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THE CHANNEL SHAPE—GRAIN SIZE RELATION IN EASTERN AUSTRALIA AND SOME PALEOHYDROLOGIC IMPLICATIONS

S.J. RILEY

School of Earth Sciences, Macquarie University, North Ryde (Australia)

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ABSTRACT

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The relation $F = 255\ M^{-1.08}$ does not hold for clay-bedded streams in the Namoi—Gwydir distributary system of eastern Australia. Of the streams studied, only those with mobile beds conform to the relation. The application of the relation in paleohydrologic studies must include investigations of the nature of the paleochannels.

INTRODUCTION

An examination of hydraulic and hydrologic regimes of paleochannels is a vital part of the reconstruction of any fluvially dominated paleoenvironment. From the original channel system only morphometric and sedimentary data are available, hence relations among channel flow, sediment load, morphometry, and sediments developed for contemporary stream systems must be applied in order to define paleochannel regimes.

In any study of past channel conditions using relations derived for present fluvial conditions two assumptions are made which should be tested whenever possible. The first assumption is that the relations derived for contemporary streams can be applied to paleochannels (uniformitarianism) and the second is that the right relation is used if there is a choice. Aspects of the second assumption are the topic of this paper.

The paleohydrology of prior streams in the Riverine Plains of southeastern Australia has been described by means of relations derived for present-day streams. One of these relations is examined in this paper to test whether it is generally applicable to contemporary streams. It will be shown that the relation is not a general one and that it should be used with caution.

THE F—M RELATION

For streams on the Great Plains of the U.S.A. and southeastern Australia Schumm (1960, 1968) obtained a highly significant relation between weighted percentage silt-clay (M) and the width—depth ratio (F):

$$F = 225\ M^{-1.08}$$

This relation was then used to estimate sediment load and discharge (Schumm, 1972), M being an index of sediment load.

The weighted percentage silt-clay variable is defined by:

$$M = \frac{wSc_{\mathrm{B}} + 2\ dSc_{\mathrm{b}}}{w + 2\ d}$$

where w and d are bankfull width and depth respectively, and Sc_{B} and Sc_{b} are the respective silt-clay percentages in the bed and banks.

The F—M relation was criticized by Melton (1961), who indicated that M is a function of F, that is:

$$M = \frac{FSc_{\mathrm{B}} + 2\ Sc_{\mathrm{b}}}{F + 2}$$

This functional relation between F and M imposes a bias on the correlation between F and M (a spurious correlation, Benson, 1965). In his reply to Melton's criticism Schumm (1961) indicated that the weighting procedure is logical because it reproduces the percentage silt-clay in a composite sample taken from the channel bed and banks. However, it is difficult to justify theoretically the linear weighting or the fact that the weighting is linear.

Schumm's regression between percentage silt-clay in the bed and banks and channel shape is:

$$F = \frac{246}{Sc_{\mathrm{B}}^{0.5} Sc_{\mathrm{b}}^{0.3}}$$

the correlation coefficient ($r = 0.74$) being significantly less than the correlation coefficient of F regressed on M ($r = 0.91$). Multicollinearity between the percentage silt-clay in the bed and banks suggests that the regression of Sc_{B} and Sc_{b} on F is not as significant as it may appear.

A TEST OF THE F—M RELATION

The general applicability of the F—M relation was tested in the Namoi—Gwydir distributary system of eastern Australia (Fig. 1). The system is composed of streams that have a wide range in sediment loads and channel shapes. Streams are in equilibrium with their floodplains although some streams in the eastern area of the system may be aggrading.

Sixty-five stream sites were randomly selected throughout the system and, at each site, the cross-sectional profile was surveyed and three sediment sam-

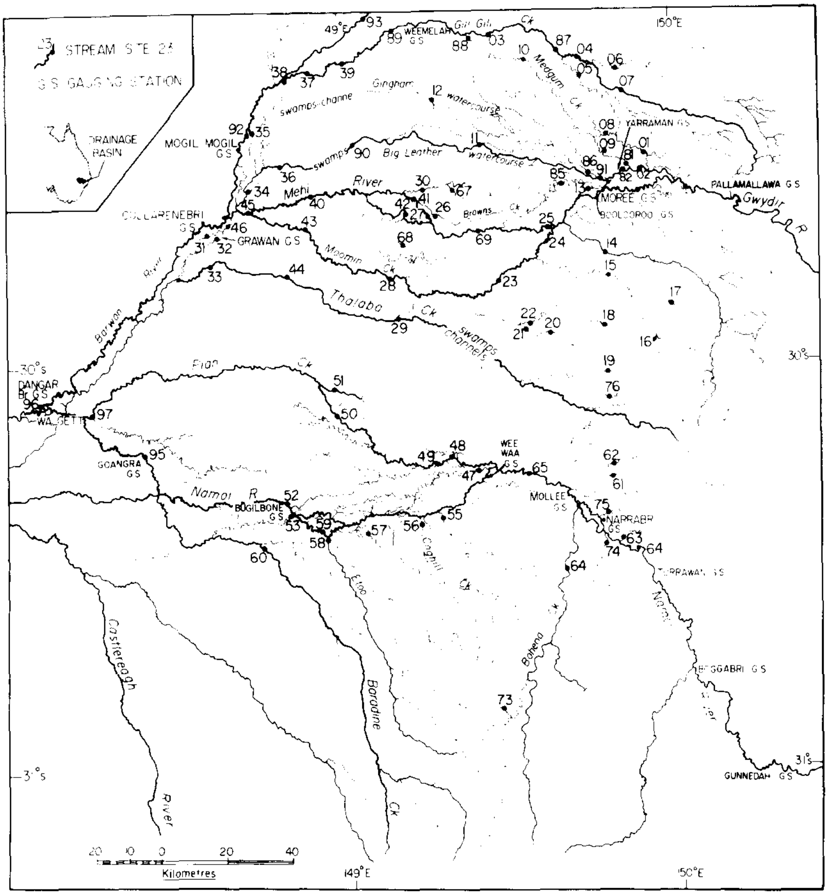

Fig. 1. The Namoi—Gwydir distributary system. The first 65 stream sites were sampled for the present study.

ples taken, one from the bed and one from each bank. The bankfull stage was estimated by means of the bench index (Riley, 1972), and the percentage silt-clay determined by dispersing a 50-g sample and wet sieving out the fraction finer than 64 μm. The bank silt-clay percentage is an average of the percentages of the two bank samples.

In general the Namoi—Gwydir data do not conform to the Schumm relation (Fig. 2), and the correlation between F and M for the Namoi—Gwydir system is not significant ($r = -0.16$).

Clay-bedded streams deviate significantly from the line while streams that have beds of non-cohesive sediments closely conform. The nature of bed sediments appears to be the controlling factor in whether a stream site conforms to the regression relation, while the bank sediments appear to have little control. Streams that may be aggrading conform to the line if they have non-cohesive beds.

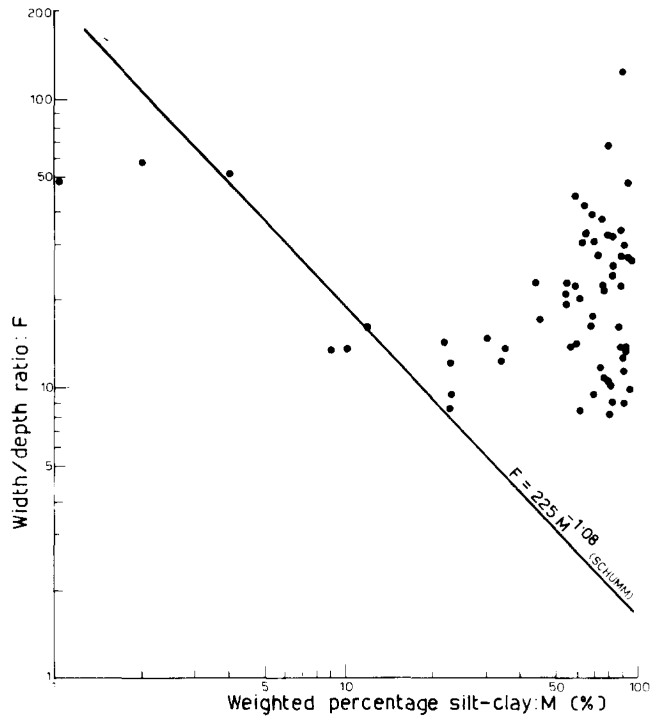

Fig. 2. The weighted percentage silt-clay/width-depth ratio relation compared with F and M values of stream sites in the Namoi—Gwydir distributary system.

DISCUSSION

Stream sites with non-cohesive bed material lie close to the regression line $F = 255\ M^{-1.08}$, probably because non-cohesive bed sediments facilitate the undermining of cohesive banks and the corrasion of their beds. There are three possible reasons for the F—M relation being non-significant in the case of the Namoi—Gwydir system. Firstly, the variable F may be an inaccurate measure of channel shape as a number of channel shapes can have the same value of F and many channel cross-sections with differing channel shapes may have identical sediment characteristics. Secondly, Schumm (1961a, p. 24) claims that F and M values of aggrading streams will plot above his regression line. However, even those streams that are not aggrading, e.g. those in the west, plot above the regression line. Also, some of the aggrading streams, for example the Gwydir River (stream site 02) fail to deviate from the regression line. Thirdly, the cohesive bed sediments may alter the hydraulic assumptions implicit in Schumm's equation. Schumm (1961a) noted that streams with gravel beds did not conform to his regression line. If the bed sediments are cohesive, then channel shape is not related to bed sediments only. That is, the relative shear strength of bed and bank sediments, in conjunction with flow regime, determines channel width. The channels with cohesive bed sediments are wider than those with non-cohesive bed sediments, and their plotted F and M values lie above the regression line.

The critical aspect of the F—M relation is that the stream must be in a live-bed condition; that is, transporting a bed-load. Streams with clay beds or armoured with gravel will not conform to the relation. In any particular paleochannel where the banks and bed were composed of clay and the channel subsequently became infilled with sand, the problem that must be solved before the F—M relation can be used is one of deciding whether the stream was in equilibrium when it transported the sand near the bed. Clay-bounded paleochannels which did not transport sand will probably not fit the relation. If the stream was aggrading the relation may or may not apply, although Schumm suggests that in an aggrading context the relation does not apply.

On large alluvial plains where there has been a complex history of aggradation and degradation, the F—M relation must be used with some caution. Paleochannels must be shown to have been in a live-bed condition and in some form of equilibrium with their floodplains before changes occurred to the channels. The cross-sections that are examined must be shown to be part of the equilibrium channel cross-section and not part of the aggrading channel. The F—M relation may apply to live-bed aggrading channels, although more research into the nature of the F—M relation is required before the relation can be confidently applied to aggrading channel systems.

CONCLUSION

The weighted percentage silt-clay/width-depth ratio relation, $F = 255\ M^{-1.08}$ does not apply to all streams, particularly those that have non-mobile beds. The implication of this non-conformity is that the relation cannot be applied to paleohydraulic interpretation without some risk of inaccuracy. Other relations among sediment, discharge, and morphometry must be used in conjunction with the F—M relation in order to interpret paleochannels with some degree of certainty.

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REFERENCE

Benson, M.A., 1965. Spurious correlations in hydraulics and hydrology. J. Hydraul. Div. Am. Soc. Civ. Eng., 91 (HY4): 35—42.

Melton, M.A., 1961. Discussion on 'The effect of sediment on the shape and stratification of some modern fluvial deposits'. Am. J. Sci., 259: 231—233.

Riley, S.J., 1972. A comparison of morphometric measures of bankfull. J. Hydrol., 17: 23—31.
Schumm, S.A., 1960. The effect of sediment type on the shape and classification of some modern fluvial deposits. Am. J. Sci., 258: 177—184.
Schumm, S.A., 1961a. Effect of sediment characteristics on erosion and deposition in ephemeral stream channels. U.S. Geol. Surv. Prof. Pap., 352-C: 31—70.
Schumm, S.A., 1961b. The effect of sediment type on the shape and stratification of some modern fluvial deposits — a reply. Am. J. Sci., 259: 234—239.
Schumm, S.A., 1968. River adjustment to altered hydrologic regime — Murrumbidgee River and paleochannels, Australia. U.S. Geol. Surv. Prof. Pap., 598: 65 pp.
Schumm, S.A., 1972. Fluvial paleochannels. In: J.K. Rigby and W.K. Hamblin (Editors), Recognition of Ancient Sedimentary Environments. Soc. Econ. Paleontol. Mineral. Spec. Publ., 16: 98—107.