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Proterozoic Palaeocurrent Directions in the Kimberley Region,
Northwestern Australia

by

D.C. Gellatly, G.M. Derrick, and K.A. Plumb

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CONTENTS

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Records 1968/141

ABSTRACT

Palaeocurrent directions from cross-beds in the Proterozoic Kimberley Basin sediments, northwestern Australia suggest that sediment was derived from the north and not from the adjacent exposed areas of older Precambrian rocks to the south. The suggested northerly source is consistent with the former position of Western Australia close to peninsular India.

INTRODUCTION

Between 1963 and 1967 the Precambrian of the Kimberley region in northwestern Australia was mapped at 1:250,000 scale jointly by the Bureau of Mineral Resources and the Geological Survey of Western Australia. Relatively undeformed Proterozoic sediments are very well exposed and strongly and consistently current-bedded over 150,000 km^2, and so are eminently suitable for palaeocurrent study and partial palaeogeographic reconstruction of the area during Proterozoic times.

GENERAL GEOLOGY

The Precambrian of the Kimberley area consists of two intersecting fold belts, known as the Halls Creek and King Leopold Mobile Zones (Traves, 1955), and the Kimberley Basin, a younger and relatively undisturbed structural basin flanked by the fold belts. The mobile zones are comprised of granites and volcanics, and highly folded metamorphics 2700 m.y. to 1800 m.y. old (Archaean to lowermost Carpentarian: McDougall et al., 1965; Dunn et al., 1966; Bofinger, 1967). The Kimberley Basin succession comprises the Speewah, Kimberley and Bastion Groups (ca. 1800 m.y. to 1700 m.y. - lower Carpentarian), and is unconformably overlain by Adelaidean (1400 to 600 m.y.) rocks.

Palaeocurrent directions have been studied from the Speewah and Kimberley Groups. The Bastion Group and the Adelaidean rocks, (which include glacials), are not sufficiently extensive for inclusion in this study.

The Speewah Group crops out only along the eastern and southern margins of the basin; it is absent from the mobile zones. The Kimberley Group underlies the entire area of the Basin; remnants of it extend across the mobile zones. The beds are flat-lying throughout the Kimberley Basin except for the southeastern and southwestern margins, where steep dips prevail close to the mobile zones.

The stratigraphy of the Speewah and Kimberley Groups (Plumb and Dunnet, in press; Gellatly and Derrick, in press; Gellatly, Sofoulis and Derrick, in prep.; Plumb, in prep.) is summarized in Table I.

TABLE I

Stratigraphy of Speewah and Kimberley Groups

		Formation	Thickness	Lithology
CARPENTARIAN	KIMBERLEY GROUP	Pentecost Sandstone	3600	Quartz sandstone, feldspathic sandstone
		Elgee Siltstone	230-1160	Siltstone, carbonate
		Warton Sandstone	700-3000	Quartz sandstone
		Carson Volcanics	750-2300	Tholeiitic basalt, spilite
		King Leopold Sandstone	2300-4400	Quartz sandstone
	SPEEWAH GROUP	Luman Siltstone	170- 240	Siltstone
		Lansdowne Arkose	1300-1600	Feldspathic sandstone, siltstone
		Valentine Siltstone	140- 270	Siltstone
		Tunganary Formation	740- 940	Feldspathic sandstone, siltstone
		O'Donnell Formation	480- 865	Quartz sandstone, siltstone
		U N C O N F O R M I T Y		
ARCHAEAN TO LOWER PROTEROZOIC		Group		
		Lamboo Complex		Granitic and basic intrusives; Porphyritic acid tuffs and lavas
		Halls Creek Group		Schist and phyllite

Sandstones

The sandstones are coarse to medium-grained with median diameters mostly between 0.66 mm and 0.22 mm and are well-sorted, with sorting coefficients ($So = \frac{Q25}{Q75}$) ranging from 1.49 to 1.76. Grains are mostly rounded to sub-rounded. Most of the sandstones have little feldspar, except for the Tunganary Formation and the Lansdowne Arkose, which consist principally of feldspathic sandstone and arkose, and the Pentecost Sandstone which has feldspathic beds locally. Both feldspathic and non-feldspathic sandstones have a mature tourmaline-zircon-rutile heavy mineral assemblage with only minor amounts of other heavy minerals. Occurrences of glauconite in the succession indicate that it is either partly or wholly marine.

Cross-beds are common throughout the sandstones and are mostly of trough type, or less commonly of the planar type (nomenclature of McKee and Weir, 1953), and fall within the pi and omikron types of Allen (1963). Both tabular and wedge shaped sets are present; the tabular predominate. The thickness of the foresets ranges from 8 cm. to about 1.5 metres: the majority are from 15 cm. to 50 cm. thick. Dips of foresets relative to bedding vary from 5^{o} to 30^{o}. Intraformational overturned cross-beds are found in several localities.

Conglomerates

Conglomerates of localized extent and limited thickness have been noted in the O'Donnell Formation, the Lansdowne Arkose, the King Leopold Sandstone, the Elgee Siltstone, and the Pentecost Sandstone. With the exception of conglomerates in the O'Donnell Formation and the King Leopold Sandstone (which include clasts of phyllite and vein quartz), clasts in the conglomerates consist of sandstones identical to those of the Speewah and Kimberley Groups. Clasts of igneous and metamorphic rocks from the underlying older Precambrian are lacking. No pre-Speewah Group sandstone formations are known from the area.

The distribution of clast sizes in the conglomerates can be related, at least in part, to spasmodic movement on major faults; e.g. the Lansdowne Arkose about 100 km. northwest of Halls Creek contains boulders of sandstone up to 25 cm. across at a distance of 3 km. from the Greenvale Fault, but these decrease in size to 2 cm. some 10 km. from the fault.

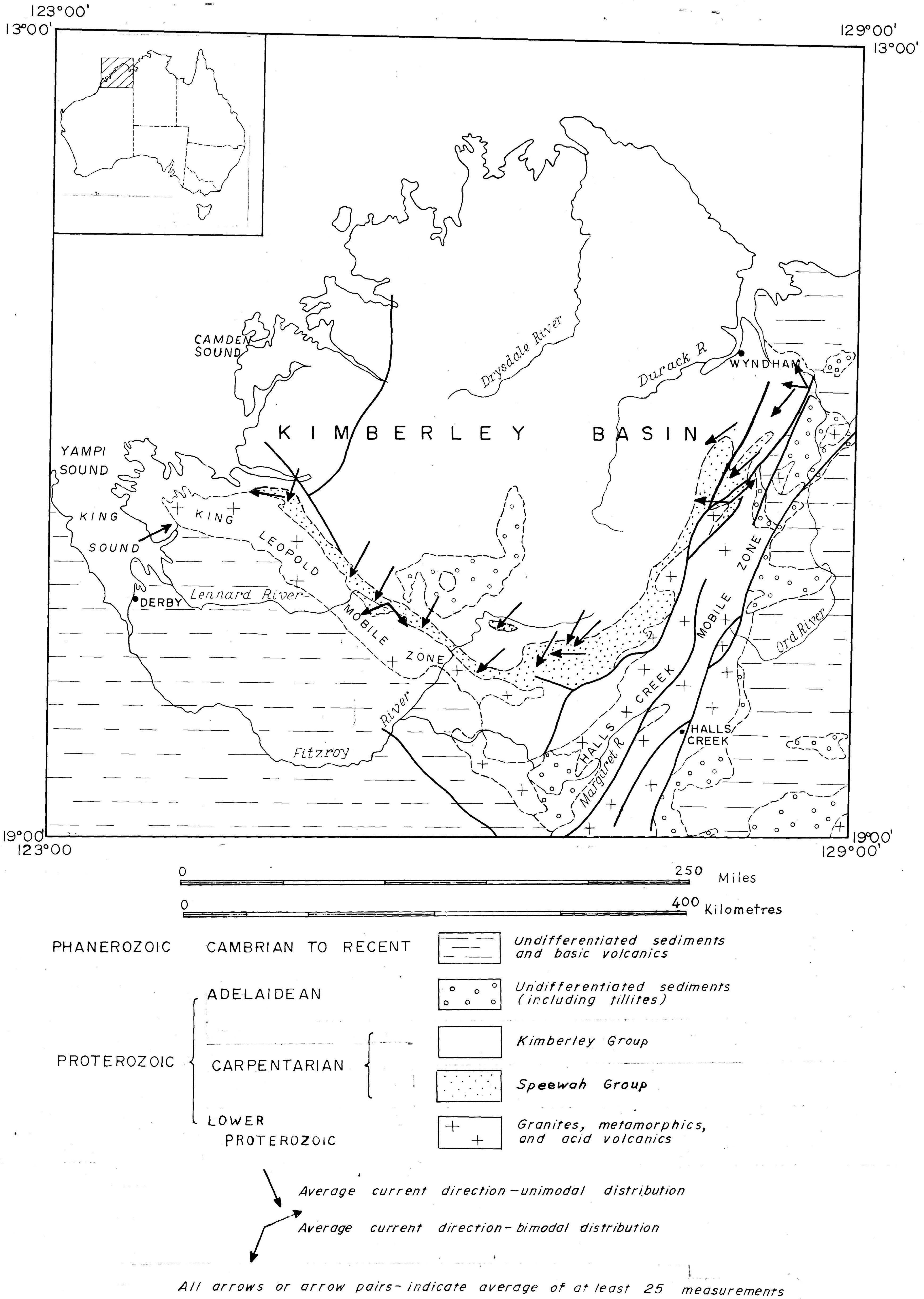

FIG. 1. CURRENT DIRECTIONS IN KIMBERLEY BASIN SEDIMENTS —— LOWER PALAEOCURRENT DIVISION

To accompany Record 1968/141

W/A194

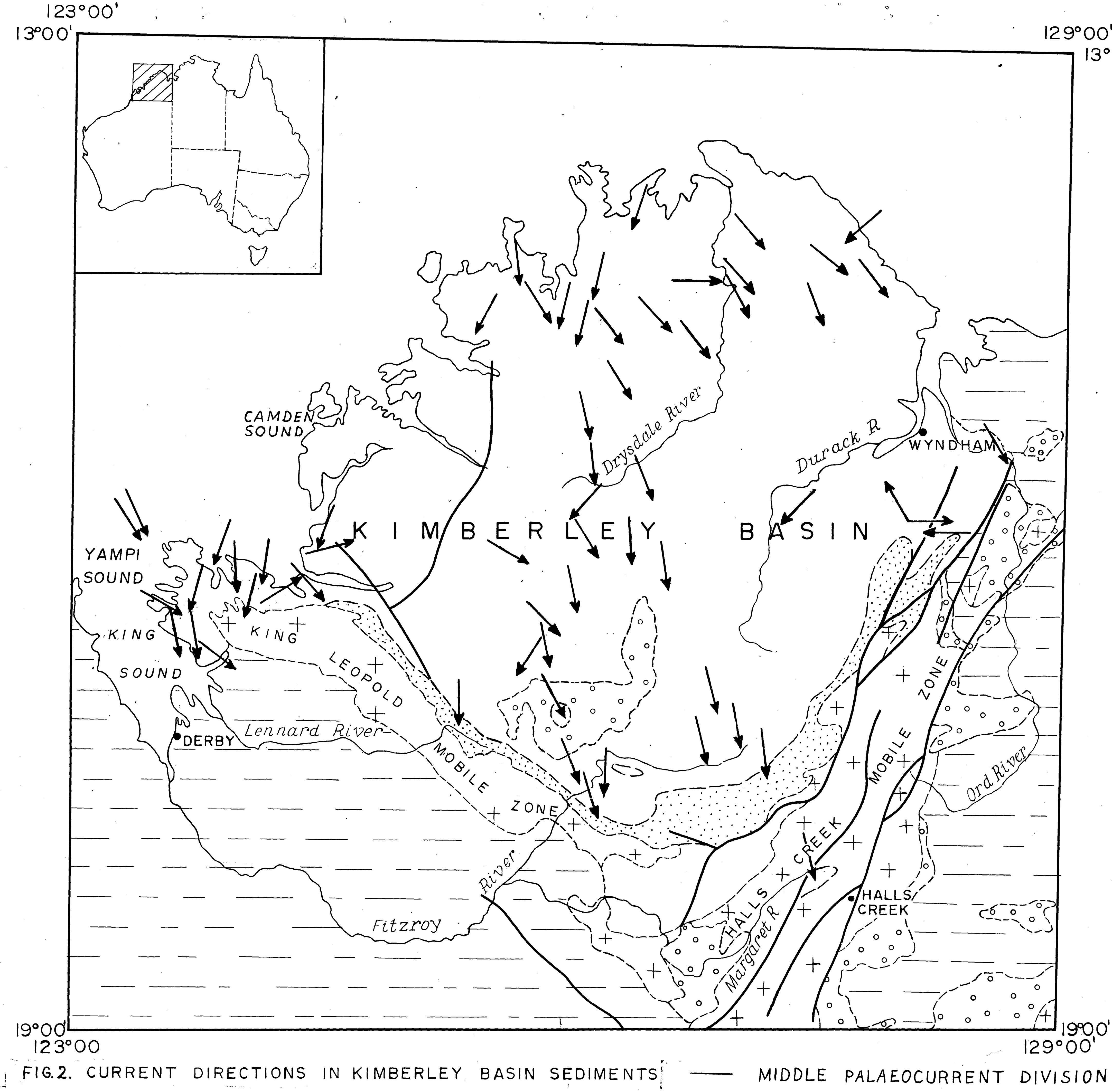

FIG. 2. CURRENT DIRECTIONS IN KIMBERLEY BASIN SEDIMENTS — MIDDLE PALAEOCURRENT DIVISION

Reference as for Figure 1.

To accompany Record 1968/141

W/A 195

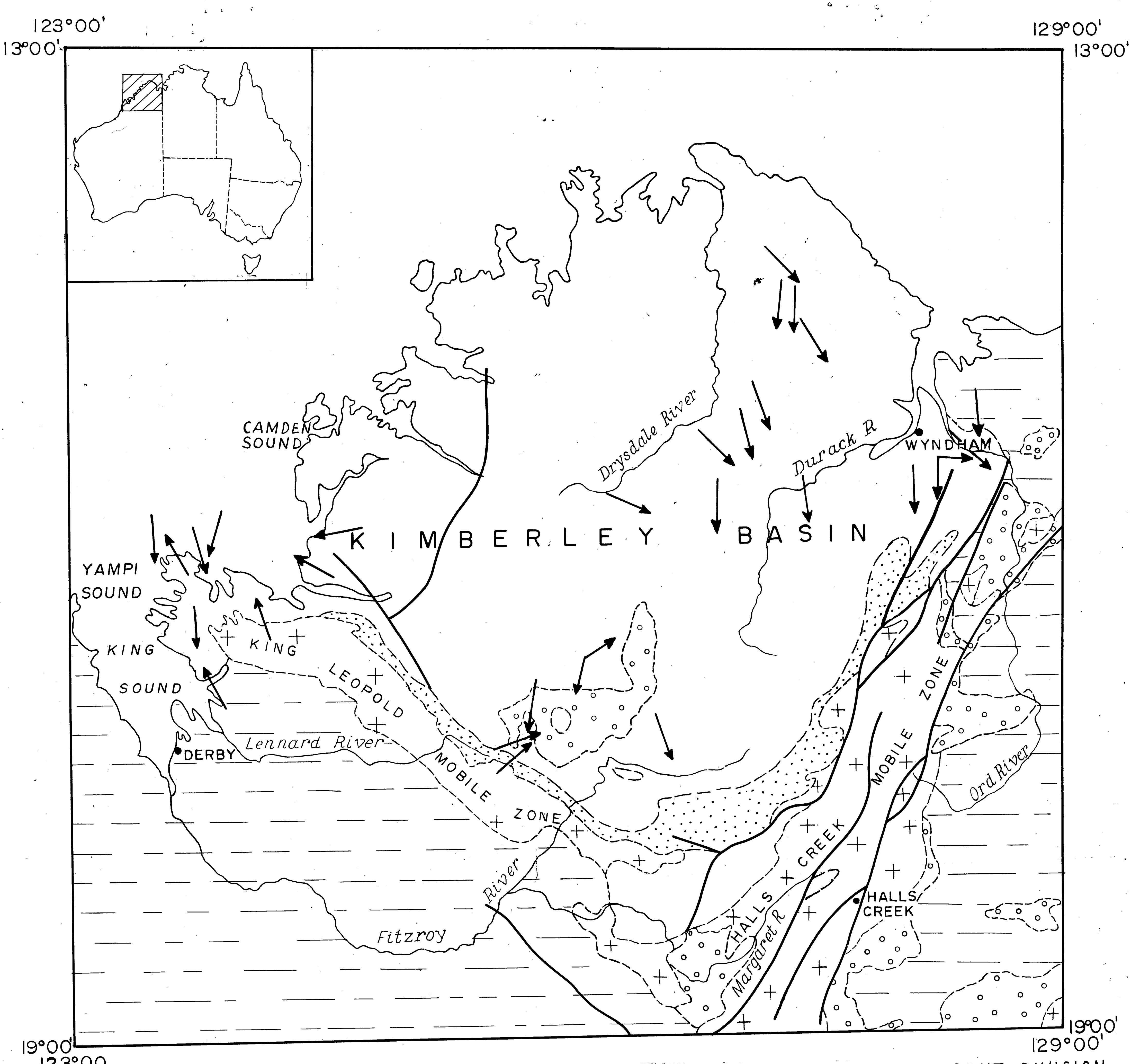

FIG. 3. CURRENT DIRECTIONS IN KIMBERLEY BASIN SEDIMENTS —— UPPER PALAEOCURRENT DIVISION

Reference as for Figure 1.

W/A 196

To accompany Record 1968/141

Palaeocurrent Directions

About 3,700 measurements of palaeocurrent directions from cross-beds in sandstones have been made with a coverage of almost the entire Kimberley Basin, an area of approximately 150,000 km^2. Where necessary measurements were corrected to remove the effects of folding. Sets of at least 25 readings were recorded from most localities and plotted on a rosette diagram to give a single average direction, or more rarely two distinct directions. These are shown on Figs 1, 2, and 3 as single arrows or as arrow pairs. Readings in sets of less than 25 from many widely distributed localities, and consistent with the results presented in Figs 1 to 3 have been omitted from this account because of their lesser statistical validity. Full details of current directions measured are given in a number of unpublished reports on individual 1:250,000 map sheet areas (Appendix I).

For purposes of description the sets of readings have been divided into three informal divisions, lower, middle, and upper based on variation in palaeocurrent direction with change of stratigraphic level. Those from the Speewah Group and the lower half of the King Leopold Sandstone have been grouped in the lower subdivision; those in the upper half of the King Leopold Sandstone and the Warton Sandstone in the middle subdivision; and those in the Elgee Siltstone and Pentecost Sandstone in the upper subdivision. Frequency distributions of the average current directions for each division are shown in Fig.4.

In the lower division the current direction is consistently from the northeast, with the exception of sets of readings from localities close to the mobile zone, two near Wyndham, one near the Lennard River, and one from near King Sound.

In the middle part of the succession current directions are dominantly from the north and northwest with a few variants from north-northeast and west. Only three directions inconsistent with these trends have been recorded, two from the King Leopold Sandstone near Wyndham, and one from the Warton Sandstone near Yampi Sound.

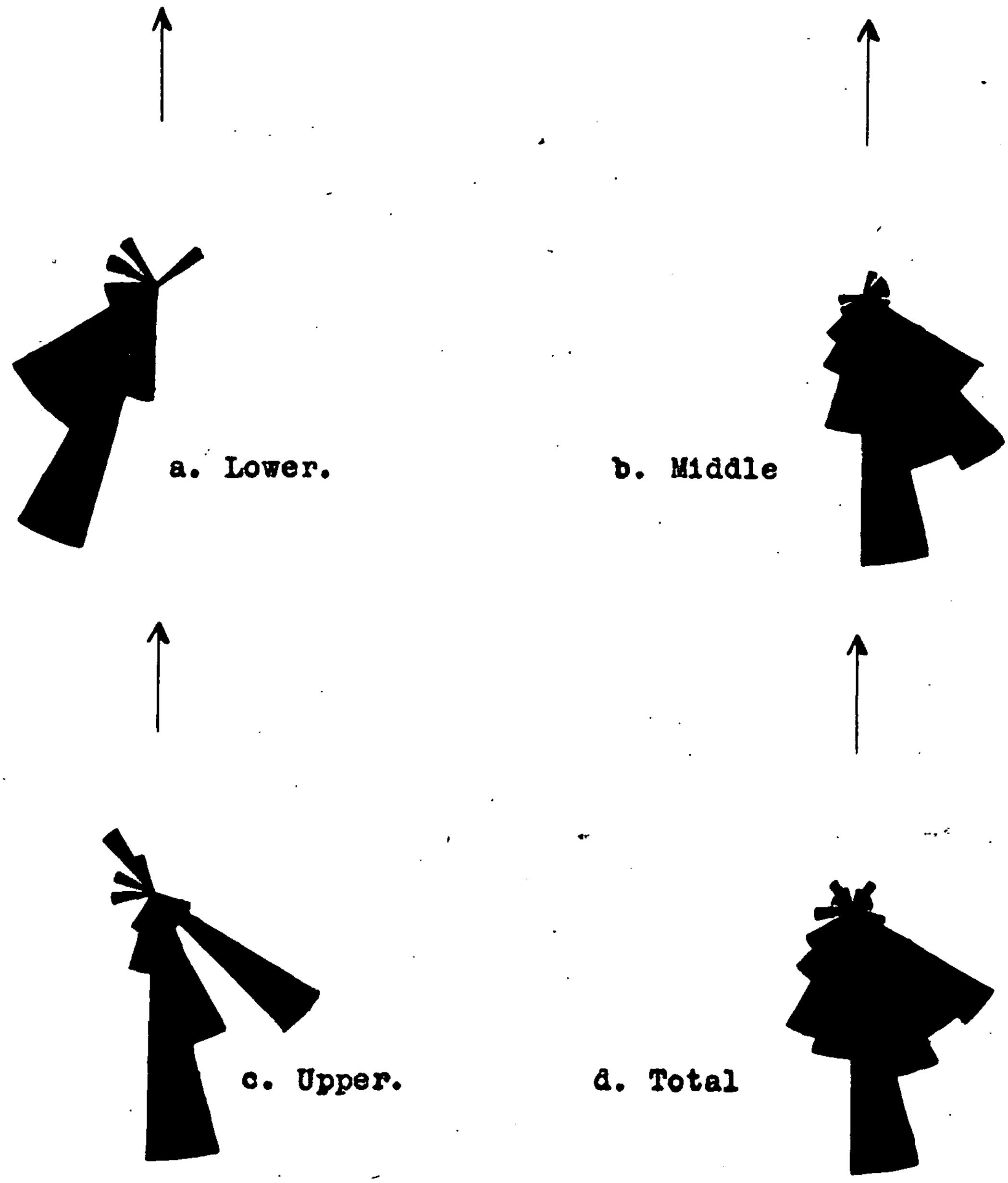

Fig. 4. Plots of average current directions - data of Figs. 1, 2, and 3: plots adjusted to give equal maxima.
(a). Lower palaeocurrent division - 18 sets of 25 or more measurements.
(b). Middle palaeocurrent division - 60 sets.
(c). Upper palaeocurrent division - 28 sets.
(d). Total: combined plot of all average current directions.

In the upper part of the succession directions are less consistent but there is still a marked predominance of current directions from the north and northwest. Directions are consistent in the central part of the basin but are more variable round the margins, especially in the south and southwest.

Direct reversals are found in the King Leopold Sandstone, the Elgee Siltstone and the Pentecost Sandstone. Although all inconsistent directions occur close to the mobile zones, it is significant that proximity to them causes no change in the general current direction, and many of the current directions trend directly across the mobile zones, whereas, if a shoreline had existed there, deflection of the currents parallel to it would have been expected.

FACIES CHANGES

The palaeogeographic significance of the current directions considered alone is uncertain. Current directions could be on-shore, off-shore or along-shore, and need to be interpreted in conjunction with evidence of facies changes.

Facies changes are numerous in the Speewah Group. They are mainly changes in the feldspar content of the sandstones and in the sand/silt ratios. Variations in the sand/silt ratio show no consistent pattern although there is a general tendency to increase westwards. The feldspar content of the sandstones decreases southeastwards, i.e. downcurrent, and suggests increasing distance from the source area.

The most notable facies changes in the Kimberley Group are those in the Elgee Siltstone which thickens down current (southeastwards) from 100 feet to 700 feet (and more where carbonates are present) and also shows a change southwards in the sand/silt ratio from 3.5/1 to 1/6. The carbonates, which are confined to the southeast, progressively increase in thickness southwards and reach their maximum development between the Fitzroy and Margaret Rivers.

Proximity to a shoreline to the northwest is suggested by the presence of halite pseudomorphs in the Elgee Siltstone in the Camden Sound area, and by the Yampi iron ores (fossil beach sands) at the base of the Pentecost Sandstone. In both these localities the dominant current direction is from the northwest.

DISCUSSION

The distribution of the conglomerates in most places can be related to temporary reversals of current directions and to localized erosional breaks within the sequence. These features and the predominance of sandstone clasts are apparently due to uplift of parts of the mobile zones and consequent erosion of previously deposited Kimberley Basin sediments from them. There is no evidence of substantial supply of sediment from the older Precambrian rocks of the mobile zones, which might appear to have been the most likely source areas.

The evidence of the conglomerates against a southerly source for the sediment, the southwestwards decrease in feldspar content, and the evidence for proximity to a shoreline in the northwest, when considered in conjunction with the palaeocurrent directions, suggest a general northerly source. Such a source is not unlikely if the approximate early position of Australia as suggested, e.g. by Wegener (1924) or Carey (1958, p.277) be accepted. Recent age determination work (Crawford, in press) which has shown similarity of patterns of ages between India and Ceylon on the one hand and southwestern Australia on the other, confirms the former proximity of western Australia to ancient Precambrian rocks of peninsular India and Burma, and lends weight to a possible northerly source for sediments of the Kimberley Basin.

The consistency of the currents, particularly in the central part of the basin, is remarkable and suggests formation of the cross-beds by a steady ocean current (of Gulf Stream type) flowing past a landmass to the northwest of the Kimberley area (or possibly between landmasses to the northwest and northeast) rather than by tidal currents, which would produce two mutually opposed cross-bed directions on account of local variation in the dominance of the flood and ebb tides (e.g. Stride, 1963).

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ACKNOWLEDGEMENTS

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APPENDIX I

List of Unpublished Reoords on the Geology of 1:250,000 map Sheet areas from the Kimberleys containing details of Palaeocurrent Measurements

ALLEN, A.D., 1966 - The Geology of the Montague Sound 1:250,000 Sheet Area (SD 51-12), Western Australia. Bur. Miner. Resour. Aust. Record 1966/201

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PLUMB, K.A., and PERRY, W.J., in prep. - The Geology of the Medusa Banks 1:250,000 Sheet area, SE 52/10. Western Australia. Bur. Miner. Resour. Aust. Record

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