

# Clues to ancient Australian geostructures

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# Clues to Ancient Australian Geosutures<sup>1)</sup>

by Emile Rod<sup>2)</sup>

With 14 Text Figures

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## ABSTRACT

The rigid Australian Platform of today consists of at least two dozen crustal blocks which are welded to form a solid assembly. Today, the ancient boundaries of the blocks, the geosynclines, geofractures and geosutures are inactive and fossilized. However, more and more facts come to light which tell a story of a great horizontal movements along the large geosutures in pre-Mesozoic time. Evidence for important lateral displacements of crustal blocks relative to each other is readily found. There are several examples where a cumulative horizontal displacement of a few hundred kilometers can be proved or strongly suggested.

These ancestral geosutures are characterized by a wide belt (up to 60 kilometers) of large-scale strike-slip faults which between them enclose numerous huge slices of shattered rock and crushed wedges. Some of the rocks within the fracture belt might be slightly metamorphosed. Intensive shearing and silicification is widespread. As a general rule the areas where ancient geosutures intersect were the most likely sites for rich mineralizations.

A palaeotectonic map for the close of the Palaeozoic is presented showing some tentative restoration of the minor crustal blocks which were torn off from the eastern side of the Australian Platform during the late Jurassic or early Cretaceous. Some of the geosutures found in New Zealand and New Guinea were originally, in their primeval stage in pre-Mesozoic time, integral parts of Australian geosutures. The perfect fit of the traces of the ancient geosutures combined with the matching facies provinces, peridotite belts and old structural axes, provide additional proof for the correctness of the postulated reconstruction and for continental drift in general.

## INTRODUCTION

Although there is a great lack of detailed knowledge of the large-scale Australian fracture zones, many isolated facts strongly suggest – and in a few localities prove – that great ancient geosutures exist on the Australian continent. Together with the geofractures, geosynclines and the continental slopes, the geosutures form the boundaries which frame the continental crustal blocks. This idea is expressed by HILLS (1965, p. 8) as follows:

«In a regional view the recognition of cratonic blocks, between which lie belts of mobility, is made of recent years by all authors on the tectonics of Australia. The overall pattern is chiefly one of intersecting lineaments, and the mobile belts between cratonic blocks must represent zones of yielding in the basement, which because of their geometry are recognized as fracture zones.»

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The purpose of this short study is to encourage detailed research on all aspects of the Australian geosutures because a thorough knowledge of the movements and deformations along those ancient geosutures is all-important for a better understanding of the tectonics in general and especially of certain mineralisations which seem to be ultimately controlled by them.

With his preliminary note on «the ancient European basement blocks», HANS CLOOS (1948a, b) showed the way to a promising direction of structural investigations and he advanced ideas which fifteen years later turned out to belong among the most significant geotectonic concepts.

HANS CLOOS greatly influenced the thinking of several structural geologists in Australasia (HILLS, 1956; COTTON, 1956; CAREY, 1956, 1958), and inspired also the present paper. The main theme as summarised in his own words (1948a) stated: «During the last two or three decades observations began to accumulate which prove that several, if not all, of the main fractures or fracture zones in Europe are old and have been active practically during all the tectogenetic periods of the Earth's history. This indicates that the Earth's crust was divided into polygonal fields or blocks of considerable depth or thickness during an early stage of its history.»

#### DEFINITION OF GEOSUTURE

For the fracture zones which separate the basement blocks in the sense of H. CLOOS, «geosuture» is being used here as done previously by COTTON (1956) and ROD (1962). HANS CLOOS (1948a) used «geofracture» and «geosuture», apparently without making any further distinction but showed in the illustrations and text a certain preference for «geosuture».

As several more or less synonymous terms are now employed it is worthwhile to briefly define «geosuture» as follows:

A zone of a minimum length of 300 kilometers formed by a bundle of more or less parallel, large-scale strike-slip faults and all their branch faults and wedges which separates crustal blocks, and cuts the crust down to the same depth as the root of the crustal block. It has a long history of intermittent activity. Its horizontal displacements are measured in tens or hundreds of kilometers. It is exactly what CAREY defined as «Megashear» (1958). Another important characteristic of a geosuture was most appropriately formulated as follows by CAREY (1958): «Now in structures of the magnitude considered here there can be no doubt that the fracture breaks the *whole* crust and that the lower limit of fracture is the zone where plastic or viscous stress relaxation is sufficiently rapid to absorb the displacement by flow».

Several workers realised that such deeply rooted master faults in the crust of the earth form a special class of fractures which should be clearly distinguished. Movements of the crustal blocks along those great faults caused many lower order structural deformations. Whole families of folds and faults were generated in an orderly pattern (MOODY and HILL, 1956; ROD, 1956; LAUBSCHER, 1958; MAXWELL & WISE, 1958; ALBERDING, 1957, 1958; CAREY, 1958; PRUCHA, 1964; PAVONI, 1961a, b, 1964). These large-scale strike-slip faults were named «great fundamental faults» by DE SITTE (1956), «Megashears» by CAREY (1956, 1958), «large-scale

strike-slip displacements» by BILLINGS (1960), and «Tiefenbrüche» (depth fractures) by ASHGIREI (1962).

SHERBON HILLS (1963) includes them in his «lineagenic movements» along strike-slip faults, and PAVONI (1964) refers to them as «Horizontalverschiebungszonen».

All workers who studied the relative movements of the crustal blocks (ground blocks) realised the dominant influence of such displacements on all structural deformations in a wide belt along the boundary faults or above ancient buried geosutures.

This relationship gave rise to MOODY & HILL's (1956, 1964) theory of «wrench-fault tectonics» and to a fascinating discussion (LAUBSCHER, 1958; ALBERDING, 1957, 1958; MAXWELL & WISE, 1958; ROD, 1958; MOODY & HILL, 1958; COREY, 1962; PRUCHA, 1964). PAVONI (1961a) discussed the secondary effects of displacements along strike-slip faults. SHERBON HILLS (1956a, b) stressed the importance of crustal blocks as fundamental geotectonic units and pointed out the persistent control their movements have on all younger structural patterns and trends, and especially on the arrangements of regional disturbances of sedimentary basins.

#### NOMENCLATURE OF CRUSTAL BLOCKS

For easy reference and good understanding the basement blocks (crustal blocks, ground blocks), as fundamental units of the continental crust, should have a name. As long as a block is relatively uplifted, deeply eroded and appears as a Palaeozoic or Precambrian shield, the terminology does not create any problems. However, many blocks were repeatedly tilted and depressed during their long history. A basin very often formed on the surface of the depressed block. The gradual sag of a block (measured in a few centimeters to 50 centimeters per thousand years) affected the whole block down to its roots. Basically there is no difference between elevated and submerged (down-warped) blocks. Both are made up of polygonal, 30 to 40 kilometer thick segments of the crust and the portion of the Upper Mantle under the crust down to the layer of plastic flow. To be consistent both should be called blocks. The elevated blocks would be the shields, nuclei, blocks, or massifs of the usual terminology. However, when the names given to the depressed blocks are considered it is at once apparent that something is wrong with the nomenclature currently employed in many regions. A down-warped block is very often called after the basin with which it is capped. The difficulty is that «basin» has several senses in geology. In structural geology a basin is «a syncline that is circular or elliptical in plan, that is, the outcrop of each formation is essentially circular or elliptical, and the beds dip inward» (BILLINGS, 1954, in Glossary of Geology, 1960), or «a segment of the earth's crust which has been down-warped, usually for considerable time, but with intermittent risings and sinkings. The sediments in such basins increase in thickness toward the center of the basin» (after Landes, in Glossary of Geology, 1960). But for DE SITTER (1956) the term basin applies only to «sedimentary series» which have not been severely folded or have not been folded – yet. But even in the same chapter basin seems to have a dual sense: in the summary DE SITTER (1956) defines basins: «subsided, sediment filled, only slightly folded or unfolded areas on the shield or on their margin».

A basin started as a topographic depression which is rimmed on all sides. Irrespective of its definition a basin is, at its best, either a topographic form on the surface of a block or the pile of sediments which was deposited in such a topographic form. It is therefore always the uppermost portion of the block, very often skin-deep compared with the total thickness of the block. The Eucla Basin of the Tectonic Map of Australia (Tectonic Map 1960; HILLS, 1963, 1965) is only a very shallow sag (0.7 kilometers) on one of the Australian crustal blocks. The origin of the Eucla basin only goes back to the Mesozoic when accumulation of shallow water sediments kept pace with the gentle sinking. No Eucla Basin existed in Palaeozoic time. The same can be said as to the Great Artesian Basin which started as a gentle depression at the close of the Permian and reached its greatest development during the Mesozoic. By the late Palaeozoic the several ancient crustal blocks which were completely welded, subsided differentially to cause this huge sag in the Australian Platform. Structurally the «Great Artesian Basin» is a Mesozoic feature. It does not make sense to use the term «Great Artesian Basin» for any older tectonic unit.

When trying to subdivide the Australian Platform into crustal blocks, it must be remembered that all those crustal blocks which up to late Carboniferous time were moving horizontally and sometimes also up or down along the boundary faults lost their individuality and were firmly united before the Mesozoic. The Australian continent was solidly consolidated. All activity along the boundaries (geosutures, geofractures, geosynclines and rifts) slowed down or ceased completely. The difficulty is now that extensive deposits of younger epochs covered the boundaries of the ancient blocks. In spite of the intensive drilling activity in the search for petroleum many boundaries are therefore still insufficiently known.

The writer is here mainly concerned with one category only of block boundaries: the geosuture. It is not intended to consider the blocks themselves or any other boundaries in any detail. To do this it is advantageous to imagine all the post Palaeozoic sediments, which mask many old structural features, stripped from the Australian Platform, and to work with a palaeotectonic map for the close of the Palaeozoic.

Such a tentative map is fig. 1.

#### PRESENT NOMENCLATURE OF MAJOR TECTONIC ELEMENTS OF AUSTRALIA

HILLS (1956a, b, 1963, 1965) has published several maps showing the subdivision of Australia into tectonic elements. HILLS' nomenclature applies to the upper levels of the crust only. He mixes topographic, geomorphologic and geologic terms, as can be seen from the following selection of names from his maps.

(1956a, fig. 1)	(1965, fig. 1)
Kimberley Plateau	Kimberley Block
Barkly Tableland	Fitzroy Trough
Desert Basin	Canning Basin
South Eastern Highlands	Darling Scarp
Redan Fault	King Leopold Mobile Zone
Darling Lineament	Carpentaria Sub-Basin

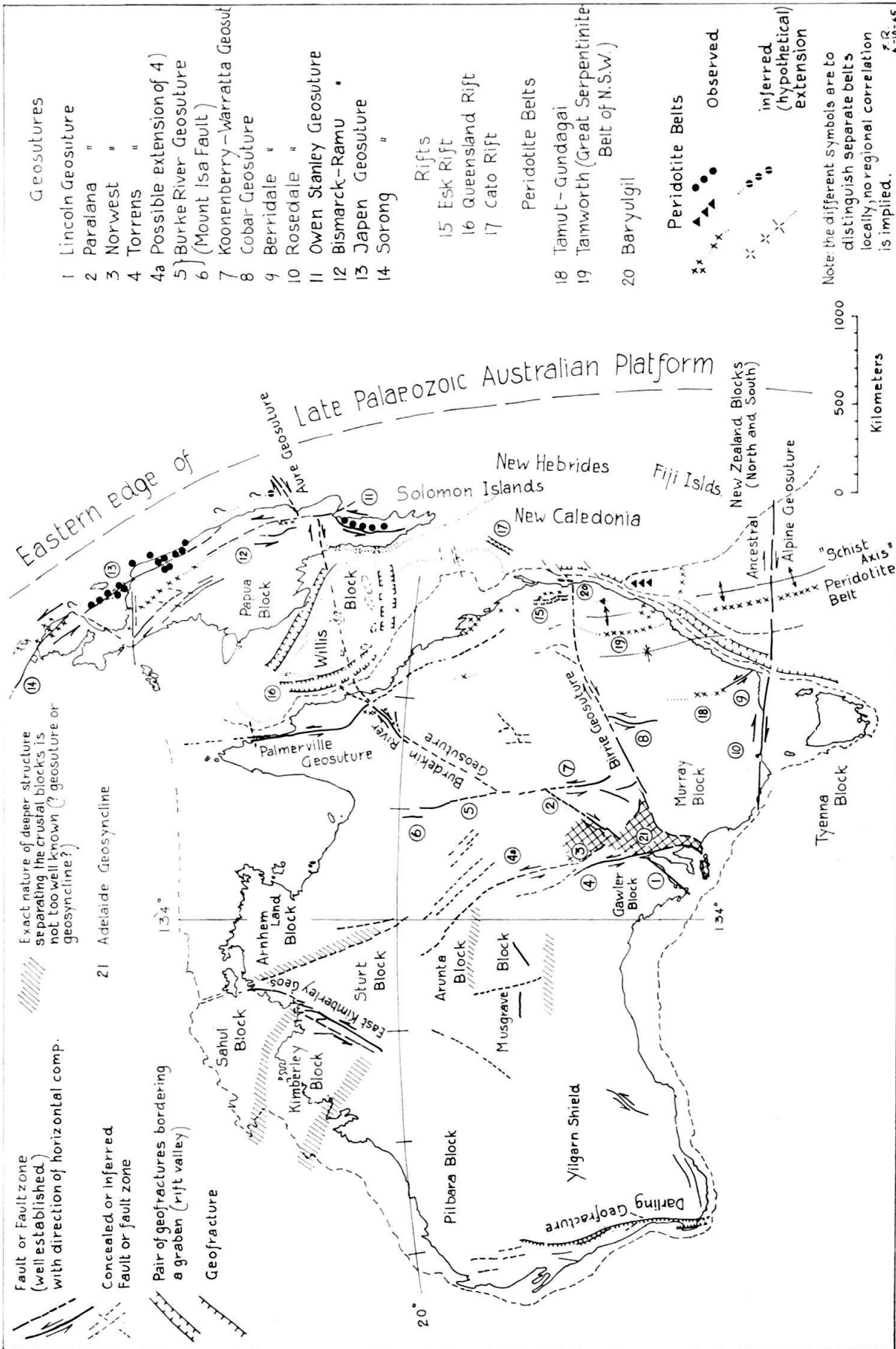


Fig. 1. Tentative palaeotectonic map of Australasia for the close of the Palaeozoic. The island of New Guinea was not restored internally to its pre-drift configuration and no allowance is made for any post-Palaeozoic sediment accumulations and deformation, because none of the reconstructions which were contemplated, are entirely satisfactory. The most plausible hypothesis for parts of New Guinea is shown in figs. 3 and 4. Queensland and Cato Rifts after KRAUSE (d, in press).

Cobar Spur

Stuart Shelf  
 Gawler Platform  
 Pine Creek Geosyncline  
 Pilbara Nucleus

As long as only the uppermost portion of the crust is considered the terminology of HILLS is quite satisfactory, as it is a practical description of structural units or sedimentary provinces which can be readily distinguished on the surface. For instance, the contact between the Yilgarn Shield and Eucla Basin is erosional. In a wide belt along its western and northwestern margin the Eucla Basin covers the Yilgarn Shield with a veneer of Cretaceous and Tertiary sediments which can be so thin that the contacts drawn on maps are rather arbitrary. Structurally, under the Eucla Basin or at least under the largest portion of it, is still the Yilgarn Shield. The Eucla Basin is not a geotectonic unit and should not figure on geotectonic maps in the same category and same prominence as genuine crustal blocks.

The writer intends to use only the following tectonic terms for continental crustal blocks and their boundaries.

- Platform: welded assemblage of crustal blocks.
- Shield: portion of a platform or an elevated individual block which forms a gently domed plateau where Precambrian rocks are extensively exposed. «A continental block of the earth's crust that has been relatively stable for a long period of time, and has undergone only gentle warping in contrast to the strong folding of bordering geosynclinal belts. Mostly composed of Precambrian rocks» (Glossary, 1960). «...a relatively large part of the earth's crust which manifestly has not been seriously disturbed since the Precambrian» (DE SITTER, 1964).
- Geosyncline: «...elongate, subsided, strongly folded basins, containing thick sedimentary series» (DE SITTER, 1956), or «...those accumulations of sediments of great thickness which have been severely folded».
- Geofractures: large-scale gravity faults which usually occur in pairs forming the boundary faults of a graben or rift valley; their traces are mostly parallel.
- Rift: «...a depressed strip between faults» (DE SITTER, 1956) associated with broad vertical movements along gravity faults and with regional doming.
- Basement: «...comprises those igneous and metamorphic rocks which underlie unconformably the unmetamorphosed, dominantly sedimentary rocks of a region» (PRUCHA et al., 1965).

The writer will try to avoid several terms too vague to be of any meaning in tectonics or because those terms are synonyms of well established ones. Among them are «lineament», «mobile zone», «nucleus», «craton», and «median belt».

All the basins distinguished on the Australian Platform will be considered as the uppermost, youngest layer of the platform or of an individual crustal block like chocolate icing or cream capping a large and tall piece of cake. Thus the Kimberley Basin of the Tectonic Map (1960) is an integral part of the Kimberley Block.

DISCUSSION OF THE PALAEOTECTONIC MAP FOR THE CLOSE  
OF THE PALAEOZOIC (fig. 1).

During late Palaeozoic time activity along the geosutures declined steadily and ceased completely for many towards the end of the Era. The geosutures observed today on the Australian continent have been, with only few exceptions, inactive since the Mesozoic. A few still had some minor displacements up to the late Mesozoic but all the large-scale fault movements occurred definitely in Pre-Mesozoic time. To study the ancient geosutures, a palaeotectonic map of the close of the Palaeozoic is needed. Such a sketch map is shown in fig. 1. It is an experimental palaeotectonic map of very unequal quality because some later deformations could be restored, others not. The many crustal blocks and fragments of crustal blocks which broke off and drifted away from the east side of the Australian Platform during the Mesozoic have to be united again with the platform. The writer did this reconstruction following ideas of DU TOIT (1937) and CAREY (1958) for New Guinea and New Zealand and indicated in a very general way where the Solomon Islands, New Caledonia, the Fiji Islands and the New Hebrides were originally located.

NEW ZEALAND

Some of the necessary steps to restore New Zealand to the position it had at the close of the Palaeozoic are shown in fig. 2, which is a slightly modified version of a similar set of illustrations by CAREY (1958). WELLMAN (1955/56) has convincingly demonstrated that the cumulative right displacement of the Alpine Fault amounts to 300 miles (480 kilometers). To restore the relative position of the fault blocks to that occupied at the end of the Palaeozoic, the displacement must at first be reversed (fig. 2). Then the powerful drag along the edges of both fault blocks has also to be eliminated by smoothing out and stretching the bent structures. As CAREY (1958) emphasised, all those movements of the different crustal blocks are interrelated and should be dealt with as a unified system in all restorations. However, as the original position of many smaller continental crustal blocks and fragments of blocks is still only very vaguely known, only the large crustal blocks will be considered here.

Many of the palaeogeographic arguments in favour of moving the restored New Zealand blocks back to the location along the eastern coast of Australia adjacent to the Sydney Basin and the New England block of today are listed by CAREY (1958), but the strongest evidence is definitely provided by the perfect fit of the zones of rock types and structural belts. In the same order and with similar spacing we find the «Basement High», Palaeozoic Basin (Southland Syncline, corresponding to the Sydney Basin), Peridotite Belt and the «Schist Axis» (see fig. 2). The structural grain checks too. At the same time all palaeogeographic problems find an answer. The riddle of «Tasmantis», «Austzealandia» and «Euronotia» is solved. Moreover, perhaps the most powerful clue is furnished by the matching double peridotite belts. As in many other alpine-type mountain chains (HESS,



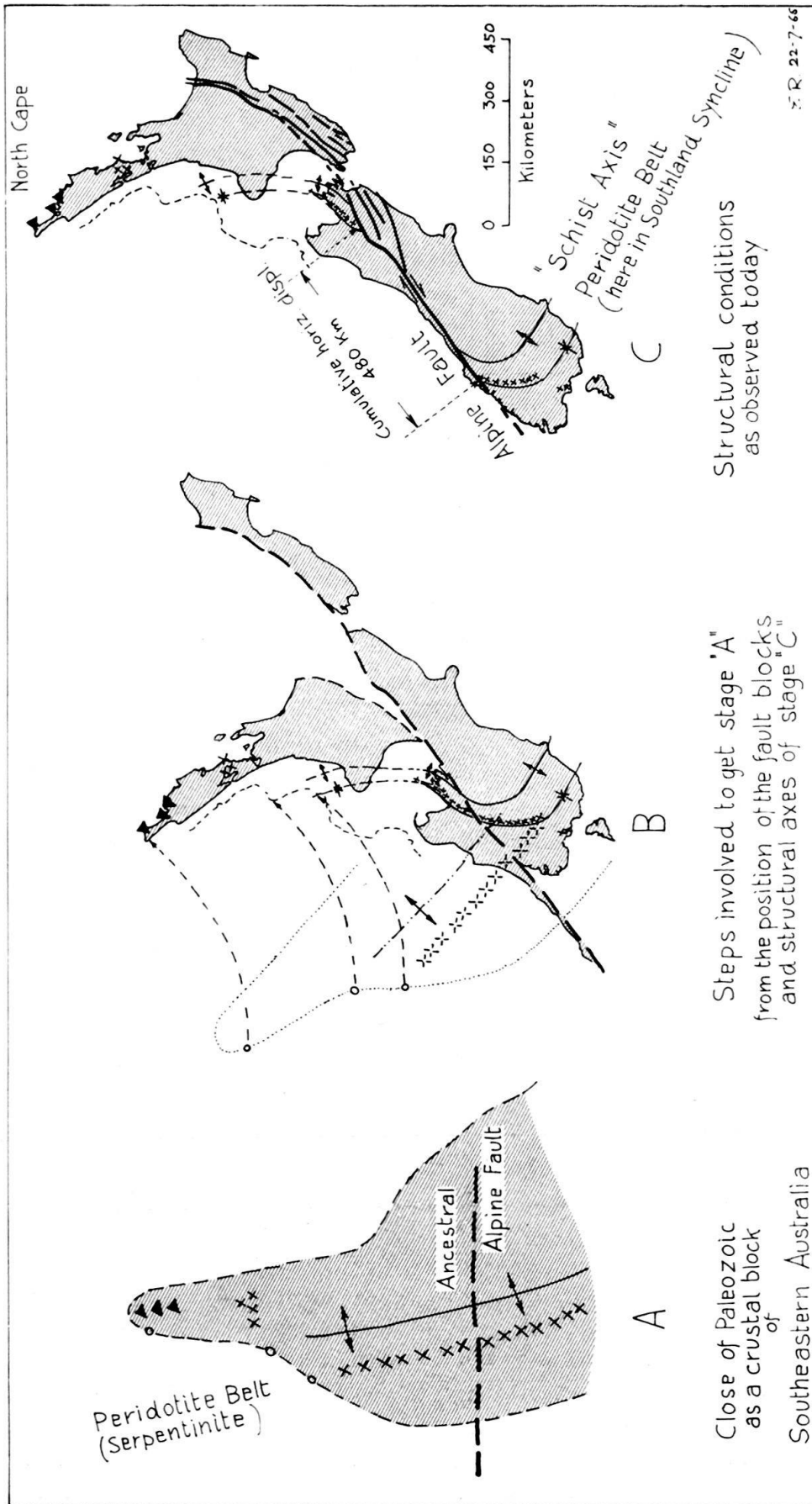


Fig. 2. Restoration of Paleozoic New Zealand.

1948, 1955) the axial zone is characterised by two more or less parallel peridotite belts at a distance of 160 to 200 kilometers from each other.

In New Zealand the western belt is prominently developed (Mt. Dun, Nelson). The corresponding one on the Australian Platform is the «Great Serpentinite Belt» of New South Wales, also called the Tamworth Serpentinite Belt. About 180 kilometers east of the main (western) serpentinite belt of New Zealand are the remains of the North Cape Peridotite Belt which finds its equivalent in the Baryulgil Serpentinite Belt of New South Wales. The Tamworth and Baryulgil belts are 200 kilometers apart. The relationship is even closer when the remnants of another, transverse belt of ultramafic rocks is analysed.

#### NEW CALEDONIA, SOLOMON ISLANDS, NEW HEBRIDES AND FIJI ISLANDS

All these islands are small blocks or fragments of blocks consisting of continental crustal material (MENARD, 1964) which broke off from the east coast of the Australian Platform and drifted to the east carried by a subcrustal flow (HESS, 1962). They are surrounded by oceanic crust or material derived from oceanic crust. All older views stating that the Pacific Ocean proper starts somewhere far out to the east along the east edge of the island arcs or east of MACDONALD'S (1949) Andesite Line are untenable (MENARD, 1964). The crust under the Tasman Basin, Coral Sea Basin or South Fiji Basin is oceanic.

It will not be attempted here to restore the islands to their original, pre-drift position, because the writer did not study their geologic history in sufficient detail. On the map, fig. 1, only the general area in which they might fit in the space between the ancient New Zealand Blocks in the south and New Guinea in the north, is indicated.

The well known peridotite belts of New Caledonia and the Solomon Islands appear here as telltale thread marks indicating that one day it should be possible to align and reassemble the island fragments correctly.

#### NEW GUINEA

Today, twenty years after, DU TOIT'S statement (1937, p. 190) that «Everyone seems to have regarded this great island as an integral and northern part of the Australian mass, rigidly anchored thereto, a view fostered by the shallowness of the parting seas», is still very true, with the only reservation that instead of «everyone», «almost everyone» should be substituted. Among the few who are convinced that New Guinea in its present relative position to the Australian Platform is not «rigidly anchored thereto» are CAREY (1956, 1958), and THOMPSON (1965).

Indeed very few geologists accepted DU TOIT'S concepts and considered restoration of New Guinea along the coast of northeastern Queensland in spite of his masterly argumentation. Today all of DU TOIT'S arguments in favour of replacing New Guinea in its original location east of Queensland in pre-Middle Mesozoic time are still valid. Moreover, in the many papers presenting the results of petroleum exploration in Papua and New Guinea during the last twenty-five years very weighty facts were added.

All the reasons in favour of a restoration of New Guinea to a position as proposed by DU TOIT (1937, fig. 7) and as advocated in this paper (figs. 1, 3, 4) are listed below.

(a) «Its present position is anomalous in that its pre-Tertiary grain is strongly discordant to that of nearby Australia» (Du Torr, 1937).

(b) If it is replaced as shown in fig. 1, then all the following observations will find an easy explanation:

1. No sediments and structural deformations which could be ascribed to the Tasman Geosyncline of eastern Australia have yet been discovered on the island of New Guinea, and no phases of Palaeozoic folding are known in Papua and New Guinea with the sole exception of some weak indications in the Vogelkop (north-western New Guinea), a lack which is at once clearly understood when its pre-Mesozoic position is considered.

2. Its trend-lines agree closely with those of the mainland, whether affecting the oldest or youngest formations present.

3. The northern prolongation of the Palmerville Geosuture should cut through the present New Guinea island but nowhere was such a fault running through New Guinea in the predicted direction observed, because the ancient, pre-Mesozoic geosuture never even touched New Guinea (see fig. 1).

4. Some of the most conspicuous structural features as peridotite belts, geosutures and fold belts are aligned parallel to similar features on the east coast of Australia and form, together with the restored festoons of island groups (Solomon Islands, New Caledonia, New Hebrides and Fiji Islands) arc-like bands (HESS & MAXWELL, 1953) between New Guinea and New Zealand parallel to the grain of the mainland (Fig. 1).

5. The Willis Block, the presently drowned continental crustal block, the surface of which forms the Queensland Plateau (KRAUSE, 1965) was during the Palaeozoic and early-Mesozoic periods the central part of a landmass consisting of the South New Guinea Geanticline (VISSER & HERMES, 1962), the Oriomo Spur (Australasian Petroleum Co. Ltd., 1961) and of the easternmost portion of the basement under the Great Barrier Reef (fig. 4).

6. Rivers and wind transported the erosional products from this landmass towards west and east into the gently dipping slopes of the elevated block and farther on into the adjoining shallow seas. Most of the clastics of the Palaeozoic and especially early Mesozoic of northeastern Queensland were derived from the east. Furthermore the direction of transport of the detritus deposited within the Upper Palaeozoic and Mesozoic rock units of the Central New Guinea stratigraphic province (VISSER & HERMES, 1962, fig. II-11), indicate a source from the south, from some part of the Australian continent.

Always provided that the relative position of New Guinea and the Australian Platform has not changed since Palaeozoic time and was then as it is today, this source of supply is, however, not easy to explain for the Vogelkop.

That a difficulty exists here was well realised by VISSER & HERMES (1962) who write:

«In the Lenggoeroe area and Vogelkop supply from the Australian continent could be expected to produce sediments in which the facies would change in a northerly or north-westerly direction. In fact, however, lines of similar facies still

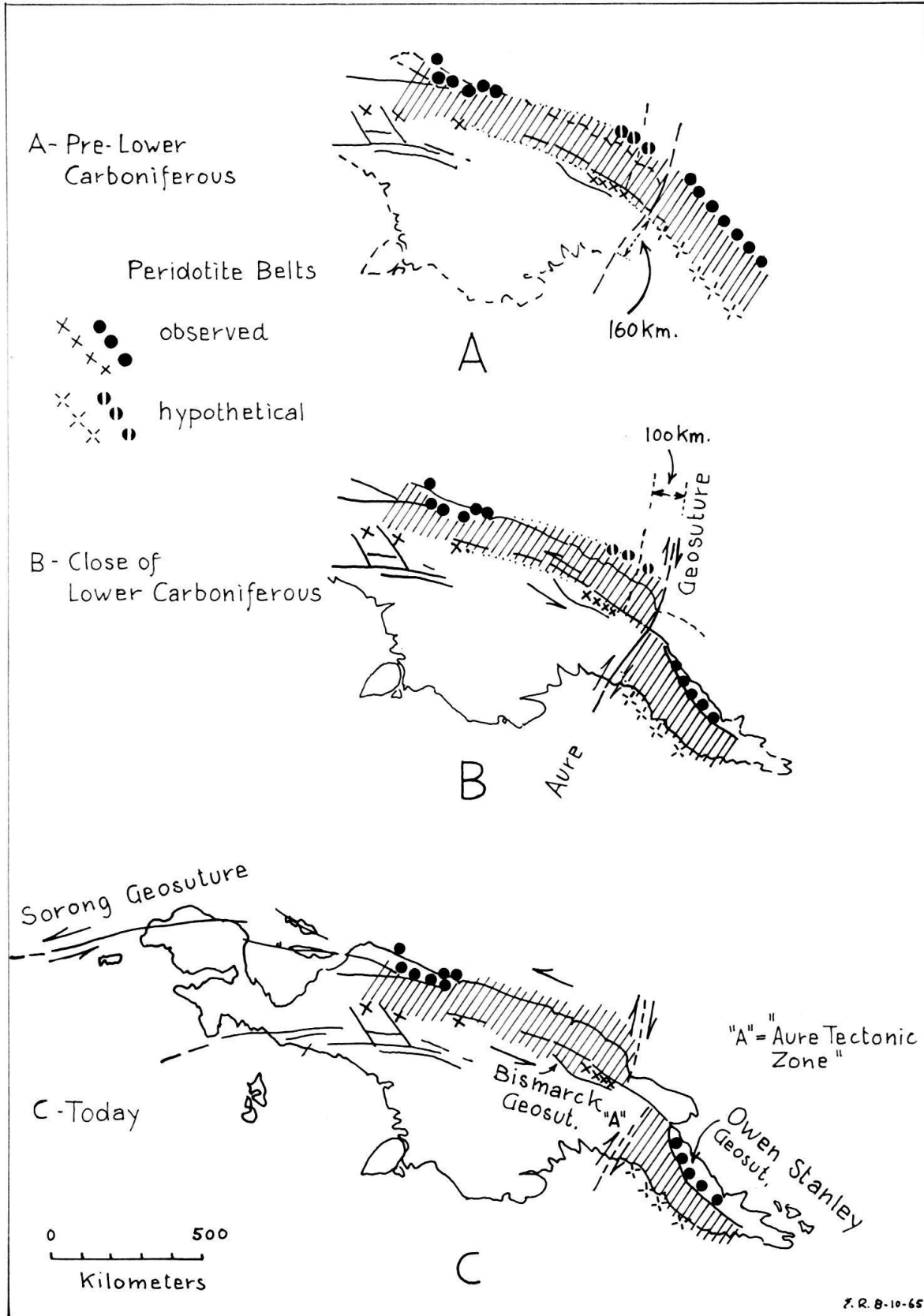


Fig. 3. Restoration of Eastern New Guinea to its pre-lower Carboniferous conditions and interpretation of «Aure Tectonic Zone».

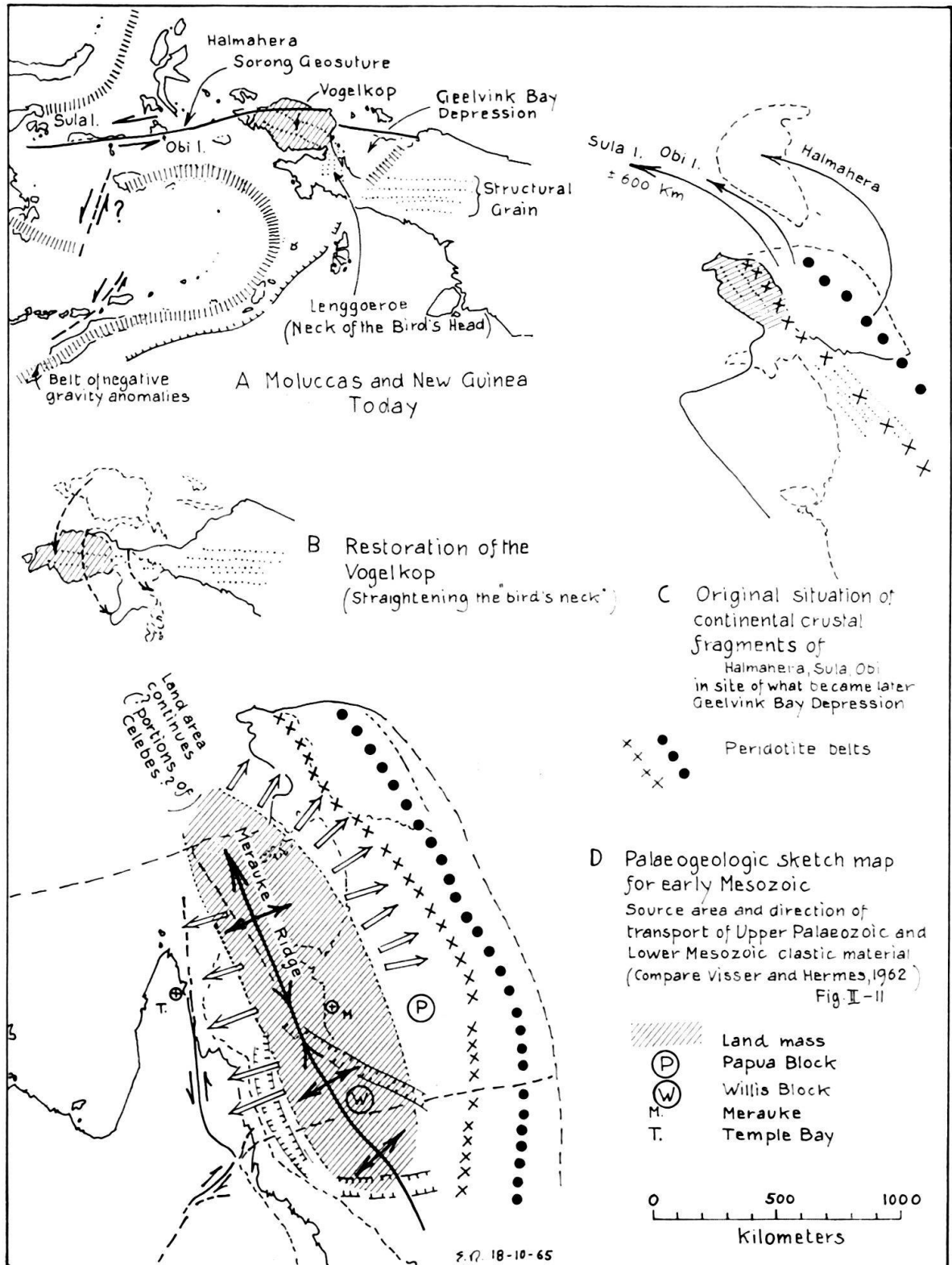


Fig. 4. Restoration of the Vogelkop (West Irian) to its early Mesozoic position.

trend parallel to the boundaries of the province. The simple solution that detrital material was derived from the Misool-Onin-Koemawa province has to be discarded since Misool at least was submerged from Triassic to Cretaceous time. Supply from a northern direction seems to be excluded by the fact that, at all events in the Juro-Cretaceous, the clastic content of the rocks decreases towards the north.»

This problem finds an easy solution if New Guinea is restored to its original pre-Mesozoic position (figs. 1, 4).

7. The major late Cretaceous and especially Tertiary faults of New Guinea are the expression of a tremendous drag towards the west combined with a small anti-clockwise rotation. This was well demonstrated by CAREY (1958, 1965) and KRAUSE (1965a, b; in press c, d). However, in the structural grain of New Guinea some strong, old, apparently Palaeozoic fault zones are prominent. Those Palaeozoic faults caused by interference some irregularities in the younger fold trends, some notches and changes of direction in the fold axes (Aure Tectonic Zone). It can be shown that the above mentioned old faults of New Guinea match perfectly with some major late Lower Palaeozoic fracture systems of Australia, especially with the Burdekin River Geosuture (fig. 3).

8. The nearest occurrence of rocks similar to the beds of the indurated, fine-grained, laminated rocks of the Kariem Formation (Upper Cambrian?) of southern New Guinea (VISSER & HERMES, 1962) is, according to the present reconstruction at Temple Bay (Bold Head), on the east coast of the Cape York Peninsula, north-eastern Queensland (fig. 4). From descriptions in private reports the assemblage of rocks found in Temple Bay, the dark-grey to black, dolomitic limestones, finely laminated siliceous claystones, the cherty intercalations and dikes of quartz porphyry is identical to the one reported from the well sections (especially Merauke No. 1) and type locality of the Kariem Formation. At the close of the Palaeozoic the two areas were situated on the slopes east and west of the elevated Willis Block, symmetrical to its northwest trending axis (see fig. 4).

THOMPSON & FISHER (1965, p. 32), in their discussion of the geotectonics of New Guinea and Papua, consider the independent movements of «detached continental fragments or slices». They clearly distinguish between continental and oceanic crust and visualise the continental blocks as deeply cut segments of the crust reaching far down, possibly into the upper mantle. They emphasise the importance of contemplating displacements along large-scale strike-slip faults in trying to understand some of the complex structural patterns of Papua and New Guinea. The explanation given here (fig. 3) for the deformation of the younger beds in the Aure Tectonic Zone is already suggested by THOMPSON & FISHER (1965).

The inferred projections and correlations of the peridotite belts of Papua and New Guinea as shown in figs. 3 and 4 and the postulated movements along the Aure and Owen Stanley (Bismarck) Geosutures are strictly a working hypothesis which is established to explain all the known distribution of rock provinces and structural deformations.

According to this hypothesis the sense of movement of the Burdekin River and Aure Geosutures is identical and the amount of visible cumulative displacement is comparable. The two geosutures might very likely belong to the same fracture system and have originally formed a single fault zone as suggested in fig. 3.

Thus the dog-leg in the fold belts of the «Aure Tectonic Zone» is the secondary effect of displacements along a masked and deep-seated geosuture and finds its parallel in the dog-leg created by the Burdekin River Geosuture (fig. 12).

#### RESTORATION OF THE VOGELKOP (WEST IRIAN) TO ITS EARLY MESOZOIC POSITION

When looking at a geologic or structural map of the Moluccas or West Irian (UMGROVE, 1949; VISSER & HERMES, 1962; VISSER, 1965) the conclusion that the present configuration is the result of great horizontal crustal movements (KRAUSE, 1965b) cannot be avoided. From the maps and descriptions of VISSER & HERMES (1962), a cumulative left horizontal displacement of Sula Island along the Sorong Geosuture of 600 kilometers is quite evident.

It is not intended to discuss here the development of the island arcs of the Indonesian Archipelago. Although all movements are interrelated only the structural history of the westernmost tip of West Irian will be considered.

Starting with the rather anomalous relation of the Vogelkop with the Central Province of New Guinea in which a very pronounced dog-leg, formed by the Lenggoeroe Fold Belt (the neck of the Bird's Head), is clearly shown as a most striking structural feature on all geologic maps of the island of New Guinea (GLAESSNER, 1950; VISSER & HERMES, 1962; KRAUSE, 1965b), and taking into account the puzzling location of the Geelvink Bay Depression, the writer tried to analyse the deformation step by step and came up with the following working hypothesis:

1. The Vogelkop and the folds of Lenggoeroe were originally a direct and straight continuation of the main New Guinea trend as expressed in the Central Range (fig. 4).

2. If the crustal masses of the Vogelkop and Lenggoeroe are shifted back as done in Stage B of fig. 4, the Geelvink Bay gets much larger. The sharp bend in the Lenggoeroe Fold Belt occurred in Tertiary times, after the fragments of continental crust, called today the islands of Sula, Obi and Halmahera, broke off from New Guinea at the site of the deep Geelvink Bay Depression of today. After these three crustal fragments drifted away and were carried passively by an upper mantle current (HESS, 1962) towards the west (relative to West Irian) they left a deep scar which is the ancient Geelvink Bay.

3. Further deformations related to the birth of the Moluccas arcs severely bent and pressed the narrow connection (Lenggoeroe) of the Vogelkop with the Central Range into the depression of the ancient Geelvink Bay and translated the Vogelkop also towards this ancient deep.

It is no coincidence that the islands of Halmahera, Obi and Sula were each displaced 600 kilometers to the west along the Sorong Geosuture.

4. The reconstruction proposed in fig. 4, is in perfect harmony with all that is known from sedimentation, stratigraphy, facies distribution and structure of West Irian and Halmahera.

#### DISCUSSION OF SOME AUSTRALIAN GEOSUTURES

The eighteen geosutures shown on the map, fig. 1, very likely represent only a little more than half of all the geosutures which will eventually be discovered on the Australian Continent. Only few of the geosutures named have ever been de-

scribed in detail, many are merely vaguely mentioned in the literature as faults or lineaments having some transcurrent movement. From his own observations in the field the writer knows no more than small parts of the East Kimberley and Palmerville Geosutures. However, during a geologic survey for Arco Limited in the exploration for petroleum, he had the welcome opportunity to examine short stretches of a few faults building up the East Kimberley Geosuture in the general area of Cockatoo Spring, south of Joseph Bonaparte Gulf (Western Australia, near the boundary with the Northern Territory).

The outstanding quality of the exposures in this area made up for the lack of a more widespread sampling. Therefore, the writer shall mainly discuss the findings of field observations in the Cockatoo Spring area and, of all the other Australian geosutures mentioned in the literature, he shall only make short remarks about some of the better known ones.

The best known of all, the Alpine Geosuture of New Zealand, is so well described and illustrated (WELLMAN, 1953, 1955, 1956) that it is now a classic example of a great strike-slip fault and well represented in all textbooks. The reason why the Alpine Geosuture should be so famous the world over and why other similar structures of comparable size on the Australian Continent of today should be rather forgotten lies in the fact that the Alpine Geosuture is still very much active today and spectacularly expressed in the topography, whereas the ones on the Australian Continent are all «fossil» now. Most of them have never been reactivated since their last large displacements in Middle to late Palaeozoic times or had only a weak rejuvenation during the Mesozoic period. This fact is best illustrated by comparing earthquake maps of Australia and New Zealand (GUTENBERG & RICHTER, 1954; RICHTER, 1958).

In central Australia it was SPRIGG (1961, 1965) who early realised the controlling influence on all surface structures of the great faults or lineaments which had predominantly a horizontal component of displacement (strike-slip faults, transcurrent movement). Judging from his descriptions and maps (SPRIGG, 1961) all these lineaments have to be classified as geosutures.

Valuable detailed information on the large-scale strike-slip faults (geosutures) of Papua and New Guinea can be found in the recent publications of the Bureau of Mineral Resources, Geology and Geophysics.

It is perhaps symptomatic for the state of structural exploration here that the first paper known to the writer which deals exclusively with a wrench fault (strike-slip fault) and discusses the evidence for strike-slip displacement was published only recently (LAMBERT & WHITE, 1965).

There is a certain reluctance in the mind of many geologists to accept the idea that, in spite of the Australian Platform looking «stable» today and consisting of welded blocks, there was a time when all the blocks moved horizontally relative to each other. A most encouraging exception is the group of geologists and engineers making detailed surveys of the ore bodies. In the excellent papers on various mines, for instance on the Mount Isa, Broken Hill, Kalgoorlie and Bendigo areas, just to mention a few, a wealth of detailed observations is presented which gives account of very complex fault zones accompanied by intense shearing, folding and by shatter-zones which can all be regarded as secondary features of powerful



horizontal displacements of crustal blocks along large-scale strike-slip faults which have to be classified as geosutures or which belong to a geosuture (see *Geology of Australian Ore Deposits*, second edition, 1965, McAndrew editor; and HILLS, 1965).

It is necessary to stress here what is well explained in many textbooks but too often overlooked, that the cross-sectional relationships of a fault only indicates an apparent displacement (M. HILL, 1947). The strike-slip faults in general and especially the large-scale ones have a very characteristic topographic expression and such distinctive geologic features (DE SITTER, 1956, 1964; HILLS, 1963) that it is not necessary to actually observe and measure the striations on the slickensides and to have the proof that two or more planar structures (BILLINGS, 1954) have been shifted horizontally to be certain that the fault considered is a strike-slip fault.

Too often a fault is described as a gravity fault only because it has an apparent vertical separation. Usually, the throw can change so rapidly from place to place and sometimes be reversed that there should be reason enough to be careful (LENSSEN, 1958; CHINNERY, 1965). Once there is certainty that the fractures are strike-slip faults the next problem is to find out their sense of movement. Here detailed observations of the joints, especially the feather joints, and of small horizontal displacements of planar features along secondary faults should be sufficient to indicate the relative direction of movement. Some good examples of Australian strike-slip faults (Giants Reef Fault, Northern Territory; Warratta Fault, New South Wales) are mentioned and illustrated in HILLS' textbook «*Elements of structural geology*» (1963).

#### THE EAST KIMBERLEY GEOSUTURE

This is perhaps one of the best exposed and best developed geosutures of Australia, mapped by all observers as a wide belt of an average width of 60 kilometers, well expressed in the topography, occupied by a complex fracture system, and bordering the Kimberley Block on the east-southeast. From a point 120 kilometers south-southwest of Halls Creek (fig. 5) the fault belt trends in a north-northeasterly direction towards the Queens Channel (southeastern Joseph Bonaparte Gulf). In the lowlands near the Queens Channel the largest part of the belt is masked by younger sediments (Upper Lower Carboniferous to Recent) and from this locality towards the north, in the area of Port Keats, only portions of the easternmost faults of the belt are visible. North of the mouth of the Daly River the geosuture is lost under the Timor Sea. The southern, well-exposed portion of the geosuture is 550 kilometers long up to the Queens Channel. Its northern continuation measures 250 kilometers.

Of all this 800 kilometers long and 60 kilometers wide geosuture, which in a cross section would show up to a dozen major and many more minor strike-slip faults, a few very small and isolated parts only are known in detail (fig. 5). The writer investigated a 48 kilometers long and 12 kilometers wide stretch of the Cockatoo Fault and its splays from the area south of Thompson Spring (figs. 6, 7) to a point 36 kilometers north of the Spring. He also visited several isolated outcrops within the faulted belt where fault planes are easily accessible for a detailed study.

The first reliable description and illustration of the East Kimberley geosuture is given by TRAVES (1955) who named it the «Halls Creek Mobile Zone». It separates

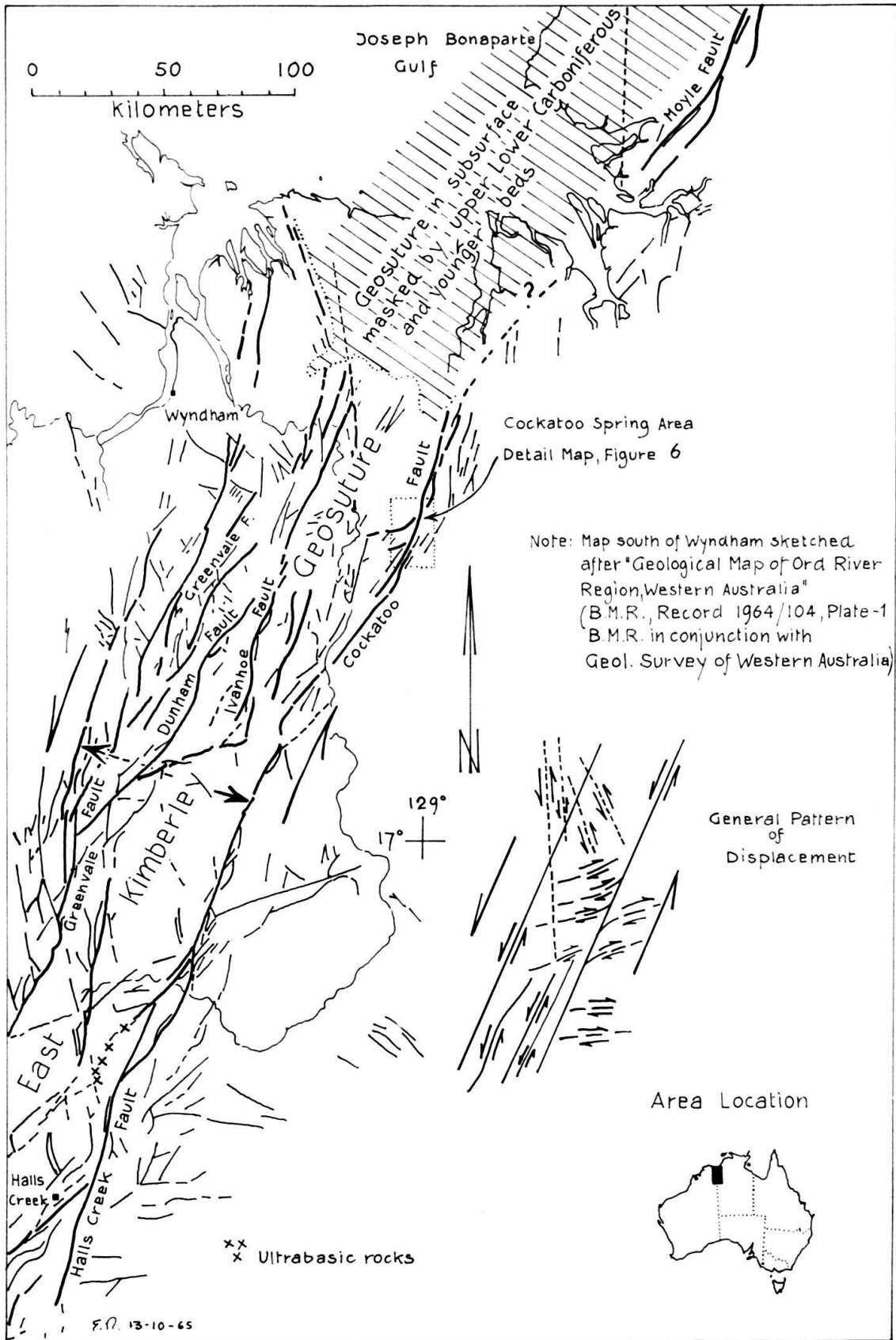


Fig. 5. Fault pattern in central part of East Kimberley Geosuture. Base map reproduced by courtesy of the Director, Bureau of Mineral Resources, Geology and Geophysics, Canberra.

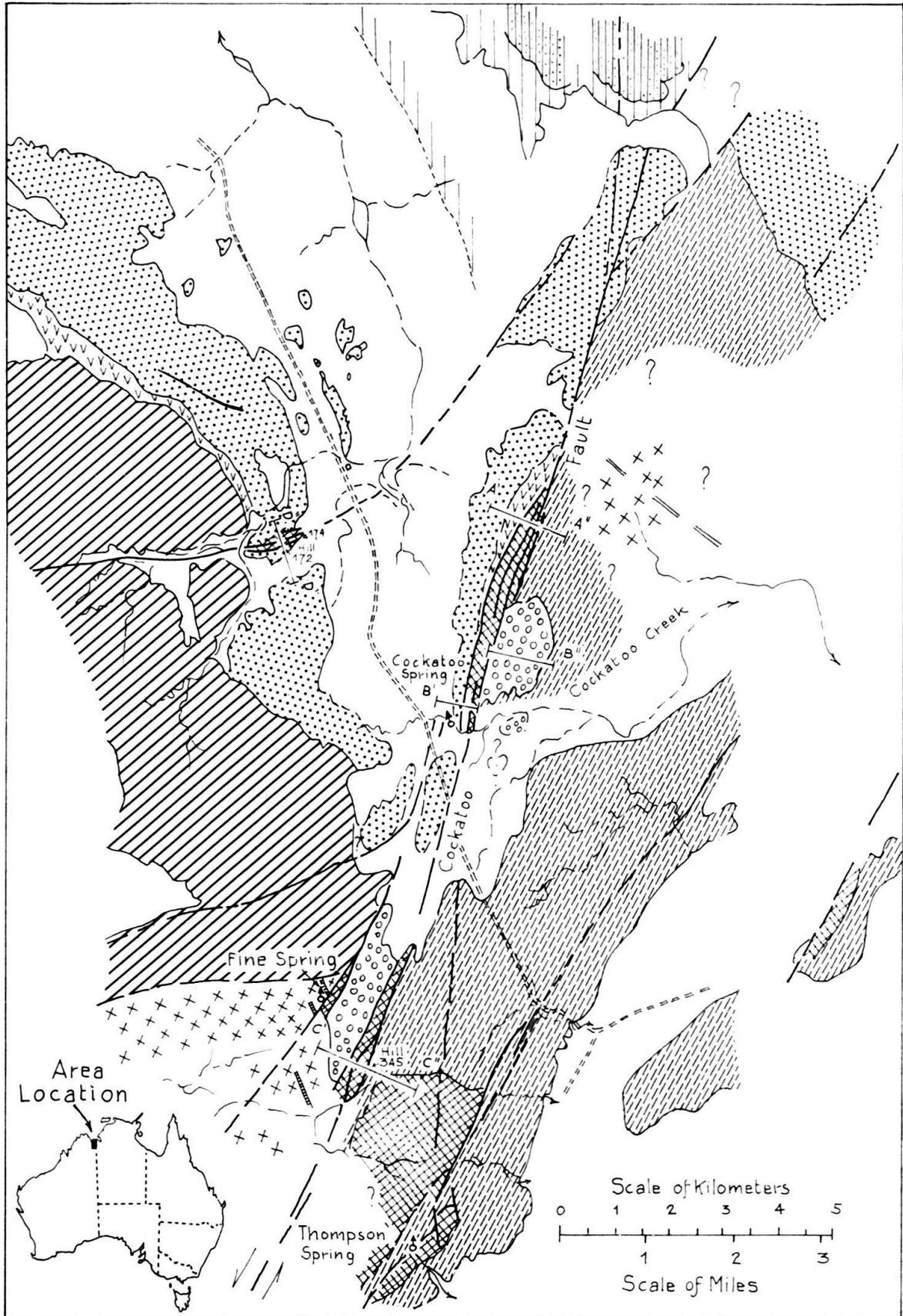


Fig. 6. Geologic sketch map of area of Cockatoo Spring, type locality of Cockatoo Fault. For legend see fig. 7.

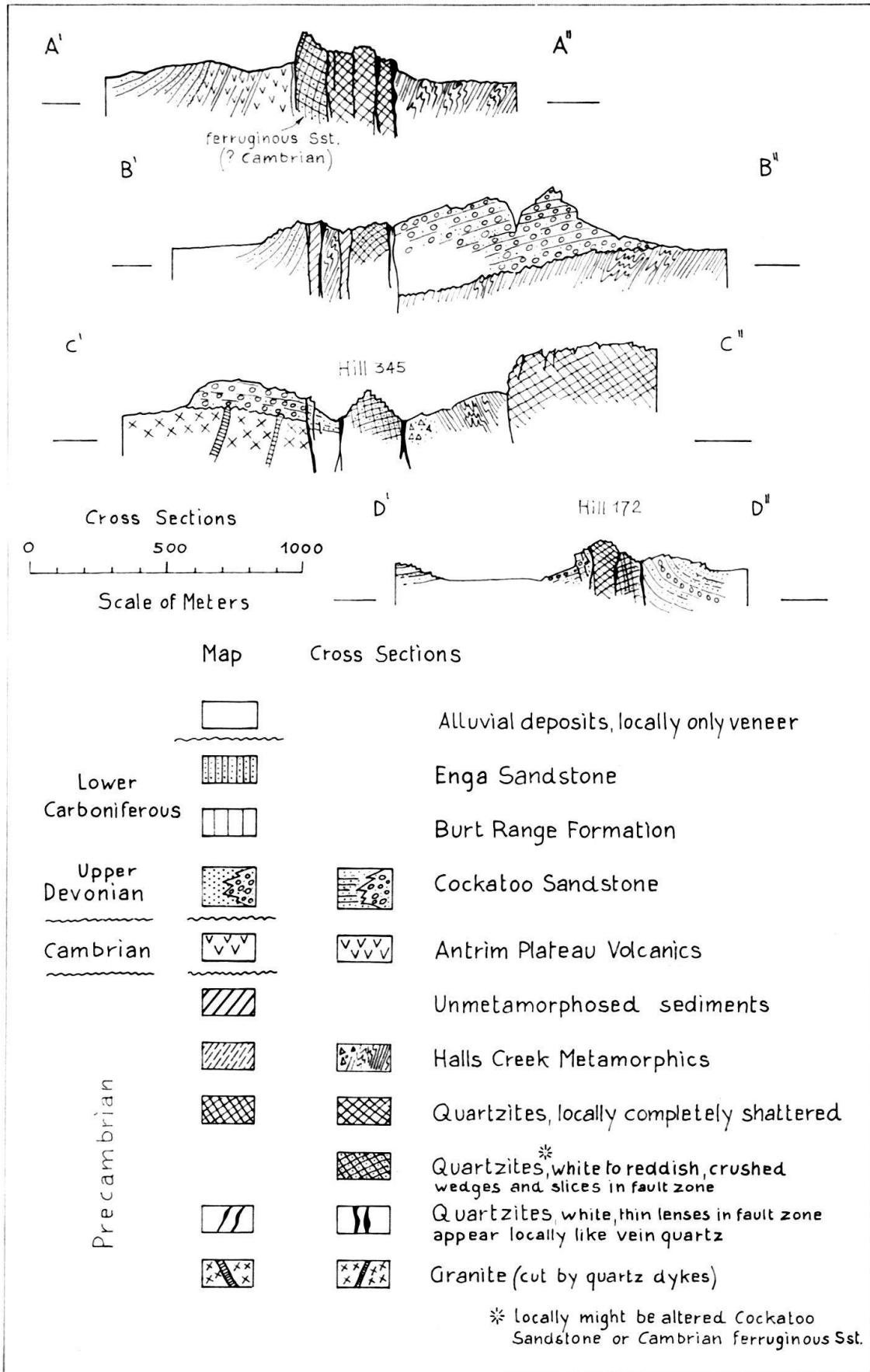


Fig. 7. Cross sections, area of Cockatoo Spring.

the Kimberley Block in the west from the Sturt Block in the east. FAIRBRIDGE (1953) called it the «Ord Fault», and in the «Geological Notes in Explanation of the Tectonic Map of Australia» (B.M.R., 1962) it is referred to as the East Kimberley mobile belt. It is beyond the scope of this paper to analyse the merits of the nomenclature accepted in various publications. The writer endeavours to use only established terms and very rarely introduces a new one to avoid possible misunderstandings.

The Cockatoo Fault (TRAVES, 1955; DRUMMOND, 1963) is one of the large-scale strike-slip faults forming the eastern edge of the geosuture (figs. 5, 6, 7). The type locality is in the elongate, sharp ridge north of Cockatoo Spring (fig. 6). This 5 kilometers long ridge which at its widest place measures 0.5 kilometers from edge to edge, is built by one of the many huge lenticular wedges within the fault. It consists of four vertical slices of fractured or crushed and partly recrystallised quartzite. Where well-preserved the fault planes are covered by highly polished silica. As seen with a hand lens in cross section, the rocks a few centimeters or millimeters from the fault plane are finely brecciated or pulverised and cemented by silica. Excellent horizontal slickensides were observed on all fault planes which are still intact. In the white or reddish silica-coating of the fault planes the parallel striations, grooves and ridges stand out perfectly. It should be emphasised that with the sole exception of large lenses of white, crystalline quartzite (vein quartz?) which have a shape like huge pumpkin seeds, all the slickensides which were observed show horizontal striations with a rake of, at the most, two to three degrees. Some of the polished fault planes mirror the sun and are thus, if the position of the observer and the sun are right, visible from a far distance.

In the fault blocks adjacent to the fault plane the beds may either be steeply tilted as if influenced by a powerful drag or not disturbed at all, and show only a gentle tilt (fig. 7, Sections A'-A'' and B'-B''). In some of the slices within the wedge the rocks may still have the bedding planes preserved, although they are broken into small cubes. Frequently the only indication of the bedding in the white quartzite are stringers of white quartzite pebbles. When walking on the crests of the ridges within the wedge the observer receives an impression of very intensive shearing, crushing, shattering and dynamic metamorphism. All the transitions can be recognised, from unaltered, light ochre or reddish, cross-bedded Cockatoo Sandstone to a recrystallized white quartzite in which the original bedding and cross-bedding are rather difficult to distinguish. That the faults are all more or less vertical is clearly visible in the deep gullies cutting through the ridges or in the cracks left after the gouge has been eroded.

North of Cockatoo Spring along the trace of the easternmost Cockatoo Fault, 20 to 30 meters long lenses of white crystalline quartzite are exposed. Many of the slickensides seen on the «rounded bellies» of these lenses are vertical or oblique. The lenses seem to have no connection with a sheet or band of quartzite farther down in the fault, they appear to have been sheared off by necking. The most plausible explanation regards the isolated white quartzite lenses as severed lenticular swellings of deeper quartz veins in the fault. During the last strong movement along the fault the lenticular body got so near to the surface that the direction of least resistance in which the stress on the lens could be released was upwards to the

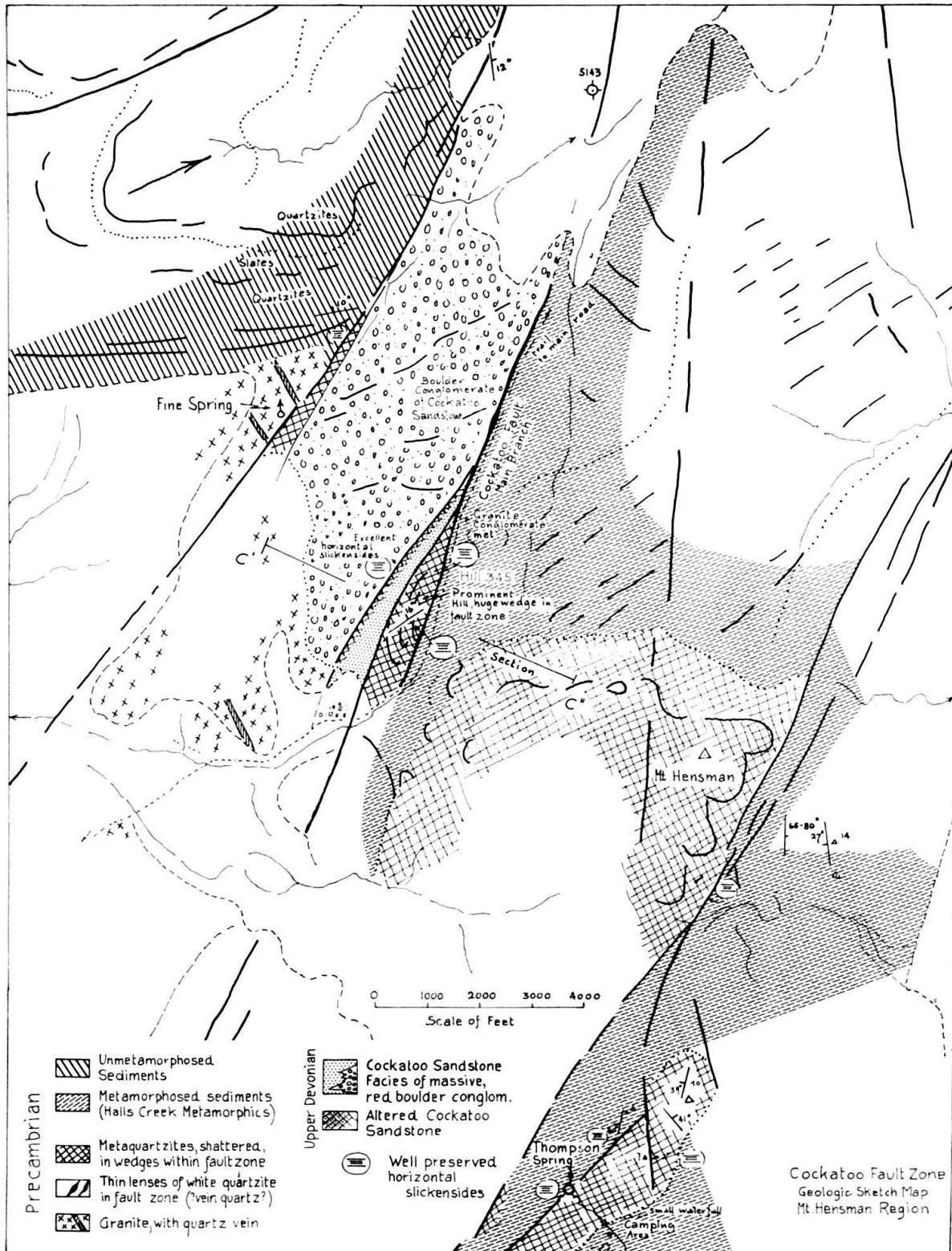


Fig. 8. Sketch map of Cockatoo Fault in Mt. Hensman region.

surface. In a very similar way a ship built for the polar seas, because of the design and the special profile of the hull, is pushed up by the pressure of the pack-ice and not crushed by it. On map fig. 6, three springs are shown. The three are directly related to the fault system. They emanate where the ground water which is dammed

by a fault block can spill over this dam into a depression. Many more springs are known from the East Kimberley Geosuture. All are related to the fault system in the same way.

A most spectacular wedge within the Cockatoo Fault is Hill 345 (figs. 6, 7 and 8), which lies 6.5 kilometers south-southwest of Cockatoo Spring. It can easily be reached from the Wyndham-Nicholson road by a new track built as a survey road for the Ord River Project. By a system of secondary faults and joints the white quartzite of the hill is sliced up in more or less rectangular blocks, some a little smaller, some larger than one cubic meter. Here too, all the slickensides which the writer could observe had horizontal striations.

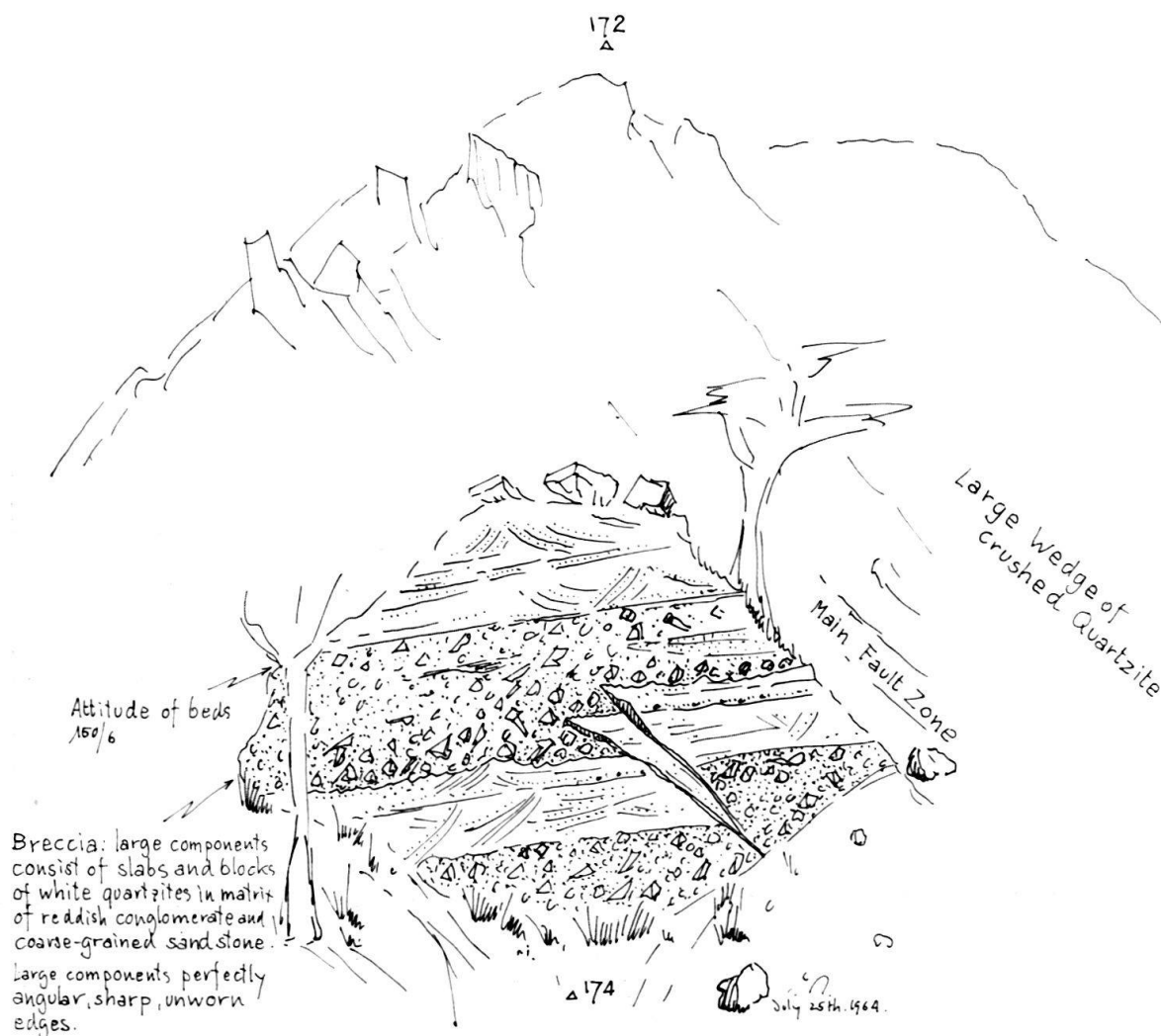


Fig. 9. Sketch of outcrop, station 174, showing faulting contemporaneous with Cockatoo Sandstone sedimentation.

Hill 172, another fault wedge in the Cockatoo Spring area, is located 4.5 kilometers northwest of the spring in a secondary west-southwest fault (fig. 6, section D'-D''). Here the Cockatoo Sandstones of the south side are only gently tilted but on the north side, adjacent to the fault wedge, they exhibit steep dips related to a

strongly marked drag. On the north side too, as a slice of the wedge, are vertically dipping ferruginous quartzites which might possibly belong to the Cambrian (fig. 6, section D'–D'').

Fault movements contemporaneous with sedimentation are demonstrated in an outcrop of Cockatoo Sandstone (fig. 9) on the east corner of Hill 172. The angular fragments of very different sizes of quartzites within the pebbly matrix would indicate material from a talus or nearby escarpment.

Further observations in the region south of Joseph Bonaparte Gulf and in the Port Keats area, at isolated localities where the branch faults were well exposed, confirm the findings in the Cockatoo Spring area, namely, that all the last strong movements within the East Kimberley Geosuture had a predominant horizontal component.

For the East Kimberley Geosuture the pattern of displacement of planar features along secondary faults (see diagram in fig. 5) definitely determines a left movement for the geosuture. Based on the hypothesis that in Cambrian times the southeast Bonaparte Basin and the Daly River Basin formed one continuous unit, a cumulative left displacement since the late Cambrian of 230 kilometers is suggested. If a restoration is attempted using the figure of 230 kilometers then the



Fig. 10. Horizontal slickensides on one of the minor secondary faults within the East Kimberley Geosuture (Pander Ridge area:  $15^{\circ} 29' 48''$  South and  $128^{\circ} 9' 30''$  East).



Hardman Basin (Ord Basin) will be brought in juxtaposition with the Fitzroy Trough.

All the activity within the East Kimberley Geosuture ended with the close of the Lower Carboniferous when the clastics of the Point Spring Formation unconformably covered all the complexly deformed beds along the fault zones and the complicated fault wedges. This Point Spring Formation blanket was never sliced by faults of a system belonging to the ancient East Kimberley Geosuture. However, some adjustment owing to differential compaction and draping over some fault scarps might be expected.

The rocks adjacent to the faults within the East Kimberley Geosuture are silicified in different degrees. Silica covers the fault planes with a thick coat, a fact which explains the perfect preservation of the fine grooves and striae on the slickensides (figs. 10, 11). Galena mineralisation was observed only in the fault breccia and dolomitic limestones adjacent to the fault at a locality near the north-eastern tip of the Pincombe Range, 53 kilometers north of Cockatoo Spring (fig. 5). The widespread silicification made the rocks on both sides of the fault more resistant to erosion than the beds more distant from it. By differential erosion many faults were carved out as sharp-crested thin walls or ramparts, a phenomenon which is also reported by CRIBB (1960) from the Hodgkinson River area in north-eastern Queensland.



Fig. 11. Horizontal slickensides on one of the minor secondary faults within the East Kimberley Geosuture (Pander Ridge area:  $15^{\circ} 29' 48''$  South and  $128^{\circ} 9' 30''$  East).

## THE PALMERVILLE GEOSUTURE

The Palmerville Fault was named and defined by DE KEYSER (1963), who gave a careful account of its distinctive features. Previously, portions of this fault were also mentioned under the name «Tasman Line» (DOROTHY HILL, 1951, 1960) and «Chillagoe Fault» (WHITE, 1961). From DE KEYSER'S description (1963, 1965) it is beyond any doubt that the Palmerville Fault is a large-scale strike-slip fault or a group of such faults which can be classified as a geosuture (fig. 1).

Although DE KEYSER thinks that «transcurrent movements have probably also played their part...», he mentions four recurrent phases of vertical movements with alternating sense. These vertical throws are certainly here, but in the writer's opinion they indicate an apparent dip-slip movement only.

On a reconnaissance trip in 1963, from Laura over Fairlight to the Palmer River at Palmerville, the writer visited the outcrops of the Permian Little River Coal Measures not far from the abandoned Fairlight telegraph station. The shearing is so intense and the coal beds, sandstones and shales are so contorted that they have to be regarded as belonging to a squeezed Permian wedge within a strike-slip fault.

DE KEYSER'S discovery on a photomosaic of a weak fault trace in the Herbert River area, and his suggestion that the Palmerville Geosuture extends from its intersection with the Burdekin River Geosuture towards the southeast, is significant. This hypothetical extension may very likely represent a new Mesozoic splay of the Geosuture, whereas the ancient deformed branches are presumably located farther to the west-southwest (fig. 12).

The northern well-established portion measures 665 kilometers; the southern hypothetical prolongation would add 200 kilometers to the total figure.

The interpretation of the sense of displacement is admittedly based on the single good evidence yielded by the consistent orientation of a group of secondary left strike-slip faults on the east side of the geosuture, south of the Palmer River. The secondary faults form an angle of 40 to 50 degrees with the master fault. A few weak clues point to a left displacement too.

From an examination of the facies developments and the general affinities of the Middle and Upper Palaeozoic sediments in the area of the Hodgkinson and Laura Basins, on the eastern fault block, north of the Palmerville-Burdekin River fault intersection (fig. 1), the writer visualises that Middle Palaeozoic sediments of the Hodgkinson Basin were originally closely related to deposits of an identical age and more or less similar lithology found in the northern Drummond Basin. This would indicate a left cumulative displacement of the order of 500 kilometers.

Changes in the direction of the fault traces in the area where the Burdekin River and Palmerville Geosutures intersect are characteristic of strong interference of the movement of one crustal block on the movement of the other (figs. 1, 12).

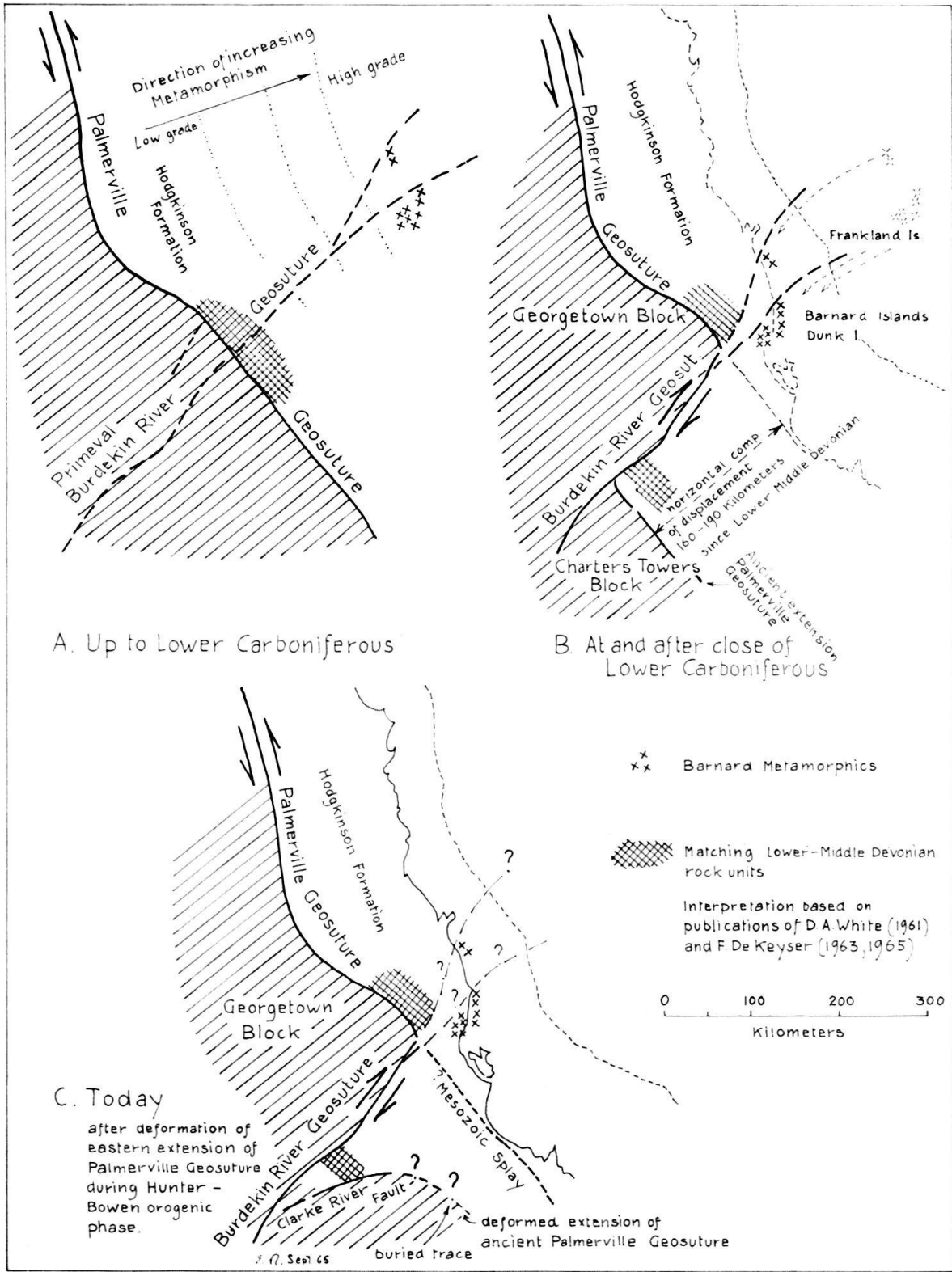


Fig. 12. Displacement along Burdekin River Geosuture.

## BURDEKIN RIVER GEOSUTURE

Although the sense of movement and the amount of the cumulative displacement is not as obvious and clear-cut as with the Giant's Reef Fault of the Northern Territory (HILLS, 1963) or the Berridale Geosuture of New South Wales (LAMBERT & WHITE, 1965), the horizontal shift along the Burdekin River Geosuture can still be readily determined. Already a quick inspection of WHITE's (1961) several palaeogeologic maps reveals a conspicuous dog-leg.

The evidence for a cumulative right displacement of 160 to 190 kilometers is good. Three phases in the development of the Burdekin River Geosuture are sketched in fig. 12.

Here is the place to say a good word for dog-legs on structural maps. They usually give valuable hints to the geologist, they tell him to watch out for deep-seated displacements along strike-slip faults.

## THE BIRRIE GEOSUTURE

Not too much is known of this 1400 kilometer long geosuture (fig. 1) because extensive stretches of its trace are covered by the Mesozoic and Tertiary sediments of the Great Artesian and Ipswich Basins. It is hoped that the seismic and drilling operations in the exploration for oil will add much to our knowledge of this important fracture zone. It was at first designated under the name «Darling Lineament» (HILLS, 1956a, b) and later called the «Darling-Brisbane Shear Zone» by MACK (1962). As the name Darling for a fault is preoccupied by the well-established Darling Fault of Western Australia (published on the Tectonic Map, 1960), the writer proposed the name Birrie Fault (from the Birrie River) in private Company reports (1962) and later submitted this term to the Tectonic Map Committee of the Geological Society of Australia.

WOPFNER (1960) postulated a right movement. This is fully confirmed if an attempt is made to match facies belts and stratigraphic provinces across the geosuture. The best example is the tie of the projected Great Serpentinite Belt of New South Wales (Tamworth serpentinite) with the serpentinite belt east of the Esk Rift (fig. 1), from the outcrop at Pine Mountain towards the north. A right displacement of 160 kilometers can be measured here.

## EMPLACEMENT OF PERIDOTITE BELTS

The writer is not competent to discuss the merits of the two opposed views on the emplacement of peridotite masses, building up the belts either by intrusion of peridotitic magma or by a purely mechanical squeezing up and severance of solid, huge peridotite lenses. However, a study of many detailed descriptions of peridotite belts in the literature convinced him that, at least during their last phases of transport within the master fault zones (mainly geosutures), all the bodies of serpentinized peridotites now exposed near or at the surface, came up along the fault zone in solid form. This is a conclusion already reached by ROEVER (1957), who gives an analysis of the pertinent problems of emplacement. For the belts of ultrabasic bodies of West Irian, VISSER & HERMES (1962) find ROEVER's interpretation of tectonically emplaced solid lenses as the most likely mode of origin. DAVIES

(1965) considers the peridotite belt of Papua as a «fault-emplaced segment of the sub-oceanic mantle». An exciting new development which very likely will tilt the balance completely in favour of tectonic emplacement appears now in the results of RALEIGH'S & PATERSON'S (1965) experimental investigations into the deformation of serpentinites. They sum up some of the tectonic implications of their findings as follows: «The hypothesis of tectonic emplacement of serpentinites of the alpine type thus becomes highly plausible at temperatures great enough for dehydration weakening while being difficult to accept at lower temperatures where the strength of the serpentinite is high. Weakening upon heating to the appropriate dehydration temperature in the range 300–600°C of a partially serpentinitized oceanic lower crust or upper mantle should also serve to concentrate deformation in the heated belt, thus facilitating mountain building.»

This concept does not exclude the possibility that initially during the first phase in the development of the deep-seated fracture zone in the early stages of orogeny a peridotite magma could have been intruded. The whole process of migration of the peridotite masses from their original location within the root of the fracture zone in the Upper Mantle upward to the surface might have taken tens to hundreds of millions of years.

As it was stressed by HESS (1955) the peridotite belts are usually much older than they might appear judging from surface observations. The emplacement as visualised here is a very slow process, with every fault movement the peridotite masses were pressed up a little bit until they reached a point near the surface from where, during a final shock, they were squeezed up to the surface. An excellent description of this process is given by HESS (1955): «Slickensided, slippery shear zones form easily in serpentine. Once formed, movement takes place readily along them. Thus solid serpentine bodies may move into overlying sediments in much the same way that a watermelon seed moves when squeezed between one's fingers.»

As a rule all the serpentinitized peridotite bodies in a belt are intensely sheared, sliced up by closely-spaced faults. The fault planes are covered by slickensides; completely shattered lenses are quite common.

The dating of peridotite belts is therefore not an easy task. It is not the time when the serpentinitized peridotite lenses popped up at the surface which is of interest but the time when they entered and were caught in the ancestral fault zone parallel to the ancient alpine-type mountain system.

As HESS (1955) emphasises: «...mountain systems should be dated from birth...»

#### MECHANISM CREATING BRECCIATED WEDGES AND SHATTER ZONES WITHIN A GEOSUTURE

A detailed field examination in the Cockatoo Spring area of several strike-slip faults belonging to the East Kimberley Geosuture revealed that after the last fault movement along the master fault – which can be dated at the close of the Lower Carboniferous – the two blocks along the fault were dissected by a system of medium to very small sized strike-slip faults which left the faults like two inter-locked saw blades.

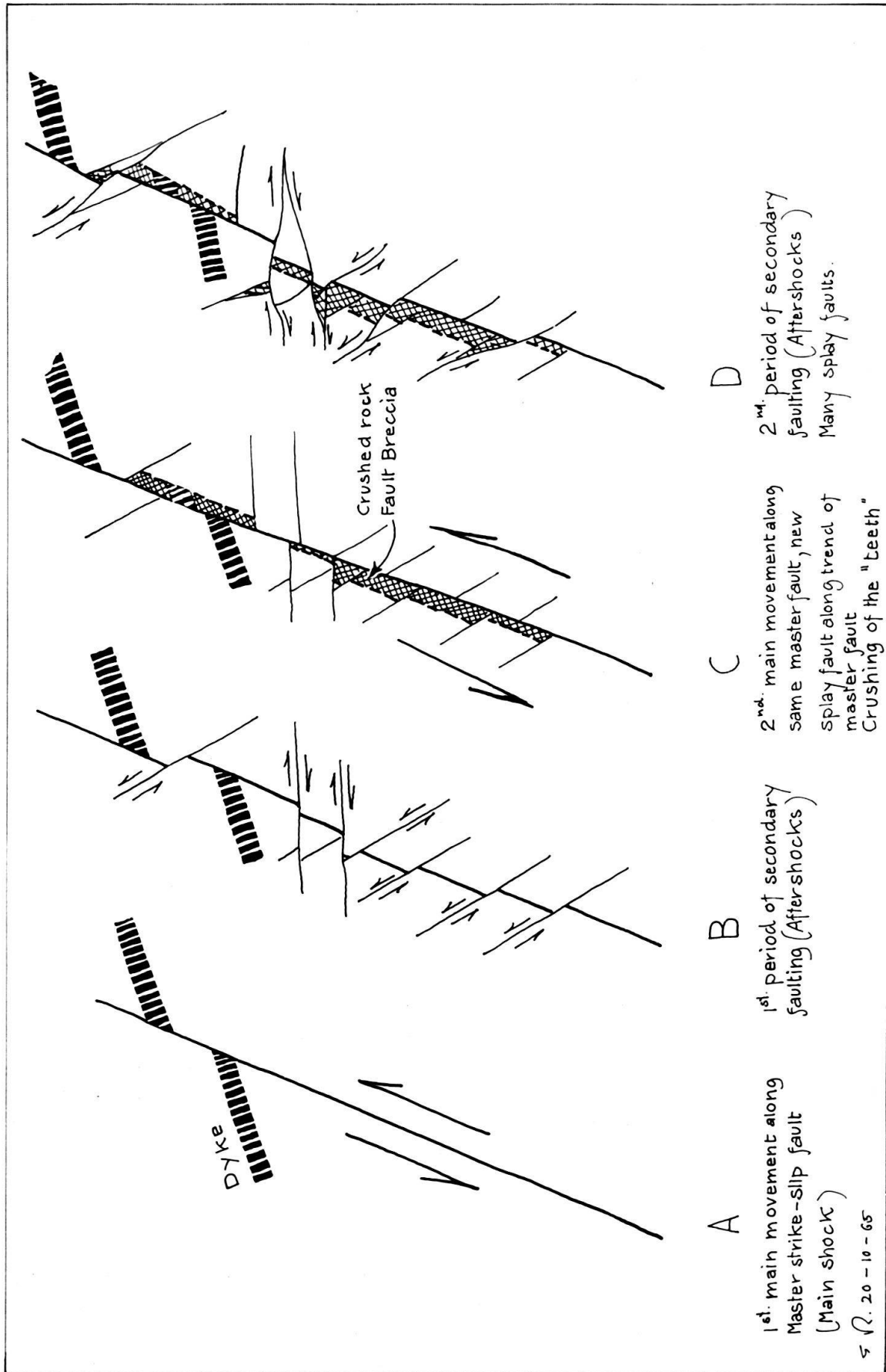


Fig. 13. Mechanism producing fault breccias along strike-slip faults (plan view).

At regular intervals, from fractions of a centimeter to tens of meters, the master fault is cut by oblique faults having a horizontal component of a few centimeters to several meters. Some had a left, others a right displacement. The perfect slickensides on the silica-coated fault planes of the secondary faults do not leave any doubt that the largest components were essentially horizontal. The same observation was made repeatedly every time the faults were examined in great detail. In every case the plan view of the master fault was toothed.

Further surveys revealed that the walls of all fault blocks consist of brecciated and recrystallised rock. At some localities only a thin layer next to the fault is brecciated, at other places the brecciated zone is thicker, from several meters it can amount to several hundred meters in width. Splay faults separate huge wedges, completely shattered and crossed by numerous faults.

The above observations led to the deduction that, if a displacement along the master fault should occur again, all the interlocking teeth making up the actual fault would be broken off and crushed or a new splay fault might form a couple of meters to the right or left.

With the main movement along the master fault all the strain in the fault blocks is not yet released. But soon after the main displacement many secondary fractures open up and many small faults are produced until the blocks find their equilibrium through this internal readjustment. All those small fault movements cause the aftershocks (RICHTER, 1958). With every new major movement along the master fault the process will be repeated and the brecciated zone along the fault will grow thicker and thicker (fig. 13).

From field observations there is definite proof that the so-called conjugate and secondary (second-order) faults are not conjugate in the sense of simultaneous, they can be regarded as contemporaneous as they happen within a few months after the movement on the master shear. This does not mean that their orientation and sense of displacement does not follow an orderly pattern. What is important is the sequence in the strain release and the area involved in the final readjustment. Thus the mechanics of aftershocks explains the occurrence of the fault breccia (crush breccia of HILLS, 1963) and the huge shattered lenses (figs. 1, 13).

#### CONCLUSION

From published information and from the many new facts coming up daily from the accelerated exploration activities in the search for hydrocarbons and minerals, it is now an established fact that the stable and rigid Australian Platform of today consists of at least two dozen continental crustal blocks which have been welded to form a solid assembly. Today the many different structures which a long time ago formed the boundaries between the blocks, the geosynclines, geosutures and geofractures, which in pre-Mesozoic time showed great mobility and along which the blocks were displaced relative to each other, are now dead, they can be regarded as fossilised.

However, there are now sufficient observations to demonstrate convincingly that in Pre-Mesozoic time the blocks and their border zones were not less active than the crustal blocks and geosutures of New Guinea and New Zealand, which are still vigorously mobile. In relatively young geologic time the Sorong Fault of New

Guinea had a left cumulative displacement of at least 600 kilometers (VISSER & HERMES, 1962), the Alpine Fault has a well-documented shift of 480 kilometers (WELLMAN, 1953, 1955, 1956) and for the Philippine Fault, ALLEN (1962) suggests a displacement of 500 kilometers. Recently KRAUSE (1965b) described the Papua-Solomon Shear Zone and mentions a possible left movement of at least 180 kilometers. There is good reason to assume that during the Palaeozoic Era the blocks of the Australian Continent were as restless as the ones of New Guinea and New Zealand today. The great deformations along the borders of the blocks, the numerous fault and fold belts, the wide zones of sheared and crushed rocks attest to the ancient large-scale movements of the crustal blocks.

After a detailed analysis of the geosutures, in order to find out the sense and the amount of lateral displacement, it will be possible to restore the blocks to the position they held during a certain time interval and to prepare thus palaeogeologic maps, for instance for the Cambrian. All the palaeogeologic or palaeogeologic

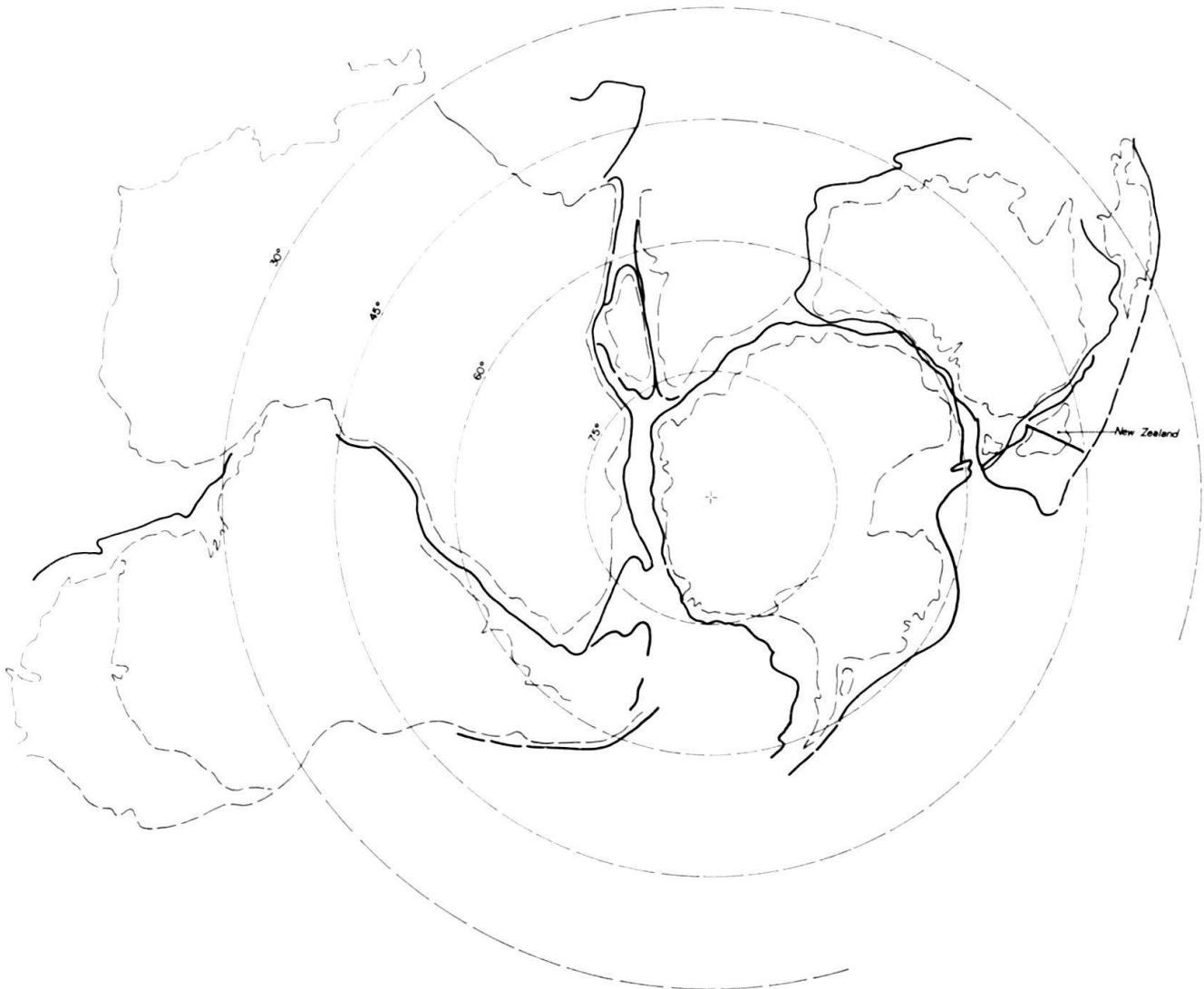


Fig. 14. Reassembly of Gondwanaland for the Carboniferous following ideas of Du Toit and Lester King with a few modifications by the writer. (The map is not a correct projection, sketched only.)



graphic maps produced without making allowance for internal crustal movements of the order of 300 to 600 kilometers must be in error and give quite a wrong picture as pointed out by CAREY (1958).

There is no fundamental difference between horizontal movements of blocks in contact with each other along geosutures and of blocks separated from each other and drifting away, surrounded by oceanic crust. Both are carried passively by an upper mantle current. Both might have the same velocity of drift of one to two centimeters a year. This rate of movement is sufficient to account for all displacements.

As a corollary it can be stated that if two crustal blocks or fragments of crustal blocks can move past each other along a geosuture by a distance of 600 kilometers they can also be separated from each other at the same rate by an equal distance. From a tentative reconstruction of the late Palaeozoic Australian continent, the geologist passes thus naturally to a consideration of continental drift and cannot avoid the problem of Gondwanaland (fig. 1; TUZO WILSON, 1963; HARLAND & RUDWICK, 1964; HARLAND, 1965).

With few exceptions the main movements along the Australian geosutures occurred before the close of the Palaeozoic. From then on the assembly of blocks formed a rigid platform. Only along the easternmost part is there evidence of movements during the Mesozoic. Therefore the ancient geosutures will end abruptly in the continental slope and not continue into the oceanic crust which is very likely not older than Jurassic or Cretaceous (HESS, 1962). Yet, if a block with a portion of the old fracture zone tore away from the main continental mass, the continuation of a certain ancient geosuture might be found, across some oceanic basins hundreds or thousands of kilometers apart (see restoration of New Zealand, fig. 1), in this isolated fragment of the continental crust.

The more the writer studies the geologic history of eastern Australia, New Zealand, New Guinea and all the island festoons between the two big islands, the more he thinks that the most up-to-date and enlightened geotectonic synthesis is presented by H. H. HESS (1962) in the recapitulation of his paper on the history of ocean basins.

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