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RECONSTRUCTIONS OF THE CAMPBELL PLATEAU AND THE LORD HOWE RISE

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Reconstructions of the southeastern margin of Gondwanaland require either a separation of East and West Antarctica or movement between the Lord Howe Rise and the Campbell Plateau Previous plate tectonic reconstructions based on sea-floor spreading data eliminated the Lord Howe Rise–Campbell Plateau separation prior to 36 m y ago because of overlap This conclusion is dependent on the reconstruction of Australia and Antarctica, interpretation of magnetic anomalies between Antarctica and the Campbell Plateau and the nature of the plate boundary in New Zealand Revised reconstructions of the fit between Australia and Antarctica, and a reinterpretation of the magnetic anomalies between the Campbell Plateau and Antarctica suggest that there is no problem of overlap between the Lord Howe Rise and the Campbell Plateau, and that continued motion between these plates prior to 36 m y ago is a more plausible alternative to separation between East and West Antarctica

1 Introduction

Continental reconstructions of Australia, Antarctica, the Lord Howe Rise and the Campbell Plateau [1,2], which are based on magnetic anomalies, require either a separation between East and West Antarctica or between the Lord Howe Rise and the Campbell Plateau in order to achieve a reasonable fit The hypothesis that the Lord Howe Rise and the Campbell Plateau were separate plates during the early Tertiary was rejected because the sea-floor spreading pattern resulted in overlap of these continental elements [2] The alternative separation, between East and West Antarctica, would have considerable significance for reconstruction of the southern continents and their subsequent evolution The following discussion will demonstrate that these conclusions are dependent on the interpretation of the initial fit of Australia and Antarctica and on the interpretation of the magnetic anomaly pattern between the Campbell Plateau and Antarctica Relative motion between the Campbell Plateau and the Lord Howe Rise is an acceptable alternative to the separation of East and West Antarctica A new model describing the nature of the boundary between the Campbell Plateau and the Lord Howe Rise must be considered

2 Previous reconstructions

The Alpine Fault in New Zealand is an active plate boundary connecting the Macquarie Ridge and the Kermadec Trench (Fig 1) Offset along this zone, measured from pre-Cretaceous rock belts is estimated at 480 km [3–5] although total offset has been estimated to exceed 1000 km (e g [4]) Reconstruction of sea-floor spreading between the Indian and Pacific plates also indicates deformation in New Zealand of 300–600 km since 38 m y B P [2,6,7] If a constant displacement rate based on offset terraces is assumed, 480 km is consistent with the initiation of the Alpine Fault 30 m y ago [3] However, several authors believe the Alpine Fault existed prior to the Tertiary [4,8,9] Despite the correction of 480 km of offset on the Alpine Fault, in reconstructions prior to 36 m y Molnar et al [2] were forced to place a plate bound-

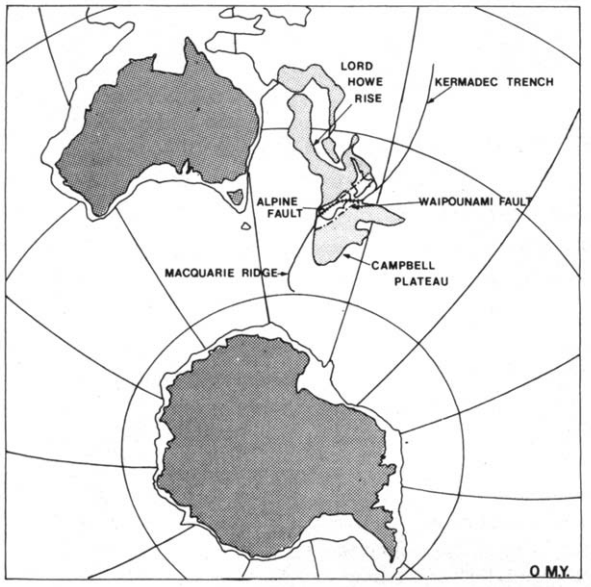

Fig 1 Present-day map of Australia, Antarctica and New Zealand indicating important features Lambert equal area projection centered at 60°S, 160°E with 30° grid lines for scale

ary between East and West Antarctica These reconstructions were based on magnetic lineations between the Lord Howe Rise and Australia [1], a simple, symmetric spreading model between the Campbell Plateau and Antarctica [2] and previously described motions between Australia and Antarctica [10] The motion between Australia and Antarctica from 55 to 38 m y used by Weissel and Hayes [10] was based on the best morphological fit of Sproll and Dietz [11] These constraints result in an overlap between the Campbell Plateau and the Lord Howe Rise if the reconstruction is made without a separation between East and West Antarctica Since Molnar et al [2] were forced to place a plate boundary within Antarctica by these constraints, they assumed that this plate boundary was active between 80 and 36 m y B P They assumed no plate boundary between the Lord Howe Rise and the Campbell Plateau prior to 36 m y B P

However, the morphologic fit of Sproll and Dietz [11] requires a change in the direction of motion for the early spreading history between Antarctica and Australia If the fit of Australia and Antarctica is made according to Griffiths [12], which implies a more uniform spreading pattern, the fit of Australia is shifted approximately 250 km west with respect to Antarctica This revision appears more consistent with detailed sedimentary and structural evidence from Antarctica [13] With this fit, there is no overlap between the Lord Howe Rise and the Campbell Plateau in the original reconstruction (Fig 2) and therefore the necessity for postulating a plate boundary between East and West Antarctica must be reexamined

Weissel et al [14] used a revised fit very similar to that of Griffiths for Australia and Antarctica and revised data between the Lord Howe Rise and Australia suggested by Weissel and Hayes [15] Weissel et al [14] also assumed that there was a plate boundary between the Lord Howe Rise and the Campbell Plateau from 80 m y to the present (i e no boundary between East and West Antarctica) The reconstruction between the Campbell Plateau and Antarctica is based on the symmetric model of Molnar et al [2] With the revised fit of Antarctica and Australia, the majority of the overlap between the Lord Howe Rise and the Campbell Plateau is removed However, we find that overlap still occurs between these two plateaus (see Fig 3) between anomalies 18 and 26 (42–60 m y using the time scale of LaBrecque et al [16])

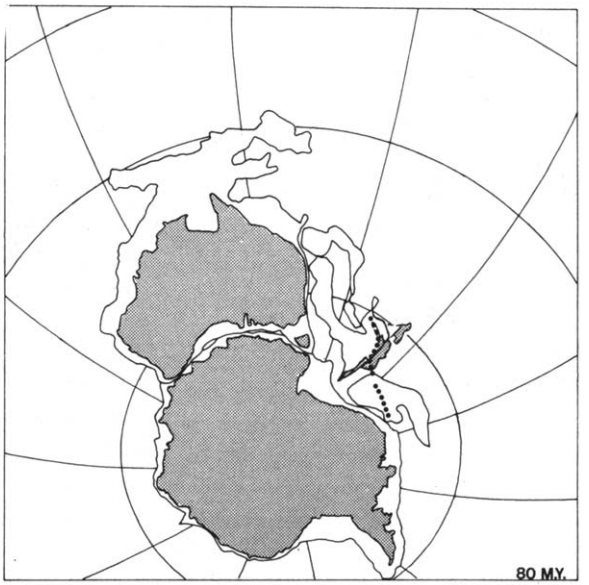

Fig 2 Initial reconstruction of the southeastern margin of Gondwanaland indicating no overlap Included is the reconstruction of the Stokes Magnetic Anomaly Lambert equal area projection centered at 60°S, 160°E with 30° grid lines for scale Antarctica is in its present-day position, in this and all subsequent maps

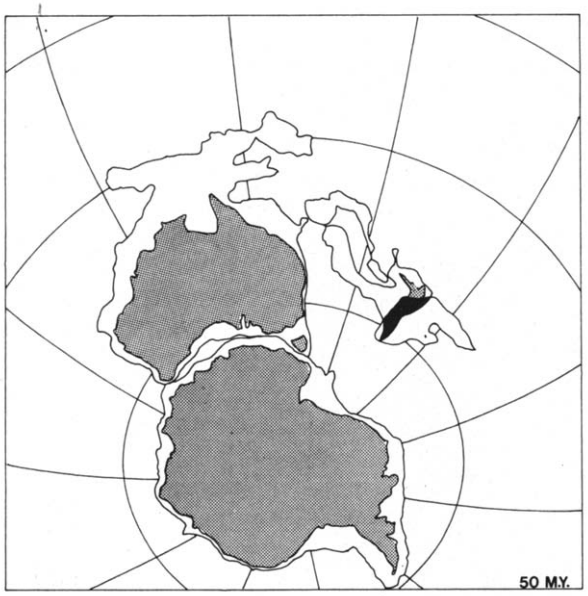

Fig 3 Plot at 50 m y using the revised reconstruction of Australia and Antarctica [12], the rotations of the Lord Howe Rise with respect to Australia described by Weissel and Hays [15] and the rotations of the Campbell Plateau with respect to Antarctica described by Molnar et al [2] The Campbell Plateau includes most of the South Island of New Zealand in the manner of Weissel et al [14] The overlap of the continental fragments occurs between anomalies 18 and 26 (42–60 m y) if symmetric spreading is assumed and is shown here in black Lambert equal area projection centered at 60°S, 160°E with 30° grid lines for scale

3 The nature of the plate boundary in New Zealand

The degree of overlap is also dependent on the nature of the plate boundary in New Zealand Weissel et al [14] have assumed that the Alpine Fault intersecting the Kermadec Trench (the intersection occurs to the south of North Island) constitutes the plate boundary during the last 80 m y Consequently most of South Island is part of the Campbell Plate This results in an increased overlap with New Zealand's North Island Overlap at anomalies 13, 18 and 26 between present "above sea level" continental outlines were removed by reducing the size of New Zealand's North Island [14] A slightly larger degree of overlap is calculated for spreading between anomalies 18 and 26 using the model of Weissel et al [14] We propose that the Alpine Fault is only one aspect of a complex boundary which resulted from the convergence of the Campbell Plateau with New Zealand and that the boundary drawn by Weissel et al [14] is oversimplified The convergence is also responsible for the Kaikoura orogeny of the southern Alps (e g [8])

Cullen [17] proposed the Waipounami Fracture, which is parallel to the southern margin of New Zealand Although there is no indication of the amount of offset, this is based on the pronounced linearity of the 500-m isobath and the scarp associated with transition from New Zealand to the Campbell Plateau The offset of the Stokes Magnetic Anomaly System [18] is a much more important indication of relative motion in addition to offset on the complicated Alpine Fault System The Stokes Anomaly is associated with the Dun Mountain-Red Mountain ophiolite belt of Permian age which is offset by the Alpine Fault [19] Davey and Christoffel [18] have delineated a positive anomaly belt on the Campbell Plateau which they believe is a continuation of the Stokes Magnetic Anomaly belt The anomaly on the Campbell Plateau is offset from the Stokes Anomaly on South Island Davey and Christoffel [18] postulate 330 km of dextral displacement on a newly named fault, the Campbell Fault This is slightly southward but parallel to the fault proposed by Cullen [17] This displacement is not accounted for in any other reconstructions of the Campbell Plateau and Antarctica, however approximately 300 km offset is required in our reconstruction (see Fig 2)

4 An alternative hypothesis

Several important aspects of this analysis should be noted

(1) The majority of the overlap is removed by the revised fit of Australia and Antarctica,

(2) Overlap occurs between anomalies 18 and 26 in the model of Weissel et al [14],

(3) Alignment of the Stokes Magnetic Anomaly in our reconstructions at 80 m y (Fig 2) strongly suggests that there is no need for a plate boundary in Antarctica at this time, and

(4) Since previous reconstructions based on magnetic anomalies [2,14] have not taken into account any offset in addition to the Alpine Fault, we must reexamine the data used to obtain these sea-floor spreading rates and directions

Of the three sets of data, the motion between the Campbell Plateau and Antarctica is the least well constrained There are very few identifiable anomalies between the ridge crest and Antarctica, largely because of the paucity of ship tracks through the area The few recognizable anomalies which occur are located close to the Eltanin fracture zone, southeast of the northeastern portion of the ridge crest When Molnar et al [2] calculated rotation parameters for the movement between the Campbell Plateau and Antarctica they assumed that the spreading had been symmetric about the ridge crest

The alignment of the Stokes Magnetic Anomaly in our reconstruction at 80 m y implies Antarctica was probably a single unit Therefore, separating East and West Antarctica to explain the overlap between 40 and 60 m y and then rejoining Antarctica in a similar configuration seems an implausible explanation Consequently, the offset of the Stokes Magnetic Anomaly is difficult to reconcile with symmetric spreading between the Campbell Plateau and Antarctica

Asymmetric spreading has been noted at many locations (e g , Stein et al [20]) For instance, there is very good evidence for asymmetric spreading between Australia and Antarctica [21] Since the spreading between the Campbell Plateau and Antarctica is constrained only by anomalies on one side of the ridge crest, except for anomalies adjacent to the Eltanin fracture zone, we calculated the degree of asymmetry which would exactly remove any overlap (Figs 4–6) between 40 and 60 m y (Table 1) In other words, as there is no evidence as to the timing of offset on the Campbell Fault (or Waipounami Fault) we have assumed the offset occurred between 40 and 60 m y , just prior to the initiation of major offset on the Alpine Fault The amount of asymmetric spreading calculated to remove overlap between 40 and 60 m y is consistent with removing the offset on the Campbell Fault This strongly suggests that asymmetric spreading occurred during the convergence of the Campbell Plateau with the Lord Howe Rise We have thus changed the scenario from one in which there is a plate boundary in Antarctica and no plate boundary between the Campbell Plateau and the Lord Howe Rise prior to 36 m y to one in which there is no plate boundary in Antarctica and a plate boundary between the Lord Howe Rise and the Campbell Plateau at least to 60 m y B P

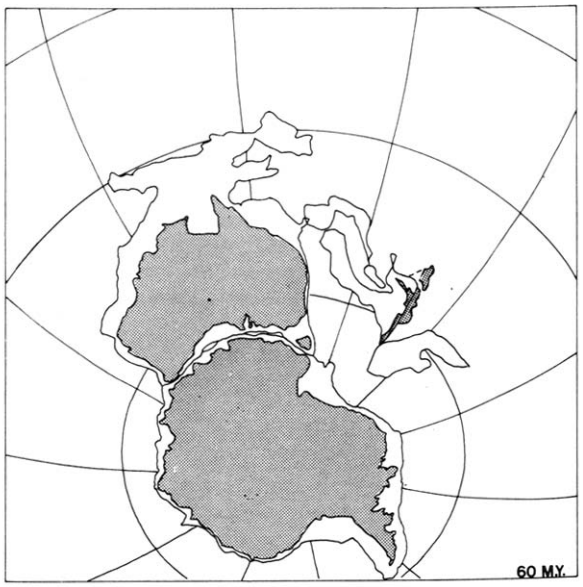

Fig 4 Reconstruction at 60 m y after modification of the rotations described by Weissel et al [14] The Waipounami Fault is considered the plate boundary and offset on the Alpine Fault is reversed Lambert equal area projection centered at 60°S, 160°E with 30° grid lines for scale

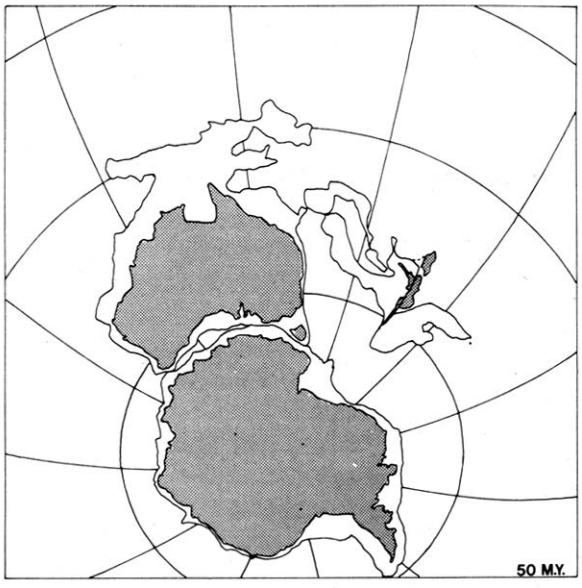

Fig 5 Reconstruction at 50 m y (period of maximum overlap in the case of symmetric spreading between the Campbell Plateau and Antarctica) after modification of the rotations described by Weissel et al [14] The projection is the same as in Fig 4

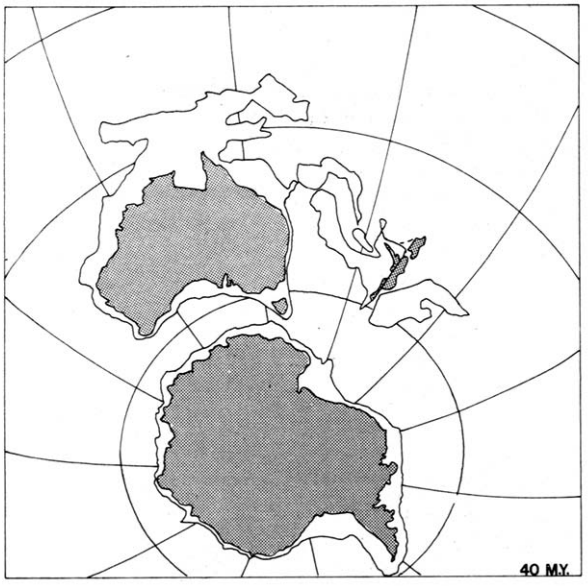

Fig 6 Reconstruction at 40 m y after modification of the rotations described by Weissel et al [14] The projection is the same as in Fig 4

TABLE 1

Rotations of the Campbell Plateau to Antarctica from Weissel et al [14] Rotations are counterclockwise The additions to the rotations by Weissel et al [14] shown above were obtained as follows Since spreading is symmetric about the ridge crest close to the Eltanin fracture zone, our poles of rotation were constrained to be located at the ridge crest close to this fracture zone, so that spreading remains symmetric there The amount of rotation was calculated so that overlap between the Campbell Plateau and the Lord Howe Rise was just removed

Age		Rotation angle	Latitude	Longitude
9	10 *	9 4	68 7	−79 7
19 5	21	15 7	72 0	−72 0
35 6	38	27 9	74 7	−57 0
42 1	45	26 9	70 2	−78 2
58 9	65	30 7	60 3	−89 7
66 1	71	43 6	65 3	−71 3
74 0	81	66 0	68 0	−50 0
Additions to the rotations of Weissel et al [14]				
42 1		8	−60 0	−128 4
58 9		16	−61 8	−121 5
66 1		8	−63 9	−115 2

* Old time scale used by Weissel et al [14]

There is additional evidence for a Maestrichtian to Oligocene marine depositional axis along the southern margin of New Zealand [8]

Griffiths [22] reinterpreted the magnetic anomaly record and proposed a two phase spreading model south of the Campbell Plateau to support his morphologic fit [23] This is an alternative to a model of asymmetric spreading

5 Discussion

On making reconstructions of the plates we have used the spreading information between Australia and Antarctica determined by Weissel et al [14], who used a revised fit very similar to that of Griffiths for these two continents and the data between the Lord Howe Rise and Australia determined by Weissel and Hayes [15] We reverse the 480 km of offset on the Alpine Fault along a trend which continues through North Island [3,6,24] We take into account 300 km of offset on the Campbell Fault [18] which offsets the Stokes Magnetic Anomaly All previous reconstructions based on magnetic anomalies [2,14] do not take into account any offsets other than along the Alpine Fault The analysis suggests that a small amount of asymmetric spreading consistent with this additional offset is a more reasonable alternative to separation of East and West Antarctica Sea-floor spreading between the Campbell Plateau and Antarctica is only constrained by anomalies on one side of the ridge crest except for anomalies adjacent to the Eltanin fracture zone Consequently, this hypothesis is well within the constraints of the magnetic anomaly data

These conclusions have considerable significance for reconstructions of the southern continents which propose a single-unit Antarctica [25] We have demonstrated (the fact) that it is not necessary to consider Antarctica as two plates

A major impetus for reconstructing the Lord Howe Rise and the Campbell Plateau to a Mesozoic configuration is to align the "geosynclinal" axes of Gondwanaland's southeastern margin which presently is like an "S"-shaped curve The margin becomes a linear axis of deposition in the morphologic fit of Griffiths [23] Basically, the rotation of New Zealand's South Island (south of the Alpine Fault) as part of the Campbell Plateau [14] also partly aligns the axis of the

"geosyncline" In one of these cases the continental side of the axis should be reversed with respect to the oceanic side Which of these hypotheses is correct is by no means academic In fact, Austin [26] suggested that a "gulf-like" geosyncline was more appropriate than a linear feature We are unqualified to interpret either model geologically

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