PARTICLE SHAPE

Course : M.Sc. Geology
Semester – IV

Course Code : MGELEC-1

Unit : Unit - III

Prepared By :

Bhavuk Sharma

Assistant Professor

Department of Geology ,

Patna University , Patna

bhavuksharma1@gmail.com

CONTENTS

1. Introduction
2. Definitions
3. Measuring Particle Shape
4. Particle Form
5. Particle Roundness
6. Surface Texture
7. Exercise
8. References.

INTRODUCTION

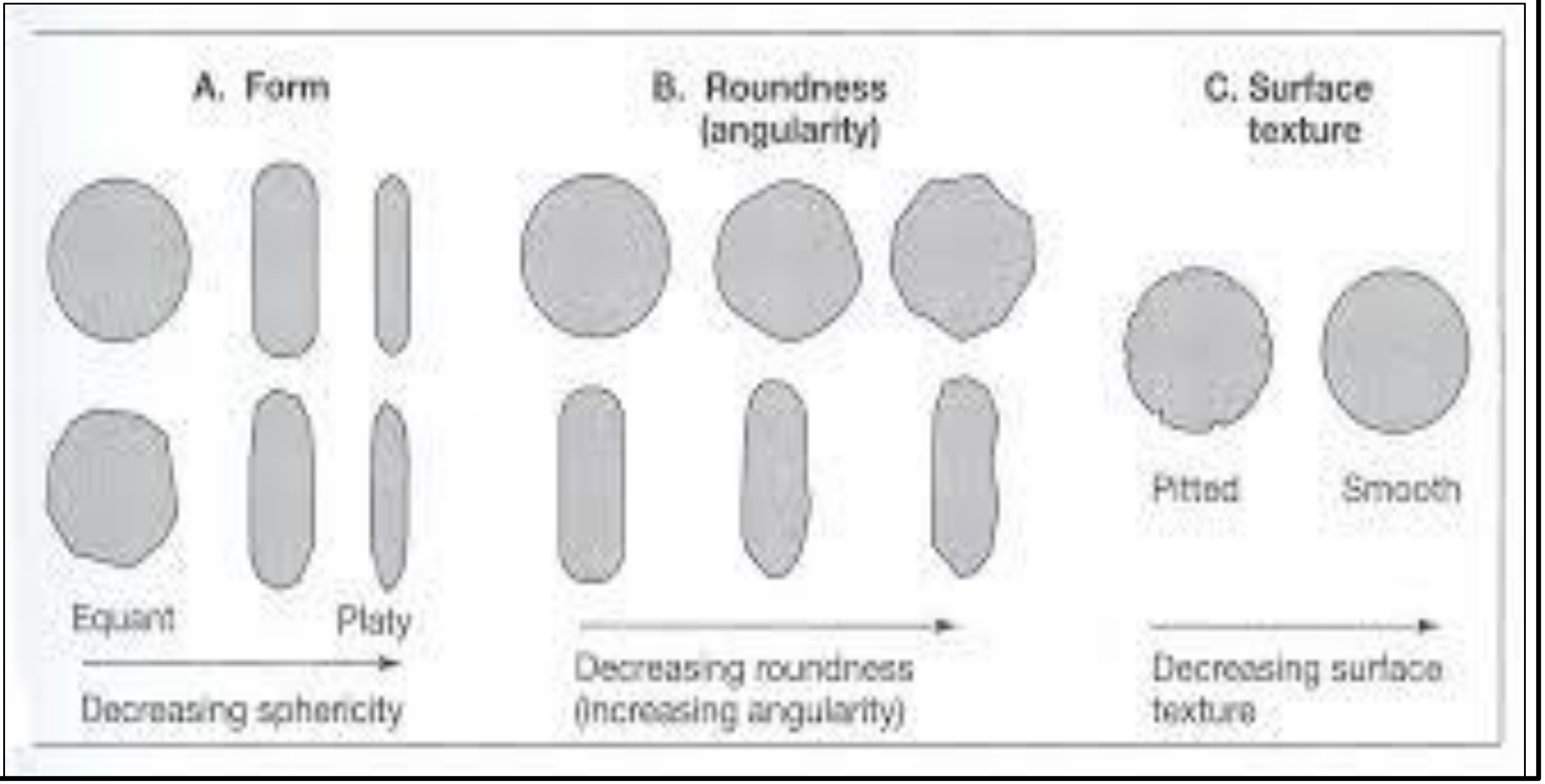
The shape of sedimentary particles is an important physical attribute that may provide information about the sedimentary history of a deposit or the hydrodynamic behavior of particles in a transporting medium. It is determined by the following factors :

- Original shapes of mineral grain in the source rocks
- Orientation and Spacing of fractures in bedrock
- Nature and Intensity of sediment transport
- Sediment burial processes

Particle shape, however, is a complex function of lithology, particle size, the mode and duration of transport, the energy of the transporting medium, the nature and extent of post-depositional weathering, and the history of sediment transport and deposition.

DEFINITIONS

Particle Shape is defined by three related but different aspects of grains :
Form , Roundness and Surface Texture



Measuring PARTICLE SHAPE

- Standardized numerical shape indices have been developed to facilitate shape analyses by mathematical or graphical methods.
- Quantitative measures of shape can be made on two-dimensional images or projections of particles or on the three-dimensional shape of individual particles.
- Two-dimensional particle shape measurements are particularly applicable when individual particles cannot be extracted from the rock matrix.
- Three-dimensional analyses of individual irregularly shaped particles generally involve measuring the principal axes of a triaxial ellipsoid to approximate particle shape.
- The two-dimensional particle shape is generally considered to be a function of attrition and weathering during transport whereas three-dimensional shape is more closely related to particle lithology.

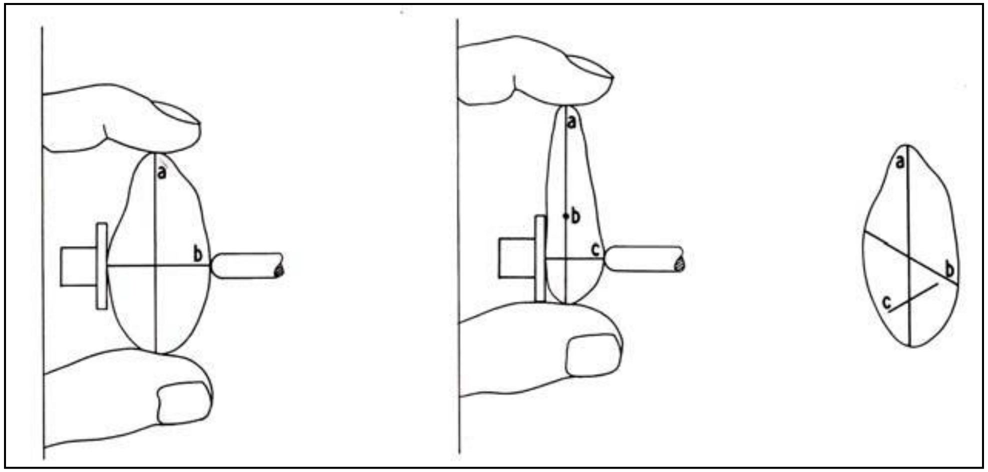


Fig.:Concept and measurement of pebble diameter (Krumbein, 1941 in Pettijohn, 1975, Figure 3-1)

PARTICLE FORM (Sphericity)

- **Form** refers to the gross, overall configuration of particles and reflects variations in their proportions.

- **Form** reflects variations in the relative lengths of their three major axes(short,intermediate , long).**Wadell**(1932) introduced the term Sphericity to express this relationship.

- **Krumbein**(1941) developed the relationship mathematically such that if all three axes have about the same length , a particle has high sphericity and vice versa.In this , a perfect sphere has a value of 1.

- **Zingg**(1935) proposed the use of two shape indices D_I/D_L and D_S/D_I to define four shape fields on bivariate plot : Oblate , Equant , Bladed and Prolate.

Wadell (1932) defined true sphericity as the ratio of the particle surface area to the area of a sphere with the same volume. Unfortunately, this index proves to be difficult to measure. Operational Sphericity (Wadell, 1932) is given by

$$\psi = (Vp/Vcs)^{1/3}$$

$$= (Vp/Vcs)^{1/3}$$

$$\text{Sphericity} = \sqrt[3]{\frac{\text{Volume of the particle}}{\text{Volume of the circumscribing sphere}}}$$

where *Vp is the particle volume and Vcs is the volume of the smallest circumscribing sphere.*

This equation may be approximated by;

$$\psi = abc/a^3$$

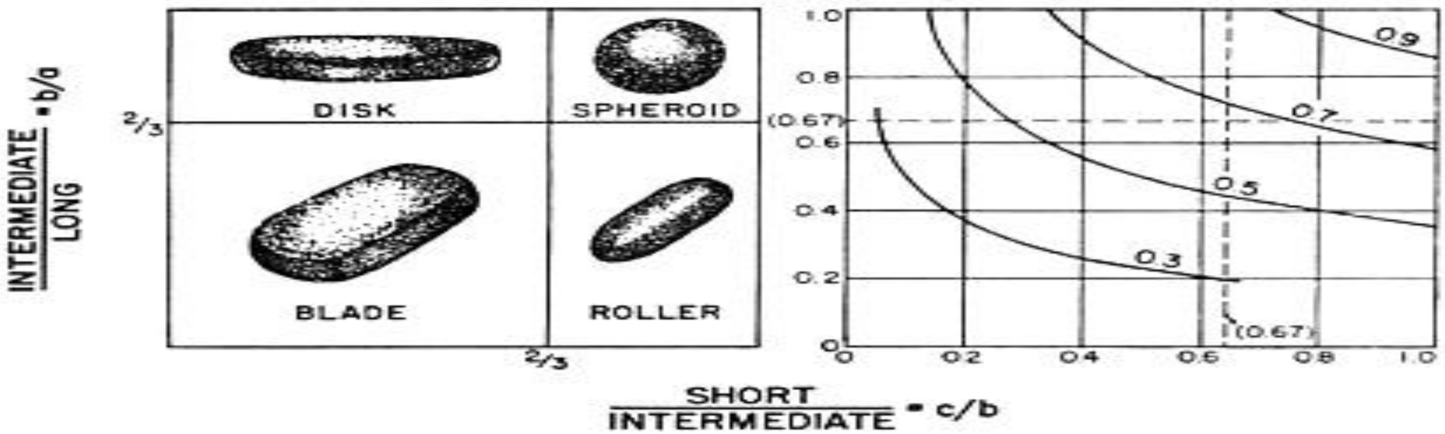
where *a, b. and c are the long intermediate and short axis dimensions, respectively, of the particle (**Krumbein**, 1941). Sphericity values range from 0 (nonspherical) to 1 (perfect sphere) with most sedimentary particles falling in the range of 0.3 to 0.9.*

Zingg Shape Classification

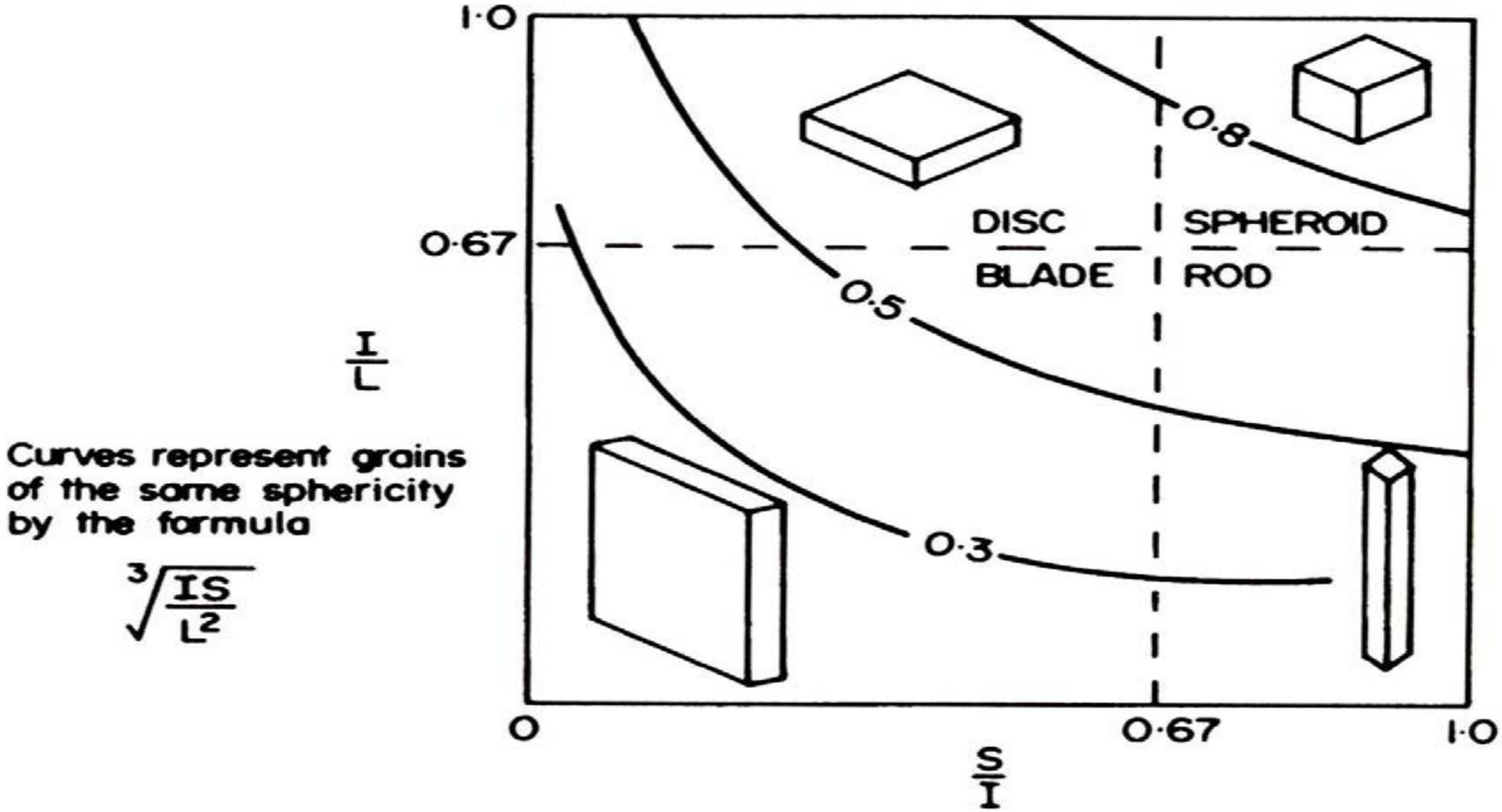
- Zingg (1935) developed a more versatile shape classification scheme that uses the particle dimensions along the three principal axes. Particles are classified into four form categories; spheroids, discoids, rods, or blades based upon the b/a and c/b ratios as shown in the Table . These classes are shown graphically in the Zingg diagram (Figure), which includes representative solids of equal roundness (roundness = 0).

Table 1. Zingg shape classes (after Zingg, 1935 in Pettijohn, 1975)

Class	b/a	c/b	Shape
I	> 2/3	< 2/3	Oblate (discoidal, tabular)
II	> 2/3	> 2/3	Equiaxial (spherical, equant)
III	< 2/3	< 2/3	Triaxial (bladed)
IV	< 2/3	> 2/3	Prolate (rods)



• Lines of equal sphericity, based on the Wadell-Krumbein sphericity index are added to the Zingg diagram. It is important to note that the same value of sphericity may be applied to differently shaped particles, thus sphericity and geometric form are different measures of particle shape.

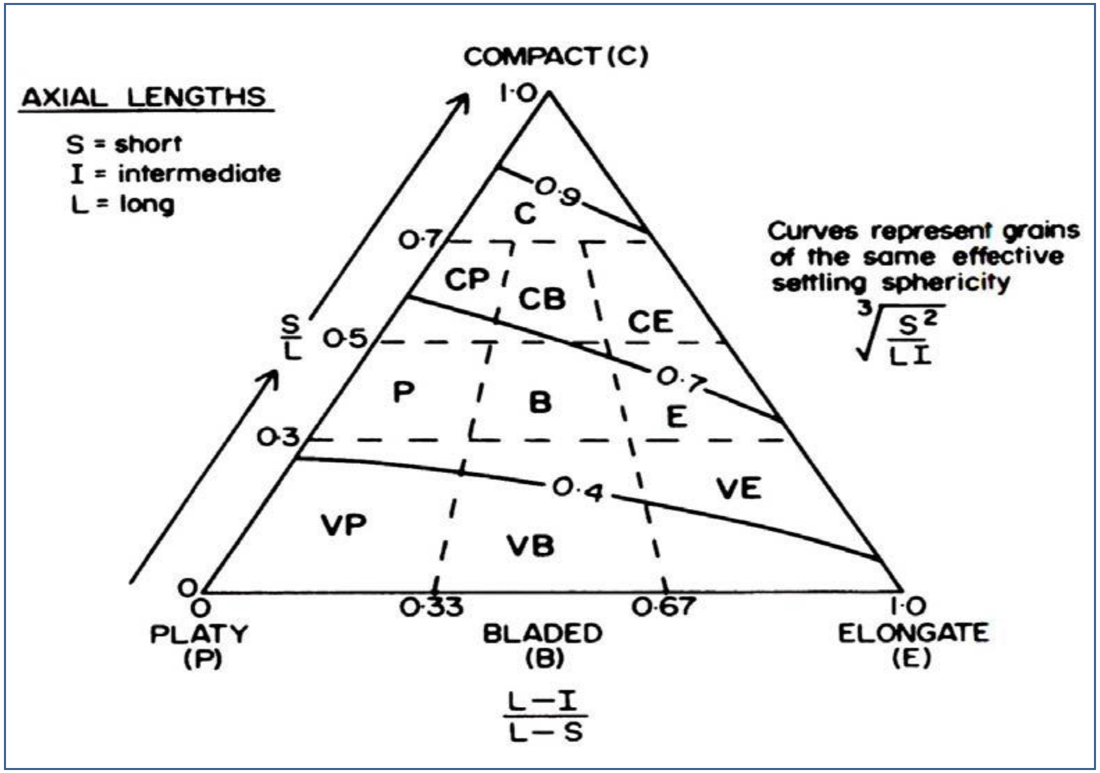


Sneed and Folk Sphericity-Form Diagram

- Sneed and Folk (1958) developed a different sphericity index, the maximum projection sphericity, which they believed represented the hydrodynamic behavior of particles in a fluid. The maximum projection sphericity of a particle is given by the equation;

$$\psi_p = (c^2/ab)^{1/3}$$

- The maximum projection sphericity is represented in the sphericity-form diagram of Sneed and Folk (1958) (Figure). As in the case of the Zingg diagram , lines of equal maximum projection sphericity span several form fields in the diagram.



Cailleux Flatness Index

Cailleux (1945) developed the flatness index based upon the relationship between the particle dimensions along the three principal axes. The index is given by;

$$F = (a + b)/2c$$

The index ranges from a minimum value of 1 for an equant particle and becomes progressively larger the flatter the particle. There is no maximum limit.

PARTICLE ROUNDNESS

- Particle Roundness refers to the degree of sharpness of the corners and edges of a grain.
- If the corners and edges are quite smooth , the grain is said to be well rounded.
- If the corners and edges are sharp and angular , the grain is said to be poorly rounded.
- Roundness indices generally compare the outline of the two-dimensional projection of the particle to a circle Wentworth (1919) first defined roundness as;

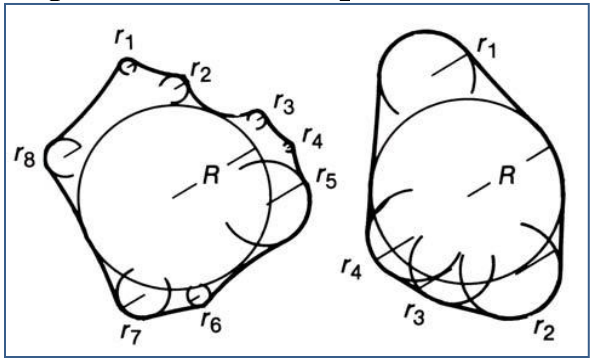
$$\text{Roundness} = r_i/R$$

where r_i is the radius of curvature of the sharpest corner and R is the radius of the smallest circumscribing sphere.

- The Wadell Roundness (Wadell, 1932) index is given by:

$$\text{Roundness} = \sum_{i=1}^{n}(r_i/R)/n$$

where r_i is the radius of curvature of particle corners, R is the radius of the largest inscribed sphere, and n is the number of particle corners measured



Two-dimensional particle images showing definitions for the radii of individual corners (r^1, r^2, *and etc.) and the maximum inscribed circle (R) (Krumbein, 1940 in Friedman, et al., 1992)*

Power's Scale of Roundness

Powers (1953) developed visual comparison chart of reference particles of known sphericity and roundness (Figure). The chart offers a quick and easy way to estimate two-dimensional particle shape, although the comparisons can be subjective. The method is particularly useful in cases where the individual particles cannot be removed from the rock matrix.

The roundness classes are based upon another Wadell roundness index given by;

$$\rho = r/R$$

where r is the radius of curvature of the largest inscribed circle and R is the radius of the smallest circumscribing circle. The index ranges from 0 to 1, with 1 indicating a perfect circle. The roundness classes are based upon a logarithmic scale because the distinction of differences at the high roundness end of the scale is more difficult than at the low roundness end of the scale. The class between 0.00 and 0.12 is excluded, because natural particles generally have roundness values greater than 0.12.

Power’s Scale of Roundness

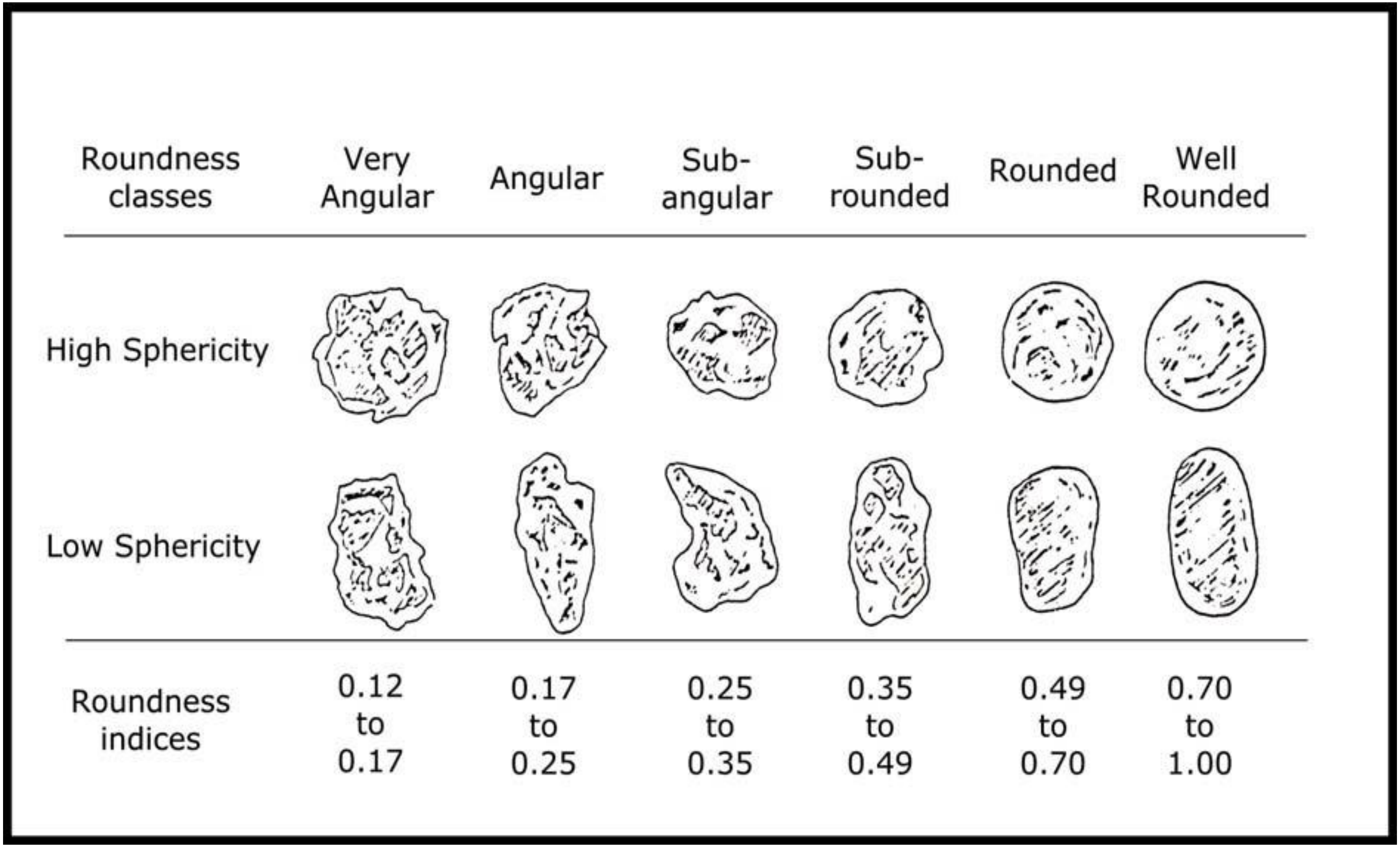


Chart for estimating the roundness and sphericity of sedimentary particles based upon comparisons with particles of known sphericity and roundness (based on Powers, 1953).

SURFACE TEXTURE

- Surface texture, which is the smallest scale to describe the particle morphology, defines the local irregularities and asphericities of particle surface in term for the inter-particle contact areas (Blott & Pye, 2007, Barrett, 1980, Cumberland & Crawford, 1987, Cho et al., 2006).
- Statistical measures of the asphericities have been used to characterise surface texture (Alshibli & Alsaleh, 2004), as well as the use of fractal analysis of the projected particle outline (Hyslip & Vallejo, 1997).

- The surface of pebbles and mineral grains may be polished , frosted or marked by a variety of small-scale , low relief features such as pits, scratches, fractures and ridges .
- These originates in diverse ways : mechanical abrasion during sediment transport , tectonic polishing during deformation and chemical corrosion , etching and precipitation of authigenic growths on grain surfaces during diagenesis and weathering.
- It appears to be more susceptible to change during sediment transport and deposition than do sphericity and roundness.

Exercise

State true or False .Justify your answer:

1. The sphericity of particles in sedimentary deposits is a function of the original shapes of the grains.
2. The roundness of grains in a sedimentary deposit is a function of grain composition , grain size , type of transport process, and distance of transport.
3. Surface texture is more likely to record the last cycle of sediment transport or the last depositional environment.

REFERENCES

1. Alshibli, K. A. & Alsaleh, M. I. (2004) Characterizing surface roughness and shape of sands using digital microscopy. Journal of Computing in Civil Engineering, 18 (1), 36-45.

2. Barrett, P. J. (1980) The Shape of Rock Particles, a critical review. Sedimentology, 27(3), 291-303 .

3. Blott, S. J. & Pye, K. (2007) Particle shape: a review and new methods of characterization and classification. Sedimentology, 55, 31-63.

4. Cho, G. C., Dodd, J. & Santamarina, J. C. (2006) Particle shape effects on packing density, stiffness, and strength: natural and crushed sands. Journal of Geotechnical and Geoenvironmental Engineering, 132(5), 591-602.

5. Cumberland, D. J. & Crawford, R. J. (eds.) (1987) The Packing of Particles, Amsterdam, New York, Elsevier.

6. Hyslip, J. P. & Vallejo, L. E. (1997) Fractal analysis of the roughness and size distribution of granular materials. Engineering Geology, 48 (3-4), 231-244.

7. Boggs Jr. ,Sam(2006). Principles of Sedimentology and Stratigraphy, Fourth Edition, Pearson Prentice Hall

8. https://core.ac.uk/download/pdf/77002459.pdf

9.https://serc.carleton.edu/files/NAGTWorkshops/sedimentary/activities/particle_shape.pdf

THANKS