Available online at www.sciencedirect.com
ScienceDirect
Sedimentary Geology 202 (2007) 383–401
Sedimentary Geology
www.elsevier.com/locate/sedgeo

From reality to model: Operationalism and the value chain of particle-size analysis of natural sediments

Daniel Hartmann *

Ben Gurion University of the Negev, Beer Sheva, Israel

Abstract

This paper deals with key issues concerning operationalism and the value chain in particle-size analysis (PSA), and addresses conceptual problems of PSA measurement. In order to obtain the highest quality of information contained in a set of sediment samples, one has to follow an approach called operationalism, i.e. a set of recipe-like sequential operations by which a scientific proposition can be verified or rejected. Review of the literature indicates that particle sizing as a methodology suffers from excessive verbosity and professional jargon, and has never really matured. Is the PSA crisis a result of a fundamental failure of concepts and paradigms, or is it just a technical problem related to work methods? Although PSA is fundamental to the understanding of sedimentary processes, as well as being a basic tool in earth sciences and engineering, there is still no generally accepted and standardized mode of operationalism after more than a century of intensive scientific work. The sedimentological community is called upon to come up with a unified and standardized approach.

Keywords: Sediments; Grain size; Paradigms; Measurements; Scales; Standards

1. Introduction

1.1. General

The study of sedimentary systems and processes is essential to the understanding of present and past earth-surface processes. Three main factors interact in dynamic sedimentary systems: a) The size, shape and specific gravity of the sedimentary particles, b) the two- and three-dimensional morphology of the system, and c) the forces acting upon the system (Fig. 1). These factors constitute a process–response system which evolves in time and space, and fall under the heading 'depositional sedimentary environments' (Friedman et al., 1992; Boggs, 2001; among many others).

Ancient sedimentary systems are subjects of study where the acting forces cannot be directly measured or quantified. Indeed, often even the morphological evidence has faded or vanished. Geological research on sedimentary deposits is therefore by definition a *post mortem* approach. Subsequently, earth scientists have developed the study of proxies to replace the missing information. Particle size, for example, is used as a proxy for climate change and sea-level fluctuations (Prins et al., 2000; Stuut et al., 2002a,b).

Unlike the rock record, most modern depositional environments enable to observe the three control factors of the dynamic system. However, such studies are usually limited to low- and medium-energy situations, not representative of high-energy forces and morphologies.

* Tel.: +972 523932373; fax: +972 86472821.
E-mail address: danielh@bgu.ac.il.

0037-0738/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.sedgeo.2007.03.013

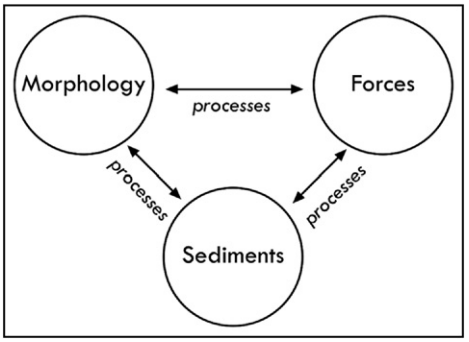

Fig. 1. The sedimentary–morphodynamic process response system.

Moreover, field studies are limited in extent and time span, mapping and measurements on both large and small scales being often reduced to a few spot locations. Therefore, the information content of the obtained evidence is an important, often the only option, for reconstructing the entire dynamic system.

The idea that there is process-related information in the textural properties of sediments is relatively old (Udden, 1894, 1898), and much sedimentological research during the first six decades of the 20th century was devoted to particle-related studies (see Pettijohn, 1957). During these times, the oil and gas industries were the driving force in the search for a predictive capacity, i.e. the recognition and discrimination of ancient sedimentary environments. Such geological reconstructions are usually based on a small number of localized samples, mostly from boreholes. In reconstructing these environments, sedimentologists adopted the geological paradigm 'the present is the key to the past', and more and more geological work was done on modern sedimentary environments for basic understanding, ground-truthing and calibration purposes (Folk and Ward, 1957; Friedman, 1967; Folk, 1971; Flemming, 1988; Hartmann, 1988a, 1991). Induction from these empirical studies showed the way to the interpretation of fossil data.

The study of sediment dynamics proceeds along four major branches (Fig. 2):

1) The study of the morphodynamics of sedimentary systems, where the three factors (sediments, forces and morphology) can be sampled and measured directly. The sub-environments of a coastal-dune system (Mason and Folk, 1958; Hartmann, 1991), the sub-environments of dunes (Folk, 1971; Vincent, 1986; McArthur, 1987), or the sub-environments of a fluvial system (Folk and Ward, 1957) are some examples. Sampling is usually along profiles in the direction of the assumed major sediment transport direction. Such an approach only captures a limited temporal and spatial snapshot of the dynamic system, and should therefore aim at a high spatial and temporal resolution. Work is often restricted by limited resources, and difficulties in sampling high-energy events. To understand the system and its sub-environments a population approach, here called "*P*rocess *O*riented *P*opulation *S*tatistics" or *POPS* (Hartmann, 1988a; Hartmann and Christiansen, 1992), is suggested. This approach has been employed for quite some time, and can be found in many classical sedimentary studies (Fox et al., 1966; Friedman, 1967, 1979; and many others). The approach requires that the sedimentary sub-environments and samples have to be mutually connected by the process and therefore should not be spaced too far apart.
2) The study of surface sediments over relatively large areas without distinct sub-environments is here called "*Se*diment *Di*spersal and *Tr*end *An*alysis" or *SEDITRANS*. This approach was first used by Swift et al. (1971), Swift et al. (1972), and Swift and Ludwick (1976), and subsequently developed further by McLaren (1981), McLaren and Bowles (1985), Gao and Collins (1992, 1994), and Le Roux (1994). SEDITRANS is limited to surface sediment samples which are mutually connected by the sedimentary dispersal process and should therefore be taken from the active layer only. Sampling is usually conducted under relatively calm conditions following major dynamic events. The resulting SEDITRANS maps can be supported by measurements of the acting forces before and during the sediment sampling and by morphological surveying of the investigated area.
3) Samples taken from sediment traps (Shih and Komar, 1990a,b; Greeley et al., 1996). Depending on the nature of the investigated sedimentary system and the flux of

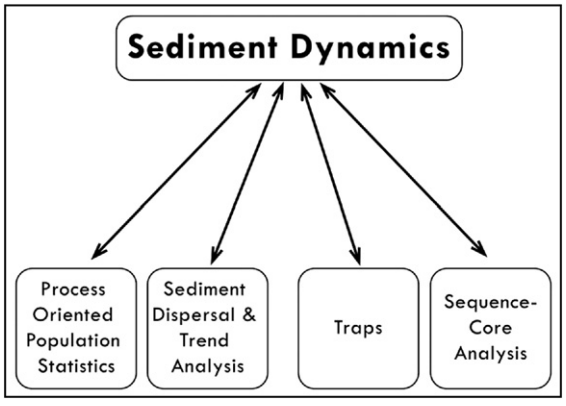

Fig. 2. The four branches of particle-size analysis.