Mathematica Code for Quantitative Characterization of Sedimentary Grains

Tunwal M.[1,2], Mulchrone K.[2], Meere P.[1]

[1]School of BEES, UCC, Distellary Fields, North Mall, Cork
[2]Department of Mathematical Science, UCC, Western Gateway Building, Western Road, Cork

Introduction

Shape and size characteristics of sedimentary particles provide important source of information. They can be used for postulating the genesis, transport and settling history of the sediments. Grain shape has been researched thoroughly for the past century and as a result a number of methods have been proposed to define and characterize the particle morphology. Here we present a suite of Mathematica code for quantitatively characterizing sedimentary grains. A semi-automatic method is introduced for the textural analysis of siliciclastic sedimentary rocks from their thin section images.

Methodology

A semi-automatic method is introduced for textural analysis of siliciclastic sedimentary rocks using information obtained from thin section images. Fully automatic techniques are likely to succeed using high definition images of rocks exhibiting a clear contrast between matrix and grains. However, such specimens rarely exist in nature. Therefore a semi-automatic approach is proposed here, whereby a human operator identifies grain boundaries and software automatically completes the mathematical analysis of grain shape and related parameters. Grain boundaries are identified by either manual tracing of grains on tracing paper followed by digitalization or by direct tracing on a graphics tablet.
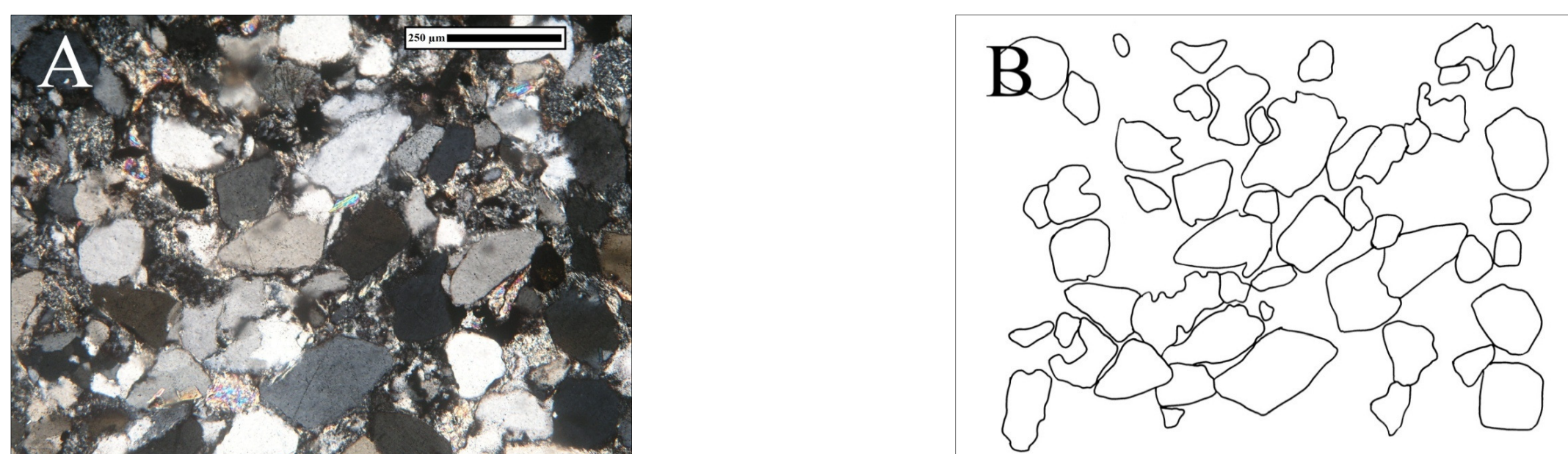

Figure 1: (A) Thin section image of Sandstone sample from Dingle Basin (B) Manually traced out image

Software Description

Mathematica software has been used as a platform to write this code. It is a powerful computational software which is used for image analysis, computing textural analysis parameters and summarizing the result. Mathematica Package is used to store a suite of code which can be loaded and its functions can be called during the session. In the package, all the required code related to performing the following tasks: image analysis, computation of shape and size parameters and exporting of results to .xls file are clubbed together. In the following sections image analysis techniques and parameters used for textural analysis are discussed:

(A) Image Analysis

Two specific functions **ProcessImage** and **RefineImage** are written for the image analysis purpose. **ProcessImage** function takes the traced image file in bitmap(.bmp) format. It binarizes, inverts and applies Watershed Transformation. Image analysis tasks are as follows:

1) **Binarize Image**: Converts the input image to binary image by replacing all the values to 0 and 1
2) **Invert Image:** Converts the binary image into its inverted image
3) **Watershed Transformation:** Generates a matrix by applying Watershed transformation on the inverted image. All the grains are separately identified at this step
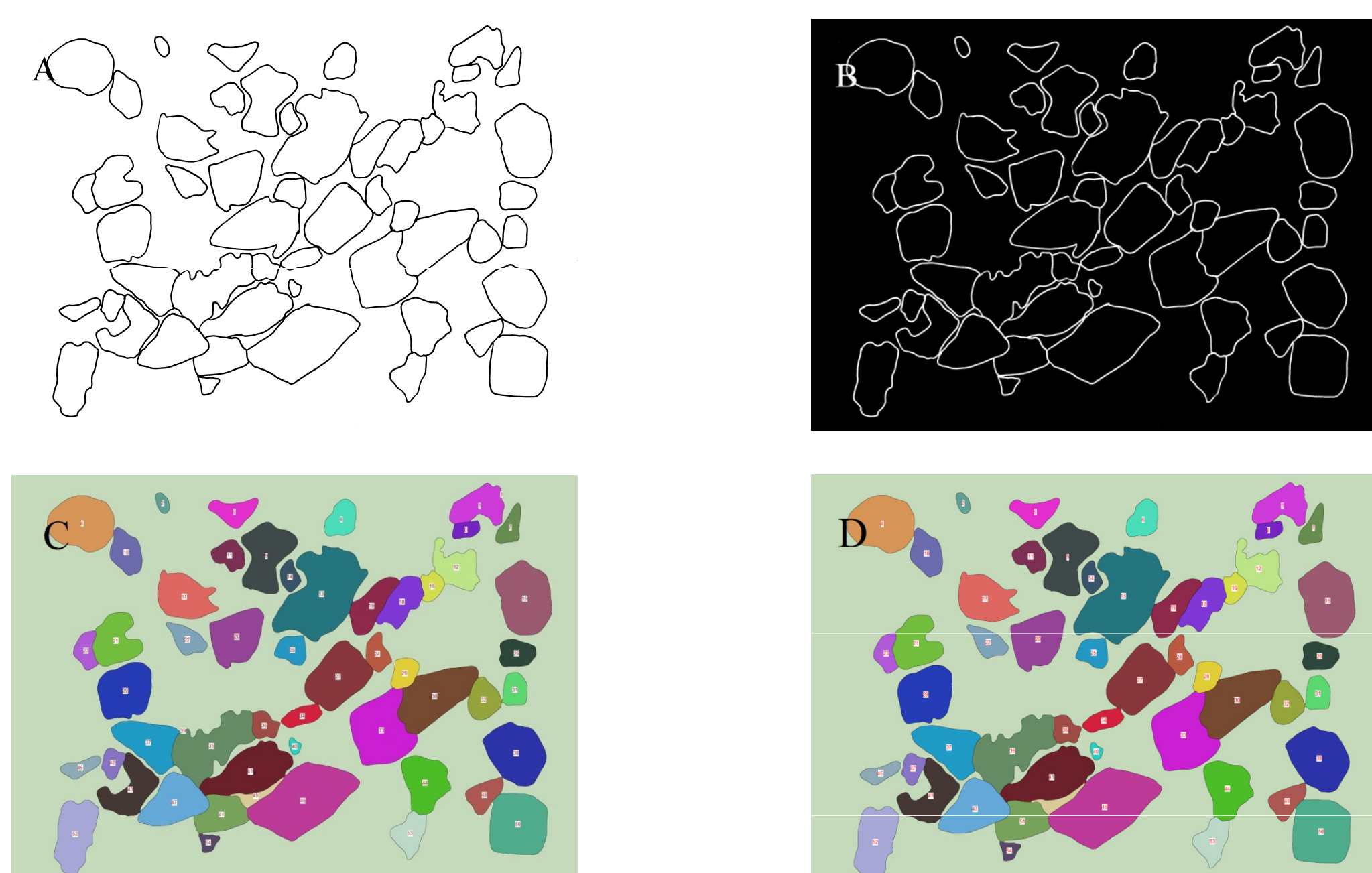4) **Refine Image:** To remove the unwanted grains erroneously identified and labeled. In this case: 3, 39 & 49

Figure 2: (A) Binarized image (B) Inverted image (C) Watershed Transformation applied on the image (D) Refined image

(B) Parameters used

Roundness, Angularity, Irregularity, and Circularity are some of the conventional shape parameters available. Fourier Descriptors and Fractal Dimension are less-conventional parameters, possibly due to mathematical complexity and labour intensity, however they are available in this software and provide valuable information on grain morphology. Other common geometric shape parameters such as Aspect Ratio, Convexity, Solidity, Compactness, ModRatio and Rectangularity are not typically utilised but are included for completeness. Along with shape parameters, grain size is also extracted.

Results

Two parameters are presented here with results for the contrast:

(A) Irregularity

To compute this parameter, first a best fit ellipse of the sedimentary particle is drawn. Next, it is overlapped over the sedimentary particle taking both of their centroid as the common point. Au is the area which is uncommon between both ellipse and sedimentary particle. Ae is the area of ellipse. The irregularity I is given by:

$$I = \frac{Au}{Ae}$$

Figure 3: (A) Area of grain particle (B) Best fit ellipse (C) Overlap of grain particle and best fit ellipse

(B) Fractal Dimension (Box counting)

The number of square boxes of equal dimension required to cover the boundary of sedimentary particle would vary according to the size of the square box. Let Ns be the number of squares that are required to cover the whole coastline and s be the side length of one square of the mesh. Then the box-counting dimension D is given by:

$$D = \lim_{s \to 0} \left(\frac{Ns}{1/s} \right)$$

Figure 4: (A)Decreasing order of unit box size s (B) Graph plot of Log(Ns) vs Log(1/s)

Increasing Irregularity
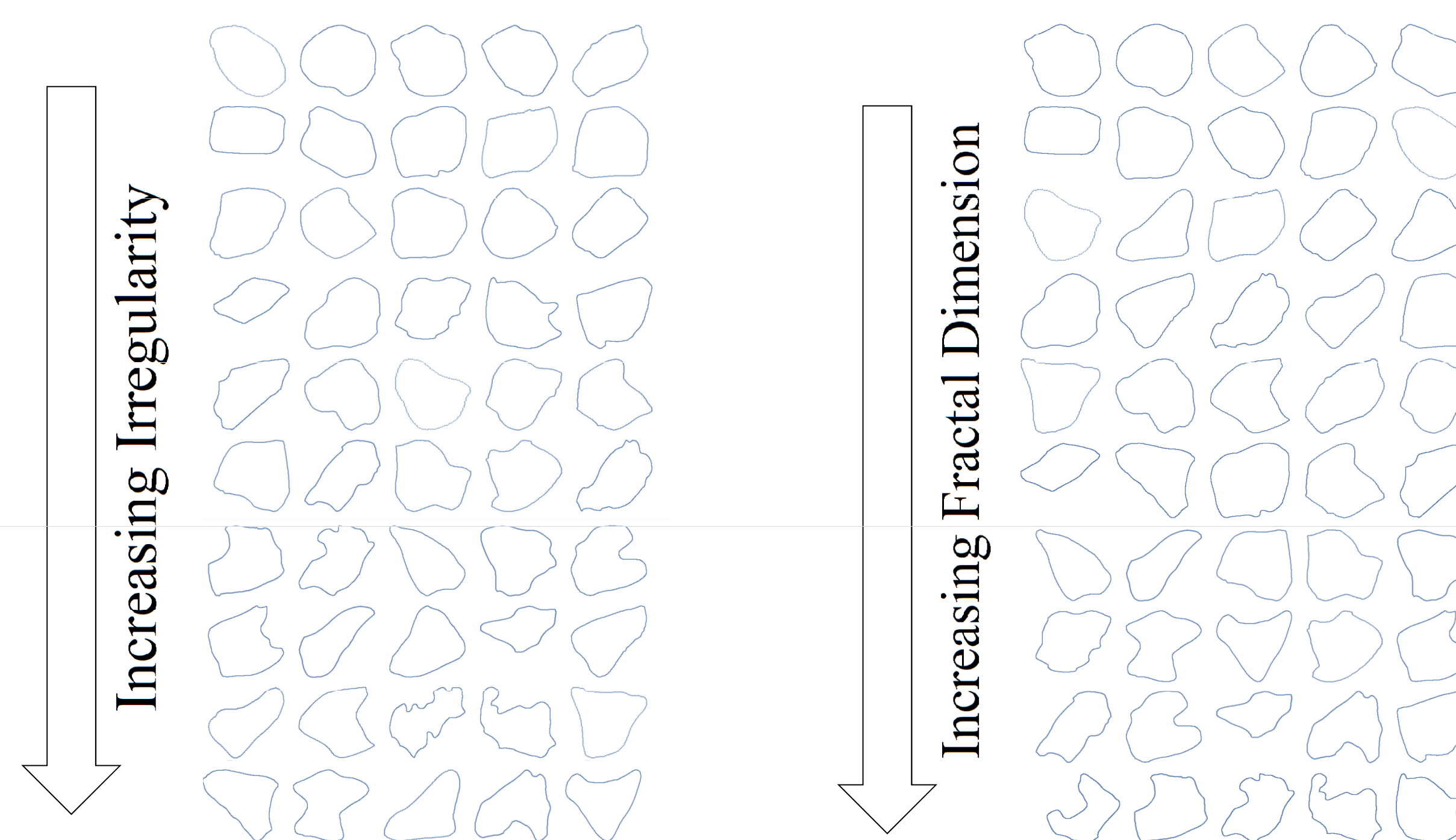
Increasing Fractal Dimension

Figure 5: (A) Increasing order of Irregularity (B) Increasing order of Fractal Dimension

Conclusion

This Mathematica package is presented as a tool to characterized sedimentary grains. Labour intensive manual textural analysis process and deficiency of automatic grain boundary identification has been addressed by this semi-automatic method coupled with powerful computational ability of Mathematica to compute in a fast manner. Modern sediments from different depositional can be possibly characterized and fingerprinted by the provided parameters.

Acknowledgement