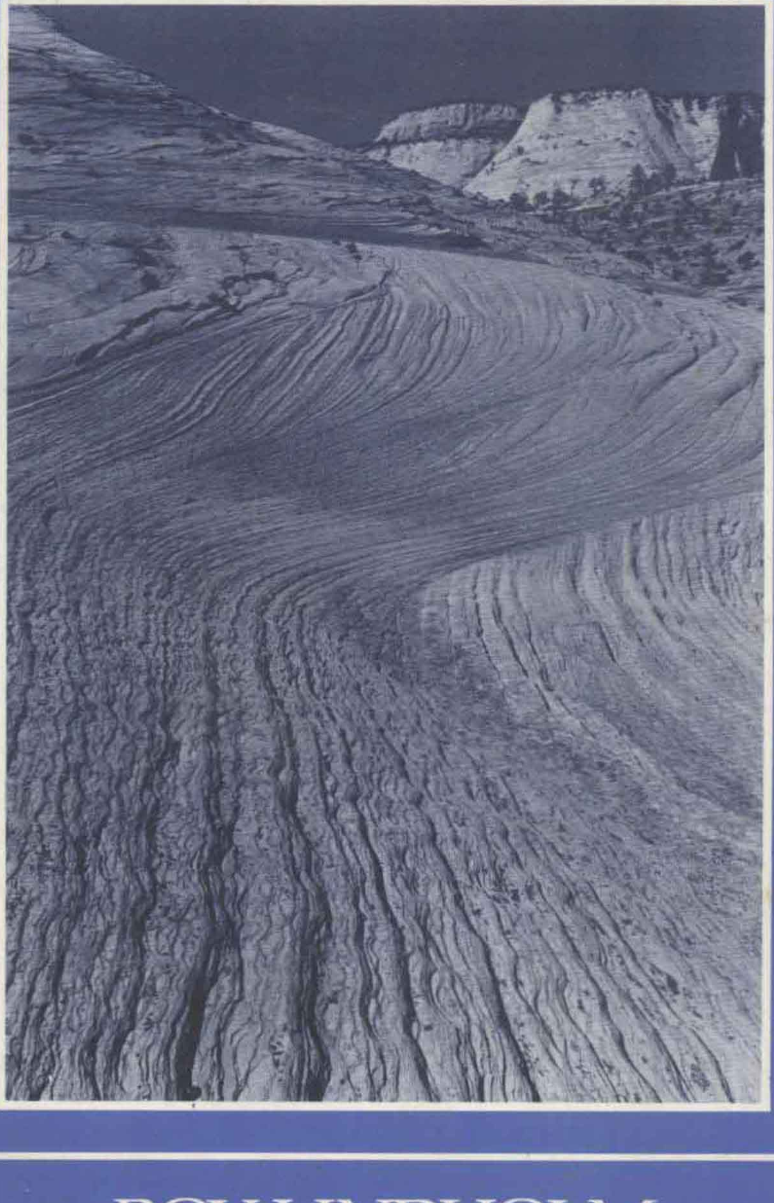
A Practical Approach to
Sedimentology



ROY LINDHOLM

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Sedimentology

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To my wife Betty, without whose patience and understanding this book would not have been written

Preface

This book is designed for a one-semester course in sedimentology taken by advanced undergraduate or graduate students. It gives detailed descriptions of sedimentary features and the analytical methods used to evaluate them and is intended to support and reinforce principles presented in lectures. Discussion of principles and processes is found in complimentary texts, such as Leeder's (1982) *Sedimentology: process and product* and selected readings in professional journals.

This book is not an exhaustive treatise of laboratory techniques and theory. The subject matter includes topics generally covered in courses entitled "Sedimentology" or "Sedimentation". Sandstone and carbonate petrography is commonly given in a separate course. Furthermore, this topic is covered in several current texts. For these reasons I have omitted petrographic methods, with the exception of those applying to heavy minerals. I have included a rather extensive discussion of heavies because this topic is generally lacking in most modern texts. Every course in sedimentology is highly individualistic and material covered varies with the interests, background, and point of view of the instructor. For these reasons some topics presented in this book are not necessarily covered in all courses. Similarly some instructors may find that their favorite topic is missing. I can only hope that this problem is minimal.

Several chapters contain precise exercises to be completed by the student. Some must be done in the classroom, where specimens are available for study. Others may be done outside of the classroom. In some case (e.g. sedimentary structures) the materials will have to be provided by the instructor. In others (e.g. measurement of cross-bed azimuths) the data given in this book may be supplemented or replaced by data collected by the student.

I have tried to present methodology in a step-by-step format which allows independent student work. Some techniques which are standard fare in most sedimentology courses include determination of vector mean, vector magnitude, and grain-size parameters, as well as Markov chain analysis of vertical sequences. Several useful tests (chi-square and Mann–Whitney *U*) are presented to stress the value and need for statistical analysis in sedimentologic research. Extensive presentation of two-theta values and sample diffractograms are included to allow students to become familiar with X-ray diffraction techniques, even if the necessary equipment is not available. Detailed descriptions, together with identification keys, will aid in the identification of heavy minerals and trace fossils.

Roy C. Lindholm

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1.1 Introduction

Primary sedimentary structures are formed at the time of deposition or shortly thereafter. The character of these structures depends mainly on current velocity, water depth, grain size, and sedimentation rate. As such they are critical to the understanding of the processes and conditions of deposition and lead to an interpretation of the depositional environment. In addition, some are useful in determining "stratigraphical-up" or "way-up" in folded sequences and paleocurrent directions.

All too often the terminology used is unnecessarily complex and confusing. One problem is that a particular structure may be quite variable in shape, and each variant is given a different name. Tool casts, for example, are subdivided as groove casts, chevron casts, prod casts, bounce casts, brush casts, and roll casts. This mainly reflects the complex nature of natural phenomena and to a certain extent it is unavoidable. A bigger problem is the use of numerous terms to describe a single feature, or worse, the use of the same term to describe different structures. In this book I have tried to present the most commonly used terms. This will meet your primary need to have a working vocabulary. You will also require an expanded vocabulary in order to use the literature, so I have included frequently used synonyms in the tables and have introduced them parenthetically in the text.

The organization of this chapter is based on the position of the structure relative to the bedding surface. The purpose is to familiarize you with the most common structures and give you an appreciation of their significance. Details concerning the processes involved in their formation can be found in books by Blatt *et al.* (1980) and Leeder (1982) as well as in those listed below. This text contains numerous illustrations, but you should look at as many other examples as possible. This is best done in the field and in the laboratory with hand specimens. Photographs will further enhance your ability to recognize sedimentary structures and to appreciate their variability. Especially recommended are books by Potter and Pettijohn (1963, 1977), Pettijohn and Potter (1964), Picard and High (1973), Reineck and Singh (1975), Allen (1982 a & b), Collinson and Thompson (1982), and Scholle and Spearing (1982).

1.2 Structures on the upper bedding surface

1.2.1 Undulatory bedforms produced by unidirectional water currents

Most bedforms produced in unidirectional water currents are asymmetric with a gentle surface sloping up-current (stoss surface) and a steeper surface (25–35°) sloping down-current (lee surface or slipface) (Fig 1.6b). Bedforms migrate in the direction of flow as sediment is accreted onto the lee surface. As water passes over the crest, the flow separates from the bed to form a zone of reverse flow (backflow) (Fig. 1.15). At the point where the mainflow reattaches to the bed, turbulent eddies are produced. In the case of bedforms with irregular (three-dimensional) crestlines, the erosive power of these eddies is concentrated on the bed to form spoon-shaped scours which migrate ahead of the crest. Scour pits of this sort are absent in straight-crested bedforms.

Current ripples are the smallest subaqueous forms commonly developed on silt to medium sand beds. They do not occur in sand coarser than 0.6 mm. Only in water depths of a few centimeters are ripple forms coupled with surface waves, and as is the case with megaripples, they are out of phase. Ripple height ranges from 0.5 to 5 cm, and ripple wavelength ranges between 10 and 60 cm (Table 1.1). The ripple index (L/H) ranges between 10 and 40. In plan view, ripple crests are straight (referred to as two-dimensional – see Fig. 1.1) or irregular (three-dimensional – see Fig. 1.2). Some work suggests that the variation from 2-D to 3-D ripples is systematically related to flow conditions (especially velocity and depth). However, it does not seem that these variations are regular, or large enough to be useful in the interpretation of paleoflow conditions (Harms *et al.* 1982: 2–17).

Megaripples (also known as dunes) are dynamically different from ripples. Although similar in shape, they are separated by a distinct difference in size (Table 1.1). Megaripple size increases with greater water depth, for depths of a few meters.

The term **sand wave** is used by some geologists to describe bedforms that are usually larger than megaripples (Table 1.1). Sand waves have less relief and generally straighter crests than megaripples (based on studies of streams and in laboratory flumes). Some workers do not agree with such a distinction, but consider both to be elements in a single bedform type, simply called large ripples (Harms *et al.* 1982). This rather basic, and as yet unresolved, problem is complicated by a lack of uniform usage (see Table 1.2).

Small bedforms are commonly superimposed on the stoss surfaces of larger ones. Examples include ripples on megaripples and sand waves,

Table 1.1 Characteristics of undulatory bedforms. From numerous sources (especially Reineck & Singh 1975 and Allen 1982a). Values commonly represent a compromise which I hope is near the truth.

Origin	Name	Height (H)	Length* (L)	Ripple index* (L/H)	Ripple symmetry index	Plan view shapes†	Other terms
subaqueous – currents	current ripples	0.5–5 cm	15–30 cm (10–60 cm)	10–40	2.5–15	3-D (2-D)	ripples, small ripples, small-scale ripples
subaqueous – currents	megaripples	10–200 cm	1–4 m (0.5–30 m)	10–40	high	3-D, 2-D	dunes, large ripples
subaqueous – currents	sand waves	1–20 m	20–200 m (5–100 m)	10–100	?	2-D (3-D)	large ripples, giant ripples, bars of various types
subaqueous – currents	antidunes	0.5–50 cm	0.1–5 m	low	low	2-D (3-D)	
subaqueous – waves	wave ripples	0.5–20 cm	2–100 cm	6–8 (2–16)	1–3	2-D, partly bifurcating	oscillation or symmetrical ripples when RSI < 1.5; wave-current or asymmetrical wave ripples when RSI > 1.5
wind	wind sand ripples	0.5–5 cm (0.2–10 cm)	5–80 cm (2–200 cm)	15–40 (10–70)	2–4 (1.5–8)	2-D, partly bifurcating	wind ripples, ballistic ripples
wind	wind granule ripples	2.5–60 cm	2.5–20 m	12–20	?	2-D, 3-D	wind ripples
wind	dunes	0.1–100 m	3–600 m	–	–	2-D, 3-D	numerous varieties (e.g. barchan, transverse, seif)

* Length and ripple index: complete range in parentheses if greater than commonly occurring range.
† Plan view shape: if one shape is markedly subordinate it is in parentheses.