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# Evolution of the New River drainage system, Westland

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**Abstract** The small catchment of the New (Paroa) River, on the West Coast of the South Island, displays a markedly asymmetrical drainage pattern which reflects its tectonic and Quaternary glacial history. Outwash from ice in the Taramakau valley and Lake Brunner basin during the Nemona Glaciation created a new surface on which the forerunner of the modern drainage pattern developed. This pattern was modified through successive glaciations as valleys were deepened and streams diverted in a series of captures. Continuing deformation where the streams crossed the nose of the Brunner Anticline also played a part. A chronological framework of the capture sequence is provided by the input of sediments during the Waimea and Otira Glaciations.

**Keywords** drainage patterns; geomorphology; Quaternary history; glacial sequences; West Coast; South Island; river capture

## INTRODUCTION

Unravelling the evolution of drainage systems is a long-standing theme in geomorphology, and one that can be usefully applied in New Zealand, as Cotton (1913) demonstrated when he used the anomalies he discerned between Davisian concepts and the realities of the New Zealand landscape to interpret the influence of geology and tectonics on that landscape. Following this approach, Gage (1950) analysed the drainage pattern of the Paparoa Range. He noted in conclusion that, "The stream pattern in the area east of the Paparoa Range presents problems calling for further study", and specifically drew attention to the course of Card Creek, in the New River catchment. Gage envisioned a history of drainage elements consequent on regional tectonics.

Since 1950, changes to the understanding of both tectonic evolution and Quaternary history of New Zealand in general, and the West Coast in particular, provide the basis for analysis of landform development involving a number of complex factors. Reconstruction of the stages by which the drainage reached its present pattern illustrates the interactions of tectonics, glaciation, and processes of fluvial development. This paper presents a case study of the New River catchment, and demonstrates the extent to which major changes in the landscape can take place in a relatively short time.

### Sources of data

The recently published map of the geology of the Kumara–Moana area (Suggate & Waight 1999) gives a comprehensive picture of the New River catchment. It has been supplemented by extensive fieldwork and airphoto interpretation. Elevations of surfaces were derived from spot heights shown on NZMS 270 maps of the area, from New Zealand Forest Service maps, and also from aneroid barometer readings calibrated to trig points and against a continuous pressure record for the period of the readings.

## CHARACTERISTICS OF THE NEW RIVER CATCHMENT

The courses of the New River and its tributaries have been determined by the tectonic and glacial history of the area, as well as by the erosional capabilities attributable to a high rainfall. They drain a relatively small area between the Taramakau and Grey Rivers (Fig. 1), and are crossed by the hinges of the Brunner Anticline and the Grey Valley Syncline (Fig. 2).

The drainage pattern is remarkable for its asymmetry. Only one significant tributary, Card Creek, joins the New River on the true right bank, but a number of subparallel streams flow from the watershed with the Taramakau drainage and join on the left bank (Fig. 2). The continuing deformation of the Brunner Anticline, which forms the Kaiata Range and Peter Ridge on the northern side of Card Creek, may be assumed to influence this pattern (Fig. 2), but since the streams flow towards the anticline other factors

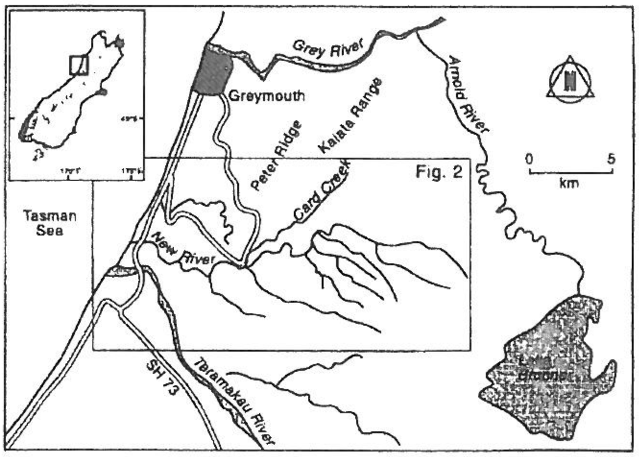


**Fig. 1** Location of New River catchment.

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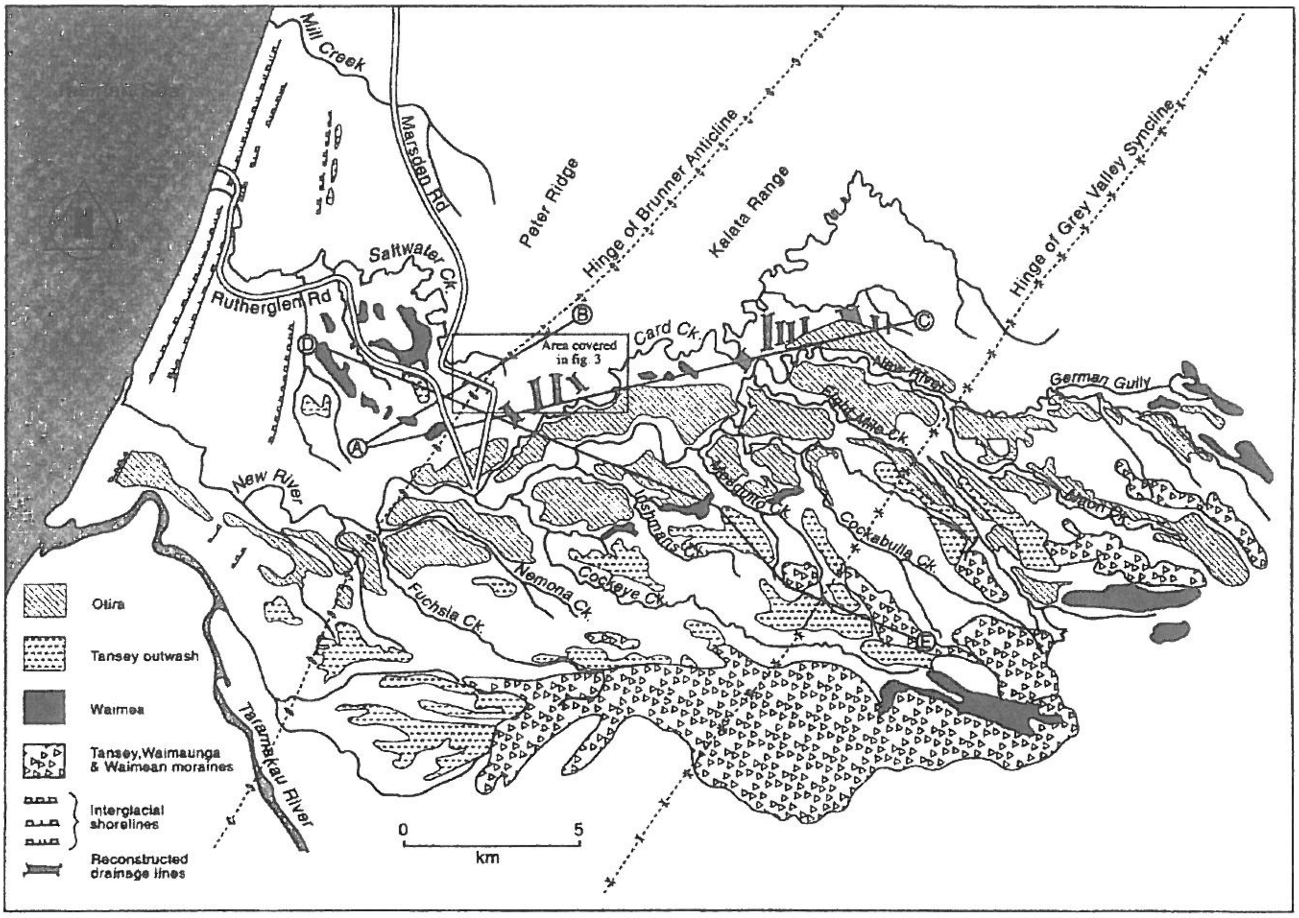


**Fig. 2** General map of drainage pattern, major structural features, late Quaternary shorelines, moraines, and outwash. Lines of cross-sections A–B, B–C, and D–E (Fig. 4A, B, C) are also shown.

are clearly involved. An abandoned meander which cuts across the nose of the anticline shows that Card Creek drainage at least was able to maintain a course across the possible obstacle at no very distant date in the past (Fig. 3).

Continuous warping of both the Brunner Anticline and the Grey River Syncline has been demonstrated by Nathan (1978), Suggate (1987), and Suggate & Waight (1999). Evidence of regional uplift throughout the late Quaternary is provided by the series of raised shore platforms, beaches, and cliff lines along the length of the West Coast (McPherson 1978; Nathan 1978; Soons & Lee 1984; Bull & Cooper 1986; Suggate 1965, 1985, 1990; Suggate & Waight 1999) (Fig. 2). Rates of deformation cannot be precisely determined, owing to the lack of good radiometric dates extending beyond the mid Otiran (Table 1). Suggate (1987) estimated the amplitude of folding since the Kumara $2_2$ advance (Table 1) at 7–8 m, on the basis of measurements of deformation of the Larrikins (late Otiran) surface in the New River valley. Assuming a constant rate of deformation, and given that the Kumara $2_2$ advance has an age of 22–18 ka BP (Suggate 1990), an average rate of deformation can be estimated as 0.35 m/ka.

Late Quaternary glacial and glacifluvial deposits cover much of the area in Fig. 2. They are underlain throughout by Stillwater Mudstone (Blue Bottom Group), with the exception of a small area of Cobden Limestone in the nose of the Brunner Anticline (Fig. 3).

## IMPACT OF EARLY GLACIAL ADVANCES OF THE LATE QUATERNARY

As well as tectonic influences, the climatic events of the late Quaternary have been important. The main supplier of ice to the area was the Taramakau glacier, which, during successive glaciations, spread down the valley and into the basin now occupied by Lake Brunner (Suggate 1965, 1990). Moraines were constructed around the basin and across the Taramakau valley, and outwash gravel spread out to the coast (Suggate 1965, 1990; Suggate & Waight 1999). The earliest advance for which substantial evidence permits reconstruction of a contemporary landscape is that of the

**Table 1** West Coast late Pleistocene glacial sequence (Suggate & Waight 1999).

| Glacial | Advance | Interglacial | Formation | $O^{18}$ stage |
|---|---|---|---|---|
| | | Aranuian | | 1 |
| | Kumara $2_2$ | | Larrikins | 2 |
| Otira | | | | 3 |
| | Kumara 1 | | Loopline | 4 |
| | | Kaihinu | | 5 |
| Waimea | | | Waimea | 6 |
| | | Karoro | | 7 |
| Waimaunga | | | Tansey | 8 |
| | | ? | | 9 |
| Nemona | | | Cockeye | 10 |

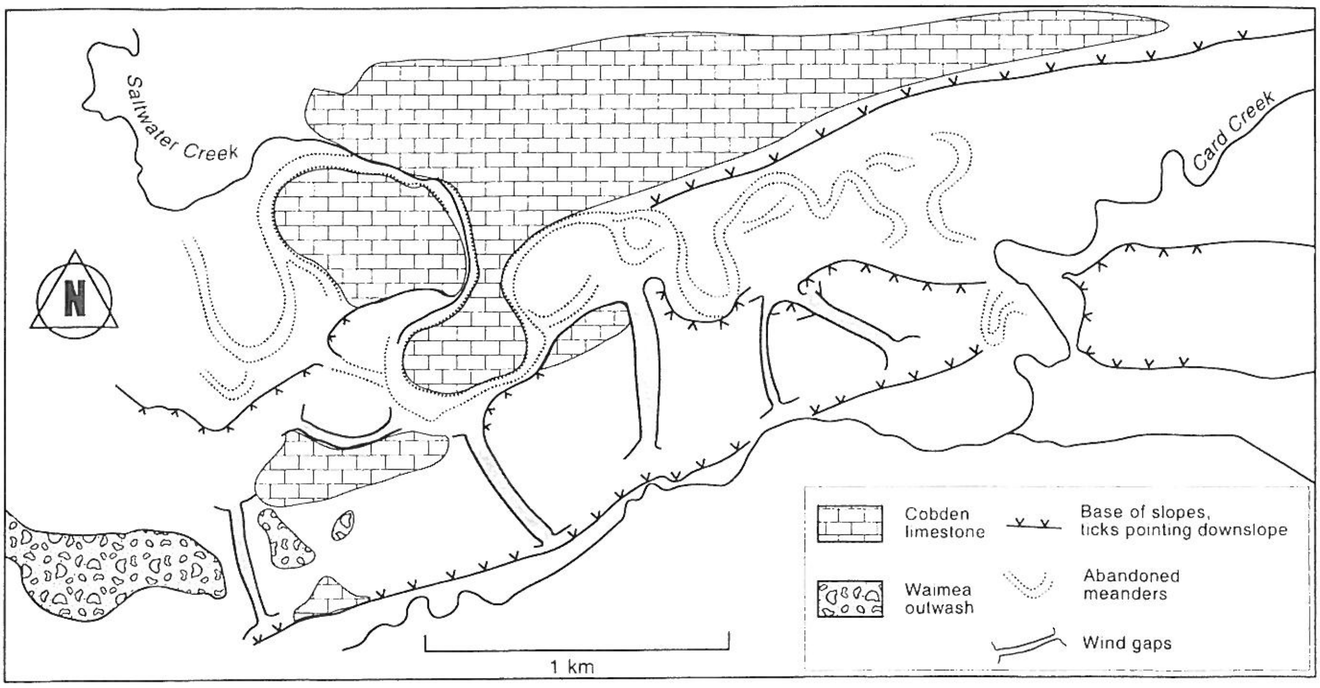


**Fig. 3** Geomorphology of lower Card Creek and upper Saltwater Creek valleys. Ticked lines show base of slopes, arrowheads pointing downslope.

Waimaunga Glaciation (Suggate 1990; Suggate & Waight 1999) (Table 1). Lines of moraine run roughly west–east from the Taramakau valley to the head of Cockeye Creek, forming a watershed which is continued east and north, between the New River system and the Brunner/Arnold drainage (Fig. 1), by remnants of moraine of the preceding Nemona Glaciation (Fig. 2).

Little remains of Nemona outwash (Cockeye Formation) (Table 1), but extensive areas of outwash of Waimaunga age (Tansey Formation) are present as the gently sloping crests of spurs separating New River tributaries (Fig. 2). Small patches of Tansey sediments on the high ground on either side of the Rutherglen Road, and along the crest of the ridge between Mill Creek and Saltwater Creek (Fig. 2), indicate the former extent of the Tansey surface at a level above the valleys and ridges of the modern landscape (Fig. 2, 4A,B). They represent a continuous outwash surface sloping to a former coastline which was probably located somewhat west of the present coast. It was on this surface that the left bank tributaries of the New River originated as meltwater streams (Fig. 5A). Any expression of the Brunner Anticline was unlikely to affect their direction, except insofar as the Kaiata Range limited the extent of the outwash surface, and forced some of the streams to converge to form a forerunner of Card Creek. Figures 4A and 4B show a reconstruction of the Tansey outwash surface, derived from interfluve remnants between Cockeye and Mosquito Creeks (Fig. 2). At the downstream end, this surface was appreciably above that of the saddle, for convenience referred to in this paper as the Marsden saddle, between the Card Creek and Saltwater Creek valleys (Fig. 4A).

Incision into and through the Tansey outwash would have started as recession of the ice began. The relatively easily erodible nature of the outwash surface, and the energy provided by a high rainfall and more or less continuous regional uplift, would have resulted in rapid valley downcutting. The succeeding Waimea advance terminated against the Waimaunga moraines in the Taramakau valley and the Lake Brunner basin (Fig. 2). Only scattered remnants of Waimean outwash are to be found in either the Taramakau or New River valleys. Enough is present to show that, in contrast to the situation during the Waimaungan, Waimean drainage reached the New River system by way of pre-existing valleys. The saddle separating the headwaters of the New River from the Arnold drainage was overtopped, and the open heads of Maori and Cockeye Creeks carry Waimea outwash which must have continued down these valleys (Fig. 2). Patches of Waimea sediments on the ridge between New River and Card Creek, and on the high ground between Saltwater Creek and Rutherglen Road, show that the outwash surface spread through the Marsden saddle and across the area west of Saltwater Creek (Fig. 2, 4). The removal of much of the Waimea deposits points to substantial erosion through the succeeding interglacial and the next glaciation, favoured by the gravels being largely confined to relatively restricted valleys.

The topography resulting from this erosion can only be inferred from the placing of the sediments of the next glaciation (Otira). These are also confined, forming low-level terraces in the New River valley, in places much modified by gold dredging and subsequent landscaping. Otiran moraines pushed up against the watershed with the Arnold/Brunner lowlands, and breaches across the saddle carried outwash down the headwater valleys. Cols at the heads of Maori and Eight Mile Creeks (Fig. 2) had also been lowered enough to allow sediments of the Loopline and Larrikins advances to enter the New River system (Suggate & Waight 1999). Loopline sediments reached the Card Creek valley by cols between the New River and an unnamed Card Creek tributary (Fig. 2), but Larrikins outwash is confined to the New River valley, where it is present as low terraces only a few metres above the present valley floor.

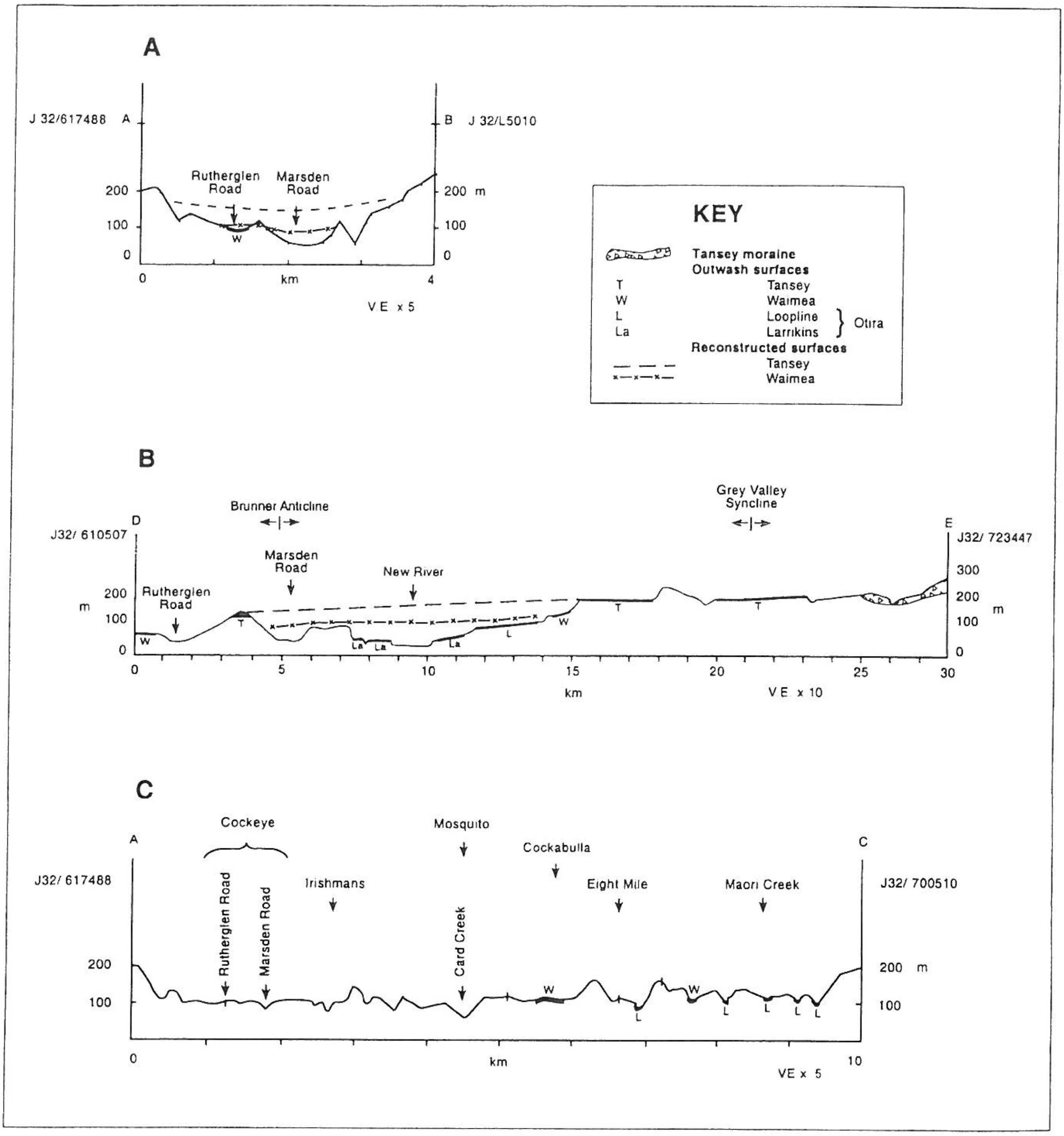


**Fig. 4** **A**, Former levels of Tansey and Waimea valley floors in the Marsden saddle. **B**, Profile along line D–E (Fig. 2) showing relationships of outwash surfaces. The former extension of Tansey and Waimea surfaces across New River valley and Marsden saddle are shown. **C**, Card Creek/New River interfluve, showing positions of remnants of Waimean and Loopline outwash, together with wind gaps used by labelled streams before diversion to New River.

## DRAINAGE MODIFICATIONS OF OTIRAN AND ARANUIAN AGE

Loopline gravel in low cols on the interfluve between the New River and Card Creek, extending down the unnamed tributary of Card Creek, shows that Loopline meltwater entered the Card Creek valley, as well as that of the New River (Fig. 2). The col opposite the junction of the New River and Eight Mile Creek (grid ref. J32/685504, and Fig. 2) is <20 m above the present level of the New River. Thus, at least during the early Otiran, the upper New River system still drained into the Card Creek valley (Fig. 5C).

No Larrikins outwash is present in this or the Saltwater Creek valley, but the terraces formed by recent adjustments to base level are mapped as of Larrikins age (Suggate & Waight 1999). At the lower end of its valley, Card Creek turns south, to cross a low interfluve ridge and join the New

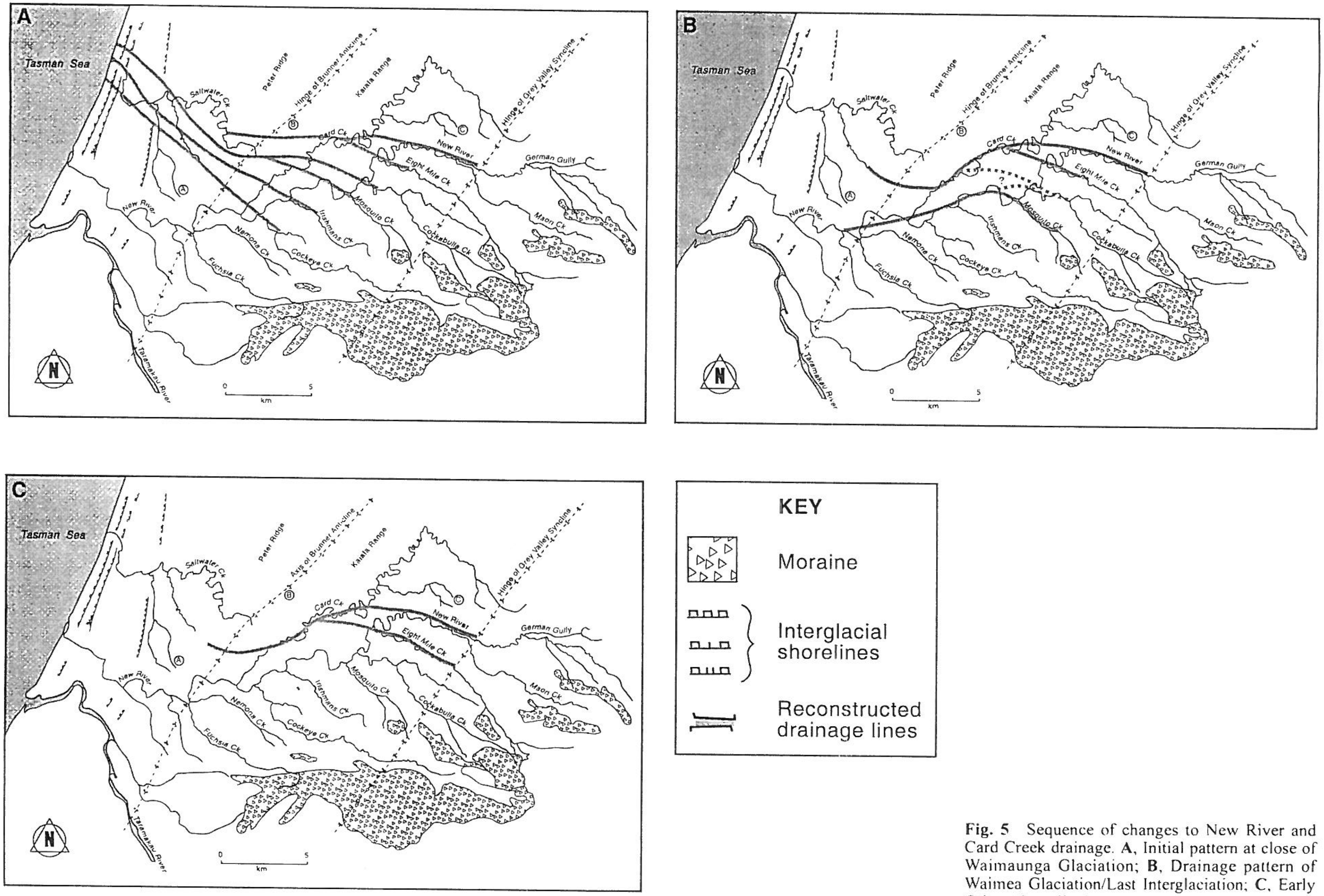


**Fig. 5** Sequence of changes to New River and Card Creek drainage. **A**, Initial pattern at close of Waimaunga Glaciation; **B**, Drainage pattern of Waimea Glaciation/Last Interglaciation; **C**, Early Otiran (Loopline) pattern.

River. Abandoned meander loops, clearly visible on airphotos, trace a course from the change of direction to the deeply incised meander across the nose of the Brunner Anticline (Fig. 3). These meanders mark a recently abandoned course of Card Creek.

### Evolution of the New River drainage pattern

The construction of the Tansey outwash plain would have effectively obliterated any earlier stream pattern. Meltwater streams fanned out towards the coast, obstructed only to the north by the Kaiata Range, and developed valleys which were the forerunners of the present system. The present streams largely preserve this early pattern (Fig. 5A), except that diversion of their lower courses has created the aptly named New River. Reconstruction of the original courses is assisted by the numerous cols which lie along the ridge separating the New River from Card Creek (Fig. 4C).

At the western end of the catchment, the Marsden saddle offered a direct route to the sea for Cockeye Creek (Fig. 4A, 5A). Its eastern neighbours either crossed the same saddle or joined a stream that did (Fig. 5A). The reconstructed Tansey and Waimea surfaces both lie well above the present level of the saddle (Fig. 4B), and deformation at the hinge of the Brunner Anticline was minor by comparison with the aggradation of the outwash surfaces. This, together with a high rainfall and the ease with which streams could lower their channels in the outwash gravels, enabled Cockeye Creek to maintain its course across the hinge for a considerable time.

Several factors probably contributed to disruption of this initial drainage pattern. Fuchsia and Nemona Creeks had much shorter routes to the sea than Cockeye Creek and its tributaries, and therefore had steeper gradients. A minor tributary of one of these creeks would have been able to extend its course headward, tapping into the larger and slightly higher Cockeye Creek. This would have been a classic situation for stream capture, possibly enhanced if Cockeye Creek encountered the Cobden limestone in the nose of the anticline while Nemona Creek continued to erode in gravel.

The presence of Waimea gravel above Saltwater Creek valley (Fig. 2) shows that Cockeye Creek maintained its course across the Brunner Anticline hinge through Waimea time, but the distribution of Otiran sediments show that it was diverted before these were deposited (Fig. 2, 5B). Once this relatively large stream was diverted to the embryo New River (Fuchsia/Nemona), the potential for piracy of its eastern neighbours would have increased. Given the distribution of Loopline and Larrikins gravel in the lower catchment (Fig. 2) (Suggate & Waight 1999), it is probable that Irishmans and Mosquito Creeks were also added to the growing system before the onset of the Otira Glaciation (Fig. 5B). Cockabulla Creek may also have been diverted, but Loopline sediment in the low col opposite the junction of Eight Mile Creek indicates that this stream continued to join Card Creek until some time during the Otiran. Similarly, Loopline sediment in small cols farther east along the Card Creek/New River interfluve suggests continued drainage to Card Creek by the New River headwaters (Fig. 2, 4C, 5C).

The successive diversion of tributaries would have reduced the discharge of Card Creek, and this would, in turn, have decreased its ability to maintain flow across the Brunner Anticline hinge. Nevertheless, the deeply incised meander across the nose of the anticline shows that flow did continue for some time. During Waimean times, the obstacle presented by warping at this site would have been minimal, but throughout the Otiran it would have become of increasing importance, as the low gradient of the valley upstream of the hinge crossing shows. Coinciding with the progressive reduction in competence of Card Creek, abandonment of the channel was inevitable, although the traces of meanders still visible on airphotos (Fig. 3) show that some drainage continued along this route through the Larrikins advance, and possibly into the Holocene.

By the time of the Larrikins advance, the present configuration of the New River drainage system had been established, with Eight Mile Creek and the head of the New River itself being added to the system (Fig. 5C). The poor drainage of the entire Card Creek valley, and the abandoned meanders of the lower part of the valley, show the effects of gradual reduction in gradient, associated with continuing growth of the Brunner Anticline. This, together with the reduction in flow as its tributaries were diverted, led to the inability of Card Creek to maintain its course across the anticline. A final switch resulting in the abandonment of its course to Saltwater Creek valley may have been due to further piracy by a small tributary of the New River, working its way headward through the gap abandoned by Mosquito Creek. A cave which at times carries water from the abandoned valley (Crossley 1990) suggests that solution in the Cobden Limestone may also have contributed to a loss of competence by Card Creek.

## CONCLUSION

The New River catchment provides an example of a dynamically changing valley system, with classic stream captures. Changes are associated with a variety of factors, starting from a surface that was probably as near the Davisian concept of an initial surface as is likely to be found in any part of the world. To that extent, the streams which developed on it may be classified as consequents. Card Creek, in spite of the conformity of its course to a regional consequent direction, which Gage (1950) noted, was probably always controlled by the barrier presented by the Kaiata Range. Departures from the pattern established on the Tansey outwash slope are related to the interaction of an initially easily erodible surface, a short path to the sea for certain small streams compared with their upstream neighbours, and ongoing uplift. The loss of competence of Card Creek, consequent on progressive loss of headwaters, was compounded by the effect of warping along the axis of the Brunner Anticline, and together with the probable loss of water through the increasingly exposed limestone in the nose of the anticline, led to the abandonment of an original drainage line.

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