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FUTURE CONTINGENCIES

1. NATURAL DISASTER

G.F. PREDDEY
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C O N T E N T S

Cover: Napier 1931

(1) "Global Future : Time to Act", Report to the President on Global Resources, Environment, and Population, p ix (Council on Environmental Quality, US Department of State, 1981).

(2) "The Global 2000 Report to the President : Entering the Twenty-First Century", vol 1, pl (Council on Environmental Quality, US Department of State, 1980).

(3) Lester Brown in <u>The Futurist</u>, vol 9, 1975, pl22.

(4) Rt. Hon. B. Tallboys Speech to the United Nations General Assembly, 10 October, 1977.

(5) This is recognized, for example, in the NZ National Party's 1975 General Election Policy (Para 3, Policy number 32, on National Development).

(6) Heinemann New Zealand Dictionary (Heinemann, 1979).

(7) "Yearbook of World Problems and Human Potential", ref. 3561 (Brussels : Union of International Associations - Mankind 2000, 1976).

PREFACE TO THE 'FUTURE CONTINGENCIES' SERIES

The next few decades are a period about which it is much easier to be cautious and reserved rather than welcoming. Recent reports from a number of major institutions including the United Nations and the World Bank have persistently sounded a warning. The 'Global Future' Report has summed up the position as follows:

> Severe stresses on the earth's resources and environment are apparent. With the persistence of human poverty and misery, the staggering growth of human population, and ever-increasing human demands, the possibilities of further stress and permanent damage to the planet's resource base are very real. To reverse the present trends, to restore and protect the earth's capacity to support life and meet human needs, is an enormous challenge(1).

The world in 2000 is depicted by most futurists as being significantly more crowded, more polluted, less ecologically stable, and more vulnerable to disruption than the world we live in now - if present trends continue(2). But future resource impoverishment, environmental degradation, and soaring population growth are not a new discovery. What the recent reports have emphasized, however, are the accelerating pace and scale of the problems, and their interrelationships.

Accumulating evidence from around the world suggests that "we may be on the edge of one of the greatest discontinuities in human history - economic, demographic, political"(3). The New Zealand Foreign Minister has commented that "All of us, I think, can feel in our bones that in its economic, no less than its political condition, the world is not many steps away from chaos"(4).

One of the most important functions of the emerging discipline of futures studies is to call attention to possible future disasters(5). The intention is of course to alert policy makers and others so that mitigating steps can be taken.

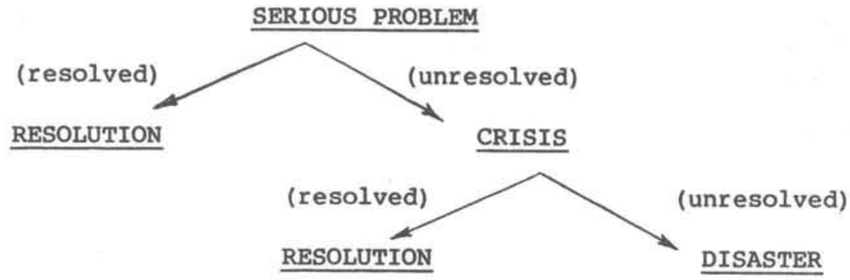
What is a disaster? A New Zealand dictionary (6) defines a disaster as "a greatly unfortunate accident or event" (DIS = 'not or without' + Italian ASTRO = 'a lucky star'). This is a useful starting point, but more helpful is the detailed definition in the Yearbook of World Problems and Human Potential(7) which describes a disaster as:

> ... an event concentrated in time and space, in which a society or a relatively self-sufficient subdivision of a society undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfillment of all or some of the essential functions of the society is prevented. Thus a disaster disturbs the vital functioning of a society. It affects the system of biological survival (subsistence, shelter, health, reproduction), the system of order (division of labour, authority patterns, cultural norms, social roles), the system of meaning (values, shared definitions or reality, communication mechanism), and the motivation of the actors within all these systems.

A useful distinction can be drawn between 'crisis' and 'disaster', although these terms are often taken as synonymous. A crisis is "a crucial time or turning point in any series of events" (Greek KRISIS = decision). It results

(8) "Anticipating World Crises : Five Overarching Crises in Prospect" by Theodore J. Gordon, in Current, No.168, 1974, p48.

from an unresolved serious problem. If the crisis itself is not resolved, a disaster ensues, as illustrated below.



It is not enough that there is a range of potential disasters lying before us in the future. There is also the possibility of 'megacrisis' - a number of crises occurring simultaneously. When these crises are interrelated, the potential for megacrisis is greatly increased. Its overall impact may greatly exceed the individual impacts of the contributing crises. Its consequences may well be beyond an administration's ability to cope. A nuclear holocaust could be an example.

The taxonomy of disaster can be treated in various ways. For instance, Theodore Gordon identified what he called 'five overarching crises' confronting mankind (8) viz.

- nuclear war
- severe food shortage
- deterioration of the biosphere
- imbalance in the distribution of wealth
- material shortages

For the 'Future Contingencies' reports, the taxonomy is derived from the predominant discipline invoked: natural science, social science, economics. Nuclear war, because of the potential magnitude of its impact, is considered as a separate issue. Wherever possible, a New Zealand perspective is adopted. The 'Future Contingencies' series includes the following reports:

1.	Natural Disaster	ISBN-0-477-06222-9
2.	Societal Disaster	under preparation
3.	World Economic Disaster	under preparation
4.	Nuclear Disaster	under preparation
5.	Summary Report for wider dissemination	under preparation

These reports are from ad hoc study groups working under the auspices of the Commission for the Future. The views expressed in them are those of the contributing authors, and do not necessarily represent the views of the Commission.

The analytical input to this report ('Natural Disaster') by the inaugural study group viz.

Michael Crozier	(Ministry of Defence)
Ewen McCann	(University of Canterbury)
Michael Munro	(Prime Minister's Department)
Marijke Robinson	(NZ Police Department)

is gratefully acknowledged.

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(1) For a discussion of disasters originating outside the earth's physical environment (e.g. supernova, meteor strike) see 'A Choice of Catastrophes' by I. Asimov (Hutchison, 1980).

(2) A climatic change is not necessarily a disaster. Increased rainfall over the Sahel, for instance, would be of considerable benefit to the region. But other possibilities, such as the return of another Little Ice Age (p 17) or persistent drought over the wheat belts of the USA and the USSR (p 25) could fairly be described as disasters.

1. NATURAL DISASTER : AN INTRODUCTION

Most natural disasters can be traced to events occurring in the earth's physical environment - the land, the sea, the atmosphere(1). Their essential ingredients would be appreciated by early philosophers - earth, air, fire, water. In more recent times, the study of the causes of natural disasters has been the domain of the physical scientist - e.g. geophysicist, seismologist, meteorologist, hydrologist etc.

The human response to natural disaster has become the domain of the social scientist - e.g. disaster sociologist etc. (This aspect is considered elsewhere in the 'Future Contingencies' reports - viz 2. Societal Disaster).

There are many ways a natural disaster can strike. The New Zealand National Commission for UNESCO, through a 'Task Force on Natural Hazards', is currently undertaking a review of the present knowledge of natural hazards in New Zealand. This work is being conducted at a detailed level, and will, in 1982, result in a very valuable information base for policy makers.

It is not the intention of this CFF report on natural disaster to duplicate, let alone pre-empt, what is already being done admirably by the UNESCO Commission. Rather, it is the intention to focus on just two kinds of natural disaster which (in the writer's perception) assume special importance for New Zealand, but which do not yet receive adequate recognition.

These are:

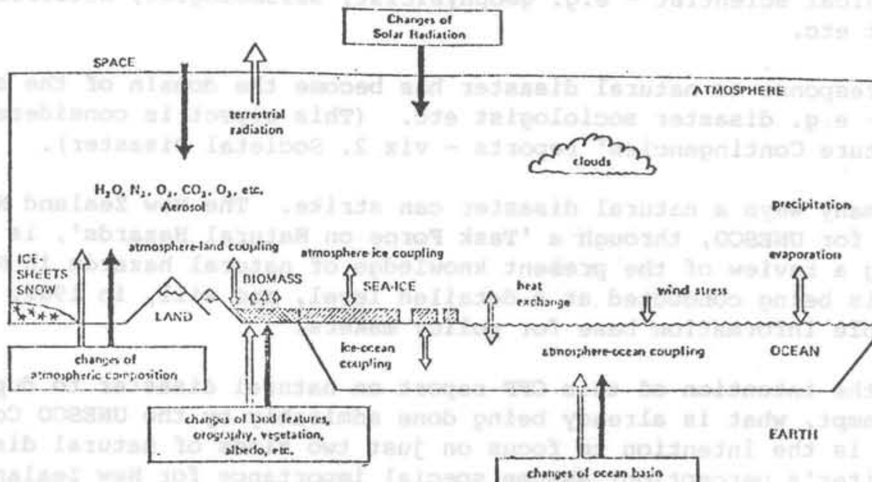
- climatic change (2) : important because of its potential global impact, and because the New Zealand economy is based on agriculture.

- tectonic disaster : important for New Zealand because of her geographic location on a plate margin, and because of the potential scale of the impact.

Another significant distinction between the UNESCO and CFF methodologies is the CFF's 'future studies' perspective. Relecting this, the present report places emphasis on the longer-term potential for an adverse 'climate' change, rather than localized drought, flooding, and other extremes of 'weather' which fall within the domain of the UNESCO report.

This CFF report may then be viewed as a 'precursor' both to the UNESCO report on natural hazards and to further CFF reports in the 'Future Contingencies' series - on societal, world economic and nuclear disasters.

Figure 2.1



The Climatic System (p.9)

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(1) S H Schneider in The Futurist, Vol 10, 1976, p 192.

(2) W W Kellogg, R Schware, G Friedman in The Futurist, Vol 14, 1980, p 50.

(3) For example 'A matter of ice and death' by P Barrett, 'NZ Listener', 21 Feb 1981.

(4) 'The Physical Basis of Climate and Climate Modelling', GARP Publication Series 16, World Meteorological Organisation, Geneva, 1975.

(5) G B Tucker in 'Carbon Dioxide and Climate: Australian Research', (Aust. Academy Sciences, 1980), p 24.

2. CLIMATIC DISASTER

2.1 OVERVIEW

2.1.1 A Perspective

The earth has always been subject to great natural fluctuations in its climate. This variability tends to pass unrecognised by decision-makers, yet future climate may become increasingly important in determining the human prospect for the twenty-first century. The causes of these natural fluctuations are largely unknown.

The middle decades of the twentieth century have been among the warmest and most favourable periods for agriculture in history. A protracted period of less favourable climate is bound to return, and perhaps already has begun. "There are good reasons for creating reserves for the inevitable lean years ahead, and for developing more effective ways of monitoring resources and of anticipating future climatic changes." (1)

Climate has a profound effect on the world economy. The vicissitudes of climate and weather impose global costs of $30 billion each year (2). This amount is growing, and represents three-quarters of all losses by natural hazards. In spite of the importance of future climate, many unresolved problems make statements about it rather uncertain. These problems have not discouraged the dissemination of alarming scenarios by some researchers in the field (3).

2.1.2 The Climatic System

The surface of the earth and its atmosphere form a complex interactive climatic system. Its normal behaviour is characterised by a high variability over a wide range of different spatial and time scales - the 'weather'. The concept of 'climate', meaning 'average weather' is not straightforward. 'Weather forecasting' only succeeds in the medium (synoptic) scale for a few days ahead. No established technique for 'climate forecasting' yet exists. Current quantitative analyses are essentially sensitivity studies of how a balanced climate will re-establish itself once one or more of its physical properties have been changed.

The main components of the system (atmosphere, ocean, ice, land surface, biomass) are shown in figure 2.1(4). Arrows denote processes which are capable of causing a climatic change. Of great importance are those involving the rates at which energy enters the system (intercepted solar radiation) or leaves the system (terrestrial re-radiation into space). The fluid atmosphere and ocean respond by developing winds and currents, which re-distribute heat energy, and thereby create 'weather' variations.

Present understanding of the system allows adequate 1-5 day 'weather' forecasts, but not longer-term 'climate' forecasts. This may be because slow processes of little significance for the weather may become dominant for climate (5), and these slow processes are not well understood.

2.1.3 Climate Change to the Year 2000

In view of the potentially serious implications of climate changes, the National Defense University (of the US Department of Defense) initiated a

(6) 'Climate Change to the Year 2000', National Defense University, Washington DC, 1978.

(7) 'The Global 2000 Report to the President', Vol 2, (Council on Environmental Quality and the US Department of State, 1980), p 256.

(8) Ibid, p 267.
A possible relationship between depletion of the ozone layer and global climate is considered elsewhere in the 'Future Contingencies' reports viz. 4. Nuclear Disaster.

research project to quantify the likelihood of significant change in climate. A Delphi-type survey of 24 climatologists was used to construct five possible climate scenarios for the year 2000 (6). These scenarios showed a broad range of perceptions of future climate, and suggested as most likely a climate resembling the average for the past 30 years. Collectively, the respondents tended to anticipate a slight global warming, but their assessments indicated only one chance in five that changes in mean global temperature by the year 2000 would lie outside the range -0.3°C to +0.6°C.

In a report prepared for President Carter by the Council on Environmental Quality and the Department of State, three simplified scenarios were presented to indicate the range of possibilities (7).

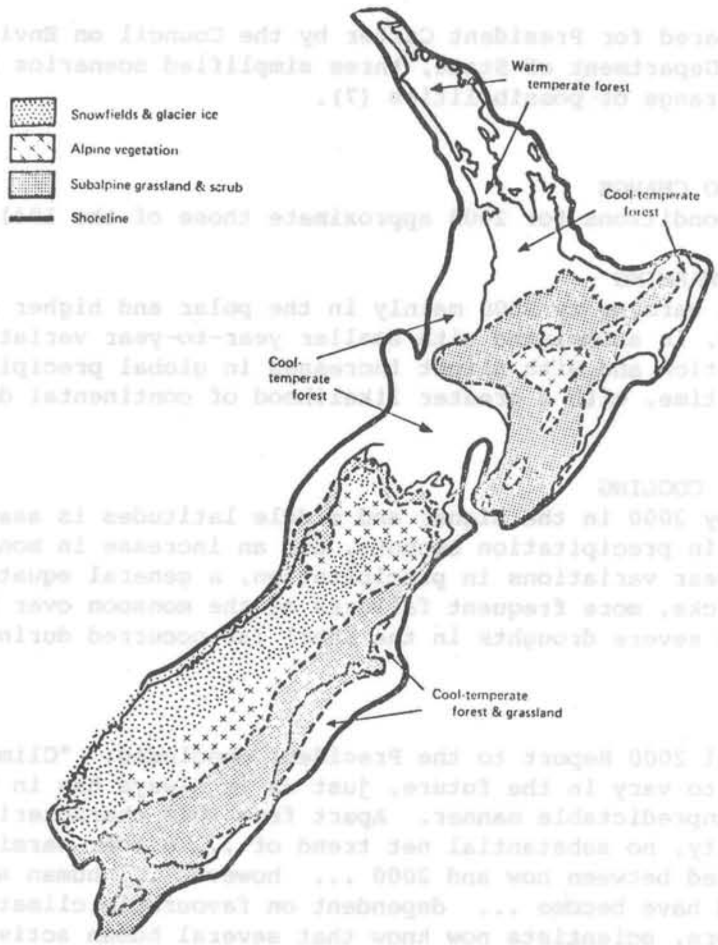
CASE I: NO CHANGE
Climate conditions for 2000 approximate those of the 1941-70 period.

CASE II: WARMING
A general warming by 2000 mainly in the polar and higher middle latitudes, is associated with smaller year-to-year variation in precipitation and with slight increases in global precipitation, but, at the same time, with a greater likelihood of continental drought in the US.

CASE III: COOLING
Cooling by 2000 in the higher and middle latitudes is associated with a decrease in precipitation amounts, and an increase in month-to-month and year-to-year variations in precipitation, a general equatorward shift of storm tracks, more frequent failures of the monsoon over India and recurrent severe droughts in the Sahel (as occurred during the 1972-74 period).

The Global 2000 Report to the President concluded: "Climate will continue to vary in the future, just as it always has in the past, in a largely unpredictable manner. Apart from this characteristic variability, no substantial net trend of ... either warming or cooling is anticipated between now and 2000 ... however ... human societies around the world have become ... dependent on favourable climate ... Furthermore, scientists now know that several human activities have ... the potential to alter the world's climate significantly. These anthropogenic influences on global climate include carbon dioxide emissions and release of chemicals affecting the ozone layer as well as potential land-use changes, aerosol and particulate generation, and heat releases ... In the decades ahead, the finite capacity of the atmosphere to absorb various anthropogenic chemical emissions without catastrophic climate change must be recognised as an extremely important resource, a resource vital to and held in common by all nations. Protecting this resource will raise perplexing and troublesome questions ..."(8)

Figure 2.2



New Zealand during a glaciation (p.13)

(9) J W D Hessell (NZ Meteorological Service) in <u>NZ Listener</u>, March 1981.

(10) G. Stevens, 'New Zealand Adrift', p 342 (Reed, 1980).

(11) Ibid, p 323.

2.2 A COOLER EARTH

2.2.1 The Climate Record

In popular press articles about the 'greenhouse effect', and the melting of the polar ice caps, it is often overlooked that, on a geological time scale, the earth has recently emerged from, or may still be in, an ice age. Indeed, the surface temperatures at Scott Base, Antarctica, are now the lowest since recordings began in 1959 (9). A consistent trend is also found for the Arctic, inconsistent with the global warming hypothesis which predicts that the largest response will occur in polar regions.

The term 'ice-age', although convenient, is a misnomer. During the Pleistocene period (between 2 million and 100,000 years ago), the earth experienced about 20 periods of intense cold (called 'glacials'), separated by briefer periods of warmer climate (called 'interglacials') when the mean temperature was about 14°C higher; the whole constituting the Pleistocene 'ice age'.

Thus the pattern for the Pleistocene was a succession of glacial periods, each lasting about 100,000 years. It seems unduly optimistic to assume that the most recent glacial period (which ended 10,000 years ago) was the last of the current series. Another could reasonably be expected to begin in the next few thousand years or so (10).

Past Ice Age	beginning (millions of years before present)	ending (millions of years before present)	duration (years)
Pleistocene	2m	0.01m?	2m?
Carboniferous-Permian	305m	255m	50m
Ordovician	465m	440m	25m
Precambrian	680m	650m	30m
(earlier)	(?)	(?)	

New Zealand's climate during glacial periods was moderated by the warming effect of the sea. Auckland's climate resembled that of Dunedin's today. Temperate forests survived only in Northland and the Waikato. The rest of the North Island and all of the South Island were either subalpine grassland and scrub, or permanent snowfields and glacial ice. As ice sheets formed on land, the sea level fell, perhaps by as much as 170m, exposing areas of what is now sea bed. Around New Zealand, the Hauraki Gulf, Hawkes Bay, the Taranaki Bight across to Tasman Bay, the Canterbury Bight, and Foveaux Strait were dry land, then largely covered by beech forests (11). (See figure 2.2)

The retreat of the ice began in New Zealand some 14,000 years ago. By the end of the last glacial period, about 10,000 years ago, the sea had risen to a level 75m below its present level. It continued to rise, reaching its present level 5,500 years ago. It rose above this by about 3m during a 'climatic optimum' some 4,000 years ago, when the earth was several degrees warmer than at present. This 'climatic optimum' was followed by conditions similar to today's, and the sea retreated to its present level.

Another warming occurred between 350 AD and 1200 AD. Once again the sea rose (by 0.5m), and the favourable weather allowed the Vikings to colonize

(12) G. Stevens, 'New Zealand Adrift', p332 (Reed, 1980).

(13) J Gribbon in <u>New Scientist</u>, Vol 85, 1979, p 891.

(14) G Stevens, op cit, p 335.

Greenland and Labrador in 1000 AD, 500 years before Columbus 'discovered' the Americas. It may also have encouraged the Polynesian discoveries of New Zealand.

After 1200 AD, the climate deteriorated again, and the earth entered a 'Little Ice Age' between 1550 and 1850. At its peak (1740-50) there was widespread hardship in Europe - famine, depopulation of Norway, villages engulfed by advancing glaciers, etc. The Vikings were forced to abandon their colonies, but several Eskimos were able to reach Scotland by sea ice and kayak. The 'Little Ice Age' may have deterred the Maori from reaching Australia (12).

The climate improved again after 1850, and reached a warm peak around 1940-60, (about +0.5°C above the mean temperatures for 1880-1900). As noted earlier, the middle decades of this century have been among the warmest and most favourable periods for agriculture in history, although other factors (e.g. returning servicemen) may have contributed.

Since the late 1960s, there appears to have been a significant change in world weather patterns (13). This shift has seen a slight global cooling, and, more significantly, an increase in seasonal variability, attributed to a weakening of the global atmosphere circulation.

2.2.2 Possible Causes and Effects of a Global Cooling

During the past 650 million years, the earth has experienced long periods of equable climate (during which the polar ice caps virtually disappeared), punctuated by four ice ages, each lasting several tens of millions of years. During these ice ages, the climate fluctuated between glacials (each of about 100,000 years duration), and warm interglacials each of about 10,000 years duration.

Ice ages have been attributed to decreases in solar output, to the passage of the solar system through interstellar dust, and to the massive injection of volcanic ash into the atmosphere. While major volcanic eruptions have caused short-term global cooling, no evidence exists for unusual volcanic activity preceding or during ice ages.

A more likely contributing cause is the location of land at the South Pole. There is no geological evidence that a land mass has ever straddled the North Pole, but Antarctica now, and other fragments of the ancient Gondwanaland continent in the past, have been astride the South Pole, as a chance result of continental drift. One theory holds that a polar land mass restricts oceanic circulation and so reduces the flow of heat from more temperate latitudes towards the pole. The growing ice cap causes a greater proportion of solar radiation to be reflected back into space. Progressive cooling results in an ice age. (For a discussion of continental draft, see p.29)

Past Ice Age	Land Mass at South Pole (14)
Pleistocene (present)	Central Antarctica
Carboniferous-Permian	Eastern Antarctica
Ordovician	Sahara
Precambrian	Eastern USA-Sahara (joined)

'The Sixth Winter' (p. 17)

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(15) New Scientist, Vol 84, 1979, p 90.

(16) A T Wilson quoted in 'New Zealand Adrift' by G. Stevens, p340 (Reed, 1980).

(17) 'The Sixth Winter', by Dorgill and J Gribbon (Bodley Head, 1979).

(18) M Allaby in New Scientist, Vol 88, 1980, p 116.

(19) M Allaby, ibid.

(20) 1980 Energy Plan, p 46 (Government Printer, 1980).

The present (Pleistocene) ice age can be expected to continue until the Antarctic plate drifts away from the South Pole, several tens of millions of years into the future.

Continental drift alone cannot, however, account for the alternating glacial and interglacial periods which characterize an ice age. There is some support among climatologists today for a theory developed by Milankovich in 1938 viz.orbital changes of the earth itself cause glacial-interglacial fluctuations during ice ages (15). (Seasonal changes in the rate of accretion of polar ice are controlled by the combined influence of cyclic variations in orbit eccentricity, spin axis inclination and precession). The orbital changes are not in themselves strong enough to initiate a glaciation, but may initiate a sequence of 'surges' of the Antarctic ice cap (16).

The onset of another glacial period has been described as an unprecedented human catastrophe. As the central character of the novel 'The Sixth Winter' (17) reminds us: "We are Interglacial Man. For the past 15,000 years there has been an unnatural warm spell, during which we have all got terribly soft. We have advanced down an evolutionary blind alley, betrayed by the freak climate. We should have remained as super-Eskimos, and stuck to the ice cap."

While probably inevitable on a geological time scale, there is no evidence that another glacial period is imminent. Its likely effect on future New Zealand has already been described (p13).

More likely is a return to another Little Ice Age. A global cooling of less than 2°C would suffice (18). The resultant decline in agricultural production in many developing countries, where the balance between food supply and demand is precarious at best, could be disastrous. More frequent droughts are predicted for India, the Sahel, and elsewhere. In some areas where more rain could be expect, there may be an increase in food production.

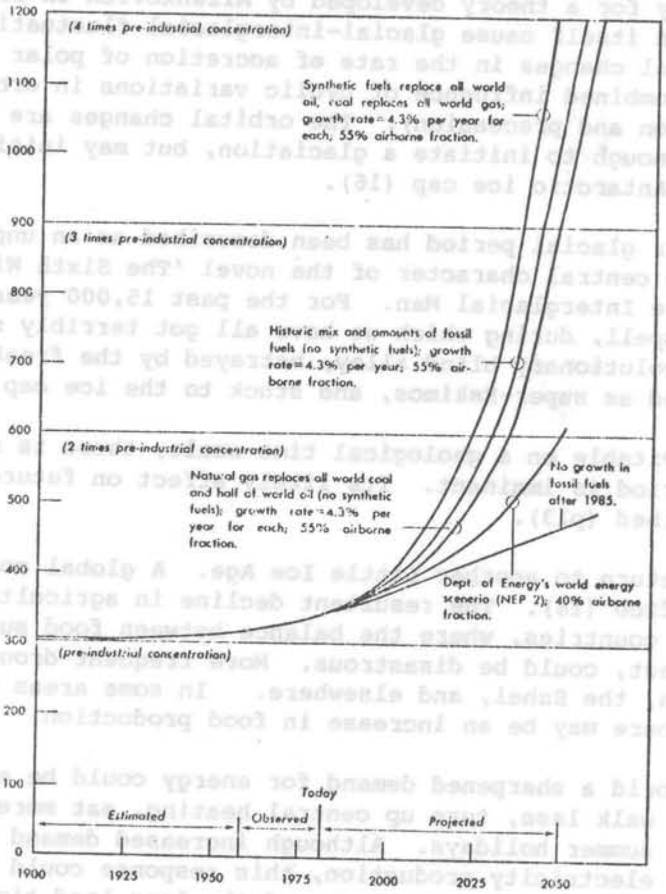
In the developed world a sharpened demand for energy could be expected, as people drive more, walk less, turn up central heating, eat more hot food, and travel further for summer holidays. Although increased demand would tend to stimulate fuel and electricity production, this response could be blocked by rising energy prices, uncertain supplies, and the long lead times for alternative sources. Energy conservation (e.g. retrofitted insulation, combined cycle power generation and district heating schemes) could, with foresight, make life more comfortable. One commentator predicts that "The actual result could be power blackouts, fuel shortages, reduced industrial production, and cold, possibly hungry people, many of whom might well feel aggrieved at their plight... (In Britain) a cold, angry population may turn out to be far more dangerous than any number of Russians" (19).

The impact of a Little Ice Age on New Zealand would be moderated by the sea, but an adverse effect on agricultural output, and the economy, would be inevitable.

Electricity planning customarily has incorporated a 7% margin of electricity supply over normal demand in a dry year of low rainfall (85% of normal hydro generation). Recent commitment of surplus electricity to energy intensive industry has eliminated the 7% margin between 1985/86 and 1992/93, unless oil-fired plant is used (20). In the past, supply cuts have been imposed to reduce oil consumption. A global cooling trend during this period could have the same consequences.

Some future implications of a global cooling are summarized on p67 .

Figure 2.3



Atmospheric carbon dioxide levels (p. 21)

(21) G I Pearman, P Hyson, P J Fraser in 'Carbon Dioxide and Climate: Australian Research' (Australian Academy of Science, 1980) p 33. D J Beardsmore, ibid, p 41. P J Fraser et al, ibid, p 49. P Hyson et al, ibid, p 65.

(22) G I Pearman, in 'Carbon Dioxide and Climate: Australian Research', (Aust. Academy of Sciences, 1980), p 18.

(23) J Kiely 'World Energy in the 21st Century', Chartered Mechanical Engineer, 1980, p 26.

(24) G I Pearman, op cit, p 19.

2.3 A WARMER EARTH

Although the present trend may be towards cooler and possibly more erratic weather conditions, popular interest has focussed on the so-called 'greenhouse effect' -a global warming caused by increasing carbon dioxide in the atmosphere. It is worth emphasizing that the global warming hypothesis is based on rather simplistic models, and, in the absence of corroborative data, a continuation of the present cooling trend cannot be discounted entirely.

2.3.1 Carbon Dioxide in the Atmosphere

The potential effect on climate of changing carbon dioxide levels in the atmosphere has been recognised since last century. More recently, the possibility that human activity can cause such changes has become recognised. It is now certain that atmospheric carbon dioxide levels are rising globally. It is generally believed that the main cause is the accelerating consumption of fossil fuels such as coal and oil, although processes of deforestation and soil degradation may also be acting as additional sources.

There is no definitive observational evidence that increasing atmospheric carbon dioxide levels are having any effect on the present climate. Growing interest in the carbon dioxide-climate problem has been influenced by general agreement among climate modellers as to the likely effect of further carbon dioxide increases. This agreement has occurred even though it is widely recognised that the models themselves do not adequately simulate the real climatic system in all respects.

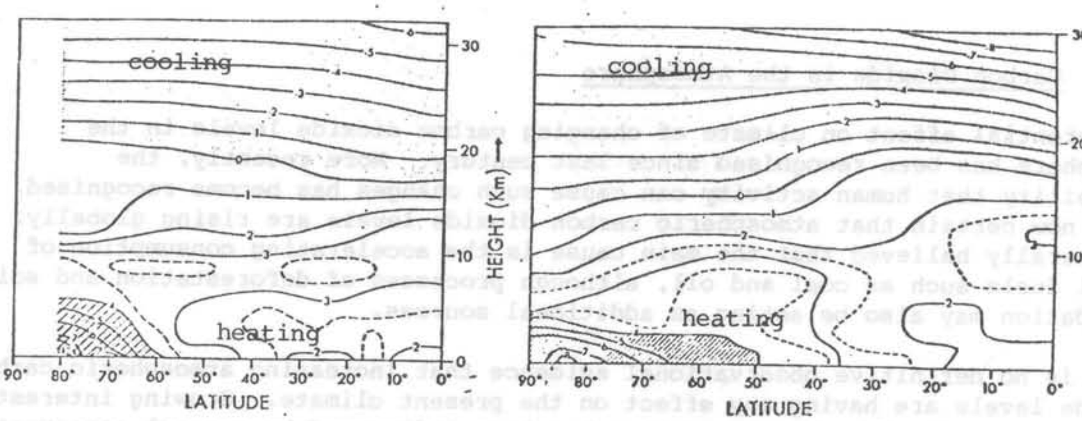
Atmospheric carbon dioxide measurements began at the South Pole and Hawaii during the International Geophysical Year of 1958, and have been extended since to several other stations including Cape Grim (Tasmania) and Baring Head (Wellington, NZ). The use of non-dispersive infra-red gas analysers yields results with a precision of better than 0.5 parts per million by volume (ppmv). The results show conclusively that atmospheric carbon dioxide levels have increased from a generally accepted pre-industrial value of 290 ppmv to 336 ppmv in 1980. The present rate of increase is slightly above 1 ppmv per year (21).

Rather simple representations of the oceans in the models indicate that the increase in carbon dioxide levels results from the release of carbon from fossil fuel combustion, and the uptake of about half of this by the oceans. If additional carbon is being released by the biosphere (eg by deforestation or soil degradation), the oceans must be acting as a much larger sink of carbon dioxide than current theories can account for (22).

Estimates of atmospheric carbon dioxide levels in the future depend on assumptions made about the biospheric and oceanic response. The greatest uncertainty probably arises in the prediction for future fossil fuel consumption. However a projection of world primary energy demand in 2020 of 1000 EJ/y is in broad agreement with a large number of studies, including those of a working party set up by the 1978 World Energy Conference (23). Using this projection, the atmospheric carbon dioxide level can be expected to increase by 60% to 100% (ie double) by 2020, depending on the rate of introduction of non-fossil energy sources (24).

(E = exa = 10^{18})

Figure 2.4



Manabe-Wetherald models (p. 21)

(25) **From 'The Global 2000 Report to the President', vol 2, p 262. (Source: US Department of Energy) (Council on Environmental Quality and the US Department of State, 1980).**

(26) **G B Tucker in 'Carbon Dioxide and Climate: Australian Research', (Aust. Academy of Sciences, 1980), p 21.**

(27) **S Manabe and R T Wetherald in J Atmos. Sci, Vol 32, 1980, p 3.**

(28) **Geophysics Study Committee, 'Energy and Climate', Washington: National Academy of Sciences, 1977. Cited in 'The Global 2000 Report to the President', p 261, op cit.**

(29) **World Meteorological Organisation statement WMO/No. 373, 2 March 1981 (Geneva).**

(30) **G B Tucker in 'Carbon Dioxide and Climate: Australian Research' (Aust. Academy of Sciences, 1980).**

Actual increases are dependent on energy strategies yet to be chosen, but an illustrative range of cases is shown in figure 2.3 (25). All (except the 'no growth' scenario) indicate a doubling of atmospheric carbon dioxide levels between 2025 and 2050.

2.3.2 Climatic Response to a Doubling of Carbon Dioxide Levels

Any assessment of the climatic response to a doubling of atmospheric carbon dioxide levels requires a three-part approach: an understanding of the physical bases of climate and climatic change, a quantitative synthesis of the interactive processes involved, and observations of the composition, structure, and behaviour of the atmosphere. The observations are essential not only for providing the raw material for understanding and synthesis, but also for validating any predictions which the assessment provides (26).

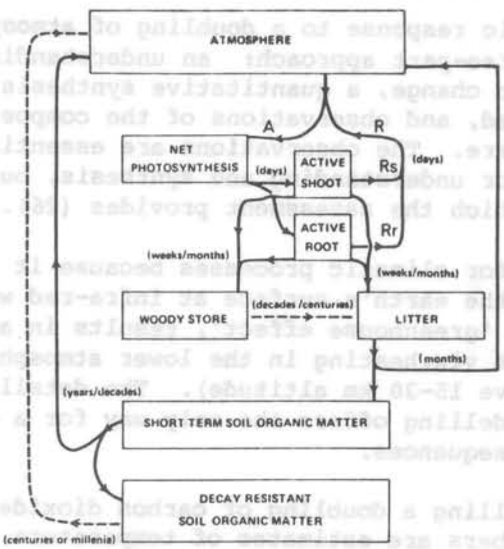
Carbon dioxide is important for climatic processes because it interrupts the re-radiation of energy from the earth's surface at infra-red wave lengths. This process, commonly called the 'greenhouse effect', results in an enhanced vertical temperature gradient viz.heating in the lower atmosphere, and cooling in the upper atmosphere (above 15-20 km altitude). The detailed calculations are so complex that numerical modelling offers the only way for a quantitative assessment of the likely consequences.

Some typical results of modelling a doubling of carbon dioxide levels are given in figure 2.4 (27). The numbers are estimates of temperature change as a function of latitude and of altitude - viz.an increase at lower altitudes, a decrease at higher altitudes. The increase in ground level temperature ranges from 2°C at the earth's equator to 8°C at the pole. The right hand diagram represents an improved model in which a crude attempt has been made to simulate cloud response (omitted for the left hand diagram).

These results are representative of a consensus opinion of climatic modellers. For example, the Geophysics Study Committee of the (US) National Academy of Sciences observed: "For even a doubling of carbon dioxide in the atmosphere, (modelling) predicts about a 2-3°C rise in the average temperature of the lower atmosphere at middle latitudes ... the temperature rise is greater by a factor of 3 or 4 in polar regions. For each further doubling of carbon dioxide, an additional 2-3°C increase in air temperature is inferred (28)." The World Meteorological Organisation issued a statement in March 1981 noting another consensus view of expert opinion (representing WMO, the United Nations Environmental Programme, and the International Council of Scientific Unions) that: "... the increase in carbon dioxide changes the atmosphere's energy balance resulting in a temperature rise at the earth's surface and in the lower layers of the atmosphere. Experiments carried out with global atmospheric models strongly suggest that the carbon dioxide concentrations that might be reached early in the next century as a result of the projected consumption of fossil fuels would increase global average surface temperature by 1°C or more. This temperature change would be significantly greater in high latitudes of the northern hemisphere ..." (29).

Because of the necessary idealizations and simplifications implicit in the models, independent corroboration of the predictions using meteorological observations is essential. Tucker has tested the Manabe-Wetherald predictions (figure 2.4) against Australian temperature and rainfall records, and finds very weak corroborative signals among the strong random pattern of weather variations (30). Hoyt similarly finds weak evidence for a 0.4°C increase in temperature

Figure 2.5



Carbon flow in the biosphere (p.23) (35)

(31) D Hoyt in Nature, vol 282, 1979, p 389.

(32) R Madden and V Ramanathan in Science, vol 209, 1980, p 763.

(33) B G Hunt in 'Tellus', 1980 (in press). Cited in 'Carbon Dioxide and Climate: Australian Research, op cit. (Albedo is a factor representing the proportion of radiation falling on a planetary surface which is reflected by it).

(34) P J Webster and G L Stephens in 'Carbon Dioxide and Climate: Australian Research', p 185, op cit.

(35) G B Tucker, op cit. R.M. Gifford, ibid, p 177 (fig 5).

(36) M Stuiver in Science, vol 199, 1978, p 253.

(37) A T Wilson in Nature, vol 273, 1979, p 40.

(38) World Meteorological Organisation Statement WMO/No.373, 2 March 1981 (Geneva); G I Pearman, op cit, p 18. 'Global 2000 Report to the President', op cit, p 261.

(39) J H Mercer in Nature, vol 271, 1978, p 321. W F Budd in 'Carbon Dioxide and Climate: Australian Research', op cit, p 115.

(40) J H Mercer in Nature, vol 271, 1978, p321. R H Thomas, T J O Sanderson, K E Rose in Nature, volume 277, 1979, p 335. World Meteorological Organisation Statement WMO/No.373, 2 March 1981 (Geneva).

over the last century, after subtracting other effects, which he notes is consistent with the 10% increase in carbon dioxide over the same period (31). But other workers have pointed out that the thermal capacity of the oceans will delay the response of the atmosphere to a greenhouse effect, perhaps by as much as 20 years (32). Thus the absence of an unambiguous warming may not disprove the validity of current equilibrium estimates of the effect of carbon dioxide on global temperature. The predicted equilibrium temperature for 1980 levels of carbon dioxide may not be validated by meteorological observations until the year 2000, when the effects of 1980 levels become apparent.

2.3.3 Cloudiness, Deforestation, West Antarctic Ice Cap

In spite of the lack of corroborative meteorological evidence, concern over the climatic effect of increasing atmospheric carbon dioxide levels has been generated by computer modelling of the climatic system. Although predictions by a number of workers using different approaches have been reasonably consistent, the models are known to have weaknesses. A number of compensating feedback processes omitted from the models can be identified. Sensitivity studies have shown that quite small changes in cloudiness, or in surface albedo, could compensate for a doubling of carbon dioxide levels (33).

The resolution of the relationship between temperature and cloudiness is a major obstacle for climate research. The problem is complicated by the known sensitivity of surface temperature to cloud type and height. For example, low and middle altitude clouds tend to cool the surface, whereas high altitude clouds tend to warm it (34). A 10% increase in cloudiness is considered sufficient to cancel the heating effect of a doubling of carbon dioxide levels, but the available models are not capable of incorporating cloudiness to this precision. Further, presently available meteorological data would not be adequate to establish whether a 10% increase had actually occurred (35).

Deforestation has been recognised as an important source of atmospheric carbon dioxide. Undisturbed forests, as climax ecosystems, have no direct effect on carbon dioxide, because their growth (which removes carbon dioxide) and their decay (which adds carbon dioxide) are in balance (fig 2.5). Deforestation adds carbon dioxide, partly due to the loss of trees (especially in the tropical rain forests), and partly to the loss of underlying humus. Some estimates suggest that deforestation in the past has added more carbon dioxide than has fossil fuel consumption (36). The pioneer land clearances in North America, Eastern Europe, Australasia, and South Africa in the late 19th Century may have ended the Little Ice Age (37). However, recent opinion has tended to favour fossil fuel consumption as the major cause of increasing atmospheric carbon dioxide levels, with the role of the biosphere unproven (38).

Antarctica is important in assessing the effects of increasing carbon dioxide levels. Firstly the various computer models all predict that the surface temperature increase will be greatest in polar regions. In part this is caused by the positive feedback effect of a reduction in the extent of sea ice (which absorbs solar radiation poorly). The monitoring of sea ice by satellite is now feasible, and may provide the earliest indication of the onset of a global warming (39). The ice sheet itself is a valuable scientific record, in that air bubbles trapped in the ice provide a record of carbon dioxide levels stretching back 20,000 years. Ice cores consistently show that carbon dioxide levels were reduced by about half during glacial periods.

Concerns have been expressed that the West Antarctic ice sheet may disintegrate during a global warming, raising sea levels by perhaps 5 metres (40). This

(41) W W Kellogg et al in The Futurist, vol 14, 1979, p50. P Barrett in New Zealand Listener, 21 Feb, 1981.

Two events predicted by physical scientists have been cited in this CFF report as unprecedented human catastrophes. These are the onset of another glacial period (ref 17), and a melting of the West Antarctic ice sheet (ref 41). Their mutual exclusiveness reflects the limitations of present understanding of climatic processes.

(42) W F Budd in 'Carbon Dioxide and Climate: Australian Research', p115 (Aust. Academy of Sciences, 1980).

(43) World Meteorological Organisation Statement WMO/No.373, 2 March, 1981 (Geneva).

(44) T M L Wigley, P D Jones, P M Kelly in Nature, vol 283, 1980, p 17.

(45) S Manabe, R T Wetherall in J. Atmos. Sci, vol 32, 1980, p3.

(46) J Gribbon in New Scientist, vol 86, 1980, p 15.

(47) W J S Downton, P Bjorkman, C Pike in 'Carbon Dioxide and Climate: Australian Research, op cit, p 143. C Wong, ibid, p 159. R Gifford, ibid, p 167.

The effect of atmospheric carbon dioxide level on the rate of photosynthesis can be understood in terms of the competitive interactions of atmospheric oxygen and carbon dioxide with ribulose 1,5 bisphophate carboxylase/oxygenase, the enzyme which catalyzes photosynthesis. Increased carbon dioxide in the atmosphere favours carboxylation (i.e. photosynthesis) over oxygenation (i.e. photorespiration) in C_3 (but not C_4) plants. A second effect (for both C_3 and C_4 plants is a reduction in transpiration rate resulting from stomatal closure. These two effects may combine to produce an improvement in water-use efficiency viz.an improvement in plant yield for the same water consumption.

(48) C Wong, op cit. (ref. 47)

(49) J P Kerr, Plant Physiology Division, DSIR, pers. com. 1981.

(50) U. Benecke, Forest Research Institute, NZFS, pers. com. 1981.

(51) W W Kellogg et al in The Futurist vol 14, 1980, p50.

event could cause more human misery than any other in history (41). While the consensus is that the West Antarctic ice sheet would melt during a major global warming, there is disagreement over the response time. Estimates range from 50 years to several centuries, but some workers caution that the melting, once started, would be irreversible and fairly rapid (42).

2.3.4 Implications for Agriculture

Since it is the temperature difference between the poles and the equator that helps to drive the weather systems which influence temperature and rainfall patterns, a global warming (which decreases this difference) could materially affect regional ecosystems and hence agricultural production and water supply. Similarly, protein harvest from the sea could be affected by changes in ocean currents and upwellings, upon which fishing production depends (43).

A number of studies have considered the likely climatic consequences of a global warming, both by comparing historically warm and cold years (44) and by numerical modelling (45). The modelling is not inconsistent with the historical records viz. decreased rainfall over the northern hemisphere midlatitude wheat belts of the USA and the USSR, with ominous implications for world food production (46).

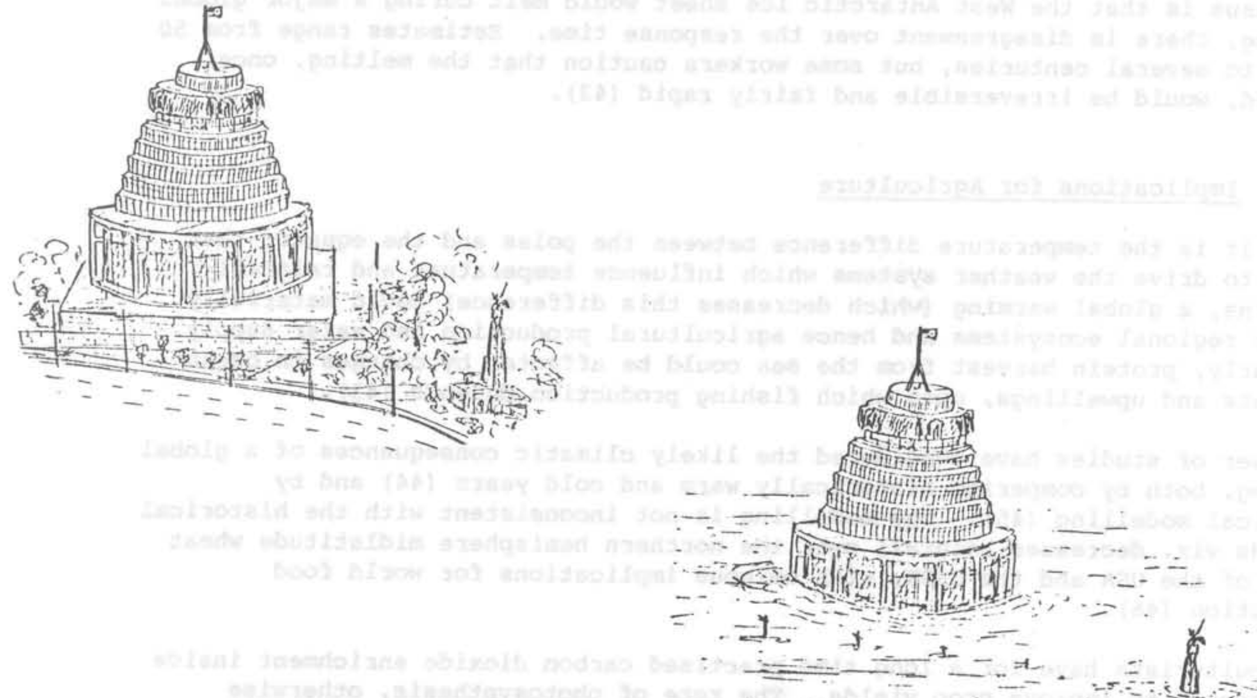
Horticulturists have for a long time practised carbon dioxide enrichment inside glasshouses to improve crop yields. The rate of photosynthesis, otherwise limited by the low partial pressure of carbon dioxide in the atmosphere, is increased. Australian research has shown that an increased carbon dioxide level tends to close leaf stomata, and so reduces plant water losses by transpiration (47). Plants become more efficient in their water use, and may be able to grow in habitats which would, for normal carbon dioxide levels, be too arid. The global areas available for agriculture could expand in the future, as carbon dioxide levels rise (48).

These results, based on single specimens, must be viewed with caution. For instance, New Zealand research has shown that for most local crops the stomatal effect on water use efficiency is small (49). As a generalization, water use by most New Zealand plants is primarily determined by climatic variables, and the control by the plant is only secondary. Much has still to be learnt about the net uptake of carbon dioxide under conditions which approximate those occurring in the field. It is perhaps fortunate that plant breeders will tend to produce plants adapted to the increasing carbon dioxide level, because cultivars are bred and selected under field conditions.

Although atmospheric carbon dioxide is recognized as a major limiting factor in primary forest production, predicting the long-term consequences of increasing levels is extremely complex (50). The increased potential for fixing carbon by photosynthesis will be quickly influenced by other factors such as soil nutrients, available moisture, and ambient temperature.

Warmer and longer growing seasons may change the frequency, severity, and distribution of crop losses to insect pests and crop and livestock diseases (eg facial eczema). The epidemiology of human diseases (eg malaria) may also be changed (51).

New Zealand's trading economy is largely based on a comparative advantage in agriculture. Tentative results derived from plants in enhanced carbon dioxide levels indicate improvements in growth rate and water-use efficiency. The



(52) A B Pittock in 'Carbon Dioxide and Climate: Australian Research', p 197. (Aust. Academy Sciences, 1980).

(53) There appear to be important variations in the response of plants to increasing carbon dioxide levels. Wheat (a C_4 species) shows a marked increase in the rate of photosynthesis whereas for maize (a C_3 species) the change is minimal. These results have been demonstrated for single plants but may be complicated by canopy effects in the field. The plant response is further modified if other limiting factors are operating (e.g. moisture, nutrients, ambient temperature). In general, Australian research indicates that increasing carbon dioxide levels mitigate these other limiting factors (e.g. by improved water-use efficiency) but some plants (e.g. wheat) respond better than others (e.g. maize).

(54) Reported in 'The Dominion', April 17, 1980.

(55) 'The Global 2000 Report to the President', vol 2, p 269. (Council on Environmental Quality and the US Department of State, 1980).

(56) J Gribbin in <u>New Scientist</u>, vol 189, 1981, p 635.

(57) G Speth reported in <u>New Scientist</u>, vol 189, 1981, p 635.

(58) G I Pearman, Division of Atmospheric Physics, CSIRO, pers. com. 1980.

(59) J Gribbin, op cit.

(60) T Lones in <u>New Scientist</u>, vol 188, 1980, p 866.

(61) G F Preddey, 'Fast Track Self-Sufficiency: an Alternative Energy Plan', Commission for the Future, Oct 1980.

(62) 'Global 2000 Report to the President', vol 2, p 269. (Council on Environmental Quality and the US Department of State, 1980).

economic consequences of a global warming may be due more to the climatic effects on the economies of other countries, than to its direct effect on the local economy (52). For New Zealand, any change in comparative advantage could have important consequences, and merits study (53).

2.3.5 Implications for Energy

A panel of internationally recognised scientists has told the US Congress that the world may face an ecological disaster unless a global strategy is developed to control the addition of carbon dioxide to the atmosphere. Burning of fossil coal, oil and natural gas was cited as the principle source, but deforestation was also recognised as a factor. The panel was critical of US plans for a synthetic fuels programme based on coal (54).

The carbon dioxide problem is global in scope, and there is no institution now established that can adequately address it. In the future the capacity of the atmosphere to absorb carbon dioxide may be a resource that is even more limited than either fossil fuels or forests. Protecting this resource will raise perplexing and troublesome problems and could conceivably overshadow all other energy issues (55).

One way to reduce the risk is to reduce the growth in use of fossil fuels (56). The Chairman of the US Council on Environmental Quality (G Speth) has noted that present global levels of fossil fuel use could continue for 200 years without drastically disturbing the climate (57).

This view is supported by Australian climate modelling. The present trend for rapidly increasing use of fossil fuels will cause a doubling of carbon dioxide levels in the next forty to sixty years, according to the models. To maintain present levels (336 ppmv) would require a reduction in fossil fuel burning to 0.6 Gt/y of carbon, about one-tenth of the present rate of 5 Gt/y of carbon. However, if the present rate of 5 Gt/y of carbon is maintained (ie zero growth), the doubling time is increased to 300 years (58).

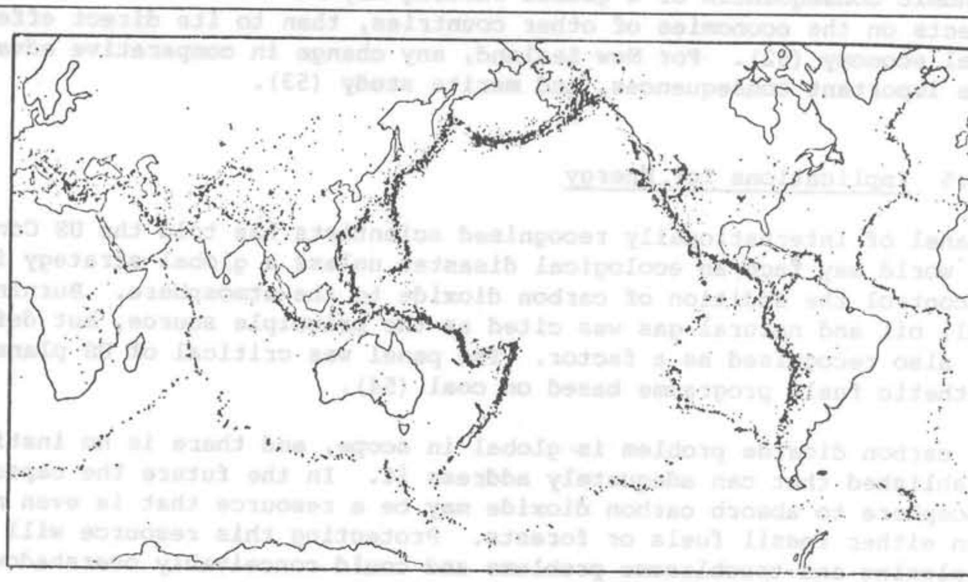
According to Speth, the developed world could easily adopt a policy of 'no growth' in fossil fuel use. But the Third World is geared for a reliance on coal for development, and unless this growth is to be curtailed (how?) the rich North must actually cut back. Speth suggests decision makers are faced with a clear choice between accepting the consequences of a carbon dioxide increase, or an enormous promotion of nuclear power - not in the North but in the developing world. What restraint might there be on nuclear proliferation if the choice is between nuclear power for the Third World and drought in the US (59)?

A sustainable programme of energy farming may be another option, especially for Third World countries. Brazil and Papua New Guinea have already embarked on a scheme to substitute alcohol derived from biomass for imported oil (60). Biomass may be more attractive than coal as a feedstock for indigenous transport fuel production in New Zealand, in the context of the carbon dioxide-climate problem (61). (Carbon dioxide released by the combustion of fuels derived from biomass is taken up by the replacement crops).

Even within individual nations, decisions in these regards can be expected to strain existing institutions, and require long periods for debate. On a global scale, there are no adequate institutions and no precident for such decisions or the co-operation they would require (62).

Will the atmosphere conduct the experiment for us?

Figure 3.1



Earthquake epicentres 1962-67 (p.29)

Figure 3.2

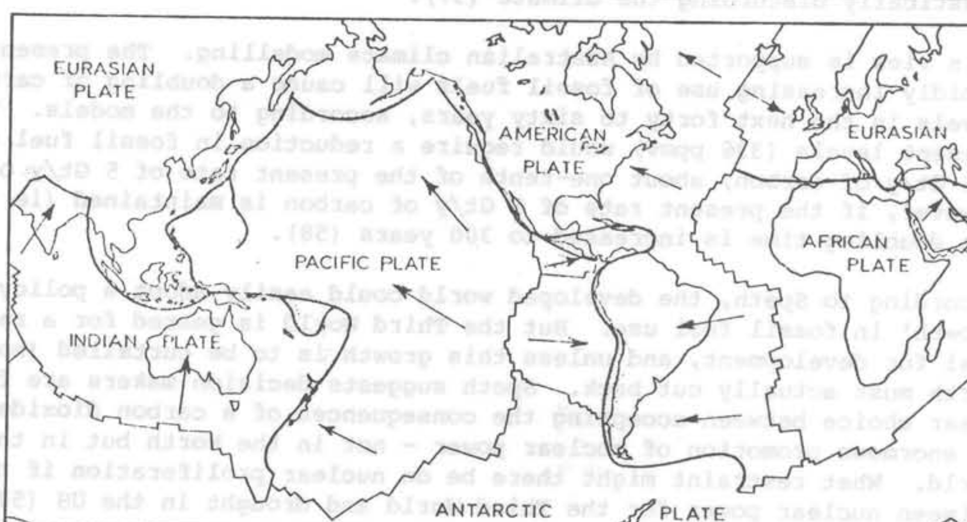


Plate boundaries (p.29)

(1) Psalm 90, v 10.

(2) The term "plate tectonics" is used in preference to "continental drift" because the continents are simply part of larger "plates" comprising both oceanic and continental material. The continents drift along with the plates.

(3) G. Stevens, "New Zealand Adrift", p xxi (Reed, 1980).

(4) G.A. Eiby, "Earthquakes", fig 52 p74 (Heinemann, 1980).

(5) G.A. Eiby, op cit, fig 53, p75.

(6) R.I. Walcott, paper presented at the Conference on Large Earthquakes, Napier, 1981 (fig 1).

3. TECTONIC DISASTER

tectonic	of or relating to the structures of the earth's crust and the forces which cause it to move.

A SELECTED GLOSSARY of underlined technical terms used in this section is appended (pp63-65)

3.1 A RESTLESS EARTH

3.1.1 Plate Tectonics

A human lifetime of 70 years (1) is insignificant on a geological time scale. For this reason it is hard to imagine the land and sea changing. Local changes - those wrought by earthquake or volcanic eruption - are sudden enough to demand attention. But others, taking place at infinitesmal rates over millions of years, have been recognized only recently, and yet are transforming the entire geography of the planet.

The perspective of plate tectonics (2) gives a new view: "of continents drifting majestically from place to place, of mountains and island chains forming like rumples in rugs pushed together, and of oceans opening and closing. The earth's seemingly rigid crust is now thought to consist of a patchwork quilt of great rafts or 'plates' that are much like huge ice floes jostling about on a frozen sea. Sliding over a hot, semi-plastic layer below, the rigid plates slowly move, carrying the continents and oceans with them. The plates grind and crash together, causing earthquakes and volcanic eruptions."(3)

Some 20 years ago, the World Wide Standardized Seismograph Network was established, allowing the accurate determination of the epicentres of all major earthquakes. Figure 3.1 shows epicentres of large shallow earthquakes (focal depths less than 100 km) for the period 1962-67 (4). The striking pattern of continuous narrow zones of seismic activity has lead to the identification of large areas essentially free of earthquakes. These are the 'plates', effectively behaving as coherent, rigid units of the lithosphere. The plate boundaries are shown schematically in figure 3.2. Arrows indicate the directions in which the plates are believed to be moving (5).

Figure 3.3 shows plate boundaries from a local perspective (6). New Zealand is located across the boundary of the Indian and Pacific plates.

3.1.2 Tectonic Volcanism

The differential motion of a few centimetres per year between adjacent plates is taken up by deformation and fault movement (causing earthquakes) along the boundary. Volcanism may also occur where crust is either being created (mid-ocean ridges) or being consumed (subduction zones).

3.1.2.1 Mid-Ocean Ridges

Underwater surveys have revealed a continuous range of mountains bisecting the major oceans - the mid-ocean ridges. These features coincide with the seismic

Figure 3.3

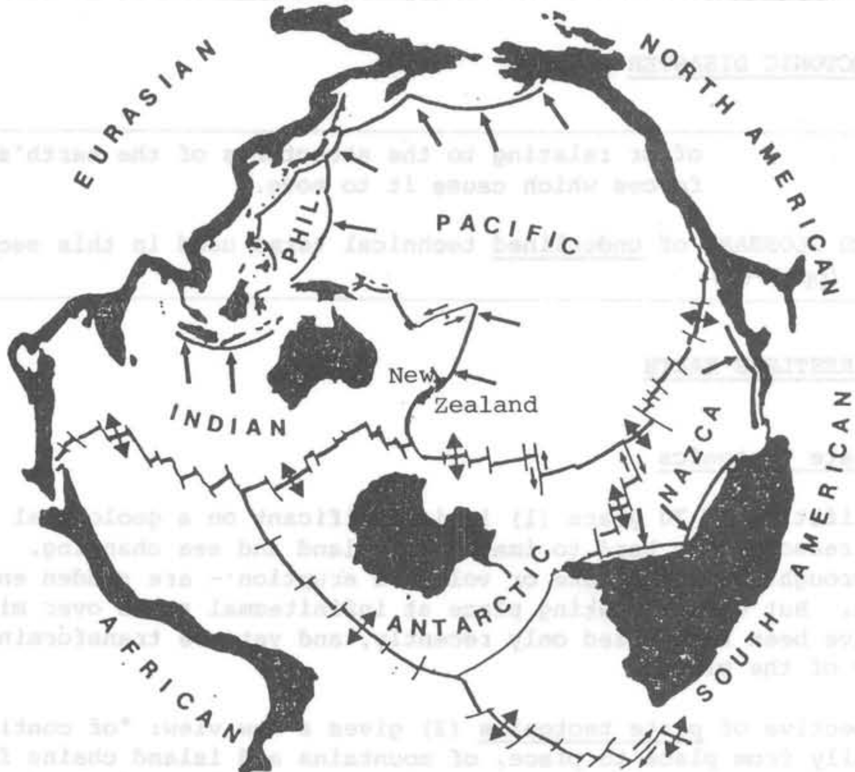
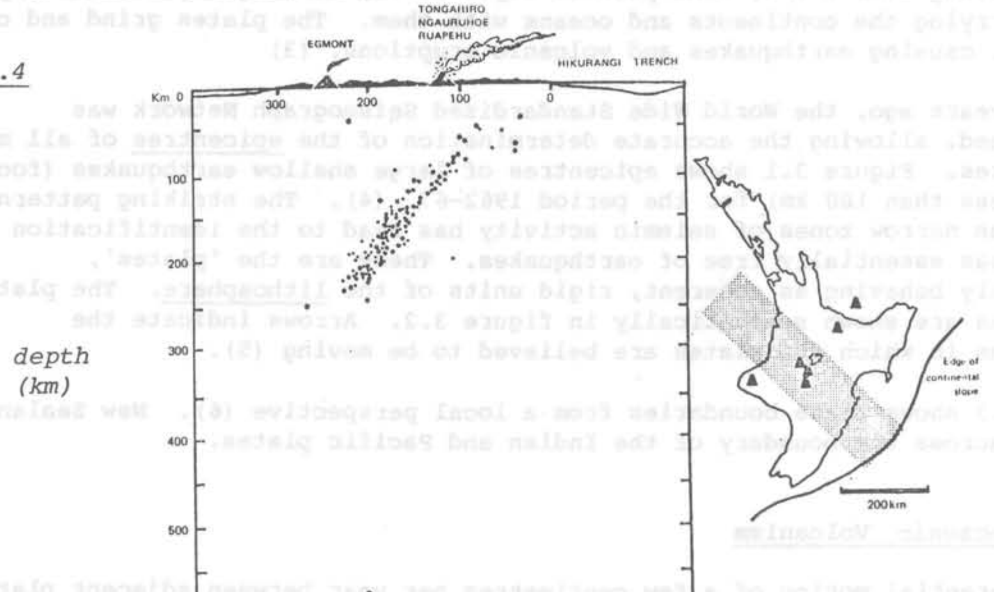


Plate boundaries (p.29)

Figure 3.4



Benioff zone under the North Island (p.31)

(7) R.I. Walcott, op cit.

(8) The chain of Hawaiian Islands similarly comprises shield volcanoes, but their magma source is a fixed rising plume (which has punctured the moving Pacific plate) rather than a tension fracture at a plate boundary. The north-westerly drift of the Pacific plate (see figure 3.2) can account for the occurrence of active volcanism only in the easternmost island of the chain (Hawaii), and for a new eruptive centre located to the southeast. This may in time emerge as a new island (Loihi).

(9) G. Stevens, "New Zealand Adrift", fig 18.14 p367 (Reed, 1980).

zones marking plate boundaries where spreading is thought to be occurring. Corroborative evidence is provided by symmetrical patterns of sea floor magnetisation running parallel to the ridges. Underneath the ridges solid rock is melting and the resulting magma rises by its own buoyancy to break through the crust where tension fractures exist. As further material is injected, solidified material is pushed away from the ridges, carrying its magnetic signature along with it (7).

Melting of this kind produces basalt rock, relatively uncontaminated by lighter crustal rocks. Most basalt eruptions occur underwater along the mid-ocean ridges, and pass generally unnoticed. Very large basalt flows may create giant shield volcanoes, so called because basalt, flowing easily, builds gently-sloping domes. Iceland, astride the mid-Atlantic ridge, has been built up in this way over the last 25 million years, i.e very recently on a geological time scale (8).

3.1.2.2 Subduction Zones

The creation of new oceanic crust at mid-ocean ridges requires that crust be consumed elsewhere, and seismology showed where. Most earthquakes are shallow, being located in the cold, brittle lithosphere. At greater depths in the asthenosphere, the rocks are too plastic to accumulate earthquake-generating stresses. But in compression zones such as island arcs, earthquakes as deep as 650km can be identified. The earthquake foci map out a dipping Benioff zone (figure 3.4) interpreted as a slab of oceanic crust descending into the asthenosphere at a plate boundary (9). The slab retains its brittle behaviour (and thus can accumulate earthquake stress), until it is heated by conduction over several tens of millions of years and is absorbed into the underlying mantle.

This process of subduction drags cold oceanic crust (basalt) and waterlogged sediments down into a hot environment. Melting, typically at depths of 100 to 200 km, creates water- and gas-rich magmas which rise by their own buoyancy into the overlying crustal rock. A modest degree of mixing creates andesite magma, but if large volumes of crustal rock are assimilated into the rising magma, stiff rhyolite magma is produced instead.

Much of the magma consolidates at depth in the crust. However some rising bodies of magma may breach the overlying 'roof', and an eruption follows. The release of pressure near the surface releases trapped gases, causing an explosion. Pumice represents fragments of the frothy top of an exploding magma column.

Magma viscosity (stiffness) determines the violence of the eruption. Viscous rhyolite generally erupts more violently than freely-flowing basalt. Water trapped in the magma may cause phreatic (steam) explosions. If, in the process, rock is torn from the vent or the magma body, the eruption is phreatomagmatic.

3.1.3 Tectonic Earthquakes

Convection processes in the mantle cause the plates to move relative to each other. At a subduction zone, cold dense oceanic crust sinks at a few centimetres per year into the hot asthenosphere, allowing new material to well upwards through tension fractures at a mid-ocean rise. Thus the connecting lithospheric plates are pulled as much as pushed from the rises to the

CIVIL DEFENCE

PERSONAL SAFETY MEASURES

This pamphlet has been written to give you knowledge which may be applied in a local emergency where for a few critical minutes lifesaving action may depend entirely on your own initiative.

You spend much of ycur time in the City and cities are vulnerable to the hazards of violent earthquakes.

Your attention is drawn therefore to the constant threat of an earthquake disaster and the measures necessary for personal safety.

Wellington may at any time suffer an earthquake of great severity. Maximum violence of the shock would probably be reached within 10 seconds of the first tremor.

There will be no warning

Buildings will be damaged, gas, water and sewer mains fractured, some streets made impassable, power and telephone lines will be cut and personnel may be incapacitated.

---

(10) R.I. Walcott, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(11) The scenario was written by CD organiser C. Fraser.

subduction zones. The plate boundaries act as the zones of deformation between adjacent plates.

Earthquakes are generated by abrupt motion along a fault line caused by the release of elastic strain energy stored in the deformed rock. This strain energy accumulates over a long period by continuous deformation caused by differential plate motion. It is suddenly released when slip occurs by catastrophic failure along a fault plane. The amount of energy released in the earthquake is determined by the area of the fault plane over which slip occurs, and by the magnitude of the slip. A great earthquake is generated by a slip of several metres over an area of fault plane typically 20 km deep and extending several hundred km. A small (felt) earthquake requires a slip of several cm over an area of perhaps 10 km x 10 km (10).

The differential plate motion determines whether the faulting is normal (i.e. tension/pull-apart motion at a mid-ocean ridge or compression/thrust motion at an island arc) or shear (where the plates are slipping sideways). Normal and shear faulting often occur simultaneously.

Rock failure usually occurs on a pre-existing fault. To a first order, rocks are elastic viz. stress is proportional to strain. As the strain increases, the stress increases (along with elastic strain energy) until the fault slips. A comparison of the energy released in earthquakes with the energy absorbed at the plate boundaries (the latter calculated from rock parameters and from measured strains) shows that not all of the energy is accumulated as elastic strain and then released as earthquakes. Undoubtedly some of the differential plate motion is taken up by continuous slip (or creep) along fault planes which does not generate earthquakes (10).

3.2 EARTHQUAKE HAZARD IN NEW ZEALAND

3.2.1 1981 Wellington Earthquake (a hypothetical Civil Defence scenario)

By good fortune, the 1981 Wellington earthquake was only a paper exercise, designed to test the Civil Defence organization (11). It does however reflect the potential consequences of a major earthquake for an urban area.

Monday, 16 February 1981:

> "Wellington is in a state of chaos after a major earthquake rocked the region shortly after noon today, toppling buildings and severing all communication lines... The Wellington fault has dislocated with a 4.8 metre displacement in Wellington and a 5.1 metre displacement in the Hutt Valley. This has immediately cut all services and communications in the area. The Karori reservoir emptied in minutes; water, telephone, and electricity cables have been severed plus road and rail links... At Seaview, oil storage tanks have crumpled and oil is spilling into the harbour. The Hutt River is in full flood. Many hill suburbs are isolated by slips and mud flows, and debris have blocked all exits out of Wellington. The airport is out of action..."

Wednesday, 18 February 1981:

> "A state of civil emergency has been declared following Monday lunchtime's shake, which has virtually isolated the capital from the rest

<u>Modified Mercalli Scale</u> (abridged from (13))

I. Not felt except by a very few under especially favourable circumstances.

II. Felt only by a few persons at rest, especially on the upper floors of buildings.

III. Felt quite noticeably indoors, especially on the upper floors of buildings, but many people do not recognize it as an earthquake.

IV. During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of fallen plaster or damaged chimneys. Damage slight.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys, damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Fall of chimneys, walls; heavy furniture overturned.

IX. Damage considerable in specially designed structures; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent.

XI. Few if any (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground.

XII. Damage total. Waves seen on ground surfaces. Object thrown upwards into the air.

---

(12) From "The Evening Post" of 16,18,19 February 1981.

of the country. Nearly 3,000 people are believed to be dead and a further 24,000 injured. Hundreds more are trapped under piles of rubble and a unit with 100 people on board lies buried in the number one rail tunnel... At yesterday's CD controller's conference officials reported major shortages in food, drinking water and other resources. Sewerage services have failed... The city is without gas or electricity... Fire continues to be a major hazard, with leaking gas seeping out from broken pipes and tanks and an acute shortage of water...machines at Brooklyn and Northland stations were destroyed when the buildings collapsed... Forty percent of Wellington Free Ambulance fleet was disabled when the quake hit. The service is no longer able to exist in a transport capacity... Works staff are trying to cut an access route between Johnsonville and the airport. Health Department officers are setting up casualty clearing stations in the suburbs... The CD controller has said that the extent of the disaster is so great that the majority of people, other than the able-bodied, will have to be evacuated... Evacuation procedures would start as soon as the airport and harbour were opened..."

Thursday, 19 February 1981:

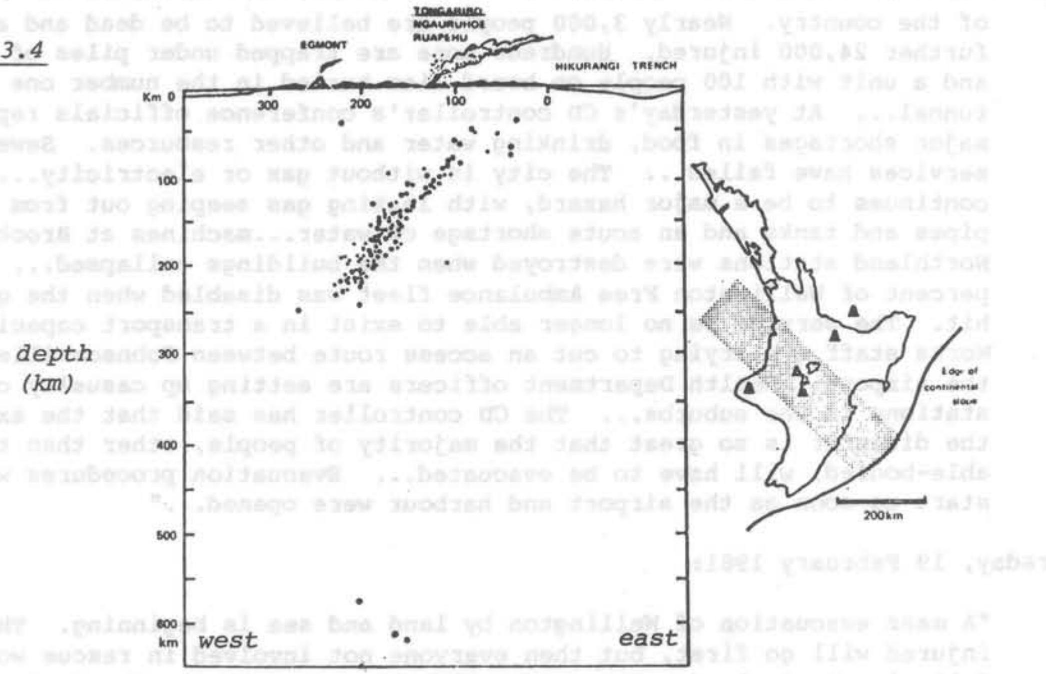
"A mass evacuation of Wellington by land and sea is beginning. The injured will go first, but then everyone not involved in rescue work following Monday's devastating earthquake must follow. The CD Controller said it was obvious that essential resources such as food, fuel, and water would not be available in sufficient quantities to support Wellington's population... Wellington is still isolated from the rest of the country by road, although the airport and harbour are accessible... The police report little problem with looting so far, but dealing with relatives' enquiries about casualties is becoming a major public relations exercise. If corpses become a public health hazard they might have to be buried systematically in a mass grave and after disinterred for identification." (12)

3.2.2 Earthquake Location, Magnitude, and Intensity

When a fault plane slips suddenly, energy is radiated outward from a focus, predominantly either as P waves (longitudinal compression waves travelling at about 8 km/s) or as S waves (transverse shear waves travelling at about 5 km/s). These waves are recorded by seismographs, instruments which continuously monitor the motion of the ground. In New Zealand there is a network of 29 earthquake recording stations, which can detect not only local earthquakes but also waves from overseas earthquakes. These can take up to 20 minutes to travel through the earth. Records from a minimum of three stations are required to locate the epicentre of a local earthquake, and the depth of its focus. These determinations can be made using the difference in arrival times of the P and S waves at the seismographs.

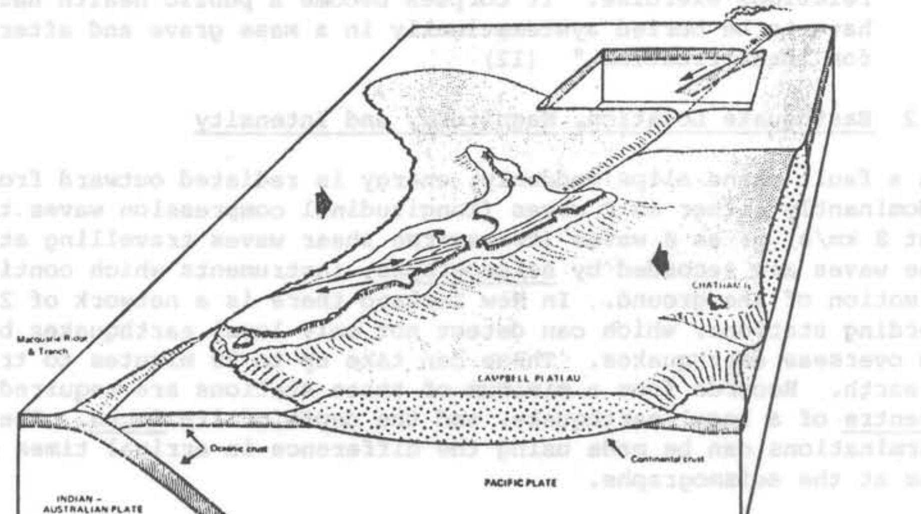
The magnitude of an earthquake is a measure of the total energy released at its focus, and is usually expressed on the Richter scale. The Richter magnitude can be derived from the trace of a standard seismograph at a standard distance from the earthquake, although in practice it is estimated using non-standard seismographs at non-standard distances by applying appropriate correction factors. The smallest felt earthquakes have a magniture of about 3, shocks of magnitude 5 may cause minor damage in New Zealand, those of magnitude 7 are seriously destructive, and those of 8 and above are disastrous.(Overseas, lesser earthquakes have been disastrous, such as the magnitude 5.8 earthquake at Agadir in 1960). The scale is logarithmic, so that an increase of one magnitude increases the energy released by a factor of about thirty.

Figure 3.4



Benioff zone under the North Island (p.37)

Figure 3.5



New Zealand subduction zones (p.37)

(13) G.A. Eiby, "Earthquakes", p184 (abridged) (Heinemann, 1980).

(14) G. Stevens, "New Zealand Adrift", fig 18.7, p360 (Reed, 1980).

(15) "The Earthquake Problem in New Zealand", DSIR Extension Information, no.1, June 1980.

(16) G.A. Eiby, op cit, pp193-6.

(17) W.D. Smith, paper presented at the Conference on Large Earthquakes, Napier, 1981 (fig 2).

The felt intensity of an earthquake is usually expressed on the Modified Mercalli scale (see p.34). This is a purely descriptive scale, and derives from the qualitative reports of observers rather than from the quantitive response of an instrument (13).

The felt intensity at any particular place is determined by the energy released (viz.Richter magnitude), the distance of the epicentre, the focal depth, and the nature of the underlying ground.

3.2.3 New Zealand Seismicity

New Zealand is located on the boundary of the Pacific and Indian plates (Fig. 3.3). Under the North Island, the Pacific plate is being forced below the Indian plate, creating an active subduction zone. A result is frequent earthquakes along a dipping plane, some as deep as 300km. (Fig 3.4) Below Fiordland the configuration is reversed, with the oceanic crust of the Tasman Sea being thrust under the South Island, as shown schematically in figure 3.5 (14).

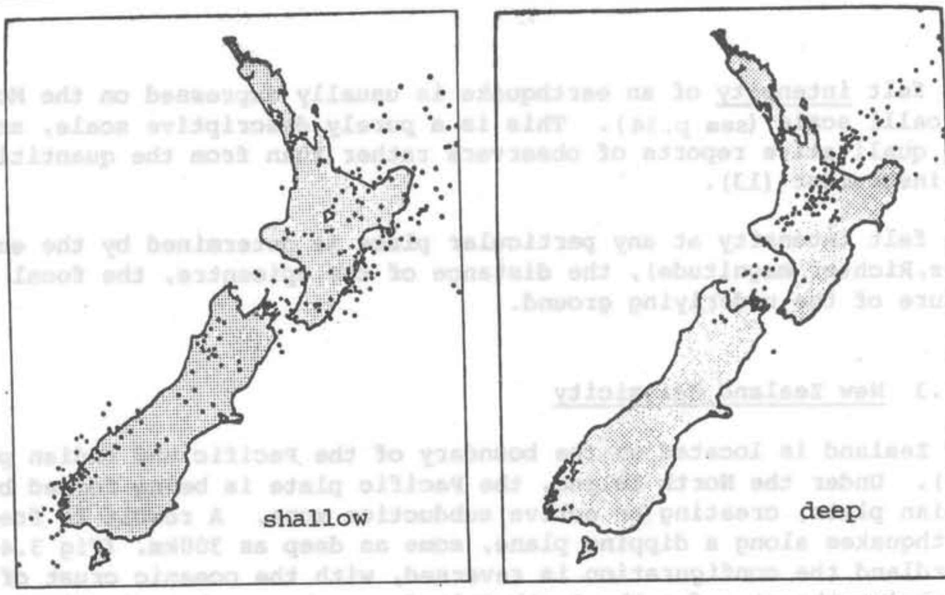
Repeated triangulation surveys have established the differential plate movement across New Zealand, and reveal a zone of large rates of strain some 100km wide extending from East Cape to Fiordland. All large historical earthquakes, and most seismic activity, have occurred within this zone.

Altogether about 200 earthquakes are felt in a typical year, and many smaller ones are recorded. On average, 80-120 exceed magnitude 4, 10-20 exceed magnitude 5, and 1 exceeds magnitude 6. A magnitude 7 earthquake can be expected about once a decade. This level of seismic activity is similar to California's, but rather less than that of Japan, Chile, or the Philippines (15).

Potentially destructive New Zealand earthquakes since 1840 (magnitude 7+, depth less than 100km) are listed below: (from (16), (17)).

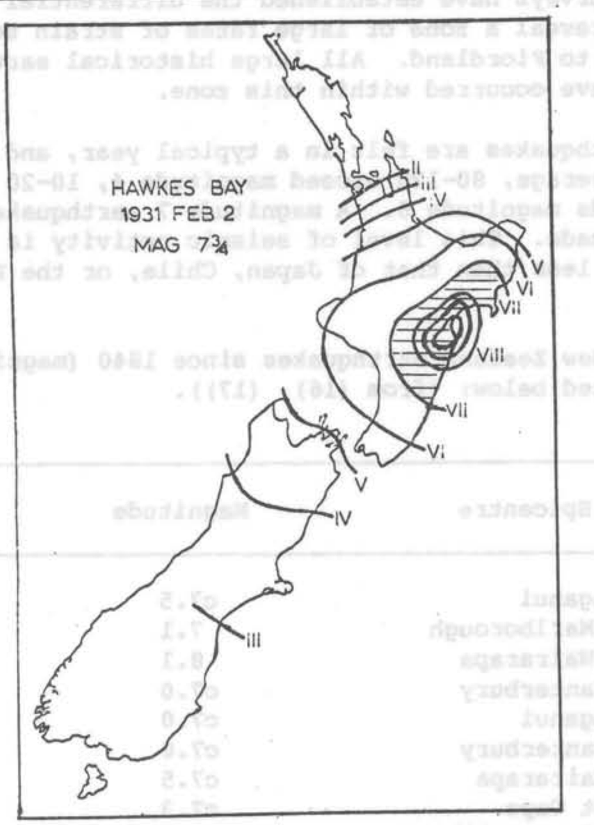
Year	Epicentre	Magnitude	Fatalities
1843	Wanganui	c7.5	2
1848	NE Marlborough	7.1	3
1855	SW Wairarapa	8.1	5
1888	N Canterbury	c7.0	
1897	Wanganui	c7.0	
1901	N Canterbury	c7.0	1
1904	E Wairarapa	c7.5	
1914	East Cape	c7.3	1
1921	Hawke's Bay	c7.0	
1929	Arthur's Pass	6.9	
1929	Buller	7.7	17
1931	Hawke's Bay	7.9	256
1932	Wairoa	7.0	
1934	Pahiatua	7.5	1
1942	S Wairarapa	7.0	
1960	Fiordland	7.0	
1968	Inangahua	7.1	3
1976	Fiordland	7.0	

Figure 3.6



New Zealand earthquakes 1971-72 (p.39)

Figure 3.7



1931 Hawke's Bay earthquake (p.39)

(18) G. Stevens, op cit, figs 18.12, 18.13 p366.

(19) W.D. Smith, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(20) W.D. Smith, op cit, fig 4.

(21) W.D. Smith, op cit, figs 6,7.

(22) R.I. Walcott in Bull. NZ. Soc. Earthquake Eng., Vol 12, 1979, p87.

(23) F.F. Evison in J. Roy. Soc. NZ, Vol 9, 1971, p161.

(24) R.I. Walcott, op cit.

Major New Zealand earthquakes have been sporadic, with bursts of activity (e.g. 1929-34, 5 in 5 years) followed by relatively quiet periods (1935-81, 4 in 46 years). The geographic distribution of earthquakes exceeding magnitude 4 for the years 1971-72 is shown in Fig 3.6(18). Shallow earthquakes (left diagram) define the seismic belt along the active plate boundary running through New Zealand. These probably result from magma movement (and consequent swelling or contraction) or from surface faulting. Deeper earthquakes (focii below 40km, right diagram) define the dipping Benioff zones (Figure 3.4).

The absence of earthquakes in Northland and in the South East of the South Island in 1971-72, is not unusual, although, occasionally, earthquakes are recorded in both regions.

3.2.4 Future Earthquake Hazard in New Zealand

Likely ground motion is a more useful indication of risk than earthquake magnitude. Traditionally, ground motion has been described by a qualitative intensity, usually rated on the Modified Mercalli scale. In determining the risk to structures (buildings, dams etc), quantitative estimates of ground motion such as acceleration, amplitude, and period are more applicable, but in practice these quantities are not readily available. For this reason, intensity is used as a more general and robust measure of ground motion (19).

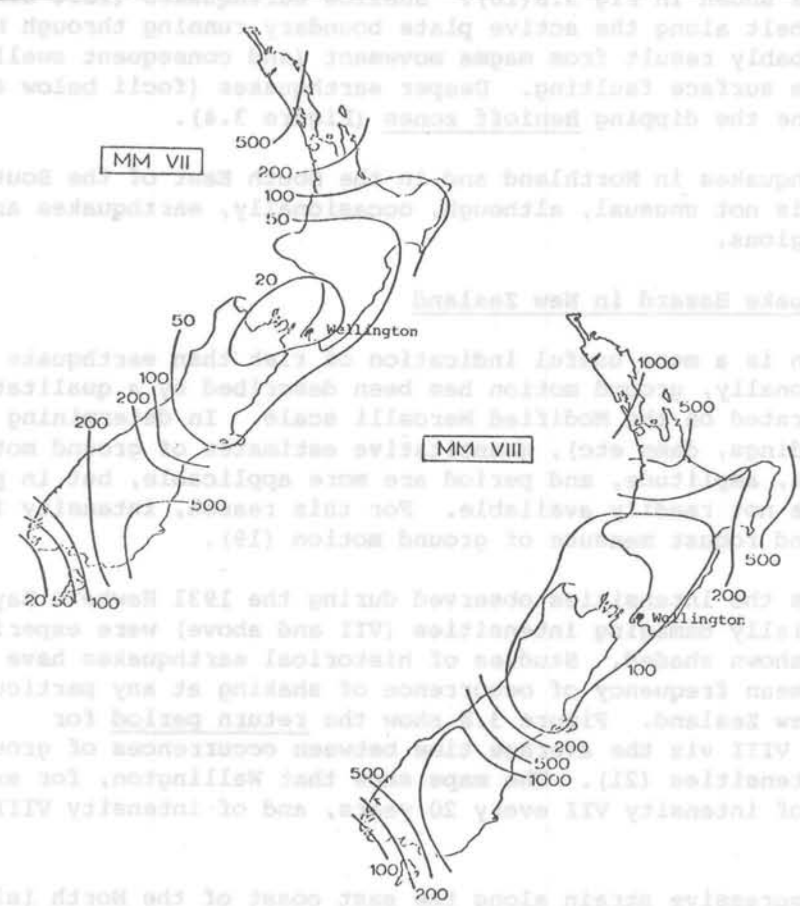
Figure 3.7(20) shows the intensities observed during the 1931 Hawke's Bay earthquake. Potentially damaging intensities (VII and above) were experienced over a large area, shown shaded. Studies of historical earthquakes have allowed estimations of the mean frequency of occurrence of shaking at any particular intensity through New Zealand. Figure 3.8 show the return period for intensities VII and VIII viz the average time between occurrences of ground shaking at these intensities (21). The maps show that Wellington, for example, can expect shaking of intensity VII every 20 years, and of intensity VIII every 100 years.

The direction of compressive strain along the east coast of the North Island has shifted abruptly since the 1931 Hawke's Bay earthquake. A possible interpretation is that the fault between the subducted plate and the overlying crust becomes locked every hundred years or so. The consequential compressive strain accumulates until released by a large thrust-type earthquake (like the 1931 event) allowing aseismic creep to recommence.

Further south, the distribution of foci of small earthquakes detected by a network of seismographs has been interpreted as evidence for a locked subduction zone east of Wellington. Compression of the overlying crust by the descending Pacific plate is estimated to have begun around 1920, implying the accumulation of strain equivalent to 3m of shortening. Whether this has already been released by aseismic slip, or whether it will cause a future earthquake, is not known (22).

No large historical earthquakes have been located in the seismic belt between Fiordland and the northern part of the South Island, in the vicinity of the Alpine Fault. Seismicity at all magnitudes is low in this region (23). Either a very large earthquake will occur in the future to release the accumulated strain, or the strain is being accommodated by aseismic creep along the fault without earthquakes. Present information cannot resolve the uncertainty (24). Episodic compression appears to apply only to the deformation occuring in the two subuction zones (see figure 3.5). In the central region of the South Island, the compression is continuous, and is manifest in the rise of the Southern Alps.

Figure 3.8



Return period (years) for MM VII and MMVIII earthquakes (p.39)

(25) G.L. Berlin, "Earthquakes and the Urban Environment", Vol 1, p184 (CRC Press 1980).

(26) G.L. Berlin, op cit, p187.

(27) G.A. Eiby, "Earthquakes", p88 (Heinemann, 1980).

(28) G. Stevens, "New Zealand Adrift", p53 (Reed, 1980).

3.2.5 Tsunamis

A tsunami is a sea wave generated by certain earthquakes whose epicentres underlie or border the ocean floor. Most are generated by earthquakes along the trenches marking the subduction zones encircling the Pacific Basin (25). Tsunamis can inflict damage, injury, and death along coastlines thousands of kilometres from their points of origin, or their effects can be local, occuring within minutes of their generating earthquake.

In the deep ocean, the wave velocity can approach 1000km/h, but the trough-to-crest height is slight (less than a metre) and the wave poses no hazard. In shallow water the speed is reduced often to less than 65km/h, but the height may increase to 10m or more with devastating consequences.

Between 1900 and 1970 a total of 181 tsunamis were recorded in the Pacific; of these, 34 caused local damage, and 9 were destructive both locally and at great distances (26). New Zealand has escaped lightly. The only clear instance of a damaging local tsunami was in 1947 when waves generated by a moderate earthquake off East Cape caused damage to bridges and a seaside hotel (27).

The most troublesome tsunamis for New Zealand have originated near Chile. A tsunami in 1868 caused a drowning in the Chatham Islands, and surges in New Zealand ports. The Chilean earthquake of 1960 disrupted shipping briefly in Lyttelton Harbour, but was destructive in Japan. Evidently New Zealand's more extensive continental shelf offers some protection.

The cataclysmic destruction of the island volcano of Krakatoa in 1883 affected much of SE Asia and the Indian Ocean. Giant tsunamis, cresting at 35m, struck the coasts of Java and Sumatra, and caused 36,000 drownings (28).

NEW ZEALAND VOLCANIC CENTRES (p 43)

magma type	field	recent vents	recent eruptions (years before present)	reference	fatalities (year)
(a) basalt	Northland	Te Puke	c1,500	(33)	
	Auckland	Rangitoto Is	760	(34)	
		Mt Wellington	9,100		
(b) andesite	Bay of Plenty	White Island	*		10(1914)
		Mt Edgecombe	c2,500		
	Tongariro	Mt Tongariro	85	(32)	
		Mt Ngauruhoe	*		
		Mt Ruapehu	*		151(1953) +
	Taranaki	Egmont	250	(35)	
(c) rhyolite	Okataina	Tarawera	95	(36)	153(1886)
		Lake Okaro	900	(37)	
	Taupo	Lake Taupo	1,795	(29)	

* Active at present, or within the past 5 years.

\+ Tangiwai rail disaster

(29) The average of many radiocarbon ages dates the eruption at about 130AD. C.J.N. Wilson, N.N. Ambraseys, J. Bradley, and G.P.L. Walker in Nature, vol 288, 1980, p252, suggest a date of 186AD using ancient Chinese and Roman records.

(30) G.P.L. Walker reported in "NZ Listener", Oct 7, 1978.

(31) G. Stevens, "New Zealand Adrift", p365 (Reed, 1980).

(32) "Volcanoes in New Zealand", DSIR Extension Information, No.6, Nov 1980.

(33) D. Kear and B.N. Thompson in NZ.J.Geol.Geophys. Vol 7, 1964, p87.

(34) "City of Volcanoes" by E.J. Searle (Paul's Book Arcade, 1964).

(35) "The Volcanic History of Taranaki" by V.E. Neall (Egmont National Park Board, 1974).

(36) B.N. Thompson in NZ.J.Geol.Geophys. Vol 7, 1964, p45.

(37) E.F. Lloyd in NZ.J.Geol.Geophys. Vol 2, 1959, p141.

3.3 VOLCANIC HAZARD IN NEW ZEALAND

3.3.1 186AD Taupo Eruption (29)

"Had anyone been around to witness the event, it would have seemed like the end of the world. With an awesome roar... a huge bulge in the Earth's crust, near what is now Taupo, split apart blasting a pillar of red-hot pumice 50km into the stratosphere. An immense mushroom-shaped cloud blocked out the sun, showering volcanic fallout many hundreds of kilometres downwind. As the towering column of gas and magma at last began to subside... the worst was yet to come... it became a fire-fountain, spewing ignimbrite - a sand-like molten pumice - (which) began to roll outwards like a gigantic tidal wave.

"Quickly gathering momentum, a fiery avalanche perhaps 100m high thundered across the land in all directions at more than 100km/h, filling river valleys and obliterating entire forests. So vast was the pumice avalanche that to the north it poured out across the Waikato Plains on a 25km front 50m high, only finally spending its force when it reached the barrier of the Bombay Hills (30km S of Auckland city).

"There is not much doubt... that trees and all other vegetation and wildlife within 80km of the volcano would have been destroyed. Such was the force of the burning avalanche that it went straight over all but the very highest mountain ranges in its path... Yet by the standards of past Taupo eruptions the (186AD) pumice flow was of only modest size. Although it filled most of the river valleys within the 160-km wide circle of destruction, it left just a thin pumice layer on the hills. In contrast, the very biggest Taupo pyroclastic waves smothered hills, valleys and entire mountain ranges, leaving only a featureless desert of steaming ignibrite in their wake." (30)

3.3.2 New Zealand Volcanism

Two subduction zones - Tonga-Kermadec and Macquarie - run into the New Zealand continental mass from north and south respectively. North-east of New Zealand, a plate boundary is very clearly defined by a Benioff zone dipping westward from the Tonga-Kermadec trench. An extension of this zone underlies the North Island from the Hikurangi trench lying off its east coast, and is the source of modern volcanism.

Post-glacial activity has been confined mainly to the Tonga-Kermadec ridge adjacent to the trough, and to the Taupo-Rotorua volcanic zone. Raoul Island is the main eruptive centre in the Kermadecs, although four active undersea volcanoes have been located between it and White Island. Propagation of the plate boundary south through the Taupo-Rotorua region has caused rifting and massive eruptions of lava and ash over the last 2 million years. Recent isolated eruptive episodes have also occured in Northland, Auckland, and Taranaki, and may be related to deeper crustal processes at the plate margin (31).

The eastward-dipping Macquarie subduction zone south of New Zealand seems to be in a waning phase, since the most recent volcanism occurred 1.5 million years ago on Solander Island. It is, however, still an active seismic region (p37).

Volcanic centres which have erupted in the past 10,000 years are listed opposite. Any of these centres may be expected to erupt again (32).

AIR-FALL DEPOSITS (p 45)

ash thickness	likely effect: humans/livestock	likely effect: property/vegetation	area covered (km^2): St Helens (1980)	area covered (km^2): Taupo (186AD)	area covered (km^2): Tarawera (1886AD)
1mm	little or none	water supply pollution			
1cm	no visibility, vehicles immobilized		20,000	100,000	30,000
10cm	power blackout, respiratory distress	crops destroyed, trees stripped	3,000	20,000	7,500
1m	injury through building collapse	building collapse, trees destroyed	200	1,000	100
10m	widespread loss of life	long-term disruption of land-use			

(39)

(38) I.E.M. Smith, paper presented to NZIE (Auckland Branch), June 1981.

(39) B. Houghton, paper presented to NZIE (Auckland Branch), June 1981.

(40) E.J. Searle in NZ.J.Geol.Geophys. Vol 7, 1964, p94.

3.3.3 Future Volcanic Hazard in New Zealand

3.3.3.1 Possible effects

The eruption products, and how they are released, determine the effects of an eruption, and may include (38):

(a) lava flows - slow moving (10m/s or less), generally presenting little danger to life, although they cause total destruction in their path. Location of site, and (possibly) diversion procedures may reduce losses.

(b) air-fall deposits - (ash) little danger to life, except near the vent. Damage is determined by thickness, temperature, and water content. Whereas dry ash may slide off sloping roofs, wet ash is more destructive due to its greater density and cohesiveness (see table opposite).

(c) pyroclastic flows - hot, particulate material which flows like a fluid, often at high speed (200m/s) and radially from the base of a descending column or jet of material. Pyroclastic flows are potentially dangerous and destructive (determined by magnitude and violence) and may be produced by half of all volcanoes at some stage.

(d) lateral blast (pyroclastic surge) - a flow directed more or less horizontally from a vent, and potentially more dangerous and destructive than a radial (non-directed) flow (e.g. Mt St Helens 1980).

(e) sector collapse of flank of volcano (e.g. Mt St Helens 1980); lahar or mudflow representing water displaced from a summit crater lake or ice/snow field (e.g. Ruapehu 1951); tsunami, see p.41 (e.g. Krakatoa 1883); earthquakes from all volcanoes; flooding especially when the vent is in a lake; poisonous gas emission (e.g. Laki in Iceland, 1783).

3.3.3.2 Possible locations

(a) Northland field (basalt)

Recent volcanism, viz.basalt scoria cones and lava flows, is represented in the Kaikohe-Kerikeri and Whangarei centres. Eruptions have occurred about every 1,000 to 2,000 years, the last (Mt Te Puke) about 1,500 years ago, so that a further eruption seems likely in the next 500 years. Unless the initial phase is explosive (risk zone 1km radius), fire-fountaining leading to the formation of a scoria dome, and subsequent basalt lava flows should entail minor risk to life. An area of $25km^2$ is likely to be covered by ejecta from a single vent, and to be unproductive for a few hundred years (33).

(b) Auckland field (basalt)

At least 50 basalt volcanoes have erupted during the last 50,000 years within urban Auckland. Few show evidence of multiple eruptions, hence it may be inferred that any future outbreak will be at a new site. Statistically there has been one eruption per thousand years, or a 10% chance of an eruption in any particular century. It is considered more likely there was a spasm of eruptions involving 3 or 4 volcanoes simultaneously, thus implying an average period between spasms of about 4000 years, or a 2% chance (of a spasm of eruptions) in any particular century (40).

RHYOLITIC ERUPTIONS (p 47)

Eruption	Taupo field	Okataina field	Welded ignimbrite
max dormant period	9500y	5000y	200,000y
min dormant period	less than 200y	less than 200y	10,000y
mean dormant period (44)	2800y	2000y	-
typical volume/ eruption	1-10km^3	1-10km^3	20-500km^3
previous eruption (years before present) (45)	1800y (Taupo) 2100, 2700, 3400, 6200, 8850, 9700...	95y (Tarawera) 900, 4000, 4800, 7000, 9000, 11250...	140,000y (Maroa)
eruptive centres	Lake Taupo (46)	Tarawera, Rotokawa, Haraharo, Matahina, Rotoma, Tikitapu(47)	

(41) R.N. Brothers and J. Golson in NZ.J.Geol.Geophys. Vol 2., 1959, p569.

(42) H.S. Jansen in NS.J.Sci. Vol 5, 1962, p74.

(43) E.J. Searle in NZ.J.Geol.Geophys. Vol 7, 1964, p94.

(44) I.E.M. Smith, paper presented to NZIE (Auckland Branch), June 1981.

(45) B. Houghton, paper presented to NZIE (Auckland Branch), June 1981.

(46) G.P.L. Walker in J.Volcano.Geotherm.Res., Vol 9, 1981, p395.

(47) C.G. Vucetich and W.A. Pullar, NZ Geological Survey Bulletin 73, p62 (DSIR, 1964).

(48) B.N. Thompson in NZ.J.Geol.Geophys. Vol 7, 1964, p45.

(49) C.P.L. Walker, op cit.

(50) C.P.L. Walker, R.F. Heming, C.J.N. Wilson in Nature, Vol 283, 1980, p286.

The volcanoes can be classified as either mainly explosive (phreatic or phreatomagmatic - see p31) or mainly effusive. The explosive volcanoes are indicated by craters and tuff deposits, tend to occur in low-lying regions (especially near the sea), and were most likely catastrophic and short-lived. The effusive volcanoes are distinguished by scoria cones and flows of basalt lava, tend to occur in higher ground, probably erupted with less initial violence, but eventually devastated a greater area. Locality may largely determine the course of future eruptions.

The most recent eruption produced Rangitoto Island and has been dated as 760 years before present (41), i.e, 1221AD, and possibly may be much more recent (42). It is not in the least improbable that new volcanoes will erupt in the Auckland field, and perhaps build another Rangitoto (43).

(c) White Island (andesite)

White Island has been active almost continuously since 1976. The present volcano has grown on the remains of two older (2-5 million year) volcanoes, and its crater is breached, almost to sea level. The proximity of magma and seawater has created a tsunami hazard for coastal Bay of Plenty.

(d) Taupo - Okataina Fields (rhyolite)

The rhyolite fields of the central North Island - Rotorua, Okataina, Maroa, and Taupo - lie between the andesite volcanoes of Tongariro National Park and the Bay of Plenty. Rhyolite, being more viscous than andesite, tends to be produced explosively, creating pumice which is conspicuous throughout the region. About 16,000km^3 of rhyolite has been erupted during the last 1.2 million years, as domes (e.g. Tarawera), airfall deposits, and pyroclastic flow deposits. The larger flows (tens of cubic km) have created ignimbrites - masses of hot, particulate rock and trapped gases - which have travelled freely to great distances, ponding to great thicknesses in low-lying areas but leaving only a thin veneer on higher ground. The hottest flows (above 700°C) have formed welded ignimbrites, but fortunately these events are extemely rare (see table opposite).

Future volcanism may include dome building and explosive pumice emissions. Dome building, such as occurred at Tarawera 900 years ago is more likely to occur in the Okataina field than elsewhere, and to be accompanied by pumice avalanches and showers (48). The greater danger however lies in explosive eruptions, of which two types have been noted.

The last pumice eruption from Lake Taupo in 186AD was not exceptional in magnitude (24km^3, mostly fallen into the sea more than 220km from source), but exceeds known limits in the extent of its dispersal. The eruptive column exceeded 50km in height, and as a consequence airfall deposits were thickest (1.8m) some 20km downwind of the vent (49). Even more remarkable was the mobility of the pyroclastic flow caused by column collapse. Its resulting 'ignimbrite veneer deposit', average thickness 1m, covers 15,000km^2 viz a circular area of 80km radius centred on the vent (50). Such events are difficult to contemplate.

More likely are phreatic or phreatomagmatic episodes, such as occurred at Lake Rotomahana during the 1886 Tarawera eruption. The main danger area probably is located between Tarawera and Mauringakakaromea (Rainbow Mt)

Mt Egmont

(51) B.N. Thompson in <u>NZ.J.Geol.Geophys</u>. Vol 7, 1964, p45.

(52) G. Stevens, "New Zealand Adrift", p410 (Reed, 1980).

(53) W.W. Topping in <u>NZ.J.Geol.Geophys</u>. Vol 16, 1973, p397.

(54) D.R. Gregg, in <u>NZ.J.Geol.Geophys</u>. Vol 7, 1964, p106.

(55) D.R. Gregg, op cit.

(56) G. Stevens, "New Zealand Adrift", p409 (Reed, 1980).

(57) T.L. Grant-Taylor in <u>NZ.J.Geol Geophys</u>. Vol 7, 1964, p78.

(58) B. Houghton, paper presented to NZIE (Auckland Branch), June 1981.

(51), although other thermal areas cannot be considered immune, as evidenced by the minor Taupo event of 20 June, 1981.

(e) Tongariro Field (andesite)

Andesitic volcanism has occurred more or less continuously in the region over the past 2 million years. The total volume (400km^3) is modest compared with the Taupo-Okataina rhyolites (16,000km^3), and has been produced steadily, rather than by paroxysmal eruptions such as have occurred at Taupo. Nevertheless both Ruapehu and Tongariro have been truncated at some stage by explosive activity (52). Currently the most active volcano, Ngauruhoe is very recent, about 2500 years old.

Nine vents (Ruapehu crater lake, Tama Lakes (2), Ngauruhoe, Tongariro viz, Blue Lake, Red Crater, North Crater, Te Mari craters (2)) have erupted in the last 13,800 years; five (Ruapehu, Ngauruhoe, Red Crater, Te Mari craters) since 150AD(53).

The risk from future lava flows is considered small, and would be confined to the slope of the volcano itself(54). Andesite ash falls cold, and would present largely a nuisance value, although a particularly heavy air fall could endanger the Tongariro power scheme. Pyroclastic flows, such as occurred on Ngauruhoe in 1975, could be lethal for incautious spectators.

The greatest danger is lahars, particularly from Ruapehu crater lake which has been the eruptive centre for the last 30,000 years. Damage could extend down the river valleys to the seas. Lahar debris has been noted in the lower courses of the Rangitikei, Wanganui, Whangehu, and Mangawhero Valleys (55). The 1953 lahar resulting in the Tangiwai train disaster was small - the lake level dropped only 8m. Lahars have covered parts of the Ruapehui ski fields (in 1969, 71, 75, 77) with damage to facilities but no loss of life. This outcome was perhaps fortuitous, because three of the lahars occured at night when the ski fields were deserted.

(f) Taranaki Field (andesite)

Volcanism began 1.75 million years ago at the coast and has progressed through centres at Kaitake (575,000 years ago), Poukai (240,000 years ago) and Egmont (70,000 years ago). The most recent eruptions of Egmont were in AD 1500, 1600, 1665, and 1755 (56). Egmont must therefore be considered dormant rather than extinct, although in the future activity may shift to a new eruptive centre somewhere in the vicinity of Kaponga.

The crater of Egmont was breached in the west by the most recent eruption. Consequently, lava and pyroclastic flows from future eruptions may tend to be diverted into the sector occupied by the villages of Pungarehu, Warea, Puniho, and Okato (57). The potential for sector collapse and lateral blasts (as occurred at Mt St Helens, 1980) is perhaps greater for Egmont than for other New Zealand volcanoes (58).

(59) G. Stevens, "New Zealand Adrift", p 398. (Reed, 1980).

(60) F.F. Evison, Proceedings of Earthquake Prediction Research Symposium, p187 (Science Council of Japan, 1980).

(61) G.A. Eiby, "Earthquakes", pp101-3 (Heinemann, 1980).

(62) F.F. Evison, Proceedings of Earthquake Prediction Research Symposium, p187 (Science Council of Japan, 1980).

(63) G. Stevens, "New Zealand Adrift", p400 (Reed, 1980).

(64) T. Rikitake in <u>Tectonophysics</u>, vol 54, 1979, p293.

3.4 RESPONSE TO TECTONIC HAZARD

3.4.1 Forecasting

Modern plate tectonic theory offers insight into the causes of earthquakes and volcanic eruptions. Most earthquakes can be related to processes at plate boundaries. In general those associated with convergent boundaries (subduction zones) are more hazardous than those associated with divergent boundaries (mid-ocean ridges, rift valleys). Volcanism too is generally more violent at convergent boundaries (59).

Until recently, earthquake prediction has been probabilistic. Factors such as return time or greatest expected intensity have been displayed on seismic zoning maps, which essentially indicate a time-invariant seismic risk. Zoning provides a useful basis for permanent countermeasures, which may include appropriate codes for earthquake resistance of buildings, siting of critical plant, civil defence etc.

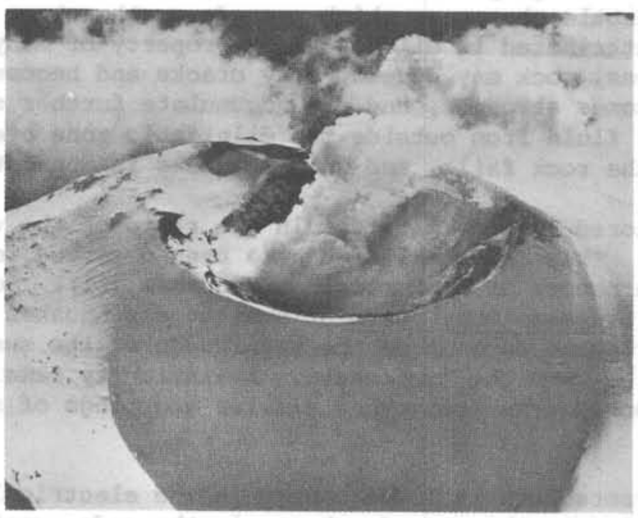
An earthquake forecast, by contrast, concentrates on a particular future event, and is predictive (60). The introduction of a time variability in seismic risk can allow for effective temporary countermeasures, in addition to the permanent countermeasures mentioned above.

Earthquake forecasting based on periodic influences such as earth tides and weather systems has been largely unsuccessful. More promising has been the study of <u>precursors</u>: subtle phenomena which precede earthquakes. Many precursors have been attributed to <u>dilatancy</u> - a property of many granular materials. Under stress, rock may develop tiny cracks and become dilatant. In this condition, it becomes stronger, and can accumulate further strain. However, the inflow of fluid from outside the dilatantic zone eventually reverses the effect, the rock fails, and an earthquake is generated (61).

Dilatancy can be monitored by abnormalities in the ratio of the velocities of P and S waves (see p35). These abnormalities have been observed to disappear immediately prior to a number of historical earthquakes (61). Some earthquakes have been preceded by a <u>premonitory swarm</u> of smaller earthquakes (62). The magnitude of the major quake depends on the magnitudes of the swarm earthquakes, and on the time delay between the two events. A difficulty remains in distinguishing precursor swarms from other similar groupings of small earthquakes.

Other suggested precursors have included change in the electrical resistance between electrodes buried in the ground, change in the radon content of ground water, change in the water level in wells, and even unusual behaviour of animals observed before major earthquakes. Perhaps the most notable success has been the prediction by the Chinese authorities of a magnitude 7.4 earthquake in Liaoning province in February 1975. Although countermeasures undoubtedly saved many lives for this particular event, a subsequent magnitude 8.0 earthquake in Tang Shan province in July 1976 was not predicted, and killed 650,000 people(63).

For long-term precursors, a relationship has been established between the time lag and the magnitude of the ensuing earthquake (64). The warning time is typically one week for a small earthquake, but for a very large earthquake it can be several decades. This relationship initially does not aid prediction, since the time lag and the magnitude are determined retrospectively, but once a long-term precursor has been recognized, the likely magnitude of the anticipated



Mt Ngauruhoe

(65) F.F. Evison, Proceedings of Earthquake Prediction Research Symposium, p187 (Science Council of Japan, 1980).

(66) G. Stevens, "New Zealand Adrift", p402 (Reed, 1980).

(67) D. Crandell and D. Mullineaux reported in Scientific American, 1981, p52.

(68) "Volcano : the Eruption of Mt St Helens" by the staffs of two newspapers (Longview Publ. Co. Washington, 1981).

(69) "Volcanoes in New Zealand," DSIR Extension Information, No.6, Nov 1980.

(70) B. Houghton, paper presented to NZIE (Auckland Branch), June 1981.

(71) N.R. Britton in Bull. NZ. Soc. Earthq. Eng., vol 13, 1980, p365.

earthquake increases with time. Unfortunately it is not known how general the relationship might be viz.how many earthquakes lack precursors, and how many precursor-like events are not followed by major earthquakes (65).

Integrated earthquake forecasts may become available in the future, based on systematic studies of precursory phenomena (65). These forecasts might include: (i) estimates of the risk refinement factor (defined as the ratio of risk deduced from precursory phenomena to the risk deduced from historical seismicity); (ii) regional seismic maps indicating the probability of ground shaking at a specified intensity within a specified period, derived from a recognized precursory event.

A probabilistic assessment of volcanic risk can be drawn from the history of previous eruptions of a volcano. Where the subduction process is very slow, the associated volcanoes can be dormant for periods of 20,000 years or more (66). Not unexpectedly, some catastrophic eruptions (e.g. Santorini in 1400 BC, Vesuvius in 79 AD, Mt Lamington in 1951) have occurred from volcanoes considered to be extinct. Plate tectonics can help in distinguishing between dormant volcanoes of long repose period and extinct volcanoes.

A US Geological Survey report in 1978 identified Mt St Helens as the most active volcano in the contiguous United States, although it had been dormant for 120 years (67). The 1980 eruption has provided a test for forecasting techniques. Seismic monitoring of an earthquake swarm gave one week's warning of the first small eruption from a summit crater. Surveying of a bulge on the flank of the volcano allowed State authorities to maintain an evacuation of the surrounding region, in spite of insistent demands for freedom of access encouraged by the apparently low level of activity. Although the catastrophic sector collapse of 18 May, 1980 was not preceded by any useful precursory warnings, the firmness of the authorities undoubtedly saved thousands of lives. As it was, 62 persons, including Government geologists, were killed by the blast (68).

In New Zealand, DSIR and University research has concentrated on Ruapehu, Ngauruhoe, and White Island, the currently active volcanoes. Instrumental data (from seismographs, magnetometers, tiltmeters and thermometers) and chemical analyses are being used to study changes which precede eruptions. Networks of fixed points are being resurveyed regularly to detect ground swelling. It is hoped that this work will eventually lead to a reliable method of predicting eruptions, although at present it constitutes research rather than continuous monitoring (69).

Seismic records for the Auckland field are processed at rather longer intervals than the anticipated warning time for the next eruption (a few days) (70). Lahar warning systems have been proposed for the Ruapehu ski fields, but none are presently installed. However a flood warning device is monitoring the Whangaehu River, to prevent a recurrence of the 1953 Tangiwai rail disaster.

The development of methods of forecasting earthquakes (and volcanic eruptions) will raise major social and economic issues. A forecast, likely to be fairly unspecific, could create public anxiety as well as allow for effective additional countermeasures. It could create economic disruption, for example by triggering population movement and changes in patterns of lending, purchasing, and investment. An economic downturn, and increased unemployment, could be adverse consequences of a long-range prediction (71).

The value of forecasting is the potential it offers for reducing vulnerability and increasing preparedness, even although the damage to fixed structures caused

(72) R.H.F. Holloway, Paper (on the effect of earthquake prediction on civil defence) presented at the Conference on Large Earthquakes, Napier, 1981.

(73) N.R. Britton, in Bull. NZ. Soc. Earthq. Eng., vol 13, 1980, p365.

(74) D.G. Elms, J.B. Berril, D.J. Darwin, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(75) A. Ciborowski (Warsaw Technical University), ibid.

by the anticipated event is unlikely to be changed significantly. The requirements for civil defence and other countermeasures against unforeseen disasters are not likely to be changed by the development of forecasting techniques. In the predicted disaster area, civil defence should logically be strengthened (72).

Little is known about how a population will respond to an earthquake forecast. Social science research can only be conjectural at present, because no major earthquake has been successfully predicted in the western world (73). In 1960 in New Zealand, a tsunami warning was counterproductive because people were attracted into potentially dangerous areas by their curiosity. In countries where tsunamis are more commonplace (Hawaii, Japan), and the population is more aware of their possible consequences, this outcome is less likely. Public awareness, and confidence, are required if a forecast is to mitigate a tectonic disaster. These can be achieved only through a process of public education.

3.4.2 Pre-disaster Phase : Planning and Construction

Various measures can be taken to reduce earthquake hazards in a city. These might include stringent design requirements for new buildings, demolition of old buildings, attention to areas of special vulnerability (hospitals, telephone exchanges etc). However resources are finite. While great emphasis on earthquake protection could create a very safe city, it could be impoverished in other ways by excessive economic, functional, aesthetic and cultural restrictions (74).

Resource allocation has to be balanced not only between earthquake countermeasures and other investments (e.g. cultural amenities, sanitation) but also between the various countermeasures available. These might include:

- increased earthquake resistance of new buildings.
- strengthening of existing buildings.
- demolition of unsafe buildings.
- securement of primary access routes.
- reduction of secondary hazards (e.g. fires, flood).
- increased earthquake resistance of key structures.

At a Conference on Large Earthquakes (Napier, 1981) Professor A. Ciborowski presented an international view of the planning of human settlements in earthquake-prone areas. He suggested that risk, defined as the product of hazard and vulnerability, can be manipulated (75).

Hazard (viz. the probability of occurrence of a disastrous earthquake) can be influenced by site selection. At the macro scale this may not be practical, unless the reconstruction of a devastated settlement is being planned. A greater potential exists at the micro scale (e.g. in siting reservoirs, oil tanks, and other potential sources of secondary hazard).

Vulnerability is determined by variables such as population density, and land-use patterns, building design and standards, and services infrastructure (e.g. gas, water, sewerage, electricity). In general terms, a lower population density reduces vulnerability (but has to be balanced against loss of productive land to urban sprawl). Ciborowski suggested that road networks should always provide alternative access routes to a region. Open (green) spaces, while desirable from environmental and aesthetic considerations, can also serve vital functions during an evacuation and as firebreaks. (Fires have caused many

(76) L. Andrews in New Zealand Engineering, vol 36, 1981, p21.

(77) N.R. Britton, in press, 1981.

(78) K.S. Mulholland, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(79) L. Andrews, op cit.

(80) R.C. Cooney, A.H.R. Fowkes, paper presented at the Conference on Large Earthquakes, Napier, 1981.

deaths and much destruction after historical earthquakes, because they raged uncontrolled for long periods due to the dislocation of water supplies). Earthquake resistance of buildings can be adjusted according to function : from highest (e.g. places of public assembly) to lowest (e.g. warehouses). On services infrastructure, Ciborowski gave some general rules : dual sources and supply lines (e.g. reservoirs and pipelines) should be provided where possible taking into account secondary hazards such as flooding from burst reservoirs. He was critical of two unquestioned practices in New Zealand : reticulated gas distribution, and high voltage power lines over residential areas. (Gas reticulation is presently being expanded to take advantage of the Maui field).

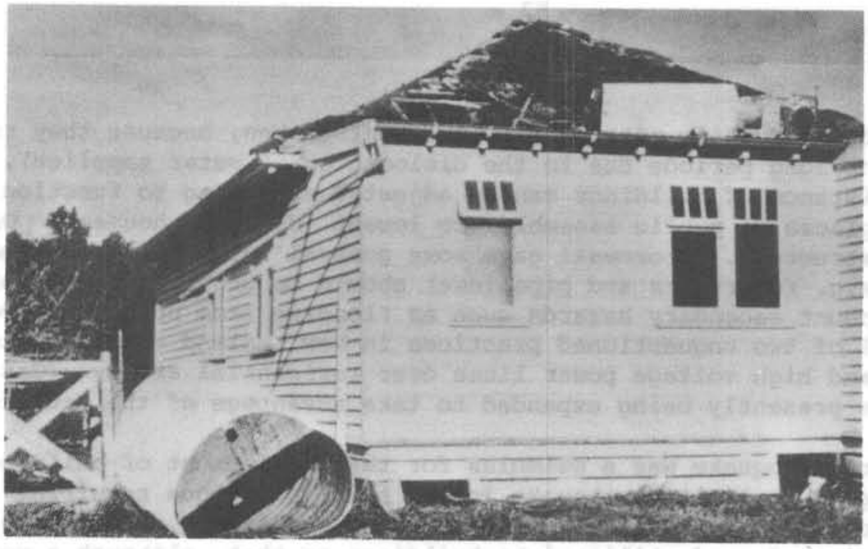
The 1931 Napier earthquake was a stimulus for the development of building practices designed to limit earthquake loss. A building code requiring designers to consider earthquake-induced stress was a direct consequence. Ways were sought to introduce ductility into buildings so that, although a very severe earthquake might cause some damage, they would not collapse on their occupants. Furthermore these earthquake-resistant buildings were to be designed to sustain no, or minimal, damage from the largest earthquakes they were likely to be subjected to during their lifetimes. A recent (1976) amendment to the code introduced a requirement for a capacity analysis, by which designers must establish a hierarchy of building failure modes. In this way, designs for buildings incapable of dissipating earthquake-induced stress in a safe way can be identified, and suitably modified (76).

Under the 1964 building code (NZS 1900) and its 1976 revision (NZS 4203), New Zealand is divided into three zones of (different) earthquake risk. There has been some debate concerning the criteria by which these zones were delineated. A further concern is that the national building code is not legally binding on construction firms or local bodies, which allows variations in earthquake resistance to arise for reasons unrelated to seismic risk. This situation demonstrates the reluctance of successive governments to enact statutes making compliance with the national building code mandatory (77). It raises the fundamental question of who should control building standards : local or central government?

Old brick masonry buildings present an earthquake risk because they are brittle. None would satisfy present design criteria. Local bodies have powers to take action on earthquake-risk buildings by requiring their demolition or strengthening. Of 1875 buildings surveyed in the commercial area of Wellington in 1974, some 758 were in a category allowing the local Council to use its powers. The necessary remedial work is required to be completed by 1983 in the main retail areas (i.e. owners have been given 10 years to comply), and by 2000 in other less critical areas. Council policy has been one of encouragement rather than enforcement. No financial compensation has been granted, although other incentives have been offered (such as a relaxation of siting requirements for a building erected on a site presently occupied by an earthquake-risk building (78).

A number of proposals have been made to retrofit strong ductile frameworks inside brittle brick masonry buildings of historic or aesthetic value. Essentially a brick facade, rather than a building, is preserved. Appropriate seismic standards have been much discussed, but are unresolved (79).

A popularly-held view is that New Zealand houses are earthquake-resistant. However, in spite of building bylaws introduced in response to the 1931 Napier earthquake, a portion of the existing house stock will be severely damaged in any future, large earthquake (80). Adequate resistance is often lacking in



Inangahua 1968

(81) Civil Defence Act 1962 : Civil Defence Amendment Act 1965, 67, 68, 71, 75.

(82) R.H.F. Holloway (Director of Civil Defence Wellington), paper presented at the Conference on Large Earthquakes, Napier, 1981.

(83) R.T. Jones (Australian Counter Disaster College), paper presented at the Conference on Large Earthquakes, Napier, 1981.

(84) R.H.F. Holloway, ibid.

(85) "Government Action in Major Disaster" (Ministry of Civil Defence, Wellington, 1980).

(86) R.H.F. Holloway, paper presented at the Conference on Large Earthquakes, Napier 1981. Major-General Holloway is the director of Civil Defence.

The term 'regional' requires qualification in this context. Civil defence is a statutory function of Local and United Councils. A major Wellington earthquake (see pp 33-35) would directly involve 25 of these, with conceivable problems of coordination. However there has been a development of regional civil defence organizations; six of these are now responsible for the southern half of the North Island, formerly covered by an unwieldy group of 48 Local and United council CD organizations. "Regional Civil Defence planning here and elsewhere for the first time should be practicable". (ref. 86) aspects of foundation and subfloor framing construction, masonry veneer walls, concrete and clay tile roofs, chimneys, water tanks and hot water cylinders. The potential for damage results from lacking or non-specific bylaws or from non-compliance with bylaws. This potential may be increased by future public demand for more open-plan living, basement double garages, large windows in load-bearing walls, and heavy low-maintenance tile roofs and masonry veneer walls.

3.4.3 Disaster Phase : an Effective Initial Response

Since 1962, every local authority, either by itself or jointly with its neighbours, has been required by law to maintain a civil defence plan (81). By a declaration of a state of local civil defence emergency, a local authority can assume special powers in the interests of public safety.

On average, 3 to 4 emergencies arise each year, mainly from flooding. Loss of life has been rare. Civil Defence has never been tested by a major disaster, and there is little practical experience on which to assess its capacity to cope (82).

Various problems must be overcome in an effective initial response to a major disaster. These include (83)

- information : generally neither reliable nor comprehensive at a time of enormously increased demand.
- communication : likely to be disrupted and under stress. Informal networks of uncertain reliability may dominate.
- convergence : of people (over-reaction to sightseers could deny access to required expertise), of communications (as demand for information increases), and of material (resources, not all useful).
- control structures : likely to be disrupted by overload, or loss of essential personnel.

Taken together, these problems adversely affect the performance of the two functions most necessary for an effective initial response (83) viz

- co-ordination, which must be planned for and practised in advance.
- resource management, which requires identification of needs according to their priority, and the location and deployment of resources to satisfy these needs.

The lack of communication and the immobility in the immediate aftermath of a tectonic disaster require that communities have to act on their own resources to survive. The ability of territorial local authorities to operate effectively in a New Zealand emergency through their civil defence organizations varies widely. In urban areas the workplace is often widely separated from the home, where interest usually lies. In rural areas, the resources are thinly spread. For these and other reasons, an ideal organization can rarely be attained (84).

In 1966, plans were developed for procedures to be followed in the event of a disaster on a scale which required the Government to assume control (85). Nevertheless, present national civil defence plans are still mostly concerned with the organization and function of civil defence at the local level. The belief that all disasters are manageable at local authority level has persisted throughout the history of Civil Defence. The lack of regional plans seems a disadvantage in meeting the threat of widespread disaster posed by a major tectonic event (86).

(87) N.R. Britton, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(88) N.R..Britton, op cit.

(89) G.J. Lensen in Bull. N.Z. Soc. Earthqu. Eng. Vol 12, 1979.

(90) J.E. Sherburd, paper presented at the Conference on Large Earthquakes, Napier, 1981.

(91) N.R. Britton, ibid.

(92) J.E. Sherburd, ibid. ($2000m represents a 20% loss on the total sum insured at risk. Worse calamities have occurred overseas (e.g. Peru - 70,000 dead in 1970; China - 830,000 dead in 1556), but the victims were largely uninsured).

(93) N.R. Britton, ibid.

(94) R.H.F. Holloway, ibid.

3.4.4 Post-disaster Phase : Recovery and Evaluation

Social science research suggests that there is a lack of commitment by policy-makers and decision-makers toward the tectonic threat to New Zealand, and a lack of understanding of, and indifference to, the same threat by the general public (87). The response has been directed more to relief and compensation than to hazard reduction and has incorporated

- Civil Defence organizations for relief.
- Earthquake and War Damage Commission for compensation.
- building codes for hazard reduction.

Public attitude to these is one of complacency and near-apathy, stemming from the assumption that any emergency can be handled by Police, Civil Defence, Government, Fire Service, hospitals, and armed forces. This assumption is not fully shared by the personnel of these agencies (88).

The earthquake threat remains a serious one. New Zealand society has collectively, either through ignorance or otherwise, succeeded in constructing its own death traps (89). While substantial progress is being made in removing earthquake-risk buildings, the fact that the national building code is not legally binding on either building contractors or local government raises uncertainties which may not be resolved until the next major earthquake strikes.

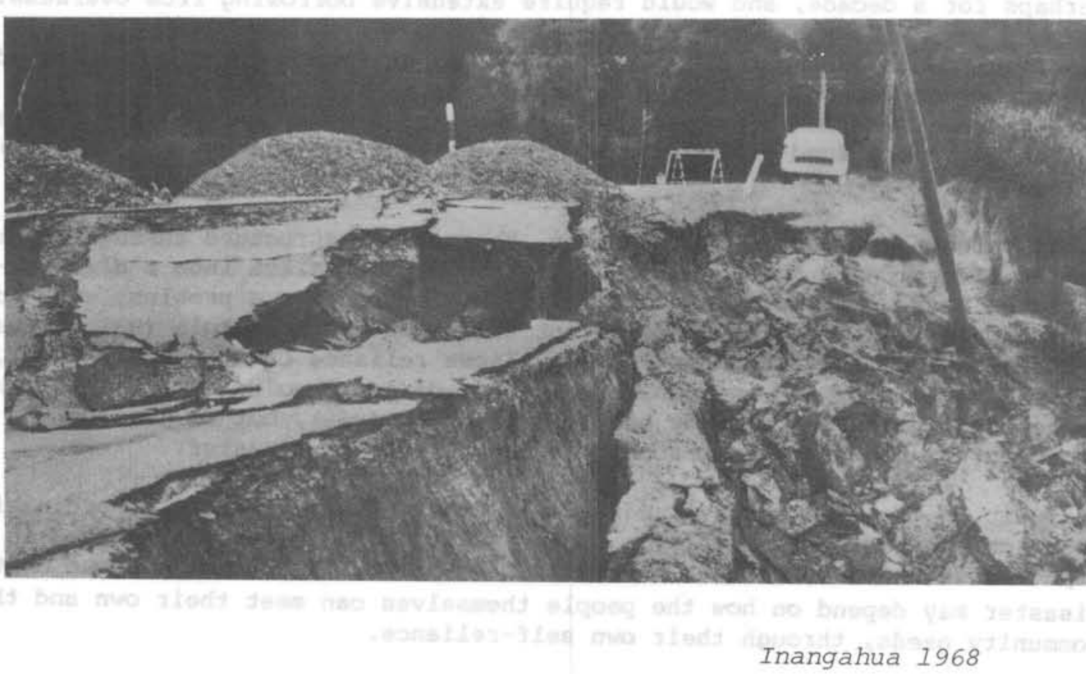
In 1944, a Commission was established to administer a joint Earthquake and War Damage Fund, financed by compulsory premiums on fire insurance policies. The Commission's jurisdiction has since been extended to provide compensation for damage caused by other hazards, such as storms, flooding, and landslips. There is provision for compensation up to indemnity value only, which in general is much less than replacement value (90). For some previous disasters (1968 Inangahua earthquake, 1978-79-80 Southland floods, 1979 Abbotsford landslip) the compensation paid did not cover the losses experienced (91).

The size of the fund ($410m in 1980) will not cover the claims anticipated for a major disaster. A Wellington earthquake, for example, could generate 250,000 claims totalling $2000m, the greatest number of claims for a single event anywhere in the world (92). Its effect on the whole economy would be marked, perhaps for a decade, and would require extensive borrowing from overseas.

A serious drain on the Earthquake and War Damage Fund are the claims for damage caused by non-tectonic events (storms, floods, landslips). In most years these have exceeded claims for earthquake damage, and have subverted the original intention of the fund viz.to provide compensation for earthquake (and war) damage.

Civil Defence provides a satisfactory, theoretical structure through which national, regional, and local resources can be channelled into a disaster-stricken area. Financial responsibility for it remains a problem, with both central and local government reluctant to assume a strong role (93). "There are serious shortcomings in a system that places reliance on non-professional, largely untrained, and inexperienced groups of local volunteers" (94). The lack of regional plans has already been commented on (p59), but as yet the organization has not been tested by a major tectonic disaster.

While it is the role of Civil Defence to provide the necessary co-ordination and resource management in any major disaster, it is the people themselves in the impact area who have to make the initial response. The final outcome of the disaster may depend on how the people themselves can meet their own and their community needs, through their own self-reliance.



Inangahua 1968

3.5 SELECTED GLOSSARY

airfall deposit particulate material (ash), often deposited downwind of a volcanic vent.

Alpine Fault a major well-defined fault extending along the Southern Alps from Fiordland into Marlborough.

andesite volcanic rock intermediate in composition between basalt and rhyolite. Andesite lava flows slowly and is often accompanied by explosions and ash showers from the source.

aseismic creep gradual slip not accompanied by earthquakes.

asthenosphere soft internal layer of the earth upon which the semi-rigid plates move.

basalt volcanic rock which flows readily in its molten state.

Benioff zone downward dipping region of earthquakes, identified with a descending plate.

breccia fragmented volcanic rock.

brittle lacking of ductility. A brittle material fractures under stress before significant deformation occurs.

capacity analysis method for calculating the seismic resistance of a building which involves consideration of the ways in which the building might fail.

carbon dating method of measuring age of fossil animal or plant remains.

crust uppermost layer of the earth.

ductility ability of a material to deform without fracture.

elastic strain energy energy stored as deformation in rock (etc), and recovered when the undeformed state is restored.

epicentre point on earth's surface above the focus of an earthquake.

fault plane of fracture in a rock mass along which movement has occurred.

focus the point or plane of origin of an earthquake.

fire fountain vertical jet of molten rock.

ignimbrite volcanic rock formed by consolidation of major pumice flows.

intensity volcanic - rate at which material is erupted.
earthquake - measure of severity of ground shaking.

island arc chain of volcanic islands marking a subduction zone.

lahar — mudflow down the flank of a volcano.

lateral blast — horizontally directed pyroclastic flow.

lava — molten material extruded onto the earth's surface or the rock derived from its solidification.

lithosphere — rigid outer shell of the earth comprising crust and upper mantle.

magma — molten rock material generated within the earth.

magnitude — volcanic - volume of material produced.
earthquake - energy released at the focus.

mantle — layer of the earth between the crust and the core.

mid-ocean ridge — a continuous underwater volcanic range extending through the major oceans, which acts as the source of new crust by seafloor spreading.

normal stress, strain — stress and strain perpendicular to the plane of reference (see also shear).

phreatic eruption — explosive steam eruption resulting from interaction of water with magma.

phreatomagmatic — phreatic eruption in which rock is torn from the vent or underlying magma.

plate tectonics — a theory of geology which accounts for continental drift, earthquakes, and volcanoes. The earth's lithosphere consists of semi-rigid plates moving with respect to one another on the asthenosphere.

precursor — a subtle event or change preceding an earthquake.

premonitory swarm — a cluster of small earthquakes preceding a large earthquake.

pumice — highly porous volcanic material ejected explosively during rhyolitic eruptions.

pyroclastic flow — hot, particulate volcanic material which flows like a fluid due to its gas content.

return period — average time between earthquakes of a specified intensity at a particular location.

rhyolite — volcanic rock of high viscosity (stiffness) in its molten state, with a tendency to block vents causing violent explosions and pumice showers.

risk refinement factor — ratio of predicted risk to the statistical risk based on historical seismicity.

seafloor spreading — the separation of plates along midocean ridges, leading to the creation of new oceanic crust (sima).

sector collapse	collapse of a flank of a volcano, causing a lateral blast.
seismograph	an instrument which detects and records ground movement during an earthquake.
shear stress, strain	stress or strain parallel to the plane of reference (see also normal).
shield volcano	basalt volcano characterised by gentle slopes.
sial	comparatively light rock comprising the upper part of continental crust (see sima).
sima	comparatively dense rock comprising oceanic crust and lower part of continental crust.
slip	offset movement along a fault line.
strain	fractional (or percentage) distortion in (eg) rock subjected to stress.
stress	applied force per unit area.
subduction	the forcing of one plate beneath another at a plate boundary.
tsunami	a sea wave generated by an underwater landslide, earthquake, or volcanic eruption.
tuff	fragmentary volcanic material surrounding a vent.
violence	volcanic - destructive potential of an eruption, determined largely by the momentum of pyroclastic flows.
welded ignimbrite	volcanic rock formed by consolidation of unusually hot ignimbrite.

Carbon dioxide may be good for crops

EVEN IF an increase in atmospheric carbon dioxide produces no detectable change in climate it may have a direct and beneficial effect on plant growth. Professor Norman J. Rosenberg of the University of Nebraska-Lincoln argues that a general increase of growth rates in most crops and forest trees should result from such an atmospheric change, all else being equal (*Climatic Change*, vol 3, p 265).

Such crops as rice, oats, barley, rye, wheat, sugar beet and soybean belong to the C_3 group of plants whose photosynthesis is most sensitive to carbon dioxide levels. C_4 plants such as millet, sugar cane, sorghum and maize also photosynthesise faster at higher carbon dioxide levels such as those forecast for the next 50 years, but the increase in reaction rate is smaller.

In C_4 plants, the closure of the stomata—the leaf pores through which they exchange gases and water vapour with the atmosphere—is more affected by carbon dioxide levels than in C_3 plants.

This means that C_4 plants lose less water through their stomata at higher concentrations of carbon dioxide. Both groups of plants should be able to use water more efficiently, under such circumstances. □

4. NATURAL DISASTER : CONCLUSIONS AND RECOMMENDATIONS

(1) The world in 2000 is depicted as more crowded, more polluted, less ecologically stable, and more vulnerable to disruption than the world we live in now, if present trends continue (p3). In a harsher world environment, countries may have to rely more on their own resources in adversity than on help from outside. Self-reliance then becomes a more valuable attribute for any country, especially those prone to natural disasters.

Climatic Disaster

(2) The earth has always been subject to great, natural fluctuations in its climate. However, the middle decades of the twentieth century have been among the warmest and most favourable periods for agriculture in history. A protracted period of less favourable climate is bound to return (p9). This should not be overlooked by policy makers, especially those in the fields of agriculture and energy.

(3) Technically, the earth is still in an ice age. While another glacial period is probably inevitable, there is no evidence that one is imminent. More likely is a return to another 'Little Ice Age' in which global climate reverts to that characteristic of the period between 1550 and 1850. If this happens, energy conservation could, with foresight, make life more comfortable (p17).

(4) A continuation of the present cooling trend could increase the risk of electricity supply shortages in New Zealand during dry years, particularly if long-term planning margins are not maintained (p17).

(5) There is not yet any definitive observational evidence that increasing atmospheric carbon dioxide levels are having any effect on present climate. There is, however, considerable agreement among climate modellers as to the long-term consequences (a global warming), even although it is recognized that the models themselves are inadequate in important respects (p23). This consensus should be accorded some consideration by policy makers in agriculture and energy.

(6) The long time delay predicted for the atmospheric response to increasing carbon dioxide levels is capable of accounting for the present lack of observational evidence in support of a global warming (p23).

(7) New Zealand is well placed to participate in the satellite monitoring of changes in the distribution of Antarctic sea ice, which may provide the earliest indications of the onset of a global warming (p23) if such should occur.

(8) An enhanced global atmospheric carbon dioxide level could have important consequences for agriculture, even if the predicted, consequential global warming does not eventuate. Horticulturalists have, for a long time, practised carbon dioxide enhancement inside glasshouses to improve crop yields. Australian research has indicated that increased carbon dioxide levels improve the water-use efficiency of some plants. These results are for single specimens, and so must be considered tentative. The very limited research in New Zealand on the implications for agriculture of a

We suggest that the following are minimum research goals necessary to ensure that Australians will be in a position to make intelligent policy decisions in the areas of economic investment, energy policy, trade and foreign affairs in the decades ahead when questions of climatic change may well come to play a significant role in world affairs:

(*a*) Continuing and new research initiatives to gather, refine and interpret data on CO_2, O_3, particulates, and their precursors, and other relevant species in the atmosphere, with particular emphasis on data from Australia, Antarctica and the southern oceans.

(*b*) Major new theoretical and experimental efforts to understand the processes controlling the concentrations of CO_2, O_3, particulates and other relevant chemical species in the atmosphere. Australian scientists have made and should continue to make significant contributions to the world effort in this area.

(*c*) Increasing research work of both a modelling and empirical nature on global and regional climates so as to better understand the nature and magnitude of environmental changes likely to be brought about by global pollution. Our regional perspective is vital to a balanced global picture, which must involve special consideration of the role of the oceans and Antarctic ice.

(*d*) Active Australian involvement in and support of regional and global efforts to understand, model and predict the impact of global pollution on the regional and global economies and societies, including the effects of possible regulations and controls.

While the present state of knowledge is sufficient to show that there are potentially serious environmental problems induced by human activities, it is totally inadequate to predict the extent to which that potential will be realized. Our contention is that it is very much in Australia's interests to increase relevant environmental research which takes special account of Australia's interests, in order both to avoid deleterious effects and unnecessarily restrictive controls.

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A. B. Pittock, P. J. B. Fraser, I. E. Galbally, P. Hyson, R. N. Kulkarni, G. I. Pearman
CSIRO Division of Atmospheric Physics, Mordialloc, Victoria
E. K. Bigg
CSIRO Division of Cloud Physics, Epping, NSW
B. G. Hunt
Australian Numerical Meteorology Research Centre, Melbourne

global increase in carbon dioxide levels does not seem to support the Australian findings(p25).

Given the dependence of New Zealand's trading economy on her comparative advantages in agriculture, any changes in these comparative advantages (not necessarily adverse) could have major consequences, and merit study (p27).

(9) Most energy planners see coal replacing oil in the twenty-first century, an outcome supported by present trends in energy use. However, in the context of the carbon dioxide - climate problem, an irreversible switch from oil to coal may have disastrous environmental consequences (p27).

(10) In the (improbable?) event of international co-operation to avert a potentially disastrous global warming, countries like New Zealand, with biomass or solar options, may come under international pressure to reduce their dependence on fossil fuels (p27).

(11) The Third World is now geared for a reliance on coal for development. Policy makers in the developed world are faced with a clear choice between accepting the consequences of a carbon dioxide increase (whatever these might be) or a policy of zero growth in fossil fuel consumption to reduce these consequences (p.27).

Tectonic Disaster

(12) Because of her location on an active plate margin, New Zealand will continue to experience large earthquakes and volcanic eruptions in the future (p37).

(13) Large, thrust-type earthquakes can be anticipated along the eastern North Island, northern South Island, and Fiordland, although no part of New Zealand can be considered immune from damaging earthquakes (p39).

(14) Large, rhyolitic eruptions have occurred in the Taupo-Okataina volcanic fields in the past, and will undoubtedly occur in the future (p43). Planning for these vast (but fortunately very infrequent) events is perplexing to say the least, but should at least include ground monitoring, and sufficient public education for a credible evacuation to be carried out.

(15) Considering the size of the population at risk, continuous monitoring in the Auckland volcanic field would be prudent, and relatively inexpensive (p45).

(16) An effective lahar warning system on Mt Ruapehu is essential, if the risk to life on the skifields is to be reduced (p49).

(17) The energy developments in Taranaki provide an additional economic incentive for the monitoring of Mt Egmont. The siting of plant and services should take into account the propensity of this active volcano for sector collapse (p49).

(18) Probabilistic earthquake forecasting, based on historical seismic risk, will continue to provide a useful basis for permanent countermeasures in the future (p51).

NAPIER, H.B. FEBRUARY 4, 1931.

A Catastrophe

SHOCKING DISASTER

EARTHQUAKE and FIRE

MANY FATALITIES

Napier, overtaken by the worst catastrophe that has ever occured in New Zealand, has been levelled, the disaster bringing with it a death roll which cannot yet be assured. An

The Death Roll

LIST OF THE IDENTIFIED DEAD

NUMBERS OVER FIFTY

The death roll around the district already numbers well over 50 identified and numbers unidentified or missing. The list is as follows :—

KILLED

Miss Meta Dewes, of Napier
Mr Val Harrison, of Napier
Mr Alf Bonnor, of Napier
Nurse Nancy Thorne-George of

(19) Predictive earthquake forecasts, based on systematic studies of precursors, may become available in the future, and thus allow additional countermeasures to be carried out (p53).

(20) Current research on some of New Zealand's active volcanoes is expected, in time, to lead to reliable methods of predicting eruptions, based on continous monitoring (p53).

(21) Public awareness and confidence will be required if a forecast is to mitigate a tectonic disaster. Nevertheless, the forecasting of tectonic disaster is not without its adverse social and economic consequences (p. 53).

(22) Road networks should always provide alternative access routes to a region (p 55).

(23) Open (green) spaces should be recognized for their intrinsic value as permanent earthquake countermeasures as well as for their environmental benefits (p55).

(24) The uneven application of building codes relating to seismic resistance is a cause for concern within New Zealand (p57).

(25) Traditional public confidence in the seismic resistance of the typical New Zealand house is not entirely justified (p57).

(26) The Civil Defence organization in New Zealand has never been tested by a major disaster. A lack of regional plans, and a reliance on largely untrained and inexperienced local volunteers, seem to be major weaknesses (p59).

(27) The Earthquake and War Damage Fund would not cover the claims anticipated for a major disaster in New Zealand (p61).

General Conclusion

The natural environment of New Zealand is often perceived in terms of the resources it represents. This beneficent viewpoint should be tempered by the warnings of future climatic and tectonic disasters. Recognition of the potential for a future disaster is a necessary first step towards its mitigation or avoidance.