TECTONIC AND EARTHQUAKE RISK ZONING IN NEW ZEALAND[1]

by

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presented by   G. J. Lensen

INTRODUCTION

Though New Zealand is a small country it has not suffered
uniformly from past earthquakes. It would be desirable to assess
the risk from damaging earthquakes by using an adequately long
instrumental record, but systematic instrumental records of large
shallow earthquakes cover a period of less than 40 years and extend
back only to 1940 for those of magnitude 6 to 6.9. These short-term
records provide no justification for detailed seismic zoning in New
Zealand, and therefore if the relative frequency of occurrence of
major earthquakes in different areas is to be estimated, geological
evidence must be used. Most of the historical major earthquakes in
New Zealand have been accompanied by measurable tectonic deformation,
revealed by warping, tilting or faulting of the earth's surface.
Assuming that the present-day geological processes are the key to the
past, the geologist infers that earthquakes will have accompanied most
of the similar pre-historic deformation shown in the relatively recent
geological record, and conversely that major earthquakes will have been

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Footnote:

1. This paper is one of three reports produced by a subcommittee of
    the Royal Society of New Zealand. The reports are published in
    the Transactions of that Society.

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rare where there is no measurable deformation.   It is not asserted
that all surface deformation takes place at times of major earthquakes,
or that all major earthquakes are accompanied by surface deformation.

Given sufficient time, major earthquakes can occur anywhere;
but some areas have earthquakes more frequently than others, and some
have virtually none.   Calculated risks are inherent in any zoning
scheme anywhere, and these risks should be assessed in terms of
probability of destruction from major earthquakes within a given period
of time.

GEOLOGICAL SETTING FOR LATE QUATERNARY TECTONIC MOVEMENT

In the following discussion various periods of geological time
are referred to, and these are listed below.   The lengths of time
involved are not known exactly but the orders of magnitude are likely
to be correct.

Years

115   Historic)   )
)   )
20,000   ) Recent)   )
)   )   Quaternary
500,000   ) Late Quaternary   )
)
3 to 5×10^{6} . . . . Early Quaternary)

11×10^{6} . . . . Pliocene . . . . .

                                                        Miocene

The most seismically active regions of the earth are in belts
of late Tertiary and Quaternary deformation, and one of these belts runs
through New Zealand.   The tectonic activity of which the present day
earthquakes are a manifestation is not a new phase, but continues from
the geologic past.

Pliocene and Early Quaternary sediments were originally
deposited almost horizontally and the present dips (angles of slope) of
their bedding planes register the sum of the tectonic movements since
deposition.   Figure 1, on which the dips are shown, indicates the long
term tectonic setting in which the Late Quaternary deformation has taken
place.   This figure shows angles of dips, averaged where many observa-
tions are available, of Early Quaternary and Pliocene beds.

The absence of observations in substantial areas of Figure 1
results from the absence of preserved Pliocene and Early Quaternary
deposits that would have registered deformation within those areas.

The only one of these which can be reasonably inferred not to have suffered deformation in the Pliocene and Early Quaternary is North Auckland. North of where observations are recorded on Fig. 1, strata even older than Pliocene are not deformed. Thus, two broad Quaternary tectonic regions can be distinguished:

(a) The North Auckland Peninsula. This region has not experienced measurable deformation since the Miocene, and apart from local volcanic activity, appears to have been tectonically stable during the Quaternary.

(b) The "Quaternary Tectonic Zone". This comprises the remainder of the country. Its north-west limit can be fairly closely defined from the mouth of the Waikato River through the Hauraki Gulf, but the south-east limit lies beyond the New Zealand coast.

LATE QUATERNARY TECTONIC DEFORMATION

The principal evidence of Late Quaternary deformation is provided by fault traces on Late Quaternary deposits or topographic features no older than Late Quaternary. These fault traces are shown in Figure 2. To illustrate all that are known, the lengths of some short traces have been exaggerated diagrammatically.

The coverage of the country cannot be perfectly uniform from area to area; fault traces can be easily seen in open country but not in bush country; not all the country is covered by aerial photographs nor has every photograph been examined. The four-mile mapping programme of the N.Z. Geological Survey has, however, now largely covered the country, and field work and air photograph study have been an essential part of this programme. It is confidently believed that the relative densities of fault traces from region to region will not be significantly changed by further work.

There are two main groups of fault traces. The first covers the central volcanic district and extends south-west to include the set of traces in the Wanganui region. The second group comprises the major transcurrent faults (faults with dominantly horizontal movement) and a great number of minor traces. The greatest of the transcurrent faults is the Alpine Fault, which is active at points along its full length from the Wairau River to Milford Sound and probably further south-westwards just off the Fiordland coast.

The first group differs from the second in that the faulting is dominantly tensional instead of dominantly transcurrent. The tectonic setting of this group is one of tension and volcanic activity; that of the second is one of horizontal shear. Both groups, in different tectonic settings, are adjacent, and show that even a country as small as New Zealand cannot be regarded as a single entity from a tectonic —

and hence seismic — point of view.

One consequence of the contrast in tectonic settings is that surface displacement can occur with lower magnitude earthquakes in the tensional region.   Thus surface faulting accompanied the Taupo (1922) earthquake of magnitude less than 6, while in the shear region surface faulting is not known to have occurred during earthquakes of magnitudes less than 7.

In the South Island, comparatively few Late Quaternary fault traces are known north-west of the Alpine Fault, but warping and tilting of Late Quaternary surfaces indicate that several of the major folded structures of north Westland and southern Nelson are active.   Although no traces are known from the Grey River to the Cascade River in Westland, elevated marine shorelines show that this part of the region west of the Alpine Fault is also unstable.   South and east of the Alpine and Hope faults over 90 per cent of the fault traces lie within 80 miles of these faults.   South-east of this 80-mile belt only the trace on the Akatore Fault, south-west of Dunedin, is definitely Recent.   Other traces, in south Canterbury and north Otago are late Quaternary in age but not Recent.

In the North Island, north-west of the central volcanic district, only a few traces are known, the furthest north-west being those at Bombay south of Auckland, which are almost certainly associated with local volcanic activity.   In the lower Mokau River two parallel traces are the only Recent ones known west of the central volcanic district.

The absence of fault traces in the Gisborne region is striking, particularly as it lies along the north-east trend of the main belt of East Coast deformation.   The whole of this belt is tectonically active; judging by terraces, warping in late Quaternary times has taken place, and possibly warping rather than faulting characterises Quaternary deformation in the Gisborne region, as is also the case in parts of California.   Factors militating against the formation and preservation of fault traces are considerable thicknesses of intensely fractured and incompetent upper Cretaceous and lower Tertiary beds, and in the southern part of the region a thick sequence of relatively unconsolidated upper Tertiary sediments.

By far the majority of fault traces shown on Fig. 2 are of Recent age, and a "Recent Tectonic Zone" — the zone of frequent tectonic deformation in the last 20,000 years — can be defined on the basis of the distribution of these traces.   The Akatore and Mokau traces lie far from the Recent Tectonic Zone, but within the Quaternary Tectonic Zone based on Fig. 1.   Thus tectonic deformation has not ceased in that part of the Quaternary Tectonic Zone that lies outside the Recent Tectonic Zone, and the rarity of fault traces there is merely an indication of the rarity of deformation.   This emphasises that subdivision of New Zealand in terms of tectonic deformation and of risk of major earthquakes must be based on relative frequency of deformation.

HISTORIC TECTONIC DEFORMATION AND EARTHQUAKES

Both in New Zealand and overseas, most measured historic surface displacements of the order of feet have been indisputably associated with destructive shallow earthquakes, of magnitude 7 or greater, rarely less except in tensional regions.

In the New Zealand area there have been fourteen shallow earthquakes since 1848, of M7 or greater, and surface displacement during at least seven of them (Fig. 3). Making allowance for the uncertainty of position of many of the epicentres, particularly the older ones, for the three epicentres definitely given as at sea, and for the six epicentres possibly at sea because of low confidence of location, at least 80 per cent of destructive earthquakes were accompanied by surface tectonic deformation (Appendix 1). The deformation comprises surface faulting, warping, tilting and regional changes in level.

Of the instances of historic surface deformation since 1848, six are of faulting accompanied by changes in level, and the seventh, Wairoa, of horizontal movements established by re-triangulation.

The historic deformation and major earthquakes serve to define a "Historic Tectonic Zone".

In California, two instances of "creep" along faults have been recorded, one on the San Andreas Fault. This creep has been accompanied by only minor earthquakes, the larger ones of which were associated with the larger of the individual small sudden fault movements. Records of such creep are rare in comparison with those of sudden large movements accompanying major earthquakes. No creep has been established on any New Zealand fault, although it cannot be ruled out as a factor producing some fault displacements. It seems improbable that creep at faults amounting to more than a fraction of the known sudden displacements could have gone unrecorded. As in historic times, so in earlier times, faulting was dominant over creep, as is shown by the abruptness and freshness of the fault scarps cutting Recent deposits and recording successive movements.

THE SUCCESSIVE TECTONIC ZONES

The Quaternary Tectonic Zone, that is the zone of measured Quaternary tectonic deformation based on Fig. 1, refers to a period of several million years. If the frequency of deformation varies from area to area within this zone, then the areas prone to more frequent deformation should show as areas within this zone when deformation that has taken place over shorter time spans is considered. The north-east trend of the Historic Tectonic Zone (Fig. 3), shown also in the distribution of late Quaternary fault displacements (Fig. 2), is consistent

with the trend showing in Quaternary deformation indicated by the geological structure of the country. This structural trend is the basis for inferring the trend of the Quaternary Tectonic Zone and for inferring a common median axis for the three successive zones shown in Fig. 3.

The progressive restriction of zones with decreasing time is consistent with a maximum frequency of deformation at a median axis, decreasing outwards. Nevertheless it would have been desirable to illustrate this from different periods of time randomly distributed through the Quaternary, because Fig. 3 could also be interpreted as showing progressive areal restriction in measurable tectonic activity with time. Even if this were so, non-measurable tectonic activity (accompanied by smaller earthquakes) would still be expected beyond the Historic Tectonic Zone, and zoning could be on the basis of intensity not frequency. The conclusions with respect to earthquake risk would be substantially similar, but because some rare Recent deformation has taken place over an area greater than the Recent Tectonic Zone (of frequent deformation), it is thought that Fig. 3 indicates the influence of frequency of measurable tectonic activity and not areal restriction with time.

EARTHQUAKE RISK

Earthquake risk may be defined as the risk of serious damage from earthquakes within a defined period of time. Minor damage resulting from distant destructive earthquakes, or from smaller earthquakes nearby, is an acceptable risk.

It is first necessary to define (a) the zones within which earth-quakes of particular magnitudes are to be expected. Then it is necessary to define (b) the distances to which isoseismals of destructive intensity extend.

Tectonic geology can help in defining a zone within which epicentres of magnitude 7 and over may be most frequently expected. The Historic Tectonic Zone, based on 115 years of destructive earthquakes, cannot be considered representative of subsequent equal periods. The zone of maximum frequency of earthquakes of magnitude 7 and over will be greater than the Historic Tectonic Zone, but it will be smaller than the Recent Tectonic Zone (Fig. 3) which refers to a period of about 20,000 years, two orders of magnitude greater than the time that is being planned for. Nevertheless the boundaries of the Recent Tectonic Zone are recom-mended as the boundaries of a zone of most frequent earthquakes of magnitude 7 and over. This zone can be made the basis of earthquake risk zones by considering the distances to which destructive effects are likely to extend from the epicentres.

Destructive effects do not extend to equal distances in all

directions from earthquake epicentres as is evident from isoseismal
maps. One major factor influencing the incidence of destruction
(MM 8 felt intensity, and greater[6]) is the nature of the ground at the
place from which reports are received. The influence of ground con-
ditions on the isoseismals is evident, for example, from the values at
Blenheim in the isoseismal maps of the 1929 and 1931 earthquakes;
Blenheim lies predominantly on young Post-glacial thick alluvium. In
1929 a value of MM 7 contrasts with MM 6 a few miles to the south; in
1931 a value of MM 5 - 6 contrasts with MM 3 - 4 a few miles to the
north. Thus isoseismals locally reflect bad ground conditions for
which additional allowance in assessing risk is essential, as discussed
in a separate report.

A second major factor causing asymmetry in isoseismals is
regional trends of geological structure, as is broadly shown by the
available isoseismals for major historic earthquakes (Fig. 4). The
north-east axes of the isoseismals are greater than the north-west axes,
as is to be expected from the regional structural trends which are
north-east in the region within which the historic earthquakes fall.
In the Auckland peninsula and in Otago and Southland, the trends are
north-west, and their influence should be allowed for.

These factors cause asymmetry in isoseismals; but the magnitudes
of the earthquakes and the depths of foci greatly affect the distances
to which destructive effects extend, and provide the greatest contrasts
between the isoseismals of different earthquakes shown on Fig. 4.

For the MM 8 isoseismals of Fig. 4, the maximum recorded
distances from epicentres range from 135 to 25 miles, and the average
maximum is 73 miles; Minimum distances range from 70 to 10 miles, and
the average minimum is 35 miles. These distances reflect the north-
east structural trend. See Table below.

Reference	Earthquake	Distance of Isoseismal MM 8 from Epicentre	
		Max.	Min.
1	1848	75	40
2	1855	120	70
3	1929	135	55
4	1931	60	30
5	1932	25	10
6	1934	75	30
7	1942	30	10
	Average:	74	35

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[6]With MM 7 earthquakes there is negligible damage to well-designed and
constructed buildings; some chimneys are broken. With MM 8 earthquakes
damage is considerable to ordinary substantial buildings, with partial
collapse, but is slight to specially designed structures.

In assessing risk of destruction from major earthquakes, the maximum radius of known destruction applied to the outside of the Recent Tectonic Zone would provide maximum assurance. But it is thought justifiable to bear in mind that special allowance will be made for the worst ground conditions in each area, that the structurally-controlled trend of isoseismals is not to be ignored, and that, since frequency is important in any consideration of risk, the outer margins of the Recent Tectonic Zone are expected to suffer major earthquakes less frequently than the middle. Except in Otago and Southland an average figure of 55 miles is recommended to be added to the outer margins of the Recent Tectonic Zone to provide the outer margins of a zone of destruction from major earthquakes, on average ground conditions. Because of the structural trends in Otago and Southland, the figure of 75 miles based on the average maximum distance of destructive effects, should be added.

A median area through the zone of destruction from major earth-quakes will be subject, because of its median position, to the destructive effects of more earthquakes than will the marginal areas; this median area is arbitrarily made one-third the width of the whole zone. Hence the zone of destruction from major earthquakes (M 7 and over) provides two zones of relative risk, the median Zone 1 flanked by Zone 2 (Fig. 5).

Serious damage may result from smaller magnitude earthquakes — magnitudes 5 to 6.9. The records of earthquakes of these magnitudes 5 to 6.9 indicate that they have a general north-east to south-west distribution pattern and that they do not extend north-west and south-east to the limits of the Quaternary Tectonic Zone. Nevertheless it is recommended that the boundary of the Quaternary Tectonic Zone should be taken as the boundary of the zone of most frequent M 5 to M 6.9 earth-quakes. In terms of earthquake risk zones the area of destructive influence of magnitude 5 to 6.9 earthquakes must be added to the Quaternary Tectonic Zone to provide the outer boundary of a third zone of risk. The radius of destruction from earthquakes of these magnitudes will be smaller than for the larger earthquakes but in view of the north-west structural trend in North Auckland, the radius of destructive influence should not be less than the 55 miles used for earthquakes of M 7 and over in the greater part of the country. Thus by adding a 55 mile zone to the boundary of the Quaternary Tectonic Zone, two additional zones may be recognized outside the zones of higher earthquake risks, and these are distinguished as Zones 3 and 4. Only part of the North Auck-land Peninsula lies within Zone 4.

It must be appreciated that the earthquake risk does not differ significantly in crossing a zone boundary — that each zone grades into the next. As the zones are unrelated to administrative divisions of the country, it may be justified, if thought is given to applying such a zoning, to upgrade rather than downgrade an area crossing or close to a boundary. It is also important to stress that the effects of ground conditions may be such that, for example, the risk on poor ground in Zone 3 is greater than the risk on good ground in Zone 2, especially near the boundary between the zones.

The following is an attempt at a simple description of the
estimated risks in the different zones; "destruction" is based on a
felt intensity of MM 8 or greater, and "damage" on a felt intensity of
MM 7 to MM 8.

Zone 1.   Destruction is probable in several parts of the zone in
           any period of a hundred years.   Damage is to be expected
at numerous places in any period of tens of years.

Zone 2.   Destruction is probable in several parts of the zone in any
           period of a few hundred years.   Damage is to be expected
at numerous places in any period of a hundred years.

Zone 3.   Destruction is possible though not probable in several parts
           of the zone in any period of a few hundred years.   Damage
is to be expected in numerous places in any period of a few hundred
years.

Zone 4.   Destruction is possible though not probable in several parts
           of the zone in any period of a few thousand years.   Damage
is to be expected in several places in any period of a few hundred
years.

       It must be stressed that it is not possible to forecast how soon
or where the next destruction or damage will occur in any zone.

SUMMARY

       Quaternary tectonic deformation in New Zealand shows a north-
east trend and this is also shown by historic deformation and earth-
quakes.   A study of Quaternary deformation shows that zones of
relative frequency of tectonic movement can be inferred and related to
a common median axis.   Where tectonic activity is most frequent,
destructive earthquakes are expected to be most frequent.   Conversely,
where tectonic activity is least frequent, destructive earthquakes are
expected to be least frequent.   With this as a basis, together with a
knowledge of the distances to which destructive effects extend from
earthquakes of particular magnitudes, zones of earthquake risk are
suggested.   These are zones of relative frequency of destruction from
earthquakes, not of absolute liability to destruction; the boundaries
are necessarily somewhat arbitrary as each grades into the next.

REFERENCES

(1)   Hayes, R.C., 1936. N.Z. J. Sci. Tech. 18, p.609.

(2)   Hayes, R.C., 1936. N.Z. J. Sci. Tech. 18, p.610.

(3)   Evison, F.F.,   report to this committee.

(4)   Evison, F.F.,   report to this committee;   and Adams, et al.,
           1933,   N.Z. J. Sci. Tech. 15, p.98.

(5)   Bullen, K.E.,   1938.   N.Z. J. Sci. Tech. 20, p.37.

(6)   Hayes, R.C.,   N.Z. J. Sci. Tech. 19, p.383.

(7)   Hayes, R.C.,   N.Z. J. Sci. Tech. 24, p.191.

APPENDIX 1.   CORRELATION OF MAJOR CRUSTAL EARTHQUAKES AND

SURFACE DEFORMATION IN NEW ZEALAND

Year	Epicentre listed as:	Surface Deformation
1848	land	Awatere Fault
1855	land	Wairarapa Fault
1888	land	Hope Fault
1897	sea	
1901	land	
1904	sea	
1914	land	
1929	land	White Creek Fault
1929	land	
1931	land	Several traces, e.g. near Paki Paki
1932	land	Triangulation network deformed
1934	?	
1942	land	Fault north of Taureu
1960	sea	

Of these 14 major crustal earthquakes, 7 were definitely
associated with simultaneous surface deformation.   This led Hayes
(1953) to state that nearly half of the major crustal earthquakes in
New Zealand were associated with faulting.

In order to obtain a closer ratio between faulting and major
earthquakes only those epicentres which can be proved beyond doubt to
be on land should be considered, as evidence of deformation at sea cannot
be produced.   The epicentres listed for the earthquakes of 1897, 1904,
and 1960 are at sea, and must be disregarded.

The accuracy of location of an epicentre depends entirely on its
geographic position in relation to the recording instruments.   At
present the highest accuracy of an epicentre (Class A) is a circle with
a radius of 5 miles (the epicentre lies somewhere in an area of 79
square miles).   A class B epicentre lies somewhere in an area of 314
square miles (10 mile radius) while a class C epicentre lies somewhere
in an area of 700 square miles (15 mile radius) and a class D epicentre
has an unlimited radius of at least 30 miles.   When the areas in which
the epicentres fall are drawn, it is found that the epicentres of the
1901 and 1914 earthquakes cannot be proven to be on land; for the 1934
earthquake Bullen (1936 and 1938) gives three different epicentres, one
of which lies at sea, and again this epicentre cannot be proven to be
on land.   These three epicentres too, must be disregarded, and the
ratio of surface displacements known to have accompanied major crustal
earthquakes to the number of epicentres located on land then becomes
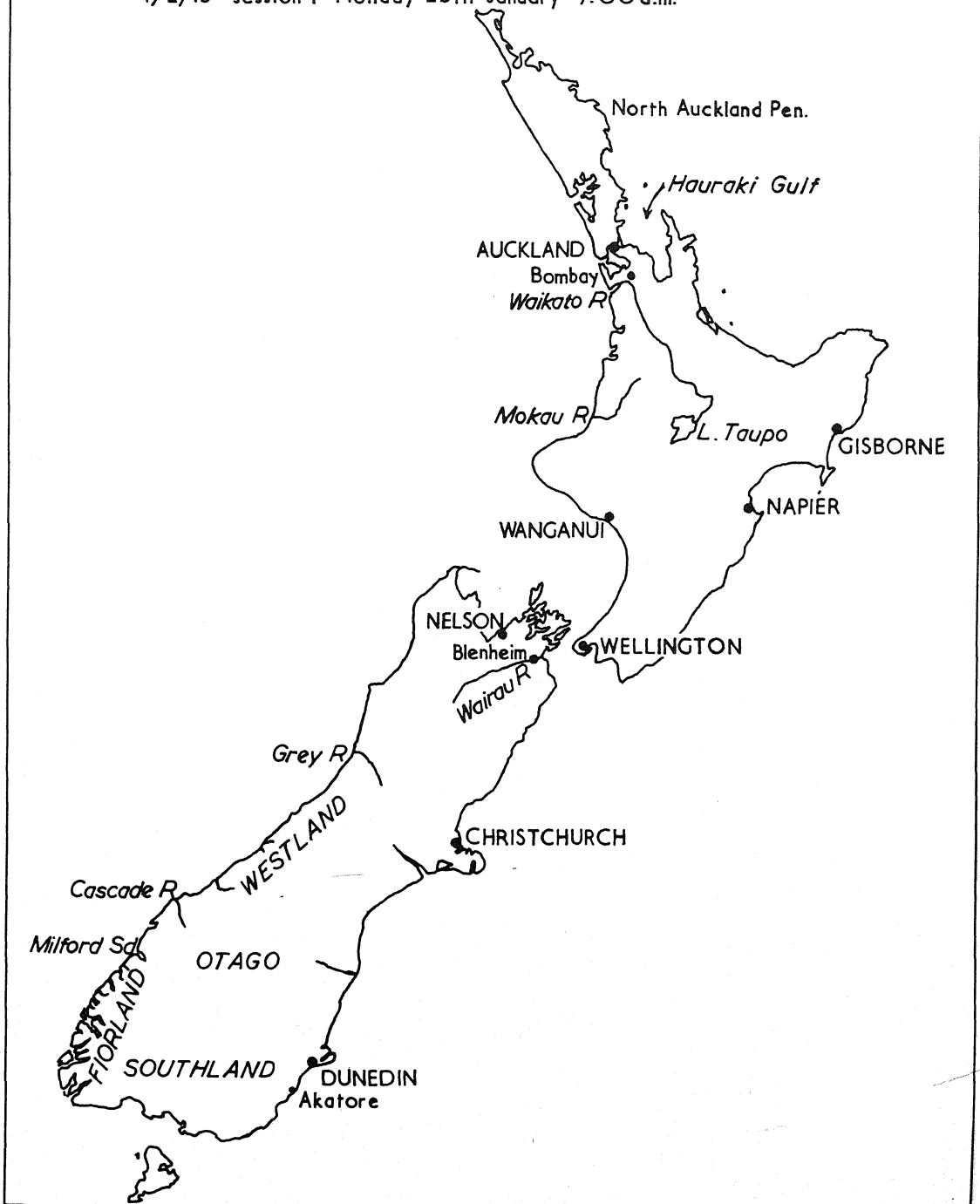7 to 8, or an 87% correlation.

References

Bullen, K.E., 1936. On Near Earthquakes in the Vicinity of New
    Zealand.   N.Z. J. Sci. Tech. 18.

Bullen, K.E., 1938. On the Epicentre of the Pahiatua Earthquake.
    N.Z. J. Sci. Tech. 20.

Hayes, R.C., 1953. Some aspects of Earthquake Activity in
    New Zealand.   Proc. 7th Pacific Science Congress.

Captions

Fig. 1.   Showing dip angles on Early Quaternary (10)
          and Pliocene 45 beds, where not overlain by
          Early Quaternary sediments.

Fig. 2.   Late Quaternary (mainly Recent) Fault Traces.
          Recent Tectonic Zone (Zone of frequent tectonic
          activity during the last 20,000 years).

Fig. 3.   Historic Major Earthquakes and Tectonic Zones.

Fig. 4.   Isoseismals of Destructive Earthquakes in
          New Zealand.

          — — — — — — — — Modified Mercalli Scale

          — — — — — — — — Rossi-Forel Scale

Fig. 5.   Earthquake Risk Zones.

LOCALITY MAP to accompany
Tectonic and Earthquake Risk Zoning in New Zealand
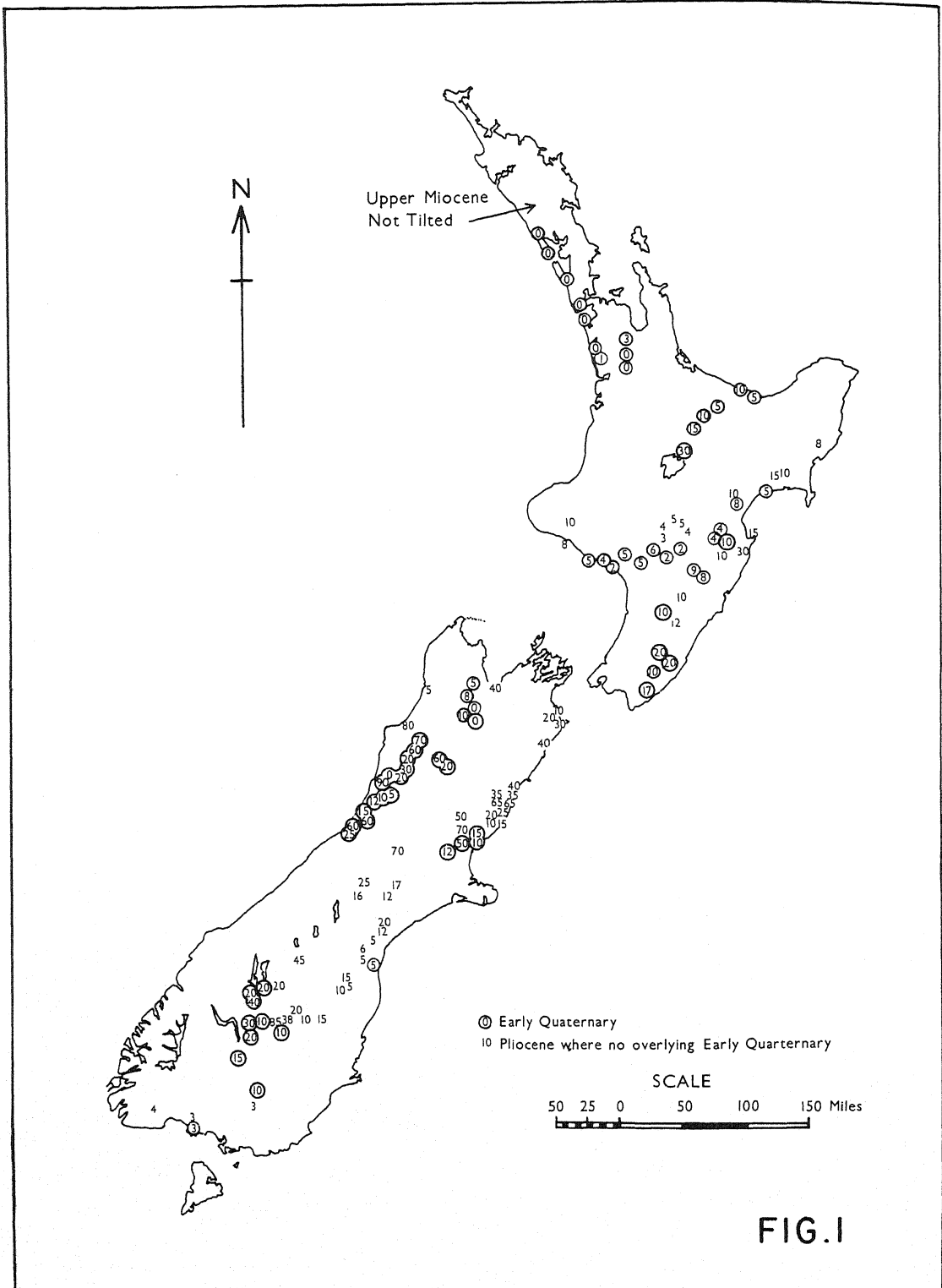1/L/15 session 1 Monday 25th January 9.00 a.m.

North Auckland Pen.
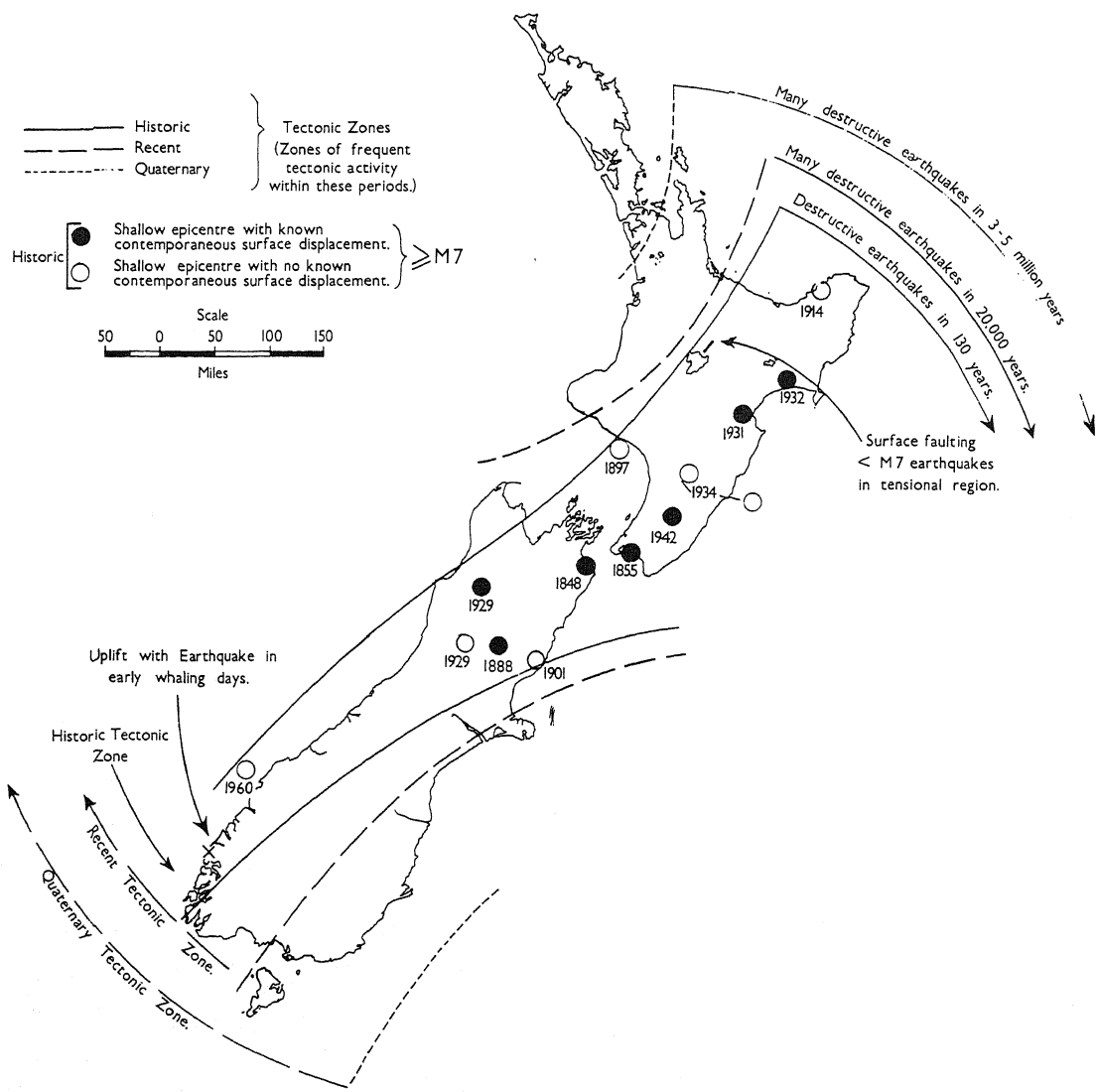
Hauraki Gulf

AUCKLAND
Bombay
Waikato R.

Mokau R.

L. Taupo

GISBORNE

NAPIER

WANGANUI

NELSON
Blenheim

WELLINGTON

Wairau R.

Grey R.

WESTLAND

CHRISTCHURCH

Cascade R.

Milford Sd.

OTAGO

FIORLAND

SOUTHLAND

DUNEDIN
Akatore

N

Upper Miocene
Not Tilted

8

○ Early Quaternary

10 Pliocene where no overlying Early Quarternary

SCALE

50 25 0   50   100   150 Miles

FIG.I

Recent Tectonic Zone

(Zone of frequent tectonic
activity during
the last 20,000 years.)

Scale

50   0   50   100   150
Miles

HOPE FAULT

ALPINE FAULT

FIG. 2

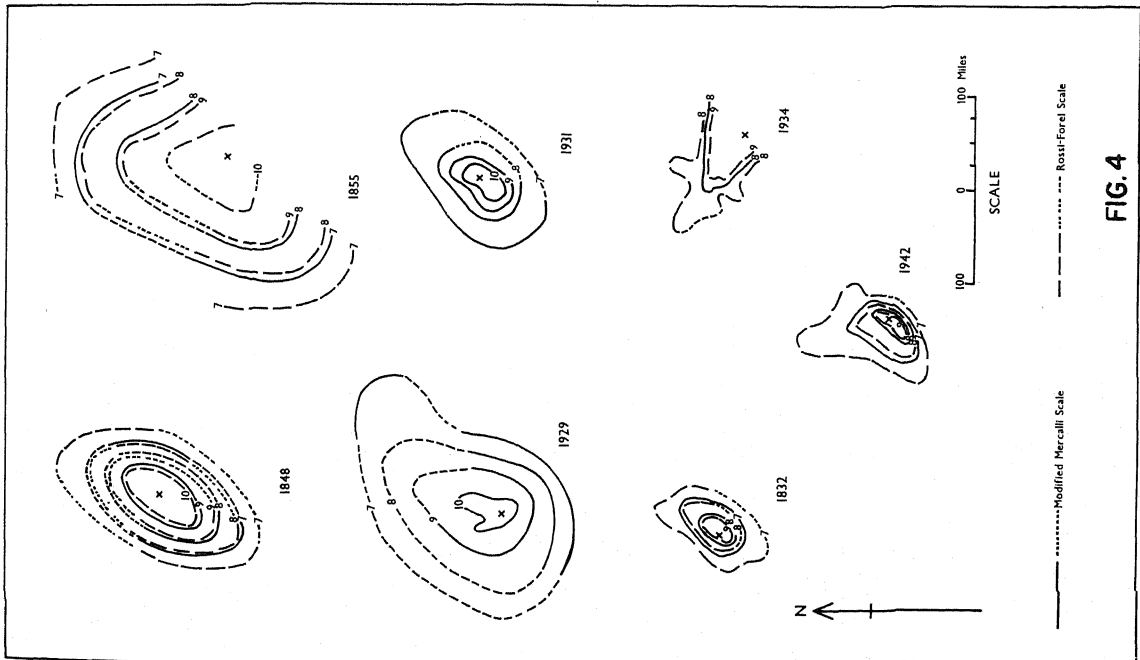FIG. 3 HISTORIC MAJOR EARTHQUAKE AND TECTONIC ZONES

I–122
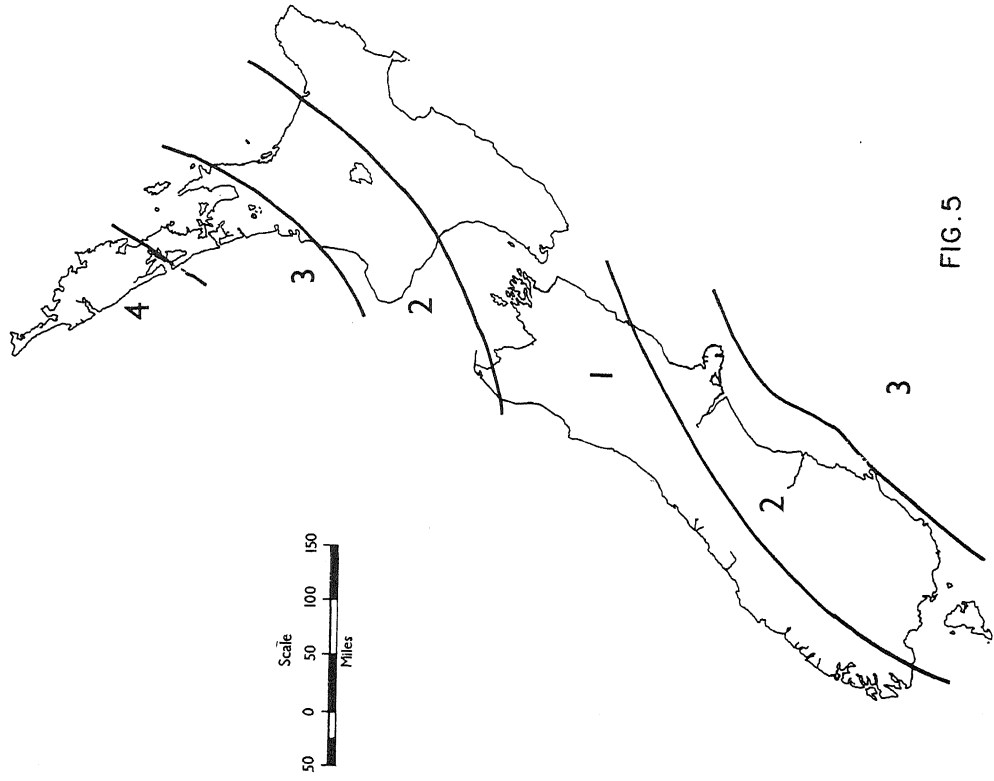
FIG.5

FIG. 4

E R R A T A

TECTONIC AND EARTHQUAKE RISK ZONING IN NEW ZEALAND

BY R.H. CLARK, R.R. DIBBLE, H.E. FYFE, G.J. LENSEN, R.P. SUGGATE

PAGE 107 Footnote 1. Line 2: The reports ...., should read:
      This report is published .....

PAGE 116 (3) Evison, F.F.; delete:"report to this committee"

         replace by: "pers. comm."

TECTONIC EARTHQUAKE RISK ZONING IN NEW ZEALAND

BY R.H. CLARK, R.R. DIBBLE, H.E. FYFE, G.J. LENSEN, R.P. SUGGATE

QUESTION BY:

G.A. EIBY – NEW ZEALAND

The wording of this paper could possibly give visitors the impression that it represents the views of a committee of the Royal Society of N.Z. on the zoning problem. Mr. Lensen will excuse me for pointing out that it is only the opinion of certain geologist members of that Committee. Seismologists in this country have been consistently and unanimously opposed to zoning, on the grounds that the known distribution of large shallow earthquakes, and the distance to which the effects of these shocks can extend, establish that all New Zealand is subject to earthquake risk.

This is a long narrow country surrounded by sea. The fact that submarine information is necessarily lacking will always limit the usefulness of geological consid- erations. If Mr. Lensen and his colleagues were suggesting an extension to the zone we know to be seis- mic, we should, as prudent men, take careful notice; but this is not the case. The proposition that future earthquakes will remain with areas geologically dis- turbed in the past is too tenuous a hypothesis to form the basis of a practical decision. New Zealand seis- mologists, therefore, oppose zoning of this country, and rest their case upon the known distribution of earthquakes.

REPLY BY:

G.J. LENSEN

Mr. Eiby was misleading the conference when he claimed seismologists in this country have been consistently and unanimously opposed to zoning as we define it. Firstly, one of the authors of this paper (R.R. Dibble) has been a professional seismologist working alongside Mr. Eiby for over 14 years and has published the only previous analysis of earthquake risk based on seismo- logical data. (N.Z. Science Review 1956, vol. 14). He is also the only New Zealander to develop a new and successful seismograph system (J. Geol. Geophys. 1964 vol. 7 (3).)
Secondly, Mr. Eiby himself published a paper to show that Northland appeared to be aseismic (J. Sci. Tech. 1955 vol. 36B pp. 488-94).

The statement that N.Z. seismologists cannot accept zoning brings to the fore the critical question of whether frequency of, rather than absolute liability to,

destructive earthquakes; is the more important. It is
undeniable that there are significant variations in
frequency (Dick's paper in these proceedings). The N.Z.
Seismological Observatory rejects frequency in favour
of a universal value of felt intensity, but frequency
is something which engineers neglect at their peril.
A building may withstand one intensity 8 earthquake, but
not several of them, and if several occur, there will
probably be one of intensity 9 as well. The viewpoint
of Mr. Eiby and Dr. Adams leads to maximum earthquake
precaution throughout the whole world. Absolute safety
from earthquakes is impossible, but our paper will be
the best basis for attaining a uniform standard of safe-
ty until a much longer historical record of New Zealand
earthquakes is available.

QUESTION BY: A.M. QUENNELL – NEW ZEALAND

While this paper gives a welcome emphasis to the point
which structural geology must play, not all the stated
conclusions will be accepted by all geologists. It is
unfortunate that there has not been an opportunity for
geologists to resolve their difference, especially as
related to tectonic zoning.

Fault trace features cannot be given such simple inter-
pretation. For example, where they are in soft sedi-
ments of some thickness overlaying a dense basement, the
following must be remembered:

(a)   fault traces do not necessarily reflect the move-
      ment on the basement faults; e.g. the Wanganui
      features.

(b)   similar features are produced by uneven compaction
      of young sediments; e.g. in the Manawatu. They are
      more reliable when in hard rock.

Strike slip components will have no permanence, and be
easily obliterated, and yet the important movements are
nearly all strike-slip. Auckland Peninsula has exper-
ienced depunation in very late times, this is shown by:
late movement on the Kawakawa fault and the tilting of
the blocks; fault trace features on at least one import-
ant fault; warping of upper tertiary, probably Quatern-
ary surfaces at Kaitaia; and Hokianga; faulting of
young basalt flows; tilting of blocks of Tangihua
volcanoes on the west coast.

The arbitrary tectonic zoning which places Auckland
Peninsula in zone 4, is hasty and unjustified.

I fully endorse Mr. Eiby's remarks on this matter.

REPLY BY:

G.J. LENSEN

Fault traces are evidence that earthquakes have taken place; whether they reflect the movement in the basement or not is an academic point which does not affect this paper. Also whether strike slip components have been preserved or not is of no importance in this paper; it is the <u>existence</u> of the faults that is important. We must ask Mr. Quennell to produce his evidence for Late Quaternary and Recent Faulting in North Auckland other than that associated with volcanism or due to slumping or settling.

In the paper it is stated that the relative densities of fault traces from region to region will probably not be significantly changed by further work. A similar conclusion is thought to be certain for tectonic movement in general.

QUESTION BY:

R.D. ADAMS – NEW ZEALAND

I must object to Mr. Lensen's statement that his paper represents a "majority report" of the committee of the Royal Society. Matters of scientific truth cannot be decided on facts alone. I wish to re-affirm that New Zealand seismologists do not condone earthquake zoning in New Zealand. We prefer to look at the earthquakes rather than the faults. Finally, I wish to refer to the occurrence of an earthquake of magnitude $5\frac{1}{4}$ in the far north of New Zealand in 1963, in the author's zone 4, in which no observed faulting is reported.

REPLY BY:

G.J. LENSEN

Dr. Adam's remark about facts and scientific truth is absurd, and is therefore ignored.

The damaging (not destructive) Northland earthquake (subsequent to the report on which this paper was based) occurred in zone 4, in which the authors expected damage in several places in any period of a few hundred years. Its isolation (Eiby 1955) from areas of frequented earthquakes and from regions of important young tectonic activity, indicates that the earthquake is one of those that do not appear to belong to a pattern of activity, although not uncommon in the world as a whole.

QUESTION BY:

E. ROSENBLUETH – MEXICO

Attempts have been made in Mexico to correlate the distortion of isoseismals with geologic structure, but they have been unsuccessful. An unpublished work by J. Figueroa, R. Valdes, F. Mooser, and L. Estera concludes that 90 per cent of the lines of least gradient on isoseismals of Mexican macroseisms pass through a circle with a diameter of 50 km and center at Tehvacan,

Puebla. This center coincides with the centroid of the
most severely fractured zone of the country but is not
especially earthquake prone. Further, isoseismals in
the southern portion of the country are almost system-
atically distorted in a direction perpendicular to that
of the main faulting, while in the northwestern region
the distortion is almost always parallel to that of
the main faulting. These observations suggest that in
relation to the geologic structure, trends in the
shape of isoseismals are not well understood and
those trends should be interpreted with caution, even
if in all likelihood, a complex relationship does exist.

REPLY BY:

G.J. LENSEN

Fig. 4 in this paper shows the elongation, which in this
paper is related to the geological structure.

Further in the paper "The New Zealand Sub-Crustal Rift"
by G.A. Eiby in vol. 7, No. 1 of N.Z. J. Geol. Geophys.,
1964, the rift has a north east – south west orientat-
ion. On page 130 the author notes "Isoseismal patterns
of felt earthquakes show anomalous features that appear
to be associated with the rift."
and on p. 131:
"In New Zealand, the radius of an isoseismal that does not
cross the Rift boundary may be several times as great
as the radius of the same isoseismal where it is re-
stricted by the Rift."

This again indicates a north east – south west
elongation of the isoseismal pattern.

Mr. Ambraseys' paper on the Buyin-Zahra Earthquake of
1st September 1962, presented at this conference also
clearly illustrates that a correlation between the
isoseismal pattern and the geological structural
pattern exists.

We fully appreciate Dr. Rosenblueth's statement that
such a correlation does not hold in parts of Mexico.
Not being intimately conversant with the detailed geol-
ogy of Mexico we can make but little comment, except
perhaps that lava flows do not necessarily flow along
the strike direction of structural features but can
flow in the dip direction perpendicular to such features.

Where such flows are buried by volcanic detritus and
sediments, density and compaction differences could
cause an isoseismal distortion perpendicular to the
structural trends.

QUESTION BY:

O.A. GLOGAU – NEW ZEALAND

The following point is often lost sight of: the aim
of the proposed zoning in New Zealand is to provide
protection of life in all zones and better protection
against damage in those zones where the geological
evidence (and also substantially the statistical
evaluation of the seismological evidence ref. paper
by Dick) indicates a greater risk.

REPLY BY:

G.J. LENSEN

Mr. Glogau's comments on the objectives of zoning are
welcome; perhaps it might be added that all danger
cannot be avoided and some assessment of what risks
are worth taking cannot be avoided.