

# The Kati Formation: A Review

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**Abstract** This paper reviews the Kati Formation and provides comprehensive descriptions and an amended stratigraphic name for the Kati Formation. We have reviewed substantial literature on the Paleozoic stratigraphy in the western zone of Peninsular Malaysia and revised the nomenclature of the Kati Formation, changing “Kati Beds” to “Kati Formation” as more information has been available.

**Keywords** Kati Formation · Paleozoic · Clastic rocks · Seri Iskandar · Arenaceous series

## 1 Introduction

The Kati Formation constitutes a large portion of the Upper Paleozoic rocks in the western zone of Peninsular Malaysia; it lies between the granites of the Bintang and Kledang ranges and extends southward to Tapah and Teluk Intan. It is exposed in the west and southwest parts of Kinta Valley and the surrounding district of Kuala Kangsar. The rock exposures are very rare in areas that are still mostly covered by dense tropical forests and Quaternary alluvium.

Recently, interests in the Kati Formation has been directed particularly at Seri Iskandar and the Kinta Valley area, where several studies have been conducted with the newly developed idea of “Paleozoic hydrocarbon plays,” e.g., Pierson et al. [24, 25] and Alkhali et al. [2].

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The Kati Formation, however, was not previously reviewed in detail. This paper updates the knowledge so far reported about Kati Formation to improve the understanding of these clastic rocks, which will be beneficial for future work.

In this paper, we review previous studies of clastic deposits exposed in Kati Formation outcrops. This review is based on previous literature, especially recent contributions from Alkhali et al. [2], in which fieldwork and laboratory analysis were conducted to determine the sedimentological and petrographic properties at near Seri Iskandar, which is the southward extension of the Kati Formation.

## 2 Paleozoic Formations in the Western Zone

Peninsular Malaysia has traditionally been divided into three zones: western, central, and eastern [4, 6, 11, 12, 20, 21, 23, 31]. Each of these three zones (basins) is characterized by distinctive tectonic, stratigraphy, metamorphism, structure, and sedimentary histories. The western zone is subdivided into the northwestern zone and western zone. The western zone covers a large area stretching from the Perak–Thai border southward to the state of Malacca, whereas the northwestern zone covers Langkawi, Kedah, and Perlis [6]. The Lower Paleozoic rocks are confined to the northwestern zone of the western zone. The Upper Paleozoic rocks are found in all three zones. The geological ages of the rock formations become younger from west to east. The Upper Paleozoic rocks, which crop out along the western zone, are the Silurian to Permian Kinta Limestone, the Terolak Formation, and the Kati Formation in Perak. Along with these are the Lower Palaeozoic Dinding and Hawthornden Schists, the Kuala Lumpur Limestone, and the Carboniferous to Permian Kenny Hill Formation in Selangor (Fig. 1). The limestone and argillites of Kinta Valley are classified as the Kinta Limestone and the Baling Group, respectively, whereas the westerly clastic rocks along the Perak River are grouped under the Kati Formation [6]. The western zone formations are mostly poorly dated because thermal metamorphism has affected the fossils in most of the sequences [1, 6, 21].

In general, Paleozoic clastic formations of the western zone of Peninsular Malaysia are comprised of the Kubang Pasu Formation exposed in Langkawi, Kedah, and Perlis; the Kati Formation in Perak; and the Kenny Hill Formation in Selangor [6, 14, 16, 19, 21]. The western basins include most, if not all, Lower Paleozoic formations and some Upper Paleozoic formations [6].

## 3 Review of Previous Work

Limited geological investigation of the Kati Formation has been conducted in Kinta Valley and the surrounding areas. The geology of this region was first described and mapped by Scrivenor [28], and one of the best early descriptions of rocks of the Kinta Valley area is those of Scrivenor and Jones [29], particularly in the Dindings area (currently known as Manjung), where they identified three dominant geological units [17, 32].

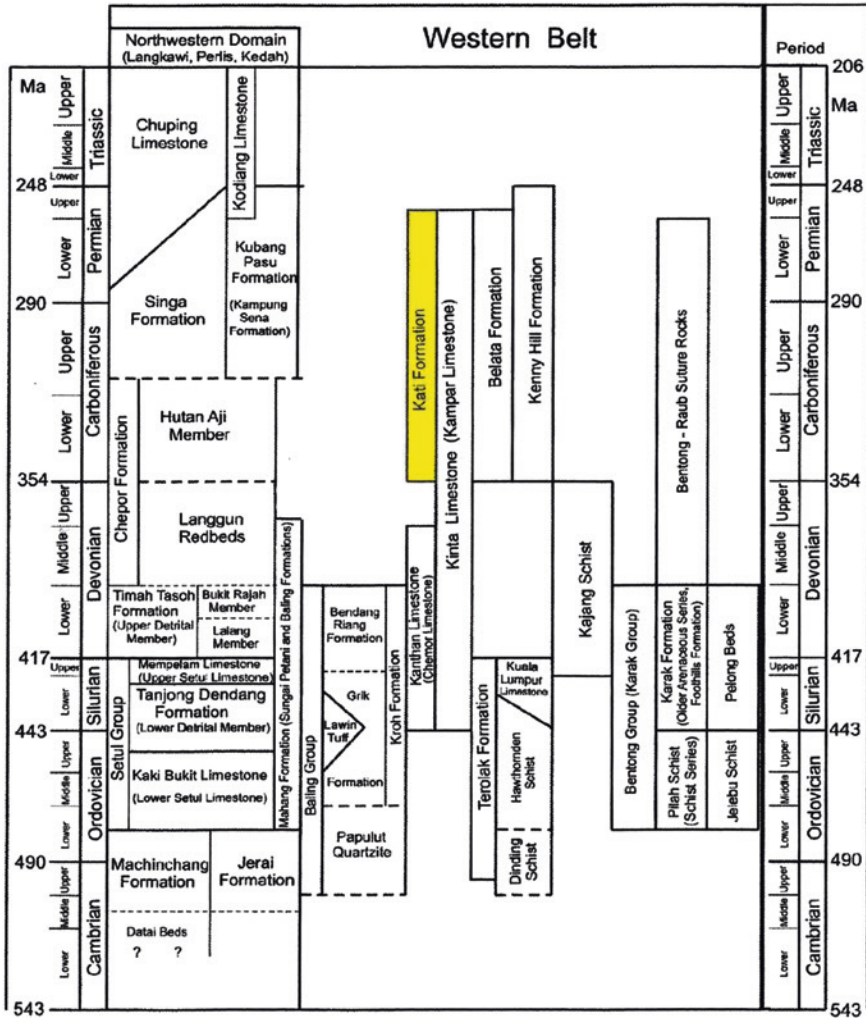


Fig. 1 Stratigraphic chart of Paleozoic sequences of the Western Belt of Peninsular Malaysia. Modified from Lee [21]

Savage [27] conducted investigations in Sungai Siput and the adjacent areas (northern part of Kinta Valley), and he recognized the existence of five distinct stratigraphic units.

Ingham [18] examined the rocks exposed in Tapah and Telok Anson currently known as the Teluk Intan area (southern part of Kinta Valley).

Ingham and Bradford [17] extended the work over to the northeastern part of the Kinta Valley. According to Ingham and Bradford [17], rocks in the Kinta Valley area can be divided into three main series: the calcareous series, the granites and allied rocks, and the arenaceous series.

Foo [5] investigated the Paleozoic exposures in the Kuala Kangsar and Taiping area (northern part of Kinta Valley). Three sedimentary formations were reported: the Pondok Marbles, the Kati Beds, and the Salak Baharu Beds. Wong [32] conducted investigations in the Lumut and Teluk Intan areas (southern part of Kinta Valley) and recognized three sedimentary successions and their metamorphosed equivalents, namely the Kati Beds (the arenaceous and argillaceous series), the Tualang Limestone (part of Kinta Valley Silurian–Permian limestones), and the Gelubi Schists. These units are believed to be contemporaneous and are classified as Carboniferous to Permian age. The Tualang Limestone and Gelubi Schists make up the so-called calcareous series.

Foo [5, 6] and Wong [32] noted that Ingham [18] and Ingham and Bradford [17] described the same formation (arenaceous series) in the west and southwest Kinta Valley area. They based their interpretation on correlation between lithology and structures of arenaceous rocks of the Kuala Kangsar area and the arenaceous series of the west and southwest Kinta Valley area. The Kati Beds (Formation) extend southward to the Seri Iskandar area [2].

## **4 The Kati Formation**

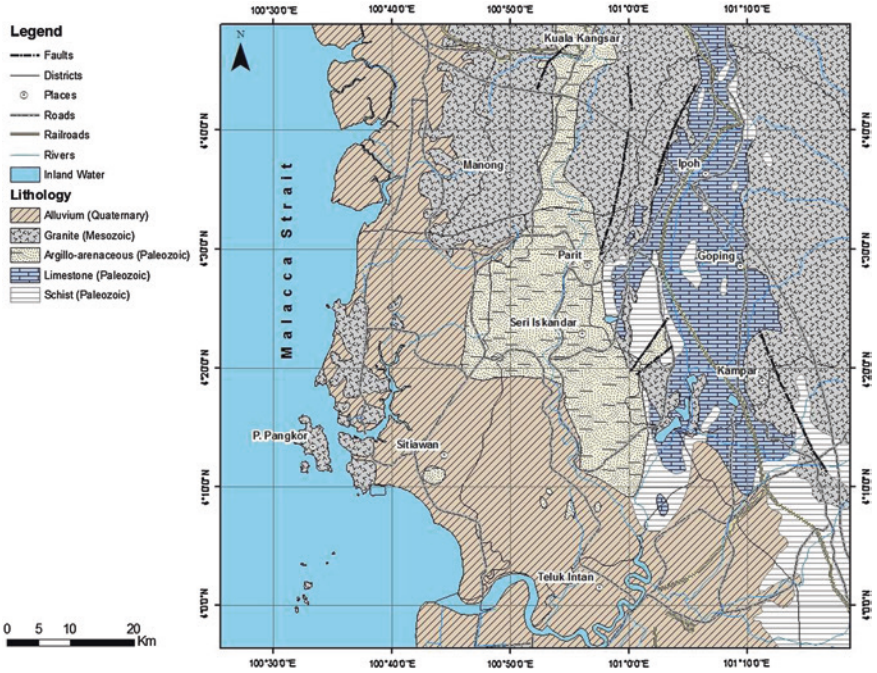
### ***4.1 Name and Distribution***

The term “Kati Beds” was introduced by Foo [5] to describe a formation that occurs in the Kuala Kangsar area and extends southward along the western bank of Sungai Perak into Kinta Valley (west and southwest Kinta Valley). This formation lies between the granites of the Bintang and Kledang ranges (Fig. 2) [5, 6, 15, 21, 32]. We have reviewed the literature concerning the Paleozoic stratigraphy in the western zone of Peninsular Malaysia and revised the nomenclature of the Kati Formation, changing “Kati Beds” to “Kati Formation” as more information has been revealed.

Foo [6] renamed Kati Beds to Kati Formation after considering the work of Wong [32] in the Lumut and Teluk Intan areas (no data were presented). Alkhali et al. [2] concluded that their findings are consistent with Foo [6]. The Kati Formation is a lithostratigraphic unit defined by lithological characteristics, and the outcrops at Seri Iskandar fit the definition (Alkhali et al. [3]). Thus, our definition of the Kati Formation follows that of Foo [6] in order to avoid confusion.

### ***4.2 Outcrops (Exposures)***

As a generalization, these rocks are poorly exposed, very scarce, and sparsely distributed. Kati Formation outcrops are deeply weathered due to low topographic positions and the tropical climate, an exception being more resistant siliceous metasediments. The existence and position of this formation has been confirmed mainly by boreholes because it is largely located within dense tropical rain forest or is covered by Quaternary alluvium [5, 22, 32].



**Fig. 2** Geological map of Kinta Valley and the surrounding areas illustrating the distribution of rock units in the western basin (yellow color in the northern and central areas represents the Kati Formation). Based on work by Wong [32], Ingham and Bradford [17], Ingham [18], Foo [5, 6], Gobbett [10], Alkhali et al. [2], Tate et al. [30], and the geological map of Peninsular Malaysia [7]

### 4.3 Bed Thicknesses

The actual thicknesses of these rocks exposed in the Kuala Kangsar area are very difficult to determine because some of these beds are highly folded [5]. However, at Cangkat Hulu Denak (Lumut and Teluk Intan area), the exposed thickness of the Kati Formation is estimated to be 900 m [32]. At Seri Iskandar, the exposed thickness is estimated to be 780 m [2].

### 4.4 Lithology

The Kati Formation is generally composed of a predominantly monotonous sequence of interbedded metamorphosed reddish brown carbonaceous shale, mudstones, and sandstones, with minor siltstone “argillaceous and arenaceous rocks” [5, 32]. The siltstone and shale beds are characteristically laminated or thinly banded and vary from gray to dark gray. The thicknesses of sandstone and siltstone beds are in general 7–10 cm, but can reach meters thick. Shale beds are

much thicker, approximately 30 cm, gray to whitish gray, although in some places, secondary staining may produce a pinkish, mottled color to shale and mudstone. Quartzite conglomerate, which is common in some other parts of Peninsular Malaysia, is absent in the Kati Formation [5, 6, 15, 21, 32].

#### ***4.5 Contact with Other Formations***

Although the Kati Formation can be traced along strike northward between the granites of the Bintang and Kledang ranges, no contact with younger sediments or calcareous rocks was observed apart from Quaternary alluvium [5, 17, 32]. Moreover, because there is no evidence of an unconformity between the Kati Formation and Salak Baharu Beds, the Kati Formation is interpreted as a lateral facies change in the Salak Baharu Beds [5].

#### ***4.6 Age***

No fossils have been found within the Kati Formation, and a probable Late Paleozoic Carboniferous to Permian age is assigned [5]. Moreover, Foo [5] disagreed with Ingham [18] and Ingham and Bradford [17], believing that the arenaceous series (Kati Formation) is older than the Semanggol Formation in northern Perak, which is Triassic. The Kati Formation was interpreted to be older than the Semanggol Formation based on dissimilarities in the lithology and the style of folding; the Kati Formation is more highly flexured than the Triassic Semanggol Formation [5, 15, 32].

#### ***4.7 Metamorphism***

The Kati Formation is weakly metamorphosed and not directly affected by regional metamorphism, as thermal metamorphism is largely confined to the far northeastern part of the area [5, 32]. In the vicinity of the granite intrusive, these rocks are metamorphosed to hornfels. A fault contact between the Kati Formation and the granite was observed along Sungai Dal, in Kampong Buaya [5].

#### ***4.8 Structural Features***

These clastic sequences (arenaceous series) are characterized by the presence of large- and small-scale structures and are locally highly folded into relatively open anticlines and synclines [2, 5, 32]. The most common structural features observed

in Kati Formation outcrops include well-developed faults, joints, veins, infilled joints, and fractures striking approximately N to NNW and dipping  $45^{\circ}$ – $60^{\circ}$  to west or southwest. A relatively open flexural fold of wavelengths varying between 2 and 8 km was also observed in the Lumut and Teluk Intan area [32].

The overall structural style and character of these outcrops suggest that these rocks are structurally complex. It also offers some ideas about the deformational history because these structures show a wide variety of chaotic structure deformation and faults and relatively tight folds. The existence of this complex structural style suggests that these clastic rocks have undergone moderate to strong deformation, probably as a result of a compressional phase or tectonic activity in the Late Triassic at the time when Sibumasu collided with the East Malaya and Indochina blocks. They were not affected by contact metamorphism.

#### ***4.9 Sedimentary Structures***

From observation on outcrops reported by Wong [32], the most noticeable primary sedimentary structures occurring within the Kati Formation, other than regular bedding, are rhythmic bedding, load structures, flame structures, and flute casts with some graded sandstone beds [5, 6, 32].

#### ***4.10 Depositional Environment***

Based on our current understanding of the literature and results from the recent study by Alkhali et al. [2], we are in agreement with previous studies of Foo [5] and Wong [32]. The observation and interpretation of sedimentary structures and rock compositions in the clastic sequence of the Kati Formation and the rocks at Seri Iskandar are all consistent with a deep marine slope environment of deposition. The tectonic setting and depositional environment of the Kati Formation suggest it is regionally confined to the slope and basin in the western part of Peninsular Malaysia.

#### ***4.11 Provenance (Sediment Source)***

The results of petrographic analysis showed that the sandstones are compositionally mature with high quartz/feldspar ratios which probably indicate that these deposits were subjected to significant chemical weathering at the source area or depositional site. The high chemical maturity coupled with the predominant suite of a well-rounded resistate zircon in the heavy minerals would suggest derivation from preexisting sediments. Moreover, the flute casts show a upcurrent direction toward the N-NW. Therefore, it appears that the source areas were located to N-NW and the depositional site in the SSE [32].

### 4.12 Regional Correlation

There are many similarities both lithologically and stratigraphically between the clastic sediments of the Kubang Pasu Formation in the northwestern zone and the Kenny Hill Formation in Selangor and Kati Formation in west-southwest Kinta Valley [5, 6, 15, 32] (Fig. 3). The Kati Formation is interpreted as equivalent to the Kubang Pasu Formation [6, 15]. Moreover, the Kati Formation can be correlated with the Upper Paleozoic Kenny Hill Formation of the Kuala Lumpur area [32].

After careful review of previous work on clastic deposits of the entire western part of Peninsular Malaysia, it appears that Kati Formation outcrops have been described by only two workers, Foo [5, 6] and Wong [32]. Foo [5] and Wong [32] examined and documented in great detail the sedimentological and petrological characteristic of these rocks, as well as some general structural observations. Moreover, they interpreted the depositional environments based on sedimentary features. However, they did not present any stratigraphic columns (lithologies).

Since the publications of Foo in 1968 and Wong in 1973, and more recent publications in 1990 and 1991, there has been a rapid increase in geological knowledge of Peninsular Malaysia and a considerable amount of work has been published on the geology of Kinta Valley and the surrounding district [8, 9, 12, 13, 26]. These publications contribute to our understanding of the Kati Formation.

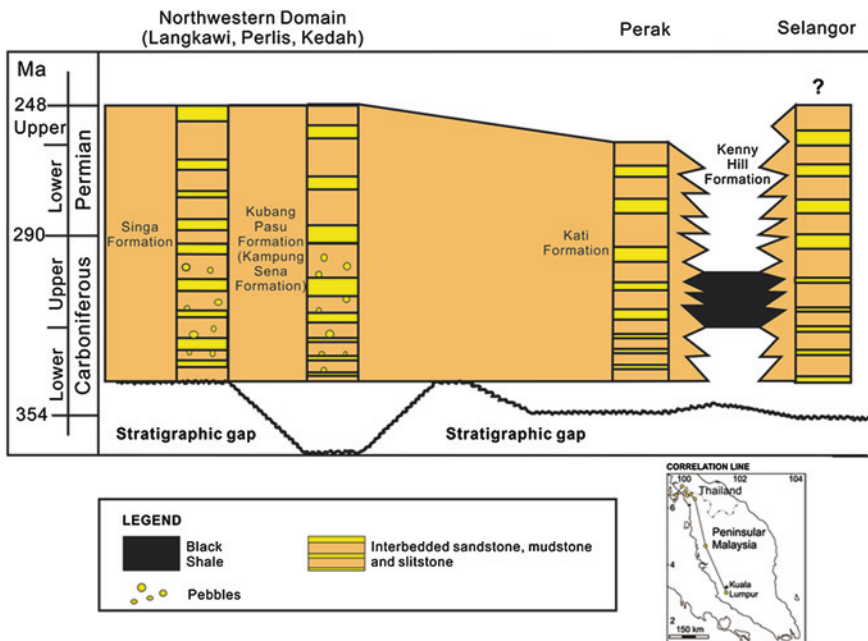


Fig. 3 Stratigraphic correlation of the Paleozoic clastic successions of the Western Belt of Peninsular Malaysia



**Acknowledgment** This investigation was conducted under the auspices of the South East Asia Carbonate Research Laboratory, Department of Geoscience, Universiti Teknologi Petronas, which is funded principally by Sarawak Shell Berhad.

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