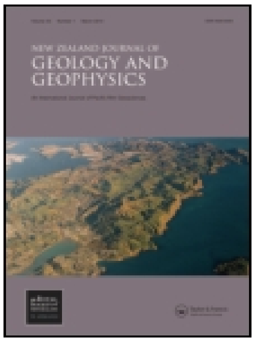

New Zealand Journal of Geology and Geophysics

ISSN: 0028-8306 (Print) 1175-8791 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzg20

Vertical displacement rates on Quaternary faults, Wanganui Basin

Brad Pillans

To cite this article: Brad Pillans (1990) Vertical displacement rates on Quaternary faults, Wanganui Basin, New Zealand Journal of Geology and Geophysics, 33:2, 271-275, DOI: 10.1080/00288306.1990.10425684

To link to this article: http://dx.doi.org/10.1080/00288306.1990.10425684

New Zealand Journal of Geology and Geophysics, 1990, Vol. 33: 271–275
0028–8306/90/3302–0271 $2.50/0 © Crown copyright 1990

Vertical displacement rates on Quaternary faults, Wanganui Basin

BRAD PILLANS
Research School of Earth Sciences
Victoria University of Wellington
P.O. Box 600
Wellington, New Zealand

Abstract Wave-cut platforms of late Quaternary marine terraces between Hawera and Marton in Wanganui Basin are vertically displaced by several faults. The faults are probably high-angle normal, and strike generally northeast. Of the four faults that are known to displace surfaces of different age, two show increasing displacements with increasing age, and two show no change with age. Fault traces typically consist of discontinuous, subparallel scarps, up to 1.5 km long and up to several metres high. Some scarps display a left stepping, en echelon pattern, consistent with a component of dextral horizontal movement, though horizontal displacement of terrace risers is not evident. Average rates of vertical movement on the faults vary between 0.02 and 0.2 mm/yr, much less than rates of vertical and horizontal movement documented for many other faults in New Zealand. One fault, the Nukumaru Fault, shows a constant rate of vertical movement averaging 0.07 mm/yr for the last 2.2 million years. The faults are tentatively interpreted as bending-moment faults, associated with folding.

Keywords Quaternary; faults; Wanganui Basin; displacements; terraces

INTRODUCTION

Stern & Davey (1988) recognised two contrasting basin types formed in continental lithosphere, behind the Hikurangi subduction zone in New Zealand. The first is the Central Volcanic Region (CVR), an extensional back-arc basin characterised by high heat flow and active volcanism. The second is the Wanganui Basin, a broad compressional basin immediately south of the CVR (Fig. 1), which contains 4–5 km of Pliocene–Pleistocene shallow marine sediments. Wanganui Basin is an area of intense crustal seismicity and is the centre of a large negative gravity anomaly with Bouguer and isostatic gravity values as low as −150 mgal.

Although there is much current research on many well-known areas of active faulting in New Zealand (see Berryman & Beanland 1988 for a recent summary), there is little information on late Quaternary faulting in less active areas such as Wanganui Basin. Seismic data (largely offshore) reviewed by Anderton (1981) suggested that major faults intersecting Pliocene–Pleistocene sediments in Wanganui Basin are both high-angle reverse and high-angle normal. Anderton (1981) also interpreted the fault pattern as consistent with a component of dextral horizontal movement. Yeats (1986) noted that the pattern of folding associated with some of the faults is also consistent with dextral fault movement. Stern & Davey (1988) demonstrated, using enhanced seismic data, that several faults on the eastern, offshore margin of the basin are high-angle reverse.

The only detailed observations on late Quaternary faulting in the onshore part of Wanganui Basin are those of Fleming (1953), who described several active faults between Waverley and Marton. Fleming noted the generally short, discontinuous nature of associated scarps compared with the more continuous scarps of the major strike-slip faults elsewhere in New Zealand, and classified all the faults he studied as normal.

Wellman (1972) pointed out that the general absence of reference lines makes it impossible to determine the true direction of displacement (slip) for most faults, and that at best all that can be determined is the component of displacement (separation) normal to some plane such as bedding. In this paper, I use wave-cut platforms of dated marine terraces as reference surfaces to calculate the vertical component of Quaternary fault movement for several faults, including those studied by Fleming (1953), in Wanganui Basin. Given the generally excellent preservation of marine terraces in the Hawera–Wanganui area, and their detailed mapping (Pillans 1981, in press), it is unlikely that further significant faults displacing wave-cut platforms will be discovered.

DESCRIPTION OF FAULTS

The distribution of the nine faults discussed here is shown in Fig. 1. All of the faults strike northeast, and all except two (Leedstown and Upokongaro Faults) vertically displace wave-cut platforms of dated marine terraces described by Pillans (1983). Vertical displacements are given in Table 1. Known strike lengths vary up to 15 km for the faults displacing terraces, and up to 30 km for Upokongaro Fault (Fig. 1).

The westernmost fault, here named **Ararata Fault**, is on the Patea–Tongaporutu High (Anderton 1981), which separates Wanganui and Taranaki Basins. It is downthrown to the east and is known to extend some 500 m across Brunswick Terrace, but it has little surface expression. The next five faults to the east (Waverley, Moumahaki, Ridge Road, Waitotara, and Nukumaru) occur near the crest of Whangamomona Anticline between Patea and Wanganui.

G89042
Received 27 July 1989; accepted 2 March 1990

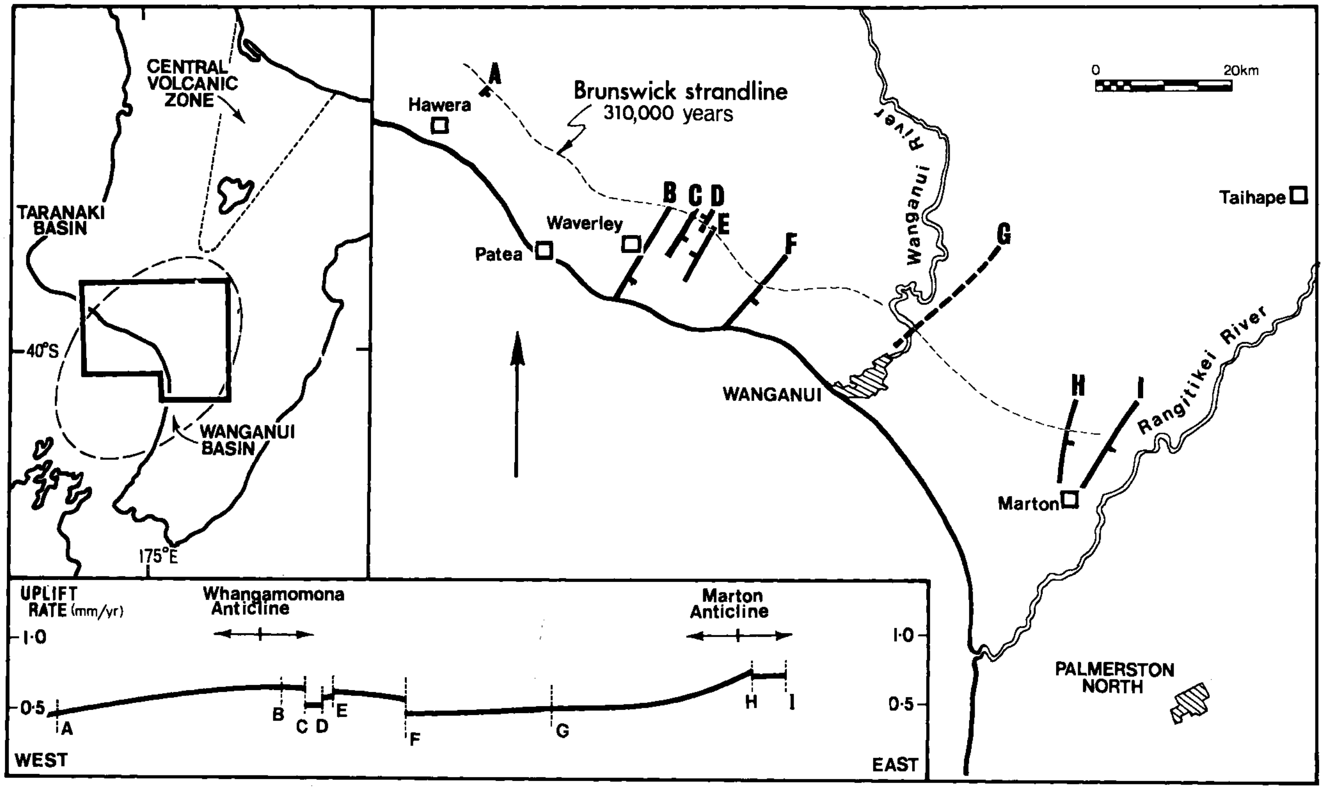

Fig. 1 Location of faults (A–I) discussed in the text. A, Ararata; B, Waverley; C, Moumahaki; D, Ridge Road; E, Waitotara; F, Nukumaru; G, Upokongaro; H, Galpin; I, Leedstown. Lower inset shows uplift rates and fault offsets based on height of the c. 310 000 year old Brunswick strandline.

Whangamomona Anticline was first recognised from gravity survey data by Fleming (1953), and is clearly evident from marine terrace deformation documented by Pillans (1983; in press). Waverley, Moumahaki, and Nukumaru Faults are downthrown to the east, while the Ridge Road and Waitotara Faults are downthrown to the west. Fleming (1953) showed that the Moumahaki and Nukumaru Faults dip east and are therefore normal; Fleming measured the dip of the latter as varying between 60 and 80°. The fault plane of the Waitotara Fault is exposed on a farm track (NZMS 260 grid reference R22/568553), and dips 75° to the west; the sense of movement is therefore also normal. The dips and dip directions for the Waverley and Ridge Road fault planes are unknown.

Surface traces of the Waverley and Moumahaki Faults are shown in Fig. 2; scarps are up to 5 m high along the Waverley Fault, and up to 25 m high along the Moumahaki Fault. Surface traces along the Waverley, Moumahaki, and Waitotara Faults are generally left stepping, suggesting a dextral component of horizontal movement (cf. Sylvester 1988). A series of right-stepping en echelon scarps, up to 4 m high,

Table 1 Vertical displacements (in metres) for each fault listed by age of offset feature. Quoted displacements are measured on wave-cut surfaces for marine terraces.

		Fault*								
Offset feature	Age	A	B	C	D	E	F	G	H	I
Hauriri Terrace	80 ka	–	2	–	–	–	–	–	–	–
Inaha Terrace	100 ka	–	–	–	–	–	–	–	–	–
Rapanui Terrace	120 ka	–	–	–	–	–	15	–	–	–
Marton Terrace†	140 ka	–	–	–	–	–	–	–	–	10
Ngarino Terrace	210 ka	–	–	40	–	15	20	–	–	–
Brunswick Terrace	310 ka	7	–	40	30	15	25	–	–	–
Braemore Terrace	340 ka	–	–	40	–	–	–	–	–	–
Ararata Terrace	400 ka	–	–	–	80	–	30	–	15	–
Rangitatau Terrace	450 ka	–	–	–	–	–	30	–	–	–
Ball Terrace	520 ka	–	–	–	–	–	40	–	–	–
Piri Terrace	600 ka	–	–	–	–	–	50	–	–	–
Kuranui Limestone‡	2.2 Ma	–	–	–	–	–	150	–	–	–
Hautawa Shellbed‡	2.4 Ma	–	–	–	–	–	–	25	–	–

* A, Ararata; B, Waverley; C, Moumahaki; D, Ridge Road; E, Waitotara; F, Nukumaru; G, Upokongaro; H, Galpin; I, Leedstown. † Data from Milne (1973). ‡ Data from Fleming (1953).

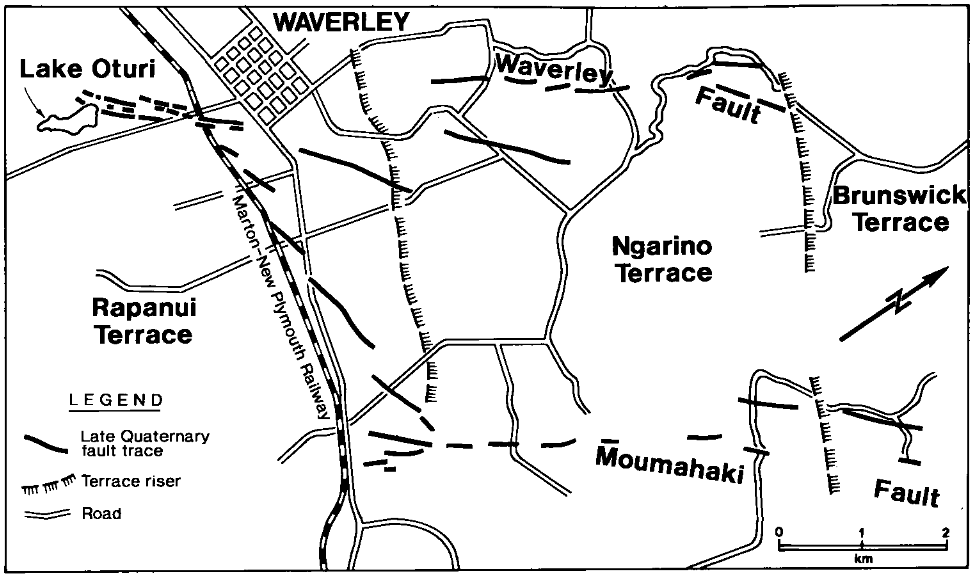

Fig. 2 Surface traces of Waverley and Moumahaki Faults; all scarps are downthrown to the east.

links the Waverley and Moumahaki Faults (Fig. 2). Measurements of slickenside orientations on faults not displacing wave-cut platforms in the area also indicate a dextral component of movement (Wellman pers. comm. 1989). The apparent absence of horizontal displacement at the marine terrace risers may be the result of obscuring by erosional and depositional processes.

The Nukumaru Fault shows progressive displacement of wave-cut platforms over a period of at least 500 000 years. Surface traces are difficult to recognise because of fluvial dissection along the fault. Fleming (1953) reported scarps up to 5 m high and also noted that a prominent scarp was evident from echo-sounding offshore.

In Wanganui valley, Upokongaro Fault was mapped by Fleming (1953). The fault is downthrown to the east and vertically displaces Hautawa Shellbed (c. 2.4 million years ; Beu et al. 1987) by 25 m (Fleming 1953, p. 292). Borehole data (Beu et al. 1987) suggest vertical movement in late Castlecliffian time (300–500 000 years). Displacement of marine terraces across the Upokongaro Fault cannot be determined with any precision because of the width of Wanganui valley, but is unlikely to exceed 10 m.

Further to the east, near Marton, the Galpin and Leedstown Faults occur on the west and east flanks, respectively, of the Marton Anticline (Fleming 1953; Milne 1973). Both faults are downthrown to the east. Fleming (1953) mapped the Galpin Fault as a normal fault. Unlike the faults to the west, the Leedstown Fault offsets river terrace treads, not marine terraces. The scarp of the Leedstown Fault is generally more continuous than the scarps associated with the other faults.

RATES OF FAULT MOVEMENT

A plot of vertical displacement versus age of displaced surface is shown for each fault in Fig. 3, using data from Table 1. Of the four faults that displace surfaces of more than one age, two (Moumahaki and Waitotara) show no change in displacement with age, and two (Ridge Road and Nukumaru) show increasing displacement with increasing age. The data suggest that for the Moumahaki and Waitotara Faults, the time of first movement is younger than 210 000 years. However, since the scarps are typically of smaller height than the offsets measured on the underlying wave-cut surfaces, progressive movement is also indicated for these two faults. In contrast, the height of scarps developed in Holocene dunesand on the Waverley Fault is similar to the offset on the underlying Hauriri wave-cut platform, indicating possible initiation of this fault in the Holocene.

The Nukumaru Fault shows progressive displacement over a period of more than 500 000 years, averaging 0.08 mm/yr. Fleming (1953) reported a maximum throw of 150 m on Kuranui Limestone for the Nukumaru Fault. Kuranui Limestone has an estimated age of 2.2 million years (Beu et al. 1987), giving an average vertical displacement rate of 0.07 mm/yr over that time. These data indicate a constant rate of movement over a considerable period of time.

Average rates of vertical movement vary between 0.2 and 0.02 mm/yr for all the faults (Fig. 3). Because fault movement is likely to be coseismic rather than by continuous creep, the interpretation of these rates is equivocal. For example, an average rate of movement of 0.2 mm/yr for the Waverley Fault, based on displacement of the Hauriri wave-cut platform, is misleading, and probably too low, because initiation of the fault may have occurred only in the Holocene. The Waverley Fault, which is linked to the Moumahaki Fault by a series of en echelon scarps (Fig. 2), may represent the westward continuation of Holocene activity on the Moumahaki Fault.

DISCUSSION

The rates of fault movement reported here are low by comparison with many other New Zealand faults. Average rates vary between 3 and 50 mm/yr on major strike-slip faults of the axial tectonic belt (Berryman & Beanland 1988), and up to 3 mm/yr on normal faults of the CVR (Berryman & Hull 1984; Nairn & Hull 1985; Beanland et al. 1989). The rates are most similar to those of reverse oblique faults of the northern South Island (Berryman & Beanland 1988).

The low rates of fault movement are consistent with generally low rates of deformation in the region west of Marton, as evidenced by uplift rates and folding. Late Quaternary uplift rates reach a maximum of 0.65 mm/yr on the crest of Whangamomona Anticline, and tilt rates are less than 1°/500 000 years on its flanks (Pillans 1981, 1986). Tilt

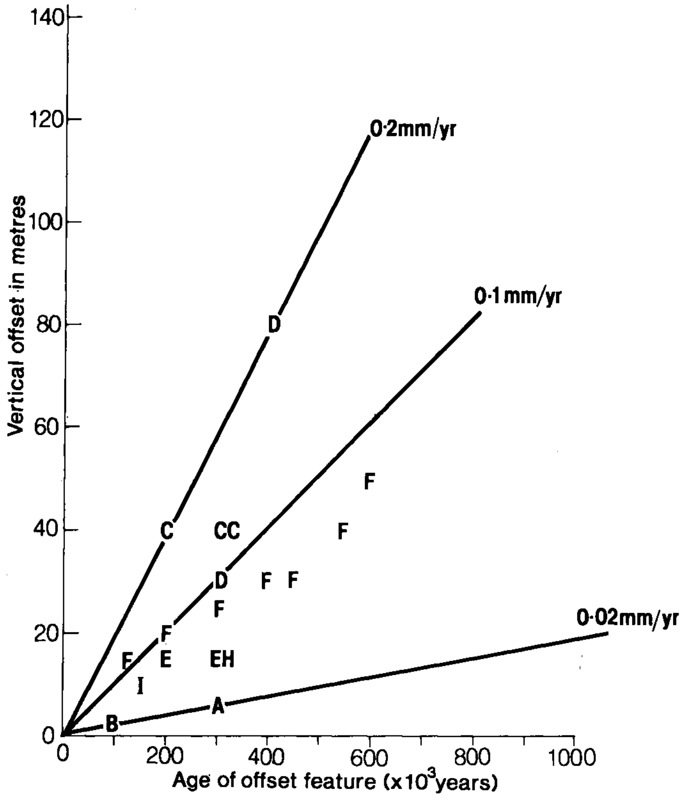

Fig. 3 Vertical displacement rates for late Quaternary faults in western Wanganui Basin (see Table 1 and Fig. 1 for names of faults and displacement data).

rates are higher near Wanganui, where mid-Castlecliffian strata dip at about 3°, but tilt rates are still less than 1°/200 000 years. Uplift rates reach 0.75 mm/yr on the crest of Marton Anticline; but only to the east of Marton do deformation rates increase substantially as the main axial ranges are approached (Pillans 1986).

The dip direction of the fault plane is uncertain for some of the faults, but where fault planes can be seen, they are high angle (>60°). They predominantly indicate normal fault movement, including Moumahaki, Galpin, and Nukumaru Faults, and a number of other faults not displacing wave-cut platforms (Fleming 1953; Wellman pers. comm. 1989). For the faults considered here, total vertical displacement is 142 m, as measured on the Brunswick (310 000) wave-cut platform (Table 1). If all the faults are normal, and with greater than 60° dip, there is a maximum of 82 m total horizontal extension over the distance (c. 100 km) from Hawera to Marton (i.e., < 0.3 mm/yr across a major portion of Wanganui Basin). This rate contrasts markedly with rates of extension of c. 7 mm/yr in the CVR to the northeast (Grapes et al. 1987), but is consistent with low shear-strain rates derived from retriangulation data in western Wanganui Basin (Walcott 1984).

The data presented here indicate that, in the western two-thirds of Wanganui Basin, low to moderate rates of uplift during the late Quaternary are accompanied by low rates of dominantly normal faulting. The implied extension associated with this normal faulting, although small, appears somewhat anomalous in the context of Stern & Davey's (1988) description of the Wanganui Basin as a flexurally controlled compressional basin. Stern & Davey (1988) developed a conceptual model for the development of the basin, in which the driving load for downward flexure is the vertical component of shear coupling between the Australian and the underlying, subducting Pacific plate. The model is consistent with the high-angle reverse faulting evident in their seismic sections, as well as the pattern of crustal earthquakes beneath the southeastern part of the basin (Robinson 1986). The presence of a number of late Quaternary folds within the basin (including Whangamomona and Marton Anticlines) with axes trending approximately northeast (see also Te Punga 1957; Yeats 1986), is also consistent with compression. One possible interpretation of the late Quaternary normal faults described here is that they are second-order flexural effects related to the folds—termed bending-moment faults by Yeats (1986). The occurrence of the faults in near-crestal positions on the folds, and the similar strikes of faults and fold axes, is consistent with a bending-moment origin.

ACKNOWLEDGMENTS

I thank Alan Hull and Yoshihisa Hoshino for discussion and assistance with fieldwork, and Dan May, Sarah Beanland, and Susan Cashman for reviewing the manuscript. I particularly thank Harold Wellman for providing unpublished data on slickenside measurements, as well as stimulating discussions of things too numerous to mention.

REFERENCES

Anderton, P. W. 1981: Structure and evolution of the South Wanganui Basin. *New Zealand journal of geology and geophysics 24*: 39–63.

Beanland, S.; Berryman, K. R; Blick, G. H. 1989: Geological investigations of the 1987 Edgecumbe earthquake, New Zealand. *New Zealand journal of geology and geophysics 32*: 73–92.

Berryman, K.; Beanland, S. 1988: Ongoing deformation of New Zealand: rates of tectonic movement from geological evidence. *Transactions of the New Zealand Institute of Engineers 15*: 25–35.

Berryman, K.; Hull, A. 1984: Guidebook to the North Island scientific excursions. International Symposium on Recent Crustal Movements of the Pacific Region. *Royal Society of New Zealand miscellaneous series 8*: 115 p.

Beu, A. G.; Edwards, A. R.; Pillans, B. J. 1987: A review of New Zealand Pleistocene stratigraphy, with emphasis on the marine rocks. *In*: Itihara, M.; Kamei, T. *ed.* Proceedings of the First International Colloquium on Quaternary Stratigraphy of Asia & Pacific Area, Osaka, 1986. Science Council of Japan. Pp. 250–269.

Fleming, C. A. 1953: The geology of Wanganui subdivision. *New Zealand Geological Survey bulletin 52*: 362 p.

Grapes, R. H.; Sissons, B. A.; Wellman, H. W. 1987: Widening of the Taupo Volcanic Zone, New Zealand, and the Edgecumbe earthquake of March 1987. *Geology 15*: 1123–1125.

Milne, J. D. G. 1973: Map and sections of river terraces in the Rangitikei Basin, North Island, New Zealand. Four sheets. *New Zealand Soil Survey report 4.*

Nairn, I. A.; Hull, A. G. 1985: Post-1800 years B.P. displacements on the Paeroa Fault zone, Taupo Volcanic Zone. *New Zealand Geological Survey record 8*: 135–142.

Pillans, B. 1981: Upper Quaternary landscape evolution in south Taranaki, New Zealand. Unpublished PhD thesis, Australian National University. 202 p.

———1983: Upper Quaternary marine terrace chronology and deformation, South Taranaki, New Zealand. *Geology 11*: 292–297.

————1986: A late Quaternary uplift map for the North Island, New Zealand. *Royal Society of New Zealand bulletin 24:* 409–418.

————in press: Late Quaternary marine terraces, south Taranaki–Wanganui (sheet Q22 and part sheets Q20, Q21, R21 & R22), 1:100 000. *New Zealand Geological Survey miscellaneous series map 17*.

Robinson, R. 1986: Seismicity, structure and tectonics of the Wellington region, New Zealand. *Geophysical journal of the Royal Astronomical Society 87*: 379–409.

Stern, T. A.; Davey, F. J. 1988: Crustal structure and origin of basins formed behind the Hikurangi subduction zone. *In*: Price, R. A. *ed*. Origin and evolution of sedimentary basins and their energy and mineral sources. *American Geophysical Union geophysical monograph 48*: 73–85.

Sylvester, A. G. 1988: Strike-slip faults. *Geological Society of America bulletin 100*: 1666–1703.

Te Punga, M. T. 1957: Live anticlines in western Wellington. *New Zealand journal of science and technology B38*: 433–446.

Walcott, R. I. 1984: The kinematics of the plate boundary zone through New Zealand: a comparison between short- and long-term deformations. *Geophysical journal of the Royal Astronomical Society 79*: 613–633.

Wellman, H. W. 1972: Recent crustal movements: techniques and achievements. *Tectonophysics 13*: 373–392.

Yeats, R. S. 1986: Faults related to folding with examples from New Zealand. *Royal Society of New Zealand bulletin 24*: 273–292.