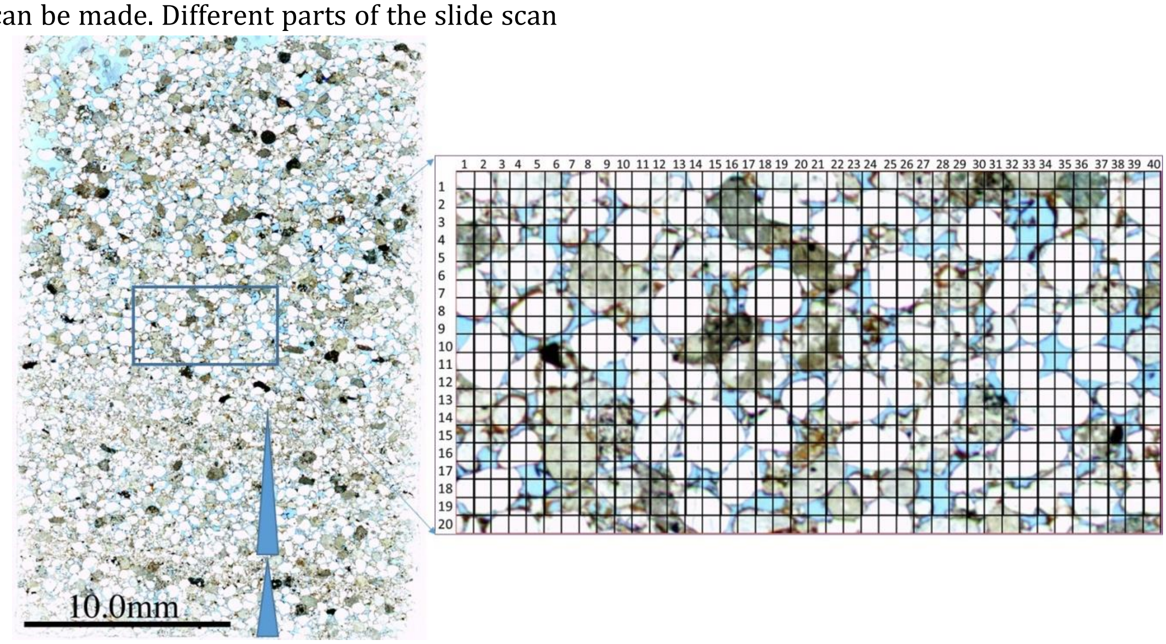

Figure 7. Porosity estimation using manual point counting (gridding method)

Fine grained, angular grains make-up the sandstone on Figure 8. The interconnectedness of the pore spaces is revealed in this sample by zooming-in the slide scan image.

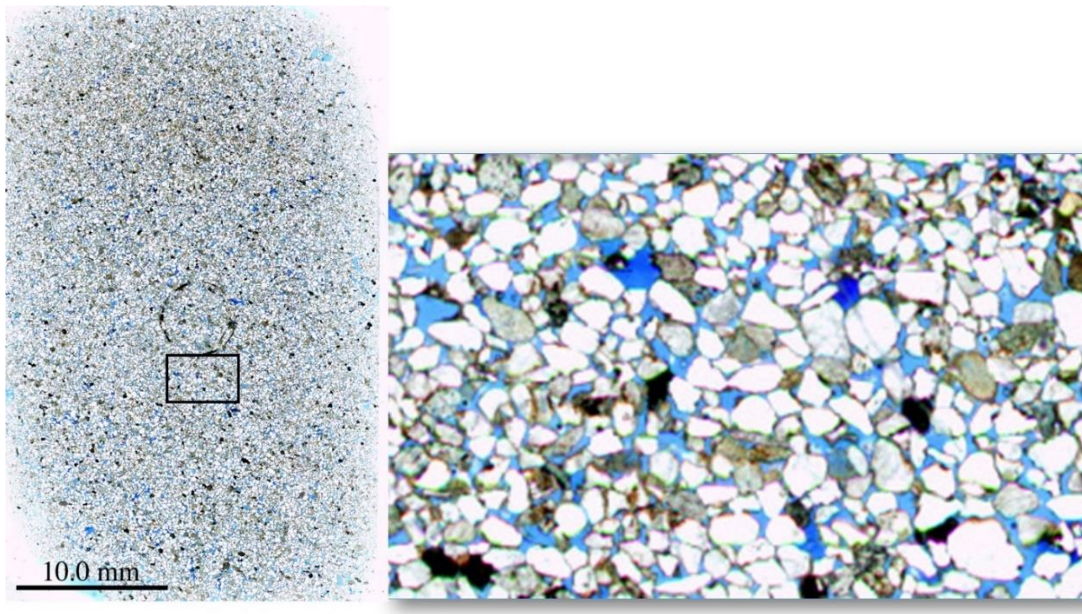

Figure 8. Interconnected pore spaces.

4.0 Discussion

Before the advent of technologies leading to direct acquisition of high resolution digital images the conventional photography was used to indirectly obtain digitized images of whole rock thick sections. This method has been practiced for decades and involves the production of negatives which were scanned and stored in CD ROMs or diskettes. The images were loaded to photography softwares and enhanced before printing digitally. However, with the arrival of more advanced digital imagery such as high resolution scanners, it is possible to obtain images at very high pixels which could be uploaded directly to personal computers for viewing and further processing. This has led to bridging of gaps between photography (as explained above) and phomicrography obtainable from conventional petrological microscopes. More recently, slide scan images were used in solving issues pertaining the detailed description of complex textures such as reef framework in carbonate rocks at very high resolution thereby providing alternative ways in institutions where capacity for acetate peels production are lacking. This is common in laboratories that are ill equipped.

The study of slide scan images has also bridged gaps between different magnifications. In conventional microscopy, different objective lenses are inserted in order to observe features at different magnifications. Whereas if a slide scan image is directly viewed with a computer, it is easier to just crop an area in the image for further studies. Also the relationship between features of interest and the adjacent grains or features are better observed on slide scans. This means that inserting different objective lenses can be avoided.

The information gathered from the slide scan images are all vital sedimentological features that give lots of insight in to hydrodynamic conditions and processes in the environments of deposition. For example, the coarser grain sizes reflect deposition by faster flowing currents while finer grained laminae reflect deposition by slower or quieter moving currents whereasthe degree roundness may reflect the transport distance and degree of reworking of the sediments. Sorting on the other hand generally reflects depositional processes; better sorting is achieved by agitation and reworking processes. For example, to-and-fro movement of current around the beach environment causes better sorting.

The fabric entails documentation of both grain orientation and packing. These information give important insights to the paleocurrent direction and mechanism of deposition of the sediments. For example, in both clastic and carbonate rocks, the recognition of grain support fabric without matrix suggests reworking by currents/wind/waves as the possible mechanism of deposition. It may also reflect deposition by turbulent flows where the suspended sediment load were separated from the coarser bedload materials that where deposited. Matrix support fabric may simply indicate deposition in low energy environments by deposition by low energy flows.

Alternation of coarse and fine grained laminae displayed by cross laminated sandstones reflects sorting of grains at the time of deposition on the foresets of sand dunes. The processes of grain flow and grain fall are two processes that causes sorting of the type displayed by the studied samples. Here, the coarser and thicker beds record avalanching of sediments on foresets while the thinner finer beds reflect suspension settling. These two processes may be the reasons for the alternation of these beds/laminae. Sedimentological interpretation discussed herein can be found in general sedimentology and stratigraphy textbooks such as Pettijohn (1978), Turcker (1994), Reading (1996) Tucker (2003), Boggs (2005), Nichols (2008), Boggs (2009), Selley (2000) and several other papers.

5.0 Conclusions

The following conclusions can be made from this paper.

1. Slide scan images can be obtained using common flatbed scanners or dedicated scanners

2. Studies of slide scan images provide quick, cheap and easy way to gather sedimentological information such as texture, macro-structures and porosity of sandstones

3. Ill equipped research institutions can take advantage of this method to provide services

4. Researchers can also take advantage of this method when access to laboratory is denied during periods of lock-down

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