Classification of Bedforms and Cross-Bedding

Approach

This publication uses a new classification scheme that relates the geometry of cross-bedding directly to the morphology and behavior of the bedforms that deposited the beds (Fig. 1). This scheme was developed because existing classifications of bedforms are generally not applicable to cross-bedding, and because existing classifications of cross-bedding do not adequately relate bedding geometry to bedform behavior. The approach toward both the modeling and classification in this publication emphasizes the shape and behavior of bedforms rather than size, flow, or fluid medium, and, consequently, bedforms are not subdivided into such categories as ripples, dunes, or sand waves, and the term bedform is used in a broad sense that includes all cyclic topographic features.

Most classifications of modern bedforms cannot be applied to cross-bedding because the morphologic and behavioral properties that can be determined from observation of bedforms are significantly different from the properties that can be determined from cross-bedding. Specifically, instantaneous observation of bedforms gives a detailed view of morphologic properties such as height, spacing, asymmetry, crestline sinuosity, and trough profile, but gives no indication of changes through time in bedform morphology or of transport-related characteristics such as the relative migration speeds of the main bedforms and superimposed bedforms, spurs, or scour pits. In contrast, cross-bedding commonly contains less information about the morphology of bedforms that existed at any one time but contains more information about morphologic history and transport-related behavior of bedforms. Existing bedform classification schemes generally cannot be applied to ancient bedforms because the ancient morphology is usually too imprecisely known, and, even in those cases where the classification schemes are imprecise enough to be applied or where the deposits are exceptionally revealing, the bedform morphologic history and behavior cannot be included in the classification.

Similarly, existing cross-bedding classifications have overlooked observable features that relate to bedform morphology and behavior and instead emphasize features that depend as much on outcrop orientation as on bedding geometry. For example, such classifications do not consider divergence in direction of dip between cross-beds and bounding surfaces, a feature which is included here because it is a FIG. 1. Scheme used to classify bedforms and organize the depositional situations and structures in this publication. From left to right the first three vertical columns define the classification parameters: three-dimensionality, variability, and orientation relative to transport. Column 4 shows block diagrams of bedform morphology and vertical sections, column 5 shows block diagrams with horizontal and vertical sections, and column 6 shows polar plots of cross-bed and bounding-surface dip directions. The examples in the horizontal rows are simplifications of Figures 5, 17, 34A, 46H, 55, 59, 71, and 77.

The approach in this publication is to group cross-bedding and ancient bedforms into four main classes: (1) invariable two-dimensional bedforms and cross-bedding (illustrated in Figs. 2-11 with computer images and real examples that show salient depositional features), (2) variable two-dimensional bedforms and cross-bedding (Figs. 12-30), (3) invariable three-dimensional bedforms and cross-bedding (Figs. 31-56), and (4) variable three-dimensional bedforms and cross-bedding (Figs. 57-79). Bedforms can be further subdivided into transverse, oblique, and longitudinal categories depending on bedform orientation relative to the resultant sediment transport direction. The resulting classification groups bedforms by morphology (two-dimensional or three-dimensional), variability of bedform morphology and migration through time and space (invariable or variable), and bedform trend relative to the transport direction (transverse, oblique, or longitudinal). The same classification scheme can be applied to cross-bedding, because each of these classes of bedforms produces a distinctive kind of structure. Consequently, classifying the bedding simultaneously describes bedform morphology and behavior. In effect, classifying cross-bedding using this scheme is a first step in the interpretive process, rather than an end in itself. The following discussion explains the meaning of these classes, explains how to recognize examples of each class, and discusses the general properties of the bedforms required to produce structures of each class.

Terminology

Two-dimensional bedforms are defined as bedforms with straight crestlines, constant crest and trough elevations relative to the generalized depositional surface, and identical across-crest profiles at all locations along the crestline. Two-dimensional bedforms deposit two-dimensional cross-bedding—cross-bedding in which all foresets and bounding surfaces have identical strikes (Fig. 1). Three-dimensional bedforms differ from two-dimensional bedforms in having one or more of the following characteristics: sinuous crestlines (either in plan form or in elevation), sinuous troughs (either in plan form or in elevation), or across-crest profiles that vary along the crestline. All of these variations produce three-dimensional cross-bedding—cross-bedding in which cross-bed strike varies within a set of cross-beds.

Invariable bedforms are defined here as bedforms that do not change in morphology or path of climb through time or space. Invariable bedforms deposit sets of invariable cross-beds—sets in which all foresets, when considered in three dimensions, are geometrically identical. In contrast, variable bedforms change in morphology or path of climb through time or space; individual foresets in the sets of variable cross-beds are not geometrically identical.

Just as no bedforms are perfectly two-dimensional (because their crestlines cannot have infinite extent), no bedforms are perfectly invariable (because they cannot exist indefinitely without changing). Nevertheless, the terms two-dimensional and invariable are useful for describing bedforms with relatively simple morphology and behavior. No attempt is made here to define limits to the deviations from perfect two-dimensionality and perfect invariability that are allowable within these classes.

Bedforms can also be classified as transverse, oblique, and longitudinal, depending on their orientation relative to the long-term resultant sediment-transport direction. Transverse bedforms trend roughly parallel to the transport direction, longitudinal bedforms trend roughly normal to the transport direction, and oblique bedforms have intermediate trends. Previous studies have arbitrarily selected 15° as the maximum permissible divergence from perfectly transverse or perfectly longitudinal before bedforms are considered to be oblique (Hunter et al., 1983).