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CARPENTARIA AND KARUMBA BASINS EXPLANATORY NOTES AND STRATIGRAPHIC COLUMNS

by

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Introduction

The Jurassic-Cretaceous Carpentaria Basin and the Cainozoic Karumba Basin underlie parts of northern Queensland and the Northern Territory, and extend beneath much of the Gulf of Carpentaria. The Karumba Basin is superimposed on the Carpentaria Basin (Fig. 1), but separated from it by an unconformity. The basins form a shallow oval depression and occupy an area of about 560 000 km^2. Seismic data (Pinchin, 1973) indicate that the thickest sequences, 1200 m for the Carpentaria Basin and 300 m for the Karumba Basin, are offshore.

The basins are intracratonic features that have undergone only minor deformation. In terms of their geological and tectonic histories, the basins are separate entities, and here they will be discussed separately.

Data Compilation

Most of the information was taken from selected studies and reconnaissance field surveys of the basins made by the Bureau of Mineral Resources, Geology and Geophysics and the Geological Survey of Queensland since 1969, results of which have been summarized and synthesized by Smart & others, (in press). Lithological data for the well columns (Fig. Au 2a) were compiled from company reports and Meyers (1969), but nomenclature (Figs. 2, 3) and correlations follow Smart & others (in press). Only named units or those generally thicker than 20 m are included in Figure 3. Palynological divisions and formation ages for the well columns are chiefly from Burger (1973; personal communication, 1978).

Onshore investigations have provided most of the data on the basins rocks; offshore information is limited to sparse geophysical coverage of the Gulf of Carpentaria and a few shallow mineral exploration holes drilled immediately offshore from Weipa.

Figure Au 2a and these explanatory notes were prepared as a contribution for the United Nations ESCAP Atlas of Stratigraphy.

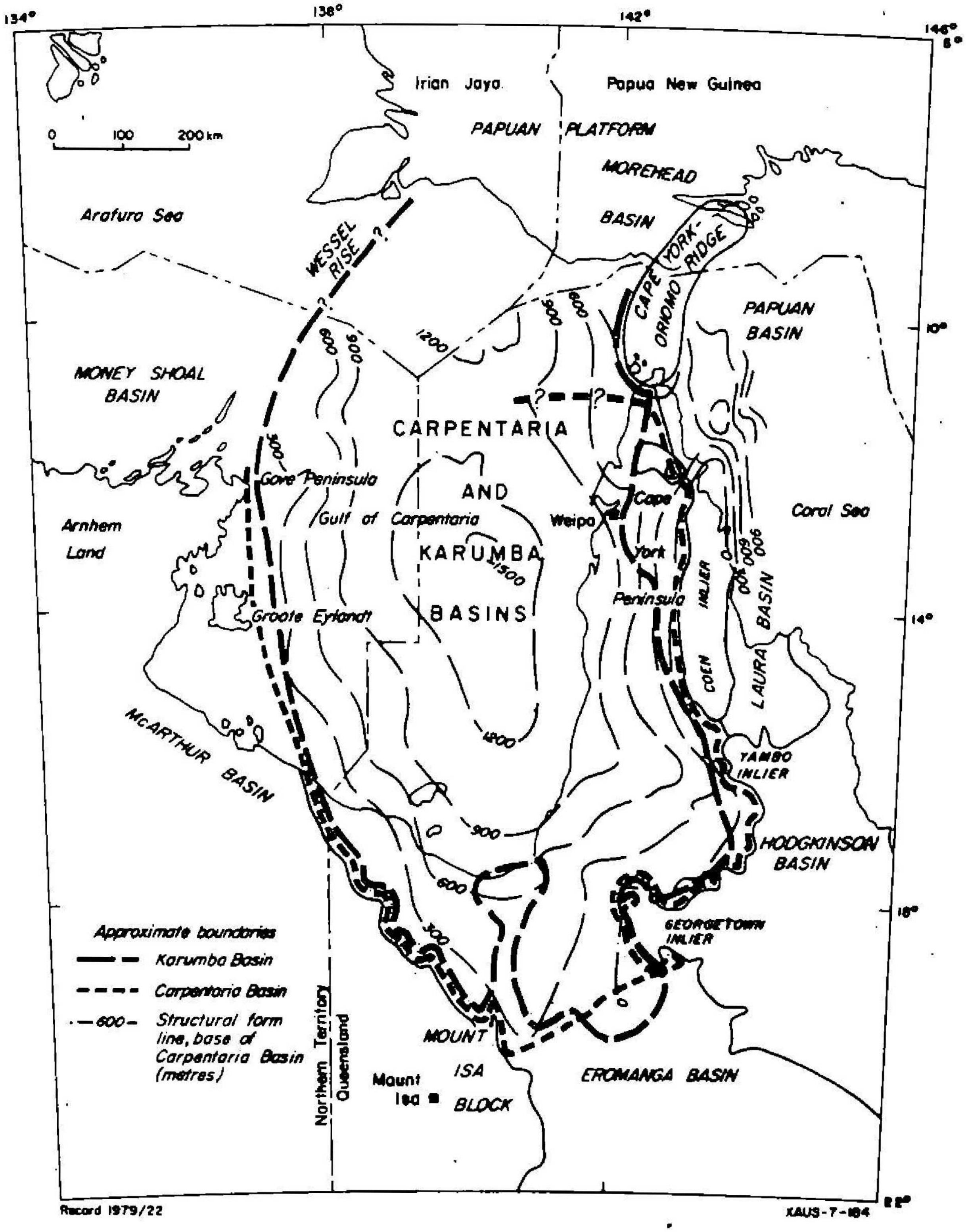

Fig.1 Regional setting

CARPENTARIA BASIN

Summary

The Carpentaria Basin is a north-trending oval depression containing a complete sequence of sediments ranging in age from ?Early Jurassic to Early Cretaceous (Fig. 2), that forms part of the Trans-Australian Platform Cover (GSA, 1971). The basin is separated from the adjacent Papuan, Laura, Eromanga, Money Shoal, and Morehead Basins, which have a comparable sequence of rocks, by the Bramwell Arch, Kimba Arch, Euroka Arch, Wessel Rise, and a broad shallow unnamed basement feature lying west of the Cape York-Oriomo Ridge, respectively (Figs. 1, 4). Jurassic and Cretaceous sediments extend across these basement arches (Doutch, 1976a), implying a connection between the Carpentaria and surrounding basins.

Basin sediments overlie a cratonic basement of igneous, metamorphic, and sedimentary Palaeozoic and Precambrian rocks. Outcropping basement rocks delineate the present basin limits (but cf. definition of Karumba Basin margins by Doutch, 1976b). Along the eastern margin, basement rocks crop out as the Cape York-Oriomo Ridge and the Coen, Yambo, and Georgetown Inliers (Fig. 1). To the south and southwest, rocks of the Mt Isa Block and the McArthur Basin flank the basin. The western edge, which underlies the Gulf of Carpentaria, is less certain, but the Proterozoic and Early Palaeozoic rocks of Arnhem Land and Groote Eylandt mark a maximum western limit (Robertson & others, 1978). The northern boundary is arbitrarily taken at about latitude 11°S (Doutch, 1976a).

Although the basement may be mainly Precambrian in age, wells in the basin have intersected sedimentary and igneous basement rocks as young as Permian (Smart & others, in press).

The Carpentaria Basin structural elements (Fig. 4) are mainly features that formed during pre-Jurassic movements in the area before initiation of the basin. There is no evidence of Jurassic movement in the basin, and sedimentation was largely controlled by basement configuration. Minor movement occurred in the Early Cretaceous, but these syndepositional movements appear to have been limited in extent and influence, and to have had only minor effects on deposition. The displacement of units and the absence of basin sediments across part of the Boomarra Horst suggest that the faults bounding this basement high were reactivated and the horst uplifted at least once during the basin's history. The Euroka and Bramwell Arches also appear to have developed syndepositionally in the Cretaceous; they remained high as the basin areas around them sagged.

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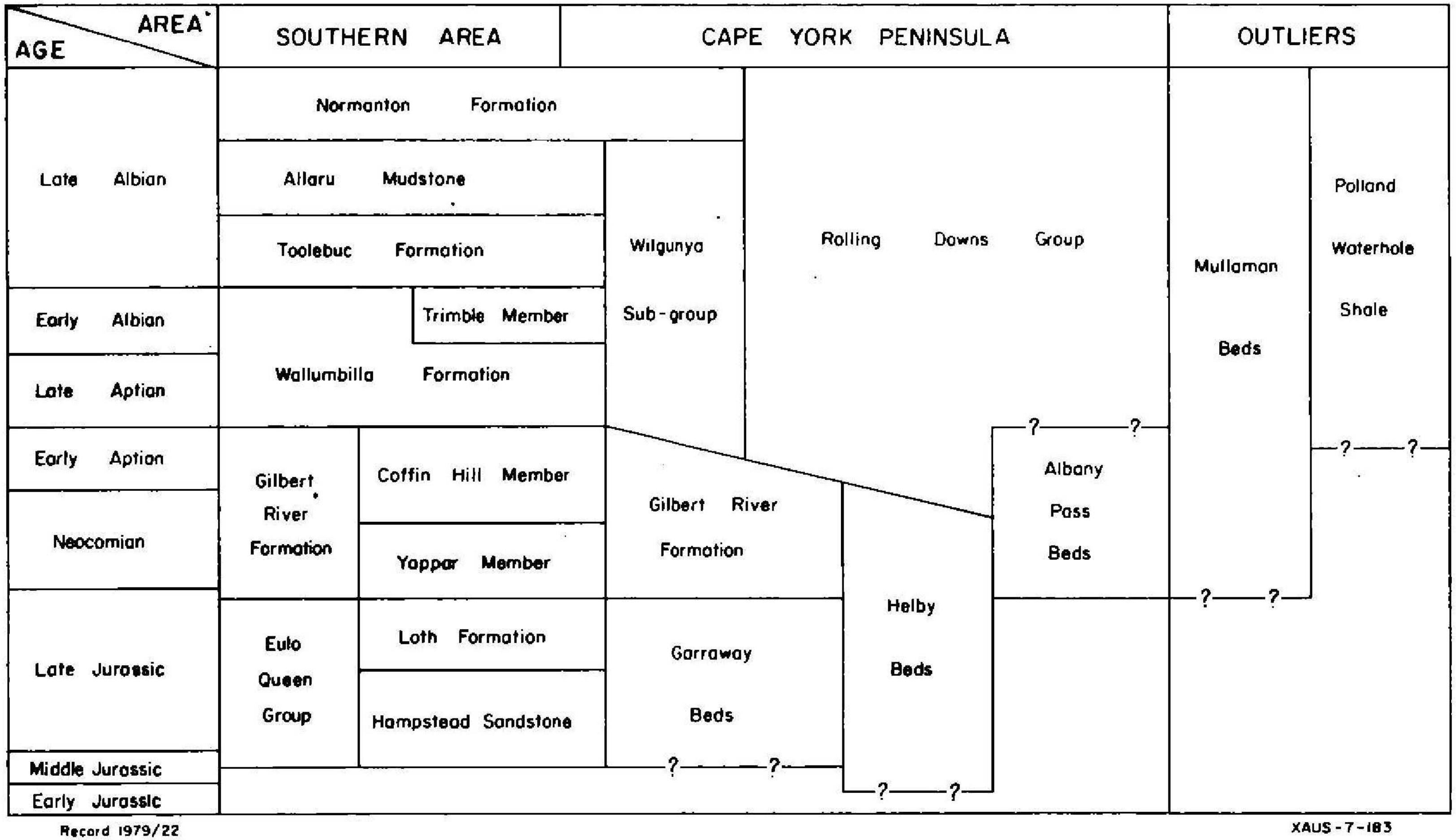

Fig.2 Carpentaria Basin stratigraphy

Basin sediments were mildly deformed by Late Cretaceous and Tertiary activity. There is no clear relation between tectonic activity in the Carpentaria Basin and regional tectonic events elsewhere. However, the interaction of the Pacific and Australian plates during this period is the most likely cause.

Widespread Cretaceous oil shale in the southern Carpentaria Basin could have potential as a source of oil in the future.

Basin Evolution

The history of the Carpentaria Basin began in the Early Jurassic (D. Burger, BMR, personal communication, 1978), when the sea entered either from the north or across the Bramwell Arch and the Olive River Sub-basin, depositing the basal Helby Beds in the northeastern end of the basin, within a large elongate erosion hollow - the Weipa Depression, and establishing an early connection with the Papuan Basin. As paralic to marine deposition continued in the north, fluvial sands (Garraway Beds) covered the southern end of the Weipa Depression, interfingering with the middle Helby Beds (Powell & others, 1976). By the Middle Jurassic, deposition of fluvial sand (Eulo Queen Group and its equivalents) had commenced farther south in other structurally controlled erosion hollows: the Millungera, Canobie, and Burketown Depressions, and the Landsborough Graben (Fig. 4). Palaeogeographically, the Canobie and Millungera Depressions belonged to the Eromanga Basin in the Jurassic, and sedimentation in these commenced with the spreading of quartzose sands from the Eromanga Basin (Smart & Senior, in press). Throughout most of the Jurassic, sedimentation was contained within these basement depressions, and was mainly fluvial, the provenance probably being the surrounding basement areas (Smart & others, in press). These early connections with the adjacent Papuan and Eromanga Basins suggest that neither the Euroka nor Bramwell Arches existed at this time, but were probably Cretaceous developments.

Towards the end of the Jurassic the depressions were filled, and they and the intervening areas were overlain by blanket fluvial sands (lower Gilbert River Formation, Albany Pass Beds), except in the Weipa Depression, where paralic sediments (Helby Beds) continued to spread southward, interfingering with and overlapping the fluvial sands. Connection with the adjacent Laura and Morehead Basins was established during this period, as sediment overlapped the basement areas separating them from the Carpentaria Basin (Smart & others, in press). Whether a connection with the Money Shoal Basin existed at this time is

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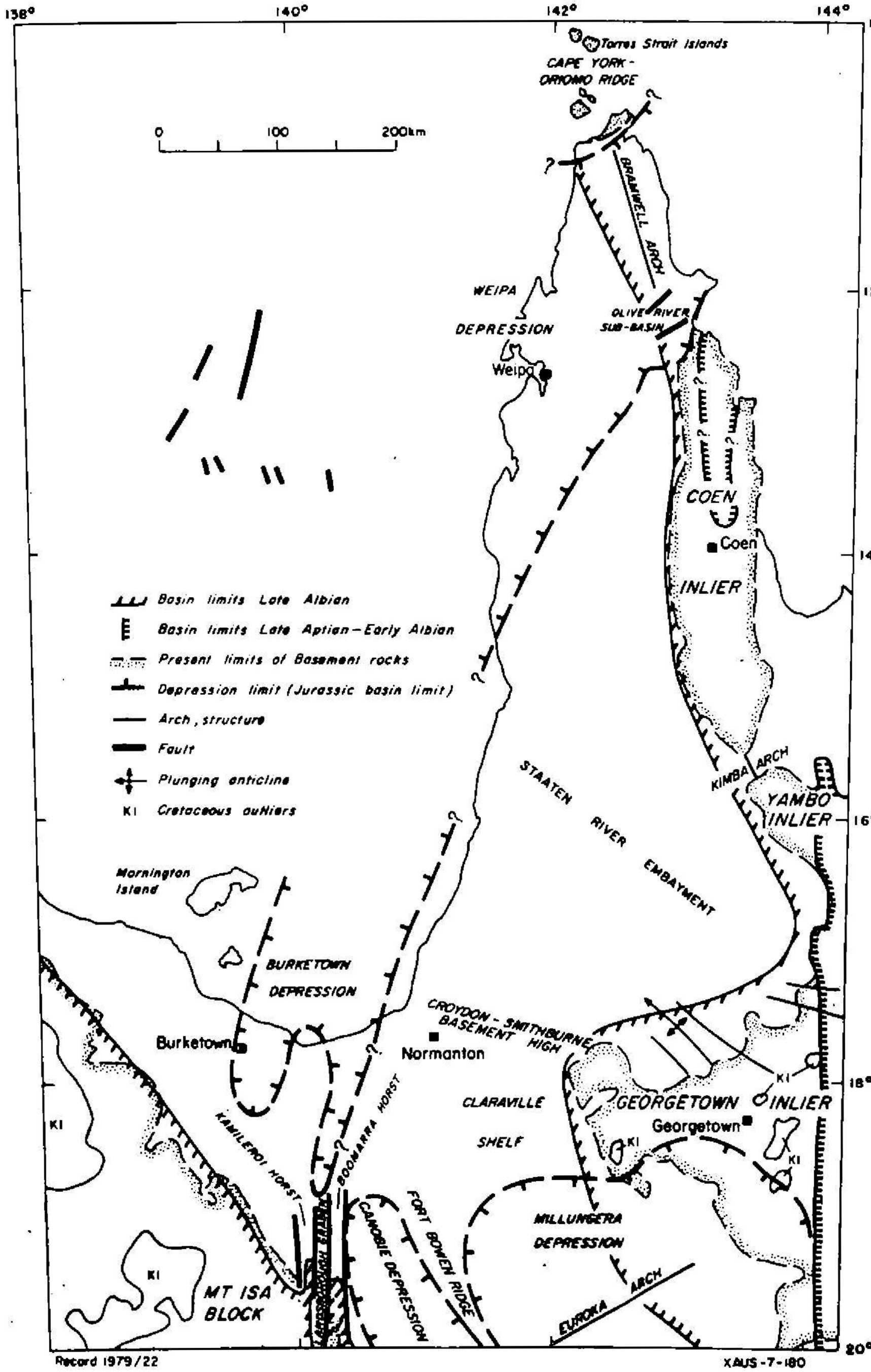

Fig. 4 Mesozoic structure and basin limits, Carpentaria Basin

uncertain, as the extent of fluvial sedimentation beneath the Gulf of Carpentaria is unknown. Basal fluvial deposits of the Mullaman Beds (Skwarko, 1966; Grimes, 1974) show that parts of the western margin were also covered by basin sediments before the Late Neocomian. Fluvial sediments, derived from uplands of exposed basement rocks around the basin, continued to blanket large portions of the basin throughout the Early Cretaceous, but gradually gave way in the Middle Neocomian to marine clastics deposited in a sea that was transgressing southward.

The inundation which began in the north in the mid-Neocomian (D. Burger, BMR, personal communication, 1978) had by Early Aptian times covered all but the southwest part of the basin. Although most of the Euroka Arch remained above sea level, a strait developed at its eastern end through which the sea passed into the Eromanga Basin to the south (Smart & Senior, in press). The connection with the Money Shoal Basin could have been established at this time, across the rocks of the underlying McArthur Basin and/or the Wessel Rise. Remnants of the Mullaman Beds west of the basin show that the sea onlapped basement rocks in the early Cretaceous (Skwarko, 1966). Deposition became most widespread in the Late Aptian (Fig. 4), when fine-grained clastics (Rolling Downs Group) were spread basinwide, overlapping older basin sediments (Gilbert River Formation) and, in some places along the basin margin, basement rocks. This Neocomian-Aptian transgression was part of a worldwide Cretaceous transgression.

The shallow marine conditions established during deposition of the basal Rolling Downs Group (Wallumbilla Formation) continued into the latest Albian, when the sea finally regressed. Local transgressions and regressions occurring in the Aptian and Albian are identified by facies changes in the south of the Carpentaria Basin, but have yet to be recognised in the north. Within the Cretaceous clastic marine sequence, there is a change from quartz-rich to quartz-poor sediment in the Aptian, implying a change in provenance. A similar change in the Eromanga Basin occurs at the Aptian-Albian boundary (Exon & Senior, 1976). Montmorillonite clays within the Albian clastics suggest the source is volcanic; Exon & Senior (1976) have postulated a volcanic chain off the present east coast of Queensland. An early Late Albian facies change occurred in the southern Carpentaria and Eromanga Basins as calcareous bituminous shale (oil shale) and limestone (Toolebuc Formation) for a time supplanted fine clastic silts and muds (Wilgunya Sub-group).

As the sea withdrew from the basin in the final regression, feldspathic and lithic sand and silt (Normanton Formation) accumulated. The absence of Late Albian sediments on the Boomarra Horst suggests possible uplift before the end of sedimentation in the basin (Smart & others, in press). The Euroka Arch also appears to have been emergent during this time. The youngest known rocks in the basin are Late Albian (D. Burger, BMR, personal communication, 1978); however, beneath the Gulf of Carpentaria the Normanton Formation could possibly extend into the earliest Cenomanian (Dettman, 1973). Most of the basin deformation, minor faulting and warping, occurred after sedimentation ceased. Uplift of the northern end of the Georgetown Inlier, and the resultant folding and faulting at the eastern end of the Staatan River Embayment (Fig. 4) which deformed consolidated Rolling Downs sediments occurred no earlier than Late Cretaceous (Doutch, 1976b). Smart & others (in press) have also suggested a Late Cretaceous or younger age for the movements that uplifted the basin margins before deposition of sediments in the overlying Karumba basin.

Resources

Groundwater is the only exploited resource within the basin limits; however, deposits of oil shale could have potential for future development. Manganese ore is mined from outliers west of the basin.

Fossil Fuel

Oil shale occurs within the southern part of the Carpentaria Basin, in the Toolebuc Formation, and is the most prospective fossil fuel known in the basin. The deposits are presently classified as uneconomic (NEAC, 1977). Within the basin, the Toolebuc Formation is approximately 12 m thick. It has an oil yield of between 20 and 100 litres/tonne, and averages over 50 litres/tonne (Smart & others, in press). The oil is high in sulphur, nitrogen, and unsaturated compounds, and both the vanadium and uranium contents are above normal. Inferred resources for the Toolebuc Formation (Carpentaria and Eromanga Basins together) are 455×10^9 m^3 of oil (NEAC, 1977); approximately 20% of these resources lie within the Carpentaria Basin.

Petroleum prospects in the basin are not encouraging. Petroleum exploration wells, stratigraphic holes, and water bores have tested much of the onshore part of the basin, and although minor hydrocarbon shows have been recorded (Meyers, 1969) source rock analyses (Saxby & Bruen, 1978) of exploration wells and BMR stratigraphic holes (Fig. 7) indicate the basin rocks, except for the Toolebuc Formation, are often a poor oil source and generally immature (Bissada & others, 1977; K. Jackson, BMR, personal communication, 1978), owing to shallow depth of burial. In several of the deeper exploration wells (Fig. 7) the organic matter in the Gilbert River and Wallumbilla Formations was shown to be in the very early stages of hydrocarbon generation, and the source rocks are considered to be transitional between immaturity and maturity. The Middle Jurassic section of the Helby Beds also contains source rocks in the transitional stage. Given greater depth of burial and/or an additional heat source, these units may generate liquid hydrocarbons. Offshore, the prospective source rocks are probably at a greater depth, but the shallowness (1500 m maximum) of the whole basin makes it uncertain whether the depth of burial will be sufficient for thermal maturation.

The onshore part of the basin, therefore, appears to have limited hydrocarbon potential, as it is doubtful if the prospective source rocks reach a sufficient depth of burial and the Jurassic reservoirs rocks are freshwater flushed. The offshore part of the basin is untested, but there is little evidence to suggest a significant increase in potential. The sparse seismic coverage suggests a general absence of adequately closed structures onshore and offshore (Robertson & others, 1978).

Coal has been explored for by Utah Development near the Olive River Sub-basin. Results of this investigation have not been released.

Manganese

The manganese oxide deposits of Groote Eylandt (Fig. 1) are Australia's largest, supplying nearly all of the country's production. The orebody occurs within the Mullaman Beds as a single, generally flat bed of cryptomelane and pyrolusite, 5 to 15 m thick (Knight, 1975). The ore is a marine precipitate and is present as both massive and loose pisolites. Reserves are estimated at 490 million tonnes. In 1977, 1.3 million tonnes was mined (BMR, in press), of which 75% was exported.

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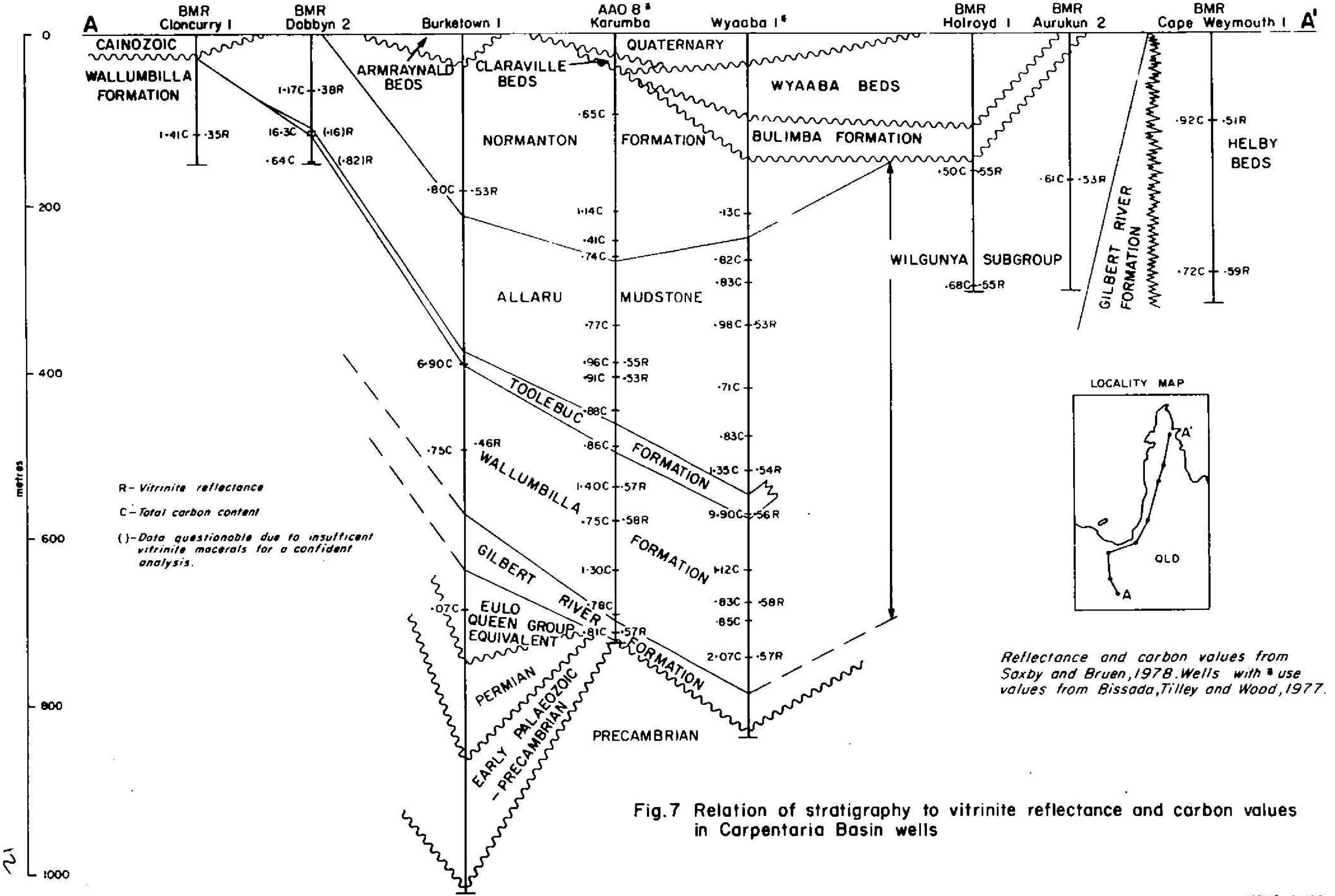

Fig. 7 Relation of stratigraphy to vitrinite reflectance and carbon values in Carpentaria Basin wells

Groundwater

Over 200 water-bores, many of which flow to the surface, have been sunk in the Carpentaria Basin. They supply much of the potable water in the basin, but in the south, where rainfall is lowest, are used mainly for stock watering (Smart & others, 1975).

Hydrologically, the Carpentaria Basin forms the northern part of the Great Artesian Basin. The main aquifers are the predominantly Jurassic fluvial sandstones, which supply water generally having a salinity of less than 1000 ppm total solids (GSQ & IWSC, 1973). The Eulo Queen Group and its equivalents contain important aquifers in the south, but are often at depths uneconomical to drill. In the north, artesian water can be obtained from the Garraway Beds (Smart, 1977). The shallower Jurassic-Neocomian fluvial part of the Gilbert River Formation provides water in all parts of the onshore basin except the north of Cape York Peninsula, where it becomes argillaceous. A high concentration of fluorine in groundwater is a problem in many areas.

KARUMBA BASIN

Summary

The Karumba Basin is a shallow, saucer-shaped, intracratonic depression underlying the Gulf of Carpentaria and much of its river drainage system (Fig. 1). Originally considered the upper or Cainozoic part of the Carpentaria Basin, the Karumba Basin was recognised as a separate tectonic entity by Doutch (1976b) and differentiated from the Carpentaria Basin on the basis of lithological differences, a regional unconformity between the two, and age.

Generally the onshore boundaries for the basin shown on Figure 1 correspond to areas of basement (pre-Late Cretaceous) outcrop or the edge of thicker Cainozoic sediments (deposits exceeding 10 m). Lack of drilling, and blanket Holocene sedimentation offshore render the offshore limits uncertain. Basement rocks cropping out on Arnhem Land and Groote Eylandt form a tentative western limit, and the Wessel Rise is taken as the boundary between the upper part of the Money Shoal Basin and the Karumba Basin, although Cainozoic sediments appear to cross this feature (Robertson & others, 1978). The northern limits are debatable, as the basin margin appears to have migrated with time. Doutch (1976b) suggest an emergent area, recognised in Papua New Guinea, be taken as the Late Cretaceous-Early Tertiary northern margin, and the Oriomo

Plateau (part of the Papuan Platform) as the Pliocene - Quaternary margin. These northern margins of the Karumba Basin lie well north of the underlying Carpentaria Basin margin.

Three cycles of development (erosion, deposition, and weathering) are recognised in the Karumba Basin (Smart & others, in press): the Bulimba, Wyaaba, and Claraville Cycles (Fig. 5). Deeply weathered surfaces separate the sediments of each cycle. The ages of these surfaces (Fig. 3) are derived, for the most part, from regional correlation, as the sediments they have developed on are dominantly fluvial and mostly unfossiliferous.

Tectonism within the basin has been minor, for although there have been several periods of movement, basin sediments are virtually undeformed. Faulting and small scale uplift of basin margins began each cycle, and the second cycle was accompanied by downwarping of the Gilbert-Mitchell depositional trough. The movements can probably be related to the interaction of the Pacific and Australian plates, and possibly to crustal adjustments of the Australian plate as it migrated northward in the Tertiary.

Significant deposits of bauxite occur near Weipa and on Gove Peninsula. The Weipa deposits rank among the largest in the world, and provide about half of Australia's production.

Basin Evolution

The age of inception of the Karumba Basin is uncertain, but it has been placed as early as Late Cretaceous (Doutch, 1976b) and as late as Paleocene (Smart & others, in press). Karumba Basin sedimentation began as the areas uplifted and deformed at the close of Carpentaria Basin sedimentation were eroded. Clastic sediments (Bulimba, Floraville, and Louisa Formations) were laid down as fluvial deposits over basement rocks composed largely of the consolidated sediments of the underlying Carpentaria Basin (Smart & others, in press). The Kamileroi and Boomarra Horsts (Fig. 4), reactivated at the close of Carpentaria Basin sedimentation, along the southwestern edge of the basin, and possibly basement rocks of the Mt Isa Block were a source area for the Floraville Formation; and the eastern margin, including the ancestral Coen, Yambo, and Georgetown Inliers (Fig. 6), was probably the provenance of the Bulimba and Louisa Formations.

The most extensive unit was the Bulimba Formation, which was deposited over the western half of Cape York Peninsula. The feldspathic clastics of this

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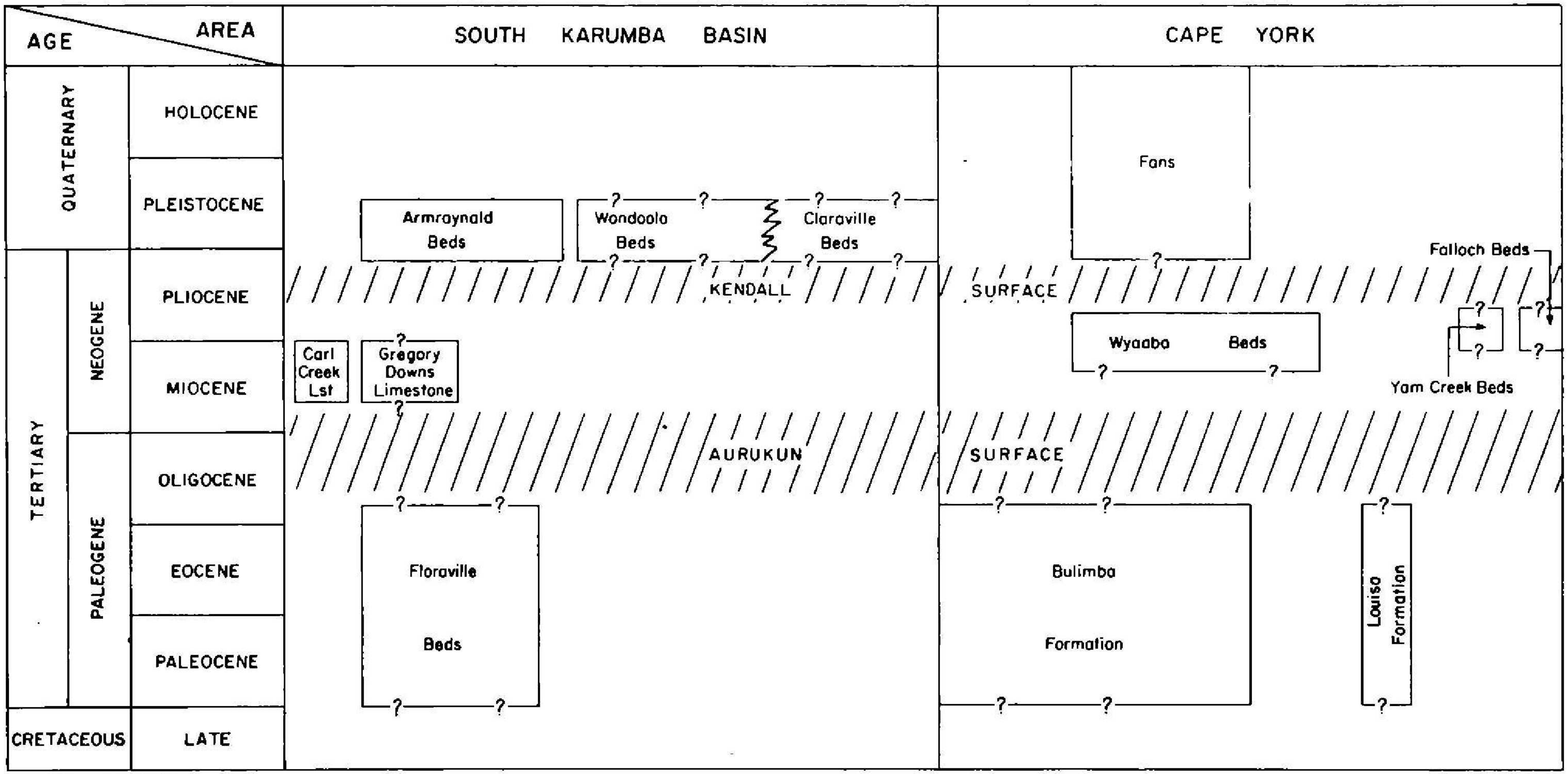

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Fig.3 Karumba Basin stratigraphy

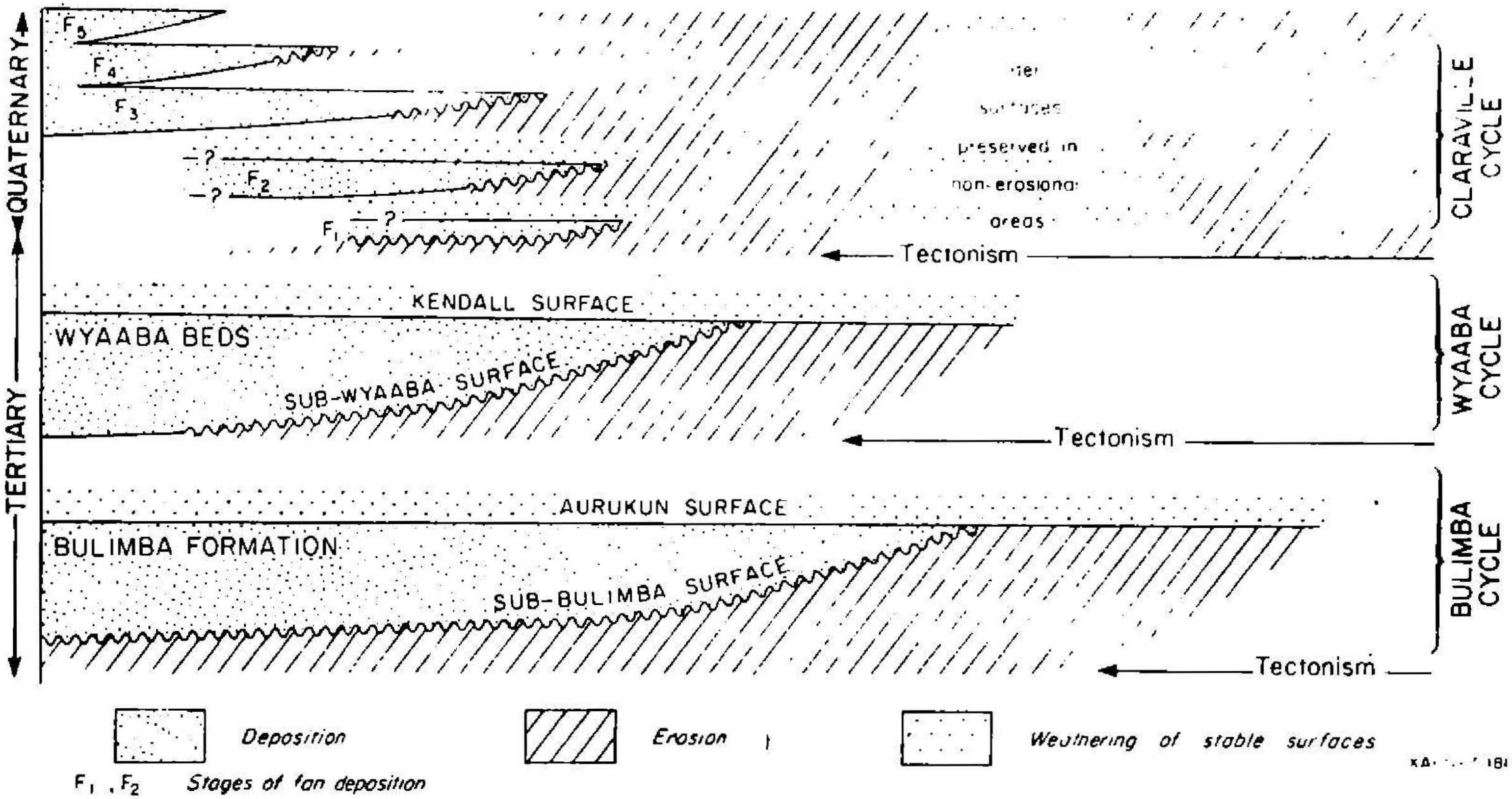

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Fig. 5 Cyclic development of the Karumba Basin (after Grimes & Doutch, 1978)

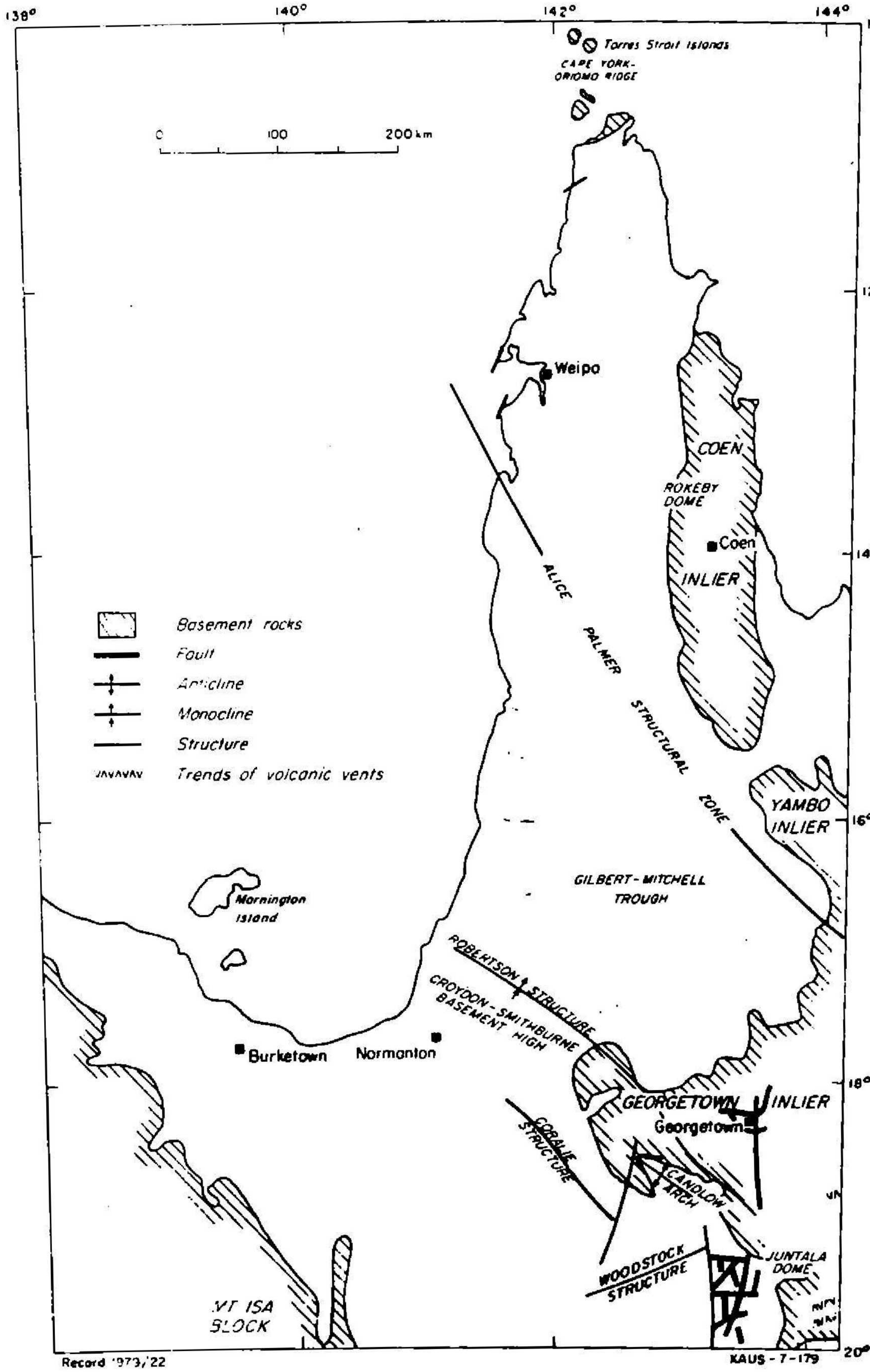

Fig.6 Cainozoic structural development, Karumba Basin

unit became the parent rock from which the large Weipa bauxite deposits developed (Smart, 1977). The Bulimba Formation is absent over the Croydon-Smithburne Basement High (Fig. 6) and the areas south and west of it. Whether the Croydon-Smithburne Basement High remained emergent as a result of simple downwarping north of it or penecontemporaneous arching of the high to form a depositional barrier is unclear.

Deposition in the Bulimba Cycle (Fig. 5) continued through the Early Tertiary, possibly prograding westward, but in the Oligocene, sedimentation may have ceased as the relief of the provenance areas was reduced and the stream channels were filled. The extent of the Bulimba Cycle sediments is uncertain, but rocks of that approximate age are known to underlie at least part of the Gulf of Carpentaria, and a pre-Miocene emergent area existed on the southern Papuan Platform north of Cape York Peninsula (APC, 1961). The end of sedimentation resulted in the development of the stable terminal Aurukun Surface across the basin. This surface and the basin margins, including the Cretaceous parent rock of the Gove bauxite deposits, were lateritised and deeply weathered (Doutch, 1976b). Mottling throughout the Bulimba Formation suggests lateritisation or deep weathering may have also been penecontemporaneous with sedimentation (Smart & others, in press). The Aurukun Surface has been tentatively dated by correlating it with weathering surfaces south and west of the basin (Doutch, 1976b), as the underlying sediments are unfossiliferous.

The Aurukun Surface was disrupted in the Late Oligocene to Early Miocene by renewed tectonic movement that preceded the Wyaaba Cycle sedimentation. The eastern margin was again uplifted, along with the southern margin, becoming the main provenance; and the area between the Croydon-Smithburne Basement High and the Alice Palmer Structural Zone was slightly downwarped, forming the Gilbert-Mitchell Trough (Fig. 6) (Doutch, 1976b; Smart & others, in press). Much of the northern end of the Cape York Peninsula area remained emergent, in part due to uplift of the Rokeby Dome (Fig. 6).

Sedimentation probably began in the area beneath the Gulf of Carpentaria in the Early or Middle Miocene. Whether these basal deposits are continental or marine is unknown, but Miocene marine sediments blanketed the Papuan Platform (APC, 1961) and may have extended as far south as the Karumba Basin. By the Middle to Late Miocene, clastic sediments derived from the basin margins were also being deposited in present onshore areas - fluvial deposits (continental facies of the Wyaaba Beds) covered the eastern end of the Gilbert-Mitchell Trough, and also accumulated (Yam Creek and Falloch Beds) in small intermontane basins along the eastern margin (Smart & others, in press). Freshwater limestones were precipitated locally along the southwestern edge of the basin.

The sea which entered the basin from the north sometime during the Wyaaba Cycle had transgressed to the west coast of Cape York Peninsula by the Pliocene; marine conditions may have existed over most of the present Gulf of Carpentaria at this time. There is relatively little information on the marine phase of sedimentation in this cycle. Along the west coast of the Cape York Peninsula fine-grained clastics were deposited, while north of the basin limestone was precipitated in the Miocene.

As the relief of the source areas was reduced and subsidence in the Gilbert-Mitchell Trough decreased, sedimentation ceased and another terminal land surface, the Kendall Surface, developed in the Pliocene (Grimes & Doutch, 1978). Like the Aurukun Surface, the Kendall Surface was lateritised and deeply weathered. The formation of the Kendall Surface also exposed parts of the underlying Aurukun Surface, and both these and the Kendall Surface were modified by further weathering. At Weipa and on the Gove Peninsula the effect was bauxitisation of the older Aurukun Surface (Smart, 1977). Isotopic dating of basalt flows (Griffin & McDougall, 1975) southeast of the basin has provided some age control for events in the Wyaaba Cycle and the successive stages of the Claraville Cycle (Fig. 5).

The Claraville Cycle, presently operative, commenced at the end of the Pliocene, following renewed tectonism that uplifted the basin margins. The present structure and topography of the Karumba Basin was formed by the tectonism that preceded the cycle, and upwarping, eustatic changes, and climatic fluctuations that occurred during it (Grimes & Doutch, 1978).

Onshore sedimentation in the Claraville Cycle was mainly fluvial fan deposition. The Armraynald, Wondoola, and Claraville Beds spread across most of the southern end of the basin during the Late Pliocene and Pleistocene. In the eastern Gilbert-Mitchell Trough five stages of fan deposition are recognised, (Fig. 5) from the Late Pliocene to the Holocene (Grimes & Doutch, 1978).

Resources

Bauxite

Bauxite deposits on the west coast of Cape York Peninsula, near Weipa (Fig. 1), underlie an area 11 000 km^2, forming probably the largest single deposit of bauxite in the world (Knight, 1975). The bauxite occurs as loose or poorly cemented pisolites in a bed 1 to 10 m thick, beneath an overburden up to one metre in thickness (Smart, 1977). Reserves are estimated at over 4 000 million tonnes (Smart & others, in press).

The Weipa bauxite is chiefly an in situ deposit derived from the Tertiary Bulimba Formation, which underlies it, and is best developed where the Bulimba Formation is more permeable than average. The alumina is in the form of trihydrate (gibbsite) in the lower horizon and monohydrate (boehmite) in the upper horizon (Smart, 1977). Most of the deposit is a fossil bauxite, although in a few areas bauxitisation appears to still be in progress. Within the basin, economic grade bauxite is apparently confined to the northern end of Cape York Peninsula, where there were several periods of weathering, suitable parent rock, good permeability and drainage, and the favourable climatic conditions necessary for the development of bauxite. Investigations on the extent of the deposits offshore have been inconclusive (Smart & others, in press), but the presence of the sea in this area during much of the Tertiary probably precludes significant bauxite development.

Bauxite deposits are also present along the western margin of the basin on the Gove Peninsula, but economic concentrations are confined to an area of only 63 km^2 (Knight, 1975). The Gove deposits were derived from the Early Cretaceous Mullaman Beds, which are lithologically similar to the Bulimba Formation; however, they are largely detrital. They are fossil bauxites and most likely formed during the Middle and Late Tertiary (Plumb & Gostin, 1973). The orebody is composed of a basal bed of tubular ore, overlain by cemented pisolitic ore that is capped by loose pisolitic ore. In places the overburden is up to 2 m thick. The alumina chiefly takes the form of gibbsite (Knight, 1975). Reserves for the Gove bauxite are in the order of 250 million tonnes.

Australia is the largest producer of bauxite in the world, and over half of this production comes from the Karumba Basin (combined Weipa and Gove deposits). In 1977 over 10 million tonnes of beneficiated ore was mined from Weipa and over 4 million tonnes from Gove (BMR, in press).

Groundwater

The Bulimba Formation and Wyaaba Beds contain the main aquifers for the Karumba Basin. The Bulimba Formation is the most significant, as it provides the domestic water and much of the processing water for Weipa (Smart, 1977). The Wyaaba Beds provide shallow water for most of the central part of the basin, but high salinity limits its use primarily to stock. The formations are generally unconfined aquifer systems, except beneath the Gilbert-Mitchell

Trough, and so can be subject to the effects of drought conditions (Smart & others, in press). Smaller quantities of domestic and stock water are also supplied by Quaternary sediments.

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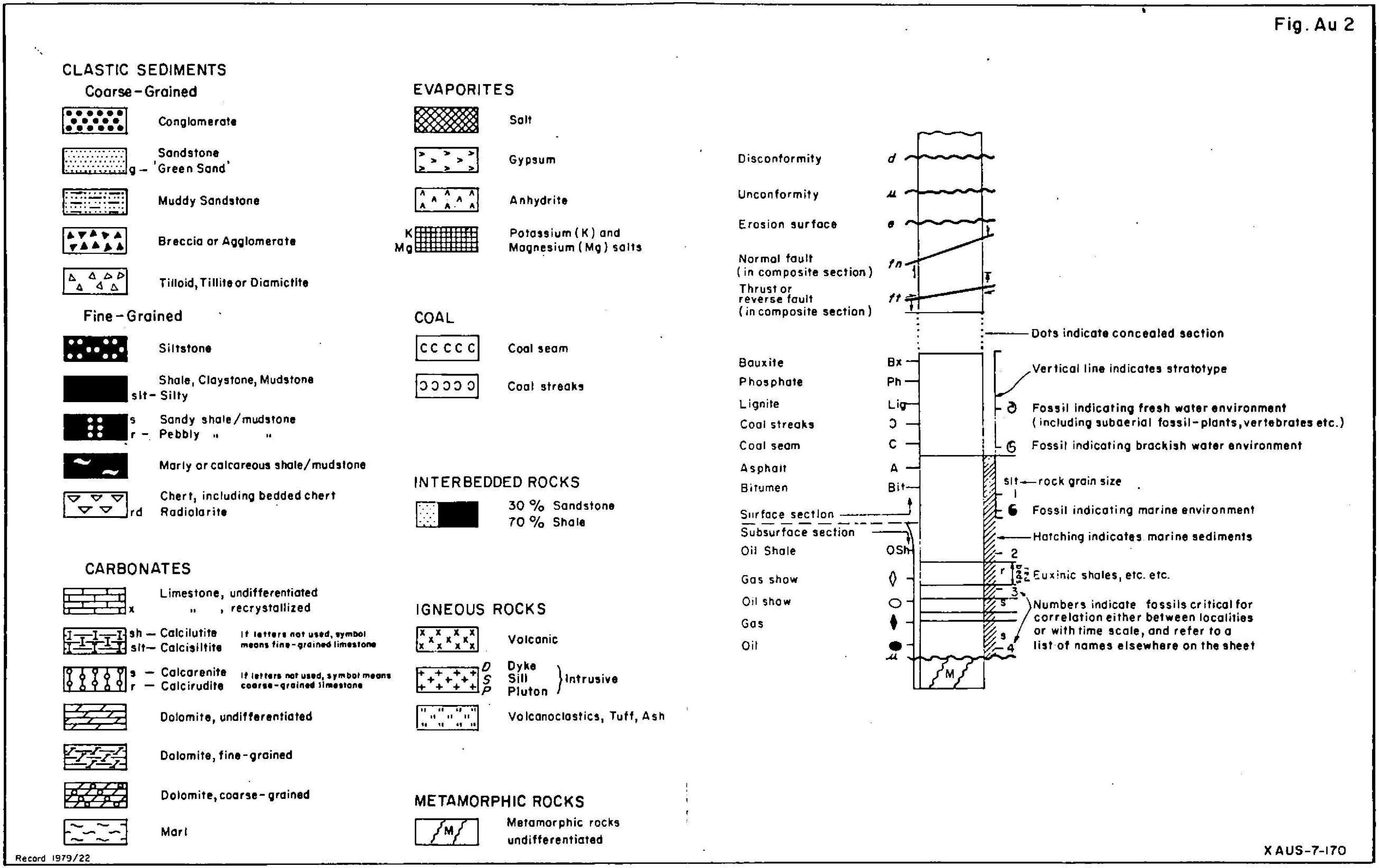

Legend for stratigraphic columns of Fig. Au 2a