Geoscience Canada

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Volume 5, Number 1, March 1978

URI: https://id.erudit.org/iderudit/geocan5_1con04

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Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

Cite this article

Middleton, G. V. (1978). Fluvial Sedimentology. *Geoscience Canada*, *5*(1), 35–36.

Fluvial Sedimentology

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Geologists have been studying rivers for a very long time: observations on rivers by Hutton, Von Hoff, and Lyell were fundamental to the development of the actualistic method and therefore to the foundation of geology as a science. G. K. Gilbert first developed the modern approach to rivers as complex systems in dynamic equilibrium, and W. M. Davis elaborated his theories of evolving landscapes first for fluvial systems.

Studies that were concerned more with the sediments deposited by rivers than with rivers as elements of landscape, however, began in the 1930s with the work of Hjulstrom and Sundborg in Sweden and (particularly) Fisk in America. Fisk made use of the abundant corehole data obtained by the U.S. Corps of Engineers to determine the geometry and origin of Mississippi river and delta sands. As much oil is found in sand bodies, and exploitation of the oil requires the ability to predict sand body geometry, it is not surprising that Fisk's work was immediately followed up in the research laboratories of several major oil companies. Bernard and LeBlanc, at the Shell Laboratory in Houston, combined corehole data with observations on vertical structural and textural sequences in trenches cut in active point bars of the Brazos River to develop (in 1963) the first modern facies model: a model which predicted the formation of fining-upward sequences by lateral sedimentation on point bars in a meandering river. At the same time, the same idea was developed independently by John R. L. Allen as an explanation for fining upward cycles observed in the Old Red Sandstone. He considerably elaborated this "meandering model" by making use of the new experimental studies of bed forms carried out in the U.S. Geological Survey hydraulics laboratory at Fort Collins, Colorado. By the mid 1960s, when Allen wrote his review of the characteristics of alluvial sediments, it seemed that fluvial sedimentology, and the behaviour of meandering rivers, in particular, was comparatively well understood.

Looking back, it seems extraordinary that no major conference on fluvial sediments was ever held, until the meeting in Calgary organized last October 20-22 by Andrew Miall (GSC, Calgary), Derald Smith (Dept. of Geography, U. of Calgary) and Norman Smith (Dept. of Geology, U. Illinois at Chicago Circle). It is not that there has been any shortage of studies of fluvial sediments, but sedimentologists interested in rivers have not been as well organized as those interested in carbonate rocks, in beach and nearshore sediments, or in shelf sediments, to name just a few groups that have been active in recent years. Sedimentologists and geomorphologists interested in rivers, therefore, responded enthusiastically to the opportunity to meet in Calgary, an opportunity whose value was greatly increased by financial support (from NRC, the Canadian Society of Petroleum Geologists, and the Canadian Geoscience Foundation) which made it possible for several well known sedimentologists to attend from countries as distant and as diverse as Great Britain, Norway, The Netherlands, South Africa, and Australia. Three days and two nights of sessions were faithfully attended, and discussion (whenever it was permitted by a schedule somewhat overcrowded by formal papers) was intense. The Proceedings will be published in full as a Memoir of the CSPG.

The papers at the symposium were divided by the organizing committee into seven major categories: sediment transport, bed forms, modern fluvial processes, sand body accretion, ancient fluvial systems, fluvial depositional models, and paleohydraulic studies. Although the announced intention of the symposium was to focus on bed forms, facies models, and paleohydraulic interpretation, some of the more interesting contribuitons fell into the "sediment transport" category: for example, an experimental study by J. R. Steidtmann (U. Wyoming) of the effect of grain density on the rate of movement of sand by traction (on a plane bed denser grains move more slowly, but on a rippled bed they move at the same speed as lighter grains, with the rate of movement of both types of particles determined by the rate of migration of the ripples).

Few studies were reported under the "bed form" category. The most significant recent development in this field has been the recognition of *sand waves* as a bed form category distinct from that of *dunes* (also called megaripples). In natural environments, these two bed configurations appear to form an heirarchy, with dunes moving over the surface of (larger) sand waves, but there is currently much debate about whether or not the two bed configurations are really distinct, or are only apparently distinct because of flow conditions which change too rapidly for these large-scale features to achieve an equilibrium condition. The data that supports the "equilibrium" interpretation comes mainly from studies of tidal sands, rather than from rivers: the reason for the backwardness of river studies seems to be mainly the difficulty of making observations of bed forms that are always covered by muddy water. G. M. Ashley (UBC) presented an interesting study of a tidal river (the Pitt River) which showed what might be done (in rivers which behave more conventionally) by using the technique of side-scan sonar to map bed-form geometry. Experimental studies of sand waves have been hampered by the small size of the forms that can be made in flumes, as compared with very large sand waves observed in deep natural flows. J. B. Southard and L. A. Boguchwal (MIT) presented a paper on a technique to produce true hydraulic models of bed forms, at a scale reduced by two and a half times from that of natural flows, by using water heated to temperatures of about 70°C. A large hot water flume of unique design (flow is driven by a giant paddle wheel) is presently under construction and should allow some very important observations to be made on large bed forms in the near future.

Two evening sessions were devoted to "large scale bed forms in shallow rivers", but unfortunately degenerated into rather long-winded and fruitless discussions about the nomenclature of bars in braided streams. Undoubtedly some agreement on nomenclature is necessary (there are now some 30 different terms that have been used to describe fluvial bars) but it seems unlikely to be forthcoming until the origin of bed forms and bars is better understood, or at the least, until sedimentologist and geomorphologists interested in these phenomena have met together rather more frequently than they have in the past.

The second day began with a few miscellaneous papers on processes operating in some modern rivers, and then settled down to a series of solid descriptions and interpretations of ancient examples: P. F. Friend (Cambridge) and C. Puigdefabregas and A. van Vliet (Leiden U.; Shell, Rijswijk, the Netherlands) described interesting exhumed meandering channel deposits in the Miocene of the Ebro Basin, Spain; M. R. Leeder and M. Nami (U. of Leeds) described Jurassic braided and meandering river deposits, well exposed on the east coast of Yorkshire; R. J. Steel and S. M. Aashein (U. of Bergen) described flood-generated cyclic sandstone units in a small, but immensely thick intermontane basin fill, in the Devonian of Norway; and A. P. Heward (Oxford) also described cyclic sequences and megasequences deposited by humid alluvial fan systems in Carboniferous basins in the Cantabrian Mountains of northern Spain. Other contributions ranged from the Canadian arctic and maritime provinces, to as far afield as the Karoo of South Africa, the molasse of the modern Himalayas, and the hominid bearing fluvial and lacustrine deposits of Lake Turkana (L. Rudolf) of Kenya. This session, more than any other, justified the international pretentions of the conference. The succession of case histories, though many of them were fascinating examples of the art of facies interpretation and the reconstruction of ancient sedimentary basins, began to weary the listener by the end of the day, and to prepare him for a session of speculative models that might make sense of the strange mixture of diversity and order so often exemplified by the stratigraphic record.

The models, when they finally arrived on the morning of the third day, were something of a disappointment. Most progress has been made in the study of braided streams: the work on braided outwash in Alaska and Iceland (J. C. Boothroyd and D. Nummedal, U. of Rhode Island and U. of South Carolina), and in both the modern and Devonian fluvial sediments of Canada (B. Rust, U. of Ottawa; D. J. Cant, McMaster U.) has led to a much greater discernment of order in the chaos of braided river deposits than was thought possible only a few years ago (for details, see R. G. Walker, *Geosci. Can.*,v.3, p. 101-109; and A. D. Miall, *Earth Sci. Rev.*, v.13, p. 1-62).

At the same time as one group of workers has been building up a model (or group of models) for braided rivers, another group - and most notably R. G. Jackson, II (Northwestern U.) - has been tearing down the "established" model for meandering streams. The result was a strange mixture of optimism, scepticism, and ultimately, bewilderment that pervaded the morning session.

The last afternoon was mainly devoted to a series of papers refining the now "classic" methods of paleohydraulic interpretation, based on the reconstructed hydraulic geometry and sediment characteristics of ancient streams, combined with purely statistical data for a group of modern streams (mainly in the southwest U.S.). These methods, pioneered by S. Schumm (Colorado State U.), appear to give quite detailed and plausible estimates of the discharge, slope, etc., of ancient rivers, though the accuracy of the estimates is not yet established.

Addresses by distinguished students of ancient and modern rivers - J. R. L. Allen and L. B. Leopold - opened and closed the conference. One may conclude that the present state of fluvial sedimentology is one of vigourous but unco-ordinated activity. Sedimentologists are clearly gearing up for a new phase of investigations, in which field observations of river flow will be carried out as carefully as the observations of the sedimentary deposits. In the past, there has been little contact between hydraulic engineers, geomorphologists and sedimentologists. In the mid 1960s most sedimentologists were barely able to understand the simplest jargon of the engineers. The Calgary conference made it clear that those days are past: sedimentologists, geomorphologists and engineers are now all speaking the same language, though they are far from all saying the same things. Cooperative multidisciplinary projects are still practically nonexistent and there is still no comprehensive hydraulic, sedimentological and geomorphological study of even a small modern river system. In the future, the type of simplified theoretical model that has served sedimentologists so well for the last 15 years must be replaced by models based on integrated field studies of modern rivers. The many studies of ancient fluvial sequences show that there *is* an order to fluvial processes; but at our present state of knowledge, one can only say that it would hardly be possible to guess at the existence of this order from what is known about modern rivers.

MS received November 22, 1977

Note. On the day preceding the conference, a series of lectures on fluvial sedimentology was presented by N. D. Smith, J. Collinson, A. D. Miall, J. R. L. Allen, R. G. Walker, D. K. Hobday, and J. C. Horne and R. S. Saxena. This series, which was attended by about 300 geologists, was presented in order to make available to a wider audience than those attending the conference itself, the highlights of recent sedimentological studies of fluvial sediments. A book of notes, softbound and 111 pages in length, that was prepared by A. D. Miall to accompany these lectures, is available from: Stacs Data Services Ltd., 801-10th Avenue SW., Calgary, Alberta T2R 0B4, Price $6.00 (plus $2.00 for postage and handling).