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

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One of the most intriguing and enduring debates in Australian geomorphology this century has centred on the origin and subsequent development of the southeast Australian continental divide and associated drainage patterns. Two principal schools of thought exist: those who advocate that individual drainage lines, and hence the divide, have remained essentially unchanged since at least the early to mid-Tertiary (Young 1977, 1983, 1989; Young & McDougall 1982, 1983, 1985, 1993; Bishop 1988; Bishop et al. 1985; Taylor et al. 1985, 1990; Nott 1992), and those who suggest that the divide has moved westward as stream patterns were reorganised (captured and/or reversed) due to tectonism, whether that be uplift of the highlands or subsidence of the flanking basins (Taylor 1911; Ollier 1978, 1982; Ollier & Taylor 1988; Ollier & Pain 1994).

These differences of opinion have arisen and continue to be perpetuated primarily because of the different methodological approaches adopted by both groups; those advocating stability base their arguments on evidence acquired from detailed field studies of generally quite large, individual stream catchments, whereas those proposing drainage disturbance rely not so much on detailed field evidence, but primarily on the recognition of so-called irregularities of stream plan form, such as 'boat-hook bends' and 'barbed drainage', and the apparent alignment of streams either side of the continental divide. Ollier & Pain (1994), members of the latter group, have suggested that the two points of view are not necessarily in conflict, because the field evidence supporting divide and drainage stability really accounts only for the post middle Tertiary geomorphological evolution of the region and is of little consequence if, as they suggest, divide migration and drainage reorganisation occurred before this time. However, such a view conveniently continues to ignore much of the published field evidence whilst perpetuating the divergence of methodological approaches.

In their paper, Ollier & Pain (1994) use the lower Shoalhaven River and its tributaries as their type example for a model which attempts to identify and explain the characteristics, particularly the development of gorges, of a reversed river along the east coast. However, considerable published field evidence exists to show that the Shoalhaven River was not reversed, but has maintained its present course since at least the early Tertiary and, most certainly, before the development of gorges across the upland plateau or palaeoplain. Published field evidence also exists showing that the coastal plain in this region developed through erosional retreat of the eastern escarpment and not by down-warping of the upland plateau or palaeoplain. Such evidence strongly contradicts the proposed geomorphic evolution of this region as outlined by Ollier & Pain. It is the purpose of this discussion to outline this evidence from the Shoalhaven catchment and its environs.

Ollier & Pain suggested that, before its reversal, the lower Shoalhaven River flowed westward to the upper Wollondilly River and thence to the Lachlan River. Gentle downwarping of the highlands to the east is suggested by these authors to have caused the Shoalhaven's reversal, so that its downstream tract, east of the Tallong bend, now flows to the Tasman Sea. Surprisingly, Ollier & Pain (p. 340) have given a maximum age for this downwarping, for they state that

> "... the evidence of silcretes, basalts and lateritic weathering quoted by Young and McDougall (1983) in support of no tectonic movement at all neglects the fact that no occurrence of these materials has been found near the base of the Great Escarpment. All are tens of kilometres to the east, which is in agreement with the present hypothesis that the palaeoplain, complete with its silcretes, basalts, and lateritic weathering profiles, was gently down-warped to the east."

This is indeed a remarkable statement to issue, for Ollier & Pain are clearly implying here that the basalts on the coastal lowland were originally extruded onto the upland plateau or palaeoplain. Given that these basalts are mid-Oligocene in age and those on the present upland plateau are Eocene to mid-Oligocene, the downwarping of these basalts to their present position at and near present sea-level must therefore, according to Ollier & Pain's argument, have occurred after the mid-Oligocene.

Here lies an outstandingly clear example of the divergence of the two methodologies mentioned earlier, for Young & McDougall (1982, 1983) clearly demonstrated that the mid-Oligocene basalts on the coastal plain near Ulladulla were extruded onto the lower parts of the Permian Snapper Point Formation, not tens of kilometres from the base of the great escarpment, as Ollier & Pain advocate, but only about five kilometres from the escarpment's base. The basalts on the 600 m high upland plateau or palaeoplain, however, were extruded onto the Permian Nowra Sandstone, which is 300 m stratigraphically above the Snapper Point Formation, of which approximately 200 m had been removed before extrusion of the mid-Oligocene basalts on the coastal plain. These obvious stratigraphic relationships show that there must have been approximately 500 m of overlying Permian strata removed before the basalts on the coastal plain were extruded; the basalts on the coastal plain, therefore, could not have been extruded originally onto the palaeoplain. Hence, erosion of all, except possibly a 5 km wide strip, of the coastal plain in this region must have occurred before the mid-Oligocene, which predates Ollier & Pain's suggested time for downwarping of the palaeoplain. Moreover, further south, near Mount Dromedary, Nott & Purvis (1995) have suggested that the coastal plain may be older than 100 Ma, based on the presence of lavas of at least this age near sea-level, and Bird & Chivas (1993) have argued, based upon the ^{18}O values of ancient regolith, that the southeast highlands were in existence before the Late Mesozoic. By the same token, Young (1989) has suggested that the close spatial association between strongly negative Bouguer anomalies and the Great Divide indicates the highland's ancient heritage and stability. Taken together, these various forms of evidence strongly contradict Ollier & Pain's assertion that the eastern portion of the highlands in the Shoalhaven region was downwarped after basalt extrusion across the palaeoplain.

In presenting their argument, Ollier & Pain also failed to address the evidence presented by Young (1977) and Young & McDougall (1982, 1983), which highlights that the 20° northeasterly dip of the Permian strata of the lower Shoalhaven catchment is syn-depositional, not post-depositional, for the overlying Triassic Hawkesbury Sandstone, immediately to the north, remains horizontal. As Craft (1932) pointed out over 60 years ago, any tectonic warping of the highlands in this

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region should be reflected in the dips of the Sydney Basin strata. Indeed, this is the case, but this warping clearly occurred before the Triassic, not during the Tertiary as Ollier & Pain suggest.

The structural contours of the Permian and Triassic strata of the lower Shoalhaven catchment also provide a ready explanation for the so-called irregularities of the drainage patterns in this area. As pointed out by Young (1977), the lower Shoalhaven River, from the Tallong bend eastward, flows down-dip across the Nowra Sandstone, and the Kangaroo River, a northern tributary, joins the Shoalhaven at an acute angle simply because it flows down the southwesterly dip of the Hawkesbury Sandstone. The supposed evidence for prior westerly drainage here—the 'barbed drainage' junction of the Kangaroo and Shoalhaven Rivers and the 'boat-hook bend' near Tallong—is really structurally controlled drainage patterns.

That the Shoalhaven River has always flowed around the Tallong bend towards the east is a difficult hypothesis to disprove. Nott (1992) showed that sediments, now silicified and lying on the plateau surface beside the present-day Shoalhaven Gorge, parallel the course of the river around the Tallong bend towards the east. These sediments, estimated to be at least Early Tertiary in age and most certainly pre-Eocene, were deposited before excavation of the Shoalhaven Gorge and show clearly that the lower Shoalhaven River flowed in this direction before formation of the gorge. Completely ignoring this field evidence, however, Ollier & Pain (p. 340) specifically state that the "gorges" of the lower Shoalhaven and its southern tributaries were in existence before down-warping of the upland plateau or palaeoplain towards the east, which, as mentioned, was suggested by them to have occurred after the mid-Oligocene. These supposedly antecedent gorges, therefore, would have developed in the upper reaches of the then supposedly westward-flowing Shoalhaven River. Of course, as gorges develop through headward retreat of nick-points or steeper gradient reaches, these gorges could only have developed after gorges first developed further downstream, i.e. between the present Wollondilly and Shoalhaven Rivers. Nott (1992) has demonstrated that before basalt damming of the Shoalhaven River at 30 Ma the bed of the Shoalhaven Gorge at the Tallong bend lay approximately 100–120 m below the plateau surface. The same was true during outpouring of Eocene basalts into the tributary Endrick River further upstream (Young 1977), which clearly predates Ollier & Pain's suggested time of downwarping and river reversal. Therefore, if the drainage reversal hypothesis is correct, there should exist a gorge or sediment-filled palaeo-valley of at least this depth and, presumably, much deeper, marking the course of the former westward-flowing Shoalhaven River between its present position and the present Wollondilly River. No such feature exists! The palaeo-valley of the Shoalhaven River during the Eocene and Oligocene has been unequivocally shown to have followed close to its present course from at least Braidwood to well downstream of Tallong (Nott 1992).

Instead of addressing the previously published evidence on the long-term drainage patterns of the Shoalhaven and its tributaries, Ollier & Pain present a model suggesting that antecedent gorges will parallel the contours of a down-warped surface and that this is evidence for antecedence. They then present a map (p. 341, fig. 7D) supposedly demonstrating this for the incised southern tributaries of the lower Shoalhaven River. However, as shown on their map the majority of these streams actually cross the contours, not parallel them and, as shown by Young (1977, p. 269, fig. 3), these tributaries run down-dip, crossing the structural contours of the Nowra Sandstone. If these tributaries were antecedent and originally joined a westward-flowing lower Shoalhaven River, their junctions with the Shoalhaven could be seen to be barbed, indicating, according to Ollier & Pain's hypothesis, that the lower Shoalhaven must have flowed east before it flowed west, prior to taking on its present easterly course. Such a scenario is very much at odds with the detailed field evidence which has been recognised within the lower Shoalhaven catchment.

The Shoalhaven River figures prominently in Ollier & Pain's account of the landscape evolution of southeast Australia. Yet, as highlighted in this discussion, these authors neglected to mention and take into account a substantial volume of published field evidence which strongly contradicts their view of the geomorphological development of the Shoalhaven region. The evidence shows clearly that the Shoalhaven River flowed east, following close to its present course, when Ollier & Pain, without any firm field evidence, suggest that the Shoalhaven River flowed westward. Any hypothesis advocating widespread reversal of east coast streams throughout southeast Australia should acknowledge this situation and attempt to explain why the Shoalhaven River, being one of the major streams of the region, flowed eastwards as it does today, whilst all other streams supposedly flowed west. Hypotheses like that proposed by Ollier & Pain cannot, after all, be verified until they have been thoroughly tested against field evidence.

References

Bird, M.I. & Chivas, A.R., 1993. Geomorphic and palaeoclimatic implications of an oxygen-isotope chronology for Australian deeply weathered profiles. Australian Journal of Earth Sciences, 40, 345–358.

Bishop, P., 1988. The eastern highlands of Australia. Progress in Physical Geography, 12, 159–182.

Bishop, P., Young, R. W. & McDougall, I., 1985. Stream profile change and longterm landscape evolution: Early Miocene and modern rivers of the east Australian highland crest, central New South Wales, Australia, Journal of Geology, 93, 455–474.

Craft, F.A., 1932. Physiography of the Shoalhaven River valley: conclusion. Proceedings of the Linnean Society of New South Wales, 57, 245–260.

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

Nott, J.F. & Purvis, A.C., 1995. Geomorphic and tectonic significance of early Cretaceous lavas on the coastal plain, southern New South Wales. Australian Journal of Earth Sciences, 42, 145–149.

Ollier, C.D., 1978. Tectonics and geomorphology of the Eastern Highlands. In: Davies, J.L. & Williams, M.A.J. (editors), Landform evolution in Australasia. ANU Press, Canberra, 5–47.

Ollier, C.D., 1982. The great escarpment of eastern Australia: tectonic and geomorphic significance. Journal of the Geological Society of Australia, 29, 13–23.

Ollier, C.D. & Taylor, D., 1988. Major features of the Kosciusko–Bega region. BMR Journal of Australian Geology & Geophysics, 10, 357–362.

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

Taylor, T.G., 1911. Physiography of eastern Australia. Australian Bureau of Meteorology, Bulletin, 8pp.

Taylor, G., Taylor, G., R., Bink, M., Foudoulis, C., Gordon, I., Hedstrom, J., Minello, J. & Whippy, F., 1985. Pre-basaltic topography of the northern Monaro and its implications. Australian Journal of Earth Sciences, 32, 65–71.

Taylor, G., Truswell, E. M., McQueen, K. G. & Brown, M. C., 1990. Early Tertiary palaeogeography, landform evolution and palaeoclimates of the Southern Monaro, NSW, Australia. Palaeogeography, Palaeoclimatology,

Palaeoecology, 78, 109–134.
Young, R. W., 1977. Landscape evolution in the Shoalhaven River catchment of southeastern New South Wales. Zeitschrift für Geomorphologie, 21, 262–283.
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.
Young, R. W. & McDougall, I., 1982. Basalts and silcretes on the coast near Ulladulla, southern New South Wales. Journal of the Geological Society of Australia, 29, 425–430.
Young , R.W. & McDougall, 1., 1983. Reply: Origin of coastal lowlands near Ulladulla, southern New South Wales. Journal of the Geological Society of Australia, 30, 248–249.
Young, R. W. & McDougall, I., 1985. The age, extent and geomorphological significance of the Sassafras basalt, southeastern New South Wales. Australian Journal of Earth Sciences, 32, 323–331.
Young, R. W. & McDougall, I., 1993. Long-term landscape evolution: Early Miocene and modern rivers in southern New South Wales. Journal of Geology, 101, 35–49.