

A Color Illustrated Guide To Constituents, Textures, Cements, and Porosities of Sandstones and Associated Rocks

Compiled by Peter A. Scholle

AAPG Memoir 28



Memoir 28

**A Color Illustrated Guide To
Constituents, Textures, Cements,
and Porosities
of Sandstones and Associated Rocks**

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U.S. Geological Survey

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Introduction

This book is designed as a companion volume to AAPG Memoir 27. As with its predecessor volume, the purpose of this book is to provide identified illustrations of important grains, textures, cements, and porosity types for geologists who may not be specialists in the petrography of sandstones and associated sedimentary rocks.

Sandstone petrography is of particular interest to the explorationist for several reasons. First, it can provide valuable information on the detailed composition of sedimentary rocks. From this, one can often draw conclusions about the lithology, climate, and tectonic history of the source area, as well as predicting the response of such units to a variety of subsurface diagenetic environments. Second, one can acquire significant data on the grain size, sorting, and rounding of sedimentary grains. For lithified sediments this may be the only way to obtain such data, which may be useful in determinations of the transport mechanisms and depositional environment of the sediment. Third, information may be obtained on the post-depositional alteration history of sedimentary rocks. This may include data on compaction, cementation, leaching, fracturing, porosity types, and other factors. These are essential for a proper understanding of reservoir rocks and, commonly, petrography provides the only technique for gathering accurate data on such diagenetic factors.

This book is intended as an introduction for exploration geologists or students and is by no means a complete textbook

or treatise. However, it does include a wide variety of color photographs of terrigenous clastic grains, cements, and textures of sandstones and common accessory rock types. Although most of the illustrations are of features seen with the petrographic microscope, some scanning electron micrographs are included. The illustrations were made from samples having as wide a range of lithologies, geologic ages, and localities as possible to insure a fairly representative presentation. In addition, the photographs were generally selected to show the most common grain and textural types encountered by the geologist and to present typical, rather than spectacular, examples of most features. Thus, the book should have applicability to any sandstone petrographic study.

This volume focuses on the descriptive aspects of petrography and includes no text other than figure captions. Bibliographies are provided in each section of the book. For more detailed descriptive and interpretive information, the references listed in both the general and specific bibliographies should be consulted.

The major emphasis of this book is on the four major fabric elements of sandstones: framework grains; detrital fine-grained matrix; cements; and pore space. The dominant framework grains of most sandstones are quartz, feldspars, and rock fragments and these are illustrated in detail. Accessory minerals, such as calcite, mica, glauconite, zircon, magnetite, or organic carbon, are present in most rocks and occasionally are significant rock-forming elements. These minerals are shown in the section entitled "Other detrital grains." Detrital matrix minerals of sandstones and shales are included in a separate section. Framework and matrix grain types can be distinguished readily with the petrographic microscope, especially when supplemented with staining, scanning electron microscopy (SEM), X-ray diffraction, and cathodoluminescence (discussed in a section entitled "Techniques").

The proper identification of framework grains is the key to the classification of sandstones. Examples are provided of the major sandstone types as seen in thin section, and brief summaries are given of the major classification schemes. It is best to consult the original reference, however, before using any particular one because of the complexity of most classifications. In addition, different authors have different definitions of their major compositional end members. For example, some authors include chert with the quartz group while others place chert with the rock fragments.

Rock textures, particularly grain size, shape, sorting, and orientation, are commonly described from thin section, especially when rocks are strongly indurated. Several examples are shown that cover the spectrum from texturally immature to texturally mature rocks. Charts are provided for the estimation of degree of sorting and the description of grain shapes.

Information about the cementation of sandstones is perhaps the most complex, yet potentially valuable, data that can be collected from thin section analysis. This book illustrates the most common cement types in sandstones as well as some complex sequences of multiple generations of cement formation. In addition, other diagenetic fabrics such as replacement, dissolution, compaction, and grain deformation are shown, as are both primary and secondary porosity types.

The information that can be gained from the types of analyses illustrated in this book can be extremely valuable in understanding hydrocarbon reservoir rocks. Such petrographic studies are best undertaken in conjunction with well-log analysis, seismic interpretation, regional geologic synthesis, and other techniques. When applied by the exploration geologist within this larger frame of reference, the results can be remarkably useful. And in the context of overall hydrocarbon exploration costs, the time and expense of such studies are minimal.

Despite the fact that sandstone petrography is a complex and varied subject, it is hoped that, using this color photographic guide, even investigators with little formal petrographic training will be able to examine thin sections under the microscope and interpret the main rock constituents and their diagenetic history. It is hoped that this volume will both stimulate and facilitate petrographic studies of subsurface and outcrop units.

Explanation of Captions

Each photograph in this manual has a description in standard format. The first two lines give the stratigraphic unit, depth (for subsurface samples), and state or country of origin. Lithologic unit names shown in full quotation marks are informal designations; names shown in single quotation marks are ones not recognized by the USGS. The locality data are followed by a description of the photograph. The last line of the caption defines the type of lighting used and the scale of the photograph. The following code is used for lighting:

- XN —crossed nicols (crossed polarizers)
- PXN —partly crossed nicols
- RL —reflected light
- RTL —reflected and transmitted light
- CL —cathodoluminescence
- SEM —scanning electron microscopy
- TEM —transmission electron microscopy.

The absence of any symbol indicates that transmitted light with uncrossed polarizers was used. All scales are given as a certain number of millimeters (or micrometers, μm , for scanning electron micrographs) equivalent to a uniform length (1.25 cm or 0.5 in.) for all photographs. Thus, a figure of 0.38 mm indicates that a length of 1.25 cm on the printed picture is equivalent to 0.38 mm on the original specimen.

Acknowledgements

An earlier, shorter version of this book was compiled at the Cities Service Oil Co. Exploration and Production Research Lab, and much of that original version is included here. I would like to express my thanks to Cities Service for their kind permission to publish this work. During the past seven years, many people have contributed samples or photographs to this book. I would particularly like to thank A. S. Boggs, G. A. Desborough, S. P. Dutton, E. J. Dwornik, R. L. Folk, A. J. Gude, III, P. L. Hansley, D. E. Hoyt, C. W. Keighin, R. R. Larson, R. G. Loucks, E. F. McBride, E. D. McKee, C. W. Naeser, E. D. Pittman, Edwin Roedder, V. Schmidt, B. C. Schreiber, R. A. Sheppard, R. F. Sippel, G. W. Smith, C. W. Spencer, R. B. Tripp, T. R. Walker, and C. R. Williamson for the invaluable material they contributed. Finally, I would like to express my appreciation to Sigrid Asher Bolinder, R. L. Folk, T. D. Fouch, P. L. Hansley, C. W. Keighin, E. F. McBride, K. A. Schwab, and C. W. Spencer, who reviewed various drafts of this book and made many constructive suggestions.

35 mm Slide Set

A set of 100 selected photographs from this book are available in the format of 35 mm slides. The set is designed to aid instructors who might use the text for teaching purposes. Photographs included in the slide set are indicated by a ★ next to the scale in the photograph description. The slide set can be ordered from AAPG, P.O. Box 979, Tulsa, OK 74101; cost \$128.00 (price subject to change without notice). A similar set of slides for carbonate rock keyed to AAPG *Memoir* 27 "A Color Illustrated Guide to Carbonate Rock Constituents, Textures, Cements and Porosities" is also available for \$128.00 from AAPG.

Grain Size Scales for Sediments

The grade scale most commonly used for sediments is the Wentworth scale (actually first proposed by Udden), which is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit. For more detailed work, sieves have been constructed at intervals

$$2\sqrt{2} \text{ and } 4\sqrt{2}.$$

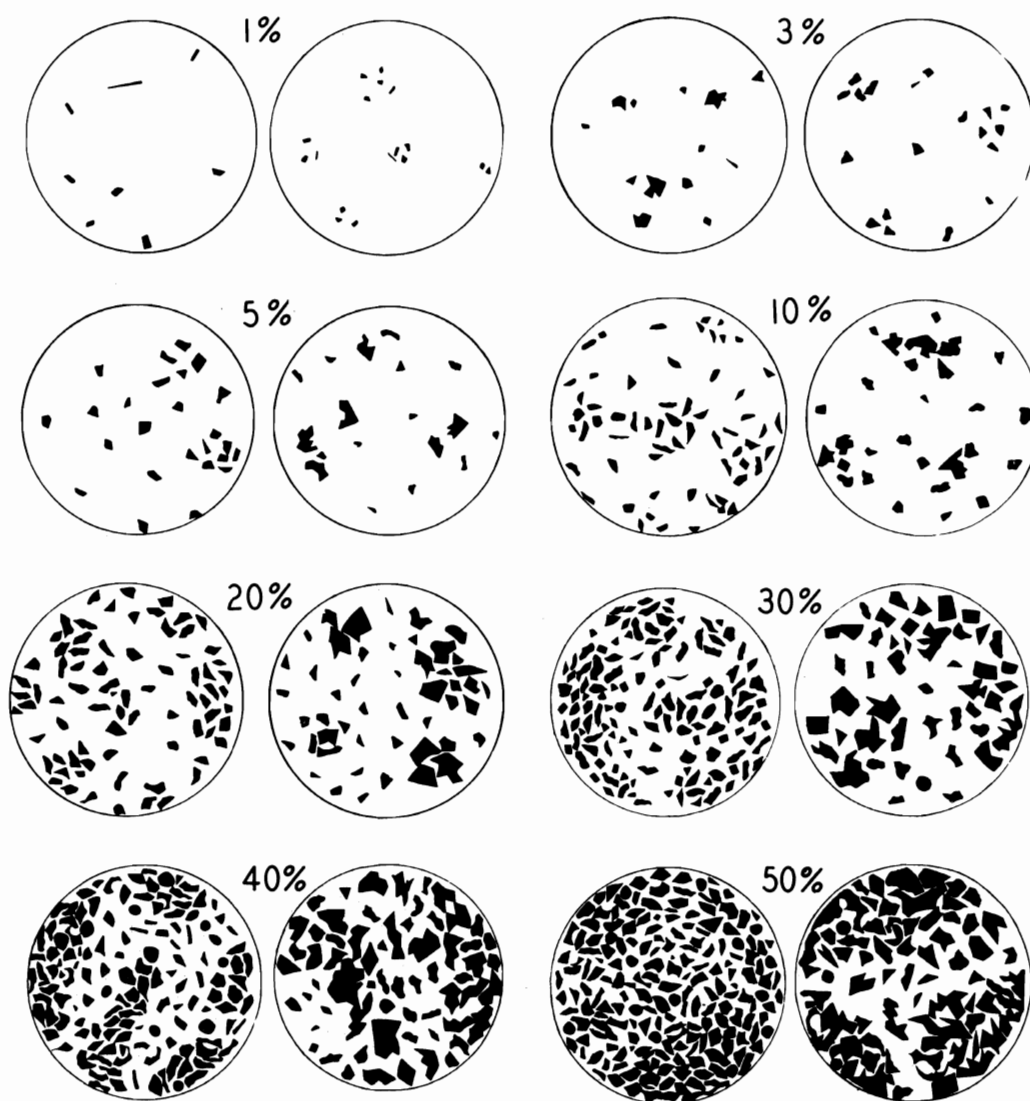
The ϕ (phi) scale, devised by Krumbein, is a much more convenient way of presenting data than if the values are expressed in millimeters, and is used almost entirely in recent work.

U.S. Standard Sieve Mesh #	Millimeters	Microns (μm)	Phi (ϕ)	Wentworth Size Class	
	4096		-12		GRAVEL
	1024		-10	Boulder (-8 to -12 ϕ)	
Use	256		-8		
wire	64		-6	Cobble (-6 to -8 ϕ)	
squares	16		-4	Pebble (-2 to -6 ϕ)	
5	4		-2		
6	3.36		-1.75		
7	2.83		-1.5	Granule	
8	2.38		-1.25		
10	2.00		-1.0		
12	1.68		-0.75		SAND
14	1.41		-0.5	Very coarse sand	
16	1.19		-0.25		
18	1.00		0.0		
20	0.84		0.25		
25	0.71		0.5	Coarse sand	
30	0.59		0.75		
35	1/2 0.50	500	1.0		
40	0.42	420	1.25		
45	0.35	350	1.5	Medium sand	
50	0.30	300	1.75		MUD
60	1/4 0.25	250	2.0		
70	0.210	210	2.25		
80	0.177	177	2.5	Fine sand	
100	0.149	149	2.75		
120	1/8 0.125	125	3.0		
140	0.105	105	3.25		
170	0.088	88	3.5	Very fine sand	
200	0.074	74	3.75		
230	1/16 0.0625	62.5	4.0		
270	0.053	53	4.25		
325	0.044	44	4.5	Coarse silt	
	0.037	37	4.75		
	1/32 0.031	31	5.0		
Analyzed	1/64 0.0156	15.6	6.0	Medium silt	
	1/128 0.0078	7.8	7.0	Fine silt	
by	1/256 0.0039	3.9	8.0	Very fine silt	
Pipette	0.0020	2.0	9.0		
	0.00098	0.98	10.0		
or	0.00049	0.49	11.0	Clay	
Hydrometer	0.00024	0.24	12.0		
	0.00012	0.12	13.0		
	0.00006	0.06	14.0		

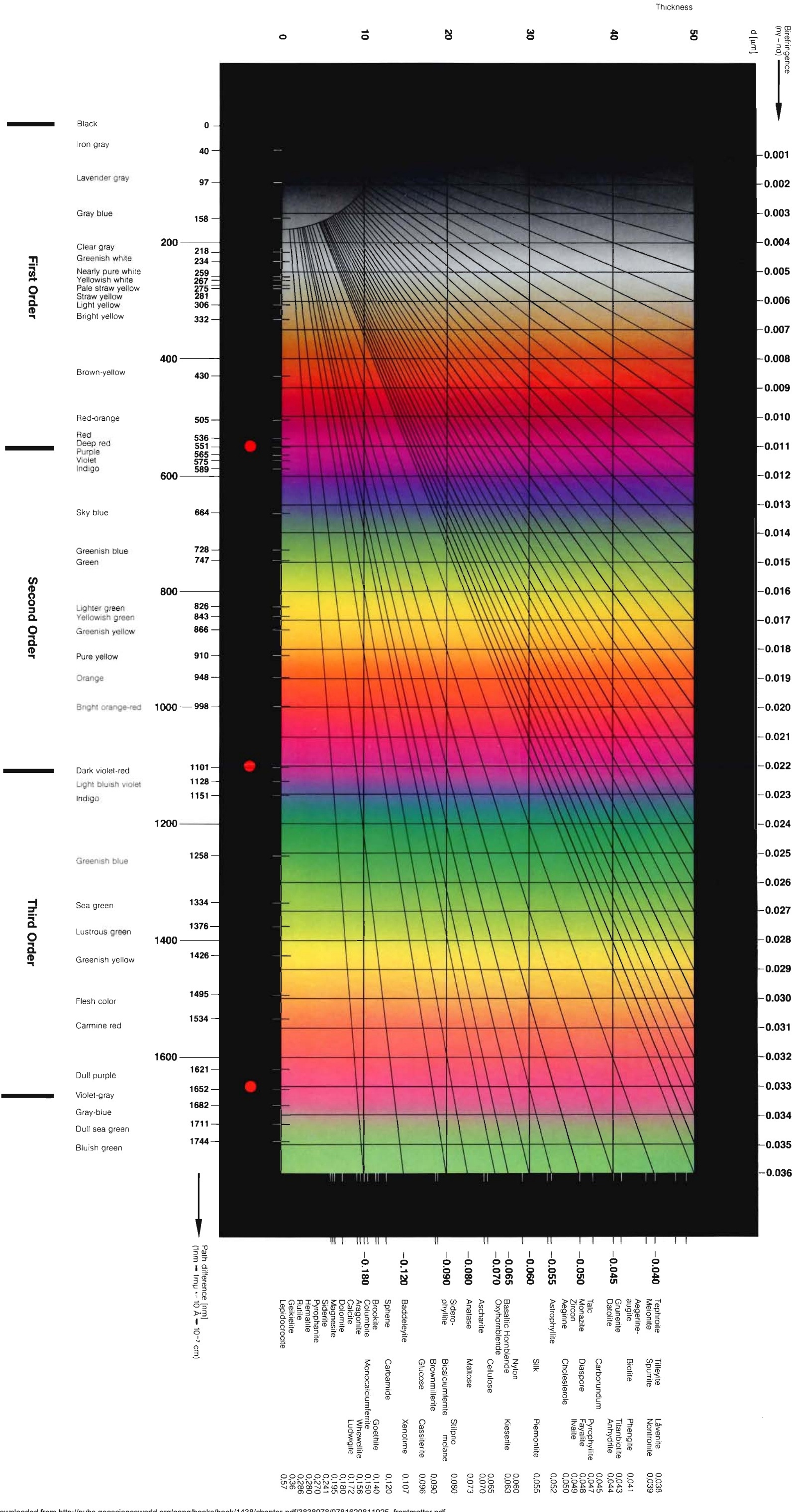
(From Folk, 1968)

Grain Scales: cont.

Comparison Chart For Visual Percentage
Estimation (After Terry and Chilingar, 1955).



Michel-Lévy Color Chart



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