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# Jurassic-Cretaceous palaeogeography of the Jagoi-Serikin area as indicated by the Bau Limestone Formation

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**Abstract:** A reef complex with minor patch reef and mud-mound model is postulated for the Late Jurassic-Early Cretaceous Bau Limestone in the Jagoi-Serikin area. Mudstone, wackestone and packstone representing the back reef area are mostly distributed in close proximity to the landmass, composed of Jagoi Granodiorite. Stromatoporoid-coral-algal boundstone representing ecologic reef with minor packstone, is mainly distributed in the centre of the embayment and farther out on the slope of the basin.

The Jurassic-Cretaceous palaeogeography of the area is modelled as the margin of a landmass, where Gunung Jagoi and Gunung Kisam formed two promontaries bordered by a fringing reef complex on the slope of a rapidly subsiding basin in which the Pedawan Formation was deposited.

## INTRODUCTION

The Jagoi-Serikin area is located within the Bau District, Kuching Division, Sarawak. It is about 10 km southwest from the Bau town, marked by grids 109°57.6'E to 110°05'E and 1°17.3'N to 1°23.8'N. Geologically, it is situated in the Kuching Zone of Haile (1974).

The Jagoi-Serikin area has first been mapped by Wilford (1955) who produced a regional map on a scale of 1:125,000 for the whole Bau area with a more detailed map on a scale of 1:50,000 for the Bau Mining District. More detailed geological map on a scale of 1:80,000 has been produced by Lau (1971) for the Bau-Gunung Undan area. Brachiopods from the Gunung Stulang have been examined by Yanagida and Lau (1978).

## GENERAL GEOLOGY AND STRATIGRAPHY

### General geology

The geology of the Jagoi-Serikin area can be divided into 4 main lithological units (Fig. 2):

(1) Igneous rocks
(2) Bau Limestone Formation
(3) Pedawan Formation
(4) Alluvium

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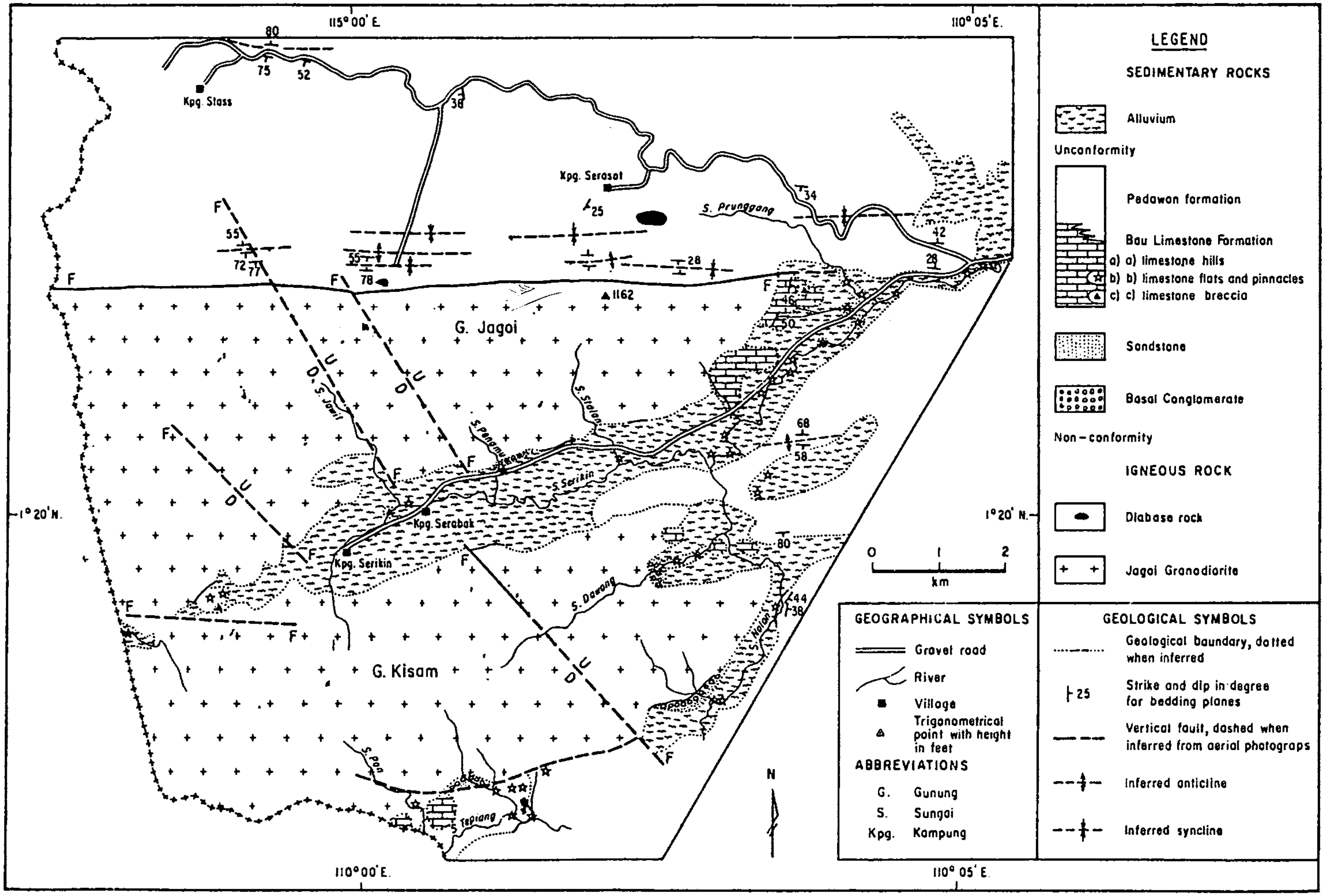


**Figure 1:** Location map of the Jagoi-Serikin area, Bau, Sarawak.

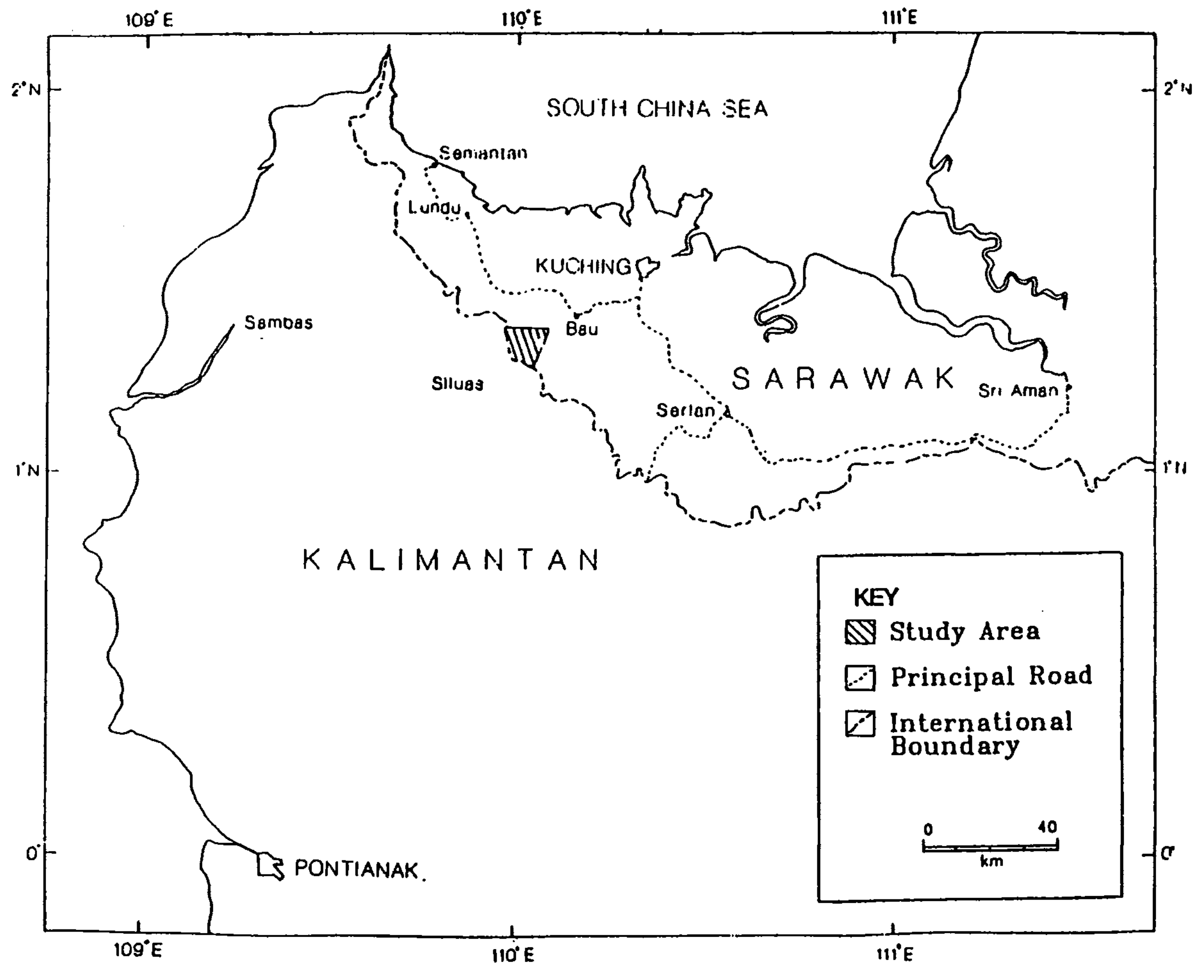


**Figure 2:** A simplified geological map of the Jagoi-Serikin area, Bau, Sarawak.

### (1) *Igneous rocks*

The major igneous rock in the Jagoi-Serikin area is the Jagoi Granodiorite, which builds the Jagoi and Kisam ranges. It comprises a series of granitoids from quartz-diorite to adamellite with granodiorite being the most dominant. Generally, the Jagoi Granodiorite is greenish to pinkish, medium-grained and non-porphyritic. Hornblende and biotite are characteristic minerals. Some of the granodiorites contain relicts of olivine. Minor granophyre and aplite dykes are also present.

The other type of igneous rock is the hypabyssal intrusion of aphanitic diabase dykes. Those intruding into the Bau Limestone are amygdaloidal and greenish black in colour. Whereas, those intruding into the Jagoi Granodiorite and the Pedawan Formation are non-amygdaloidal and black.

### (2) *Bau Limestone Formation*

The Bau Limestone Formation starts with a basal conglomerate, resting non-comformably on the Jagoi Granodiorite. The conglomerate is succeeded by a sequence of sandstone, some of which are calcareous. The typical Bau Limestone overlies the sandstone.

The basal conglomerate is composed mainly of subrounded to rounded pebble-sized, coarse-grained granodiorite clasts, fine-grained, greenish to dark green, basic volcanic clasts, bluish grey chert and pebble-sized quartz grains.

The sandstone is usually greenish grey or darkish grey, fine to coarse grained. It composes principally of bigger quartz grains, in a finer matrix mainly of feldspar, quartz and opaque minerals with occasional sandstone fragments.

The Bau Limestone occur in the area is predominantly massive, occasionally with poor, obscure bedding. It is usually white, grey, buff, dark grey to black, fine grained, moderate to very fossiliferous, pure limestone.

A sequence of sandstone beds occurring inside the Bau Limestone, suggests a break in the carbonate deposition. This sandstone consists mainly of quartz, minor chert and sandstone fragments.

### (3) *Pedawan Formation*

The Pedawan Formation is a thick sequence of moderately to steeply dipping, predominantly argillaceous rocks, dominated by black shales with rare sandstone and radiolarite beds. Towards the upper part, the lithology becomes more arenaceous with thick beds of massive sandstone and occasionally mass flow beds.

The formation can be divided into 5 facies: (1) Thinly bedded shale facies, (2) Interbedded predominantly shale and minor sandstone facies, (3) Massive sandstone facies, (4) Mass flow facies and (5) Interbedded predominantly sandstone and minor shale facies.

(4) ***Alluvium***

A thin cover of alluvium occurs mainly in the valley in between the G. Jagoi and G. Kisam as well as the eastern end of the G. Kisam. It is mainly riverine comprising sand, silt, mud and rare gravels. However, at places (e.g. Loc. 1, Fig. 4), black humic mud with stagnant water occurs. Terrace deposits are rare.

## Stratigraphy

The stratigraphy of the Jagoi-Serikin area is shown in Fig. 3. The oldest rock in the area is the Jagoi Granodiorite with an age of Early Jurassic (195±2 Ma) obtained by Rusmana and Pieters (1989).

The Jagoi Granodiorite is non-conformably overlained by the Bau Limestone Formation. The non-conformity is clearly shown by the presence of beds of basal conglomerate (with granodiorite pebbles) and sandstone. In addition, the limestones and black shales which occur in close proximity to the Jagoi Granodiorite are not thermally metamorphosed, proving that the granodiorite formed the basement.

The age of the Bau Limestone Formation has been determined to be Late Jurassic to Early Cretaceous by Wilford and Kho (1965) based on algae, *Lithocodium japonicum* and *Lithocodium aggregatum* (Elliott), by Yanagida and Lau (1978) based on *"Terebratula"* sp. and *Platythyris* sp. The Late Jurassic age is also indicated by the presence of foraminiferas (*Pseudocyclammina* with affinities to *Pseudocyclammina jaccardi* (Schrodt), (Wilford & Kho, 1965) and *Pseudocyclammina lituus* (Yokoyama) 'form' alpha Maync, (Bayliss, 1965).

The Pedawan Formation overlies conformably on the Bau Limestone Formation with gradational interbedded contact (Wilford and Kho, 1965; Wolfenden, 1965 and Pimm, 1967). The age of the Pedawan Formation ranges from Late Jurassic to Late Cretaceous. The Late Jurassic age is determined based on its intertonguing relationship with the Late Jurassic part of the Bau Limestone (Wilford & Kho, 1965; Wolfenden, 1965 and Pimm, 1967) and the presence of Late Jurassic to Early Cretaceous radiolaria (Wilford & Kho, 1965). The Early Cretaceous age is indicated by its interbedding relationship with the Early Cretaceous part of the Bau Limestone and the presence of *Orbitolina lenticularia* (Wilford & Kho, 1965). The upper age limit of Maastrichtian (Wilford & Kho, 1965) based on the *Globotruncana tricarinata* has been revised to Upper Santonian (Nuraiteng and Kushari, 1987), based on the presence of *Marginotruncana coronata*, which has an incompatible stratigraphic range with *Globotruncana tricarinata*.

The Jagoi Granodiorite, the Bau Limestone Formation, and the Pedawan Formation have been intruded by diabase dykes, probably of mid-Miocene age (Wilford, 1955; Wolfenden, 1965 and Lau, 1971).

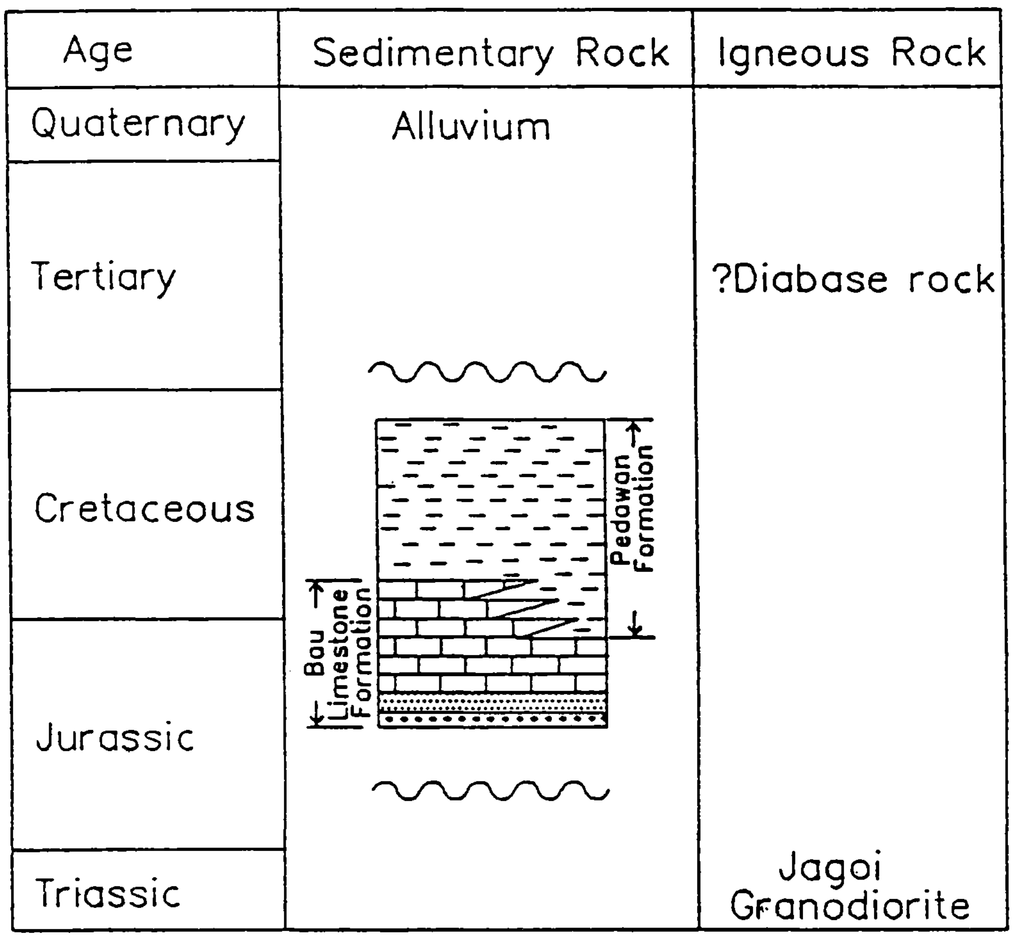


**Figure 3:** Stratigraphy of the Jagoi-Serikin area, Bau, Sarawak.

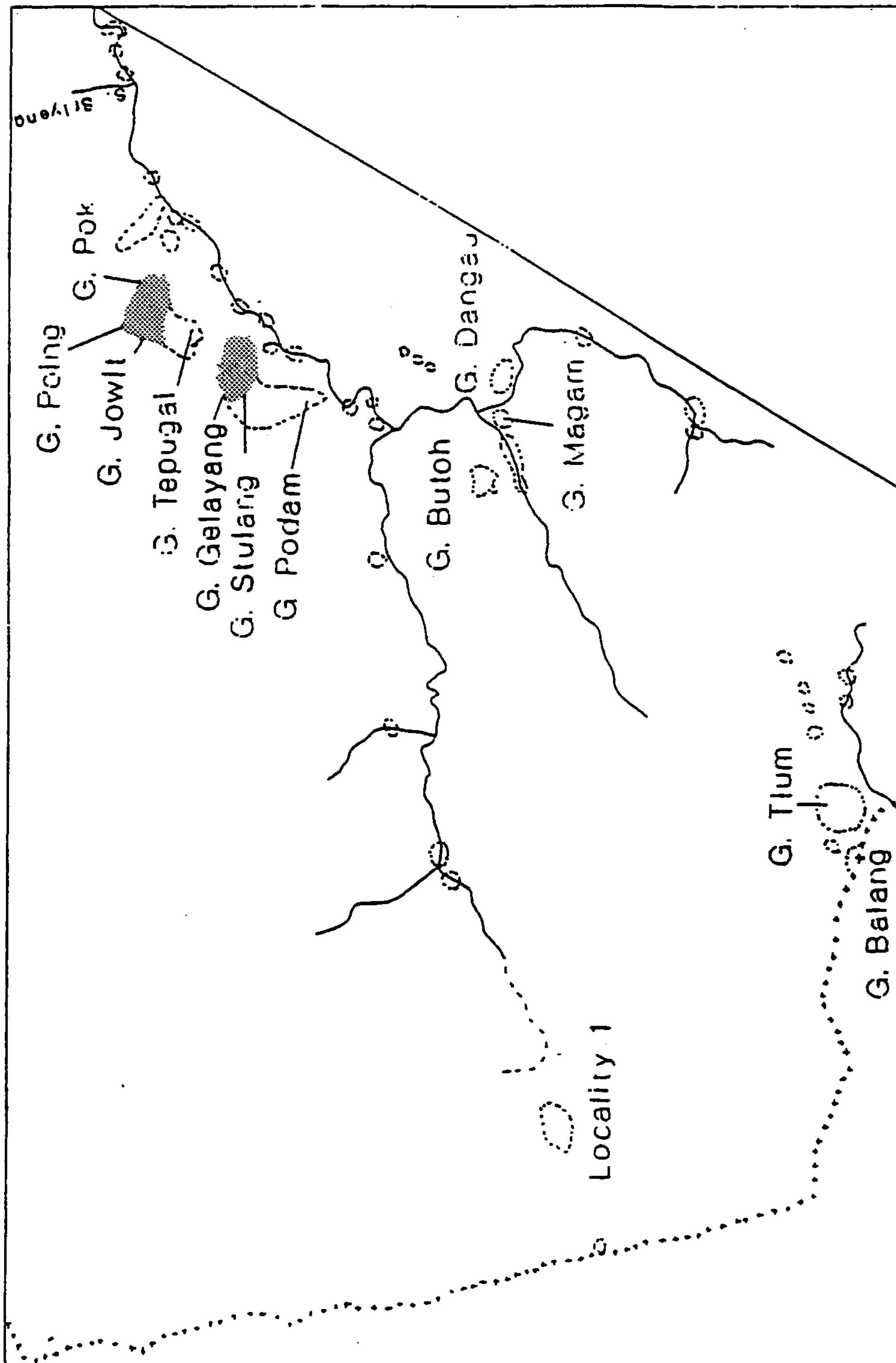


**Figure 4:** Distribution of mudstone in the Bau Limestone.

## Sedimentology of the Bau Limestone

### *Field and megascopic description*

The Bau Limestone is mainly exposed along the sides of G. Jagoi and G. Kisam. It occurs as isolated hills, pinnacles and flats.

In the field, the limestone can be divided into:

(a) massive limestone where bedding is not observed.

(b) bedded limestone where poor or occasionally good beddings are observed.

(c) nodular limestone where the limestone surface is irregular and has a nodular appearance. It is associated with stromatoporoid boundstone. For example at Sg. Penamu and G. Tepugai.

(d) limestone breccia which has been exposed at Sg. Serikin (near Kampong Serabak), at Locality 1 (Fig. 4) and at G. Poing.

Most of the limestone is criss-crossed with different phases of calcite veins intercutting each other which are usually less than 1 cm thick. At G. Podam, the limestone has been brecciated by thick calcite veins, some over 10 cm thick.

Small, thin, irregular, sutured or wavy stylolites are very common at most of the outcrops. They are usually black in colour and stand out from the limestone surface.

Chert nodules occur at almost all limestone outcrops especially those along S. Serikin, G. Podam and Locality I. They are usually disseminated. Sometimes, they attain a diameter as long as 75 cm for instance, at G. Podam. In addition, chertified burrows have been observed at Locality I. They either occur in clusters or confined to certain horizon and/or bedding planes. Branched chertified burrows are also observed.

### *Microscopic description*

The limestone classification based on depositional texture, as proposed by Dunham (1962) is utilised.

Based on this classification, the Bau Limestone can be broadly divided into four types.

(a) Mudstone
(b) Wackestone
(c) Packstone-grainstone
(d) Boundstone

(a) ***Mudstone***

Generally, mudstone consists of allochems include bioclasts like foraminiferas, algae, echinoderm fragments, brachiopods, spicules, calcispheres (possibly casts of radiolaria or cross-section of spicules) and minor amount of intraclasts. However, pure micritic mudstone also occur. The geographical distribution of mudstone is shown in Fig. 4.

(b) ***Wackestone***

Generally, wackestone contains an abundant amount of larger foraminiferas, small amount of fragmental algae, echinoderm fragments, calcispheres and minor amount of gastropods, bryozoans, brachiopod spines, intraclasts of wackestone and peloids. Occasionally, terrigenous clasts of quartz (about 1 mm) are present. The geographical distribution of wackestone is shown in Fig. 5.

(c) ***Packstone-Grainstone***

Packstone is the most dominant type of limestone found in this area. Generally, it is composed of bioclasts, pellets, micrite and a minor amount of sparry calcite. However, at Locality 1 and G. Magam, a gradation of texture from packstone to grainstone is observed indicating a higher energy of deposition.

Bioclasts present in the packstone include foraminiferas (*Pseudocyclammina* sp., *Spiroloculina* sp. and *Textularia* sp)., algae (*Bacinella* sp.), spicules, echinoderm fragments, brachiopods, minor molluscs, bryozoans, stromatoporoid fragments and calcispheres.

The geographical distribution of packstone is shown in Fig. 6.

(d) ***Boundstone***

The boundstones that have been studied can be divided into four smaller types depending on the types of binding fossils present. The geographical distribution of the boundstone is shown in Fig. 7.

(1) Stromatoporoid Boundstone

It is present at Sg. Dawong, Sg. Sam, Sg. Penamu and G. Tepugai (minor). This boundstone is characterised by the presence of stromatoporoid as the main framework builder oftenly encrusted by algae and bryozoans. Minor fossils include brachiopods, foraminiferas and echinoderm fragments. The matrix of this boundstone is very micritic except the one at G. Tepugai where the matrix is composed of peloids.

(2) Algal Boundstone

The algal boundstone here referred to is boundstone formed by algae in growth position. The matrix is made up of micrite with a minor amount of calcispheres,

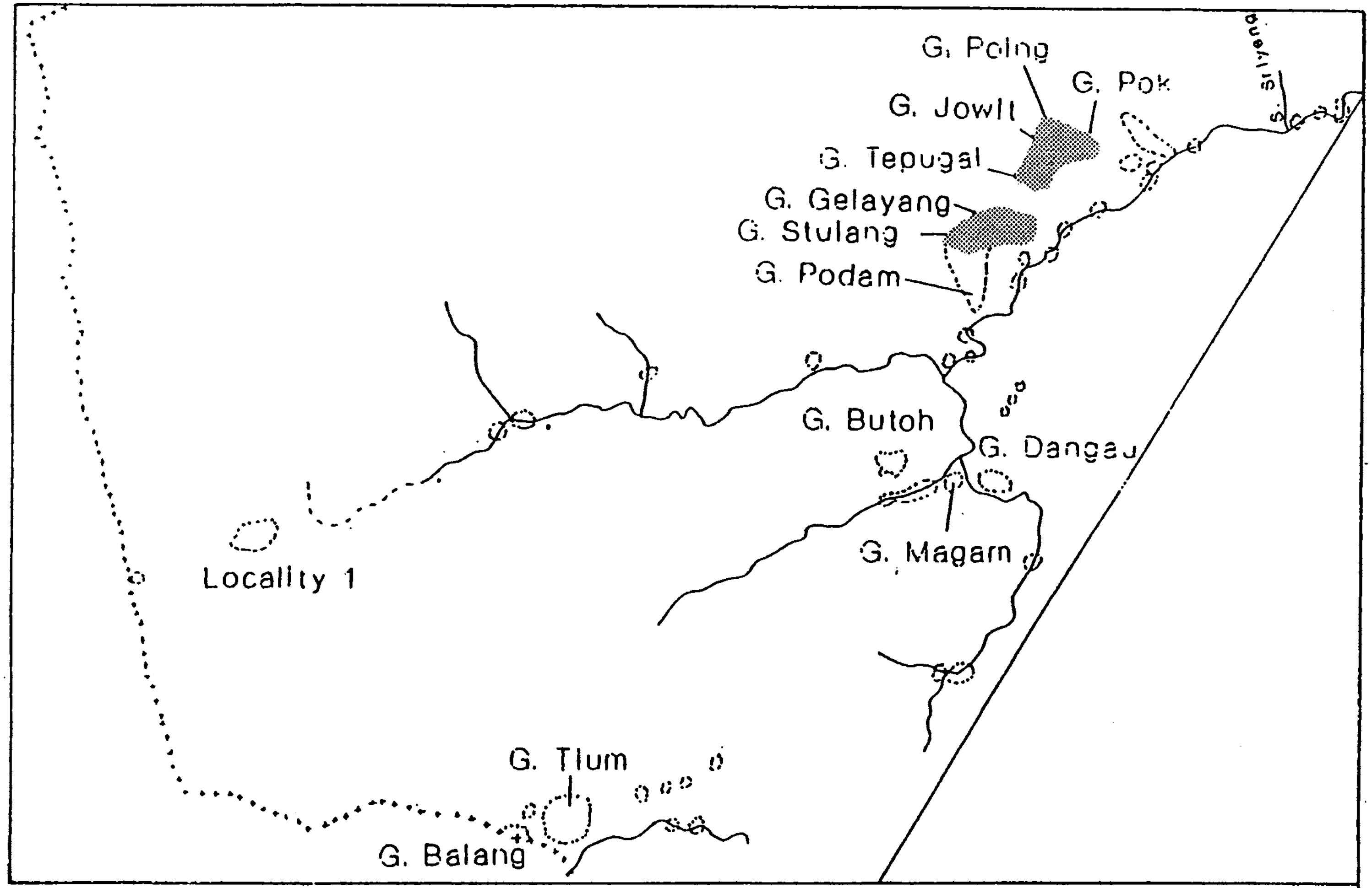


**Figure 5:** Distribution of wackestone in the Bau Limestone.

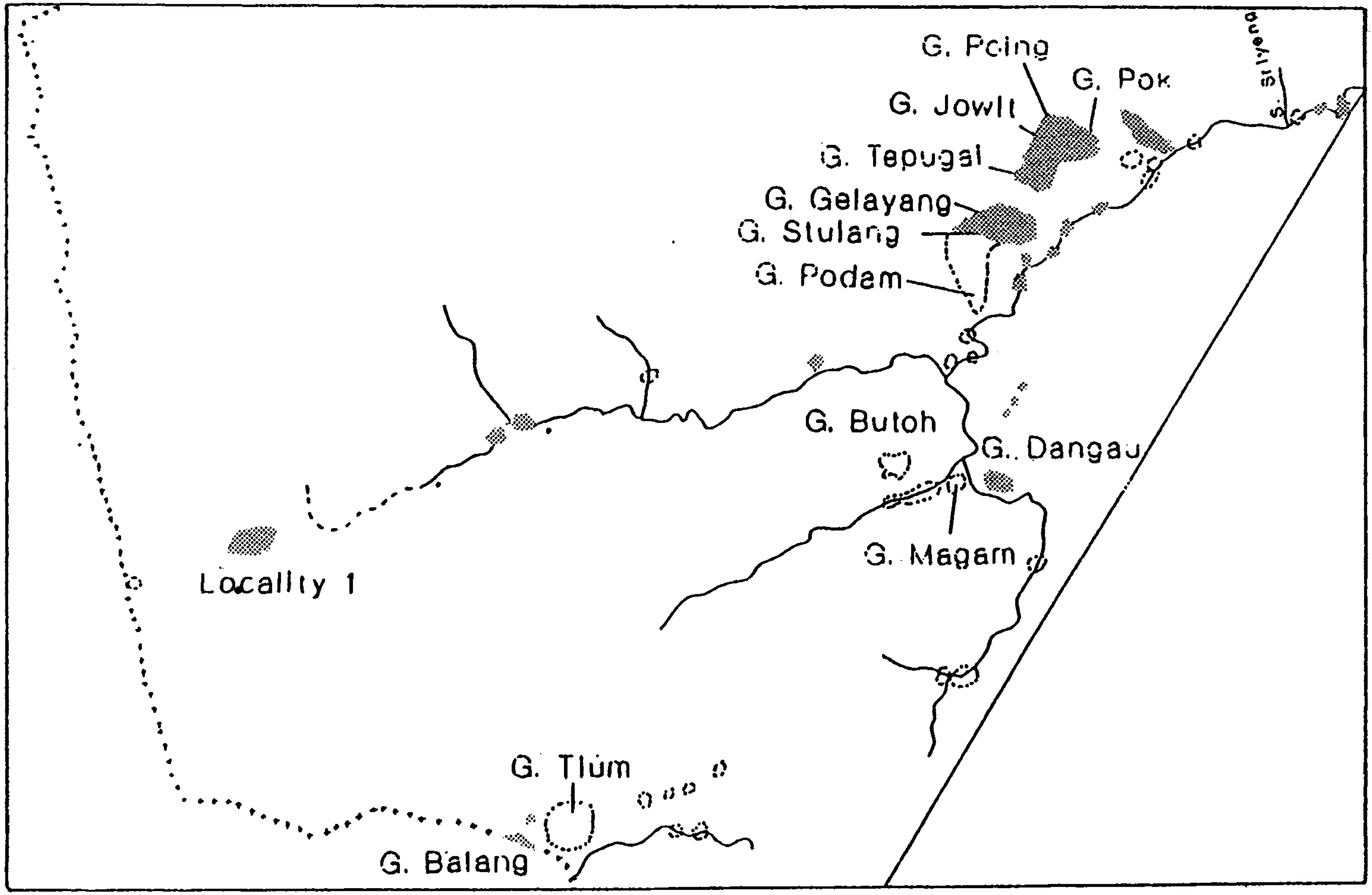


**Figure 6:** Distribution of packstone in the Bau Limestone.

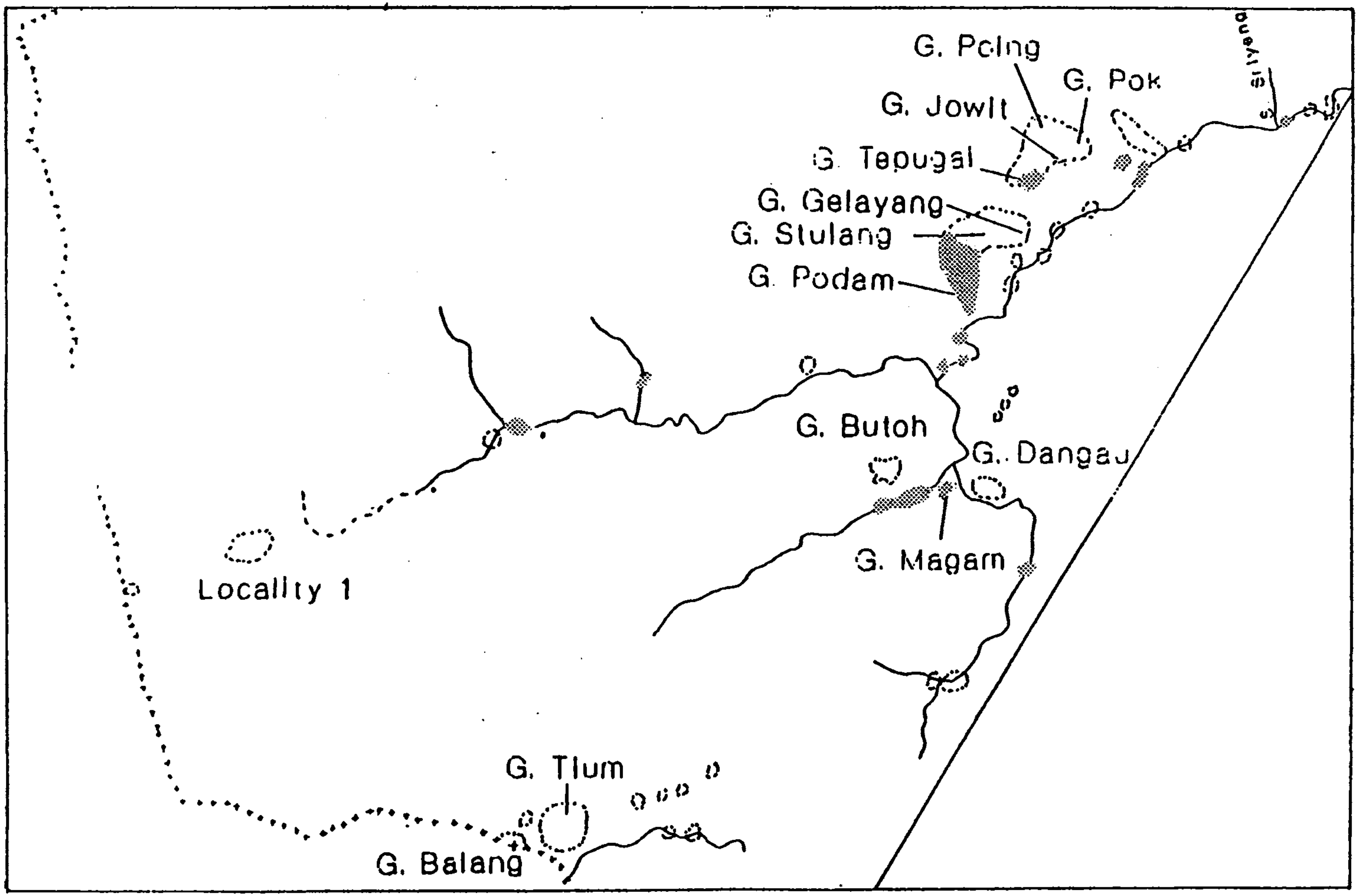


**Figure 7:** Distribution of boundstone in the Bau Limestone.

spicules and other types of algal fragments. It is found at Sg. Serikin near to the junction of its tributary, Sg. Podam.

(3) Coralgal Boundstone

Two types of corals (*Stylina* sp. and *Aplosmilia* sp.) have been observed in their growth position encrusted by algae (*Bacinella* sp. and *Girvanella* sp.). The matrix is made up of micrite and minor amount of small peloids. It is present at G. Podam.

(4) Coral Bryozoan Boundstone

This combination is observed at G. Magam. The type of coral present is *Stylina* sp.

The matrix is made up of peloidal micrite with some algal fragments. A lot of echinoderm fragments have been observed. Other bioclasts include foraminiferas and calcispheres.

### *Depositional model*

The occurrence and distribution of mudstones, wackestone, packstones and boundstones has led to the recognition of a reef model with four reef facies (Fig. 8). "Reef" is used here according to Nelson *et al.*, (1962, in De Coo and Lau, 1977) which is defined as a skeletal limestone deposit formed by organisms possessing the ecological potential to erect a rigid wave resistant topographic structure. Back reef is the area of deposition between the reef and the shore line. Fore reef is the transitional area between the reef and the deeper water and the inter reef being the deeper water parts in between different reefs and adjacent sea bottom.

In the study area, the main reef complex comprises the stromatoporoid boundstone, algal boundstone, coralgal boundstone and coral bryozoan boundstone. The back reef area is dominated by packstone and spiculitic mudstone. Limestone breccia and intraclastic packstone are deposited at the fore reef area where the inter reef area is dominated by wackestone and mudstone.

The writer believed that minor patch reefs and mud-mounds also occur in the back reef area. Local patch reefs are small subequidimensional or irregularly shaped, flat-topped organic build-ups mostly dominated by frame-building organisms and occur locally as small, thick, generally unbedded lenses of very fossiliferous carbonate (Henson, 1950; in Wilson, 1975). They could be represented by those boundstone found at Sg. Penamu and Sg. Dawong. Mud-mounds are accumulations of micrite of microbial origin (Bernet-Rollande, Maurin and Monty, 1982 in Beauvais *et al.*, 1988) and possess consistent lenticular shapes but their sizes are variable from 10 m up to 1 km or more vertically. They could be represented by the mudstone, wackestone and packstone found at G. Poing, G. Pok, G. Jowit, G. Gelayang, and G. Stulang. A hypothetical diagrammatic cross section of the reef model is represented in Fig. 9.

| | |
|---|---|
| Back reef | Packstone<br>Spiculitic mudstone |
| Reef | Coralgal boundstone<br>Stromatoporoid boundstone<br>Algal boundstone |
| Fore reef | Limestone breccia<br>Intraclastic packstone |
| Inter reef | Wackestone<br>Mudstone |

**Figure 8:** Reef facies of the Bau Limestone.

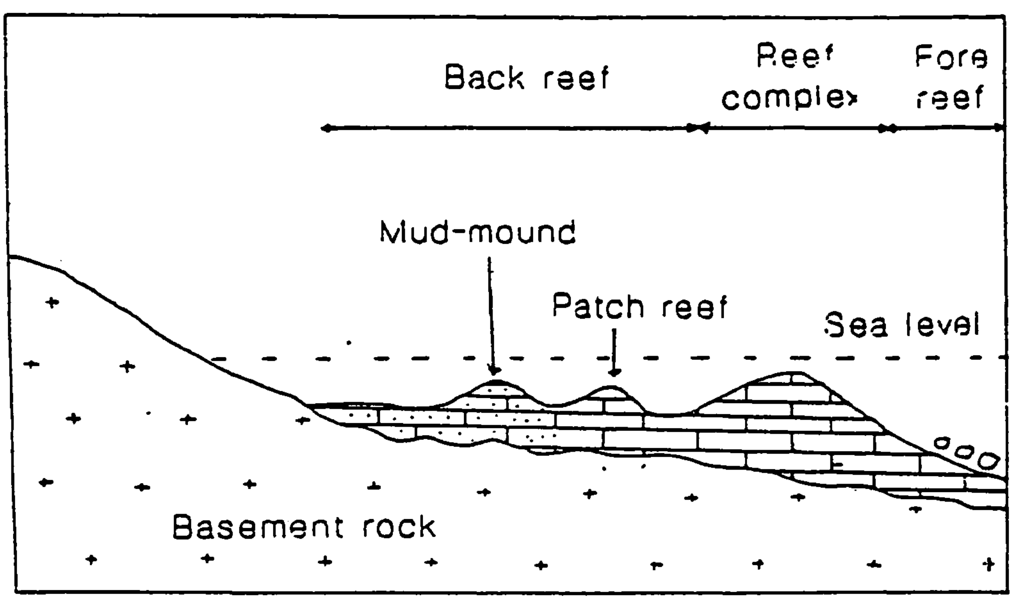


**Figure 9:** Hypothetical cross-section of the reef complex with minor patch reef and

### *Palaeoecology and palaeoenvironment*

The Bau Limestone was essentially deposited in a warm, shallow marine environment as indicated by the faunal assemblages, lithologic characters and diagenesis features. The assemblage of dasyclads and red algae indicates a warm, tropical, shallow marine water of variable salinity. The maximum depth is from 12 m - 15 m (Ginsburg *et al.*, 1971, in Wilson, 1975). Cloud, 1952 (in Wolfenden, 1965) concluded that the dasycladacean algae are most abundant at depth of 9-15 feet. In addition, the sea water was essentially clear to allow penetration of sunlight which was needed for the photosynthesis of algae.

The typical reef-building hexacorals also suggest a warm, shallow, clear marine of tropical and semi-tropical region (Hamilton, 1956, in Lau, 1973) of the characteristic Tethyan climate. Furthermore, the presence of stromatoporoids as framework builders also suggest a shallow water environment especially the dendroid type (as found in the study area) are very prominent in the back-reef, bank or lagoonal environments (Flugel, 1982). The abundant agglutinated foraminifera (*Pseudocyclammina* sp. and *Textularia* sp.) also indicate a lagoonal, back-reef and shallow neritic environment (Flugel, 1982). A combination of Textulariina and Miliolina (*Spiroloculina* sp.) indicates a shelf or neritic environment (Brasier, 1980). Other fauna like brachiopods, molluscs, echinoiderms, sponges and bryozoans are also very commonly associated with a warm shallow marine water.

The environment was essentially oxidizing as indicated by the large faunal assemblage. However, local reducing environment do occur where early ferroan calcite and early pyrite were crystallised. The salinity of the water was within normal marine salinity (about 35%). But, slightly variable salinity, up to 50%-60% might occur as evidence by the presence of abundant dasyclads and miliolids (Wilson, 1975).

### *Palaeogeography*

Based on the depositional model and palaeoenvironment of the Bau Limestone, a generalised palaeogeographical setting can be interpreted. Since the depositional environment is typically shallow marine and lagoonal, it should be in close proximity to the shoreline represented by the G. Jagoi and G. Kisam. They were promontories with a elongated lagoon in between them. This also means that, they were relatively less exposed than the present state. Their relatively drown condition is also evidenced from the presence of limestone in the rivers especially at Sg. Pon. The reef complex represents a fringing reef to the two promontories along the shoreline.

Towards the northeast and south the sea became deeper to form basin, in which the Pedawan Formation was deposited. The absence of Bau Limestone from the area north of G. Jagoi could probably be due to the subsequent down-faulting of the Bau Limestone, preserving the younger Pedawan Formation north of the fault. A diagrammatic plan view of the palaeogeography is represented in Fig. 10, while Fig. 11 shows a 3-D palaeogeographical model for the Jagoi-Serikin area.

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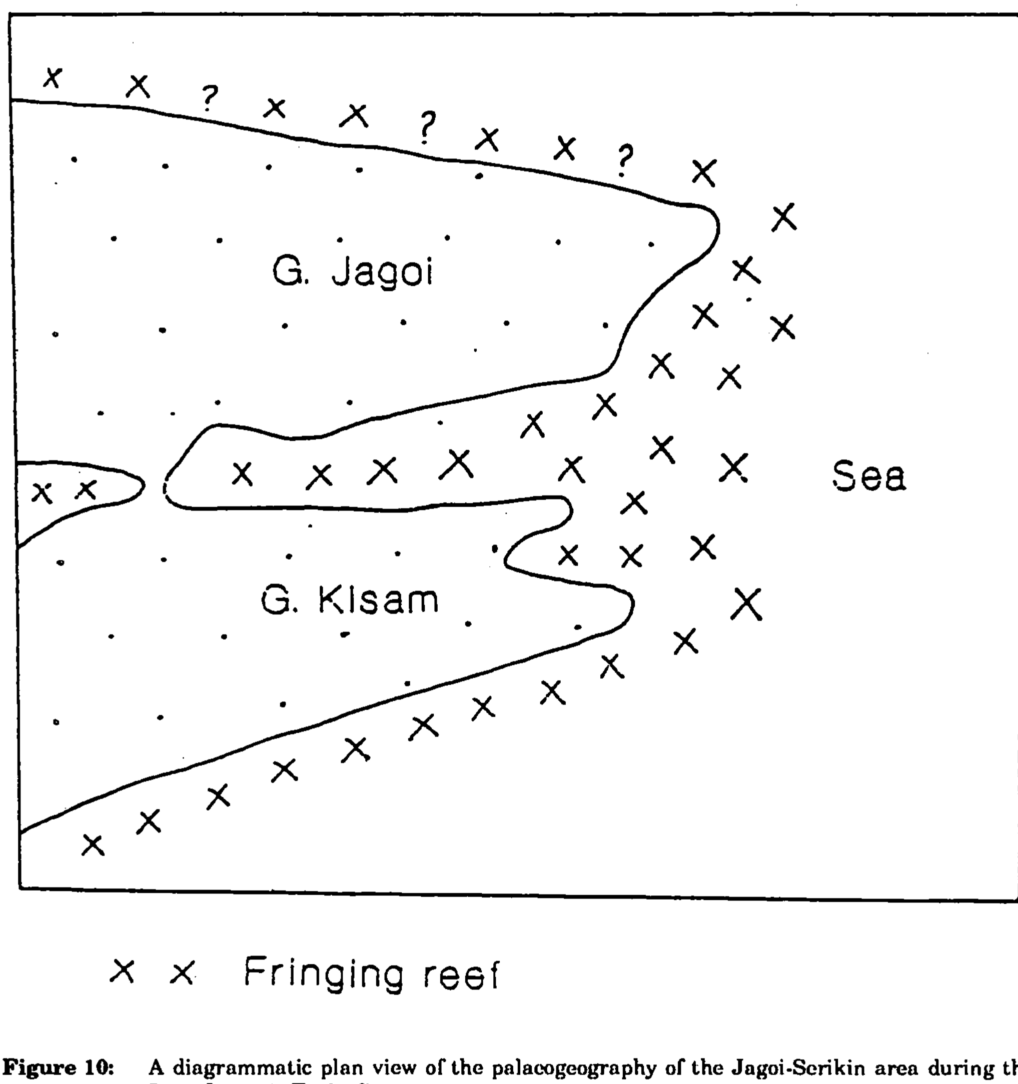


**Figure 10:** A diagrammatic plan view of the palaeogeography of the Jagoi-Serikin area during the Late Jurassic-Early Cretaceous.

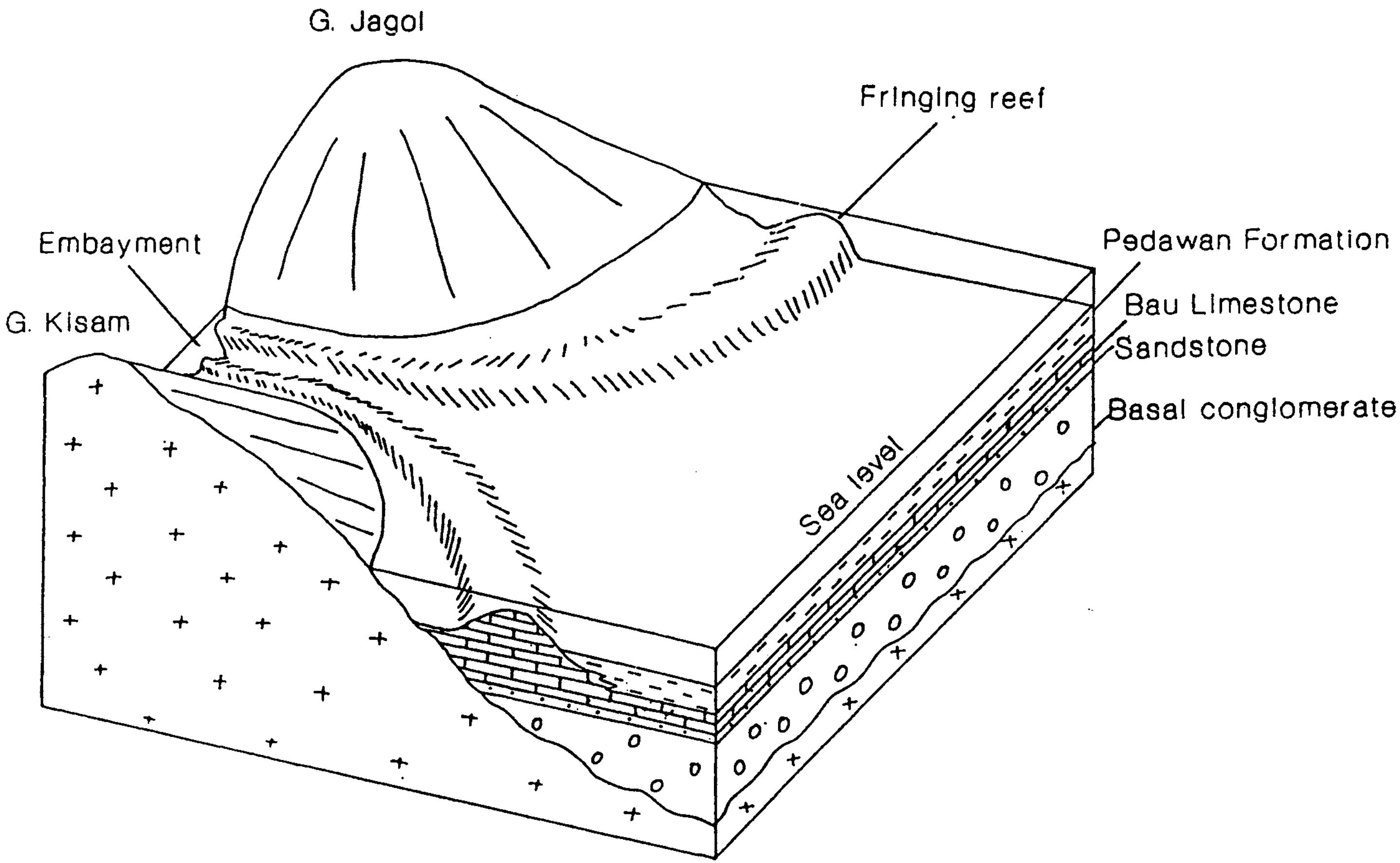


**Figure 11:** A 3-D model showing the palaeogeography of the Jagoi-Serikin area during the Late Jurassic-Early Cretaceous.

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