Journal of Sedimentary Research

Journal of Sedimentary Research, 2006, v. 76, 731–770
Research Article
DOI: 10.2110/jsr.2006.060

WIDTH AND THICKNESS OF FLUVIAL CHANNEL BODIES AND VALLEY FILLS IN THE GEOLOGICAL RECORD: A LITERATURE COMPILATION AND CLASSIFICATION

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Abstract: **The three-dimensional geometry of fluvial channel bodies and valley fills has received much less attention than their internal structure, despite the fact that many subsurface analyses draw upon the geometry of suitable fluvial analogues. Although channel-body geometry has been widely linked to base-level change and accommodation, few studies have evaluated the influence of local geomorphic controls. To remedy these deficiencies, we review the terminology for describing channel-body geometry, and present a literature dataset that represents more than 1500 bedrock and Quaternary fluvial bodies for which width (W) and thickness (T) are recorded. Twelve types of channel bodies and valley fills are distinguished based on their geomorphic setting, geometry, and internal structure, and log-log plots of W against T are presented for each type. Narrow and broad ribbons (W/T $<$ 5 and 5–15, respectively) and narrow, broad, and very broad sheets (W/T 15–100, 100–1000, and $>$ 1000, respectively) are distinguished. The dataset allows an informed selection of analogues for subsurface applications, and spreadsheets and graphs can be downloaded from a data repository.**

Mobile-channel belts **are mainly the deposits of braided and low-sinuosity rivers, which may exceed 1 km in composite thickness and 1300 km in width. Their overwhelming dominance throughout geological time reflects their link to tectonic activity, exhumation events, and high sediment supply. Some deposits that rest on flat-lying bedrock unconformities cover areas $>$ 70,000 km^2. In contrast, meandering river bodies in the dataset are $<$ 38 m thick and $<$ 15 km wide, and the organized flow conditions necessary for their development may have been unusual. They do not appear to have built basin-scale deposits.**

Fixed channels and poorly channelized systems **are divided into distributary systems (channels on megafans, deltas, and distal alluvial fans, and in crevasse systems and avulsion deposits), through-going rivers, and channels in eolian settings. Because width/maximum depth of many modern alluvial channels is between 5 and 15, these bodies probably record an initial aspect ratio followed by modest widening prior to filling or avulsion. The narrow form (W/T typically $<$ 15) commonly reflects bank resistance and rapid filling, although some are associated with base-level rise. Exceptionally narrow bodies (W/T locally $<$ 1) may additionally reflect unusually deep incision, compactional thickening, filling by mass-flow deposits, balanced aggradation of natural levees and channels, thawing of frozen substrates, and channel reoccupation.**

Valley fills **rest on older bedrock or represent a brief hiatus within marine and alluvial successions. Many bedrock valley fills have W/T $<$ 20 due to deep incision along tectonic lineaments and stacking along faults. Within marine and alluvial strata, upper Paleozoic valley fills appear larger than Mesozoic examples, possibly reflecting the influence of large glacioeustatic fluctuations in the Paleozoic. Valley fills in sub-glacial and proglacial settings are relatively narrow (W/T as low as 2.5) due to incision from catastrophic meltwater flows. The overlap in dimensions between channel bodies and valley fills, as identified by the original authors, suggests that many braided and meandering channel bodies in the rock record occupy paleovalleys.**

Modeling has emphasized the importance of avulsion frequency, sedimentation rate, and the ratio of channel belt and floodplain width in determining channel-body connectedness. Although these controls strongly influence mobile channel belts, they are less effective in fixed-channel systems, for which many database examples testify to the influence of local geomorphic factors that include bank strength and channel aggradation. The dataset contains few examples of highly connected suites of fixed-channel bodies, despite their abundance in many formations. Whereas accommodation is paramount for preservation, its influence is mediated through geomorphic factors, thus complicating inferences about base-level controls.

INTRODUCTION

River-channel and river-valley deposits are prominent in the geological record, where they range from the smallest floodplain channels to the deposits of continental-scale rivers that dominated their landscapes and filled entire basins. Over the past 20 years, studies of ancient and modern fluvial channel deposits have focused largely on their *internal organization*, following the approach of identifying architectural elements and bounding surfaces (Miall 1988, 1996; Jordan and Pryor 1992; Lunt et al. 2004), thus emphasizing the internal heterogeneity that commonly controls water and hydrocarbon flow through the channel fills.

In contrast, only a few accounts (Krynine 1948; Potter 1967; Friend 1983; Fielding and Crane 1987; Reynolds 1999) have dealt comprehensively with the dimensions and 3D form—or *external* geometry—of channel deposits and valley fills. Such information is topical for several

 1527-1404/06/076-731/$03.00

TABLE 1.—*Qualitative terms used to describe fluvial-channel bodies and fluvial-valley fills.*

Qualitative Terms	Definition of Terms That Describe Channel Bodies	Author
Fluvial channel body	Three-dimensional solid form composed of unconsolidated or lithified sediment, generated by fluvial channel processes through time. May represent an individual channel body or may be a composite of two or more channel bodies. The term includes channel fills, which represent the filling of a channel without change in its perimeter (banks and basal surface), for example the fill of an abandoned channel.	Potter 1967; Knighton 1998
Story	Erosionally based component of a channel body.	Feofilova 1954, cited in Potter 1967
Multistory	Sand body of one cycle is superimposed upon one or more earlier sand bodies. Sometimes used to indicate vertical stacking of stories. General term for channel bodies with more than one story.	Feofilova 1954, cited in Potter 1967; general useage from Bridge and Mackey 1993a
Multilateral	Laterally coalescent sand bodies.	Potter 1967
Simple and complex bodies	Single-story and multistory bodies, respectively.	Friend et al. 1979
Central body	Main part of channel body.	Bersier 1958
Wing	Thin marginal part of channel body, distinguished from central body where basal scour shows a distinct inflection point. Usually composed of levee and/or crevasse-splay deposits.	Bersier 1958
Succession dominated	Stories represent the amalgamated, relatively complete fills of distinct channels.	This paper
Erosion dominated	Stories represent amalgamated bedsets separated by scours generated by short-term events, principally floods, within channels.	This paper
Story scours	Scour surface that underlies a story.	Friend et al. 1979
Concentric fill	Infilling of a relatively narrow, single-story channel (active or abandoned) by deposition on its floor and accretionary banks, progressively reducing the cross-sectional area.	Hopkins 1985; Kirschbaum and McCabe 1992
Asymmetric fill	Infilling of a relatively narrow, single-story and active channel by a bar that accreted laterally more rapidly than the channel bank retreated.	Hopkins 1985; Kirschbaum and McCabe 1992
Aggradation index	Parameter that describes rate of climb of lateral accretion surfaces approaching a resistant bank. Defined as V/L for two successive points of maximum concavity of inclined accretion surfaces (V = height of vertical accretion, L = distance of lateral accretion).	Gibling and Rust 1990; see also Cuevas Gozalo 1985
Dendroids	Branched, elongate, and typically sinuous channel bodies with tributary or distributary patterns.	Pettijohn et al. 1972
Belts	Coalescence of channel bodies (ribbons and dendroids) to form composite body, commonly through lateral migration.	Pettijohn et al. 1972
Channeled-braided	Multistory body in which individual stories have width/thickness ratios less than 20 : 1	Cotter 1978
Sheet-braided	Multistory body in which individual stories have width/thickness ratios greater than 20 : 1	Cotter 1978
Link	Region of a channel body between branches	Horton 1945
Channel-bend scour (or valley-bend scour)	Region of unusually deep scour at the base of a channel or valley body bordering a bend.	Ardies et al. 2002
Tributary-junction scour	Region of unusually deep scour at the base of a channel or valley body at the confluence of the main channel system with a tributary.	Ardies et al. 2002
Valley-constriction scour	Region of unusually deep scour at the base of a valley body where valley narrows.	Ardies et al. 2002
Irregular scour	Region of unusually deep scour at the base of a channel or valley body that shows no apparent relation to elements of the drainage network such as bends or tributaries.	This paper
Architectural elements	Component of a depositional system equivalent in size to, or smaller than, a channel fill, and larger than an individual facies unit.	Miall 1985, 1996
Bounding surfaces	Surfaces that bound bodies of strata, including architectural elements, commonly developed in a hierarchy from local to regional in extent and significance.	Miall 1985, 1996

reasons. The discipline of sequence stratigraphy requires a strong understanding of the styles and dimensions of fluvial-channel and fluvial-valley fills because alluvial landscapes may respond rapidly to forcing factors such as base-level change and climate (Blum and Törnqvist 2000). Three-dimensional seismic surveys are providing remarkable subsurface images of channel bodies and valley fills and the geomorphic surfaces to which they are related (Posamentier 2001). The modeling of sediment transport systems (Paola 2000) and their response to forcing factors requires a fuller knowledge of Quaternary channel systems and geomorphology. Furthermore, fluvial channel deposits form

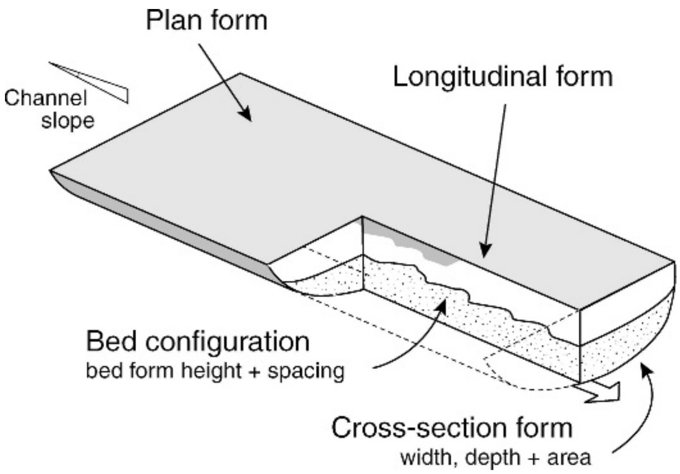

FIG. 1.— Geometric description of modern channel form. No scale implied. Modified from Knighton (1998).

aquifers and hydrocarbon reservoirs, host economic minerals, constitute roof and floor rocks in coal mines, and are associated with important fossil sites. Many subsurface investigations of channel deposits where data are sparse depend on the application of suitable analogues with a known range of dimensions.

The present paper explores the external geometry of channel bodies and valley fills preserved in the geological record. Such an enterprise requires not only an understanding of the channel bodies themselves but also a consideration of their broader geomorphic setting: the relationship of the channel to its floodplain; fluvial interaction with other depositional systems such as deltas, eolian dunefields, and glaciers; and the crucial linkage between alluvial basins and river courses in eroding uplands where fluvial deposits may accumulate as unconformity-based valley fills. The paper sets out terminology used to describe channel bodies and valley fills, and draws together a large database of case studies (hereafter termed *the dataset*) from the literature, mostly published over the past 30 years, to provide precise information on their dimensions. In order to use the wealth of geometric data most effectively, the channel bodies and valley fills are classified on the basis of internal constitution and geomorphic setting, supplemented by a consideration of their width : thickness distribution. Finally, the paper discusses the factors that control the form of channel bodies and valley fills in order to explore how channel systems familiar to us in modern landscapes generate channel bodies with the dimensions and form that we observe in the rock record, as well as exploring the use of the dataset for modeling and subsurface applications.

QUALITATIVE TERMS TO DESCRIBE CHANNEL DEPOSITS

Channel Bodies

Fluvial channel deposits comprise a suite of widely recognized components. A set of *bedforms*, such as dunes and ripples, is typically organized into *bars* and *bedload sheets*, which lie within *channels* (Bridge 1993; Lunt et al. 2004). Channel banks commonly migrate laterally as the adjacent floodplain deposits are eroded, with concomitant lateral migration of bars within the channel, and the channel base may incise into the underlying floodplain deposits, resulting in stacked bar deposits and bedload sheets. In these cases, the evolution of the channel generates a *channel body* (Table 1) that is larger than the original (instantaneous) channel dimensions. A special type of channel body involves the filling of a channel without change in its perimeter to generate a *channel fill*. For example, a large mass of landslide-derived sediment may suddenly fill an active channel (Keefer 1999), or repeated flood events may gradually fill an abandoned channel. In the case of channel fills, the dimensions of the fill approximate the instantaneous channel dimensions.

Individual channel bodies commonly amalgamate to form a composite channel body when relocation (avulsion) of the river channel juxtaposes younger and older channel bodies. The juxtaposed segments may have been deposited by the same river, typically over a short period, or may represent the emplacement on the floodplain of a different river, perhaps after a long period. Pettijohn et al. (1972) used the term *belt* to describe coalesced smaller bodies, typically formed by lateral migration of channels, and this term has been widely used as a synonym for channel body. However, the implication that belts involve coalescence of channel bodies makes the term inapplicable to single-story bodies and channel fills, and the more general term ‘‘channel body’’ is preferred here.

The majority of the channel bodies and valley fills compiled in the dataset are less than 60 m thick, but no upper thickness limit was prescribed because no natural break in thickness was apparent. Hence, composite arrays of amalgamated channel deposits may reach hundreds of meters to more than a kilometer in thickness—on the scale of ‘‘basin fills’’—and are included in the analysis.

A *fluvial channel body* can be defined as a three-dimensional form composed of unconsolidated or lithified sediment, generated by fluvial channel processes through time. This understanding follows Potter (1967), who defined a sand body as a ‘‘single, interconnected mappable body of sand.’’ He included the term ‘‘interconnected’’ to take account of the branching patterns of many bodies and the superposition of sand bodies of different cycles, and he included the term ‘‘mappable’’ to distinguish them from most single beds. Knighton (1998) defined a three-dimensional solid form parameterized at some appropriate stage such as bankfull. Modern channels can be described in terms of their cross-sectional form (width, depth, cross-sectional area, wetted perimeter, hydraulic radius), planform, and longitudinal form (Fig. 1), and constitute a general starting point for describing ancient fluvial bodies. The time required to generate a channel body may range from decades in the case of the most frequently avulsing systems (Sinha et al. 2005) to tens of million of years in the case of thick valley fills that record the prolonged transfer of sediment from active orogens (Vincent 2001).

Practical difficulties arise in defining a ‘‘channel body.’’ To be recognized as such, channel sediment must be embedded within extra-channel material, typically fine-grained floodplain sediment. However, discrete channel bodies amalgamate partly or completely to form composite bodies with varied degrees of connectedness, and describing their dimensions becomes a matter of judgment. Settings that particularly promote concentration of channel bodies include sites of drainage entrenchment (valleys), restricted entry points for drainage into unconfined plains (alluvial fans and aprons), and basins with differential subsidence that preferentially draws channels into certain areas. The degree of connectedness of channel bodies has been widely studied using computer-based models (North 1996; Bridge 2003). Criteria for the identification of valley fills are discussed below.

Terminology for 2D Analysis

Terms used to describe channel bodies are shown in Table 1 and Figures 2 and 3. Channel bodies in cross-sectional view can be divided into *single-story bodies* and *multistory bodies* (simple and complex bodies of Friend et al. 1979). Many bodies, especially single-story bodies, comprise a *central body* and *wings*. The central body represents the main topographic low and may be symmetric or asymmetric with the zone of maximum thickness near one margin (e.g., Törnqvist et al. 1993; Hampson et al. 1999a). The wings may represent a relatively wide topmost story, in which case they are part of the channel body, or may represent natural levee and crevasse splay deposits connected to but distinct from the channel fill. Channel-body and adjacent strata

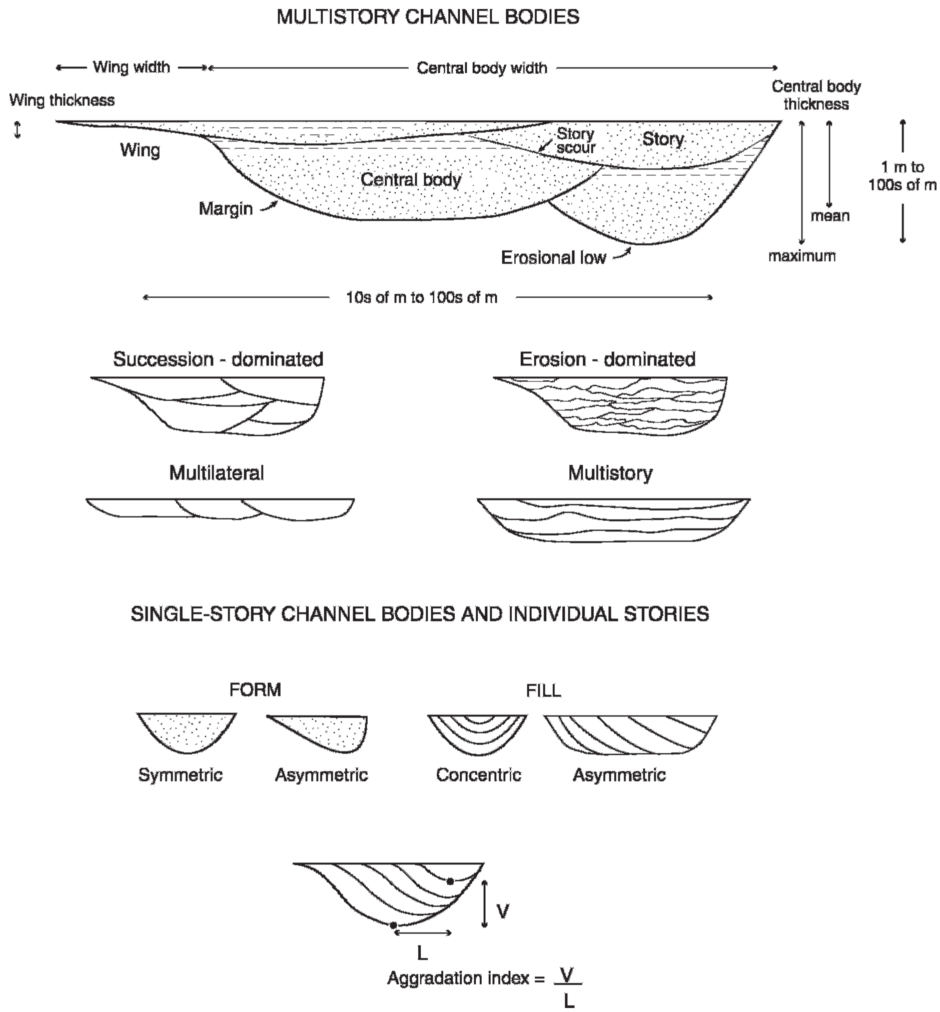

FIG. 2.—Terminology for describing the cross-sectional geometry of channel bodies. The origin of the terms is noted in Table 1.

interdigitate in some cases (Hill 1989; Nadon 1994), implying coordinated aggradation. Because central bodies and wings generally differ in aquifer and reservoir characteristics (lithology, permeability), the width and thickness of the wings, as well as the central body, may be important (Fig. 2).

Potter (1967) distinguished *multistory bodies* and *multilateral bodies*, based on vertical stacking and lateral coalescence of stories, respectively. In reality, story arrangement commonly combines vertical and lateral positioning, and the term multistory can be used to describe bodies with several stories, however disposed (Bridge and Mackey 1993a). Bodies can be termed *succession-dominated* where the stories represent reasonably complete channel fills, with only modest erosion of topmost strata beneath subsequent *story scours* (e.g., Hampson et al. 1999a). However, many bodies contain abundant erosional surfaces that could represent short-term events such as floods; these bodies are here termed *erosion-dominated*. This distinction may be difficult to draw. Many bodies contain lenses of fine-grained material, and such permeability barriers exert an important influence on fluid flow (Miall 1988; Robinson and McCabe 1997).

Following concepts set out by Allen (1983), Miall (1988, 1996) described a hierarchy of *bounding surfaces* for fluvial bodies that, although not elaborated here, constitute a crucial part of channel-body analysis. Some surfaces separate distinctive bedsets and barforms (*architectural elements*), whereas higher-order bounding surfaces delineate entire channel bodies and stories within multistory bodies. Holbrook (2001) and Miall and Jones (2003) presented good examples of the use of this hierarchy in studying complex channel bodies.

Single-story bodies and stories within multistory bodies can be described in terms of their overall symmetry and fill geometry (Fig. 2). *Asymmetric fills* form in channel bends where a bank-attached bar accretes laterally due to cutbank erosion and deposition of sediment transported from upstream. In some cases, the bar migrated more rapidly than the channel bank retreated, and the progressive rise of the accretion surfaces can be represented numerically by the *aggradation index*. *Concentric fills* represent the progressive filling of a channel (active or abandoned) by deposition on its floor and accretionary banks, progressively reducing the cross-sectional area; modern ephemeral rivers yield examples of this filling style (Schumm 1960; Taylor and Woodyer 1978; Schumann 1989; Gibling et al. 1998).

Terminology for 3D Analysis

Few terms are available to describe channel bodies in their full three-dimensional form. Pettijohn et al. (1972) identified *dendroid bodies*, typically sinuous with *tributary* and *distributary* form. Some additional terms are suggested here (Fig. 3). The intervals between branches can be termed *links*, by analogy with modern drainage networks (Horton 1945). Exceptionally thick zones represent reaches where the thalweg was

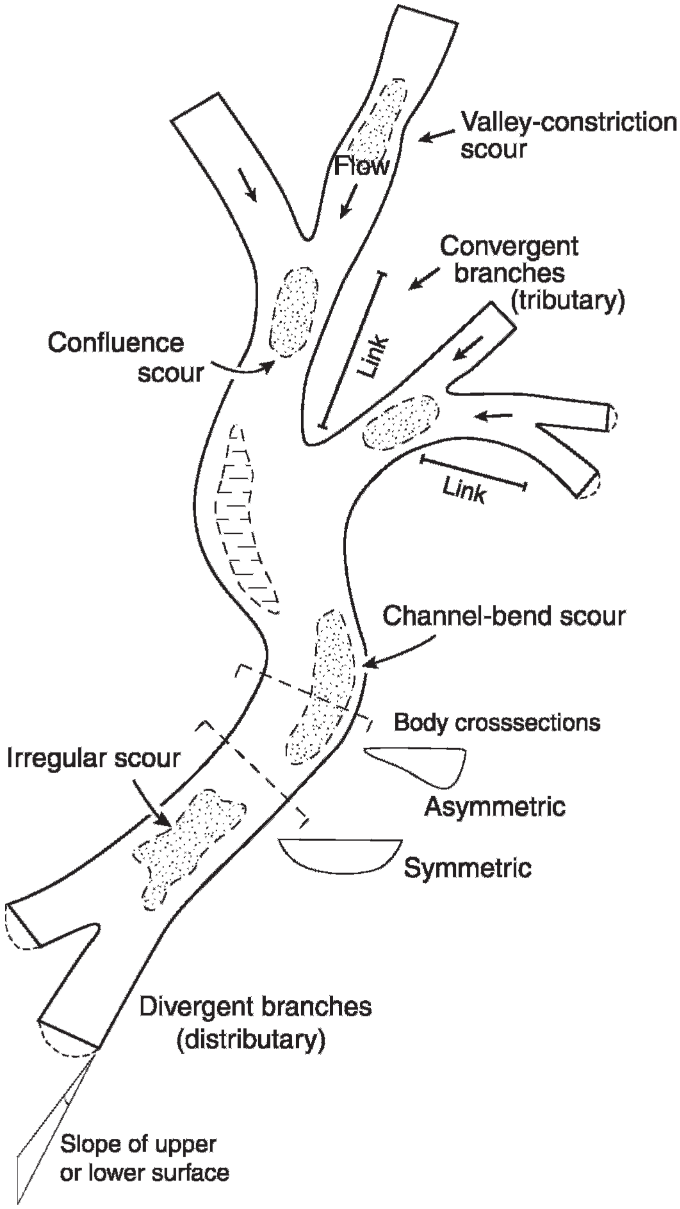

FIG. 3.— Terminology for describing the three-dimensional form of channel bodies. The diagram is based on valley fills with distinct branches and tributaries (e.g., Feldman et al. 1995; Plint 2002), but the terms may also be applicable to broad channel bodies with a complex history and internal geometry.

exceptionally deep, and include *confluence scours*, *channel-bend scours*, and *valley-constriction scours* (Ardies et al. 2002), as well as *irregular scours*—the latter showing no apparent relationship to channel or valley form. Salter (1993) noted that "scour" results from processes of erosion intrinsic to fluvial channels, especially at bends, confluences, and control points (structural elements, clay plugs, bluffs), and Best and Ashworth (1997) noted that scour depth in confluences and bends may be five times greater than mean channel depth. Zones of unusual width (e.g., Plint 2002) may reflect the influence of control points such as tributary and distributary positions (Salter 1993). If branches are present, drainage patterns (trellis, dendritic), convergent systems, and divergent systems can be identified (Thomas and Anderson 1994; Feldman et al. 1995; Ye et al. 1999; Posamentier 2001; Ardies et al. 2002; Plint 2002).

DIMENSIONS OF CHANNEL BODIES AND VALLEY FILLS

Previous Classifications

Early classifications for channel-body dimensions (Rich 1923; Table 2) focused on length/width—a combination of longitudinal and cross-sectional measures. Krynine (1948) recognized the utility of width/thickness (hereafter abbreviated to W/T), with width measured perpendicular to the local elongation of the sediment body (Friend et al. 1979) or to the measured paleoflow direction. Maximum thickness has been widely used, and represents the site of maximum thickness of a single-story body or of amalgamated stories in a multistory body. Comparison of mean and maximum values may be meaningful but has rarely been applied.

In two classic papers, Friend et al. (1979) and Friend (1983) used a W/T value of 15 to divide channel bodies into *ribbons* and *sheets* (Table 2). This division has been generally accepted and, as discussed later, accords with the aspect ratio of modern channels; some workers have preferred a higher boundary value. Blakey and Gubitosa (1984) separated narrow and broad sheets at a W/T value of 100, and Krynine (1948) defined tabular bodies (W/T 50–1000) and blankets (W/T > 1000). Potter (1967) used sheets and blankets to describe essentially equidimensional bodies (similar width and length). Friend (1983) drew an important linkage between channel-body form and channel behavior, distinguishing *mobile channel belts*, *fixed channels*, and *sheetflood settings* with limited channelization; this division is developed in the present study. Based on the dataset, Table 3 presents a revised classification of channel bodies in terms of width, thickness, W/T, and area.

Previous Approaches to Compilation

Many approaches exist for investigating and predicting channel-body geometry (see reviews by Martin 1993, North 1996, and Bridge 2003). The approach taken here involves the plotting of W/T data on a log-log scale for a large suite of Quaternary and older bedrock examples. A crucial problem in using examples from the ancient record is the sparsity of reliable data on channel-body width (Tye 2004).

Several previous studies have produced compilations. To test the lateral extent of sand bodies generated from high-sinuosity fluvial systems, Collinson (1978) plotted the dimensions of ancient channel bodies in comparison with a statistical relationship between channel depth and meanderbelt width for modern rivers. Fielding and Crane (1987) plotted channel-belt width against depth or thickness for a large suite of modern rivers and ancient bodies. Their data set spans examples 0.3 to 40 m deep or thick and 1 m to 20 km wide, with a W/T range of 3 to 2000. Superimposed on the plot in order of progressively increasing W/T were (1) an upper bounding line, also delineating incised, straight and non-migrating channels, (2) an upper bounding line for meandering channels, (3) Collinson's statistical relationship for fully meandering rivers, and (4) a lower bounding line, also delineating braided systems. However, their data sources were not recorded, and the mixing of data from modern river channels and ancient channel bodies is problematic.

Using average W/T values and range bars for data sets, Cowan (1991) and Robinson and McCabe (1997) presented log-log plots of channel-body dimensions for several fluvial groups, in relation to a W/T value of 15. They distinguished fixed ribbons, meandering ribbons, sheets deposited from low-sinuosity, braided or sheetflood systems, and sheets deposited from highly sinuous and meandering systems. Some large composite sheets had W/T values up to 20,000. Dreyer (1993) presented compilations on linear plots. Reynolds (1999) plotted data for 409 channel and valley bodies in paralic settings, identified in outcrop and subsurface studies, on a log-log plot. Although this is a large dataset, no information was provided about the localities, sedimentary features, and diagnostic features of each type, and stacked sand bodies were excluded. Reynolds generated cumulative frequency plots for sand-body width, as

TABLE 2.—*Geometric measures used to define fluvial-channel bodies.*

Author	Channel-Body Dimensions
Rich 1923	Length/width used to define "shoestring sands" (length >> width). Width and thickness noted for some bodies.
Krynine 1948	Classified sedimentary bodies of all types. Width: large > 80 km, medium 8–80 km, small < 8 km Thickness : thick > 150 m, medium 30–150 m, thin < 30 m Width/thickness: blanket > 1000:1, tabular 1000–50:1, prism 50–5:1, shoestring < 5:1 Area: large > 25,600 km^2, medium > 256 km^2, small < 256 km^2 Length: large > 160 km, medium 32–160 km, small < 32 km Volume: large > 500, medium 1–500, small < 1 cubic mile
Potter 1962, 1967 Pettijohn et al. 1972	Length/width used to distinguish: (a) equidimensional bodies (sheets or blankets, ~ 1:1), (b) inequidimensional bodies (pods < 3:1, ribbons or shoestrings > 3:1, dendroids with branching form, belts with complex patterns of coalescence).
McGugan 1965	Persistence Factor—areal extent/average thickness. Both terms measured in same units, but units of km^2 and m, respectively, are used here. No categories defined.
Cotter 1978	Width/thickness of stories within a multistory (braided) body: channeled–braided < 20:1, sheet-braided > 20:1.
Friend et al. 1979; Friend 1983	Width/thickness (or height): ribbon < 15:1, sheet > 15:1
Blakey and Gubitosa 1984	Width/thickness: ribbon < 15:1, narrow sheet 15–100:1, broad sheet > 100:1
Atkinson 1983, cited in Alexander 1992a	Width /thickness: ribbon/sheet boundary revised to 25:1
Nadon 1994	Width/thickness: ribbon/sheet boundary revised to 30:1
Friend et al. 2001	Microbodies < 1.2 m thick, minor sheets 1.2–6 m, thin mega-sheets 6–12 m, thick mega-sheets > 12 m (for Siwalik Group exposures)

a guide to most probable widths, and related fluvial style to systems tracts.

These studies have outlined the range of width, thickness, and W/T of channel bodies in the rock record. They have also shown that channel bodies form a continuum in W–T space, with mobile channel belts (braided and meandering) at larger W/T values than fixed channel bodies. The studies have tended to represent channel style in terms of planform and the 15 W/T boundary. However, there is scope for an approach that combines quantitative information with a qualitative, geomorphic assessment.

Data Compilation and Analysis

For the present study, I compiled literature in the English language on channel bodies and valley fills from the Quaternary and older bedrock records, for which the authors provided measurements of width, thickness, W/T, and (less commonly) area and length. This information is either explicitly stated or can be calculated from diagrams and maps. Channel bodies less than 1 m thick were excluded but no upper size limit was imposed. Data suites include exact width and thickness for single bodies, width and thickness ranges for suites of bodies, width ranges for a single thickness, and thickness ranges for a single width. Where the available data include ranges of width, thickness, and W/T, a more restricted distribution of width and thickness could be estimated than was possible for width and thickness ranges alone.

The inclusion of such general information reduced precision but allowed a much larger suite of examples to be considered. This helps to overcome a bias towards small and low W/T bodies accessible in small outcrops, and is especially important for extensive sheets, the full dimensions of which are unknown. Some of these sheets may represent "big rivers" comparable to the largest modern channels—a group that is underrepresented in the literature (Potter 1978; Miall and Jones 2003).

The dataset represents examples from about 155 individual stratigraphic units from all continents except Antarctica, and from Archean to Holocene, although the bulk of the examples are Devonian or younger. The number of channel bodies is difficult to assess, inasmuch as examples range from single valley fills and amalgamated bodies of basinal scale to formations with hundreds of small bodies. Additionally, some studies provide generalized estimates for fluvial bodies hundreds of kilometers long, or quote ranges of dimensions for suites of bodies but do not state the number of bodies studied. However, a conservative estimate puts the total number of discrete channel bodies at well over 1500.

Many excellent facies studies were excluded because suitable dimensional data could not be obtained from the available outcrops or wells or were not recorded by the authors. Although subsurface datasets commonly provide good isopach and length information, fluvial style may be difficult to assess from limited core, muddy fills are difficult to identify, and limited well intersections preclude accurate width assessment (Lorenz et al. 1985; Bridge and Tye 2000; Tye 2004). Consequently, most of the selected subsurface studies included some outcrop information. A compilation such

TABLE 3.—*Classification of fluvial-channel bodies and fluvial-valley fills according to size and form based on the present study.*

Width (m)		Thickness (m)		Width / Thickness		Area (km^2)	
Very Wide	> 10,000	Very Thick	> 50	Very Broad Sheets	> 1,000	Very Large	> 10,000
Wide	> 1,000	Thick	> 15	Broad Sheets	> 100	Large	> 1,000
Medium	> 100	Medium	> 5	Narrow Sheets	> 15	Medium	> 100
Narrow	> 10	Thin	> 1	Broad Ribbons	> 5	Small	> 10
Very Narrow	< 10	Very Thin	< 1	Narrow Ribbons	< 5	Very Small	< 10

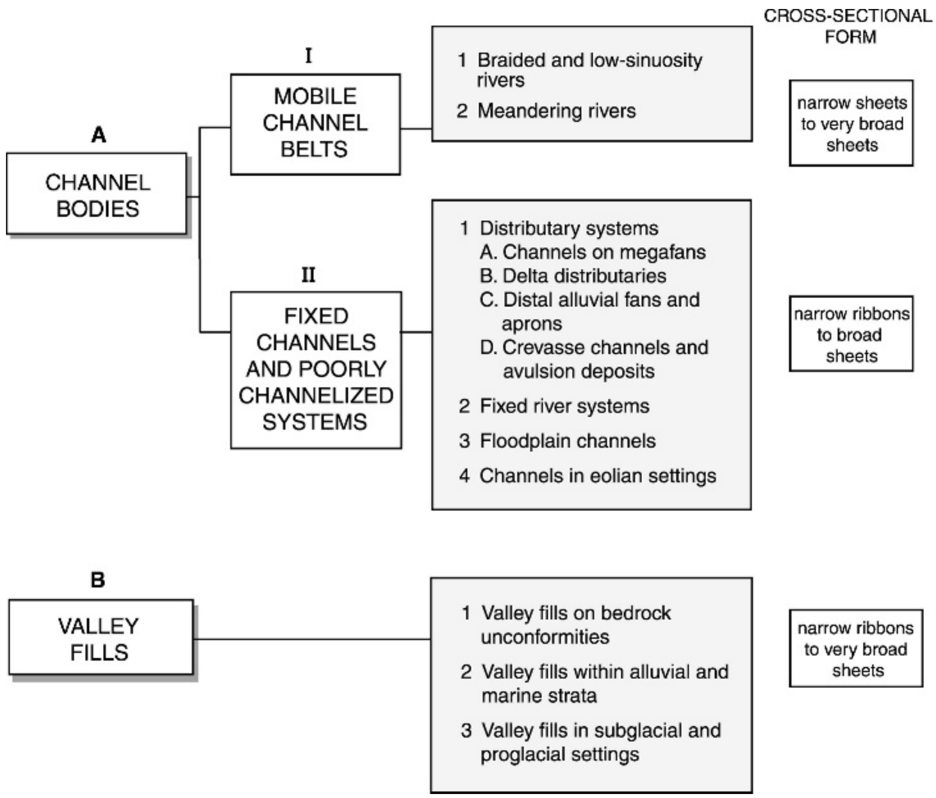

FIG. 4.—Classification of fluvial channel bodies and valley fills in the geological record, based on dimensions, geomorphic setting, and architecture. See Table 3 for form definitions and Table 4 for a detailed facies description of each category.

as this depends on the accuracy of description and the quality of interpretation of the original authors, although the present author is personally familiar with some 45 of the stratigraphic units represented. The dataset represents the reported dimensions of bodies of rock, and original thicknesses may have been greater prior to compaction. Because of the variability of data type and precision, no statistical analysis was attempted.

The large dataset allows a comprehensive classification of the channel bodies and valley fills, based collectively on their geomorphic setting, geometry, and internal characteristics (grain size, bedforms, architectural elements) (Fig. 4, Table 4). W/T plots were constructed using information of varied precision, and individual datasets were plotted as points, lines, and polygons (Fig. 5). Tight envelopes were constructed around the collective data (dashed line in Fig. 5). The diagrams (Figs. 6–10) represent the most common dimensional tendency for channel bodies and valley fills of recognized types, but the large amount of data precludes notation of more than a few key examples on the graphs. To make the dataset more accessible, the SEPM Data Repository (see Acknowledgments section) contains a much fuller account: a reference list of literature examples under each category of the classification (Appendix 1); a set of 13 spreadsheets and W/T graphs in Excel® format that can be downloaded, along with an account of how to create and modify the graphs (Appendix 2); and a set of photos of some well exposed examples (Appendices 3–9). Thus, interested readers can identify individual datasets on the graphs and select analogues that suit their purposes, as well as plotting their own data. A checklist that sets out information needed for a full assessment of channel-body geometry is included (Appendix 10), as well as a key diagram (Appendix 11) to assist in classifying an individual fluvial body under investigation. The graphs will be updated periodically on the website <http://myweb.dal.ca/mgibling>.

The data are presented as log-log plots primarily because of the large range in dimensions—more than five orders of magnitude for width and more than three orders of magnitude for thickness. One disadvantage of the log-log plots that readers need to bear in mind is that slight differences in position at high thickness and width represent major changes in body dimensions. However, log-log plots are also appropriate for hydraulic and geomorphic reasons. Channel-forming discharges have a log-normal distribution, with progressively fewer events towards the high-discharge end (Yu and Wolman 1987), and river systems tend to contain many small and few very large channel reaches. For the rock record, the present dataset tends to confirm the abundance of small channel bodies and relative scarcity of very large bodies. Thus, channels—and by extension channel bodies—may be suitably represented using log plots (Robinson and McCabe 1997). However, the superimposition of individual channel deposits through time is likely to preclude simple dimensional trends.

The dataset represents single and multistory channel bodies and valley fills that range from 1 to 1400 m in thickness, from 2 m to 1300 km in width, and in W/T from less than 1 to more than 15,000. Because no upper thickness restriction was applied, the dataset includes examples of stacked, multistory sand-bed channel bodies that fill a large proportion of their parent basins. The length of channel bodies is rarely reported, except in some subsurface studies where channel systems have been traced for more than 330 km (Plint 2002). In view of this sparse information, channel-body area is difficult to assess, with the largest bodies exceeding 70,000 km^2 but most apparently much less than 1000 km^2.

Evident from the dataset is the convergence of channel bodies and valley fills from a wide range of settings into broad ribbons to narrow sheets (W/T 5 to 100). Where many channel bodies were studied within a narrow stratigraphic interval, it is apparent that a W/T spectrum exists, with no sharp distinction between ribbons and narrow sheets (e.g., Olsen 1993; Friend et al. 2001). The plots for most groups show a proportional increase of width relative to thickness as scale increases. This results in population belts that cut obliquely across W/T lines (as noted by Fielding and Crane 1987). Although this trend may reflect in part the increase in width relative to depth observed in modern alluvial channels as discharge increases (Church 1992), the larger channel bodies are mainly those of meandering and braided rivers, which tend to generate wide sheets.

TABLE 4.—*Characteristics of fluvial-channel bodies and fluvial-valley fills in the geological record, based on dimensions, geomorphic setting, and architecture from examples in the compiled dataset.*

Dimensions	Sedimentary Features	Geomorphic Setting
	A. CHANNEL BODIES **I. MOBILE CHANNEL BELTS**	
1. Braided and Low-sinuosity Rivers T 1–1200 m; most < 60 m; common range 5–60 m W 50 m – 1300+ km; many > 1 km; common range 0.5–10 km W/T 15–15000+; some > 1000; common range 50–1000. Area may exceed 450,000 km^2	Mainly multistory, with bank-attached and in-channel bars and channel-base dunes. Sand and minor gravel; local fines as abandonment fills, bartops and slump blocks. Fining up common. In thick bodies, successive stories may show divergent paleoflow and contain paleosols. Thinner bodies encased in alluvial fines. Some thin, high W/T channel bodies rest on subplanar bedrock surfaces.	Braided and low-sinuosity rivers and braidplains on unconfined plains and deltas; variably mountain-fed and plains-fed. Vertical accretion prominent; topmost stories may show lateral accretion (underfit streams?). Paleoflow variation between stories reflects tectonism or nodal avulsion. Some thick scour fills may mark channel confluences. Thicker bodies represent superimposed channel belts that swept across plains due to avulsion or were confined in fault-bounded basins or broad valleys. Channel sheets on bedrock may represent sediment influxes under conditions of exhumation and low-subsidence.
2. Meandering Rivers T 1–38 m; common range 4–20 m W 30 m – 15 km; most < 3 km; common range 0.3–3 km W/T 7–940; most < 250; many < 100; common range 30–250	Single to multistory bodies with prominent lateral-accretion sets (point-bar deposits). Tops of bodies include accretionary ridges, scroll-bar forms, and chute channels. Channel-base bedform sheets. Sand and minor gravel (typically reworked calcrete), with fines in abandoned channels; fining up common in stories. Tidal structures in some.	Channel belts of meandering rivers with some gradation to braided systems. Relatively high W/T reflects degree of lateral amalgamation of channel segments; slightly amalgamated bodies may plot close to modern best-fit line for channel depth / meander-belt width. May cap avulsion deposits with ribbon channel bodies.
	II. FIXED CHANNELS AND POORLY CHANNELIZED SYSTEMS	
1. DISTRIBUTARY SYSTEMS	**A. Channels on Megafans**	
T 1–15 m; most < 10 m; common range 2–8 m. W 3–1500 m; most < 200 m; common range 20–200 m W/T 2–100; most < 40; common range 5–30	Conglomerate fills are mainly clast-supported and imbricated, with cross-beds, graded beds, and local fining up; rare matrix-supported and disorganized gravels. Some channels filled by single inclined stratal sets. Calcrete and volcanic clasts common. Sandstone fills are pebbly and cross-stratified to massive. Minor mudstone. Basal incision prominent, fills are concentric or asymmetric, single or multistory, with erosion surfaces and wings common. Encased in floodplain fines, commonly red.	Distributary systems up to 100 km in radius from confined entry point into basin. Channel systems represent feeder axes and minor distributaries; ribbons may pass upflow into large sheet bodies or intercalate with axial drainage systems. Degree of channelization strong to moderate. Straight to sinuous channels, locally braided, many entrenched, some confined by calcretes. Abundant coarse sediment derived from nearby uplands through stream flow and some debris flows; rapid channel filling and frequent avulsion. Vertical accretion predominates, with minor lateral accretion (rarely more than one sweep). Accretion surfaces represent bank-attached, longitudinal and transverse bars.
	B. Delta Distributaries	
T 1–35 m; most < 20 m; common range 3–20 m W 3 m to 1 km; most < 500 m; common range 10–300 m W/T 2 to 245; most < 50; many < 15; common range 5–30	Sand and mud fills, with drifted coals, minor extrabasinal and intrabasinal gravels, wide range of bedforms, mud drapes, soft-sediment deformation, slump blocks of mud and peat, and mass-flow deposits. No consistent fining up, may be coarser in center. Fossils common (shells and organics). Fills concentric or stacked, with some lateral and downstream accretion sets (commonly large solitary sets). Concave-up bases and symmetric cross sections common. Single or multistory, prominent erosion surfaces. Abandoned channel plugs mainly sandy, more rarely muddy.	Distributary systems on deltas, incised into delta-top and delta-front deposits, and locally associated with natural-levee and tidal deposits. Form isolated bodies in wetland deposits, where cohesive sediment may promote narrow form. Incision due mainly to avulsive scour. Generally low-sinuosity channels that bifurcate; lateral and side bars common, but point bars uncommon. Strongly aggradational fills, with local lateral-accretion and gravity-flow deposits. Distributary systems at distal delta margins are associated with mouth bars.
	C. Distal Alluvial Fans and Aprons	
T 1–10 m, mainly < 5 m W 2–1130 m; common range 5–200 m W/T very variable, from < 1–250	Sandstone predominates as upper-regime plane beds, cross-strata, and structureless sand. Some conglomerate, pebbly layers, and mud drapes; desiccation features common. Lateral-accretion sets locally. Single story most common, locally multistory; wings prominent. Basal scour and channel margins prominent to not prominent. Sand and mud abandonment fills.	Channel bodies encased in sandy sheetflood deposits, commonly < 10% of stratal package; thin and pass distally into floodbasin, lacustrine, playa, and eolian deposits. Degree of channelization moderate to low. Many formed from semiarid ephemeral streams, with vertical accretion in shallow washes and local bank-attached bars. Some small sinuous creeks on lake margins. Sheet forms suggest widening by floods in noncohesive sediment.

TABLE 4.—*Continued.*

Dimensions	Sedimentary Features	Geomorphic Setting
	D. Crevasse Channels and Avulsion Deposits	
T 1–9 m W 5–400 m; most $<$ 50 m; common range 5–50 m W/T 2–100; most $<$ 20; common range 5–20	Sandstone with a range of bedforms, local intraclasts; muddy and mixed fills and abandonment fills; may fine upward; internal scours. Plant debris, roots. Bases planar to concave-up with locally steep margins; tops planar to convex-up. Fills concentric to asymmetric, with local lateral-accretion sets. Paleoflow may be orthogonal to associated channel bodies. Some suites with ribbon tiers overlie wetland facies with immature paleosols, and are capped by large channel bodies; paleoflow parallel or normal to that of associated major channel bodies.	Channels associated with natural-levee and crevasse-splay deposits, in wetland and dryland settings. Rapid vertical filling common, through flood pulses that cause alternate erosion and deposition, and local lateral accretion. Convex-up forms imply overfilling or less compaction of sandy fill relative to overbank deposits. Ribbon tier sets are probable anastomosing channel fills with vertical accretion. Form part of avulsion-deposit succession, where crevassing into wetlands generates an accretionary wedge, and where multiple channels consolidate over time into a single large channel.
2. Fixed River Systems T 1–33 m; common range 3–15 m; W 3.5 m to 2.4 km; most $<$ 500 m; many $<$ 150 m; common range 15–300 m W/T 2.5–150; most $<$ 60; many $<$ 15; common range 5–50.	Sandstone, local fining up, wide range of bedforms. Minor gravel, mud and heterolithic fills. Convolute lamination and slump blocks; rare tidal evidence. Lateral accretion sets uncommon (generally in upper fill), with limited migration within confined channel. Single-story or multistory, wings common, concave-up basal surfaces and steep, fluted margins common. Story bases may step out over floodplain strata.	Fixed channels, many anastomosing as shown by plan view connections and linked tops (ribbon tiers). Some may represent single-channel or braided-sandbed networks. Locally restricted by tough paleosols and peat; rapid aggradation, avulsive style. Many represent long-lived systems, dominating tens to hundreds of meters of basinal fill. Some suites correlate with marine intervals, suggesting a link to accommodation creation through sea level rise.
3. Floodplain Channels T $<$ 2 m; many $<$ 0.5 m W $<$ 12 m W/T $<$ 35	Quartzose sand present or absent; carbonate (pedogenic) intraclasts prominent; mud fills common. Single story. Generally enclosed in fines, some cap calcretes; others cut tops of larger bodies.	Small channels and gullies in a variety of settings on floodplains, many as single-event fills. Suites of small channels may rest on widespread degradational surfaces. Large badland gully systems may contain channel deposits along with colluvium; they are prominent in modern landscapes but rarely documented in the ancient record.
4. Channels in Eolian Settings T 1–19 m W 2.5–1500 m; most $<$ 150 m W/T 1–80; most $<$ 15	Sandstone predominates, commonly massive, with cross-beds and plane beds; minor mud and gravel. Accretion surfaces in some. Channel bodies with steep sides.	Diverse group of channel bodies associated with eolian dunes. Abundance of coarse, noncohesive eolian sediment governs transport and deposition. Processes range from stream flow to debris flow and hyperconcentrated flow; tops may be deflated. Settings include ephemeral channels, locally impounded by dunes, and flows from extreme precipitation events.
	B. VALLEY FILLS	
1. Valley Fills on Bedrock Unconformities T 12–1400 m; most $<$ 500 m W 75 m to 52 km; most $<$ 10 km W/T 2–870, highly variable, mainly 2–100	Complex fills of conglomerate, sandstone, mudstone, carbonate, coal, and volcaniclastics. Brackish fossils and tidal structures in some. Some broadly fining up, with megasequences. Margins gentle to vertical, depending on substrate strength. Contain stacked and isolated channel bodies of varied type. Fills onlap valley walls, and may contain unconformities; upper parts of adjacent valley fills may connect to form unconfined sheets. Rare examples of clinoform sets with 250 m of relief.	Fills on deeply eroded land surfaces, including karsted surfaces with sinkholes; may pass laterally into sheets on subplanar unconformities. Valleys straight, branching or complexly intersecting, locally mappable as drainage networks. Fills predominantly alluvial (debris flows and stream flows) with estuarine and delta systems, colluvium, floodplain, eolian, lake, mire, and glacial deposits. Valleys commonly follow fault lines, where fills are later dismembered by fault motion. Fills linked to abundant sediment supply, tectonism, discharge variation, and river capture.
2. Valley fills within Alluvial and Marine Strata T 2–210 m; most $<$ 60 m W 0.1–105 km; common range 0.2–25 km W/T 4.6–3640, highly variable; common range 10–1000, many from 100–1000 Some mapped over delta areas of 50,000 km^2	Sandstone, conglomerate, mudstone (more common basinward), carbonate, and coal. Heterolithic facies typically show tidal structures and fossils. Local giant cross-beds (to 40 m). Paleoflow directed landward or seaward. Valley may be sinuous and asymmetric in cross section at bends; onlap of valley walls rarely visible in seismic profiles. Most rest on disconformities, with slight age difference between fill and substrate, but a few rest on angular unconformities. Fills may comprise stacked sequences. Component channel bodies typically multistory.	Mainly coastal valleys, with a common pattern of alluvial strata to estuarine strata to open-marine strata upward. Component channel types include braided sheets, low-sinuosity channels, and meandering channels. Estuarine fills may show tripartite facies distribution in plan form; delta lobes and distributaries common. Giant cross-beds form on alternate bars where valleys incised delta slopes. Correlative paleosols locally prominent on interfluves. Sea level fluctuation is major control, but some valley fills that rest on an angular unconformity have been tectonically enhanced.
3. Valley Fills in Subglacial and Proglacial Settings T 7–400 m W 25 m to 6 km W/T 2.5–42	Gravel, massive sand and graded beds, cryptic bedforms, slump blocks that include semiconsolidated sand, and dropstones. Chaotic intervals common. Strata may have parabolic form, steep sides common, and some channel margins strongly deformed.	Tunnel valleys formed by catastrophic subglacial outbursts of meltwater (jökulhlaups), steady-state subglacial meltwater erosion, and local glacial erosion. Filled with glaciofluvial, lacustrine, and marine strata. Mass flows common, and sediment piping and collapse may have assisted erosion. Proglacial channel fills originate as mass-flow beds with downslope shearing of rigid plugs (frozen?), and as subaqueous esker-fan channels.

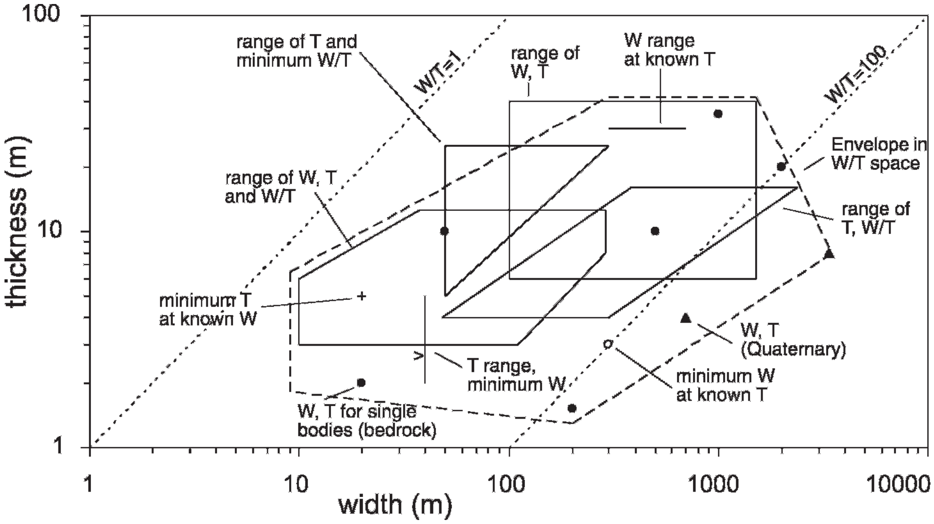

FIG. 5.—Construction methods for width : thickness plots. Note that general ranges of width and thickness reported by authors are represented by polygons, boxes, and triangles. However, width and thickness show a broad correlation, and upper left and lower right areas of these shapes are probably not occupied. Thus bounding envelopes for the datasets may cut through these areas if they project beyond other data points.

CLASSIFICATION OF CHANNEL BODIES AND VALLEY FILLS

Previous Classification Systems

Few studies of fluvial channel deposits have dealt with a wide enough range of channel bodies to allow a comprehensive classification. As noted earlier, Friend (1983) set out a tripartite classification of fluvial systems into *mobile channel belts*, *fixed channels*, and *poorly channelized systems*, which has been widely adopted along with his division of channel bodies into ribbons and sheets. The most comprehensive system available is that of Miall (1996, Chapter 8), set out in Table 5. Miall recognized 16 common fluvial styles, each essentially a facies model, and described each style on the basis of modern and ancient examples. He drew also on a classification of floodplains by Nanson and Croke (1992). Miall's classification has a strong basis in modern rivers, and the majority of styles are variants of braided and meandering systems, implying some degree of linkage between planform and channel-body style, although particular emphasis was given to the observed assemblage of architectural elements. Miall did not include alluvial-fan deposits, and no distinction was attempted between valley fills and channel bodies. Although the external geometry of the channel bodies was not included explicitly in his classification, geometry was frequently mentioned in the descriptions.

Reynolds (1999) distinguished three types of channel body (distributary, crevasse, and "fluvial") and incised-valley fills, and provided dimensional data for each type (Table 6). His data ranges are compared with those from the present study in the subsequent text.

As the present compilation of channel-body dimensions progressed, it became apparent that the large amount of information could not be plotted effectively on a single diagram. Moreover, many examples could be grouped based on their internal constitution and interpreted geomorphic setting (Table 4), and some groups tended to occupy a distinct part of W/T space. Consequently, W/T plots (Figs. 6–10) were constructed separately for each category, with line drawings constructed for some representative examples (Figs. 11–13). The classification system and its basis is presented below.

Valley Fills

The dataset yields a division of fluvial bodies into *channel bodies* and *valley fills* based on the interpretations of the authors (Fig. 4, Table 4). Because strong interest in valley fills is relatively recent (Dalrymple et al. 1994), many examples described as "channel bodies" in the dataset may lie within valleys, and only examples explicitly interpreted by the original authors or later workers as valley fills are so categorized. Although the widely used term "valley fill" is retained here, the perimeters of valleys

TABLE 5.—*Common fluvial styles, based on modern and interpreted ancient examples. From Miall (1996, Table 8.3).*

1. Gravel-dominated rivers	Gravel braided with sedimentgravity flows
	Shallow gravel braided ("Scott type")
	Deep gravel braided ("Donjek type")
	Gravel wandering
	Gravel meandering
2. Sand-dominated high-sinuosity rivers	Gravel-sand meandering ("coarse-grained meandering")
	Sandy meandering ("classic meandering")
	Ephemeral sandy meandering
	Fine-grained meandering
	Anastomosed
3. Sand-dominated low-sinuosity rivers	Low-sinuosity braided-meandering with alternate bars
	Shallow perennial braided ("Platte type")
	Deep perennial braided ("S.Saskatchewan type")
	High-energy sand-bed braided
	Sheetflood distal braided
	Flashy ephemeral sheetflood ("Bijou Creek type")

TABLE 6.—*Dimensions of fluvial-channel bodies and valley fills in examples from the ancient record, from Table 3 and figure 6 of Reynolds (1999).*

Sand-body Type	Width (W) in Meters Max.	Width (W) in Meters Min.	Width (W) in Meters Mean	Thickness (T) in Meters Max.	Thickness (T) in Meters Min.	Thickness (T) in Meters Mean	W/T	Number
Fluvial Channels	1400	57	755	24	2.5	9	25–100	6
Distributary Channels	5900	20	518	40	1	7.8	4–600	268
Crevasse Channels	400	5	58	17	0.2	2.4	6–90	44
Incised Valleys	63000	500	9843	152	2	30.3	15–3000	91

W/T ranges are estimated from figure 6. The data represent maximum width and thickness values for individual (not stacked) channel bodies. No facies information and data sources were provided.

change their position through time, and sediment volumes linked to valleys might more appropriately be termed "valley bodies."

Zaitlin et al. (1994) defined an incised-valley system as a "fluvially-eroded, elongate topographic low that is typically larger than a single channel form" (see also Schumm and Ethridge 1994). Because incision characterizes the majority of fluvial conduits (Salter 1993), the existence of an erosional margin alone cannot be considered diagnostic of valleys, especially because the prominence of erosional features may be largely a function of the most recent major flood (Wolman and Miller 1960; Nash 1994) or of confluence dynamics (Best and Ashworth 1997). For channel deposits to be identified as valley fills, Posamentier (2001) noted that the river must have cut into the floodplain sufficiently that, even at flood stage, flow does not overtop the banks, and he noted that incised tributary valleys and gullies may be important in recognizing incised systems (as in the planview of Fig. 13B). Within continental settings, fluctuations in discharge of water and sediment as a result of climate, tectonics, avulsion, and river capture may result in periods of incision and aggradation (Goodbred 2003), so that "channels" may be transformed into "valleys" (and vice versa) over periods of thousands to tens of thousands of years, as in parts of the Himalayan Foreland Basin (Gibling et al. 2005; Tandon et al. in press). Terraces are widely represented within modern valleys (e.g., Blum et al. 1994) but are rarely identified within the dataset.

Valley fills identified in the dataset are mainly incised into bedrock or into coastal and marine strata, and some contain marine units that

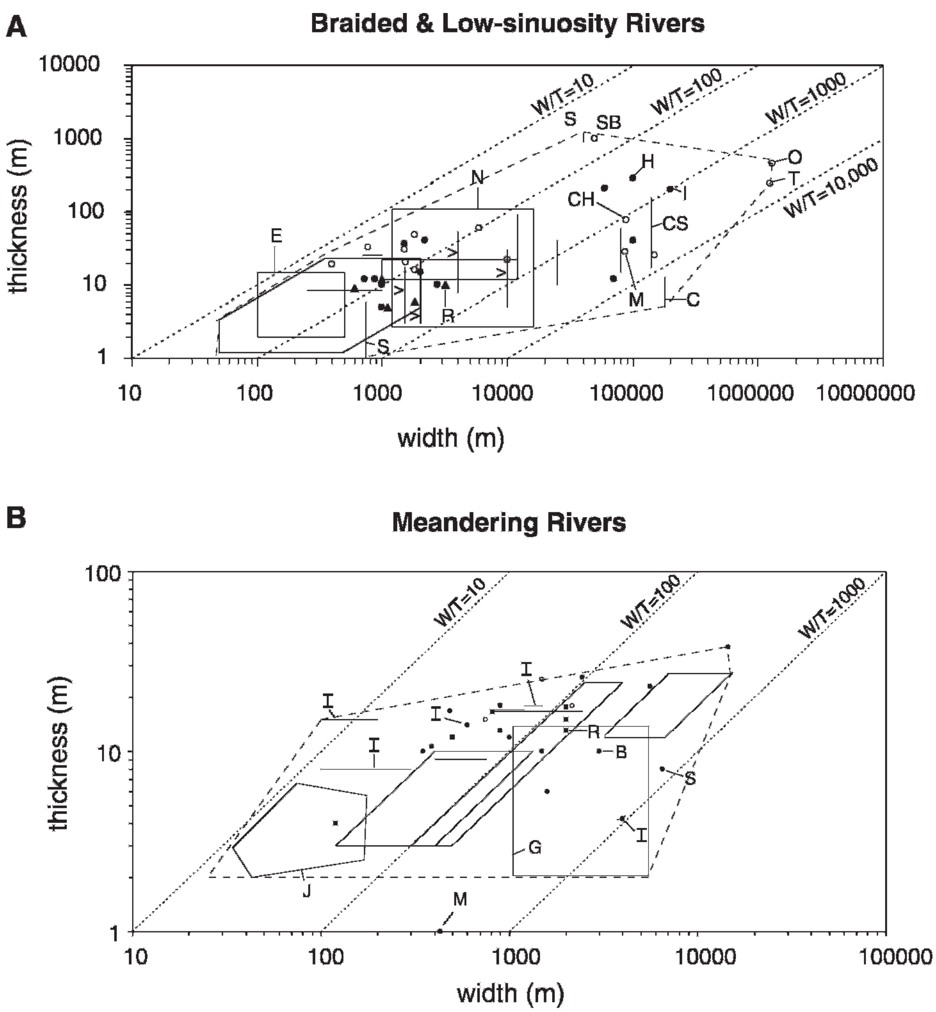

FIG. 6.—Width : thickness plots for Mobile Channel Belts. Studies used for the plots are listed in Appendix 1. Diagram format is explained in Figure 5. **A)** Braided and low-sinuosity rivers; C = Cadomin Formation; CH = Cypress Hills Formation; CS = Castlegate Sandstone; E = Escanilla Group; H = Hawkesbury Sandstone; I = Ivishak Sandstone; M = Mesa Rica Formation; N = Newcastle Coal Measures (38 bodies); O = Ogalalla Group; R = Quaternary, Riverina, Australia; S = Siwalik Group; SB = South Bar Formation; T = Tuscarora Formation. **B)** Meandering rivers; B = Beaufort Group; G = German Creek Formation; J = Joggins Formation; M = Miocene, Spain (Murillo el Fruto); I = Indonesian Cenozoic; R = Rangal Coal Measures (solid squares); S = Scalby Formation.

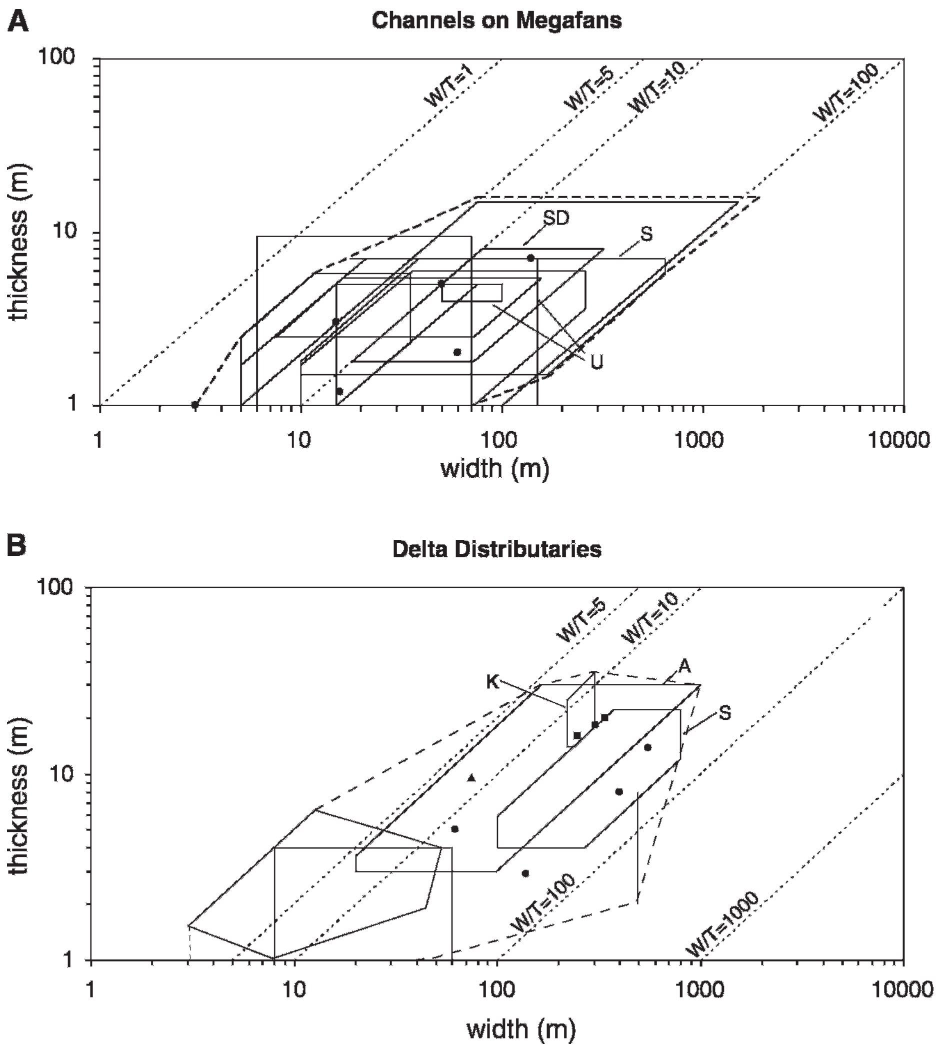

FIG. 7.—Width : thickness plots for distributary systems. Studies used for the plots are listed in Appendix 1. Diagram format is explained in Figure 5. **A)** Channels on megafans; S = Sarinema Formation; SD = Scala Dei Group; U = Uncastillo Formation. **B)** Delta distributaries; A = Atane Formation (62 bodies) and two delta-mouth bodies (solid squares); G = German Creek Formation; K = Kootenai Formation; S = Saltwick Formation (45 bodies). **C)** Distal alluvial fans and aprons. **D)** Crevasse channels and avulsion deposits; W = avulsion deposits of the Willwood Formation.

implicate sea-level fluctuation in valley cutting and filling. Valley fills incised into fluvial deposits (alluvium-on-alluvium contacts) are frequently subtle and more difficult to identify, and it may be difficult to distinguish local deep scours from regional, valley-base scours (Best and Ashworth 1997). Many valley fills contain discrete channel bodies (Iwaniw 1984; Vincent 2001). Valley recognition is in part a scale problem: within the dataset, erosionally based elements within smaller bodies tend to be described by the authors as stories rather than as channels within valleys, even though many modern valleys are very small. Miall (1988) recognized "channels within channels" through his CH architectural element.

In view of these issues, Fielding and Gibling (2005) suggested three diagnostic criteria for valley fills: (1) the basal erosion surface and correlative surfaces in extra-channel deposits can be traced widely, in some cases throughout the basin and between basins; (2) the dimensions of the overall fluvial body are an order of magnitude larger than those of other channel forms in the system; and (3) the scale of erosional relief on the basal surface is several times the depth of scour evident from component channel fills. Many of the examples grouped here as valley fills accord with all three of these criteria, although not all have been described fully enough to be certain. In cases of very small valley fills such as a Kansas valley fill 2 m thick and 80 m wide described by Feldman et al. (2005), only the first of these criteria is applicable, and the valley assessment is based on the correlation between the fluvial body and an extensive interfluve paleosol. The distinction of channel bodies and valley fills in the dataset was based on interpretations provided by the original authors. However, some examples described in the literature as channel bodies may occupy paleovalleys, and future research might change their attribution.

Valley fills are divided here into three types (Fig. 4, Table 4) based on the material into which they are incised and the processes of incision. *Valley fills on bedrock unconformities* are commonly angular and represent a lengthy period of bedrock erosion prior to sediment accumulation—typically a geological period or longer. *Valley fills within alluvial and marine strata* record a shorter period of erosion—commonly one glacioeustatic cycle in upper Paleozoic and Quaternary examples. This grouping requires the distinction of "bedrock" (fully lithified) from "sediment" (unconsolidated or semiconsolidated) at the time of deposition. This is not always realistic: for example, some valleys transect marine carbonates only slightly older than the valley fills (Fig. 13B; Feldman et al. 1995; Feldman et al. 2005) or are incised into tropical alluvium and paleosols that were lithified at the time of valley cutting (Nanson et al. 2005). Valley fills above a lengthy hiatus (representing at least a geological period but typically much longer) are included in the bedrock category. The two groups yield overlapping but substantially different distributions on W–T plots (Figs. 9, 10). A distinction based on

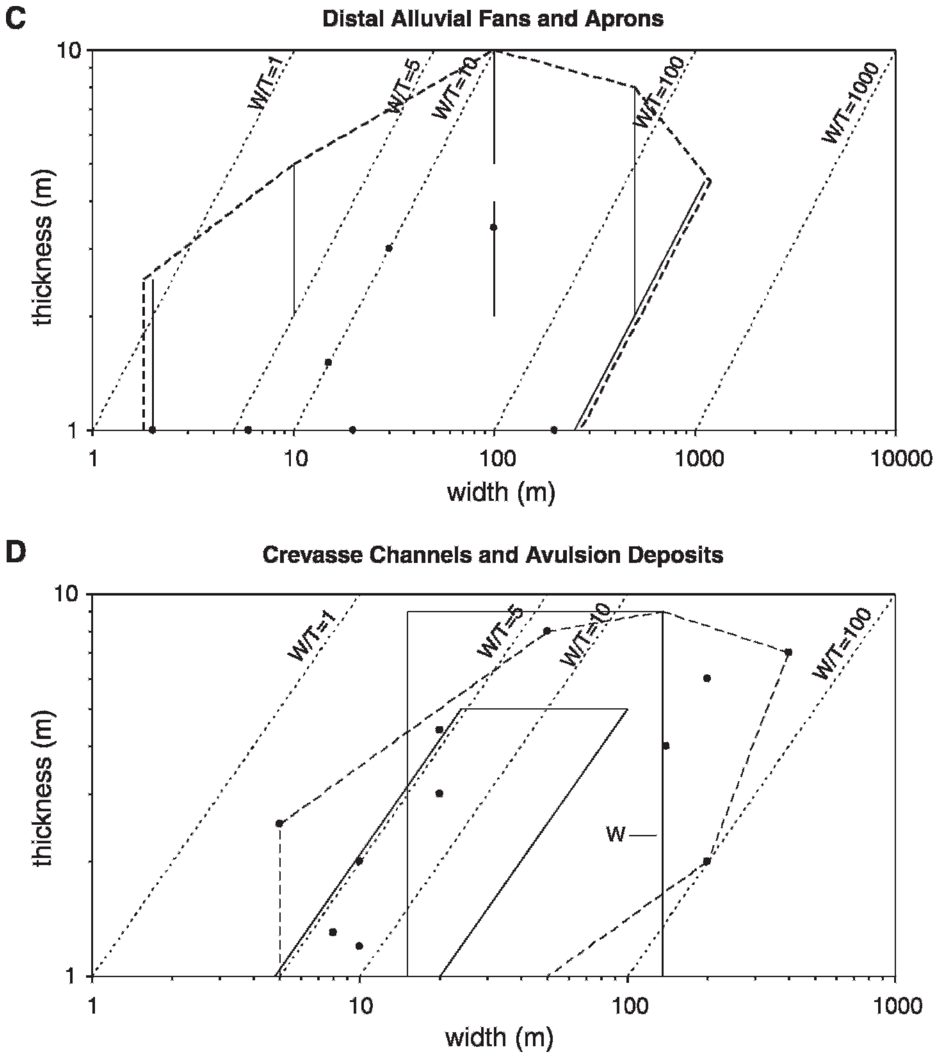

FIG. 7.—Continued.

the nature of the fill (fluvial versus estuarine and marine) did not produce distinctive W–T groupings. *Valley fills in subglacial and proglacial settings* principally comprise *tunnel valleys* formed in subglacial settings.

Channel Bodies

Nine channel-body types (Fig. 4, Table 4) are divided between two groups: mobile channel belts, and fixed channels and poorly channelized systems (following Friend 1983). For *mobile channel belts*, systematic lateral migration of channel banks and avulsive channel behavior imparted a high degree of mobility to the system. *Braided and low-sinuosity river deposits* in the dataset include a range of sandy and gravelly bar deposits and bedload sheets that were inferred by the original authors to represent braided (multi-channel) systems or slightly sinuous sandbed rivers. The parent rivers lacked systematic lateral migration, as indicated by the scarcity of lateral-accretion deposits. Most of the examples belong to the categories of gravel-dominated rivers and sand-dominated low-sinuosity rivers recognized by Miall (1996; Table 5 of this paper), who provided detailed descriptions of their facies.

In contrast, *meandering-river deposits* in the dataset show evidence that the parent channels migrated systematically through cutbank erosion at bends and concomitant point-bar migration. This process generated distinctive lateral-accretion sets with paleoflow predominantly along strike of the accretion surfaces, and such sets typically extend for tens to hundreds of meters in sections normal to paleoflow (Fig. 11B). Deposits with prominent lateral accretion deposits are grouped in this category. Examples fall in the sand-dominated high-sinuosity river group of Miall (1996). Although the prominence of lateral-accretion deposits is a key identifying feature, such a distinction may be difficult to make even where paleoflow data are available: many meandering-river point bars show components of downstream accretion, especially at their downflow ends (Sundborg 1956; Jackson 1976), and bars within braided rivers commonly show a component of lateral accretion (Bristow 1987; Lunt et al. 2004). In such cases, interpretation of the channel bodies may need to rely on a range of criteria (see Miall 1996).

Many modern braided, low-sinuosity, and meandering rivers experience frequent avulsion, resulting in the juxtaposition of deposits from different courses. This tendency is well represented in the dataset, where many deposits contain a large number of stories and are multilateral. The mobility of these river systems has resulted in relatively high W/T values, typically in the range of narrow sheets to very broad sheets.

The deposits of *fixed channels and poorly channelized systems* are divided into seven types. Four types can be distinguished as distributary in style: channel deposits formed on *megafans*, on *deltas*, on *distal alluvial fans and aprons*, and in *crevasse channels and avulsion deposits*. These types can be distinguished on the basis of their host facies and distinctive

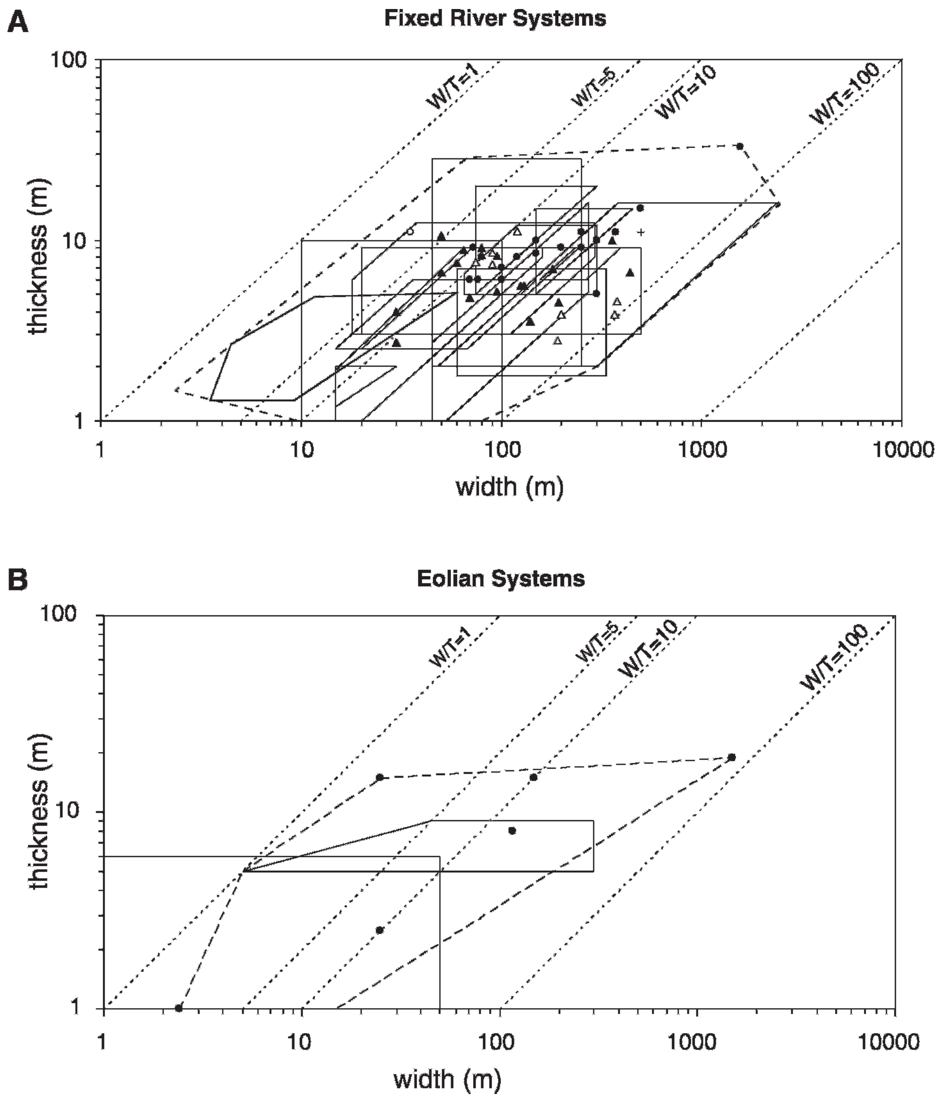

FIG. 8.—Width : thickness plots for **A)** Fixed river systems; Quaternary deposits from Rhine–Meuse system (open triangles) and Columbia River (solid triangles). **B)** Channels in eolian settings. Studies used for the plots are listed in Appendix 1. Diagram format is explained in Figure 5.

geomorphic contexts (Table 4); some of the most complete examples in the dataset are from extensively preserved megafan and delta deposits for which the landscape setting is well documented. In contrast, deposits attributed to *fixed river systems* yield little evidence for a distributary style, and were interpreted by the original authors as the deposits of through-going rivers, in some cases with inferred anastomosing planforms. They also belong to the sand-dominated high-sinuosity river group of Miall (1996). Where information is limited, the distinction between distributary and non-distributary fixed-channel systems may be difficult to draw.

Two other types are less well represented in the dataset. The deposits of *floodplain channels* are generally small-scale (less than a few meters in width and thickness) and are interpreted based on their intimate association with floodplain deposits; most were probably not part of basinal drainage networks. Channel deposits in *eolian settings* are a distinctive group for which interaction of channel flow with noncohesive sand imparts some unusual properties.

The dataset was examined closely to see whether poorly channelized systems could be distinguished as a separate group. However, numerous studies of megafan and distal alluvial-fan deposits noted that upflow regions had fixed channels whereas downflow regions had more poorly channelized systems, associated with a high proportion of sandy sheetflood deposits. These observations suggest that the depositional systems experienced transmission losses downstream, and preclude an easy separation of fixed and poorly channelized bodies.

Friend (1983) characterized fixed channels as laterally stable between episodes of abrupt switching. However, many suites of "fixed" channel bodies in the dataset include some bodies with lateral-accretion sets, although the sets typically can be traced laterally for only a few meters to a few tens of meters (Fig. 12A). The term "fixed" is used here to imply that the development of the channel body mainly took place within a non-mobile perimeter of floodplain deposits, with only modest bank erosion. Although these systems were also avulsive, there is little indication that avulsion resulted in frequent juxtaposition of channel deposits. Channel-body W/T is mostly in the range of ribbons to narrow sheets. The deposits of the two groups (mobile channel belts; fixed channels and poorly channelized systems) overlap in W–T space (Fig. 10) and do not correspond precisely with a division into ribbons and sheets.

An example of this approach to separating fixed and mobile channel bodies comes from the Joggins Formation of Nova Scotia (Rygel 2005). This formation was deposited in a rapidly subsiding extensional basin where much of the original geomorphic diversity of the drainage network has been preserved. The majority of 82 channel bodies (mostly single story) were classified as fixed channels with W/T less than 20 and vertical

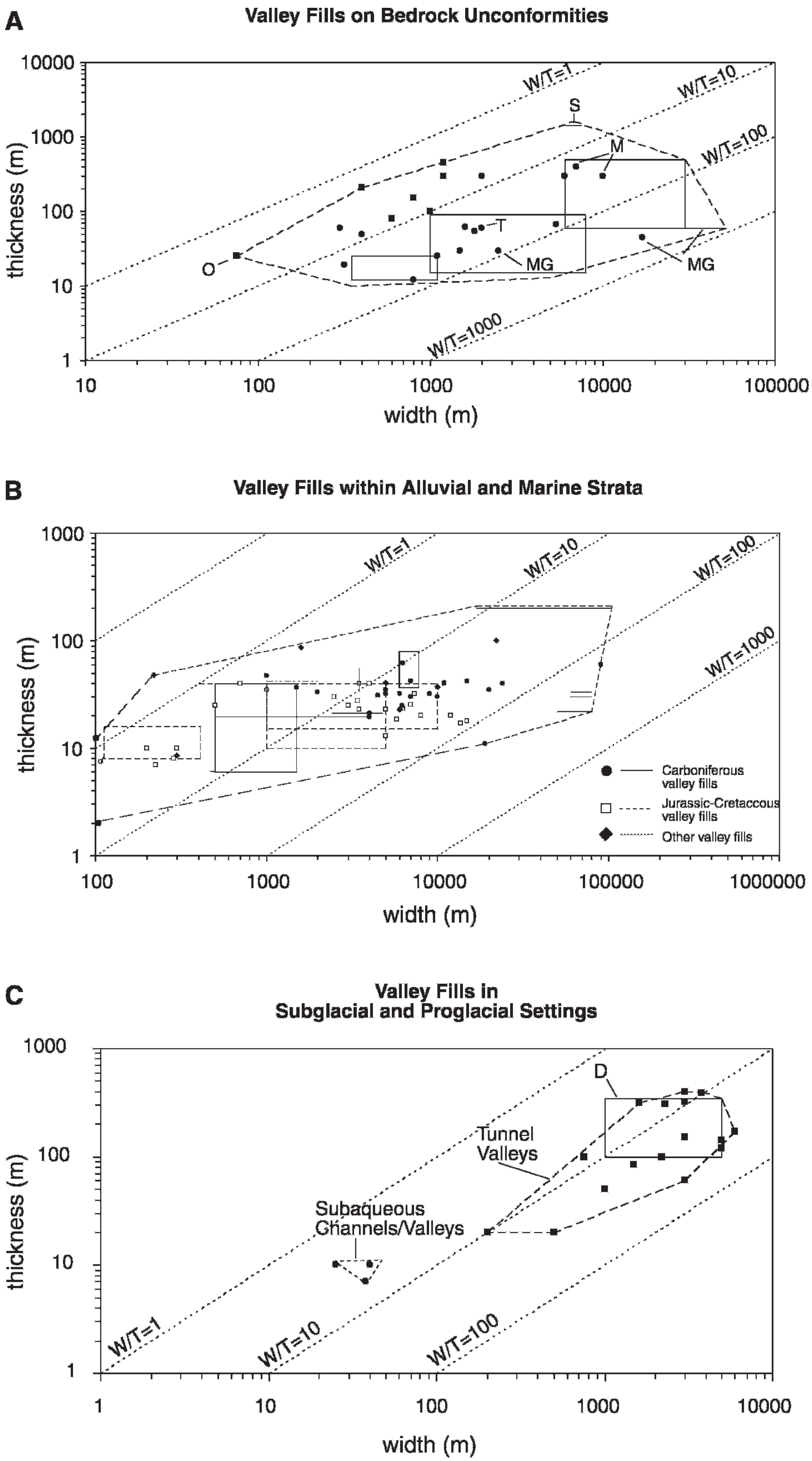

FIG. 9.—Width : thickness plots for valley fills. Studies used for the plots are listed in Appendix 1. Diagram format is explained in Figure 5. **A)** Valley fills on bedrock unconformities; O = Ocejo Formation (solid squares); M = Miocene–Pliocene of Italy and France; MG = Mannville Group; S = Sis Conglomerate; T = Miocene of Tuscany. **B)** Valley fills associated with alluvial and marine strata. **C)** Valley fills in subglacial and proglacial settings; D = tunnel valleys offshore Denmark.

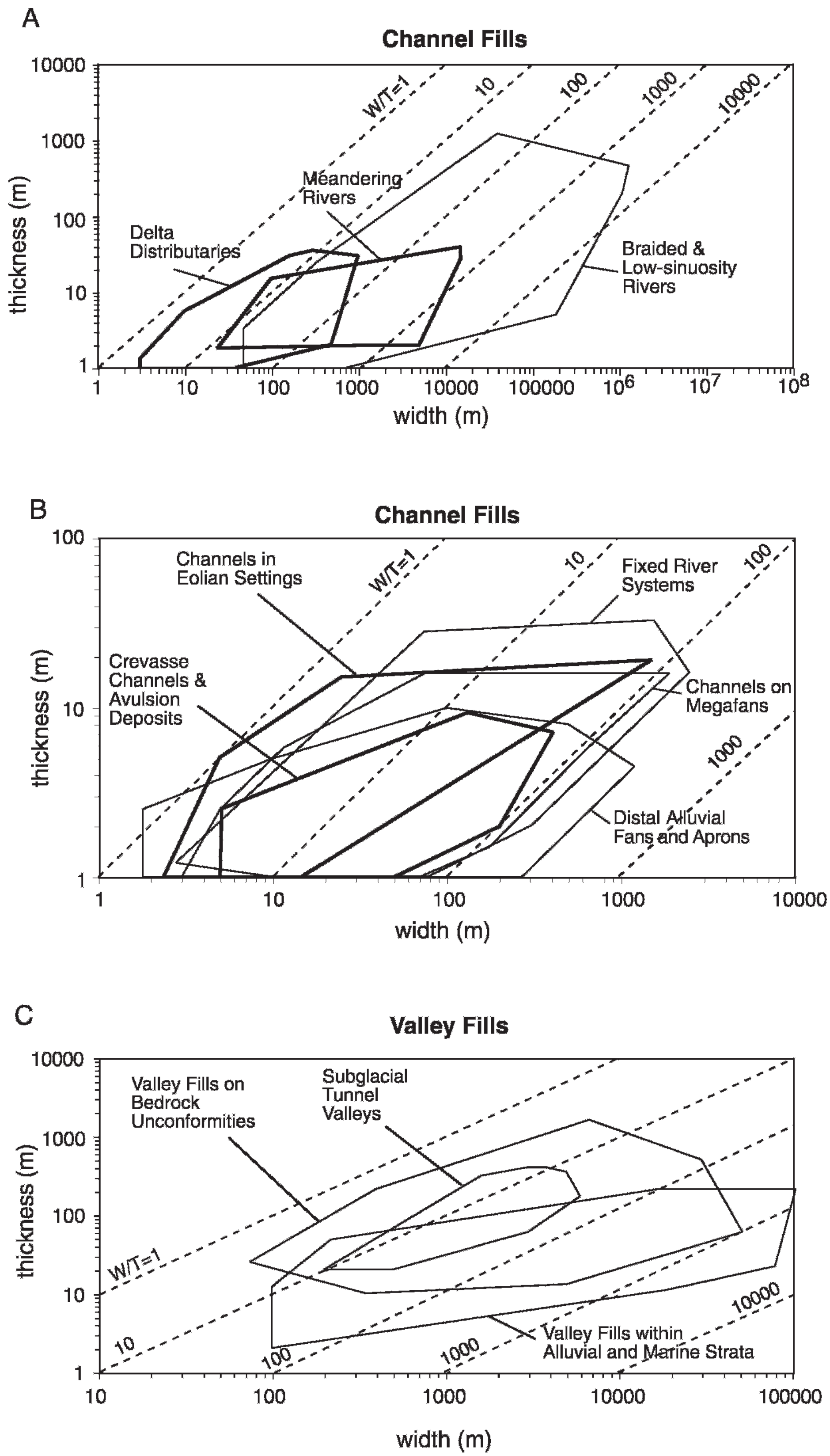

FIG. 10.— Width : thickness envelopes for channel-body groups from Figures 6–9.

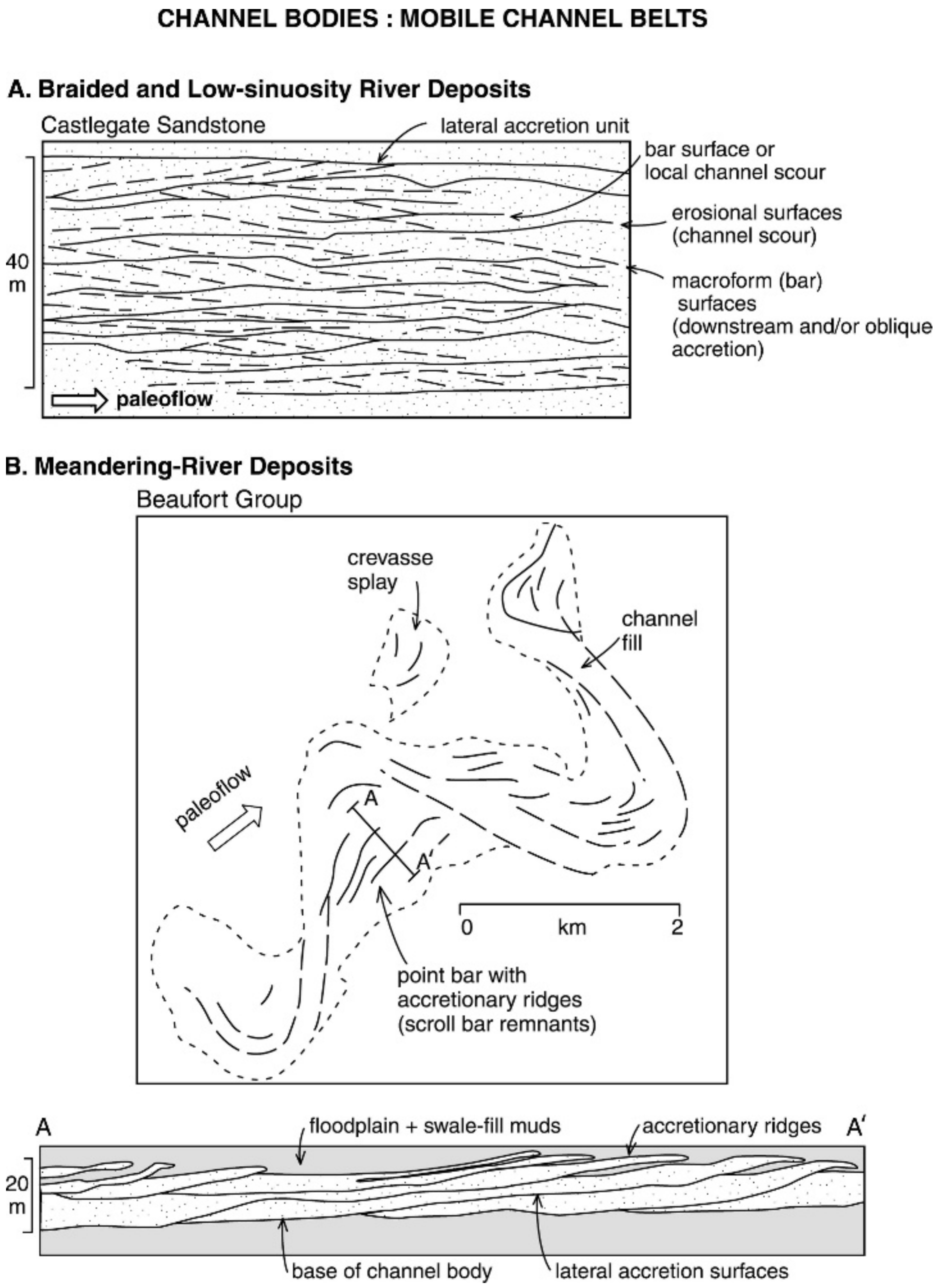

FIG. 11.—Examples of mobile channel belts. **A)** Castlegate Sandstone, Cretaceous, Utah (Miall 1993), to illustrate composite braided-fluvial channel body with stacked erosionally based stories. **B)** Beaufort Group, Permian, South Africa (R. Smith 1987). Diagrams show plan view of exhumed meander belt and cross-belt profile A–A′ from a nearby scarp, the latter shown in representative position on the plan view.

accretion predominant. Although a small proportion contain lateral accretion sets, these onlap concave-up channel margins, indicating a high aggradation index (Table 1) and a relatively stable channel perimeter. Numerous ribbon tiers (Table 1) indicate the presence of multiple coexisting channels. Bodies in redbed, dryland parts of the Joggins Formation were attributed to throughgoing fixed rivers (probably with anastomosing planforms), whereas those in greybed, wetland parts of the formation with standing trees and marine incursions were attributed to delta distributaries (Fig. 12B). A few sand-filled bodies within crevasse-splay deposits were attributed to crevasse channels. In contrast, meandering rivers (mobile channel belts) are represented by a small number of channel bodies with lateral accretion sets that onlap flat-lying channel bases over distances of tens to hundreds of meters, yielding a generally much greater W/T (up to 70) and indicating sustained lateral migration of bank-attached bars. The similar thickness of most meandering and fixed channel bodies suggests that the meandering bodies represent more mobile reaches within anastomosing networks. A few much larger channel bodies with lateral accretion sets that extend laterally for > 400 m represent large meandering rivers in coastal wetlands—probably the main drainage systems of the basin.

Comments on the Classification System

Several points about the classification system should be emphasized:

1. The classification sets out groups and types that *can be recognized within the preserved record of fluvial deposits*. Because all examples in the dataset have precise dimensional information, dimensions and W/T values could be used as supporting criteria for classification. In particular, the general distinction between mobile channel bodies with W/T commonly > 50 and fixed-channel bodies

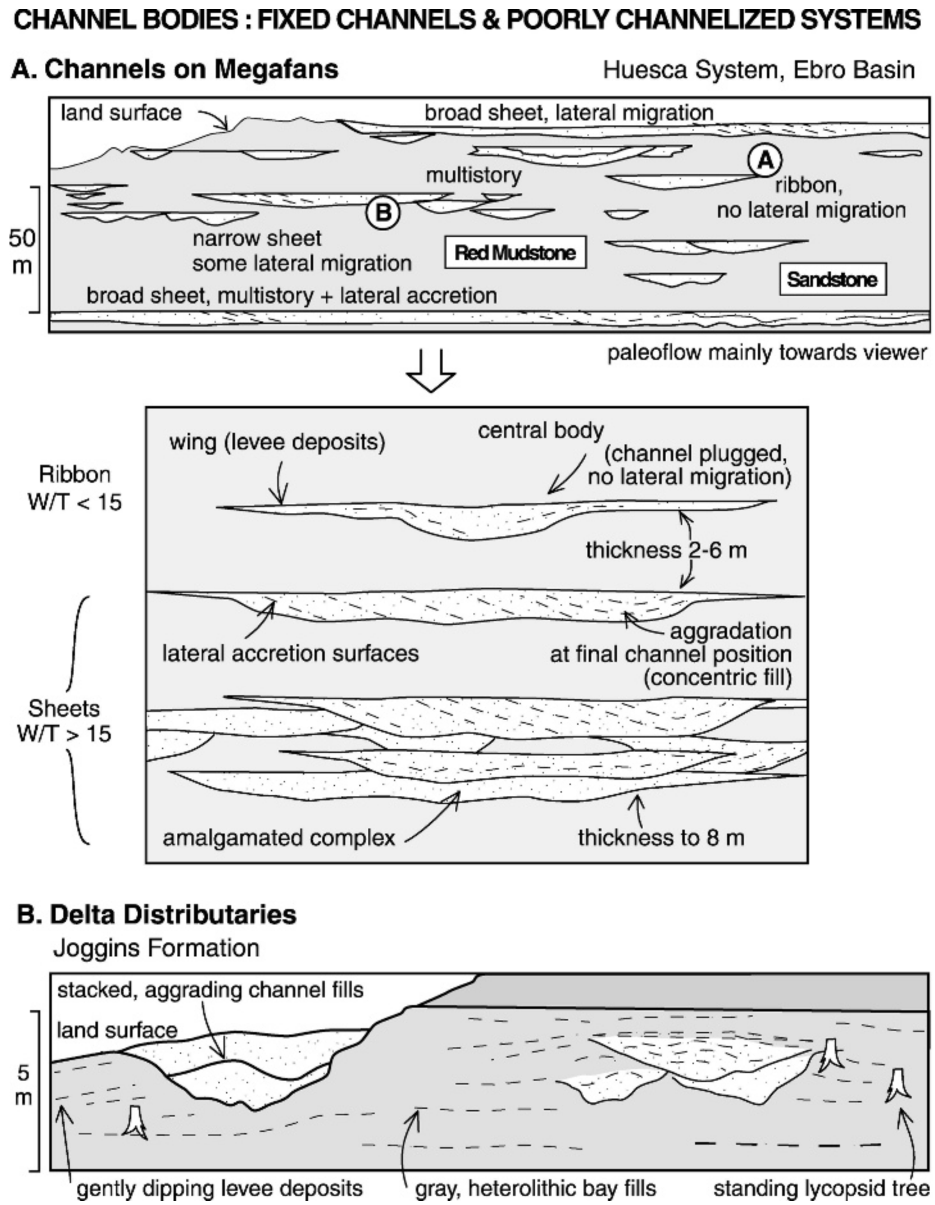

FIG. 12.—Examples of fixed channels and poorly channelized systems. **A)** Oligocene–Miocene Huesca megafan system, Ebro Basin, Spain (Hirst 1991). Upper panel shows field example with about 15% of channel bodies by area, and lower panel shows characteristic types of body in the megafan. Amalgamated complexes (lower panel) are present locally in other parts of the outcrop belt. **B)** Joggins Formation, Pennsylvanian, Nova Scotia (Rygel 2005). **C)** Waddens Cove Formation, Pennsylvanian, Nova Scotia (Gibling and Rust 1990). **D)** Quaternary of the Ganga Plains, India (Gibling et al. 2005). The right-hand body is 5 m thick with W/T of 6. **E)** Page Sandstone, Jurassic, Utah (Jones and Blakey 1997).

with W/T commonly < 50 is apparent, as is the great range in W/T for valley fills, with many high values. The classification makes it clear that certain types of channel deposits and valley fills recur repeatedly in the geological record. Thus, although every case study is different and is to some degree its own model, a useful level of generalization is possible.

2. The classification is *genetic* rather than descriptive, although the types have distinctive features (Table 4). This approach is in accord with the comments of Potter (1967), who noted that most terminology applied to sand bodies includes a mixture of descriptive and genetic terms, and noted that genetic terms are commonly landform names, reflecting the close connection between sand-body origin and geomorphology.
3. Some aspects of channel planform (for example, meandering systems) are included in the classification. However, the original channel planform can only rarely be observed (see Fig. 11B for an example), and facies are seldom diagnostic of planform type (Brierley 1989; Brierley and Hickin 1991). Thus, inferred planform was not a primary criterion.
4. Although the great majority of examples were categorized without difficulty, a small number of channel bodies were problematic. For example, a few channel bodies attributed to the fixed-river type have prominent lateral accretion sets, steep margins, and fills that contain slump blocks of cemented paleosol material (Gibling and Rust 1990); they were attributed to fixed channels because resistant banks precluded a freely meandering condition, as indicated by a high aggradation index (Fig. 2). Megafans and fixed river systems commonly include low W/T deposits of shallow sand-bed and gravel-bed streams (e.g., North and Taylor 1996).
5. Classification drew heavily upon the most extensive and completely preserved examples in the literature. Channel bodies within a poorly known subsurface setting or incomplete outcrop exposure may be difficult to classify; this is especially likely for some fixed-channel bodies, for which information about the geographic setting is

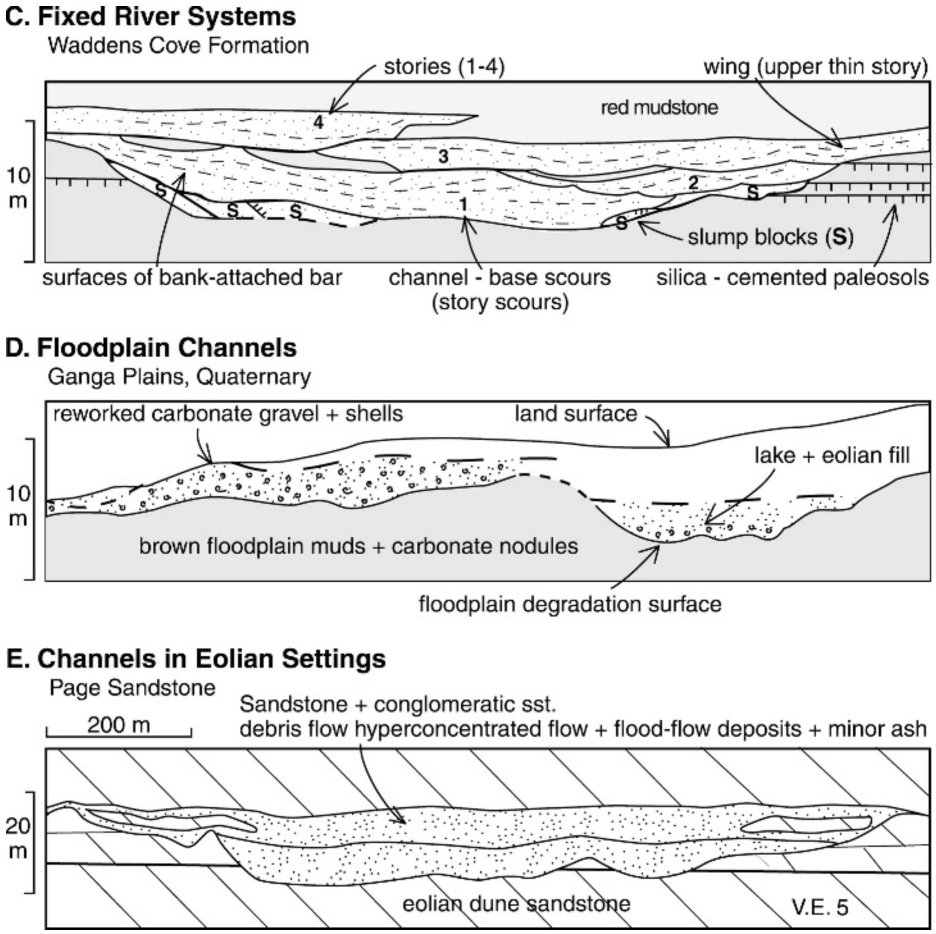

FIG. 12.—Continued.

important in distinguishing megafan deposits from through-going rivers. In such cases, it may nevertheless be productive to consider possible geomorphic settings.

6. Most examples represent outcrop-based studies or studies that combined outcrop and core because detailed facies information was available. Some especially comprehensive subsurface examples were used, including high-resolution seismic studies.
7. Most geomorphic settings contain representatives of more than one channel-body type. For example, the Neogene Siwalik Group of southern Asia was deposited on megafans traversed by large braided rivers, with abundant small channels and crevasse channels (Willis 1993a, 1993b). Deltas commonly include associations of meandering-river, distributary, and crevasse channels; Fielding et al. (1993) included wide bodies with prominent lateral accretion—indicative of large meandering channels—within the general group of "distributaries" in coastal wetland settings. The use of geomorphic terms in the classification is not intended to imply that the types are mutually exclusive.
8. Quaternary studies for which three-dimensional, subsurface data are available are included where possible. However, they represent a minor component because few studies have established the subsurface dimensions of Quaternary channel bodies, and many bodies are still in the process of formation.
9. Church (1992) noted the problem of including modern rivers from mountains to basins within one classification scheme. He divided channels into small, intermediate, and large categories based not on channel dimensions but on the relationship between grain diameter (D) and depth (d). In *small channels* (D/d > 1.0), individual boulders are significant form elements, leading to irregular steps and pools. In *intermediate channels* (D/d 0.1–1.0), flows are often wake-dominated, with a variety of pools, riffles, rapids, and bars, as well as steps and jams caused by logs and branches. *Large channels* (D/d < 0.1) are dominated by the water-flow regime, and exhibit deep shear flow and a well-defined velocity profile. The channel bodies described here were formed primarily in Church's large channels.

MOBILE CHANNEL BELTS

1. Braided and Low-Sinuosity River Deposits

These channel bodies include the deposits of a diverse suite of sand-bed and gravel-bed rivers with braided, single-thread low-sinuosity, and wandering channel planforms, and they include many of the gravel-dominated and sand-dominated low-sinuosity fluvial styles recognized by Miall (1996). The rivers traversed basin plains or large alluvial megafans at mountain fronts, and some may occupy paleovalleys.

A group of very large channel bodies is prominent in Figure 6A, with widths greater than 40 km, thicknesses up to 1200 m, and areas of tens of thousands of square kilometers. These composite bodies are composed of many smaller, erosionally based bodies that are laterally and vertically stacked and comprise barform deposits and bedload sheets, as in the Castlegate Sandstone of Utah (Fig. 11A). Channel sedimentation is dominated by vertical accretion, and evidence for systematic lateral accretion and channel migration—although present locally—is uncommon. Fine-grained lenses within the bodies represent abandoned channel fills and floodplain remnants. Examples include the Siwalik Group, the

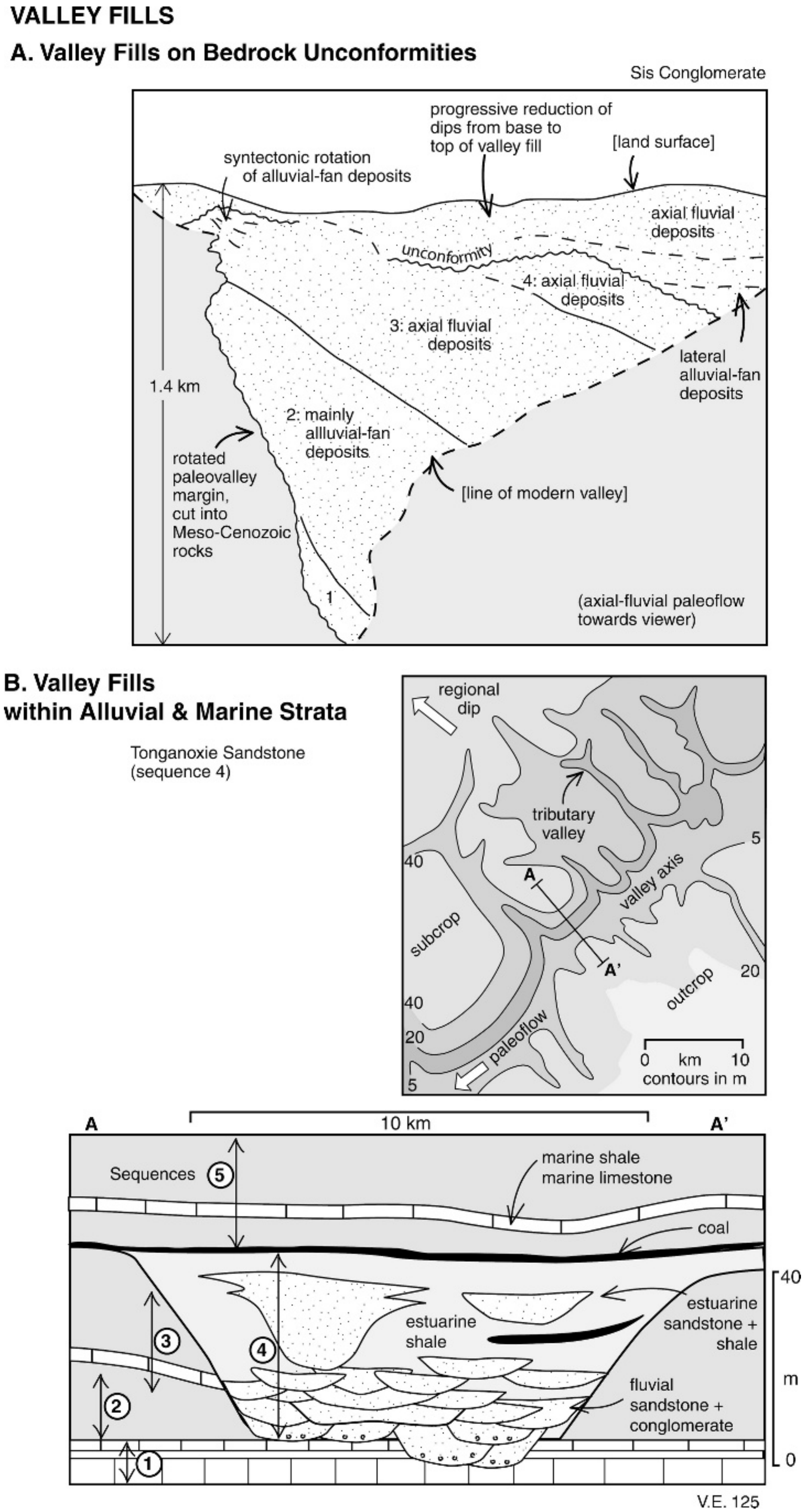

FIG. 13.—Examples of valley fills. **A)** Sis Conglomerate, Cenozoic, Spain (Vincent 2001). Diagram is a tracing of a field photo, and illustrates rotation of the valley during filling, with progressive upward reduction of dips. **B)** Tonganoxie Sandstone, Pennsylvanian, Kansas (Feldman et al. 1995). Plan view represents contoured height of paleovalley base above a lower marker horizon, and is based on a large number of intersections seen in water wells, on wireline well logs, and in outcrops and core. Gentle regional dip to the northwest has tilted the paleovalley fill. Cross-section is a schematic representation, with vertical exaggeration (V.E.) of 125, and sequences are from Feldman et al. (2005). **C)** Quaternary, North Sea, offshore Denmark (Huuse and Lykke-Andersen 2000). Plan view shows buried tunnel valleys mapped from seismic profiles, cut into older Cenozoic strata. Cross-section shows interpreted seismic profile with acoustic facies in the fill; depth is inferred from two-way travel time.

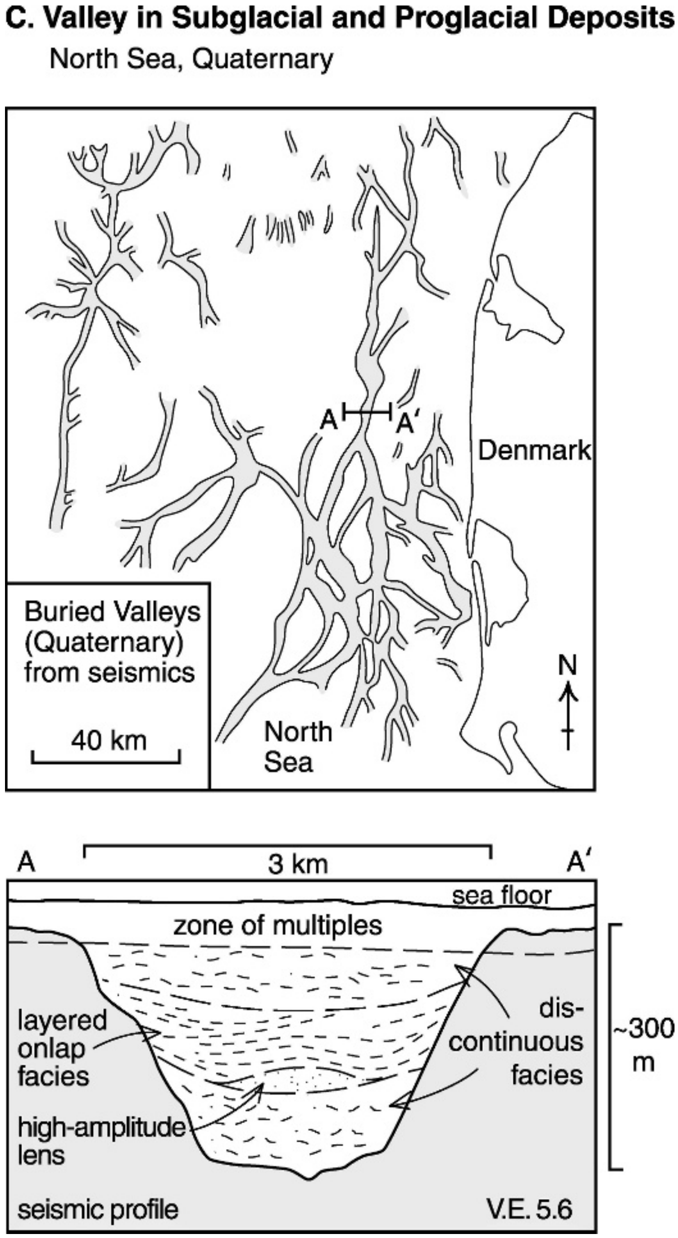

FIG. 13.—Continued.

Hawkesbury Sandstone, the Castlegate Sandstone, the Molteno Formation, the Tuscarora Formation, and the Ivishak Sandstone (Table 7). In the case of the Hawkesbury Sandstone, the scale of the fluvial system was probably somewhat less than that of the Brahmaputra River in Bangladesh, which has a main channel belt up to 20 km wide, second-order channels up to 2 km wide and 10–12 m deep, and local scours up to 50 m deep (Bristow 1987; Best and Ashworth 1997; Miall and Jones 2003).

W/T of the bodies commonly exceeds 100 and may exceed 1000 (broad to very broad sheets) although, with bodies of this scale, accurate width measurement is problematic because paleoflow may vary spatially or between superimposed stories (Rust and Jones 1987; Miall and Arush 2001). For such bodies, the *persistence factor* (area divided by average thickness: McGugan 1965; Table 2) may be a useful descriptive measure. Using units of square kilometers and meters, respectively, many of the most extensive braided sheets in the dataset have persistence factors greater than 50 and in some cases greater than 500.

How do braided and low-sinuosity rivers accumulate composite deposits more than 1 km thick? Based on the dataset examples, many of the thickest deposits represent periods of active tectonism, rapid subsidence, and enhanced coarse sediment flux, commonly within foreland basins and sometimes in response to a specific tectonic event (Table 7). For example, the Ivishak Sandstone is punctuated by numerous tectonically induced unconformities (Tye et al. 1999). Additionally, most examples include evidence that coarse-grained sediment was concentrated in certain parts of the basin. Many orogenic belts have regularly spaced river exits, the positions of which may be tectonically controlled (Hovius 1996; Gupta 1997), and these restricted points of access to basins result in superimposed deposits, as well as coalescence of channel deposits from adjacent exits, as in the Canterbury Plains of New Zealand (Leckie 2003). Rivers that deposited the Siwalik Group of India probably entered the Himalayan Foreland Basin through persistent mountain exits (Kumar 1993). In contrast, the Boss Point Formation of Canada was deposited in a narrow and rapidly subsiding extensional basin (Browne and Plint 1994). In such a setting, rivers may be drawn into more rapidly subsiding parts of the basin (Mike 1975; Alexander and Leeder 1987; Leeder et al. 1996) or drainage may persistently follow transverse faults and other tectonic lineaments (Gawthorpe et al. 1994).

Not all thick fluvial successions imply tectonic activity in the immediate area. Rivers that laid down the Pennsylvanian South Bar Formation of Canada occupied a series of valleys (Rust and Gibling 1990) that allowed the accumulation of a thick, coarse-grained succession. Although the fills were part of a thermally subsiding basin with little evidence for tectonic activity, the high sediment flux probably represents drainage from the orogenically active Appalachian Mountain Chain to the southwest (Gibling et al. 1992).

The Newcastle Coal Measures of Australia (Little 1998) comprises an unusual suite of predominantly braided-fluvial bodies, mainly gravel-dominated, that are thick but relatively narrow. The bodies are up to 109 m thick and 16 km wide, with W/T of 40–500 (Fig. 6A). Some are enclosed entirely in coal, which accumulated continuously during cycles of relative sea-level change and may have assisted in confining the channels on account of the fibrous, resistant nature of the peat. The bodies do not mark sequence boundaries formed at lowstands but rather formed in a high-accommodation Permian foreland basin where the subsidence rate continually exceeded the rate of base-level fall under conditions of high sediment supply.

More generally, thick and extensive channel deposits reflect repeated avulsion and lateral amalgamation of channel segments. In the Hawkesbury Sandstone, Rust and Jones (1987) documented up to 135° of paleoflow divergence in superimposed channel successions, which they attributed to switching of channel complexes through avulsion. Paleoflow divergence across some major erosional surfaces in the Castlegate Sandstone was accompanied by change in provenance, and the surfaces can be described as sequence boundaries that probably reflect tectonic activity (Miall and Arush 2001). Some ancient sandbed channel deposits have been inferred to represent systematic "combing" of rivers across the plain, in conjunction with avulsion (Todd and Went 1991; Cadle and Cairncross 1993). These authors envisaged that low-sinuosity channel belts migrated steadily due to preferential erosion on one side of the river, probably in response to differential subsidence. Although preferential channel migration has been observed for meandering rivers in areas of differential subsidence (Mike 1975; Alexander and Leeder 1987), it is not certain that braided and low-sinuosity rivers respond in the same manner.

Several braided-fluvial sheets of exceptional extent and W/T (Fig. 6A; Table 7) rest on truncated bedrock. The Cadomin and Cypress Hills formations of western Canada are only a few meters to tens of meters thick but may have extended for hundreds of kilometers along strike, and W/T of the Cadomin Formation may exceed 14,000 based on palinspastic reconstructions. Age dates suggest that the Cadomin spans about

TABLE 7.—*Examples of major braided and low-sinuosity fluvial deposits in the rock record.*

Rock Unit	Dimensions	Features	Authors
Siwalik Group, Miocene, Pakistan	T 1 to 1200 m W 40 km+ for thickest composite bodies, 50 m to 2 km for thinner bodies W/T ~ 15—400+	Braided and low-sinuosity channel belts on an alluvial cone in foreland basin. Linked to rise of Himalayan orogen.	Kumar 1993; Willis 1993a, 1993b; Friend et al. 2001
Hawkesbury Sandstone, Triassic, Australia	T 290 m W ~ 100 km, present area ~ 20,000 km^2 W/T 350+	Amalgamated braided-channel deposits in foreland basin. Channels to 18 m deep and 3 km wide, towards Brahmaputra scale.	Miall and Jones 2003
Castlegate Sandstone, Cretaceous, Utah	T 17–155 m W est. 140 km, extends ~ 140 km downslope; area > 20,000 km^2 W/T > 1000	Braided-fluvial deposit on coastal and marine strata in a foreland basin, with cryptic sequence boundaries. Changes in thickness, paleoflow and petrography suggest tectonic effects.	Miall 1993, 1994; Van Wagoner 1995; Miall and Arush 2001
Ivishak Sst, Triassic, Alaska	T 200 m W > 200 km, area > 20,000 km^2 W/T > 1000	Braided-river deposits in foreland basin, bordering active thrust area, with intrastratal unconformities induced by tectonism.	Atkinson et al. 1990; Tye et al. 1999
Molteno Fm. (Indwe Sandstone Mbr.), Triassic, S.Africa	T 40 m W tens to hundreds of km; area 25,000 km^2	Braided and low-sinuosity systems, unit base a single, high-energy event. Linked to South Atlantic rifting and sediment supply.	Turner 1983, 1986, personal communication, 2002
Rough Rock, Carboniferous, U.K.	T 15–60 m W 80 km+; area > 1000 km^2 W/T > 1000	Braided-fluvial unit, probably a valley fill on a sequence boundary.	Bristow 1988, 1993; Hampson et al. 1999b
Mesa Rica Sandstone, Cretaceous, SW USA	T 28 m W 87 km+, extends 100 km downdip where it splits into discrete distributary bodies W/T > 3000	Amalgamated non-braided straight to low sinuosity stream bodies. Horizontal shoreline progradation over low-gradient plain leads to cycles of overextension, aggradation, and avulsion.	Holbrook 1996, 2001
Cadomin Fm., Cretaceous, W. Canada	T 5–13 m W > 180 km (palinspastic reconstruction) W/T > 14,000?	Braided gravel-bed system in foreland basin, with original channel depth 1–2 m. Rests on truncated Mesozoic strata, gravel supply possibly from orogen rebound. Formed during tectonic lull with little accommodation creation: 9 million year timespan suggests that fluvial belt was not active simultaneously all along strike, but grew laterally by amalgamation of individual bodies.	Leckie and Cheel 1997; White and Leckie 1999
Chinle Fm. (Shinarump Mbr.), Trias, SW USA	T to 25 m W > 150 km W/T > 7500	Braided sandbed system on truncated Mesozoic strata. Thickens locally into discrete paleovalley fills. High sediment influx and low subsidence rate promoted shifting of channel belts.	Blakey and Gubitosa 1984
Ogallala Gp., Paleogene, SW USA.	T to 457 m W > 1300 km, traceable > 500 km downdip, area > 70,000 km^2 W/T > 3000	Braided rivers in coalesced valleys and plains. Rests on Paleozoic and Mesozoic strata, where coarse sediments fill preexisting drainage systems. Erosion due to exhumation rather than active tectonism.	Goodwin and Diffendal 1987; Reeves and Reeves 1996
Cypress Hills Fm., Cenozoic, W. Canada	T to76 m W > 90 km W/T > 1100	Braided rivers where confined valleys open onto "braidplain." Polycyclic origin: relaxation of Laramide thrust sheets caused reworking and extension of fluvial sheet, later exhumed and redistributed by magmatic doming.	Leckie and Cheel 1989
Tuscarora Fm., Silurian, NE USA	T generally to 200 m W > 1100 km W/T > 5500	Braided rivers on coalesced alluvial plains and fans. Origin reflects renewed tectonism.	Yeakel 1962; Cotter 1982

9 million years, implying that the fluvial belt was not active simultaneously over a strike distance of 180 km but rather reflects the lateral amalgamation of narrower, discrete channel bodies under conditions of minimal accommodation (White and Leckie 1999). The Ogallala Group of the SW USA is more than 450 m thick locally and extends along strike for more than 1300 km, with W/T of at least 3000. These formations may occupy very broad, shallow valleys or may represent braided-river plains basinward of mountain fronts. In all three cases, widespread sediment transport probably reflects exhumation due to rebound of upland source areas (Heller et al. 1988) rather than active tectonism (Table 7).

Some relatively thin braided-fluvial bodies such as the Rough Rock of UK (Bristow 1993; Table 7) advanced basinward across a marine shelf, and rest upon prominent sequence boundaries. The Mesa Rica Sandstone of SW USA is only 28 m thick but extends at least 90 km along strike (Holbrook 2001). Remarkably, it has only 15 m of basal relief over this large area, and represents the horizontal progradation of a shoreline and associated coastal-plain rivers on a low-gradient plain, resulting in periods of overextension, aggradation, and avulsion. This minimal degree of incision has parallels in the East China Sea, where the Yellow River advanced with minimal incision across a shelf with a deep shelf–slope break (Wellner and Bartek 2003).

Within the Escanilla Formation of Spain, small conglomerate and sandstone bodies encased in floodplain fines were considered by Bentham et al. (1993) to constitute a special type of braided deposit, representing small sand-bed and gravel-bed rivers, common in modern settings. The available data do not support recognition of such smaller bodies as a separate group because a continuous width and thickness spectrum exists within formations such as the Siwalik Group (Friend et al. 2001) and in the dataset as a whole (Fig. 6A).

True braidplain deposits are best known from Icelandic sandurs, where subglacial eruptions generate high-volume outbursts (jökulhlaups) that inundate a broad alluvial plain (Maizels 1993; Russell and Knudsen 1999). Such deposits are seemingly rare in pre-Quaternary strata and are not represented in the dataset.

A subsurface Quaternary analogue for extensive channel bodies is provided by the Kosi Fan of northern India which has 16,000 km^2 area and has migrated in a 280 km lateral sweep over a period of centuries (Wells and Dorr 1987; Friend et al. 2001). Singh et al. (1993) correlated a subsurface sand and gravel sheet > 60 m thick over the proximal fan area, and used the modern fan as an analogue for the Siwalik Group. On the Canterbury Plains of New Zealand, thick and extensive gravels represent amalgamation of braided-river deposits sourced in the tectonically active Southern Alps (Leckie 2003). On a smaller scale, Page and Nanson (1996) and Pucillo (2005) documented sand-bed and gravel-bed systems below the Australian Riverine plain. These shallow and avulsive bedload channels traversed a broad, low-gradient plain where they generated interconnected fills through lateral migration and vertical accretion, to generate W/T ratios of about 70–300 (Fig. 6A). Braided rivers feed numerous modern deltas, for example the Ganga–Brahmaputra Delta, and numerous examples from the dataset probably fed directly into the ocean (e.g., Rust and Gibling 1990).

Although the dataset does not provide quantitative information about the relative abundance of channel-body types in the rock record, the available information suggests that braided and low-sinuosity systems have been the dominant fluvial style throughout geological time. The development of vascular plants in the early Paleozoic resulted in stabilized land surfaces by the mid-Paleozoic, and allowed a wider range of fluvial styles and geometries (Schumm 1968; Cotter 1978; Long 1978, 2002). Nevertheless, the prominence of preserved coarse bedload deposits (mainly Phanerozoic) in the dataset suggests that such systems persisted strongly after the Devonian, reflecting the importance of orogenic systems with high sediment supply.

2. Meandering-River Deposits

A distinctive type of channel body with a sandy or heterolithic nature is characterized by extensive lateral accretion sets and scroll-bar topography, indicating the presence of point-bar deposits and rivers with meandering planform. The juxtaposition within such bodies of multiple channel-bar segments with divergent accretion dips (Gibling and Rust 1993) indicates that both systematic channel migration and avulsion characterized these meander belts. This type includes many of the sand-dominated high-sinuosity fluvial styles of Miall (1996).

Deposits with these characteristics form a coherent group with modest thickness and width (Fig. 6B). R. Smith (1987) documented an excellent exhumed example from the Beaufort Group of South Africa (Fig. 11B), where curved accretionary ridges represent the remnants of scroll-bar forms. Other good examples include the Rangal Group and German Creek Formation of Australia (Falkner and Fielding 1993; Fielding et al. 1993) and the Scalby Formation of UK (Alexander 1992a, 1992b; Eschard et al. 1991). A relatively narrow set of bodies with lateral-accretion deposits is present in the Joggins Formation (Rygel 2005), and Puigdefábregas (1973) documented a very small body 1 m thick and more than 430 m wide from the Miocene of Spain that forms an outlier in Figure 6B. The meander belts were deposited on relatively unconfined plains or within shallow valleys, and Mississippi Valley meander-belt deposits are a good Quaternary example (Fisk 1944; Potter et al. 1988; Aslan and Autin 1999).

Controls on channel-body aspect ratios are well illustrated from offshore Indonesia, where fluvial bodies with meander loops and scroll bars are superbly imaged from 3D seismic cubes (Posamentier 2001; Carter 2003). Many of these bodies represent unincised meandering systems, interpreted as lowstand bypass channels in a shelf setting. These examples lie at the W/T extremes of Figure 6B. Low-W/T bodies retain a sinuous form and failed to increase their meander-belt width through lateral erosion and accretion prior to abandonment, whereas high-W/T bodies comprise laterally amalgamated meander loops. Collinson (1978) and Lorenz et al. (1985) noted that the width of some meander-belt deposits accords with predicted relationships from instantaneous channel depth and width. This suggests that many deposits comprise a single channel belt, without lateral amalgamation. This may imply a relatively limited "residence time" for channel systems, related to avulsion periodicity (Lorenz et al. 1985; see also Carter 2003), but the limited expansion of some meander belts may also reflect in part the effect of bank vegetation, resistant floodplain muds, and tough mud plugs in oxbow cutoffs (Fisk 1944; Turnbull et al. 1966).

Braided and meandering planforms are part of a continuum of style and process (Schumm 1981), and the deposits of the two planform styles may be juxtaposed. This may happen, for example, where a single drainage system contains reaches with varied planform. Additionally, Bristow (1999) documented an instance where the topmost, fine-grained story of a coarse-grained, multistory body comprises lateral accretion sets deposited in underfit streams after avulsion of the main channel.

Meandering-river deposits occupy a discrete space in W/T plots (Figs. 6B, 10) that overlaps with braided river deposits but is much more restricted. The maximum thickness of the studied examples of meandering-river deposits is 38 m, and widths are less than 15 km and typically less than 3 km. Thus, meandering rivers do not appear to create thick or extensive deposits and, despite their familiarity in modern landscapes, their deposits probably constitute a relatively minor proportion of the fluvial-channel record. This may in part reflect the difficulty of distinguishing coarse-grained meanderbelts with cryptic lateral accretion sets from braided-river deposits (Jackson 1978), as well as difficulties in recognizing lateral-accretion deposits in varied outcrop orientations (Willis 1989). However, it more probably implies that the organized flow patterns associated with point bars rarely persisted for prolonged periods. From a broader viewpoint, many fluvial accumulations reflect the dynamics of active orogens and basins, where high gradients, abundant coarse detritus, and drainage concentration tend to promote the accumulation of thick, areally extensive channel bodies associated with braided, rather than meandering, systems. In most dataset examples, meandering-fluvial bodies appear intimately related to the associated floodplain deposits, and are not evidently related to particular tectonic or glacioeustatic events.

FIXED CHANNELS AND POORLY CHANNELIZED SYSTEMS

1. Distributary Systems

1A. Channels on Megafans.—Numerous studies document channel bodies within large distributary systems, mainly incised into fine-grained alluvium in continental settings. These systems originated in active orogens with abundant sediment supply, and entered a fault-bounded basin with their channels oriented transverse to the basin axis. Although some deposits may be the downstream fringes of alluvial fans, they rarely contain thick gravels, and the radius of the distributary systems (up to ~ 100 km) is much larger than that of most alluvial fans. Large distributary systems in the Himalayan Foreland Basin were termed "megacones" by Geddes (1960), "megafans" by Gohain and Parkash (1990), and "braided fluvial fans" by Stanistreet and McCarthy (1993). They include the Kosi and Gandak systems, described in the surface and shallow subsurface by Mohindra et al. (1992) and Singh et al. (1993), which have large, mountain-fed braided rivers and a plethora of small, plains-fed channels. The term "megafan" is widely used to describe these landforms, which include examples fed mainly from glacially derived sediment (Goodbred 2003; Mozzi 2005).

The channel fills in the dataset consist of conglomerate and sandstone, the former mainly clast-supported and imbricated (streamflow deposits) but with some matrix-supported beds (debris-flow deposits). Fills of massive and cross-stratified sandstone are prominent, especially in distal locations. The channel bodies are strongly incised and thin (most less than 8 m thick) and relatively narrow (most less than 200 m wide) and are ribbons and narrow sheets with W/T mostly less than 30 (Fig. 7A). Lateral accretion sets are uncommon and, where present, show single sweeps and a limited distance of migration within a partially confined channel (Fig. 12A; Hirst 1991). The megafan deposits include some thicker sheets, typically of braided style. The channel bodies show an avulsive and aggradational style, and most were laid down under a semiarid climate. Active channel cutting was followed by rapid vertical accretion, with evidence of abundant sediment load (including volcaniclastic material; Groll and Steidtmann 1987) and mass-flow events. Bank materials commonly include calcrete that may have restricted channel migration (Allen et al. 1983).

The dataset includes excellent examples from the Cenozoic Sarinema and Uncastillo formations and Scala Dei Group (Fig. 7A), deposited in foreland basins in Spain (Friend et al. 1979; Allen et al. 1983; Nichols 1987; Hirst 1991). In the Huesca fan system, which has a radius of about 80 km, Hirst (1991) documented radial paleoflow patterns, and noted a downstream trend of decreasing channel-body proportions and thickness, degree of channelization, grain size (mainly sand), and bedform scale. Much of the megafan deposit comprises channel-body suites with low connectedness (Fig. 12A), and most of the bodies are ribbons and narrow sheets (A and B, respectively, in the figure) with only modest indications of lateral accretion. Thicker, amalgamated complexes of bodies are present locally (lower part of Fig. 12A) but are less common. The Scala Dei distributary system studied by Allen et al. (1983) features major feeder axes with conglomeratic sheets that pass downflow into isolated conglomerate ribbons. The dataset also includes examples of megafans from extensional basins and intracratonic basins bordered by uplands. In the sub-modern Kosi system, Singh et al. (1993) attributed a near-surface sheet of intercalated sand and mud, up to 40 m thick, to the lateral sweep of belts of small channels.

1B. Delta Distributaries.—Delta distributary channels form on the low-gradient, seaward parts of deltas, commonly through river crevasses. Although distributive in form and process, the channels can rejoin downstream, creating an anastomosing form (Makaske 1998). Examples in the dataset occupied coastal wetland settings and are mostly 3 to 20 m thick, with W/T ratios mainly less than 50, with one example 35 m thick (Fig. 7B). Channel bodies are commonly deeply incised into cohesive sediments (peat, clay, and heterolithic strata), have low sinuosity, and bifurcate. Vertical accretion predominates, with some concentric fills, soft-sediment deformation, and slumps. Accretion surfaces are attributed to side bars and point bars, implying that some channels migrated laterally to some degree. Some channel deposits in subaqueous settings contain mass-flow deposits (Soegaard 1991), implying rapid deposition. Figure 12B illustrates small distributary channel bodies from the Joggins Formation, associated with standing trees and heterolithic sheets that filled bays prior to channel progradation. The channel bodies are bordered by gently dipping levee deposits, and the host sheets and channel bodies may have aggraded together.

Olsen (1993) documented 62 distributary bodies from excellent exposures in the Atane Formation of Greenland (Fig. 7B). Bodies without lateral accretion sets (representing stationary channel positions) yielded the statistical relationship $W = 6.0T$ (14 bodies, $r = 0.94$). Many bodies, however, included some lateral accretion deposits, and the full data set yielded the relationship $W = 4.9T^{1.43}$($r = 0.90$). Channel-body W/T ranged from about 5 to 33, suggesting that many distributaries migrated to some degree during their active life. Olsen (1993) also described poorly channelized and multichannel networks associated with mouth-bar deposits at the terminations of distributary channel bodies. These sandy channel bodies are up to 8 m thick and more than 500 m wide with indistinct margins. Such composite bodies could include natural levee deposits that grew simultaneously with the filling of the channels. Mjøs and Prestholm (1993) documented 45 bodies from the Saltwick Formation of UK, with evidence of both vertical and lateral accretion. At the thick end of the spectrum, the Kootenai Formation contains single-story distributary bodies up to 35 m thick and 300 m wide (W/T 9–17), with aggradational sand and mud fills (Hopkins 1985).

Modern analogues for distributary channel bodies in the dataset are present in the Mississippi and Atchafalaya deltas of Louisiana (Fisk et al. 1954; Fisk 1955; Tye and Coleman 1989). These authors documented narrow distributary-channel bodies that are typically a few meters thick, composed of cross-stratified sand (commonly convoluted), with erosional surfaces, mud clasts, and abundant organic detritus.

Based on a survey of several modern deltas, Olariu and Bhattacharya (2006) noted that delta-front deposits are typically cut by suites of small terminal distributary channels, which they considered to be under-regarded components of delta systems in contrast with the large "trunk" channels. The channels are tens of meters to kilometers wide, commonly 100–400 m wide, with depths of 1–3 m and width/depth generally in the order of 100. The channels are intimately associated with mouth-bar sands, and they are only modestly incised. Olariu and Bhattacharya (2006) identified analogues in several ancient formations.

The majority of the delta-distributary bodies represented in the present paper have much lower W/T ratios than those of the terminal channels described by Olariu and Bhattacharya (2006), and most are strongly incised into muds. They appear to represent channels in delta-plain—rather than delta-front—settings. The relatively broad, weakly incised channel bodies described by Olsen (1993) are associated with mouth-bar deposits, and they appear to represent terminal distributary systems.

Meckel (1972) noted that some delta channels scour to depths of more than 60 m below sea level along the Gulf Coast, perhaps analogous to the large, deeply incised channel bodies of the Kootenai Formation (Hopkins 1985). The distributary-channel bodies plotted by Reynolds (1999) include examples that are wider and have higher W/T ratios (Table 6) than those of the present dataset, and Reynolds noted that they overlap with his "fluvial" group; his dataset may include more larger distributary bodies than are represented here, and may also include some larger trunk systems.

1C. Distal Alluvial Fans and Aprons.—*Alluvial fans* originate at a point source, usually where a steep montane valley enters an unconfined, low-gradient alluvial plain, whereas *alluvial aprons* originate from a line source such as a volcanic edifice (G. Smith 1987). In the distal parts of fans and aprons, sandy sheetflood deposits enclose channel bodies that may constitute less than 10% of the total stratal volume, and flow in these settings becomes increasingly poorly channelized downslope.

The deposits in these settings comprise small channel bodies, many less than 5 m thick, with variable W/T from about 1 to 250 (Fig. 7C). They include examples that are slightly wider than those of some other types (Fig. 10), probably due to poorly cohesive, sandy banks. Fills are sandstone (commonly plane laminated) with minor conglomerate and mudstone, and are mainly single-story bodies with prominent wings. The channels were mainly broad, shallow washes with episodic flow, mainly vertically accreted but with local bank-attached bars. Banks are low-angle and channel margins are not strongly erosional (Love and Williams 2000; Gierlowski-Kordesch and Gibling 2002). Strata associated with the fan deposits include eolian dunes, and most settings recorded in the dataset were semiarid.

Kelly and Olsen (1993) presented a model for terminal fans, based in part on the Markanda Fan of northern India, where drainage is inferred to have terminated completely in the alluvial plain (Parkash et al. 1983). However, few modern examples are known, and the validity of the model is unclear. The channel bodies discussed by Kelly and Olsen (1993) are included here with distal alluvial-fan deposits.

1D. Crevasse Channels and Avulsion Deposits.—These relatively small channel deposits are present in both dryland and wetland settings, where they are associated with natural-levee and crevasse-splay deposits. Most are less than 5 m thick and 50 m wide, with W/T commonly less than 10 (Fig. 7D). Fills are commonly concentric and indicate vertical accretion, although some bodies contain lateral-accretion sets. Internal scours suggest several phases of reactivation. Some bodies have convex-up tops (Ghosh 1987), suggesting overfilling and/or compactional effects. Crevasse-splay and delta-distributary channels are commonly closely interconnected. Reynolds' (1999) compilation for crevasse-channel deposits (Table 6) broadly accords with the present dataset.

Avulsion deposits have been documented from the Willwood Formation of Wyoming (Kraus 1996; Kraus and Wells 1999) through analogy with a recent avulsion in the Cumberland Marshes of Canada (Smith et al. 1989; Morozova and Smith 2000; Farrell 2001). They comprise suites of small, anastomosing channels associated with splay deposits that prograded into wetlands during the early stages of channel avulsion. Subsequently, flow consolidated into a single large channel that advanced over the splay complex. The small channels are transient, with active periods of decades to centuries. Farrell (2001) provided a good description of a crevasse channel that forms part of the Cumberland Marshes avulsion succession, although the channel is still active (thus not included in W/T plots). The channel is up to 60 m wide and 3 m deep (width/depth $\sim$ 20), and the deposits are more than 2 m thick, comprising fining-up units of planar cross-stratified sand and heterolithic facies with graded beds; the multistory nature, with numerous erosional surfaces, indicates periods of reactivation and incision. In the Willwood Formation, splay channel bodies are mostly less than 3 m thick, with W/T mostly less than 15, and their anastomosing form is indicated by the presence of ribbon tiers. The stratal sets are capped by larger meandering-channel sheets.

2. Fixed River Systems

This type of channel deposit is among the best documented in the dataset. The bodies are termed "fixed" because they show little evidence for lateral migration of channels and bars. According to the authors' descriptions, they appear to represent through-going rivers rather than the distributary systems inferred for most channels on megafans. Based on paleoflow analysis and regional geology, many descriptions identify the paleochannel belts as axial drainage systems, whereas a few are oriented transverse to the basin axis and the orientation of others is unclear. The orientation may be difficult to distinguish in ancient examples where upland and basin relationships are rendered unclear through deformation and paleoflow complexity.

Sandstones predominate in these deposits, and conglomerates are rare. Vertical accretion is characteristic, with lateral accretion sets—where present—typically restricted to the upper parts of fills. Where such sets are prominent, the channel has filled in one or two migratory sweeps, indicating partial confinement (Kraus and Middleton 1987a; Gibling and Rust 1990). The channel bodies are thin (many are 3–15 m thick) with many less than 150 m wide and W/T commonly less than 15 (Fig. 8A). A few channel bodies have tidal structures and marine fossils. Good examples include the St. Mary's River Formation of Alberta (Nadon 1993, 1994), the Cutler, Dakota, Kayenta, and Straight Cliffs formations of western USA (Eberth and Miall 1991; Kirschbaum and McCabe 1992; Shanley and McCabe 1993; North and Taylor 1996), the Beaufort Group of South Africa (Stear 1983), and the Springhill Mines, Joggins, and Waddens Cove formations of Nova Scotia (Rust et al. 1984; Gibling and Rust 1990; Rygel 2005).

In the Waddens Cove Formation, tough silica-cemented paleosols restricted channel migration and are preserved locally in the channel bodies as rigid slumpblocks (Fig. 12C). Restriction resulted in vertical stacking of stories, as in the illustrated example. In other bodies in the formation, a sinuous channel migrated within a broader, restricted course, resulting in ribbon bodies that comprise superimposed stories with lateral-accretion sets.

Many of the dataset examples were attributed by the authors to anastomosing rivers, based on observed bifurcation, ribbon tiers, and splays at similar levels that taper out in opposite directions. Because of the difficulties in establishing channel planform (especially anabranching) for ancient deposits, these bodies are better attributed to the more general fixed-channel model of Friend (1983). Ribbon bodies may dominate basinal fills hundreds of meters thick, implying that these systems were long-lived rather than transient drainage features. Their cross-sectional geometry reflects the original channeling event (Stear 1983), with only modest width increase prior to filling and avulsion. For some fixed-channel bodies in coastal areas, correlation with marine strata downdip suggests that they formed during a period of base-level rise and accommodation increase (Shanley and McCabe 1993; Olsen et al. 1995).

Quaternary anastomosing rivers are represented in Figure 8A by the Columbia and Rhine–Meuse rivers (Törnqvist 1993; Törnqvist et al. 1993; Makaske 1998, 2001; Makaske et al. 2002). In some cases, channel-belt width and W/T decrease downstream, in part due to an increased resistance of the substrate to channel migration (Gouw and Berendsen 2005). Other examples for which partial dimensional data are available (thus not plotted here) include the Magdalena River of Colombia (Smith 1986), the Channel Country of the Lake Eyre basin (Gibling et al. 1998), and the Baghmati River of the Himalayan Foreland Basin (Sinha et al. 2005). The latter is one of the few documented examples from a foreland basin, although many dataset examples are situated in foreland basins. In coastal areas, Holocene deposits of the Rhine–Meuse and Mississippi deltas include anastomosing channel bodies formed during periods of rapid sea-level rise (Törnqvist et al. 1993; Aslan and Autin 1999).

In the Castissent Formation of Spain, ribbon bodies up to 8 m thick with W/T of 20–50 lie marginal to or directly underlie large braided-fluvial sheets. Marzo et al. (1988) interpreted the bordering ribbons as channels marginal to a braided system and the underlying ribbons as initial incision events associated with emplacement of the fluvial sheet (see also Eberth and Miall 1991; Miall and Turner-Peterson 1989). Alternatively, basal, amalgamated ribbons might represent preexisting fluvial systems unrelated to the overlying sheets. The lateral sweep of the Kosi Fan (Wells and Dorr 1987) allows for such an explanation: periodic avulsion of the main channel could divert flow down smaller channels on the megafan, which would fill rapidly with unusually coarse detritus before being overlaid by the braided sheet deposit. Infills of preexisting channels characterize some mountain valleys of western Canada where braided reaches are encroaching on anastomosing reaches downstream (Smith and Smith 1980).

3. Floodplain Channels

Small channels and gullies from decimeters to a few meters deep are characteristic of many modern floodplains. They include chute channels and bar-top swales in near-channel settings (Brierley 1991), as well as reticulate channel networks on unconfined plains (Gibling et al. 1998). Analogous channel bodies, typically less than 2 m thick, have received little study. They are commonly deficient in quartzose sand, and most are mud-rich with reworked pedogenic carbonate nodules and mud aggregates (Allen and Williams 1979; Tunbridge 1981; Rust and Nanson 1989).

In Quaternary exposures along rivers of the Ganga Plains of northern India (Fig. 12D), suites of small channel bodies rest upon degradational surfaces that can be traced for several kilometers within floodplain strata (Gibling et al. 2005). The channel bodies typically consist of reworked carbonate gravel with mollusk shells, and some include eolian and lacustrine sediments (Fig. 12D). Large gullies up to 9 m thick are filled mainly with colluvial sand and fines, but they contain small channel fills of reworked carbonate gravel. These former gullied landscapes represent infilled "badland" topography similar to the extensive tracts that border the modern Yamuna and Chambal rivers of northern India (Haigh 1984), and they may be linked in part to the incision of trunk channels. Similar alluvial gully fills are present in the Chinese Loess Plateau (Porter and An 2003). These gully fills have some possible analogues in the rock record (Kraus and Middleton 1987b; Bestland et al. 1997).

4. Channels in Eolian Settings

A diverse and poorly documented type of channel body intertongues with eolian dune deposits. During flow periods, the abundance of available, unconsolidated sand results in an increase in the sediment/water ratio, leading to unusual flow dynamics and rapid deposition. The deposits are mostly sandstone but include conglomerate from upland wadis, as well as minor mudstone. They mainly represent ephemeral sandbed channels (Langford and Chan 1989) impounded by the dunes. In such settings, extreme precipitation events can generate hyperconcentrated flows within short-lived channels (Simpson et al. 2002). Channel bodies vary in aspect ratio but W/T is commonly less than 15 (Fig. 8C). Larger, more stable fluvial systems are likely to show increased W/T where they interact with dunes and sources of noncohesive sands (Smith and Smith 1984). Interaction between fluvial and eolian systems is widespread in modern desert areas, and this type of deposit deserves more attention.

In the Page Sandstone of Utah (Fig. 12E), a channel body more than 19 m thick and 1.5 km wide is cut into eolian sandstones and comprises sandy debris-flow and flood-flow deposits (Jones and Blakey 1997). The authors inferred that entrainment of loose sand during floods, combined with fluid loss through infiltration, led to an increased sediment/fluid ratio and mass-flow events. Eolian and fluvial deposition was essentially synchronous, as indicated by the absence of superbounding surfaces at the level of the channel body.

VALLEY FILLS

1. Valley Fills on Bedrock Unconformities

Valley fills on bedrock surfaces in the dataset show an enormous range of dimensions—from 12 m to 1400 m thick, and from 75 m to 52 km wide, with W/T values from 2 to 870 (Fig. 9A). Although examples cover a large W/T space, the most common range is from 2 to 100, and numerous examples have W/T less than 10, reflecting incision into bedrock that resisted lateral planation, as well as incision along structural lineaments. Extensive drainage networks have been mapped on some bedrock unconformities (Siever 1951; Sedimentation Seminar 1978).

Among the most remarkable of these valley fills is the Paleogene Sis Conglomerate of Spain (Fig. 13A), which is a remnant of a sediment-transfer system that drained the deforming Pyrenean orogen and was active for at least 38 My (Vincent 1999, 2001). This syntectonic valley fill is a complex sediment body 1400 m thick and up to 7.5 km wide (W/T 5.4), and occupies a broad syncline that formed in response to uplift on a series of flanking structures that represent lateral ramps associated with the Pyrenean fold-and-thrust belt. The predominantly fluvial fill is composed largely of conglomerate with subordinate sandstone and mudstone deposited by axial fluvial systems, with minor lacustrine limestone and coal. Erosional disconformities near the valley center pass into angular unconformities towards the margins, where small alluvial fans and olistoliths were present. The dip of the valley-fill strata decreases progressively upwards, indicating syndepositional rotation (Fig. 13A). Although basal incision is difficult to identify in this setting of syntectonically generated relief, about 120 m of onlap is documented in the southern part of the valley, and more than 120 m of incision is present within the valley fill in places (S.J. Vincent, written communication, 2005). The great thickness of the formation represents a long period of tectonic growth, and relief at any time was much less than the present thickness of the valley fill.

Spectacular examples of valley fills on bedrock surfaces are also present in the Carboniferous Ocejo Formation of Spain (Iwaniw 1984), where fluvial, mass-flow, and lacustrine deposits fill a series of valleys up to 450 m deep and 1.2 km wide (W/T 2.7). The valleys follow structural lines in deformed basement, locally modified by karst weathering prior to filling. These valley fills, as well as those of the Chinle Formation (Blakey and Gubitosa 1984) variously reflect active tectonism and passive valley filling. Big valleys—up to 400 m deep and 10 km wide—in the Mediterranean area are associated with the Messinian salinity crisis, and their fills include Gilbert-type deltas with clinoforms 250 m high (Breda et al. 2002; May et al. 2002). A valley fill 60 m thick and 2 km wide in Tuscany, described by Pascucci et al. (in press), was cut and filled as a result of magmatic doming, rapid exhumation, and abundant sediment supply.

At the high W/T end of the spectrum, excellent subsurface examples of valley fills on bedrock surfaces are found in the Mannville Group of Canada, described from dense, multi-well and -core datasets (Ardies et al. 2002; Lukie et al. 2002; Zaitlin et al. 2002). These Cretaceous valley fills are cut into Carboniferous and Jurassic bedrock and are of modest thickness (up to 60 m) and great width (up to 52 km; W/T to 870). Their dimensions reflect complex structural and accommodation controls, including a varied substrate and drainage networks that were locally fault-controlled.

2. Valley Fills within Alluvial and Marine Strata

These valley fills have received intensive study, and the dataset includes 60 data points, as well as data ranges, mainly from Carboniferous and Cretaceous strata. They range from 2 m to 210 m thick, but are mostly less than 60 m thick, with widths up to 100 km but typically less than 25 km (Fig. 9B). W/T values range from 5 to more than 3500 but are typically 100 to 1000—considerably higher on average than valley fills on bedrock surfaces, suggesting that lateral planation in a poorly consolidated substrate widened the valleys. Some of the best examples are from the Carboniferous of western Europe and North America (Wheeler et al. 1990; Greb and Chesnut 1996; Hampson et al. 1999a; Hampson et al. 1999b) and from the Cretaceous of North America (Willis 1997; Lukie et al. 2002; Plint 2002). Extensive drainage networks have been mapped (Dolson et al. 1991), and Plint (2002) mapped valley systems up to 330 km long over a delta area of 50,000 km^2. The incised-valley dataset of Reynolds (1999) probably accords with this type of valley fill, and shows a range of width, thickness, and W/T (Table 6) similar to that of the present dataset. He noted that some deep, narrow valleys appear to have been incised through the shelf–slope break.

Most of the examples in the dataset are from coastal settings, where they appear to have been cut and filled in response to relative sea-level change, although some are tectonically enhanced (Hampson et al. 1999b). The Tonganoxie Sandstone in the Pennsylvanian of Kansas (Fig. 13B) is a paleovalley fill within a set of high-frequency sequences in the U.S. mid-continent (Feldman et al. 1995; Feldman et al. 2005). The axial part of the valley fill is cut into underlying limestones, and is 41 m thick and 11 km wide. The fill passes upward from braided-fluvial sandstones and conglomerates to estuarine sandstones and shales, in common with many other valley fills in the database. A suite of tributary valleys feed into the axial area (Fig. 13B).

Glacioeustatic changes of high magnitude and frequency characterized the Carboniferous icehouse period. However, in a study of a paleovalley with a predominantly fluvial fill in the Fall River Formation of western U.S.A., Willis (1997) noted that slower rates of relative sea-level rise during the Cretaceous greenhouse period—when glacioeustatic effects were modest at best—did not greatly exceed the rate of sediment supply, perhaps accounting for the fluvial nature of the valley fill. He suggested that Cretaceous valley fills more generally might be largely fluvial, but this is difficult to confirm from the database, which contains Cretaceous examples with both fluvial and estuarine fills. Quaternary analogues from the last glacial cycle underlie the continental shelf of eastern North America (Thomas and Anderson 1994), although incision of shelf systems depends also on the relationship between fluvial gradient and shelf slope (Miall 1991; Talling 1998), as well as the depth of the shelf break (Posamentier 2001; Wellner and Bartek 2003). A good example of alluvial fills is the Jurassic Blairmore Group of Alberta, where valleys up to 100 m deep, entrenched in alluvium, were filled with gravel (including volcanic material) in response to short-lived sediment pulses (Leckie and Krystinik 1995).

The Castissent Formation of Spain comprises discrete stories with braided and meandering style that, elsewhere in the basin, form distinct channel bodies encased in fines (Marzo et al. 1988). The authors inferred that amalgamation represents the conjunction within a partially confined valley of separate drainage systems with contrasted fluvial style.

To test for possible differences between the dimensions of Carboniferous (icehouse) and Jurassic and Cretaceous (greenhouse) valley fills in coastal settings, the two groups were plotted separately in Figure 9B. The two groups show a broadly similar range of W/T values. However, some differences are apparent. The thickest and widest valley fills (200 m and 80 km, respectively) are Carboniferous, whereas the largest Mesozoic valley fills in the dataset are only 40 m thick and 15 km wide. For examples that yielded individual width and thickness, Carboniferous valley fills had a mean thickness and width of 31.0 m and 10.0 km, respectively (29 examples), whereas Mesozoic valley fills had mean thickness and width of 21.2 m and 5.6 km, respectively (22 examples). The Blairmore alluvial fills were excluded. Although large and overlapping standard deviations are associated with these estimates, the results provide some support for the hypothesis that high-magnitude Carboniferous glacioeustatic fluctuations generated exceptionally large valleys in coastal areas. Both suites of valley fills include cratonic examples, where broad, interior platforms without shelf breaks might be expected to inhibit deep incision.

Climate may exert a strong control on valley form and fill. Based on a study of valley fills and paleosols in eight successive sequences in the U.S. mid-continent, Feldman et al. (2005) noted that valley fills formed during relatively dry periods tend to be small ($<$ 11 m thick and $<$ 2 km wide) and associated with small drainage networks, with locally derived limestone clasts prominent. In contrast, valley fills formed during wetter periods are much larger ($>$ 20 m deep and $>$ 4 km wide) and dominated by sandstones transported from distant sources by large drainage networks.

3. Valley Fills in Subglacial and Proglacial Settings

A diverse suite of fills from Quaternary subglacial settings have been attributed to valleys. Tunnel valleys are linear depressions formed by subglacial water (Sjogren et al. 2002), and are widespread in recently glaciated areas of Europe and North America. Many European examples have been completely filled and are known from drilling and seismic profiles (Ehlers 1981; Huuse and Lykke-Andersen 2000). Large subglacially eroded areas in North America are only partly filled, with sediment mainly transported beyond the Laurentide ice margin (Brennand and Shaw 1994; Sjogren et al. 2002). Some were filled by later events (Boyd et al. 1988; Pugin et al. 1999; Russell et al. 2003). All examples in Figure 9C are from infilled Quaternary sites, but comparable tunnel valley fills have been described from Ordovician glacial deposits (Ghienne and Deynoux 1998).

The valleys and channels are cut into older Cenozoic sediment and bedrock, generating regional unconformities. Modern partly filled examples have anastomosing patterns, and they tend to be steep-sided (up to 35°) and locally oversteepened, with flat bottoms. They have irregular longitudinal profiles, with internal sills and hanging tributary valleys. Some can be traced for $>$ 100 km, but many begin and terminate abruptly and are not apparently part of an organized drainage network. Many have convex-up longitudinal profiles and cross present-day glacial divides, indicating upslope flow and high hydraulic head (Brennand and Shaw 1994). Where filled, the channels contain gravel, sand, and fines of fluvial, lacustrine, and marine origin, with chaotic intervals. Large slump blocks are present, and sediment piping and collapse may have assisted erosion. Good examples have been mapped offshore Denmark using seismic grids (Fig. 13C), where their fills exhibit zones with discontinuous to chaotic reflectors, as well as zones of continuous reflectors that onlap the valley walls.

Dimensions are highly variable, up to 400 m deep and 5 km or more wide. W/T is typically 5–50, with many in the 7–20 range. However, unfilled systems include many smaller channels. These dimensions do not necessarily represent flow widths, inasmuch as many channel suites were generated by regional flows more than 80 km wide that overtopped the tunnels and created extensive fluted tracts (Beaney and Shaw 2000). The morphological expression of tunnel valleys is closely related to substrate (bedrock or surficial sediment), and flow durations were insufficient for full development of the conduits (Sjogren et al. 2002).

The tunnel valleys are probably polygenetic, formed by catastrophic outbursts of meltwater, steady-state subglacial meltwater erosion, and local glacial erosion (Huuse and Lykke-Andersen 2000). North American examples formed through catastrophic floods from the Laurentide ice sheet, which generated huge instantaneous discharges—akin to the jökulhlaups generated from subglacial volcanism in Iceland (Maizels 1993; Russell and Knudsen 1999). Stages in their development included transitions from highly erosive sheet floods to periods of channel deepening during waning flow (Russell et al. 2003). Hydraulic modeling by Piotrowski (1997) suggests that conductivity of underlying sediments was only sufficient to drain a portion of basal meltwater, especially if permafrost was present, and thus much of the meltwater would have been evacuated through spontaneous outburst events. Some valleys are probably composite, modifying pre-glacial drainages and sculpted by multiple outburst events and steady-state periods, and some may have been reoccupied during several glacial episodes. Some tunnel valleys contain glaciolacustrine deposits, and may be akin to the large spillways created by the rapid drainage of glacial lakes (Kehew and Lord 1986).

Tunnel-valley dimensions overlap with those of valleys in other settings (Fig. 10). They lie within the field of bedrock valleys but overall have lower W/T values than valleys cut into alluvial and marine sediments, especially at higher thickness values. This dimensional range probably reflects a combination of cutting into older Cenozoic strata and bedrock, the intensive scour associated with catastrophic floods, and perhaps thermal erosion into permafrost.

A group of smaller bodies are associated with proglacial deposits of the late Quaternary Champlain Sea of eastern North America. They include thick (up to 10 m) and narrow (less than 75 m) sand bodies with parabolic channel forms and W/T less than 7.5 (Fig. 9C). Rust and Romanelli (1975) and Rust (1977) attributed sand ribbons within gravel sheets to deposition on subaqueous esker-fan lobes emerging from ice tunnels. In a European example, a channel was filled largely with mass-flow deposits that contain huge clasts of semiconsolidated (probably frozen) sand (Postma et al. 1983). The dataset does not include fills from outwash gravel sheets (essentially braided-river deposits) nor the deposits of eskers formed where subglacial flows incised upwards into the glacier. Large meltwater flows have generated extensive braidplains in deep-sea settings (Hesse et al. 2001), but these are not discussed here.

OTHER GROUPS

The proximal parts of alluvial fans and aprons are not included in this classification in view of their complexity and typically low degree of channelization, although channel bodies are prominent in their deposits. Some volcaniclastic aprons extend for more than 100 km due to their huge yields of unconsolidated material, high discharge, and long runout distance for debris flows and stream flows (G. Smith 1987). Cycles of incision and aggradation are prominent in fan and apron deposits (DeCelles et al. 1991), especially where volcano-induced sedimentation episodes cause periods of rapid aggradation that alternate with periods of incision, during which steep-sided, narrow valleys up to 70 m deep may be generated (Vessell and Davies 1981; G. Smith 1987). The dimensions of channel bodies in these settings are among the least well constrained and await a full analysis.

Channel and valley fills that contain fluvial material but originated from processes other than fluvial are only considered incidentally. Contributing processes include glacial activity, colluvial gully creation, karst processes (Iwaniw 1985), and thermal degradation of permafrost (Hopkins et al. 1955; Brunt 2004). In volcanic areas, base surges and pyroclastic flows create channels that may be filled with water-laid volcaniclastic material (Fisher 1977). Subcircular scours several meters deep can form around standing trees (Rygel et al. 2004) and ice blocks (Russell 1993), and their fills may resemble channel bodies in their cross-sectional appearance and scale.

UNDERSTANDING CHANNEL-BODY FORM

Channel Dynamics

Geomorphic factors that are responsible for shaping channels include discharge, slope, sediment grain size and load, channel-margin composition and strength, and factors related to the local geological history; they are the subject of a vast literature (see Richards 1982; Hey 1988; Church 1992; Rosgen 1994; Miall 1996; Knighton 1998; Bridge 2003). Because it is reasonable to infer geomorphic information from channel form as deduced from preserved deposits, the following brief discussion touches on a few aspects that are especially relevant to channel bodies and valley fills in the ancient record.

Geomorphic factors affect channels through high-magnitude events and also through minor changes close to geomorphic thresholds (Schumm 1981). Planform, cross-sectional, and longitudinal adjustments are mutually dependent, adjusting over varied spatial and timescales. Width adjustment is a prominent response of channels to discharge fluctuation—for example, Schumm and Lichty (1963) and Burkham (1972) noted ten- to twenty-fold increases in channel width within a century. Cross-sectional area and width generally correlate more closely with discharge than does depth (Wharton et al. 1989), in part because depth varies greatly in many reaches, and channels tend to adjust to regime changes by width or sinuosity change rather than by incision (Schumm 1993). However, because width and cross-sectional area may be difficult to determine in exposures, channel-body thickness and, by inference, channel depth is the most commonly inferred geomorphic parameter derived from ancient channel bodies. Because width and depth adjust mutually, their ratio has little hydraulic significance, although it remains an important practical measure.

Channel parameters can be considered adjusted on average to a flow (the "channel-forming discharge") that just fills the available cross-section and is a relatively frequent event (Wolman and Miller 1960). In many rivers, this discharge is close to bankfull—essentially the level of the active floodplain (Williams 1978; Wharton 1995). Where a nearly completely preserved channel form is evident in the rock record, bankfull depth and width can be approximated. Numerous studies confirm the importance of bankfull discharge for channel form, especially for alluvial sand-bed and gravel-bed rivers in humid climates with perennial flow (Emmett 1975; Andrews 1980; Hey and Thorne 1986), although high-magnitude, low-frequency flood events may control channel form (Baker 1977). In many headwater boulder streams, individual clasts and logs exert a major influence on channel form, because they are of the same size order as channel depth (Church 1992); such channels need extreme events for particle mobilization, and their form may correlate poorly with discharge. Additionally, bankfull level has little meaning where channels are confined by bedrock or tough alluvium, and where sediment-binding vegetation extends below the geomorphically defined bankfull level (Church 1992).

Channels commonly enlarge due to extreme, rapid events, with a long time span for "recovery," and channel enlargement terminates the "memory" of previous events (Yu and Wolman 1987). Thus, "bankfull" depth and width estimated from outcrop may reflect an extreme size and discharge condition. Channel form reflects a range of discharges that includes bankfull and, although channel geometry is commonly associated with a limited discharge range, no universally consistent correlation exists between flow frequency, bankfull discharge, sediment transport, and effectiveness in creating morphological change (Yu and Wolman 1987; Church 1992; Nash 1994).

Bearing in mind this complexity, approaches for assessing hydraulic and geomorphic parameters for channel bodies have been outlined by Ethridge and Schumm (1978), Maizels (1993), North (1996), and Paola and Mohrig (1996). The hydraulic estimates are largely based upon regime equations, developed initially for Asian irrigation canals with constant discharge, and are reasonably well established for alluvial gravel-bed and sand-bed rivers (Hey and Thorne 1986; Hey 1988; Wharton et al. 1989; Church 1992). The equations link bankfull width and depth and channel slope to discharge, velocity, bed material and bank composition, and vegetation (Hey 1988).

Over the longer timescales that may represent the active life of large, multistory channel bodies, precipitation and discharge are likely to have changed substantially in many climatic settings. For example, monsoonal precipitation in the late Quaternary has fluctuated by at least 30% of its present value over periods of a few thousand to tens of thousands of years in response to orbital insolation and glacial boundary conditions (Prell and Kutzbach 1987; Overpeck et al. 1996). Knox (1993) considered that modest changes in mean annual precipitation (10–20%) and temperature could produce large changes in flood magnitude in the upper Mississippi River. Consequently, the form of many channel bodies will be a time-averaged record of response to highly variable discharges of water and sediment, with complex nonlinear responses and feedback effects (Bogaart et al. 2003).

Initial Aspect Ratio and Channel-Body Evolution

Despite the complexity noted above, the bankfull width and depth of modern channels provide an important starting point for the analysis of channel bodies (Gilbert 1914; Schumm, 1960, 1968; Rosgen 1994; Tye 2004). The term *initial aspect ratio* is used here to represent the width/depth value of modern channels recently emplaced by avulsion or self-formed within their alluvium. To explore this ratio, histograms were constructed for 347 measurements of bankfull width/depth for modern alluvial channels (Fig. 14; Table 8). The measured reaches mainly lie within valleys in erosional landscapes, and the suite comprises small to moderate size rivers, with few very large rivers or reaches from strongly seasonal areas. All are self-formed channels within their own alluvium. The studied reaches are mainly from irregularly sinuous rivers with well-formed channels, and braided rivers are underrepresented because of their complex channel and bar arrays and strong stage fluctuations, which make it difficult to establish bankfull dimensions accurately.

The histograms indicate that, in self-formed alluvial settings, a few channels have width/depth values of less than 5; most channels have values of 5 to 25 (Fig. 14A) and 5 to 15 (Fig. 14B); progressively fewer channels have ratios from 25 to 100; and very few channels have ratios greater than 100 (maximum 328). The most precise dataset (Fig. 14A) uses bankfull mean depth (calculated from cross-sectional area divided by width), whereas studies of ancient channel bodies typically record maximum thickness, broadly comparable with maximum channel depth. Table 9 suggests that, although depth may vary both systematically and unsystematically within modern channels, maximum depth is typically about 1.5 to 1.8 times the mean depth, with confluence depths more

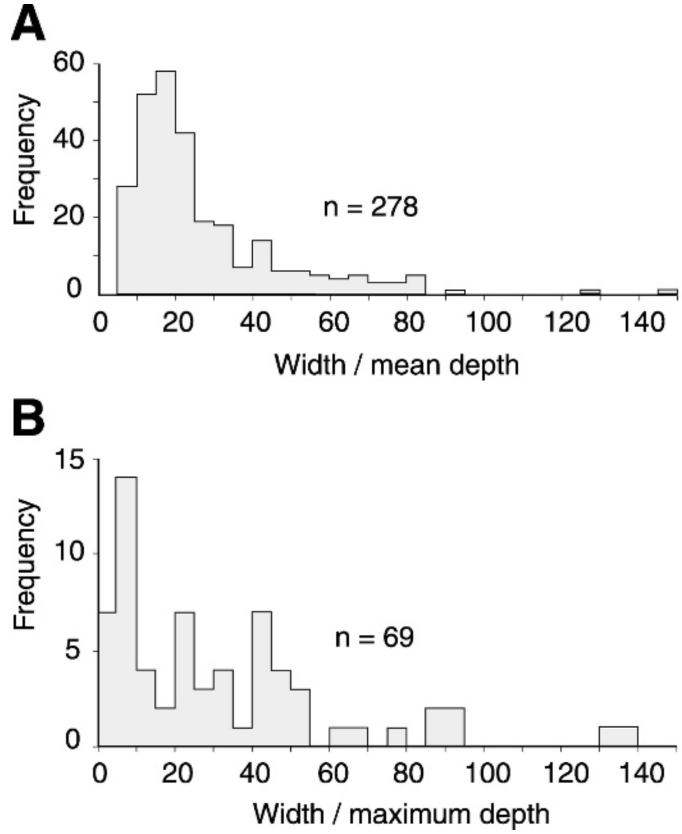

FIG. 14.— Width/depth measurements for modern channels. **A)** Width/mean depth for 278 surveyed reaches in Church and Rood (1983) and Hey and Thorne (1986), representing datasets from 16 publications; one value at 328 not shown. **B)** Width/maximum depth for 69 reaches in Schumm (1960). See Table 8 for information about these datasets.

TABLE 8.—*Summary data for modern fluvial-channel suites used for width/depth analysis. (Fig. 14).*

Description	Data from Church and Rood (1983) and Hey and Thorne (1986)	Data from Schumm (1960)
Reaches	278 stable reaches in Canada, U.K., U.S.A. and SE Asia. Mainly valley settings in erosional landscapes, with small floodplains. Dimensions based on average of 1–5 surveyed crosssections, correlated with bankfull level, mostly close to gauging stations.	69 stable reaches in mid-western and western U.S.A. Bankfull width and maximum depth measured; most reaches not surveyed; most near gauging stations
Climatic Setting	Perennial temperate and subarctic rivers.	Ephemeral to perennial, humid to semiarid rivers.
Bankfull identification	Elevation of active floodplain or valley flat (may not be active). Some by break in plot of dimensions vs. discharge. A few approximated by flow of a given recurrence interval that corresponds to bankfull for the reach. Basis for bankfull designation not indicated for some.	Elevation of first bank or terrace above channel floor. Commonly corresponds to lower edge of permanent vegetation and upper limit of recent channel-margin deposition or erosion.
Channel planform	Irregularly sinuous, or with some channel splits around islands and minor secondary channels. A few meandering and anastomosing channels. Rare braided channels.	Not noted.
Bed material	Cobble/boulder (coarse gravel) predominant, granule/pebble (fine gravel) common, sand less common, one muddy reach. Bed armoring of gravel common.	Sand predominant, with only minor gravel; 0.5 to 91% mud.
Bank material	Alluvial reaches. Mainly fine gravel and sand, with some coarse gravel banks. Many banks composite with layers of cohesive fines. Densely to lightly vegetated.	Mainly sandy, with 0.5–97% mud.
Discharge (cumecs)	Mean 682, median 26, range 0.54–16950. All channels with perennial flow.	Mean annual flood (2.33 years recurrence interval): 8.8–1359. Many channels ephemeral.
Width (m)	Mean 65, median 26, range 2–776	Mean 47.2, median 30.5, range 4.6–250
Depth (m)	Mean depth (calculated from A/w): Mean1.89, median 1.29, range 0.2–13.9	Maximum depth: mean 1.5, median 1.2, range 0.5–5.5
Width/Depth	Mean 27, median 20.2, range 5.4–150.5	Mean 42.2, median 25.9, range 2.3–328

For data compiled by Church and Rood (1983), 216 alluvial reaches were selected from a larger suite, all with dimensions and discharge related to bankfull level according to the original authors. A = cross-sectional area; w = width.

TABLE 9.— *Estimates of ratio of maximum and mean depth for modern channels.*

Author	Maximum / Mean Depth	Data Set
Schumm 1960	~ 1.5	Surveyed sand-bed channels in Midwestern U.S.A.
Fahnestock 1963	1.62 (range 1.1–2.7)	112 surveyed small gravel-bed channels, White River, U.S.A.
Hey and Thorne 1986	1.58 (range 1.3–2.1)	62 surveyed small gravelbed channels, U.K.
Ethridge and Schumm 1978	1.71	Average ratio of depth in meandering and straight reaches in experimental studies
Burge and Smith 1999	~ 1.6, 1.8	Thickness ratio of eddy-accretion and point-bar deposits in Kootenay and Beaver rivers, Canada (estimated from cross sections)
Ethridge and Schumm 1978	1.71	Experimental studies
Best and Ashworth 1997	~ 5	Maximum scour depth at confluences compared with mean channel depth, Jamuna River, Bangladesh

profound. Thus, width/maximum depth values for a large proportion of the data in Figure 14A are probably less than 15. For this dataset, discharge correlates well with cross-sectional area, width, and mean depth (in order of decreasing r^2 values), but width/mean depth correlates poorly with discharge (as noted above, this ratio has little hydraulic significance).

Little information is available about channel dimensions in the earliest stages of their formation. Schumm and Ethridge (1994) inferred that initial vertical incision generates a narrow, deep channel that widens by lateral erosion and bank failure. Rodolfo (1989) recorded a width/depth range of 3–10 for lahar-cut channels triggered by intense rainstorms, and

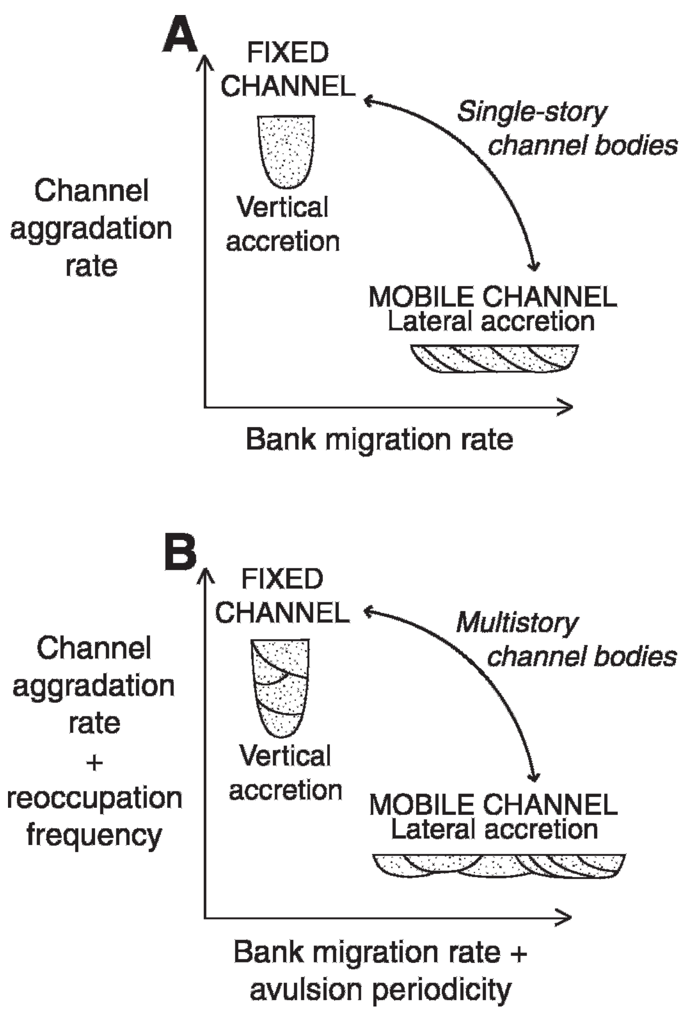

FIG. 15.— Conceptual diagram to show balance between factors that govern geometry of **A)** single-story channel bodies and **B)** multistory channel bodies.

Fisher (1977) recorded values of 1 to 4 for channels cut by volcanic processes and filled rapidly. Some cut-and-fill features in the rock record also have low W/T—8.5 to 10.4 for trough cross-beds (Robinson and McCabe 1997), and 3 for gutter casts (Olsen 1989).

In summary, the majority of self-formed alluvial channels within moderately cohesive alluvium record width/depth in the range of 3 to 100. Many channels probably commence operation with width/depth values analogous to the width/thickness values of ribbons (< 15) to narrow sheets (< 100), and the arbitrary W/T divisions suggested by Friend et al. (1979) and Blakey and Gubitosa (1984) of 15 and 100 (Table 2) bear some relationship to the dimensions of modern channels. Friend's original choice of 15 as a W/T discriminator was based on channel-body dimensions in the Ebro Basin coupled with information from Schumm (1960) (P. Friend, written communication, 2000). The convergence of channel bodies from many geomorphic settings into ribbons and narrow sheets reflects the combination of initial aspect ratio in moderately cohesive substrate with modest subsequent widening.

For single-story channel bodies with a given initial aspect ratio, the balance between *bank migration rate* and *channel aggradation rate* determines to a first approximation the channel-body geometry (Fig. 15A; see also fig. 5 of Bristow and Best 1993). Because the width of many channels is sensitive to short-term discharge variation (varying by more than an order of magnitude over decades), many channel bodies are likely to widen and show lateral accretion. For multistory channel bodies with a more prolonged history and succession-dominated style, the balance between reoccupation of preexisting channels during avulsion and the creation of new channel reaches also comes into play (Fig. 15B). *Reoccupation* is a common and possibly dominant process in many rivers (Aslan and Blum 1999; Morozova and Smith 2000; Makaske et al. 2002), and should generate vertical stacking within a composite channel body. *Avulsion periodicity* represents the formation of new channels on an unconfined plain, and leads to channel-belt expansion and amalgamation. Some multistory channel bodies with low W/T may represent repeated reoccupation of drainage lines after inactive periods (Allen et al. 1983; Gibling and Rust 1990). In the Baghmati River plains of India, the thickness of many channel bodies in the shallow subsurface appears to exceed the depth of the modern channels, possibly reflecting repeated avulsive reoccupation—the dominant avulsive mode of the modern river—in an aggradational setting (Sinha et al. 2005). In reality, reoccupation and avulsion are commonly linked, for a new avulsive course may connect the breakout point to the point of reoccupation.

Fixed Channels: Intrinsic and Extrinsic Controls

Relatively narrow channel bodies throughout the dataset yield evidence that bank strength and rapid aggradation (intrinsic factors) contributed to their low W/T values. Allen et al. (1983) and Gibling and Rust (1990) documented channel bodies bordered by calcareous and siliceous paleosols (Fig. 12C). The parent channels had undercut the banks to form steps that, upon collapse, yielded rigid slump blocks. Channel fills rich in pedogenic carbonate clasts bear testimony to early floodplain cementation, implying high bank strength. Where banks are muddy, steps in the channel cross-section may extend into the channel fill as lagged story bases, indicating episodic widening of resistant banks (Rust et al. 1984). Some narrow channel bodies in the dataset were bordered by thick peat (now coal; Warwick and Stanton 1988), and densely rooted margins also imply stabilizing vegetation.

In modern settings, channels with cohesive banks tend to be narrow (Schumm 1960, 1968; Ferguson 1973). Banks consisting of indurated paleosols or older, semiconsolidated Quaternary deposits impede channel adjustment, especially in tropical and semiarid settings (Woodyer et al. 1979; Gibling and Tandon 1997; Gibling et al. 1998; Nanson et al. 2005). Additionally, fibrous peat (Törnqvist et al. 1993) and bank vegetation influence channel stability and form, especially affecting width (Smith 1976; Hey and Thorne 1986; Stanistreet et al. 1993; Millar and Quick 1998).

For the dataset, many authors inferred that vertical and lateral accretion within the parent channels outpaced bank migration (Rust et al. 1984; Hopkins 1985; Groll and Steidtmann 1987; Kirschbaum and McCabe 1992; Dreyer et al. 1993; Nadon 1994; Jones and Blakey 1997). Numerous observations support this assertion. Many bodies contain concentric fills that drape the channel margins or rise progressively as they approach a resistant bank, indicating reduced cross-sectional area. Channel fills include debris-flow conglomerates and massive and plane-laminated sandstones, and some channel bodies are choked with volcanic or eolian material (Fig. 12E). Lateral accretion deposits are rare, and most fills are single story or consist of a heterolithic stack of scour-based layers (Fig. 12B), indicating filling during one or a few floods. Modern fluvial systems are known to aggrade following earthquakes and landslides (Goswami 1985; Keefer 1999) and changes in precipitation and discharge (Goodbred 2003).

Several studies have suggested that channel bodies with low W/T in the ancient record reflect the response of fluvial systems to the extrinsic factor of base-level rise and the creation of potential accommodation. In the Rhine–Meuse delta and the lower Mississippi Valley, anastomosing channel systems generated low-W/T channel bodies during rapid Holocene sea-level rise (Törnqvist 1993; Törnqvist et al. 1993; Aslan and Autin 1999), and high-accommodation effects have been invoked to account for low-W/T channel bodies in ancient coastal settings (Tye 1991; Kirschbaum and McCabe 1992; Olsen et al. 1995; Eschard et al. 1998; Knox and Barton 1999). In the Straight Cliffs Formation, Shanley and McCabe (1993) noted strong confirmatory evidence for this linkage by correlating stratal intervals with relatively narrow channel bodies to aggradational nearshore parasequences.

What is the balance between intrinsic and extrinsic controls in governing channel-body form? In a comprehensive study of anastomosing reaches and Quaternary deposits of the Columbia, Niger, and Rhine–Meuse systems, Makaske (1998, 2001) noted that all three systems are characterized by low gradients and a very low specific stream power (a function of slope and discharge), resulting in a limited ability for channels to transport coarse bedload, erode banks, and expand laterally. The surplus load drives accretion of the channel bed and of natural levees and floodplain, resulting in avulsion and the creation of multiple channel belts. In the case of the Columbia River, accretion of the channel bed and the channel banks produced channel bodies with W/T less than the width/depth value of the original channel. The Niger River in Mali has a low channel-flow capacity and resistant banks, and is subject to climate-specific avulsion triggers such as eolian dune migration; in this setting, reduction of discharge as a result of climate change has caused aggradation within the channels. No rapid rise in baselevel was indicated for either of these inland systems. For paleochannels of the Rhine–Meuse system, Makaske inferred that multiple channels and lateral stability reflect low stream power and low subsoil erodibility. In this coastal setting, sea-level rise promoted an increase in aggradation rate, which in turn increased avulsion frequency. A post-avulsion reduction in the stream power of individual channels promoted lateral channel stability.

Nanson and Huang (1999) and Jansen and Nanson (2004) suggested that channel anabranching increases the conveyance of sediment and water, compared with a single channel at the same discharge. Thus, anabranching rivers (likely to generate low-W/T channel bodies) may constitute a stable river pattern in dynamic equilibrium under circumstances (especially low gradient) where a single channel would be unable to maintain sediment conveyance.

The models discussed above suggest that anabranching rivers are not necessarily associated with a rapid rise in base level. Even in cases where channels are affected by base-level rise and accommodation increase, the creation of stable, multiple channels and low-W/T channels bodies reflects a complex feedback system that links low stream power, locally high aggradation rate, high avulsion frequency, and low bank erodibility.

The recent tendency in sequence stratigraphy to relate channel-body form to accommodation (e.g., Shanley and McCabe 1993) is thus subject to many caveats. Much of the evidence for this linkage has been adduced from Quaternary glacioeustatic settings, which may not be closely applicable to greenhouse periods (Willis 1997). For inland and proximal alluvial settings in the dataset, bank strength and rapid sediment supply are strongly implicated in creating low-W/T channel bodies, irrespective of accommodation effects. Based on a computer simulation of the Mississippi Valley, Bridge (1999) suggested that sequence-stratigraphic models have oversimplified the alluvial architecture of near-coastal settings by implying that deposition rate and valley width are the primary controls. In such settings, avulsion nodes (sites of repeated avulsion) and avulsion sequences (generated by progressive upstream shift in the site of avulsion) may exert a strong control on the architecture.

Channel Bodies with Very Low W/T

All the groups of fixed channel bodies and valley fills in the dataset yield a few channel bodies with exceptionally low W/T values (5 or less: narrow ribbons). Published accounts attribute these very low aspect ratios to one or more of the following factors: deep incision (low initial aspect ratio), high bank and substrate strength, rapid channel aggradation within short-lived channels, and reoccupation of drainage lines (Friend et al. 1979; Allen et al. 1983; Fielding 1984; Rust et al. 1984; Nichols 1987; Dreyer 1993; Smith 1994).

Valley fills on bedrock unconformities commonly have very low aspect ratios. This may reflect the resistance of the substrate to lateral planation, coupled in many instances with deep incision along structural lines. Faults may promote the stacking of channel bodies along hanging walls (Alexander and Gawthorpe 1993; Doyle and Sweet 1995; Carter 2003), and Fielding et al. (2005) documented an example of relatively narrow valleys (W/T of 15 or less) formed along faults. In the case of the Sis Conglomerate (Fig. 13A), the low aspect ratio is due to the syntectonic growth of the valley fill. In the Mississippi delta, compaction-driven subsidence of fine-grained sediments under the weight of delta-front sands has allowed unusually thick mouth-bar and natural levee deposits to accumulate (Fisk et al. 1954; Fisk 1955, 1960); compactionally thickened channel bodies may also be present, although Fisk did not specifically mention them. Channel-body thickness may actually exceed width under compactional conditions (Sander 1989). Some narrow channel fills on megafans and in axial drainage systems interdigitate with adjacent overbank strata, suggesting that balanced aggradation of channels and levees encouraged channel-body thickening (Hill 1989; Nadon 1994). This may also be true for some delta distributaries (Fig. 12B).

Some very narrow channel bodies are filled with debris-flow and mass-flow deposits (Rust 1977; Postma et al. 1983). These examples formed in proglacial settings, and may represent thermal erosion of permafrost in a deep thaw bulb below water courses, with undercutting of banks and the release of large collapsed blocks into the channels (Walker and Hudson 2003). In eolian settings (Jones and Blakey 1997) and volcanic settings (Fisher 1977), a combination of high-magnitude flows and high sediment availability may promote both deep incision and rapid channel filling (Fig. 12E).

Channel Bodies and Geomorphic Surfaces

Studies of Quaternary deposits for which high-resolution dates are available reveal a complex history of incision, aggradation, and lithification, with channels and floodplains responding to climatic forcing over periods of hundreds to thousands of years (Bogaart et al. 2003). The geomorphic complexity of the Quaternary record is not mirrored in interpretations of the rock record to date, in part because of the difficulty of correlating channel bodies with key stratal surfaces in the adjacent floodplain deposits, which typically constitute the majority of strata within alluvial successions.

Although our understanding of paleogeomorphology is cryptic at best, several types of geomorphic surface that link channel and floodplain deposits have been documented in the ancient record. Regional bedrock unconformities and their fluvial cover have received considerable attention (Siever 1951; Sedimentation Seminar 1978; Dolson et al. 1991), although the small and intermediate channel types of Church (1992)—widespread in modern upland settings—have received little attention. Coastal valley fills and interfluve paleosols have been linked to relative sea-level change (Gibling and Wightman 1994; McCarthy et al. 1999; Posamentier and Allen 1999), locally resulting in a complex juxtaposition of channel bodies of different geometry and composition formed at different stages in the base-level transit cycle (a *channel-body mosaic*: Batson and Gibling 2002). Some models explore the relationship between paleosols and channel bodies in inland settings (Willis and Behrensmeyer 1994), where floodplain degradational surfaces may also be linked to channel bodies (Kraus and Middleton 1987b; Bestland et al. 1997). These floodplain surfaces may be the substrate for floodplain channels and gully fills. In glacial settings, regional erosion surfaces may be associated with subglacial meltwater events and tunnel-valley formation (Ghienne and Deynoux 1998). However, in rapidly subsiding basins, discontinuities within alluvium may be cryptic and distinctive geomorphic surfaces difficult to identify.

Future studies of channel-body geometry will increasingly require correlation of channel and floodplain deposits and consideration of the broader geomorphic setting. In this respect, 3D seismic studies have begun to reveal some remarkable paleogeomorpic features (Posamentier 2001; Carter 2003).

APPLICATION TO MODELING AND SUBSURFACE EVALUATION

Models and Use of the Dataset

Alluvial deposits are typically strongly heterogeneous, and channel bodies may be too narrow and thin to permit well-to-well correlations, even where considerable subsurface information is available (Eschard et al. 1998). Consequently, several types of computer-based models have been used to investigate the spatial distribution of channel bodies within basin fills and reduce ''geological uncertainty'' (Webb and Davis 1998; Bridge 2003). *Structure-imitating models* are used to assess the volume and quality of reservoirs or aquifers within a basin, employing stochastic models to distribute channel bodies in 3D space, and are a type of simulation model (Paola 2000) intended to reproduce many equiprobable realizations. Model input includes sandstone-body thickness for each type of body (represented as single-story units), and a width/thickness plot that can generate a linear equation, typically based on width/depth relations in modern channels (Hirst et al. 1993). The models draw upon appropriate outcrop analogues where subsurface data are limited, and are conditioned to well positions and net : gross ratio for channel bodies in the studied formation. Tye (2004) used dimensional information from selected modern channels to assist in conditioning reservoir models for relatively predictable fluviodeltaic settings.

In contrast, *process-based models* simulate sedimentary processes through the application of equations and empirical data (Bridge and Mackey 1993a, 1993b; Mackey and Bridge 1995; Heller and Paola 1996; Bridge 1999). They are especially designed to explore the effects of avulsion on alluvial architecture under defined conditions, and their outputs include width, thickness, W/T, and connectedness of channel belts. Such analytical models (Paola 2000) are aimed at exploring general system behavior rather than reproducing particular cases. Although difficult to condition to observed data, recent process-based models have provided good simulations of documented Quaternary architecture (Bridge 1999) or have used Monte Carlo trial-and-error simulations to reproduce given well data (Karssenberg et al. 2001). From these experiments, the dimensions of channel bodies are understood to be controlled primarily by the following factors: channel-belt width and maximum bankfull depth, channel-belt aggradation rate, an exponent value for deposition rate on the floodplain away from the channels, spatial variation in floodplain deposition rates (e.g., tectonic tilting), mean avulsion period, avulsion location, and the ratio of channel-belt width to floodplain width.

Bridge (2003, p. 343–344) and Tye (2004) noted that, even for well exposed formations, the information available to supplement models is limited and commonly unrepresentative, and that great care is needed in selecting suitable outcrop analogues. The choice of dimensions greatly affects model results (Peijs–van Hilten et al. 1998). Bridge and Tye (2000) and Leclair and Bridge (2001) discussed predictive approaches for channel-body dimensions, based on bedform scale. Because industry data are typically restricted, Cuevas Gozalo and Martinius (1993) expressed a need for reliable *named* examples, thus removing the anonymity of datasets and allowing both facies and dimensional factors to be assessed.

The present compilation provides dimensional and facies information for ancient channel bodies of different types. Once the user has determined the appropriate type(s) of channel body, dimensions can be selected using various approaches. Dimensions in W/T space (Figs. 6–9) yield a realistic range of sizes and forms, or the most common dimensional range for each channel-body type can be obtained from Table 4. The diagrams can be used to yield a reasonable width range for channel bodies of known thickness but undetermined width—an especially common scenario in subsurface studies. Additionally, the most appropriate analogues within each category may be selected from the lists in Appendix 1 and the spreadsheets of Appendix 2. Where bodies cannot readily be attributed to particular types within the spectrum of fixed channels and poorly channelized systems, general dimensions for the group can be utilized. To improve the collection of analogue data, Appendix 10 provides a checklist for channel-body analysis.

Some useful generalizations about channel-body thickness and width emerge from the dataset (Figs. 6–9, Table 4). Within the group of fixed channels and poorly channelized systems, most channel bodies are less than 20 m thick, and many are less than 10 m thick. All meandering river bodies in the dataset are less than 38 m thick, and most braided and low-sinuosity channel bodies are less than 60 m thick, although numerous composite bodies are hundreds of meters thick. Within the suite of valley fills, most are more than 20 m thick, and those within marine and alluvial strata are mainly 20–60 m thick.

As regards width, many channel bodies in the group of fixed channels and poorly channelized systems are less than 500 m wide, and most are less than 1 km wide (Figs. 7, 8). With well spacings in petroleum fields commonly in the 500 m to 1 km range, fixed-channel bodies are unlikely to be penetrated by more than one well in a traverse normal to paleoflow, and their width would not be resolvable with this density of information. For meandering-fluvial bodies (Fig. 6B), channel bodies 10 m thick commonly range from 100 m to 6 km wide, and those 30 m thick from 1 to 10 km wide. For braided and low-sinuosity channel bodies (Fig. 6), channel bodies 10 m thick commonly range in width from about 150 m to 10 km but may exceed 100 km; those 30 m thick commonly range in width from 500 m to 25 km but may exceed 150 km. The width range of valley fills in alluvial and marine strata is commonly 500 m to 25 km, but some are more than 100 km wide. Because the width of braided and low-sinuosity channel bodies and valley fills is highly variable at a given thickness, their widths will be difficult to predict where limited subsurface information is available.

Some Implications for Modeling

The dataset has several implications for modeling procedures. Firstly, the choice of geomorphic setting evident in many modeling studies is not representative of the full range of alluvial styles. Dimensions and regression equations specified in modeling studies commonly represent meandering or braided and low-sinuosity river bodies (typically associated with alluvial ridges or natural levees), as in the initial architectural models of Allen (1978) or the models of Karssenberg et al. (2001) which used a channel-belt width of 1200 m and bankfull depth of 10 m. However, model results may be less applicable to the many thick and extensive formations that comprise bodies of fixed-channel type (low W/T bodies encased in floodplain shales): the dataset yields little indication that such bodies ever amalgamate sufficiently to generate basin fills with a high connectedness ratio. Reoccupation of older channels—a major avulsive style—is not simulated in structure-imitating models (Bridge 1999), although channel belts may be partially superimposed. Additionally, the ratio of channel-belt width to floodplain width is imposed in many models (for example, ranging between 0.1 and 0.9: Bridge and Mackey 1993a). Such values typically represent broad channel systems within valleys, and the ratio may be much smaller for broad alluvial plains and for distributary systems—widely represented in the rock record. Landscape degradation—for example, valley incision and terrace formation—is not simulated (Mackey and Bridge 1995; Bridge 1999). Additionally, many alluvial models assume a "freely meandering" condition, implying that bedrock is absent; however, strong bank materials, including abandoned-channel mud plugs, and older, indurated alluvium capable of restricting channel enlargement (Fig. 12C) are common in many alluvial settings.

Secondly, a point of particular interest arising from the dataset is the apparent absence of thick, extensive meandering-fluvial bodies. Although in theory avulsive meandering rivers can generate large, multistory bodies with high connectedness, there is little indication that they have done so. In contrast, braided and low-sinuosity rivers have frequently created multistory deposits of basinal scale.

Thirdly, most models are avulsion-based, linked to superelevation of the channel belt and its natural levees, thus creating a gradient advantage and conditions suitable for avulsion (Jones and Schumm 1999). This situation was termed "dependent avulsion" by Mackey and Bridge (1995), in contrast to randomly placed avulsions. However, many channel-body suites in the database probably experienced avulsion because high sediment supply and high bank strength promoted rapid aggradation. Furthermore, numerous authors of the database examples note that levees are poorly developed. In such cases, the choice of a new channel route may have little relationship to gradient advantage, and may be "randomly" placed. For example, anabranching rivers in the Channel Country of central Australia lack natural levees or are bordered by very low sediment mounds (Gibling et al. 1998). In this setting, new anabranches were observed where the rate of bank accretion had outpaced the rate of bank erosion, suggesting that local accretion within the channel had forced avulsion. At other sites, anabranches were forming where broad overbank floodways rejoined channels, leading to gullying and headward erosion; although the floodways follow low-elevation paths, they do not represent a site of gradient advantage associated with an alluvial ridge. Channels had also formed where scour hollows around trees had coalesced.

Fourthly, the deposits of some large megafans show a decreased proportion of channel bodies distally, as in the Spanish Cenozoic examples documented by Nichols (1987) and Hirst (1991). Using physical models of fan-like systems, Hickson et al. (2005) observed a similar downstream trend in channel-body proportions. The model runs suggest that several forcing factors, including sediment supply, base level, and subsidence, may cause upstream or downstream facies migration. Because of the spatial variation in channel-body proportions, such facies migration may exert a dominating control on 2D facies architecture. Thus, geomorphic setting may be an important parameter in interpreting trends in channel-body proportions. Mackey and Bridge (1995) and Bridge (1999) discussed some of these issues, and noted the importance of local factors such as avulsion nodes in valley settings. Fewer distributaries are noted towards the coastal margin of some deltas (Olariu and Bhattacharya 2006).

Finally, the results of modeling experiments suggest that alluvial architecture is strongly influenced by the collective effects of avulsion frequency, sedimentation rate, and width of the channel belt relative to the width of the basin (Bridge and Mackey 1993a, 1993b; Mackey and Bridge 1995; Heller and Paola 1996). These observations tend to suggest that fluvial channel bodies in the geological record represent a geomorphic spectrum and that alluvial basin-fill stratigraphy is largely controlled by these factors and not by channel morphology. This may be true in part for the deposits of mobile channel belts. However, for fixed-channel bodies, many additional factors come into play, especially bank strength and local channel aggradation, as explored in the model of Makaske (1998) for anastomosing systems. Particular care must be exercised in applying model-based interpretations to stratigraphic successions where *channel-body type changes upwards*—for example from braided-fluvial sheets to fixed-channel bodies, which may have been subject to different controlling factors, including climate change (Gibling et al. 1998). Mistakes can be avoided by recognizing changes in channel-bar and channel-fill types and vertical changes in net-to-gross, and by limiting modeling to certain stratigraphic intervals.

In theory, suites of relatively narrow "fixed" channel bodies might, where more highly connected, become broader and thicker and be classified as "mobile-channel deposits." This may be true in some cases: for example, Hirst (1991) identified some parts of the Huesca megafan where narrow sheet sandstones had amalgamated to form larger bodies (Fig. 12A), North and Taylor (1996) noted amalgamated suites of poorly channelized ephemeral-river deposits, and Eschard et al. (1998) identified zones of ribbons that had amalgamated to form a heterogeneous but laterally continuous sheet. However, most suites of fixed-channel bodies in the dataset have amalgamated to only a slight degree. Thus, the classification set out here recognizes them as distinctive types, rather than poorly connected bodies in a spectrum of connectedness.

Most model-based studies have discussed the limitations of their models, and the researchers have striven to provide more realistic simulations. In a similar vein, these comments are offered in the interests of generating more widely applicable alluvial models. Paola (2000) suggested that architectural models such as those discussed above will eventually merge with broader basin-filling models that utilize diffusion equations for fluvial transport. Such a unified approach would improve evaluation of the interplay between alluvial architecture and external forcing factors, especially those related to climate.

CONCLUSIONS

Despite its importance for subsurface applications, the three-dimensional geometry of fluvial channel bodies and valley fills has received relatively little attention since the pioneering studies of Krynine (1948), Potter (1967), and Friend (1983). A comprehensive review of terminology and controls on geometry is especially warranted because of the recent tendency to explain stratigraphic variations in channel-body geometry in terms of base-level change and accommodation. This tendency runs counter to the large body of information that emphasizes the importance of local geomorphic factors in determining alluvial channel form.

To address these questions, this paper presents a large dataset based on literature compilation for more than 1500 bedrock and Quaternary fluvial bodies. For inclusion in the dataset, width (W) and thickness (T) must be recorded, along with detailed facies information. The use of generalized information such as dimensional ranges and minimum dimensions allows the inclusion of examples that range from basin fills to outcrop scale. The dataset represents single and multistory channel bodies and valley fills that range from 1 to 1400 m in thickness, from 2 m to 1300 km in width, and in W/T from less than 1 to more than 15,000. Earlier divisions into ribbons, narrow sheets, and broad sheets at W/T boundaries of 15 and 100 are confirmed, and additional divisions suggested: narrow and broad ribbons (W/T $<$ 5 and 5–15, respectively) and narrow, broad, and very broad sheets (W/T 15–100, 100–1000, and $>$ 1000, respectively). Categories for length and area are also suggested. The dataset is available in the form of working spreadsheets and graphs in a data repository, allowing interested researchers to plot their own data along with the dataset examples and to select suitable named analogues. This may be especially useful for evaluating the width of fluvial bodies (usually difficult to define in subsurface settings) and for stochastic modeling.

The dataset allows fluvial-body geometry to be used as a factor in classifying channel deposits, along with their geomorphic setting and internal structure. Following in part the classification of Friend (1983), three major groups of deposits are recognized: *mobile-channel belts, fixed channels and poorly channelized systems, and valley fills*. These are divided into twelve types of channel bodies and valley fills that can be recognized repeatedly in the geological record. Log-log plots of W against T are presented for each type.

Mobile-channel belts (narrow to very broad sheets) are mainly the deposits of *braided and low-sinuosity rivers*. Their deposits may exceed 1 km in composite thickness and 1300 km in width, where individual channel bodies have amalgamated through avulsion. Such concentrations of bedload deposits reflects the localization of rivers at exit points from orogens and the filling of narrow extensional basins. Although no volumetric calculations are available, the apparently overwhelming dominance of these deposits throughout geological time reflects their link to tectonic activity, exhumation events, and high sediment supply. Some deposits that rest on flat-lying bedrock unconformities cover areas $>$ 70,000 km^2, and may represent amalgamation of channel bodies during prolonged periods of minimal accommodation. In contrast, *meandering river* bodies in the dataset—identified by the prominence of lateral-accretion deposits—are $<$ 38 m thick and $<$ 15 km wide, and they do not appear to have built basin-scale deposits. Despite their familiarity in modern settings, the organized flow conditions necessary for their development may have been of brief duration.

Fixed channels and poorly channelized systems are divided into distributary systems (*channels on megafans, deltas, and distal alluvial fans, and in crevasse systems and avulsion deposits*), *through-going rivers*, and *channels in eolian settings*. All these types have a similar W/T range, with most bodies in the range of ribbons to narrow sheets (W/T 5–100). A compilation of width and maximum depth for modern alluvial channels suggests that many have width/depth values of 5 to 15. Thus, fixed-channel bodies record an *initial aspect ratio* with subsequent modest widening at most, prior to filling or avulsion. Many dataset examples yield evidence that the narrow form reflects bank resistance and rapid filling, although some are also correlated with periods of base-level rise. The dataset includes some exceptionally narrow bodies (W/T locally $<$ 1) that reflect additional controlling factors: unusually deep incision, compactional thickening, filling by mass-flow deposits, balanced aggradation of natural levees and channels, thawing of frozen substrates, and channel reoccupation.

Valley fills (ribbons to very broad sheets) are divided into three groups. Those *on bedrock unconformities* contrast with those that represent a brief hiatus *within marine and alluvial successions*. Many bedrock valley fills have W/T $<$ 20 due to deep incision along tectonic lineaments or—less commonly documented—stacking along active faults. For valleys within marine and alluvial strata, the dataset allows a test for the effect of glacioeustatic fluctuations. Upper Paleozoic valley fills are generally larger than Mesozoic examples, possibly reflecting the influence of large, high-magnitude glacioeustatic fluctuations in the Paleozoic examples. The third group, *valley fills in sub-glacial and proglacial settings*, are relatively narrow (W/T as low as 2.5) due to incision from catastrophic meltwater flows. Although mainly known from Quaternary settings, they are also present in the older bedrock record.

Criteria for distinguishing channel bodies from valley fills may be difficult to apply. The W/T plots show that the dimensions of braided and meandering channel bodies in the rock record overlap strongly with the dimensions of valley fills, as identified by the original authors, possibly suggesting that many channel bodies occupied paleovalleys.

The importance of determining channel-body connectedness in economic, subsurface applications has led to a large literature on modeling and the evaluation of factors that control the geometry of channel bodies. Results to date have tended to emphasize the importance of avulsion frequency, sedimentation rate, and the ratio of channel belt and floodplain width in governing channel-body stacking. Although these controls undoubtedly influence mobile channel belts, they are less effective controls for fixed-channel systems, for which many database examples testify to the influence of local geomorphic factors, especially bank strength and channel aggradation. The dataset contains few examples of highly connected suites of fixed-channel bodies, despite their abundance in many formations. Thus, suites of channel bodies in basinal fills should not be oversimplified as sets of well to poorly connected bodies of similar type, and it is important to model separately stratigraphic intervals that feature different types of channel body. Although accommodation creation is essential for channel bodies to be preserved, its influence is mediated through geomorphic factors, and inferences about base-level controls must be evaluated carefully.

Understanding more fully the fascinating variety of channel bodies in the geological record requires investigation of their composition and three-dimensional form (internal and external geometry) in the context of their geomorphic setting. Their external geometry provides information about the scale of the rivers and about their brief or prolonged evolution from geomorphic elements to stratigraphic bodies. Documenting channel-body geometry requires more information about the relationship of the channel systems to other landscape elements, including valleys cut in alluvium and bedrock, the megafans and alluvial fans that they traverse, and the desert dunes, volcanoes, oceans, and lakes with which they interact. Hence, the fluvial-body classification set out here is strongly geomorphic in its basis. Channel deposits in eolian and glacial settings are especially poorly represented in the literature, as are those of the Precambrian record. Our aim is to understand ancient river systems in the context of the dynamic landscapes that they have been instrumental in shaping since the first drop of rain fell upon the nascent land (Hadding 1929).

ACKNOWLEDGMENTS

I am indebted to Greg Nadon, Paul Potter, Torbjorn Törnqvist, and Mike Rygel for their perceptive reviews of part or all of an earlier version of this manuscript, and to Peter Friend, Lawrence Plug, Brian Turner, and Stephen Vincent for their helpful discussion. Journal reviewers Tony Reynolds and Robert Tye and editors Janok Batthacharya and Colin North provided thoughtful comments that greatly improved the manuscript, and John Southard and Melissa Lester provided much editorial assistance. Mike Rygel assisted in designing the most suitable plotting routine, Mike Church provided a dataset of modern river data, and Hazen Russell provided information about tunnel valleys. Sue Rouillard at Exeter University and Dalhousie Graphics are thanked for their expert drafting of the diagrams. Funding was provided from the Natural Sciences and Engineering Research Council of Canada (Discovery Grant 13354). The study was carried out in part while the author was on leave at the Department of Geography, University of Exeter, U.K. I thank Maureen White for her support and encouragement during the writing of this paper. Additional material described in this paper can be found on the JSR Data Repository, URL: http://www.sepm.org/archive/index.html.

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Received 29 September 2004; accepted 10 December 2005.