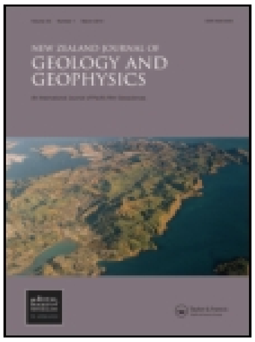


New Zealand Journal of Geology and Geophysics

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

The structure of the lower mesozoic rocks in the Porirua district

B. D. Webby

To cite this article: B. D. Webby (1959) The structure of the lower mesozoic rocks in the Porirua district, New Zealand Journal of Geology and Geophysics, 2:3, 528-540, DOI: 10.1080/00288306.1959.10423158

To link to this article: https://doi.org/10.1080/00288306.1959.10423158

THE STRUCTURE OF THE LOWER MESOZOIC ROCKS IN THE PORIRUA DISTRICT

By B. D. WEBBY, Geology Department, Victoria University of Wellington

(Received for publication, 22 December 1958)

Summary

The well indurated greywacke-argillite rocks of the Porirua district have been subjected to strong folding followed by more than one period of intense faulting and fracturing. The main axis of flexural folding trends NNE-NE and plunges 14° to 17° NE. Numerous small-scale folds are described. They exhibit a wide range of forms: from open, symmetrical, and faulted folds to isoclinal folds. A few localized folds, described as incongruous, have axes that cut across the NNE-NE trending regional fold axis.

Faults are classified, on the basis of certain field criteria, into two broad age groups, early and late. The early faults include those associated with folding and those formed during subsequent episodes of faulting. Late faults comprise those that have been active during and possibly somewhat prior to the Quaternary.

INTRODUCTION

The alternating greywacke and argillite strata in the Porirua district are well indurated, intensely fractured, and have a predominant strike varying from 10° to 50° east of north (Fig. 1). Generally the strata are steeply dipping and commonly overturned. Bed facings (Webby, 1959) are predominantly to the west. Numerous small-scale folds, observed in coastal sequences near Titahi Bay, indicate that the rocks are tightly folded. Since their folding, the rocks have been subjected to faulting of more than one age.

Quennell (1938) described a number of faults in the Porirua district, on the basis of their geomorphic expression. One of these, the Owhariu Fault, has subsequently been referred to by Adkin (1951; 1954), Lensen, Stevens and Wellman (1956), and Lensen (1958).

FOLDING

Statistical analyses, by a method developed by Sander (1948), and used by Weiss (1954) and Brothers (1956), have revealed that there is a single fold axis* in the Porirua rocks west of the Owhariu Fault. The intersections of bedding planes were plotted on a lower hemisphere projection of an equal area net, and the density of distribution of plots contoured (Fig. 2a). The pronounced maximum, which represents the

---

*The fold axis is defined by Wegmann (1929) and re-stated by Clark and McIntyre (1951, p. 594) as follows: "The axis of a fold is defined as the nearest approximation to the line, which, moved parallel to itself in space, generates the fold."

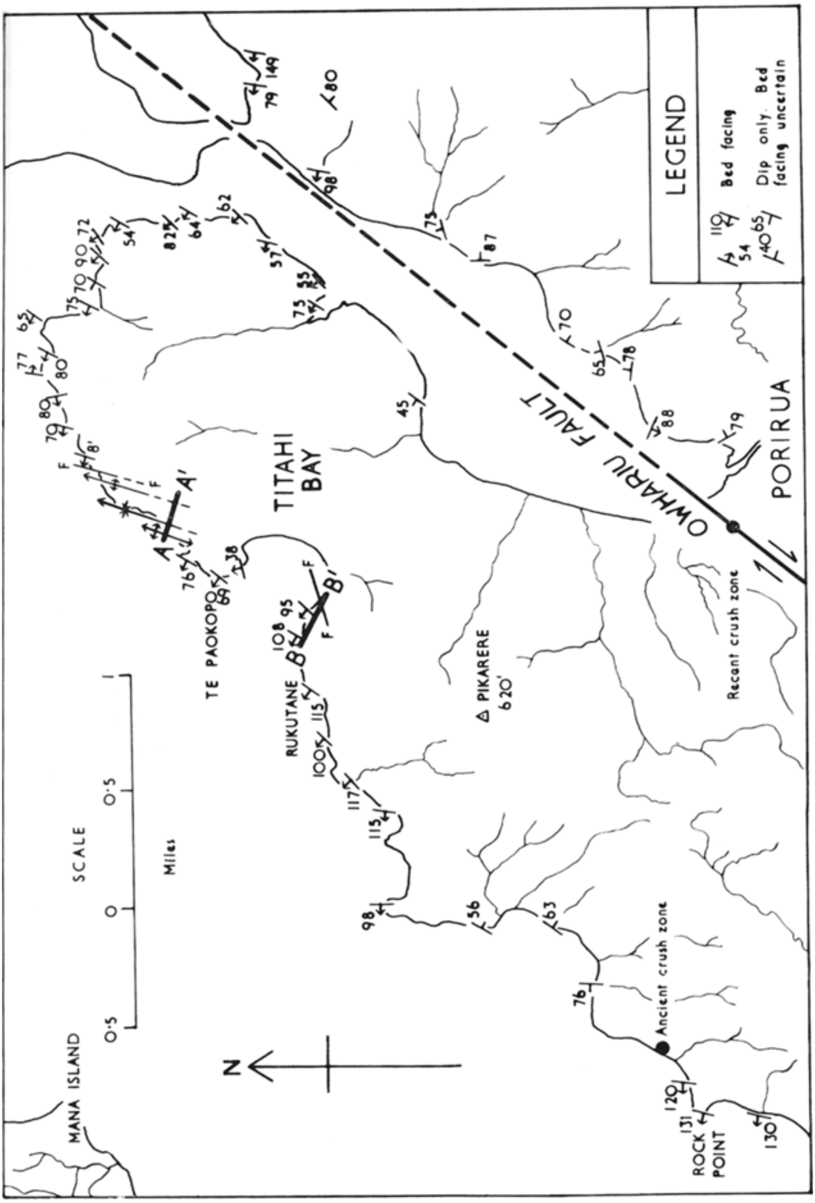
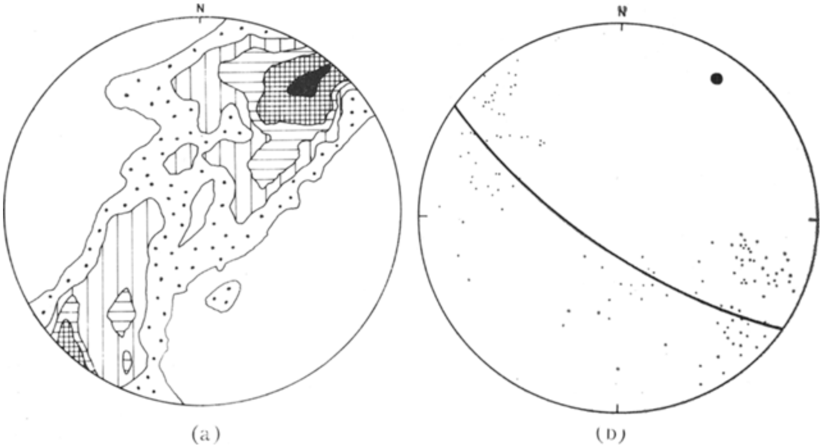


FIG. 1.—Map of the Porirua district showing the location of the cross-sections, and structural features mentioned in the text.

fold axis, trends 040° and plunges 17° NE. The poles of bedding planes were also plotted, and a great circle drawn through their maximum density (Fig. 2b). The fold axis is represented by the pole of the great circle. It trends 034° and plunges 14° NE. Similar trends and



(a) (b)

Fig. 2(a).—Contour diagram of the intersections of bedding planes at Titahi Bay, calculated on 2,145 plots. Contours at 9%, 5%, 3%, 2%, and ½% per 1% area.

Fig. 2(b).—Lower hemisphere projection of poles of bedding planes at Titahi Bay. 128 plots.

plunges are recorded from the majority of small-scale folds (see below).

The pattern of folding is illustrated by WNW-ESE cross-sections: A-A′ to the north, and B-B′ to the south of Titahi Bay (Fig. 3). These cross-sections were constructed from detailed mapping of coastal exposures and actual observation of the folds. In both cross-sections the strata are strongly folded, although more strongly in B-B′ than in A-A′. The folds plunge gently NE, and have axial planes that are almost vertical in cross-section A-A′, and dip 60° to 70° SE in cross-section B-B′.

Description of Folds

The folds described in the following account are arranged in an approximate order of increasing complexity.

An open, symmetrical and faulted anticline is exposed along the coast, north of Titahi Bay (Fig. 3, F1; Fig. 4). The plunge of this fold gradually changes when traced for 250 yards along its trend. Towards the north the fold axis has a gentle NNE plunge, and to the south a gentle SSW plunge. The fold flexes a sequence of thick graded beds intercalated with thin beds. During folding the zones of thin beds, which contain wavy bedding and bedding-plane faulting, were relatively incompetent between the thick, competent beds.

A faulted, slightly asymmetric syncline (F2), more strongly folded than F1, was observed 35 yards east of anticline F1. The syncline trends 020° and plunges 10° NNE.

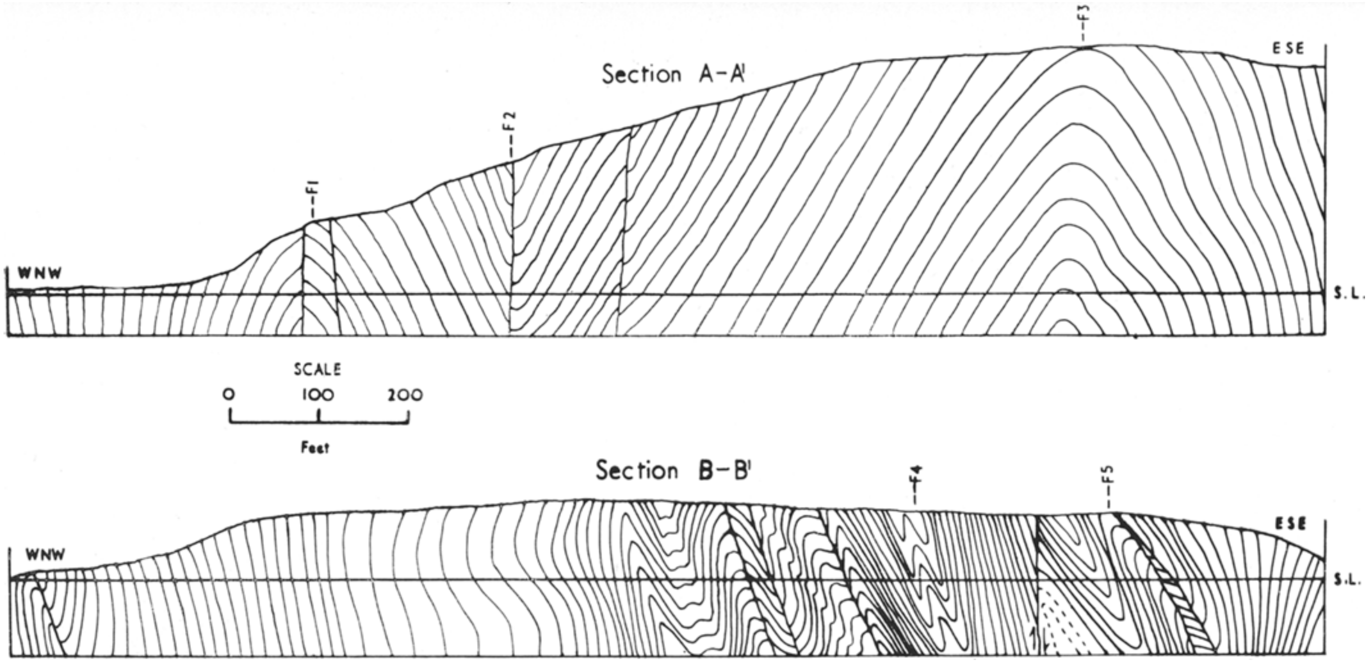


FIG. 3.—Cross-sections north (A-A'), and immediately south (B-B') of Titahi Bay, showing the pattern of folding and faulting. All folds and faults represented in these cross-sections were observed in the field.

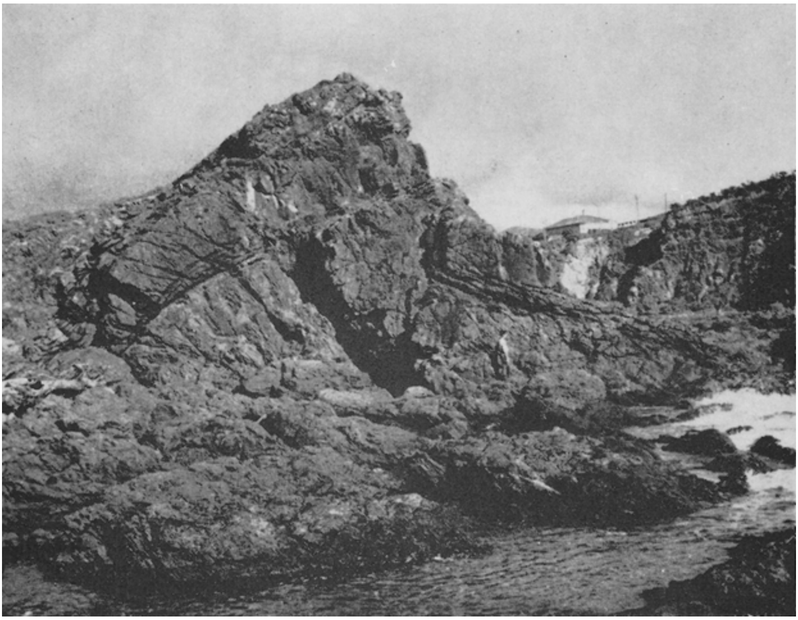


FIG. 4.—An open, symmetrical and faulted anticline (F1) exposed on the coast north of Titahi Bay.

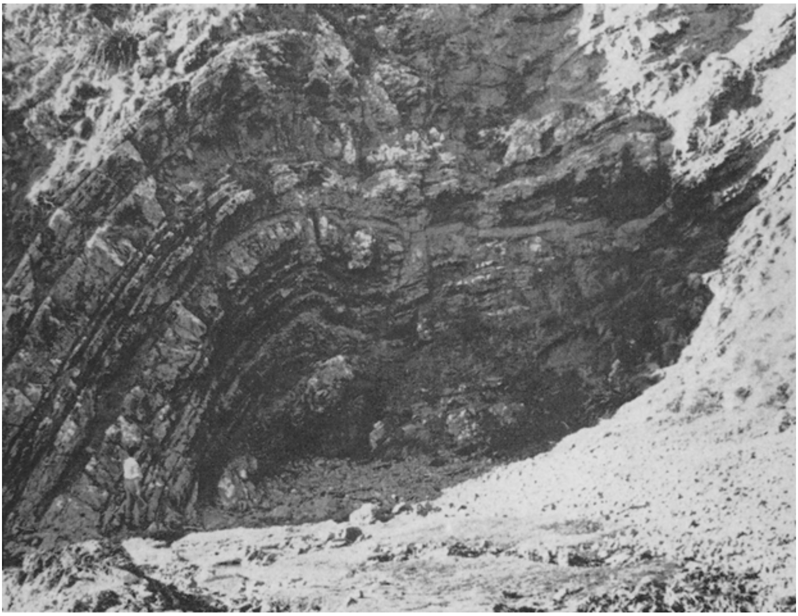


FIG. 5.—An S fold exposed at Te Paokopo.

Syncline F2 is followed, approximately 150 yards eastwards, by another open, symmetrical anticline (F3). The anticline, which occurs in thick graded beds, has a gentle NNE plunge. Between F2 and F3 there is a minor faulted S fold.

An S fold is exposed in the coastal cliff at Te Paokapo, near Titahi Bay (N160/387445) (Fig. 5). The axial plane of this fold dips steeply east, and the plunge is 5° NNE. Fracturing and small-scale faulting are particularly noticeable in the flexed portion of the S fold.

Nearby, another S fold crops out (N160/388442), more strongly folded and recumbent with an overturned middle limb. The fold plunges gently NNE, and the axial plane dips 20°E. A small fault dipping 55° E parallels the bedding in the overturned limb.

A small compact S fold (Fig. 6) was observed at Rock Point (N160/347408). The fold occurs in very thin overturned strata. Its axis has a 015° trend, no plunge, and its axial plane dips 72° E.

A typical example of the tight folding which characterizes the thinly bedded strata on the coast south of Titahi Bay is a narrow, asymmetric syncline (Fig. 3, F4; Fig. 7). Its axis trends 043° and plunges 25° NE. The axial plane of the fold dips steeply (66° SE). The south-eastern flank of the fold is overturned and dips 79° SE, and the north-western flank dips 54° SE.

The tightest folding observed is represented by a rather complex fold (F5), which is also exposed in the thin graded beds on the coast south of Titahi Bay (Fig. 8). The strata are overturned on both sides of the fold, as deduced from a careful study of graded bedding. Thus, the structure is a plunging, asymmetric, faulted S fold. Both anticlinal and synclinal portions of the S fold are complicated by faulting.

Incongruous Folds

A few folds in the region west of the Owhariu Fault have axes that cut across the NNE-NE trending regional fold axis. Two of these were studied in detail. The axis of an S fold exposed north of Titahi Bay (N160/388446) trends 065° and plunges 20° W, and is surrounded by strata that strike NE and dip 70° to 80° NW. Field observation of the fold suggests that it developed prior to regional folding about a NNE-NE trending axis. If this is so, then the fold originally had a recumbent form, an axis with a trend of about 070° and a gentle plunge to the east.

Another S fold is situated between the anticline F1 and the syncline F2, on the coast north of Titahi Bay (N160/391449). This fold has a vertical axis. The axial planes of the S fold, as seen on the coastal wave-cut platform, strike 160°. Eastwards across the trough of syncline F2 there is an intensely deformed zone. This zone may represent a continuation of the S fold present in the eastern flank of syncline F2. In this area, the regional folding was probably superimposed on an

FIG. 6.—An S fold exposed at Rock Point.

FIG. 7.—A syncline (F4) exposed on the south coast of Titahi Bay.
Professor R. H. Clark, photo

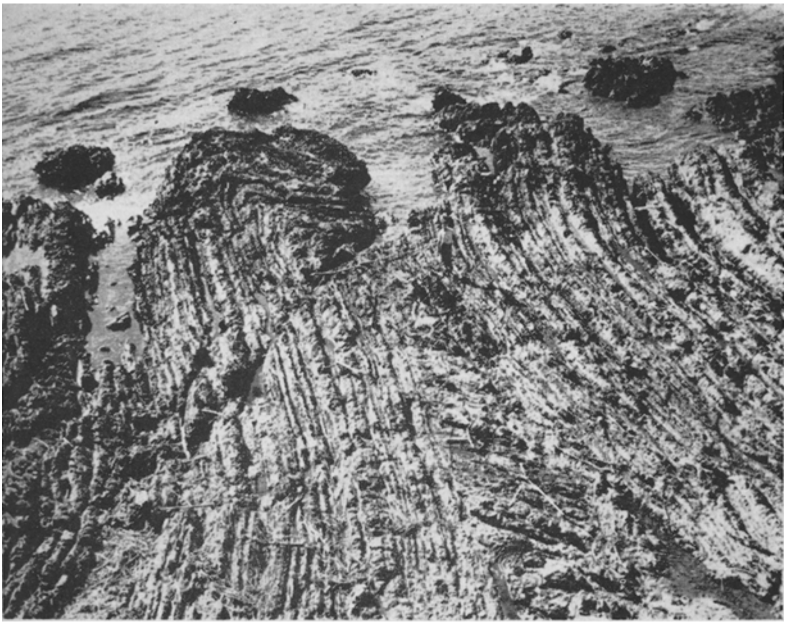


FIG. 8.—A faulted S fold (F5) exposed on the south coast of Titahi Bay.

earlier recumbent overfold, the axis of which had an original NW trend and little or no plunge.

Features Associated with the Folding

The sediments, which have formed greywacke and argillite respectively, have possessed differing degrees of competency under a uniform stress condition. In a graded bed, the greywacke unit (relatively competent) has been folded mainly by concentric shear along bedding planes, as shown by slickensiding and bedding plane faults. The argillite unit (relatively incompetent) has been folded mainly by irregular slip along a multitude of parallel shear planes oblique to bedding—*fracture cleavage.*

DISCUSSION OF FOLDING

Notwithstanding the localized nature of the area studied, the exposed folds exhibit wide variations in shape and size. If a uniform stress condition acted during the folding, variations in shape and size may be the result of differential competencies in the rocks. For example, the broad, open folds F1, F2, and F3 are developed in thick beds interspersed with thin (relatively competent), and the tight folds shown in cross-sections B-B′ are in thin graded bedding (relatively incompetent).

Alternatively, the folds may vary in shape and size because during folding differential stresses acted on the beds undergoing deformation.

The exposed folds also exhibit small variations in orientation. Some of these may be the result of subsequent faulting and associated tilting. It was noted that the axes of the folds at the coast south of Titahi Bay plunge up to 25° NE, and north of Titahi Bay axes of folds usually plunge 15° NNE. Differential tilting associated with recent faulting, as deduced from the present surface expression of K Surface remnants (Cotton, 1957) directly north and south of Titahi Bay, may account for at least 5° of the difference in plunge.

In general, the folds exhibit a range of forms from concentric folds displaying fracture cleavage in the argillite to isoclinal folds. Most of the slip during folding was along bedding planes, and to a lesser extent along a multitude of internal shear planes in the argillites.

At present only a very tentative explanation for the origin of the incongruous S folds can be given. The folds are small, localized, originally recumbent and with varying original axial trends. These four factors, when considered collectively, suggest that the incongruous folds originated by gravity slumping. The type of slump fold envisaged is a "paralloid fold" (Waterhouse and Bradley, 1957). Another possible interpretation for their origin is by overthrusting. The localized nature of the folds, however, and the varying trends are opposed to this latter view.

There are few detailed accounts of "Alpine Facies" folds available for comparison. Brodie (1953) described a large inverted overturned syncline on the south coast of the Wellington Peninsula. Recent observations by Waterhouse (1955), and Lillie, Gunn, and Robinson (1957) in the Southern Alps indicate isoclinally folded strata mainly trending between NNE and NE. The major isoclinal folds from the Alpine region, though on the whole larger, have a form directly comparable with numerous folds described in this account.

FAULTING

The faulting is classified as either early or late, on the basis of field criteria. Early faulting is indicated by indurated autoclastic breccias, cemented fault planes, and stretched and bent bedding adjacent to faults. In contrast, late faulting is indicated by soft pug in crush zones, fault planes not cemented, bedding sharply truncated by faults, weathered and unweathered strata in fault contact, faulted superficial (Quaternary) deposits, and the geomorphic expression of recent faults. Brodie (1953) also distinguished two periods of faulting in the greywackes and argillites on the south coast of the Wellington Peninsula.

Numerous small-scale lateral fault displacements were measured in *vertical* strata near Titahi Bay. These have been grouped, on the above field criteria, as early or late. In addition, displacements have been classed as sinistral or dextral, on the assumption that the faults were transcurrent. The results are shown graphically in Fig. 9. It must be stressed that where faults strike between 010° and 055° (predominant

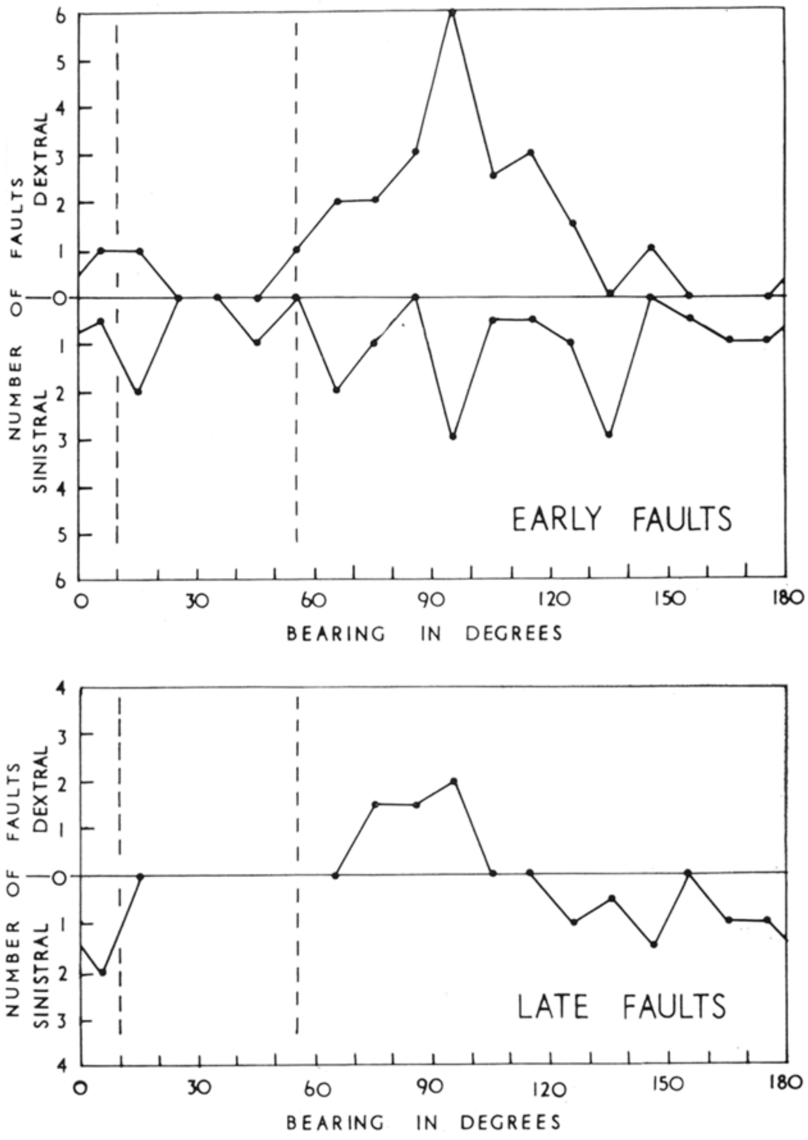


FIG. 9.—Frequency polygons of early and late small-scale lateral faults in *vertical* strata. The bearing and nature of these faults (i.e. dextral or sinistral) is shown. Note that the predominant strike of bedding is between the dotted lines.

strike of strata) no displacements can be observed, as such faults are parallel to bedding. Hence, though such faults may be observed, they cannot be represented in the graphs because the nature of their displacements is unknown.

The late faults are transcurrent, and fall into two groups: those with strikes between 65° and 105° are dextral; those with strikes between 115° and 195° are sinistral. It is probable that there are many late, dextral faults which parallel the strata, unrepresented in the graph. The graph of early faults does not show a pattern consistent with transcurrent faulting. It is suggested that these faults developed prior to a major rotation of the strata into a vertical attitude.

Description of Early Faults

Bedding plane faulting is commonly present in the alternating strata. Such faults are usually situated in the argillite units, near the abrupt contacts between successive graded beds. Bedding plane faults may have narrow crush zones up to 8 cm wide that have been cemented with quartz.

A coastal cliff explosure just east of Rock Point (N160/352413), contains an indurated autoclastic breccia, which may have developed in a crush zone of a large ancient fault (Fig. 1). The autoclastic breccia is almost as thoroughly indurated as typical Wellington greywacke, and is composed of irregular crudely aligned angular fragments of (vein) quartz and greywacke (pebbles up to 5 cm diameter). In the region associated with the autoclastic breccia, the greywackes and argillites contain numerous veins of quartz and some of calcite.

Veining

Veins* are generally rare in the greywacke-argillite rocks of the Porirua district, but are not uncommon in localized areas formerly subjected to intense shearing. The veins are up to 6 cm thick and contain quartz or, rarely, calcite.

Veinlets are fairly common in the rocks, particularly in the greywackes. They are heavily concentrated in localized areas. Veinlets studied in thin section contain mainly quartz. A few veinlets of prehnite were also recognized. Brothers (1956, p. 478) noted that "prehnite typically occurs in sandstone members of the Auckland rocks where solutions rich in Ca and Si, ————, have crystallized in tension fractures".

Description of Late Faults

In the Porirua district numerous late faults were observed, from the small-scale displacements of graded beds, to the "major" transcurrent

---

*An arbitrary figure of 1 cm is taken as the thickness boundary between veins and veinlets.

Owhariu Fault (Lensen, 1958) with a crush zone 200 ft in width.

The exposed crush zone of the Owhariu Fault (Fig. 1) consists of extensively shattered and brecciated rock fragments incorporated in a soft blue pug. Large elongated slivers of brown weathered greywacke were observed in the pug. The presence of these infaulted slivers within the crush zone confirms that the movements were comparatively recent. The slivers are irregularly aligned in a direction parallel to the topographic expression of the Owhariu Fault.

On the coast south of Titahi Bay, a small fault (which cuts across the line of section B-B′—see Fig. 1) has brought weathered and fresh rock into juxtaposition along the fault plane. The fault is vertical, and it strikes 057°. The estimated throw is 30 ft with the downthrown side to the SE.

DISCUSSION OF FAULTING

Early faulting accompanied the regional folding and was followed by further episodes of early faulting which produced the autoclastic breccia and some faults with cemented fault planes. Brodie (1953, p. 223) pointed out that the greywacke-argillite rocks at the south coast of the Wellington Peninsula, which were subjected to early faulting, must have been "buried deeply enough to permit cementation of the shattered rock with networks of quartz veins and to allow complete induration of the shattered material". The Porirua rocks were probably similarly buried during the early faulting period. In general, the folding and early faulting in the Porirua district may be considered to belong to the widespread deformation known as the post-Hokonui Orogeny.

Between the early faulting period and the late faulting period there was a large time interval, possibly represented in the Porirua district by a reduced intensity of deformation, and perhaps rotation of strata.

Late faults have been active at least during the Quaternary (Webby, 1958). Small-scale late faulting is probably directly related to transcurrent movement on "major" faults such as the Owhariu Fault.

ACKNOWLEDGEMENTS

This paper formed a portion of an M.Sc. thesis presented at Victoria University of Wellington, 1958.

The writer particularly wishes to thank Professor R. H. Clark for his critical reading of the manuscript, and Dr H. W. Wellman for his helpful advice on map symbolism.

REFERENCES

ADKIN, G. L., 1951: Geology of the Paekakariki Area of the Coastal Lowland of Western Wellington. *Trans. roy. Soc. N.Z.*, *79* : 157-76.

———,1954: Late Pleistocene and Recent Faulting in the Otaki-Porirua and Dalefield-Waipoua Districts of South Wellington, North Island, New Zealand. *Trans. roy. Soc. N.Z., 81* : 501-19.

BRODIE, J. W., 1953: Stratigraphy and Structure of the Greywackes and Argillites on the South Coast of Wellington Peninsula. *N.Z. J. Sci. Tech., B 34* : 205-26.

BROTHERS, R. N., 1956: The Structure and Petrography of Greywackes Near Auckland, New Zealand. *Trans. roy. Soc. N.Z., 83* : 465-82.

CLARK, R. H.; MCINTYRE, D. B., 1951: The Use of the Terms Pitch and Plunge. *Amer. J. Sci., 249* : 591-9.

COTTON, C. A., 1957: Tectonic Features in a Coastal Setting at Wellington. *Trans. roy. Soc. N.Z., 84* : 761-90.

LENSEN, G. J., 1958: Note on Fault Correlations across Cook Strait. *N.Z. J. Geol. Geophys., 1* : 263-8.

LENSEN, G. J.; STEVENS, G. R.; WELLMAN, H. W., 1956: The Earthquake Risk in the Wellington District. *N.Z. Sci. Rev., 14* : 131-5.

LILLIE, A. R.; GUNN, B. M.; ROBINSON, P., 1957: Structural Observations in Central Alpine Region of New Zealand. *Trans. roy. Soc. N.Z., 85* : 113-29.

QUENNELL, A. M., 1938: The Physiography and Structure of the Porirua District. Unpublished M.Sc. Thesis in Victoria Univ. of Wellington Libr., N.Z.

SANDER, B., 1948: "Einführung in die Gefügekunde der Geologischen Körper". I Teil. Springer Verlag, Vienna and Innsbruck.

WATERHOUSE, J. B., 1955: An Isoclinal Fold on Häckel Peak, Southern Alps, New Zealand (S 79). *Trans. roy. Soc. N.Z., 83* : 345-6.

WATERHOUSE, J. B.; BRARLEY, J., 1957: Redeposition and Slumping in the Cretaceo-Tertiary Strata of S.E. Wellington. *Trans. roy. Soc. N.Z., 84* : 519-48.

WEBBY, B. D., 1958: The Geology of the Porirua District. Unpublished M.Sc. Thesis in Victoria Univ. of Wellington Libr., N.Z.

———, 1959: Sedimentation of the Alternating Greywacke and Argillite Strata in the Porirua District. *N.Z. J. Geol. Geophys., 2* : 461-78.

WEISS L. E., 1954: A study of tectonic style: structural investigation of a marble-quartzite complex in Southern California. *Dep. Geol. Univ. Calif. Publ., 30* : 1-102.