[1] Hamilton, E. L., *Geol. Soc. Amer. Bull.*, **70**, 405 (1959).
[2] Richards, A. F., *US Hydrographic Office Tech. Rept.*, 63 (1961).
[3] Richards, A. F., *US Hydrographic Office Rept.* 106 (1962).
[4] Moore, D. G., *Geol. Soc. Amer. Bull.*, **73**, 1163 (1962).
[5] Emiliani, C., *J. Geol.*, **74**, 109 (1966).
[6] Cadling, L., and Oderstad, S., *Roy. Swed. Geotech. Inst. Proc.*, **2** (1950).
[7] Terzaghi, K., and Peck, R. B., *Soil Mechanics in Engineering Practice*, second edition (Wiley, New York, 1967).
[8] Taylor, D. W., *Fundamentals of Soil Mechanics*, 700 (Wiley, New York, 1948).
[9] Emiliani, C., *Aspects of Deep Sea Research*, NAS-NRC Publication, 473 (1957).
[10] Emiliani, C., *Scient. Amer.*, February (1958).
[11] Emiliani, C., *Science*, **154**, 851 (1966).
[12] Bowen, R., *Palaeotemperature Analysis*, 265 (Elsevier, Amsterdam, 1966).
[13] Trask, P. D., and Close, J. E. H., *Proc. Sixth Conf. Coastal Engineering*, 827 (1958).
[14] Trask, P. D., *Bull. Geol. Soc. Amer.*, **70**, 569 (1959).
[15] Bennett, R. H., Keller, G. H., and Busby, R., *J. Sed. Pet.*, **40**, 1038 (1970).

Late-stage Meander Growth

MEANDER plan-forms have usefully been characterized by sine-generated curves[1], with path lengths increasing as the meander develops until relatively stable smooth curves are achieved or until neck or chute cutoffs intervene[2]. Observation of gravel-bed rivers in Wales suggests that such symmetrical forms are less common, and that the later stages of meander development can involve more complex geometry.

It is well known that channel bars and intervening pools may be evenly spaced, and related to channel dimension and formative discharges, but it is also often maintained that "riffles" can be identified with cross-over points between meander bends, with the pools to be found on outer bends[3]. Path length increase can mean that the thalweg distance between cross-over points increases, so that if the simple relationship between bar spacing and channel dimension is maintained, an increasing number of bars must be accommodated within a meander loop. My observations confirm that this does in fact happen; three- or four-pool loops between cross-overs on smooth meanders have been reported[4,5]; Keller also has presented confirmatory evidence[6]. Such an occurrence can cause not only distortion but also dismemberment of the meander plan-form.

Fig. 1*A* and *B* shows meanders, bars and riffles on the River Rheidol at Lovesgrove (SN 6280) in 1951 and 1971. The low-flow channel shown here is irregular in width and dependent on bedform at all but the highest flows, but approximately even spacing of riffles is maintained on both occasions, despite growth of one meander loop and the artificial cutoff and re-development of another. It is worth noting that "riffle" can be a rather imprecise term: in this instance, the low-water riffles are either upstream tails of lobate gravel bars, or low points on diagonal bars further dissected at low flows, to use Allen's 1968 bedform terminology[7]. I have not found Keller's riffles and skew shoals to be temporally and spatially distinct, nor his 5-stage model based on their relative size and dominance to be generally applicable to the gravel rivers I have studied. On the Rheidol, three pools occur on the 1971 westerly meander loop, and the single loop is beginning to subdivide. In fact, the channel had already done so to a greater extent, but was artificially reconstructed to a single curve of trapezoidal cross-section, which it once more started to distort. The process is continuing. Further examples can be found on other Welsh rivers: growth of a section of the Tywi is illustrated in Fig. 1*C*, in which the single loop of 1886 has developed into the more complex figure of 1971. Apparently, however, the development of multiple bars within meander loops does not always lead to plan distortion in this way.

Both the dynamics and the occurrence of this phenomenon require further investigation. That the pattern is unusual may be explained in a number of ways. Rates of expansion in individual meander loops may decrease with time[8], and path lengths may stabilize once energy dissipation becomes

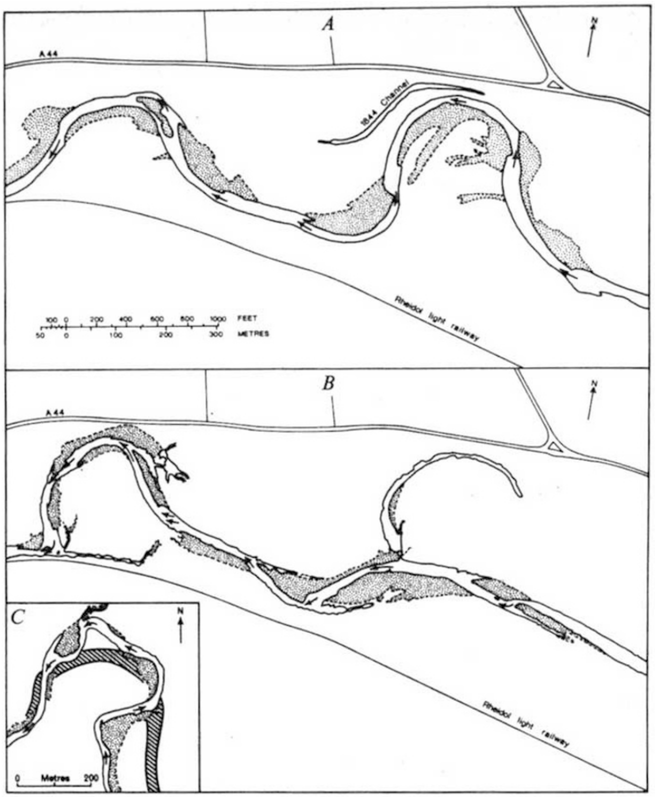

Fig. 1 Changes in course of two Welsh rivers. *A*, Course of the Rheidol; October 1951. *B*, Course of the Rheidol, June 1971. *C*, Courses of the Tywi in 1886 (□) and in 1971 (=). □, Unvegetated gravel. ←, Riffles. ≈, River courses.

uniform[1,2]; lateral restriction by relatively inerodible valley sides and greater rates of downvalley translation also appear more dominant in the areas I have studied. But these observations do suggest a further way in which meander plan-forms may be related to the development of periodic bedforms that is not generally recognized.

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[1] Langbein, W. B., and Leopold, L. B., *US Geol. Survey Prof. Paper*, 282-D (1966).
[2] Daniel, J. F., *US Geol. Survey Prof. Paper*, 732-A (1971).
[3] Dury, G. H., in *Water, Earth and Man* (edit. by Chorley, R. J.), 419 (Methuen, London, 1969).
[4] Kondrat'yev, N. Ye., *Sov. Hydrol.*, **4**, 309 (1968).
[5] Konditerova, E. A., and Popov, I. V., *Sov. Hydrol.*, **4**, 516 (1968).
[6] Keller, E. A., *Bull. Geol. Soc. Amer.*, **83**, 1531 (1972).
[7] Allen, J. R. L., *Geol. en Mijn*, **43**, 173 (1968).
[8] Handy, R. L., *Bull. Geol. Soc. Amer.*, **83**, 475 (1972).

Electron Spectra of Oxide Films on Pure Iron and an Iron-Aluminium Alloy

WE have examined oxide films on iron and on iron alloys containing small amounts of aluminium by X-ray photoelectron spectroscopy (XPS). This technique involves the direct measurement of the binding energies of electrons in the inner shells of the atoms, allowing both the nature of the atom and, through the "chemical shift", its chemical environment to be investigated. Only a thin surface layer (up to approximately