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Discussion: Landscape evolution and tectonics in southeastern Australia (Ollier & Pain 1994)

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"It's as good as any of the other stories"

Answer of a senior Australian geoscientist (neither Ollier nor Pain) when asked by Bishop whether the geoscientist 'believed' his own interpretation of the history of the southeastern Australian highlands

Introduction

Ollier & Pain (1994) make many points that have already been disputed in various fora, and I do not seek to continue here the sometimes acrimonious debate and polarisation of 'camps' that have developed in research on southeast Australian regional tectonics and drainage history. My aim is rather to explore some more general aspects of the research in these geographical and conceptual areas and to use this context to question some of Ollier & Pain's conclusions. I begin with some broader issues, and then address some particular points that I feel require clarification in relation to the broader issues.

Historical geoscience

Two general issues raised by Ollier & Pain's paper concern the objectives of *historical* geoscience and the nature of the evidence it uses. The quotation at the head of this discussion highlights a view of the task in historical geoscience, namely, to tell stories about the Earth. Baker (1994) defined the task more rigorously. The geoscientist's central task, Baker noted, consists of three principal concerns: "inspiration from natural phenomena in their real-world settings, the invention of hypotheses to explain those phenomena, and the creative application of quantitative measurement to test them" (p. 1414). The third task, the testing of our hypotheses, is the critical one for the present discussion. The quotation at the head of this discussion highlights the possibility that it may be difficult to formulate appropriate tests of our hypotheses, even suggesting that we may never be able to choose between competing 'stories' (interpretations). In other words, even though most geoscientists concerned with understanding Earth history would almost certainly claim that they want to know what 'actually went on', this may be very difficult because it may not be possible to devise adequate tests to decide between competing hypotheses of Earth history.

This difficulty may be especially problematic for landscape development: how do we address the methodological issue that erosional development of landscapes involves the removal (denudation) of that landscape (that is, destruction of substantial parts of the evidence)? Thus, even though it is now generally acknowledged that scientific endeavour advances by some form of hypothesis formulation and testing (the hypothetico-deductive method), and that the geosciences aspire to use the same methodology (cf. Haines-Young & Petch 1986; Baker 1994; and book reviews by Karl Wolf over the last three years in *The Australian Geologist* (nos 82–84)), the development of adequate tests for hypotheses of landscape evolution remains methodologically difficult. This difficulty does not relate to the Popperian notion of devising falsifiable hypotheses (cf. my rather simplistic treatment of the Davisian cycle in these terms (Bishop 1980)), but to the derivation of *any* tests that enable adequate evaluation of hypotheses, by either refutation or confirmation.

Ollier & Pain's interpretation is but one *hypothesis* for the evolution of southeast Australia. It should be clearly identified as such. Their use throughout the paper of firm, unequivocal statements, such as, for example, "In the Mesozoic, … [t]he upper Murray and Murrumbidgee united in a major stream flowing north to … the Surat Basin" (p. 341), is inappropriate. Quite simply, we do not know that this is the case. I am not suggesting that it is not the case, but simply that their 'story' is one of several possible 'stories' concerning the evolution of these river systems.

The foregoing is not meant to imply that the generation of hypotheses concerning regional Earth history is in some way inappropriate. Indeed, Ollier has been one of the most prolific generators of such hypotheses, thereby providing a framework for other studies. But this does not change the reality that they are hypotheses. Ollier & Pain should acknowledge this throughout and seek evidence to test their hypotheses.

The Tasman Divide

The Tasman Divide is Ollier & Pain's name for a proposed continental drainage divide that they suggest lay east ('offshore') of the present Tasman continental margin in the Mesozoic (before rifting, breakup and the formation of the Tasman Sea). Before breakup, they claim, this divide formed the watershed for westerly drainage to the Eromanga–Surat Basin. During rifting and breakup, the headwaters of these rivers were supposedly "cut off" (p. 335) and, after breakup, drainage rearrangement (via capture and diversion) is claimed to be responsible for westerly movement of the divide to its present position. This interpretation integrates into a plate tectonics framework the drainage history first proposed by Taylor (1911).

No one would dispute that the Eromanga–Surat Basin received sediment from the east during the Mesozoic. The untested part of their hypothesis is whether the headwaters of the systems that drained to the basin were east of the present continental divide (indeed, east of the present Tasman continental margin) and that they were subsequently beheaded during rifting and breakup, with ensuing westward migration of the divide. It is fair to say that Ollier and Pain present no evidence for their interpretation of the drainage rearrangement, apart from river patterns, which many researchers are certainly uncomfortable in interpreting in the way that Taylor (1911) did and that Ollier & Pain do (e.g. Browne 1921; Craft 1931a–d, 1932a, b; Young 1977, 1978; Bishop 1982, 1986; Nott 1992). This point is not made to polarise the debate further, but simply to note that there is long-standing dissatisfaction with the use of barbed drainage and boathook bends as support for the hypothesis of major drainage rearrangement in eastern New South Wales.

It is worth emphasising in passing that palaeocurrent and provenance studies in sedimentary basins establish drainage directions and basin–hinterland relationships in a general way only. Rarely, if ever, do the provenance and palaeocurrent studies reveal the locations of former bedrock channel systems in the way that Ollier & Pain have implied in relating the

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Eromanga–Surat Basin data and the drainage systems of eastern New South Wales. The only exception to this is perhaps in the hinterland–basin transition zone, where ancient bedrock channels may be preserved as bedrock valleys filled with later sediment (e.g. the Early Tertiary bedrock valleys of the Lachlan and Murrumbidgee Rivers at the edge of the Murray Basin—Woolley 1978). Thus, Cleaves (1989) presented several drainage diagrams for the Appalachians for the Late Palaeozoic onwards, but, where major rearrangements of drainage are suggested (e.g. Cleaves' Early Cretaceous Phoenix River), the detailed locations and lines of these palaeochannels are "hypothetical", and they are explicitly not hypothesised on the basis of being subsequently captured precursors of modern drainage lines.

The history of the supposed Tasman Divide relates to the style of continental margin evolution (Bishop 1986), as well as to the traditional geomorphological questions of denudational chronology and landscape evolution. Ollier & Pain's abstract clearly suggests that the divide migrated inland (westwards) during, and subsequent to, rifting and breakup. Other models for the development of the Tasman margin (e.g. Lister et al. 1986) just as clearly incorporate a continental divide close to its present position during rifting and breakup, an interpretation consistent with the deep crustal structure beneath the drainage divide (Young 1989).

It seems premature, therefore, to state unequivocally that the present highlands river systems, east of the continental divide, are 'descendants' of ancient rivers that formerly drained in the opposite direction, inland to the interior basins. Ollier & Pain's hypothesis that the Jurassic Pilliga Sandstone is the result of inland drainage of the Sydney Basin (p. 341) is not demanded by the evidence; indeed, palaeocurrent evidence (Conaghan et al. 1982) seems to refute it. The source area of the Pilliga Sandstone could be the present highlands, without any necessity for the drainage reversals implied by Ollier & Pain's hypothesis (cf. Arditto 1982). Indeed, there may be equal or greater justification for the hypothesis that some of the east-flowing systems (e.g. the Shoalhaven and Wollondilly–Hawkesbury Rivers) are 'descendants' of the east-flowing Mesozoic river which delivered sediment to the Sydney Basin from the area of the present divide in Middle Triassic times, an interpretation first suggested by Frank Craft in the 1930s (see Young 1978 and Bishop, 1982 for a discussion of Craft's (1931a–d, 1932a, b) contribution). This interpretation is consistent with Sydney Basin palaeocurrent data and models showing Sydney Basin drainage grossly to the east (Standard 1969; Conaghan et al. 1982). Indeed, Jones & Veevers' (1983) discussion and diagrams clearly acknowledge that their hypothesis of a Mesozoic divide east of the present New South Wales ('Tasman') continental margin, a hypothesis which Ollier & Pain use to support their suggested Tasman Divide, is least well constrained, even problematic, along this very section of the Tasman margin.

Ollier & Pain's discussion of the "reversals of rivers that followed their present course in the early Mesozoic, but in the opposite direction" (p. 341) is problematic for a less obvious reason. It is almost certainly erroneous to seek one-to-one correspondence between modern and ancestral rivers, as do Ollier & Pain in the foregoing quote and in their Figure 8 (despite their assertion that the drainage lines are generalised). It would not be expected that modern drainage lines are necessarily direct 'descendants' of ancient rivers, because significant thicknesses of the crustal section have been eroded since the supposed drainage rearrangements occurred (see Bishop, in press, for a fuller discussion of this and the following points). This eroding crustal section is the "neglected third dimension" that Twidale (1972) urged all researchers of long-term landscape evolution to remember. Its neglect can be particularly problematical in the denudation of substantial thicknesses of faulted and folded crust, such as is found in the southeast Australian highlands (and, incidentally, the Appalachians, the location of many of the classic examples of supposed drainage piracy and associated elbows of capture). If it is accepted that the continental drainage divide and the associated drainage systems in the southeast Australian highlands date from at least the early Tertiary (see references in Ollier & Pain) and that rates of denudation of the highlands are of the order of 5–10 m/Ma (Young 1983; Bishop 1985; Gale 1992), denudation of faulted and folded metasediments and granites to depths of 0.5 km or more has occurred since the divide was emplaced. An older divide implies even deeper denudation. This denudation must have provided manifold opportunities for drainage realignment as denudation proceeded, meaning that simply connecting modern drainage lines to suggest the patterns of formerly continuous rivers is probably not wise. In short, the generally neglected vertical dimension of denudation introduces further uncertainty into drainage line reconstructions at previous (higher) crustal levels.

Conclusion

Ollier & Pain's interpretation of the history of southeastern Australia incorporates many drainage rearrangements, the complexity (and untestability) of which are highlighted by the number and variety of former river connections that have been suggested for the southeast Australian highlands over the last 80 years (see Young 1978, fig. 3 and Bishop 1982, fig. 2). Ollier & Pain's Figure 8 is but the latest in this sequence and equally difficult to test. This variety and complexity of former drainage connections and disruptions east of the present continental divide in southeast Australia may be symptomatic of the shortcomings involved in seeking correspondences between ancient and modern rivers.

Ollier & Pain's dismissal of what they call "small area" studies (p. 335) is unfortunate, because these studies provide the essential testing of hypotheses of regional drainage history and landscape evolution. Their hypotheses should be consistent with these studies, which, in the case of southeast Australia, already cover a considerable part of the region. Of course, Ollier & Pain's laudable objective is to suggest a regional synthesis, which may not be provided by local area studies. Such a synthesis is necessary to provide an overview and total integration of plate margin, drainage and landscape evolution. But the synthesis does not necessarily have to encompass change (i.e. radical drainage rearrangement). Jones's (1976, p. 11) description of the actualistic approach to Earth history is apposite in this context:

> "I take an actualistic approach to be an historical form of the scientific simplicity principle. The simplest and therefore first hypothesis we should adopt is that the past resembled the present, and thus we should use observation and interpretation of the present as fully as we may in reconstruction of the past, and only go beyond it when its capacity to explain is exhausted".

Ollier & Pain have provided one story about regional landscape evolution in southeast Australia. It is not the only one, however. An alternative story, incorporating continuity of drainage systems from the Mesozoic to the present, has considerable support from theory and field studies. It may be less exciting and 'radical' than a story incorporating major drainage rearrangements in response to a supposed sequence of rifting, breakup and formation of new continental margin, but it may just be what 'actually went on'.

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References

Arditto, P.A., 1982. Deposition and diagenesis of the Jurassic Pilliga Sandstone in the southeastern Surat Basin, New South Wales. Journal of the Geological Society of Australia, 29, 191–203.

Baker, V.B., 1994. Book review: Luna B. Leopold, 'A view of the river'. Science, 266, 1414–1415.

Bishop, P., 1980. Popper's principle of falsifiability and the irrefutability of the Davisian cycle. Professional Geographer, 32, 310–315.

Bishop, P., 1982. Stability or change: a review of ideas on ancient drainage in eastern New South Wales. Australian Geographer, 15, 219–230.

Bishop, P., 1985. Southeast Australian late Mesozoic and Cenozoic denudation rates: a test for late Tertiary increases in continental denudation. Geology, 13, 479–482.

Bishop, P., 1986. Horizontal stability of the Australian continental drainage divide in south central New South Wales during the Cainozoic. Australian Journal of Earth Sciences, 33, 295–307.

Bishop, P., in press. Drainage rearrangement by river capture, beheading and diversion. Progress in Physical Geography.

Browne, W.R., 1921. Note on the relation of streams to geological structure, with special reference to boathook bends. Journal of the Royal Society of New South Wales, 55, 52–62.

Cleaves, E.T., 1989. Appalachian Piedmont landscapes from the Permian to the Holocene. Geomorphology, 2, 159–179.

Conaghan, P.J., Jones, J.G., McDonnell, K.L. & Royce, K., 1982. A dynamic model for the Sydney Basin. Journal of the Geological Society of Australia, 29, 55–70.

Craft, F.A., 1931a. The physiography of the Shoalhaven River Valley. I. Tallong–Bungonia. Proceedings of the Linnean Society of New South Wales, 56, 99–132.

Craft, F.A., 1931b. The physiography of the Shoalhaven River Valley. II. Nerrimunga Creek. Proceedings of the Linnean Society of New South Wales, 56, 243–260.

Craft, F.A., 1931c. The physiography of the Shoalhaven River Valley. III. Bulee Ridge. Proceedings of the Linnean Society of New South Wales, 56, 261–265.

Craft, F.A., 1931d. The physiography of the Shoalhaven River Valley. IV. Nerriga. Proceedings of the Linnean Society of New South Wales, 56, 412–430.

Craft, F.A., 1932a. The physiography of the Shoalhaven River Valley. V. The upper valley and stream system. Proceedings of the Linnean Society of New South Wales, 57, 197–212.

Craft, F.A., 1932b. The physiography of the Shoalhaven River Valley. VI. Conclusion. Proceedings of the Linnean Society of New South Wales, 57, 245–260.

Gale, S.J., 1992. Long-term landscape evolution in Australia. Earth Surface Processes and Landforms, 17, 323–343.

Haines-Young, R. & Petch, J., 1986. Physical geography: its nature and methods. Harper & Row, London.

Jones, J.G., 1976. Lachlan Fold Belt: an actualistic approach to environmental/tectonic interpretation. Bulletin of the Australian Society of Exploration Geophysics, 7, 10–12.

Jones, J.G. & Veevers, J.J., 1983. Mesozoic origins and antecedents of Australia's southeast highlands. Journal of the Geological Society of Australia, 29, 1–12.

Lister, G.S., Etheridge, M.A. & Symonds, P.A., 1986. Detachment faulting and the evolution of passive margins. Geology, 14, 246–250.

Nott, J.F., 1992. Long-term drainage evolution in the Shoalhaven catchment, southeast highlands, Australia. Earth Surface Processes and Landforms, 17, 361–374.

Ollier, C.D. & Pain, C.F., 1994. Landscape evolution and tectonics in southeastern Australia. AGSO Journal of Australian Geology & Geophysics, 15, 335–345.

Standard, J.C., 1969. Hawkesbury Sandstone. In: Packham, G.H. (editor), The geology of New South Wales. Journal of the Geological Society of Australia, 16, 407–415.

Taylor, T.G., 1911. A discussion of the salient features in the physiography of eastern Australia. Commonwealth Bureau of Meteorology Bulletin, 8.

Twidale, C.R. 1972: The neglected third dimension. Zeitschrift für Geomorphologie 16, 283–300.

Woolley, D.R. 1978: Cainozoic sedimentation in the Murray drainage basin, New South Wales section. Proceedings of the Royal Society of Victoria 90, 61–65.

Young, R.W., 1977. Landscape development in the Shoalhaven River catchment of southeastern New South Wales. Zeitschrift für Geomorphologie, 21, 262–283.

Young, R.W., 1978. The study of landform evolution in the Sydney region: a review. Australian Geographer, 14, 71–93.

Young, R.W., 1983. The tempo of geomorphological change: evidence from southeastern Australia. Journal of Geology, 91, 221–230.

Young, R.W., 1989. Crustal constraints on the evolution of the continental divide of eastern Australia. Geology, 17, 528–530.