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NEW ZEALAND
CRETACEOUS – CAINOZOIC TIME SLICE STRUCTURE MAPS

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PHANEROZOIC HISTORY OF AUSTRALIA PROJECT

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CONTENTS

FIGURES

TABLE

<u>MAPS</u>

<u>Page</u>

STRUCTURE MAPS:

SUMMARY

Ten Cretaceous - Cainozoic time slice structure maps of New Zealand are presented in this report. The maps have been prepared during the BMR (Bureau of Mineral Resources)/APIRA (Petroleum Division of the Australian Mineral Industries Research Association) Phanerozoic History of Australia Project. These maps will form part of the data base for the construction of interpretative palaeogeographic maps of the Indo-Australian Plate.

The structure maps cover the period from the late Early Cretaceous to the Pleistocene. Structural features which have controlled basin subsidence and inversion are shown, together with major fault zones along which portions of New Zealand have moved relative to each other, during the Cretaceous to Cainozoic.

Tensional structures dominated the late Early to Late Cretaceous, during the breakup of eastern Gondwana. Further tensional faulting occurred in the Mid- to Late Eocene, when there was another phase of extension in the New Zealand region. There was regional subsidence and transgression through the Oligocene, but an increase in fault-controlled sedimentation during the Late Oligocene signified the beginning of a new stress regime. From the earliest Miocene onwards, structures reflect an overall compressive setting, initiated when the obliquely convergent plate boundary became established in New Zealand. Zones of Neogene deformation display a regional clockwise shift in the focus of compression and associated uplift, accompanying the rotation of the subduction system to its present trend.

Aspects of New Zealand's structural development which have implications for hydrocarbon potential are briefly outlined.

1. INTRODUCTION

Ten time slice structure maps of New Zealand are presented in this report. The maps, which cover the period from the late Early Cretaceous to the Pleistocene, have been prepared during the Phanerozoic History of Australia Project, which is a joint project coordinated by the Bureau of Mineral Resources (BMR), in conjunction with APIRA, the Petroleum Division of the Australian Mineral Industries Research Association. These maps will form part of the data base to be used for the construction of interpretative palaeogeographic maps of the New Zealand region, for a number of Cretaceous and Cainozoic time intervals. The final interpretative maps, which will be presented on reconstructed bases at 1:10 000 000 scale, will be combined with compilations produced for other regions within the Indo-Australian Plate. The core of each time slice map will be the palaeogeography of Australia. Seventy non-palinspastic palaeographic maps for the Cambrian to Cainozoic of Australia were compiled during the BMR-APIRA Palaeogeographic Maps Project. New Zealand is astride the Indo-Australian/Pacific Plate boundary (Figure 1) and therefore forms the southeastern edge of the Phanerozoic History of Australia study region.

Structural features which have controlled basin subsidence and inversion are shown, together with major fault zones along which portions of New Zealand have moved relative to each other, during the Cretaceous to Cainozoic. These structural data maps are plotted on a present-day base. Preliminary plate reconstructions for New Zealand have been discussed in a separate report (Walley & Ross, 1991).

Time slices are selected on the basis of correlatable time breaks and palaeoenvironmentally significant intervals. The time slices represented by structure maps are those chosen during the BMR-APIRA Palaeogeographic Maps Project. Some of these time slices have been subdivided for the Phanerozoic History of Australia Project to more clearly define major events in the evolution of the Indo-Australia Plate. For example, time slice Cz2 has been split into time slices Cz2a and Cz2b (Figure 2). Figure 3 is a regional location map. The principal references used for each region are indicated in Table I.

The amount of structural information on each structure map reflects three factors:

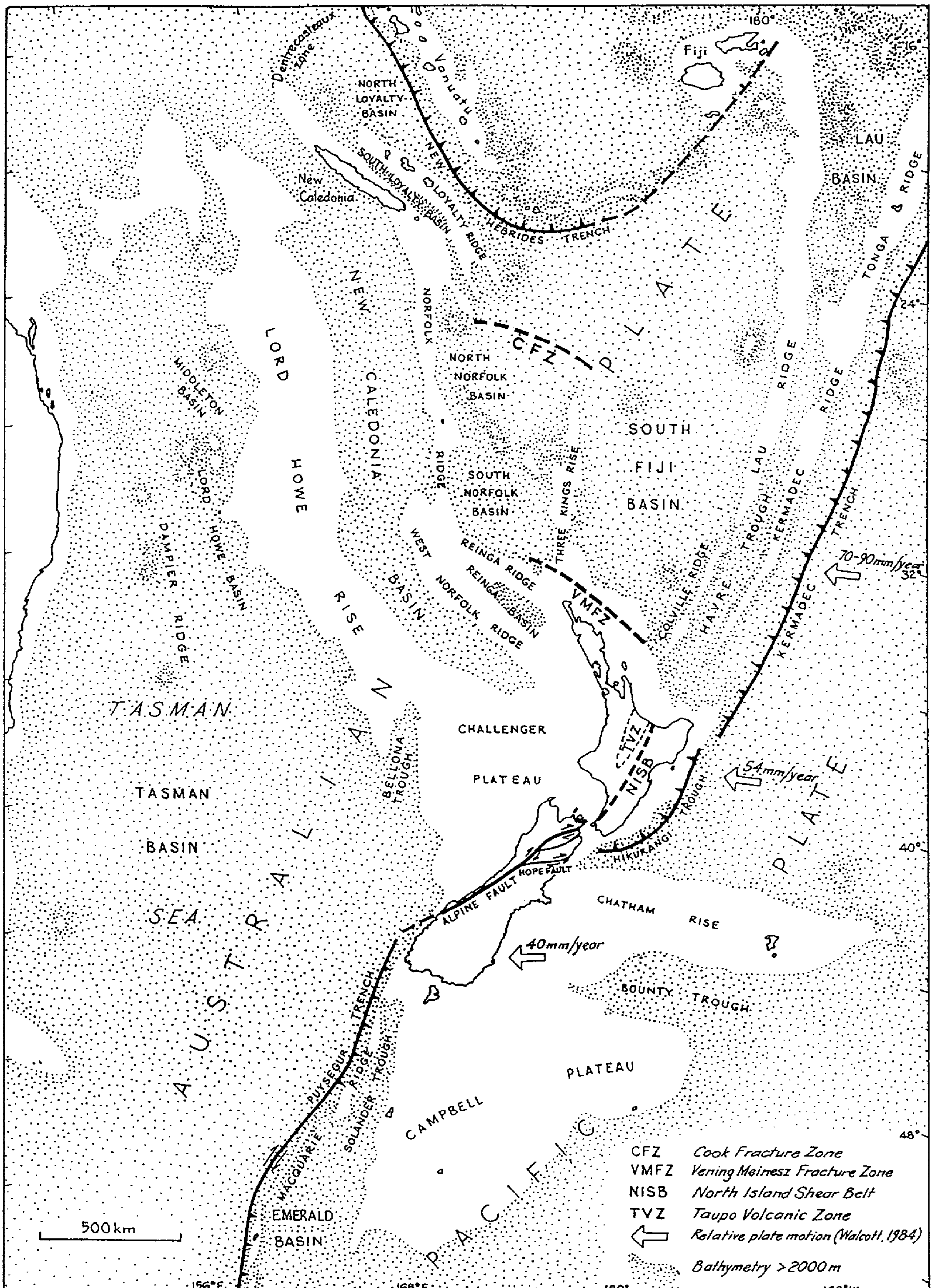

FIGURE 1 **Plate tectonic setting of the New Zealand region**

Information compiled from: Circum-Pacific Map Project (1981), Launay & others (1982), Cole (1984, 1986), Walcott (1984, 1987) and Pelletier (1990)

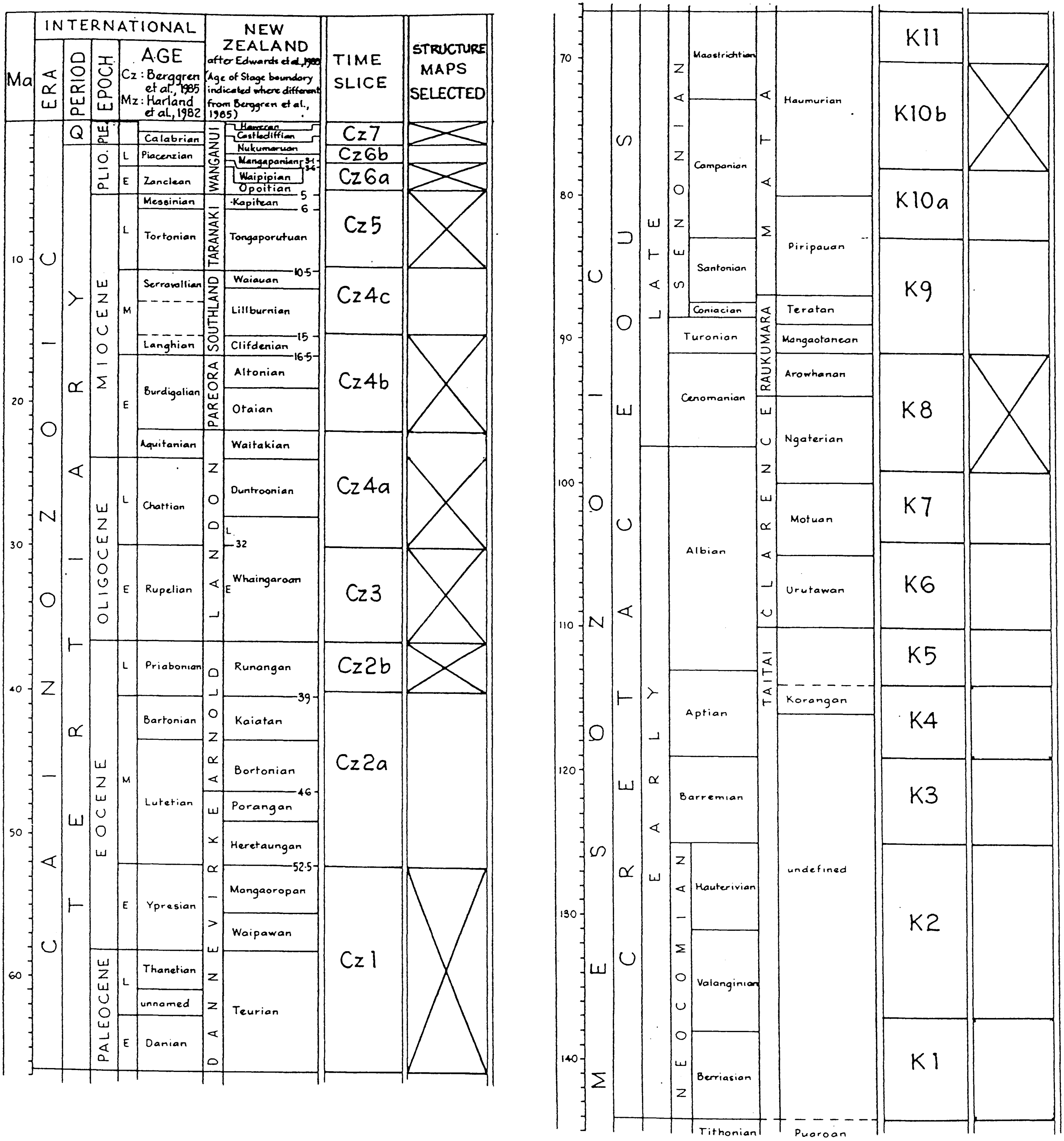

FIGURE 2 CRETACEOUS - CAINOZOIC TIME SCALE, SHOWING TIME SLICES REPRESENTED BY STRUCTURE MAPS

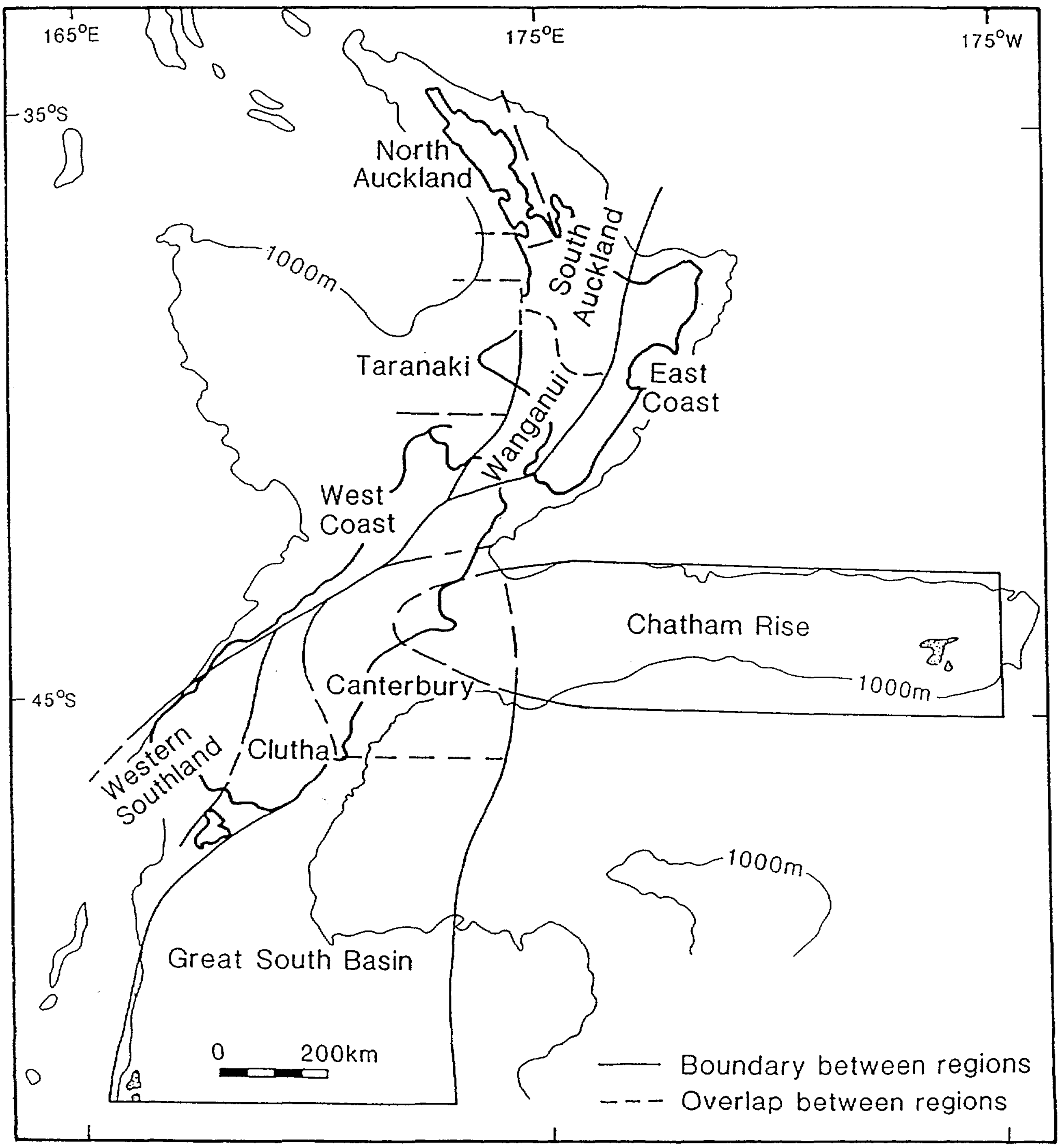

FIGURE 3 NEW ZEALAND - REGIONAL LOCATION MAP

Map from DSIR, Geology & Geophysics, New Zealand.
The map shows the eleven study regions currently under investigation by DSIR, as part of the Cretaceous - Cenozoic Basin Studies Programme. The following DSIR Basin Studies volumes have been published:

Basin Studies 1 (West Coast) - Nathan & others (1986)
Basin Studies 2 (Canterbury) - Field & others (1989)
Basin Studies 3 (Chatham Rise) - Wood & others (1989)

TABLE I

PRINCIPAL REFERENCES USED FOR EACH REGION

(See location map, Figure 3)

North Auckland
Beggs & others (1988); Brook & others (1988); Hayward (1979); Hayward & others (1989); Ministry of Commerce (1990); Suggate & others (1978); Thrasher (1986, 1988).

South Auckland
Cole (1979); Hochstein & Nixon (1979); Kear & Schofield (1978); Skinner (1986); Suggate & others (1978).

Taranaki
King (1990); King & Robinson (1988); King & Thrasher (in press); Thrasher (1989).

Wanganui
Anderton (1981); Katz (1990); King & Robinson (1988); Nelson & Hume (1977); Suggate & others (1978).

East Coast
Barnes (1988); Beu & others (1980); Carter & others (1988); Francis & others (1989); Johnston (1980); Laird (1989); Lamb & Bibby (1989); Lewis (1980); Moore (1978, 1988); Moore & Morgans (1987); Moore & Speden (1984), Riddolls (1987); Suggate & others (1978); Van der Lingen & Pettinga (1980); Walcott (1987).

West Coast Region, South Island
Grindley (1980); Nathan & others (1986).

Western Southland
Norris & Carter (1980); Turnbull & Forsyth (1988); Uruski & Turnbull (1990).

Clutha/Canterbury
Berryman & Beanland (1991); Carter (1988b); Field & others (1989); Herzer & Bradshaw (1985); Kamp & others (1989); Mortimer (1988); Suggate & others (1978); Yeats (1987).

Chatham Rise
Wood & others (1989).

Great South Basin
Anderton & others (1982); Carter (1988a, 1988b).

a) The scale of the final palaeogeographic maps (1:10 000 000); thus only larger scale structures are shown.

b) A lack of clear information on the style of deformation within certain areas in a number of time slices; in these instances, either generalised information is shown, or the areas concerned have been left blank.

c) There was minimal tectonic activity within some time slices (for example, time slice Cz1); the areas concerned have therefore been left blank.

On each time slice map, "K" = Cretaceous and "Cz" = Cainozoic.

1.1 Plate tectonic setting

From the Permian until the early Early Cretaceous, New Zealand was dominated by convergent margin tectonics, at the margin of Gondwana. The collison of the youngest segments of the convergent margin with the remainder of New Zealand took place in the Early Cretaceous (Rangitata-2 Orogeny; Bradshaw & others, 1981), associated with terrane deformation, granitoid intrusion, metamorphism and uplift (Bradshaw, 1989). There is now thought to have been only a short interval between the convergence and a change in tectonic regime to one of extension, although the age of the final deformational event varies from one region to another. Convergence is now thought to have ceased in the Albian, at about 105 ± 5 Ma (Bradshaw, 1989), in time slice K7 (Figure 2). The timing of the final convergent event is, however, controversial, because of different interpretations as to both the significance of major unconformities and the depositional environment of some Cretaceous sequences (see, for example, Speden, 1976; Feary, 1979; Moore & Speden, 1979, 1984; Prebble, 1980; Barnes, 1988; Korsch & Wellman, 1988).

Shortly after the collision of the final segments of the convergent margin, extension began in the late Albian to Cenomanian (time slices K7 to K8), associated with the breakup of eastern Gondwana (Laird, 1981; Browne & Field, 1988; Bradshaw, 1989). Extension was in part transtensional (Thrasher, 1989) and fault-controlled basins developed. From the Late Cretaceous to the Paleocene, lithospheric cooling and subsidence proceeded over the New Zealand region, coeval with sea-floor spreading in the Tasman Sea. During a further extensional phase in the Mid- to Late Eocene (time slices Cz2a - Cz2b), a zone of basins developed along western New Zealand, possibly originating within a transform margin (see, for example, Norris & Carter, 1980). Following the Eocene extension, there was regional subsidence and transgression through the Oligocene.

The modern convergent Indo-Australian/Pacific Plate boundary became established in New Zealand in the latest Oligocene/earliest Miocene (latest time slice Cz4a to time slice Cz4b), placing New Zealand once again in a convergent tectonic regime. Subduction of the Pacific Plate beneath the Indo-Australian Plate began east of North Island and Eastern North Island became an accretionary wedge. In the South Island, the initiation of the dextral transcurrent Alpine Fault marked the passage of the plate boundary through continental crust. South of the South Island, subduction of the Indo-Australian Plate beneath the Pacific Plate commenced. This obliquely convergent regime has persisted throughout the Neogene (Figure 1).

2. TIME SLICE STRUCTURE MAPS - A BRIEF OVERVIEW

Maps K8 and K10b

These maps show early extensional structures associated with the breakup of Gondwana. Grabens and half-grabens developed. Listric faulting in the Chatham Rise was associated with rifting in the Bounty Trough to the south of the Rise (Wood & others, 1989). Deposition in eastern North Island was in tectonically active shelf to slope environments, but the style and trend of active structures during the Cretaceous and Palaeogene is not at present clear.

Map Cz1

Tensional faulting continued, but to a diminished extent. There was quiescence over much of New Zealand, coeval with lithospheric cooling and subsidence at the time of sea-floor spreading in the Tasman Sea.

Maps Cz2b, Cz3 and Cz4a

Renewed extension occurred during this period, with local re-activation of Cretaceous structures; for example, in the West Coast Region. There was tensional (probably transtensional) faulting in Western Southland (Uruski & Turnbull, 1990). An increase in fault-controlled sedimentation occurred by time slice Cz4a, particularly in Taranaki and Western Southland. This may have signified the beginning of a new stress regime through the New Zealand region (see Turnbull & others, 1989; King, 1990).

Map Cz4b

Structures reflect an overall compressive regime, initiated when the obliquely convergent plate boundary became established in New Zealand immediately prior to this time slice. Eastern North Island became an accretionary wedge. Dextral transcurrent movement began along the Alpine Fault in the South Island. Thrusts in North Auckland region and northeastern North Island indicate emplacement of allochthons of ophiolitic rocks and Cretaceous - Oligocene sediments (see Brothers & Delaloye, 1982; Kenny, 1984). Normal faults were reactivated as reverse faults in Taranaki and Western Southland.

Maps Cz5, Cz6a and Cz7

Zones of deformation display a regional clockwise shift in the focus of compression and associated uplift, accompanying the rotation of the subduction system to its present trend (see Lamb & Bibby, 1989). The zone of faulting at the northern margin of the Chatham Rise reflects the increasing degree of impaction of Chatham Rise against the plate boundary (Wood & others, 1989). During time slice Cz5, compression on major faults in Taranaki ceased and oblique compression began along the Alpine Fault. Maps Cz6a and Cz7 indicate the rapid uplift along the Alpine Fault zone. Uplift and basin inversion has been a major feature of the Neogene. Tensional faulting in central North Island during time slice Cz7 represents extension within the Taupo Volcanic Zone back-arc basin (Cole, 1986).

3. COMMENTS ON HYDROCARBON POTENTIAL

The hydrocarbon potential of the New Zealand region has been briefly discussed in previous Phanerozoic History of Australia Project reports (Walley, 1991; Walley & Ross, 1991). It is useful here to highlight aspects of New Zealand's structural development which have implications for hydrocarbon potential.

Cretaceous extensional structures (see Maps K8, K10b) controlled regions of sustained subsidence. Terrestrial hydrocarbon source rocks were deposited during the early rift phase. As lithospheric cooling and subsidence proceeded during the Late Cretaceous to Paleocene (Map Cz1), marine source rocks were deposited (see, for example, Cook & Beggs, 1990; King, 1990). In the Great South Basin (Figure 3), these source rocks have been buried to at least the peak of oil generation and some of the sequence may have been mature by the Late Cretaceous. This area, together with the Canterbury Bight and Chatham Rise (Figure 3), has not undergone extensive Late Tertiary tectonic activity. This is in marked contrast to areas closer to the Neogene plate boundary zone, referred to below. Trap formation was largely complete in the Great South Basin by the Late Cretaceous (Cook & Beggs, 1990).

During the propagation of the convergent plate boundary through New Zealand in the Neogene, there was inversion of Cretaceous and Palaeogene basins, particularly west of and close to the plate boundary zone (see areas of uplift marked on Maps Cz5, Cz6a and Cz7). Thus, in these areas, Neogene structural traps have formed. Most of the hydrocarbon accumulations in the Taranaki Basin (Taranaki, on Figure 3) occur in these Neogene structural traps (King, 1990).

The regional clockwise shift in compression and associated uplift, during the Neogene, has also initiated the formation of new areas of subsidence - for example, the rapid and continuing subsidence of the South Wanganui Basin (see Wanganui, on Figure 3), which started at the beginning of time slice Cz6a (Maps Cz6a-Cz7). This foreland basin, which is adjacent to the Taranaki Basin but is under-explored, is discussed in Katz & Leask (1990).

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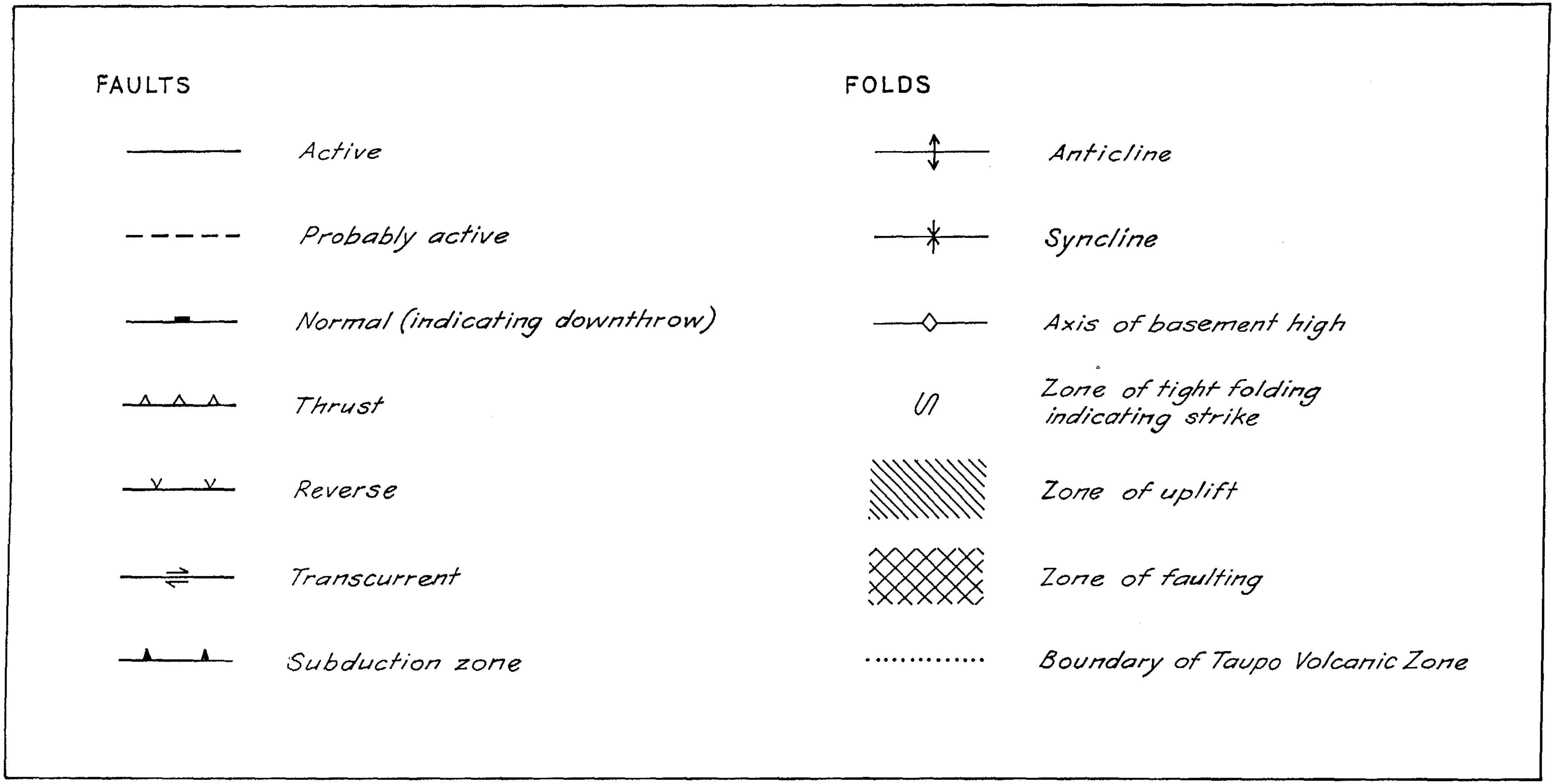
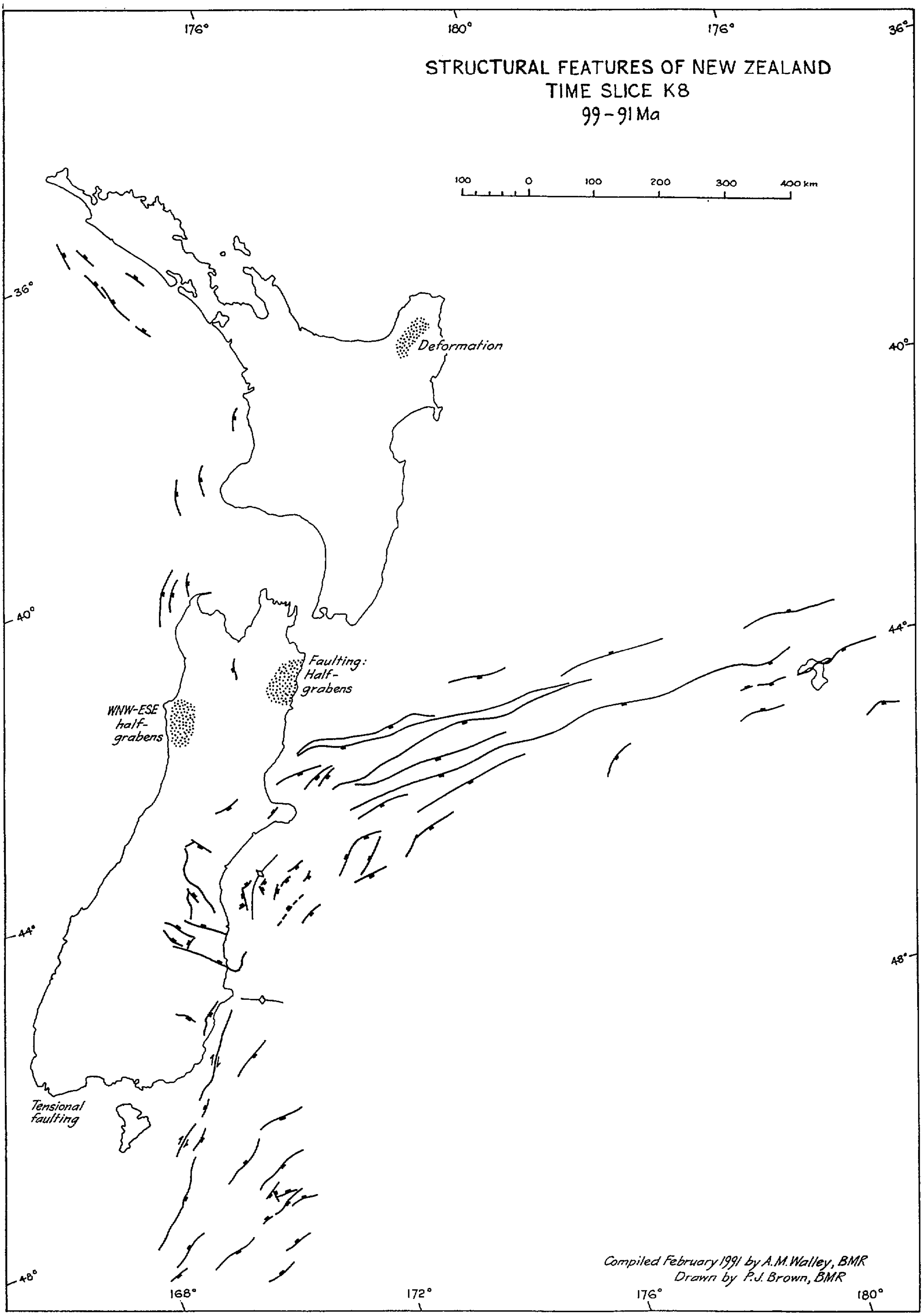
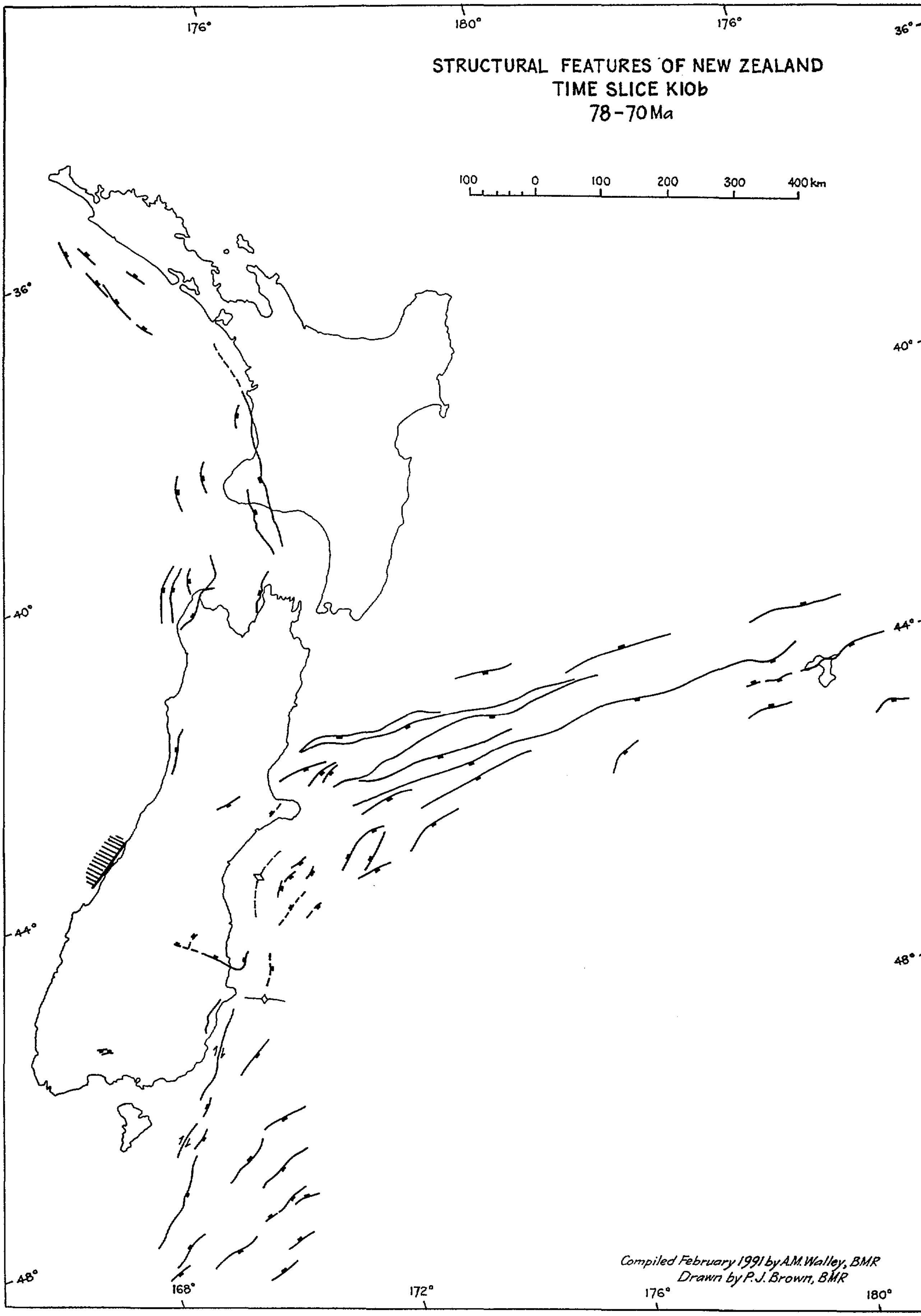


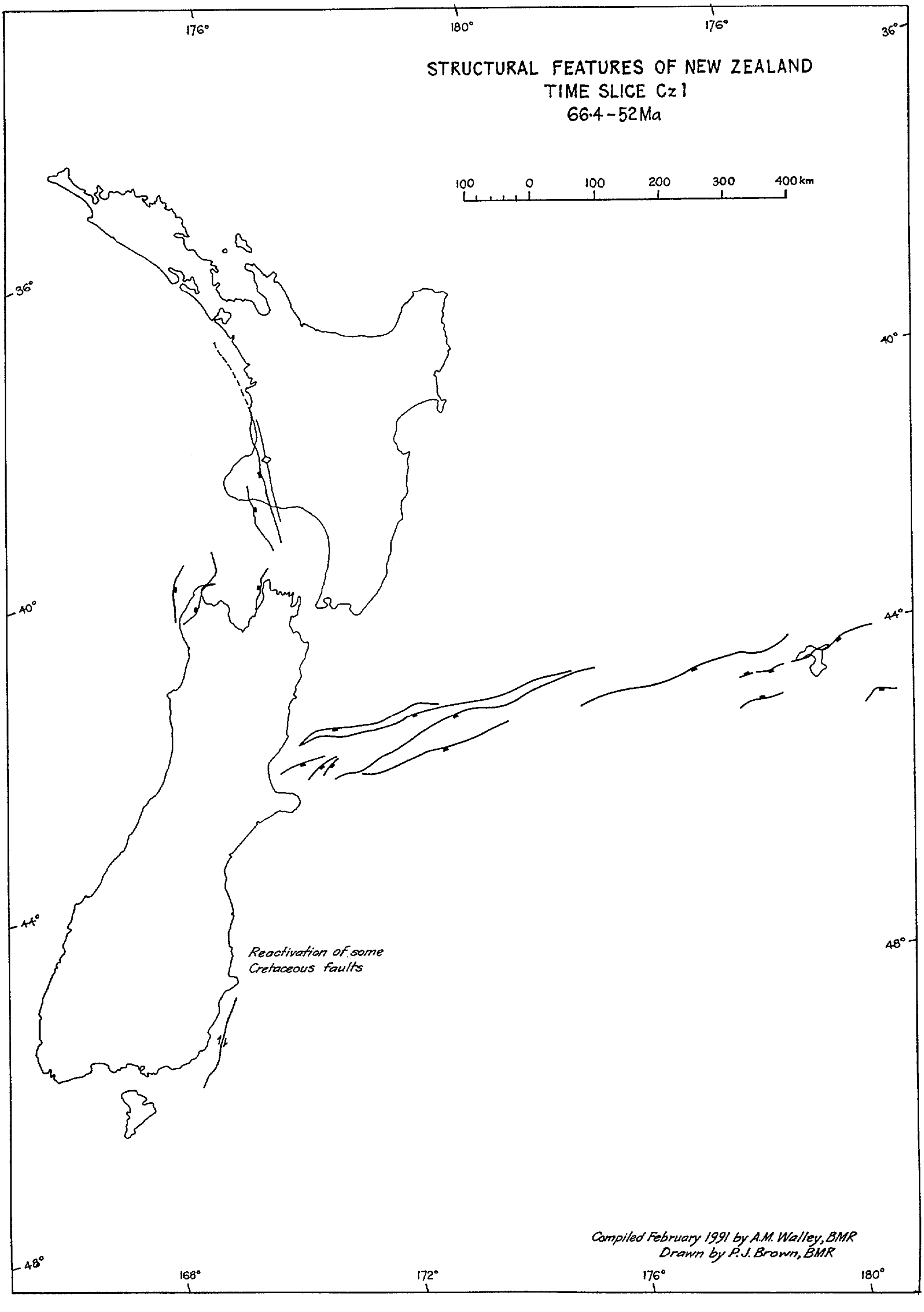
FIGURE 4 STRUCTURE MAP LEGEND



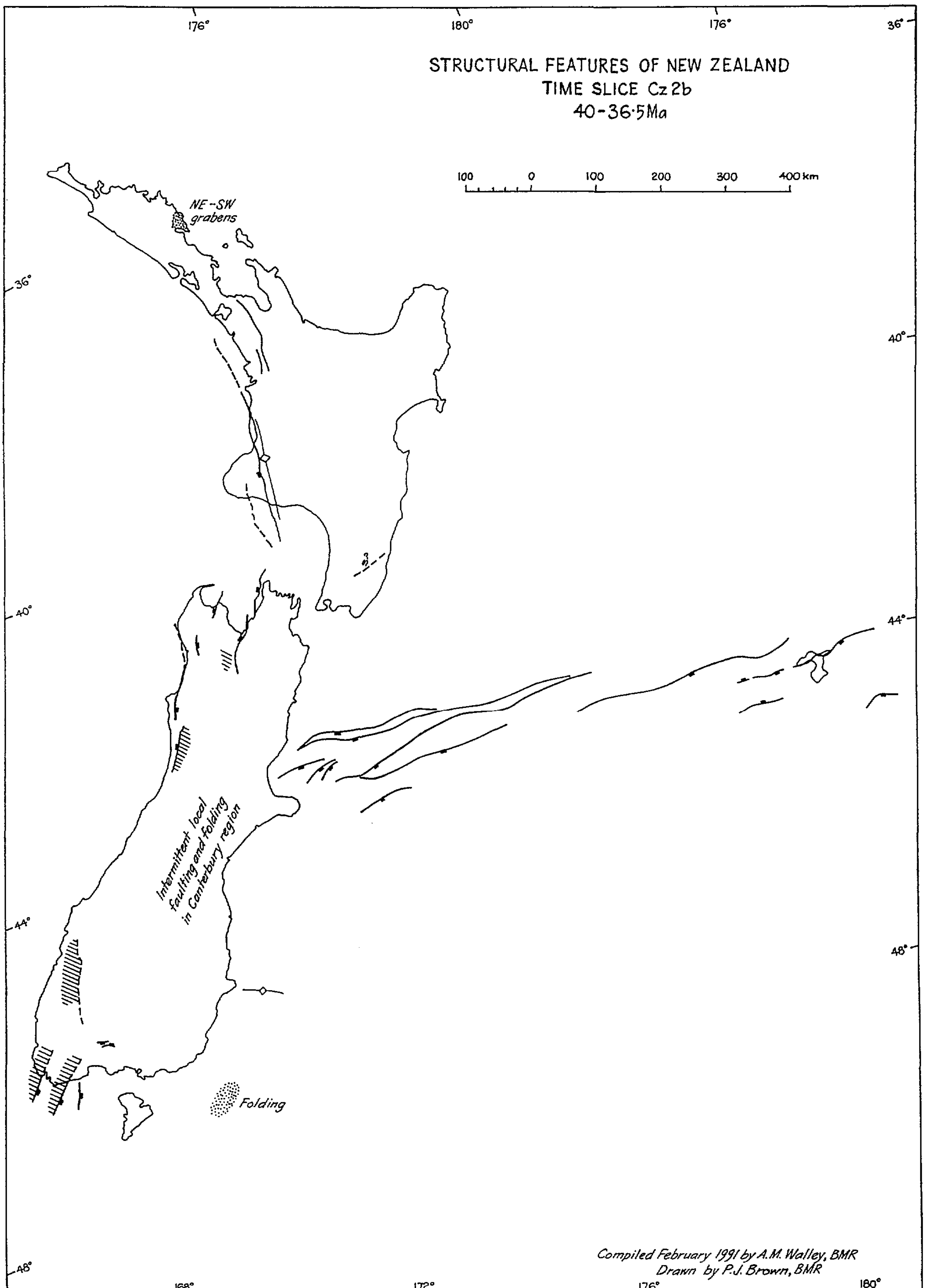
MAP K8: **Time slice K8, 99-91 Ma**



MAP K10b: **Time slice K10b, 78-70 Ma**

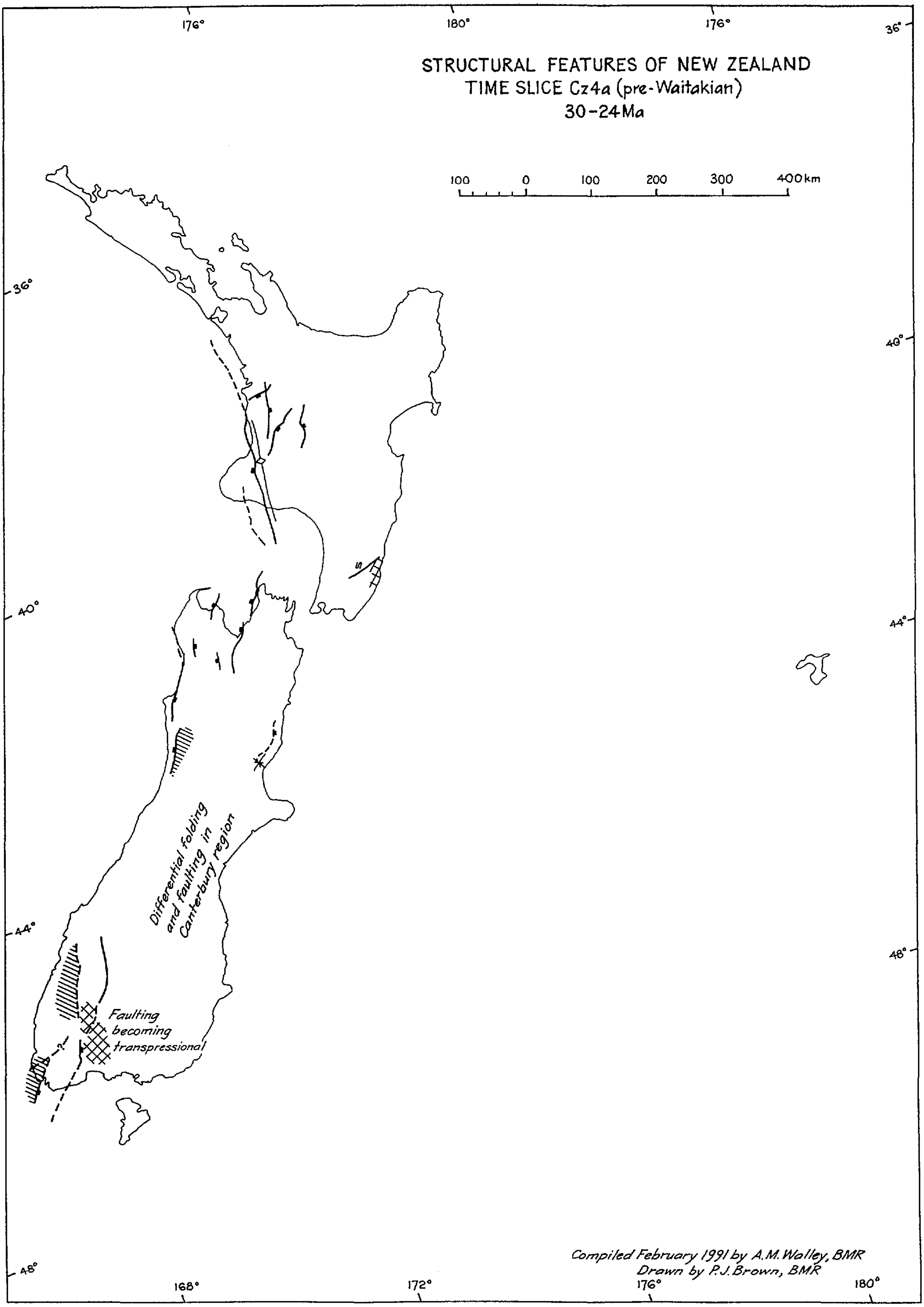


MAP Cz1: **Time slice Cz1, 66.4-52 Ma**

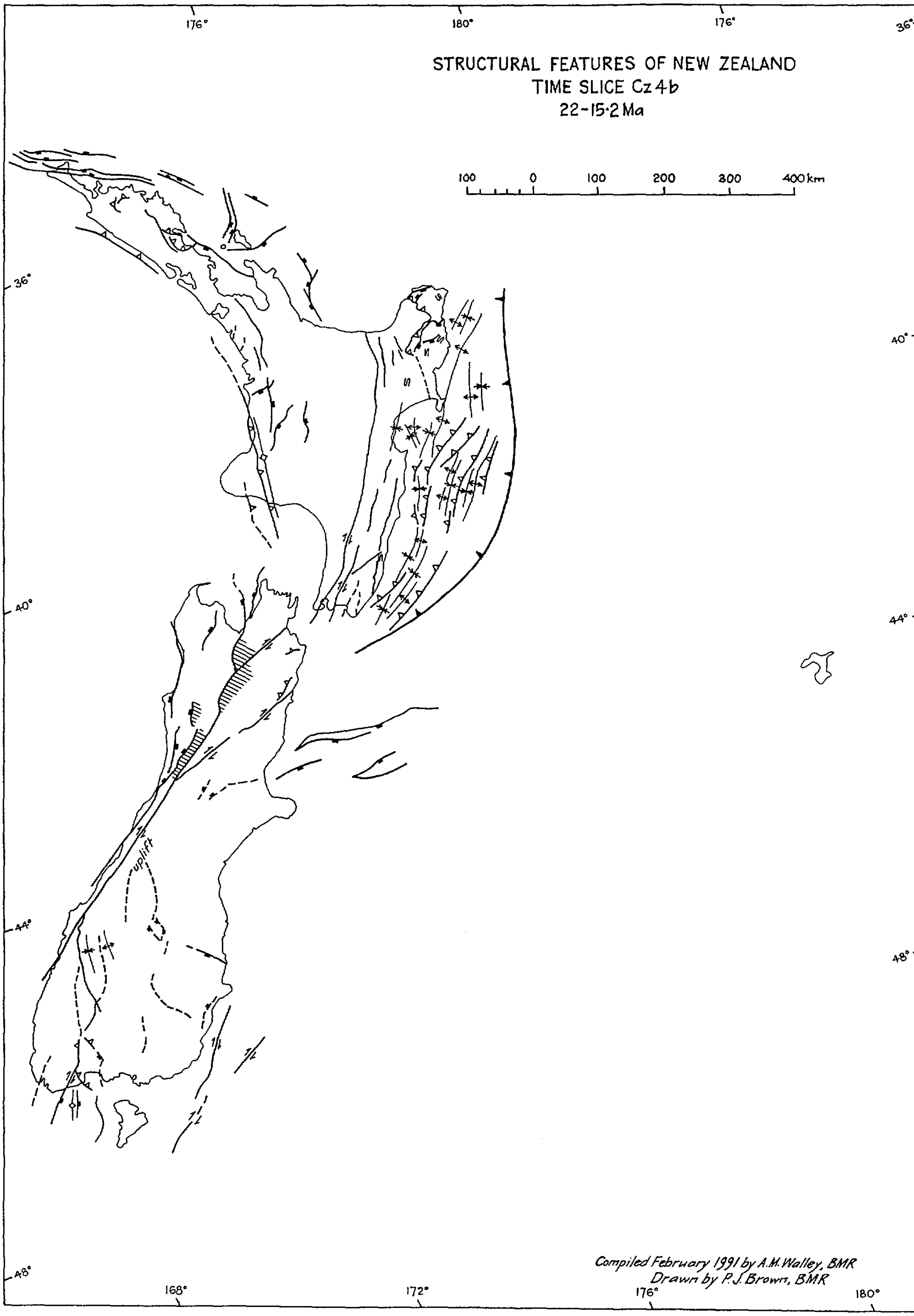


MAP Cz2b: **Time slice Cz2b, 40-36.5 Ma**

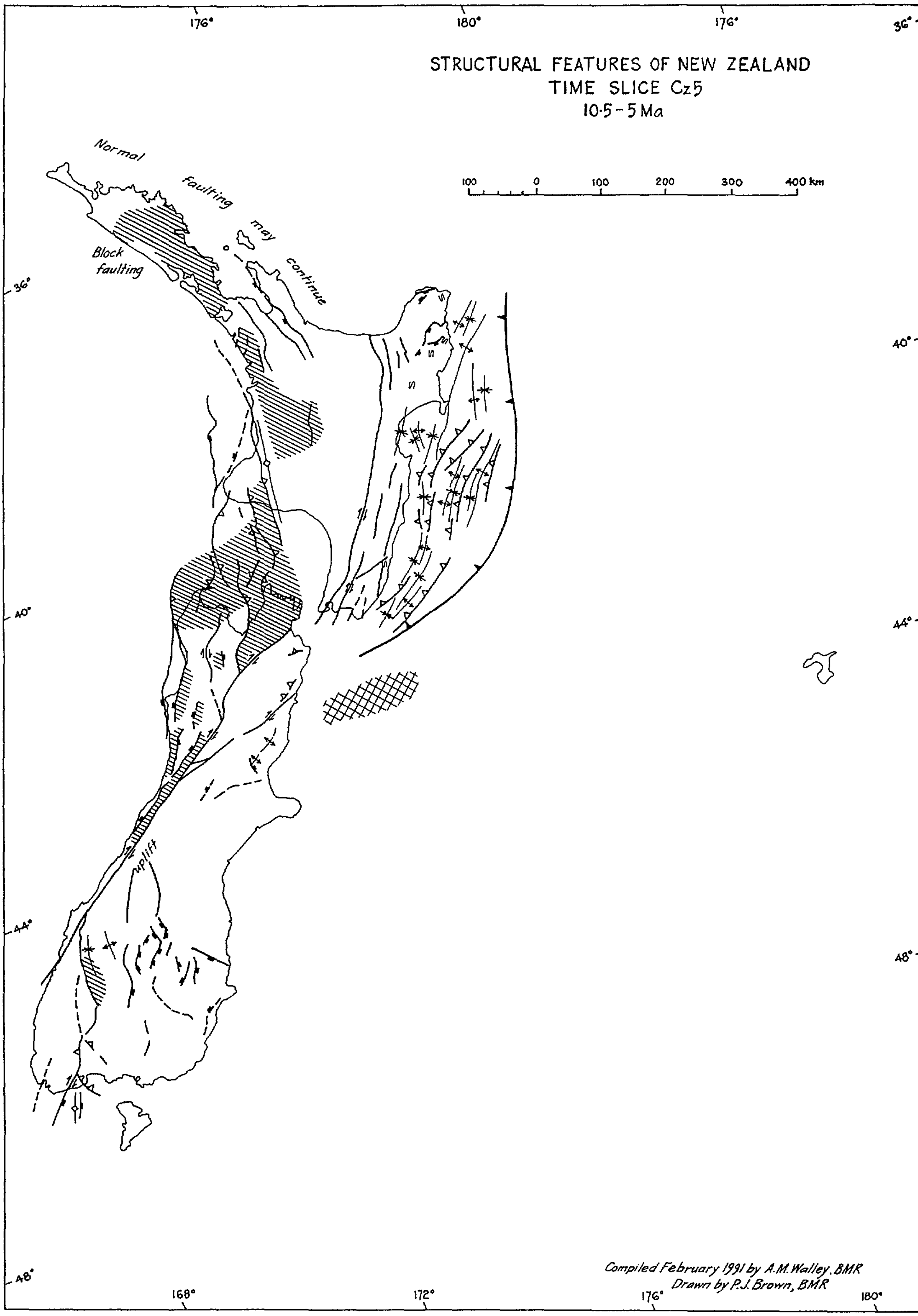
MAP Cz3: Time slice Cz3, 36.5-30 Ma



MAP Cz4a: **Time slice Cz4a (pre-Waitakian Stage), 30-24 Ma**

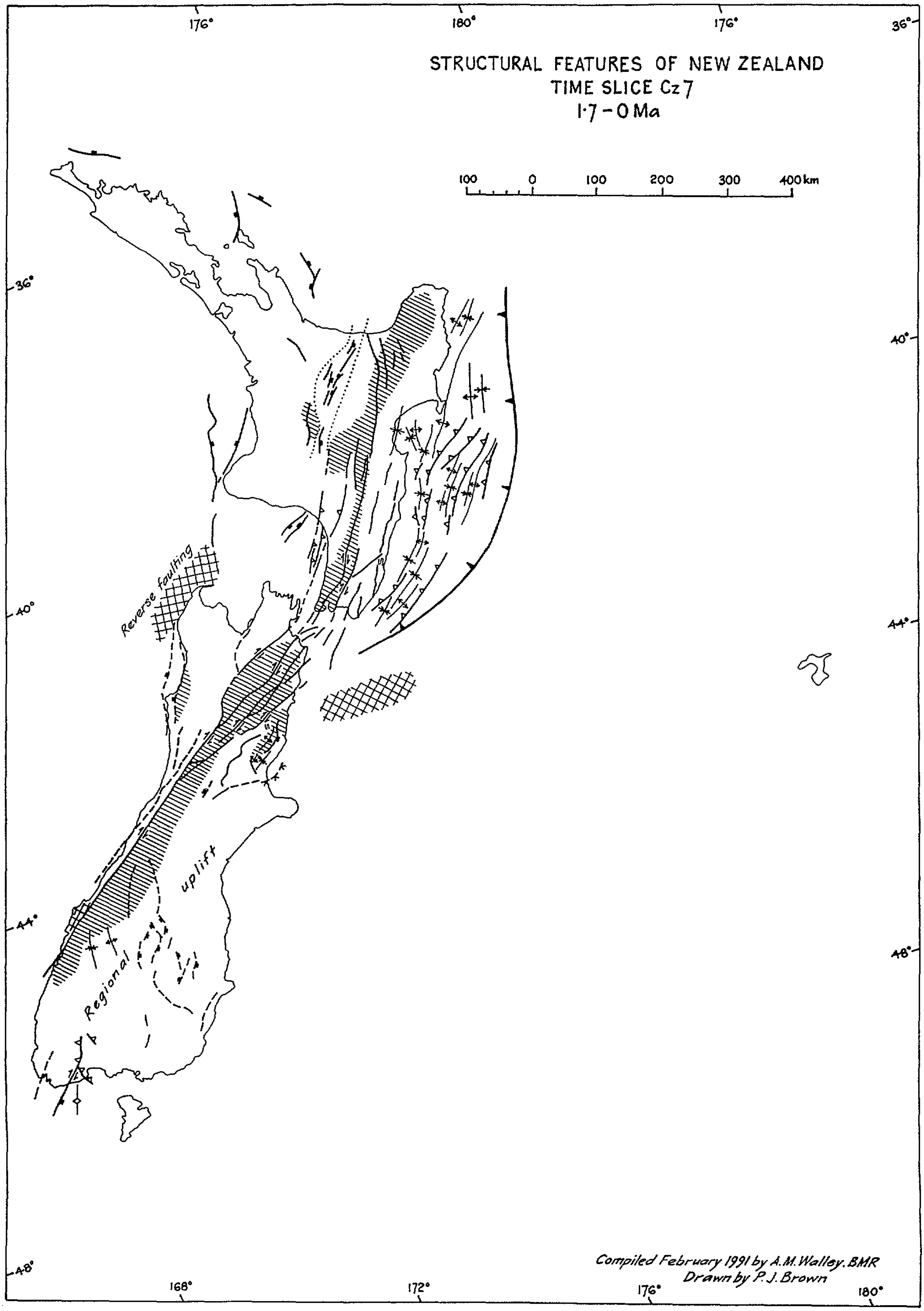


MAP Cz4b: **Time slice Cz4b, 22-15.2 Ma**



MAP Cz5: **Time slice Cz5, 10.5-5 Ma**

MAP Cz6a: Time slice Cz6a, 5-3 Ma



MAP Cz7: **Time slice Cz7, 1.7-0 Ma**