LITHOFACIES TYPES AND VERTICAL PROFILE MODELS IN BRAIDED RIVER DEPOSITS: A SUMMARY

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ABSTRACT

This article serves as an introduction to the papers dealing with braided river deposits in this volume.

A lithofacies code erected earlier by the writer is expanded to include matrix-supported gravel, low-angle cross stratified sand, erosion surfaces with intraclast conglomerates, and massive mud deposits.

The four vertical profile models erected by the writer are expanded to six. A new model, the "Trollheim type" is proposed, to include gravelly deposits characterized by abundant debris flows. The Donjek sequence type is restricted to gravel-dominated cyclic deposits and a new model, the "South Saskatchewan type", is erected for sand dominated cyclic deposits. The Scott, Platte and Bijou Creek models remain essentially unchanged.

INTRODUCTION

In a recent review of braided river depositional environments I attempted to summarize published data on lithofacies types and facies associations by erecting a code system for lithofacies descriptions and four vertical profile models which, it was suggested, represent the most commonly occurring facies associations (Miall, 1977). Subsequently, work by other writers, particularly that reported in this volume, has shown that the code system and the vertical profile models can both be usefully expanded to include a wider range of depositional variability. The following brief discussion is offered as an attempt to integrate these new data into the review published earlier, and as an introduction to the more detailed papers on braided depositional models which follow.

LITHOFACIES CODES

A revised listing of the lithofacies types identified in braided river deposits is given in Table 1. The following are added to those originally proposed by Miall (1977):

Gms: proposed by Rust (this volume) for massive, matrix supported gravel, both clasts and matrix characterized by very poor sorting; interpreted to be of debris flow origin.

Se: erosional scours with a lag deposit of silt or mud intraclasts, proposed by Rust (this volume) and identical to facies SS of Cant and Walker (1976).

Sl: low angle (<10°) cross-stratified sand, described by Cant and Walker (1976; their facies G), Rust (this volume) and McLean and Jerzykiewicz (this volume).

Facies *Sse*, *She* and *Spe* are proposed by Boothroyd and Nummedal (this volume) as eolian equivalents of facies *Ss*, *Sh* and *Sp*. However, detailed criteria for distinguishing these facies from those of water-laid origin are not provided.

Fm: originally suggested for mud or silt deposits, this facies is expanded to include massive, fine grained deposits a few to tens of centimetres in thickness, as proposed by Miall and Gibling (in press) and Rust (this volume).

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Table 1. Lithofacies and sedimentary structures of modern and ancient braided stream deposits (modified from Miall, 1977, Table III).

Facies Code	Lithofacies	Sedimentary structures	Interpretation
Gms	massive, matrix supported gravel	none	debris flow deposits
Gm	massive or crudely bedded gravel	horizontal bedding, imbrication	longitudinal bars, lag deposits, sieve deposits
Gt	gravel, stratified	trough crossbeds	minor channel fills
Gp	gravel, stratified	planar crossbeds	linguoid bars or deltaic growths from older bar remnants
St	sand, medium to v. coarse, may be pebbly	solitary (theta) or grouped (pi) trough crossbeds	dunes (lower flow regime)
Sp	sand, medium to v. coarse, may be pebbly	solitary (alpha) or grouped (omikron) planar crossbeds	linguoid, transverse bars, sand waves (lower flow regime)
Sr	sand, very fine to coarse	ripple marks of all types	ripples (lower flow regime)
Sh	sand, very fine to very coarse, may be pebbly	horizontal lamination, parting or streaming lineation	planar bed flow (l. and u. flow regime)
Sl	sand, fine	low angle (<10°) crossbeds	scour fills, crevasse splays, antidunes
Se	erosional scours with intraclasts	crude crossbedding	scour fills
Ss	sand, fine to coarse, may be pebbly	broad, shallow scours including eta cross-stratification	scour fills
Sse, She, Spe	sand	analogous to *Ss, Sh, Sp*	eolian deposits
Fl	sand, silt, mud	fine lamination, very small ripples	overbank or waning flood deposits
Fsc	silt, mud	laminated to massive	backswamp deposits
Fcf	mud	massive, with freshwater molluscs	backswamp pond deposits
Fm	mud, silt	massive, desiccation cracks	overbank or drape deposits
Fr	silt, mud	rootlets	seatearth
C	coal, carbonaceous mud	plants, mud films	swamp deposits
P	carbonate	pedogenic features	soil

The code *Fl* was proposed by Miall (1977) for laminated sand, silt and mud formed in overbank environments. This lithofacies may be of minor importance in many braided river deposits and, as such, a term which groups together a variety of fine grained lithofacies may be satisfactory. However, many fluvial deposits contain thick and varied floodplain sequences, and a subdivision of such deposits may be desirable. McLean and Jerzykiewicz (this volume) propose the following facies types:

Fsc: siltstone, silty claystone or claystone, horizontally laminated to massive.

Fcf: claystone with freshwater molluscs.

These two facies are distinguished mainly by fossil content, the presence of molluscs indicating the existence of temporary backswamp ponds.

In addition to the above, the terms *P* for pedogenic carbonate, *Fr* for root beds (seatearth) and *C* for coal or carbonaceous mudstone, may be useful.

Care must be taken in using these lithofacies codes for descriptive and interpretive purposes, because they are not a universal panacea for sorting out the complexity of fluvial deposits. It is possible for many of the facies types to be found in more than one environment within a river; for example facies *Sp* could represent mid-channel linguoid or transverse bars or sand waves migrating across a sand flat; Boothroyd and Nummedal (this volume) describe an eolian variety. Facies *Sl* could represent crevasse splay deposits, or the fill of low relief scours, or antidunes. Each example of each lithofacies must be examined with care from the point of view of its scale, grain size, internal structures, orientation and facies associations, to ensure that facies of dissimilar origin are not grouped together under one descriptive code. However, bearing these reservations in

Table 2. The six principal facies assemblages in gravel- and sand-dominated braided river deposits.

Name	Environmental setting	Main facies	Minor facies
Trollheim type (G_{I})	proximal rivers (predominantly alluvial fans) subject to debris flows	*Gms, Gm*	*St, Sp, Fl, Fm*
Scott type (G_{II})	proximal rivers (including alluvial fans) with stream flows	*Gm*	*Gp, Gt, Sp, St, Sr, Fl, Fm*
Donjek type (G_{III})	distal gravelly rivers (cyclic deposits)	*Gm, Gt, St*	*Gp, Sh, Sr, Sp, Fl, Fm*
South Saskatchewan type (S_{II})	sandy braided rivers (cyclic deposits)	*St*	*Sp, Se, Sr, Sh, Ss, Sl, Gm, Fl, Fm*
Platte type (S_{II})	sandy braided rivers (virtually non cyclic)	*St, Sp*	*Sh, Sr, Ss, Gm, Fl, Fm*
Bijou Creek type (S_{I})	Ephemeral or perennial rivers subject to flash floods	*Sh, Sl*	*Sp, Sr*

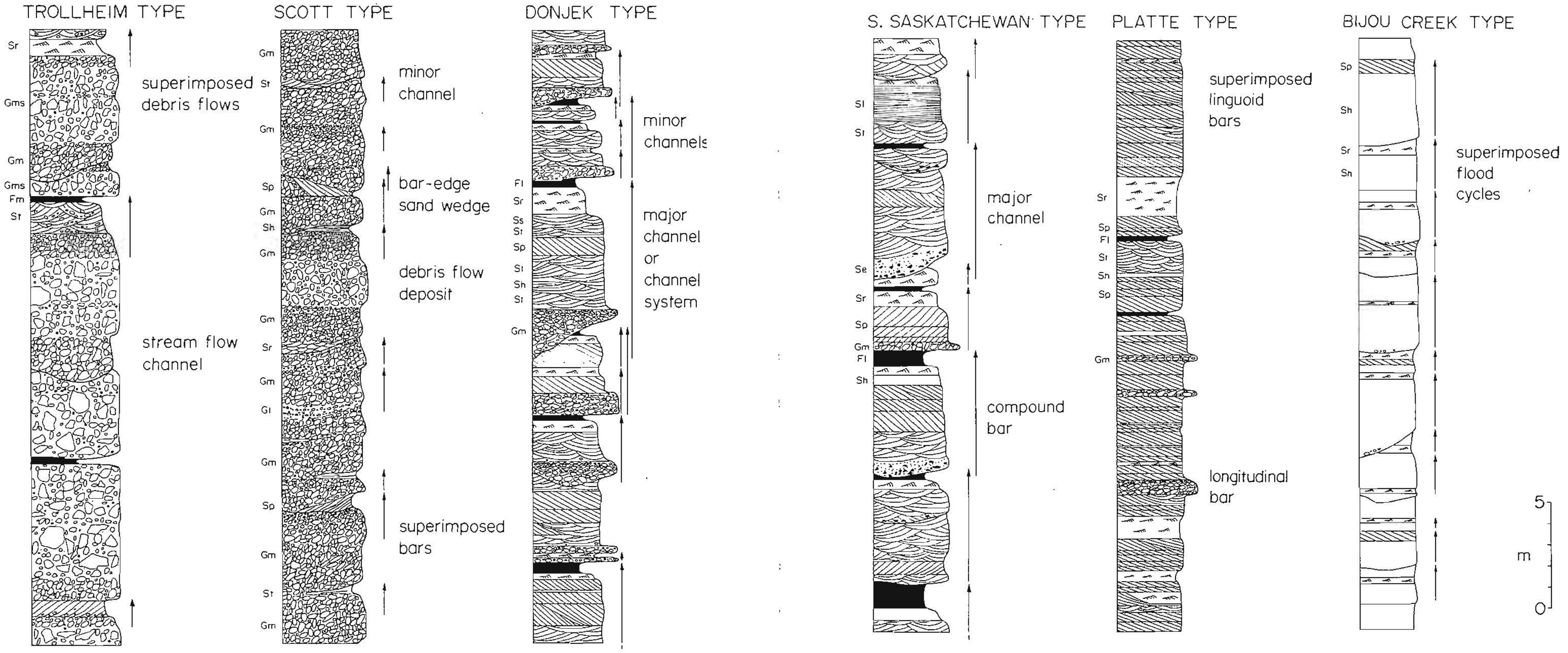

Fig. 1. Vertical profile models for braided stream deposits. Facies codes to left of each column are given in Table 1. Arrows show small-scale cyclic sequences. Conglomerate clasts are not shown to scale.

mind, it is felt that the use of the code system should aid in standardizing lithologic descriptions and will facilitate comparisons between different fluvial sequences.

VERTICAL PROFILE MODELS

Four vertical profile models for braided rivers were erected by Miall (1977) on the basis of a survey of available information on modern sedimentary processes and ancient deposits. These models were intended to encompass all the variability found in braided rivers, but further work has shown that greater clarity could be achieved by subdividing two of the profile models, so that a total of six are now offered as a basis for interpreting the ancient record (Table 2, Fig. 1). These modifications are discussed briefly below.

The Scott model was erected for proximal braided stream deposits, including those occurring on alluvial fans, where gravel is the predominant facies, particularly facies *Gm*, with rare units of *Gp* and *Gt*, and some interbedded sandy channel fill deposits. Rust (this

assemblage, termed G_I by Rust (this volume), is characterized by debris flow deposits (*Gms*), and by great lithological variability. Subaerial debris flows require a steep slope, an abundance of clastic debris and a high discharge for their initiation; these conditions are commonly, but not exclusively, met in arid or semi-arid environments where long, dry periods, during which abundant clastic detritus is generated by mechanical weathering, are punctuated by flash floods, with little or no vegetation to inhibit run-off. Alluvial fans with abundant debris flow deposits are particularly common in the desert areas of California and Nevada (Blackwelder, 1928; Blissenbach, 1954; Beaty, 1963, 1970; Bull, 1963, 1964; Bluck, 1964; Hooke, 1967, 1968) and the Trollheim Fan, California (Hooke, 1967) may be chosen as a modern analogue for this facies assemblage. Wasson (1977) describes some New Zealand examples.

Characteristics of the "Trollheim type" of vertical profile include the following (based mainly on Hooke, 1967; Wasson, 1977; Rust, this volume): 1. An abundance of poorly sorted, matrix-supported gravel of facies *Gms*. 2. Debris flow units may reach 3m in thickness, although superimposed flow deposits may not be readily distinguishable in outcrop. 3. Debris flow units commonly have flat (not channelled), generally abrupt bases and a lobate geometry, except where they infill stream flow channels. 4. Interbedded fact that stream flows require a lower slope than debris flows, and therefore commonly cause fan incision. Stream flow sheet flood deposits may also be present. 5. Minor units of *St*, *Sp*, *Fl*, and *Fm* may be present in crude fining-upward cycles (*see* Miall, 1977, for discussion of the mechanisms causing cyclicity in braided stream deposits).

Debris flows do not travel far from their source, so that the presence of Trollheim and Scott type sequences in the same braided river deposit may reflect within-fan proximal-distal variations, as suggested by Rust (this volume). Wasson (1977) records a similar down-fan change. However, tectonic, climatic or geomorphic effects may also influence fan composition (Hooke, 1967; Heward, this volume). Hooke emphasized the importance of sediment source types in generating debris flows, and demonstrated that different fans in the same tectonic and climatic setting may be characterized by different proportions of debris flow (*Gms*) and stream flow (*Gm*) gravels, depending on the availability in the source area of readily weathered detritus. Variations in source area relief or rainfall may also be a factor, and changes with time, such as scarp recession and downward erosion will also influence depositional processes in the alluvial basin.

The Donjek model was erected by Miall (1977) to encompass most types of cyclic braided river deposit. It is a common misconception that the deposits of braided rivers are disordered, whereas Miall (1977) listed a variety of mechanisms that can give rise to cyclic sequences. The Donjek River is one of the few modern braided rivers for which cycles have been clearly documented, particularly in the middle reaches studied by Williams and Rust (1969) and Rust (1972). However, most of the information available for the Donjek concerns gravel-dominated deposits. Recent work by Cant (this volume), Cant and Walker (1976; in press), Rust (this volume), Minter (this volume), Hobday (this volume) and Miall and Gibling (in press) shows that sand-dominated cycles are equally common in the ancient record. The only modern analogue for these deposits that has received sufficient sedimentological study to be used as a model is the South Saskatchewan River, Saskatchewan (Cant, Cant and Walker, *op. cit.*), and this is the basis for proposing another profile model, the "South Saskatchewan type" (Fig. 1), corresponding to facies assemblage S_{II} of Rust (this volume). In most cases facies *St* is the dominant component, with a varying proportion of *Sp, Sr, Sh, Se, Gm, Fl* and *Fm* arranged in a thinning- and fining-upward cyclic sequence. Markov chain analysis is particularly useful in studying this type of fluvial sequence (Miall, 1973; Cant and Walker, 1976; Miall and Gibling, in press). The reader is referred to Cant and to Cant and Walker (*op. cit.*) for details of the depositional processes and cyclic mechanisms prevailing in South Saskatchewan-type rivers.

The Scott, Donjek and South Saskatchewan profile types may form a gradational proximal-distal sequence in some ancient braided river deposits, reflecting a downstream decrease in gravel/sand ratio. It is proposed that the following numerical limits of gravel content be used to distinguish the three types: Scott >90%, Donjek 10 - 90%, South Saskatchewan <10%, where the total cumulative gravel thickness in a vertical section is expressed as a proportion of total section thickness.

The position of the Platte and Bijou Creek models (Table 2, Fig. 1) in this spectrum is at present unclear. Rust (this volume) did not include an equivalent of the Platte type in his discussion except as a variant of his assemblage S_{II}, but there is no doubting its existence as a discrete type (*see* examples quoted by Miall, 1977). It may represent a variety of the South Saskatchewan type, in which large bars and sand waves, rather than dunes, are the dominant depositional mode, but whether the difference relates to variations in channel topography or depth, flow velocity, discharge variations, or other causes is not clear. Further work on bedform hydraulics may throw some light on this problem.

The Bijou Creek type (Miall, 1977) was equated by Rust (this volume) with his S_I facies assemblage. It is interpreted as a proximal sandy braided stream deposit, occurring in

is the evidence it contains of high energy flow conditions, in particular, the abundance of facies *Sh*, representing an environment dominated by flash floods, possibly ephemeral in nature, and contrasting with the perennial, less variable flow of the Platte, South Saskatchewan and other sandy braided rivers. Rust (this volume) discusses a variant of the S_I assemblage containing an abundance of facies *Se, Sl* and *St*.

DISCUSSION

Undoubtedly our ideas about braided river deposits will be modified by future work, and the lithofacies code system and the facies models may require further expansion or modification. Both are designed in a flexible way to accommodate such improvements, and it is to be hoped that in future research important observations will not be glossed over in an attempt to force-fit every braided fluvial sequence into the published mould.

What is particularly needed now is more information on lateral variability in individual braided river deposits. A problem with Markov chain analysis is that it focusses attention on vertical profiles, whereas information regarding lateral variability may be critical in arriving at correct interpretations. Jackson (this volume) and Nijman and Puigdefabregas (this volume) point out that sand or gravel dominated point bar deposits in some single-channel, high-sinuosity rivers are very similar to South Saskatchewan or Donjek type braided river profiles, and could be identified as such in the absence of outcrop-scale information regarding facies geometry, lateral accretion surfaces and channel dimensions. Detailed paleocurrent analysis may also be of assistance in identifying channel morphology.

It should also be pointed out that the profiles tend to emphasize channel processes, it being assumed that overbank deposits are of little importance in braided river sediments. This may not always be correct. McLean and Jerzykiewicz (this volume) and Friend (this volume) describe examples of fluvial sequences with channel fills similar to those described in this paper, yet containing thick overbank deposits. A mechanism of lateral channel restriction on the floodplain, coupled with rapid subsidence, may be the cause.

On a broader scale, how do the six profile types relate to one another? Can some super-assemblages be erected to encompass proximal-distal variability in environments with different climates, sediment calibre and discharge characteristics? Most of the examples of braided river deposits described in the literature include only one or two of the facies models described in this paper, so that information on gross lateral facies variability is sparse.

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