# RECONCILIATION OF VISUAL CHARTS AND IMAGE ANALYSIS IN MEASURING THE ABRASION OF PARTICLES.

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## Introduction

Shape analysis of sedimentary particles has been a constant preoccupation in the scientific literature for decades. Hundreds of proposals have emerged, most often reinventing notions that were previously defined by early workers. In contrast to early definitions originating from an empirical approach, more recent proposals have incorporated a computability criteria leading to very different mathematical definitions. Up to now very few attempts have been made to reconcile both approaches. It is our opinion that this may deserve the attention given to image analysis in sedimentology and in earth sciences in general.

## Empirical morphometry

Shape analysis methods defined in sedimentology either refer to some kind of aspect ratio measurement or to a notion of roundness measurement. The first family of measures (flatness, elongation,...) was thoroughly discussed by Zingg (1935) in 3-D although bi-dimensional measurements are most often taken, following Riley's proposal for sphericity (Riley, 1941).
A roundness estimator was first introduced by Wentworth (1919) as :

$$W_W = \frac{2.\lambda_X}{D_X}$$

*with* $\lambda_X$ *: the radius of curvature of the most acute asperity along the particle*
$D_X$ *: the largest diameter passing through point X.*

an "averaged " version of the same idea was proposed by Wadell (1932) :

$$\overline{W} = \frac{1}{N}.\sum_{i=1}^{i=N}\frac{\lambda_{X_i}}{\lambda_E}$$

*with* $\lambda_E$ *: the radius of the maximum inscribed disc of the particle*
$N$ *: the total number of asperities*

Krumbein's visual charts (1941) are based on Wadell's proposal and many subsequent works are minor variations on the same theme.

## Mathematical morphometry

Mathematical methods were boosted by the development of computation algorithms and since almost three decades proposals for shape analysis are closely linked to their computability.
Fourier analysis of sedimentary particles was introduced by Ehrlich and Weinberg (1970) and since then has received much attention be it for the basic problem of contour unrolling or for the multivariate analysis of amplitude coefficients. An interesting development based on elliptic transforms has been proposed recently (Schaaf et al.,1998).
Since almost twenty years, fractal analysis has been given much attention (Flook, 1978). Here again the term refers to a vast number of methodologies (Minkowski sausage, compass, etc.) whose results are by no way similar. The fitting of a straight line on a log-log plot is a critical step in the procedure whose inaccuracy is rarely discussed.
Finally, some recent works have adopted the theoretical framework of the wavelet transform (Drolon et al.,1998).

## Computability of sedimentological concepts

In addition to some major drawbacks inherent to the previously mentioned mathematical shape analysis methods (Pirard and Hoyez, 1995), their use in sedimentology is hindered by their poor similarity with the widespread empirical definitions. The existence of a clear correlation between visual charts and image analysis would allow to make use of important results gained in the literature. Measuring aspect ratio, though accessible through a large combination of measures (Feret diameters, inertia ellipse axes, best fit ellipse axes, etc.) is not a major problem in image analysis. On the other hand, curvature analysis and identification of asperities is a complex problem often discussed in pattern recognition.
Frossard (1978) first tried to make use of the concepts of mathematical morphology (Serra, 1982) to automate Krumbein's chart. His results were strongly affected by the use of non isotropic structuring elements such as

hexagons or squares. The use of a truly euclidean metric and the computation of the calypter ("set of all maximum inscribed discs within a particle") (Pirard,1994) opened the way to a straightforward computation of the ideas initially proposed by Wentworth and Wadell. Based on the theory of abrasion, a roundness parameter called Wv was suggested by the author together with a global roughness measure ($R^{80}$).

### *Measuring roundness on Krumbein's chart.*

The table hereafter, summarises the results obtained on Krumbein's (1941) chart.

| Krumbein Class | $\overline{W}$ (Wadell) % | $\mu$ (Wv) % | $\sigma$ (Wv) % | $\mu$ ($R^{80}$) % | $\sigma$ ($R^{80}$) % |
|---|---|---|---|---|---|
| 0.1 | 22 | **21.26** | 1.91 | **15.66** | 5.66 |
| 0.2 | 29 | **28.95** | 3.94 | **13.74** | 3.63 |
| 0.3 | 29 | **38.12** | 4.66 | **13.16** | 3.23 |
| 0.4 | 32 | **41.61** | 2.91 | **11.92** | 4.54 |
| 0.5 | 49 | **53.81** | 3.41 | **9.27** | 3.13 |
| 0.6 | 43 | **59.95** | 4.36 | **6.85** | 3.59 |
| 0.7 | 57 | **65.01** | 3.71 | **4.03** | 2.17 |
| 0.8 | 48 | **74.86** | 6.25 | **1.24** | 0.97 |
| 0.9 | 58 | **72.31** | 5.08 | **0.94** | 0.93 |

It is noticeable that although Krumbein's drawings are based on $\overline{W}$ , this last parameter is not a correct measure of the indicated class. This is due to the subjective decision of taking (or not) an asperity into account. Nobody ever discussed when an asperity was significant enough to enter Wadell's formula. Obviously, Wv and $R^{80}$ do not depend on an operators choice since they take into account every point of the contour. Both Wv and $R^{80}$ clearly explain Krumbein's classification. Confusion between class 0.8 and 0.9 is evident from a simple look to the original chart. The very low standard deviation of Wv measures makes it very discriminant to detect slight changes in the sedimentary environment as will be demonstrated on real sand samples.

### *Conclusion.*

The computability of Wadell's and Krumbein's original concepts is accessible through euclidean mathematical morphology. Because these concepts as well as Wv's definition are based on a sound knowledge of the abrasion processes they give a pertinent measure of the sedimentological context in which mineral particles are found. The existing correlation between visual charts and image analysis measures is important when intending to understand and to elaborate on the huge amount of previous studies in the sedimentological literature.

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