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CLIFF OLLIER (*)

A HYPOTHESIS ABOUT ANTECEDENT AND REVERSED DRAINAGE

Abstract: OLLIER C., *A hypothesis about antecedent and reversed drainage* (IT ISSN 0391-9838, 1991).

Tectonic uplift, downwarping and back-tilting can possibly be distinguished by drainage pattern analysis. There is a possibility that in some tectonic uplands, to seek a cause of uplift is to ask the wrong question.

KEY WORDS: Antecedent and Reversed Drainage, Tectonics.

Riassunto: OLLIER C., *Una ipotesi sul drenaggio fluviale antecedente e inverso.* (IT ISSN 0391-9838, 1991).

Il sollevamento, l'abbassamento e il basculamento tettonici possono essere riconosciuti mediante l'analisi del reticolo idrografico. Ne risulta che in alcuni altopiani di origine tettonica ricercare la causa del sollevamento è in realtà porsi una questione errata.

TERMINI CHIAVE: Drenaggio antecedente e inverso, Tettonica.

Recent ideas about tectonic uplift and subsidence have been mainly based on such geophysical concepts as geothermal heating, underplating, and domal intrusion, with few constraints from the geomorphology of the land surface. Since the major features of drainage patterns often date back to the early Tertiary, Mesozoic or earlier, it would be surprising if tectonic uplift and subsidence did not leave some surface indications, which might serve as constraints on geophysical hypotheses. But there is no consensus on how to interpret ancient drainage patterns.

It is here proposed that if a tectonic obstacle is created across a major river, the river will respond by cutting an antecedent gorge. If a major river is reversed, it is by backtilting of the river basin.

EXAMPLES OF ANTECEDENT RIVERS

A classic example of antecedent drainage is provided by several rivers that rise on the Tibetan Plateau and cross the Himalayas (WAGER, 1937). Rivers such as the Arun flow from Tibet across the highest mountain range in the world, so could not be superimposed from higher land, and they cannot be explained by river capture. The bending of river terraces shows the process is broad, vertical, and continuous (fig. 1).

Himalayan rivers might the considered a special high energy example, but consider the example of rivers in the Milne Bay Peninsula, Papua New Guinea (fig. 2) (PAIN & OLLIER, 1984). The main rivers rise at an elevation of under 80 m, within a few kilometres of the south coast, yet flow north in gorges cut through a range uplifted in the Quaternary by over 1000 m.

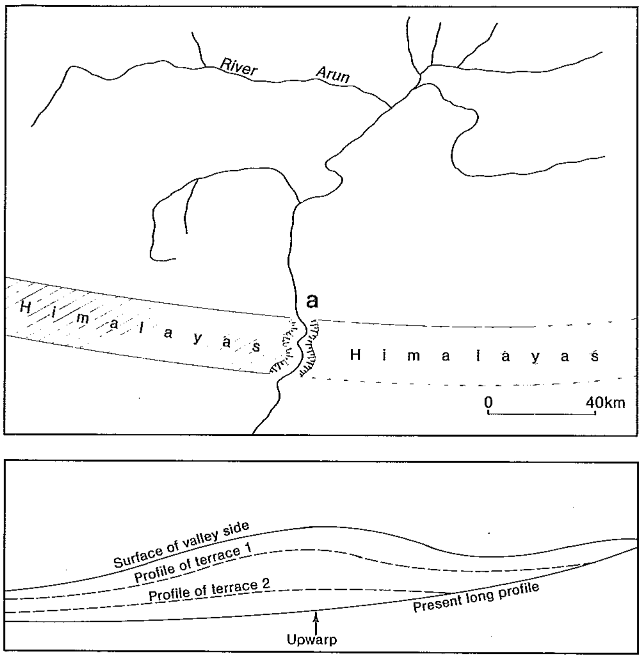

FIG. 1 - Map and cross section of part of the Arun River crossing the Himalayas. a = antecedent gorge.

(*) *Regolith Group, Bureau of Mineral Resources, Box 378, Canberra 2601 (Australia).*

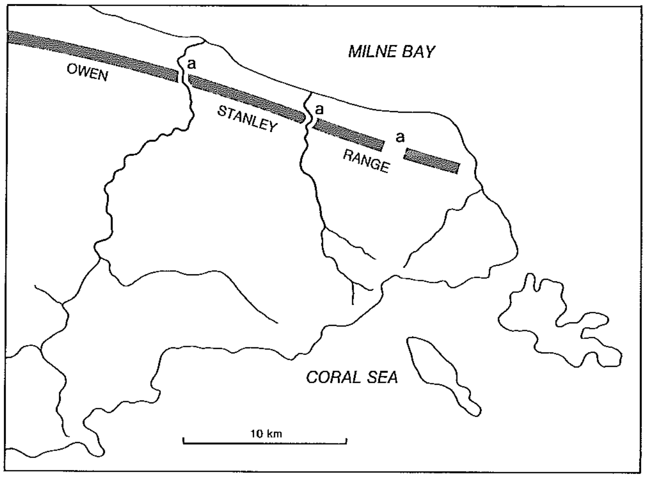

FIG. 2 - Drainage pattern, mountain range crest, and gorges, Milne Bay, Papua New Guinea. The main river rises within 1 km of the south coast at an elevation below 80 m but flows north through a deep gorge across mountains over 1 000 m high. Other rivers show the same pattern. a = antecedent gorges.

Other classical antecedent gorges include the Yangtse Gorges of China, the Rhine Gorges of Germany and these are largely associated with fault blocks.

There is much interest amongst workers in tectonic geomorphology in marginal swells (*Randschwellen; bourrelet marginaux*) along passive continental margins (BREMER, 1985; GODARD, 1982; PEULVAST, 1988). The Orange River in Southern Africa maintained its course across such a swell in an antecedent gorge (GILCHRIST & SUMMERFIELD, 1990).

EXAMPLES OF REVERSED RIVERS

Reversed rivers are detected not by gorges, but by barbed drainage patterns, in conjunction with other tectonic and stratigraphic indicators. It is assumed that the basic normal drainage pattern is dendritic, with tributaries joining the main stream at an acute angle that points downstream. If the region is backtilted the main stream will be reversed, because water cannot flow uphill, but the tributaries, being steeper, will continue to flow in their old direction, meeting the mainstream as barbed tributaries (fig. 3).

A well-known example of reversed drainage is provided by the drainage in the Lake Victoria region (fig. 4). The barbed drainage pattern is evident east of the Western Rift Valley. The valleys of the major reversed rivers can be followed right across the shoulders of the rift valley as broad, swamp-filled tracts without distinct drainage, and eventually to incised rivers flowing in the old direction into the rift valley. It has been conventionally assumed that the reversal was caused by uplift of the rise to the rift (HOLMES, 1965). But if the hypothesis presented here is correct, uplift of a rise across the major drainage (which eventually became the Nile) would have led to formation of an antecedent gorge. With such major drainage it is neces-

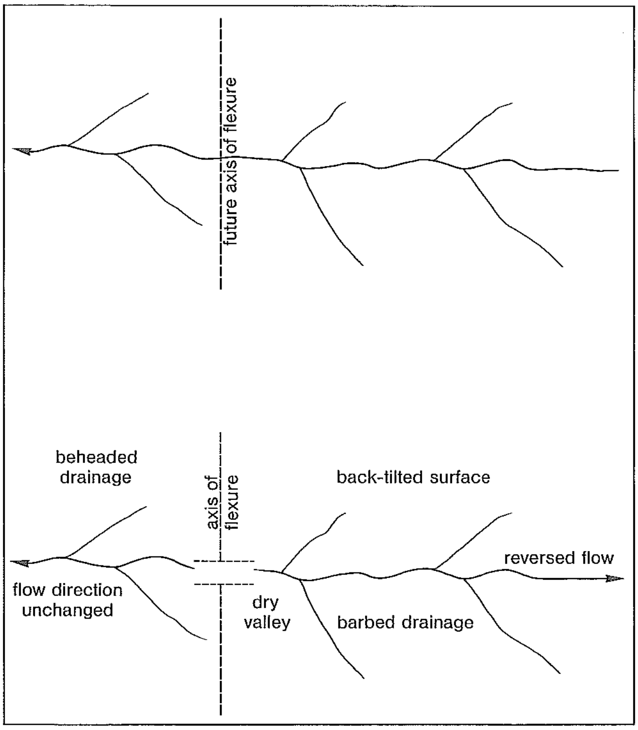

FIG. 3 - top. Normal dendritic drainage; bottom. Barbed drainage created by back-tilting the headwaters.

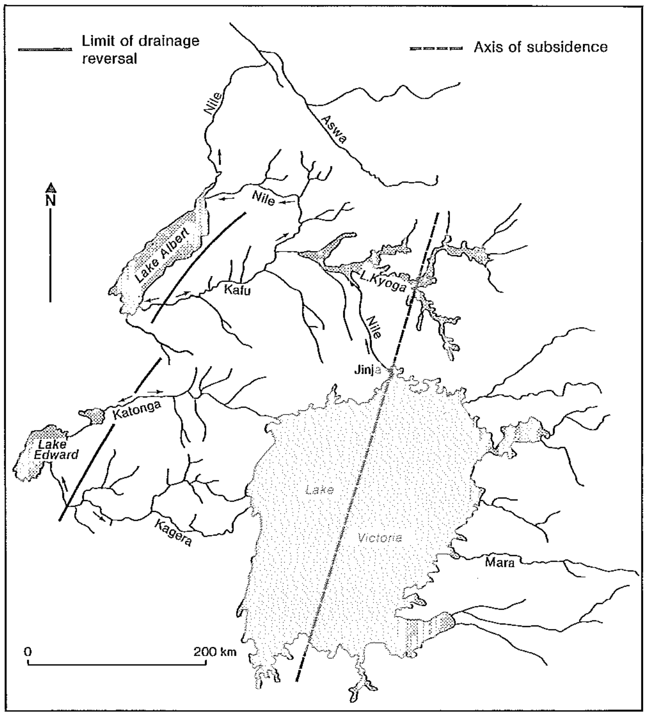

FIG. 4 - Reversed, barbed drainage in the Western Rift-Lake Victoria region, and the Lake Victoria axis of subsidence.

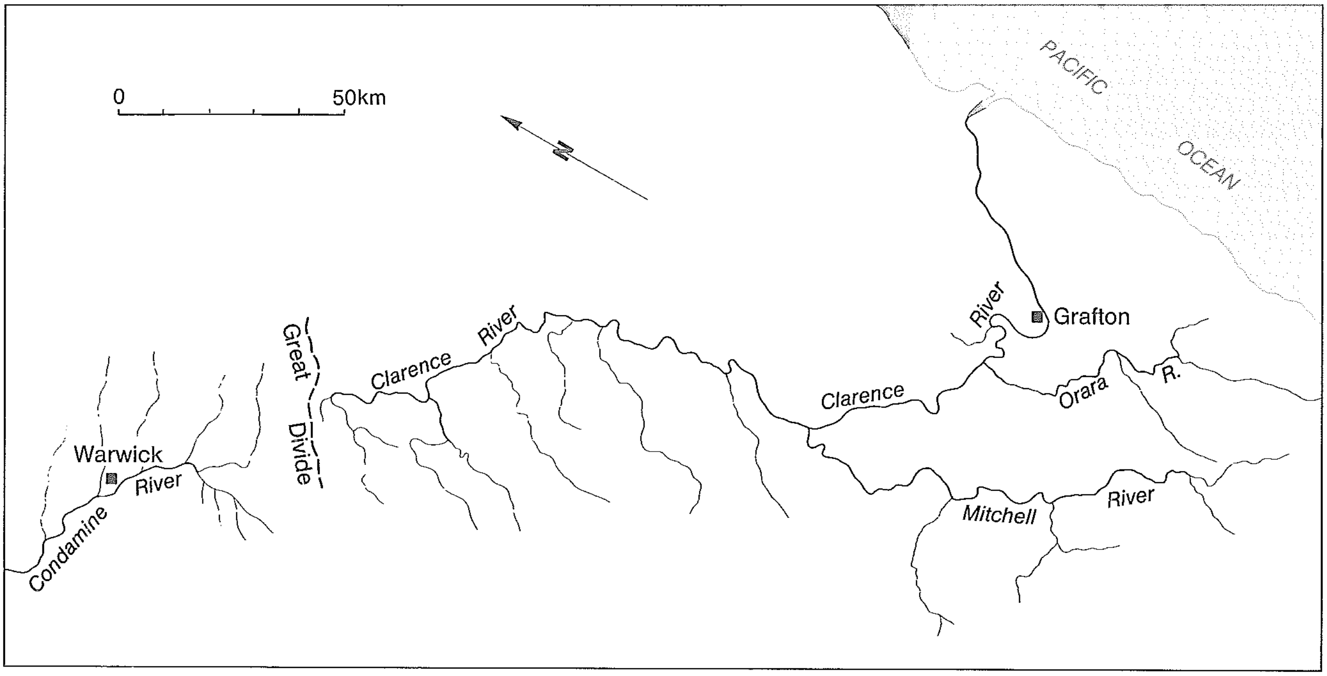

FIG. 5 - The Clarence River interpreted as the reversed headwaters of the Condamine. Left bank tributaries omitted as complicated by volcanoes. The Orara River is the real headwater river; the Clarence below Grafton is an overflow complication.

sary to back-tilt the region to cause river reversal. This reversal is associated with depression along the Lake Victoria axis of subsidence.

Many examples of reversed drainage have been postulated in eastern Australia. West of the Great Divide most of the drainage is simple and dendritic; east of the Divide there are complicated drainage patterns, with many examples of barbed drainage. Drainage reversal has been postulated since at least 1911 (TAYLOR, 1911). An example is the Clarence-Condamine drainage (fig. 5). It is postulated that drainage in the Mesozoic was from east to west, from the Pacific to the Great Artesian Basin. Since then seafloor spreading has created a new continental margin, and the drainage between the Divide and the coast has been reversed (HAWORTH & OLLIER, 1992). The conventional explanation would be that uplift of the Great Divide caused the reversal. But on the hypothesis presented here simple uplift of the Divide would have led to the formation of an antecedent gorge. On the other hand, backtilting of the region east of the divide would have caused reversal of the rivers. This is borne out by general topographic considerations, and the off-shore break-up unconformity, which is a down-warped erosion surface on which Cretaceous and younger marine sediments have accumulated.

IMPLICATIONS OF THE HYPOTHESIS

If this hypothesis is true, then uplift and subsidence are not simply relative terms and it is possible to see whether a given area has been uplifted or back-tilted.

It allows more precision in relating the chronology of drainage pattern evolution to that of tectonic events. For instance, the headwaters of the Nile were evidently once headwaters of the Congo (fig. 6) and were lost by downwarping along the Lake Victoria axis, and not only by formation of the rift valley. Hypotheses of drainage development on newly uplifted domes, such as those postulated by Cox (1989) for South America and West Africa, seem to be over-simple, for uplifted domes do not initiate a completely new drainage pattern: remnants of ancient drainage are generally preserved, either as antecedent drainage or reversed drainage. Sometimes we may have been asking the wrong questions about tectonics. For example, there

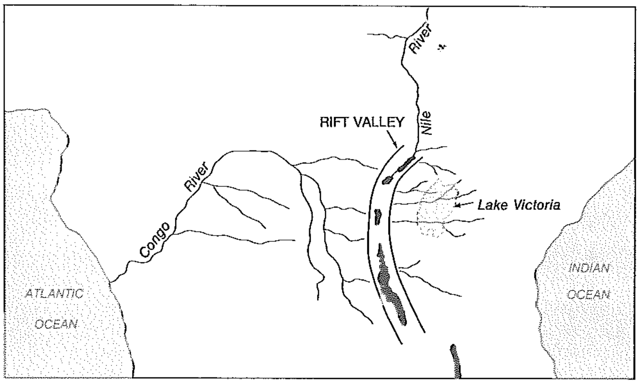

FIG. 6 - Diagram to show the Congo headwaters lost by downwarping of the Lake Victoria region and formation of the rift valley.

is much speculation on the cause of uplift of the eastern highlands of Australia, and at least 20 mechanisms can be suggested (OLLIER, 1991). All are basically incorrect if the real tectonic effect is downwarping of the coastal zone. With increasing interest in the tectonics and the geomorphology of passive continental margins there should be abundant opportunity to test this hypothesis over the next few years.

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