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Black siliceous deposits in Peninsular Malaysia: their occurrence and significance

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Abstract: Black Radiolarian cherts are found in the Setul, Mahang, Kubang Pasu formations. The occurrence of the cherts and carbonaceous material was related to high plankton productivity. The lithologic association of the chert represents the continental shelf rocks association. The geochemical data from the chert samples of the Setul, Mahang and Kubang Pasu Formations plotted on the Fe_2O_3/TiO_2 vs. $Al_2O_3/(Al_2O_3 + Fe_2O_3)$ discrimination diagram show most of the points are located in the field of older upper continental crust. The chert was deposited on a passive continental margin, which episodically received the supply of terrigenous material from the continent. During the Cambrian, both the Machinchang and Jerai Formations were deposited in a deltaic environment. The sea level rose in the Ordovician followed by deposition of the Setul and Mahang Formations. The Mahang basin was a faulted basin deeper than the Setul basin. The Singa and the Kubang Pasu Formations overlie the Setul and the Mahang Formations respectively. The radiolaria in the chert were deposited in a relatively shallow marine environment on the continental shelf.

INTRODUCTION

In Peninsular Malaysia, siliceous deposits are found as cherts and siliceous mudstones in the Paleozoic and early Mesozoic rocks. Some of them contain radiolaria and sponge spicules. Most of the bedded cherts present in a minor part of the Setul Formation, the Mahang Formation, the Karak Formation, the Kubang Pasu Formation, the Kati Formation, the Semanggol Formation, the Kodiang Limestone and other unnamed rock formations in the Raub-Bentong suture zone. The cherts were episodically deposited during the Early Silurian, Late Devonian-Early Carboniferous, Early Permian, Late Permian and Triassic.

The colour of the chert depends on its chemical composition. Basically, there are two types of siliceous deposits viz. light cherts (which are red or green in colour) and black cherts. The light cherts contain iron oxide (heamatite) and are usually found in the Mesozoic sequences. The black cherts are grayish to dull black and contain carbonaceous material and pyrite. These siliceous deposits are common in the Paleozoic. Such black siliceous deposits are known as "phtanite" in France and "domanik" in Russia.

The purpose of this paper is to study the occurrences, chemical compositions of the black cherts in Peninsular Malaysia and their significance in interpreting paleoenvironments.

OCCURRENCE AND DISTRIBUTION OF BLACK CHERT

Black siliceous deposits are found in the Lower Detrital Member of the Setul Limestone (Jones, 1981), the Mahang Formation (Burton, 1988), and the Kubang Pasu Formation (Basir Jasin, 1995; Basir Jasin and Zaiton Harun, 2001) (Fig.1).

In Langkawi Island, the Setul Formation conformably overlies the Machinchang Formation. It was divided into four members (from bottom to top) namely; the Lower Setul Member, Lower Detrital member, Upper Setul Limestone Member and Upper Detrital Member. The members are not recognized in the Setul Formation in Perlis. The black chert occurs in the Lower Detrital Member, which is exposed at Pulau Langgun and Pulau Tanjung Dendang, Langkawi. The Lower Detrital Member contains fossil trilobites and graptolites, which are indicative of an

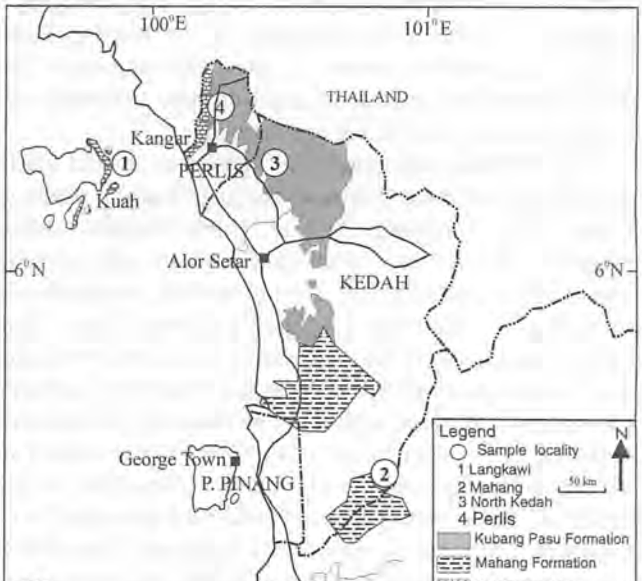

Figure 1. Map showing black radiolarian chert localities.

Early Silurian age. No radiolaria had been identified from the chert.

The Mahang Formation is exposed in central and south Kedah. Burton (1967) divided the Mahang Formation into four lithofacies:-

i) A dominant argillaceous facies
ii) A subsidiary arenaceous facies
iii) A minor siliceous that grades into the argillaceous
iv) A restricted calcareous facies

Only the first three facies were recognised in central Kedah (Burton, 1988). The Mahang Formation was deposited in a euxinic environment (Burton, 1988).

The chert of the Mahang Formation is exposed in the Bedung and Mahang areas. The chert sequence consists of well-bedded radiolarian chert interbeds with black mudstone. The chert is hard and dark in colour. Radiolaria are common in the chert but most of the radiolaria have been recrystallised and could not be identified. The age of the chert is Silurian based on the presence of graptolites (Burton, 1988). Both cherts of the Mahang and Setul Formations were deposited during Silurian.

The Kubang Pasu Formation crops out in central and eastern Perlis and extends further south to central Kedah. The base of the Kubang Pasu Formation is exposed at Bukit Wang Tangga, Kampung Binjai and Guar Jentik, Perlis. The outcrops show that the Kubang Pasu formation is conformably overlying the Setul Formation. The Kubang Pasu Formation in central Perlis consists of mudstone interbedded with sandstone in the lower part and sandstone becomes more dominant in the upper part. The boundary of the formations is well exposed at Guar Jentik where Meor Hakif Hassan and Lee (2002) assigned the section as a new formation (Jentik Formation). A 4.5 m thick, bedded chert sequence is exposed in the area.

In northwest and central Kedah, the Kubang Pasu Formation conformably overlies the Mahang Formation (Hutchison, 1989). The lithology of the Kubang Pasu Formation in Kedah consists of three rock sequences i.e. the chert sequence, an interbedded sandstone and mudstone sequence and a thick sandstone sequence.

The Kubang Pasu chert is exposed at several earth quarries in Ulu Pauh, Perlis, Bukit Inai, Ladang Cheong Chong Kaw, Kampung Belukar, Bukit Panchor, Bukit Kamelong, Bukit Telaga Jatuh and Guar Kepayang, Kedah. The chert sequence consists of thinly bedded chert interbeds with siliceous mudstone. It is known as ribbon chert. The chert is commonly folded and varies in colour from light grey to dark grey but some places it is black and contains carbonaceous material (Fig. 2). The thickness of the chert sequence varies from 3 m to 11 m. The chert is located at the base of the Kubang Pasu Formation. Nine fairly well-preserved Radiolaria were retrieved and identified viz. *Entactinia variospina, Entactinia unispina Entactinia? inaequoporosa, Callella hexatinia, Callella* cf *parvispinosa, Trianosphaera hebes, Cubaxonium? octaedrospongiosum, Duplexia? foremanae* and *Duplexia? parviperporata* (Basir Jasin and Zaiton Harun, 2001). This assemblage indicates an age of Early Carboniferous.

PETROGRAPHY OF THE BLACK CHERT

In thin section, the black radiolarian chert consists of mainly circular, and oval shaped radiolarian tests embedded in a very fine siliceous and carbonaceous matrix (Fig. 3a). The radiolarian skeletons are composed of cryptocrystalline to microcrystalline quartz grains 5-30 mm in size. Most of

Figure 2. Photograph of black chert of the Kubang Pasu Formation at Bukit Inas, Kedah (hammer in circle as a scale).

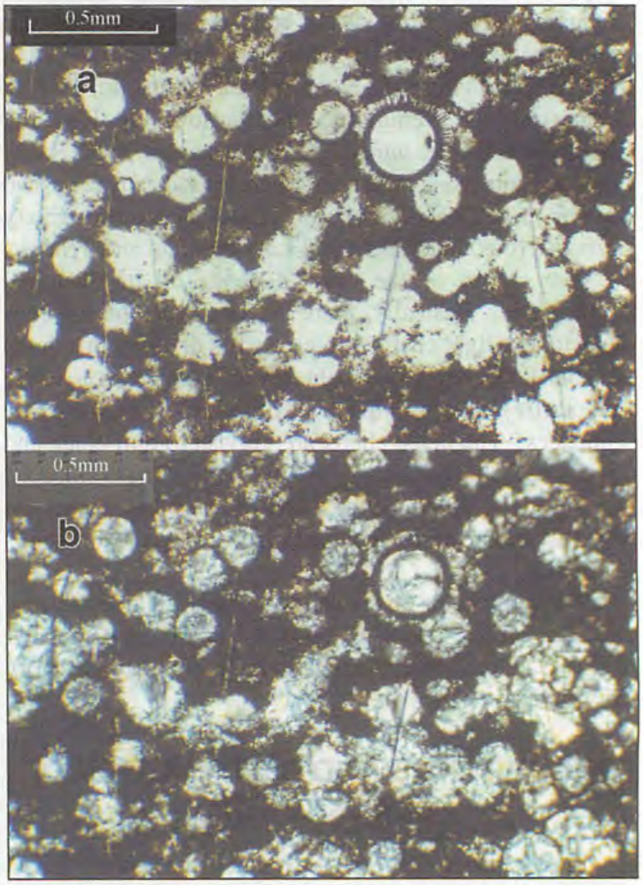

Figure 3. Photmicrographs of the black chert. (a) Under plain light. (b) Under cross nicols.

Table 1. Distribution of major elements in the black siliceous rocks.

Sample No.	Location	SiO_2%	TiO_2%	Al_2O_3%	Fe_2O_3%	MnO%	MgO%	CaO%	Na_2O%	K_2O%	P_2O_5%	LOI%	Total
	Kubang Pasu Formation												
BB1	Guar Jentik	91.82	0.12	3.12	0.54	0.01	0.33	0	0.01	0.83	0.15	3.1	100
BB2	Guar Jentik	95.44	0.07	1.54	0.41	0.01	0.08	0	0.19	0.41	0.08	1.85	100
BB3	Guar Jentik	87.16	0.16	3.55	2.99	0.01	0.28	0	0.22	1	0.84	3.8	100
BB4	Guar Jentik	95.12	0.07	1.83	0.31	0.01	0.15	0	0.07	0.48	0.08	1.94	100
BB5	Guar Jentik	91.01	0.11	2.94	0.33	9.11	0.15	0	2.11	0.67	0.07	2.068	100
BK11	Bkt. Kelubi	88.37	0.26	5.98	1.52	0.01	0.35	0	0.2	1.51	0	1.89	100
BK12	Bkt. Kelubi	85.66	0.32	7.83	1.58	0.01	0.41	0	0.18	1.84	0.01	2.26	100
PK1	Pokok Sena	77.14	0.6	10.27	3.69	0.02	1.64	0	0.44	1.53	0.01	4.73	100
	Mahang Formation												
M1	Mahang	75.15	0.48	9.71	4.01	0.09	0.62	0	0.3	2.69	0.19	6.78	100
MB1	Mahang	77.89	0.52	10.66	0.36	0.01	1	0	0.04	2.92	0.06	6.58	100
MB2	Mahang	74.33	0.51	9.8	0.37	0.01	6.17	0.06	0.28	2.72	0.07	5.66	100
	Setul Formation												
PL1	Pulau Langgun (Setul F.)	89.85	0.15	3.45	0.46	0.01	0.23	0.05	0.05	1.33	0.02	4.53	100
PL2	Pulau Langgun (Setul F.)	88.29	0.15	3.95	1.33	0.01	0.25	0	0.07	1.5	0.04	4.44	100

the radiolarian tests are filled with chalcedony, which show undulating extinction (Fig. 3b). Radiolaria vary greatly in abundance from 50% to 80%. The dark groundmass comprises silica and minute shapeless carbonaceous flecks together with minute crystal of pyrite.

GEOCHEMISTRY OF THE CHERT

A total of thirteen samples were collected for geochemical analysis. Eight samples were from the Kubang Pasu Formation, three samples from the Mahang Formation and two samples from the Setul Formation. The major elements were analysed by X-ray fluorescence spectrometry using a Phillips PW1480 instrument. The carbon content was analysed by using a CHNS-O Leco 932 instrument.

The results of geochemical analyses are listed in Table 1 and Table 2.

The SiO_2 content of the analysed samples varies from 74.33% in the Mahang chert to 95.44% in the Kubang Pasu Formation. The three most abundant major elements namely SiO_2, Al_2O_3, and Fe_2O_3 constitute more than 95% of the siliceous deposits. The carbon content of the deposits ranges from 1% in the Kubang Pasu Formation to 5.6% in the Mahang Formation. Carbon is composed of inorganic and organic carbon. The inorganic carbon is commonly found in calcium carbonate, which forms the skeletons of fossils. The absence of calcium in almost all the samples suggests that the carbon is not in the form of calcium carbonate. The inorganic carbon was probably in the form of graphitic material. The organic carbon commonly occurs as organic compounds. The presence of carbon in the deposits gives the dark or black colour to the chert.

Samples from the Mahang Formation contain more than 5% of carbonaceous material, more than 9% Al_2O_3 and relatively low SiO_2 compared to other samples. The carbon content of the chert is close to 3% for the Setul Formation and varies from 1% to 2.5% in the Kubang Pasu Formation. Percentage of inorganic carbon ranges from

Table 2. Distribution of carbonaceous material in the black siliceous rocks.

Sample No	Location	IC%	OC%	C%
	Kubang Pasu Formation			
BB1	Guar Jentik	1.0695	0.975	2.4995
BB2	Guar Jentik	1	0.7935	1.7935
BB3	Guar Jentik	1.013	1.0795	2.0925
BB4	Guar Jentik	0.9955	0.8835	1.879
BB5	Guar Jentik	0.9815	1.2035	2.185
BK11	Bkt. Kelubi	0.983	0.0225	1.0055
BK12	Bkt. Kelubi	1.0545	0.038	1.0925
PK1	Pokok Sena	1.0185	0.686	1.7045
	Mahang Formation			
M1	Mahang	4.9185	0.342	5.2605
MB1	Mahang	5.028	0.525	5.553
MB2	Mahang	5.1335	0.443	5.5765
	Setul Formation			
PL1	Pulau Langgun (Setul F.)	0.974	1.884	2.858
PL2	Pulau Langgun (Setul F.)	0.9805	1.9685	2.949
IC=inorganic carbon; OC=organic Carbon; C=Total Carbon				

approximately 1% in the Kubang Pasu and Setul Formations to 5% in the Mahang Formation and the percentage of organic carbon ranges from 0.02% in the Kubang Pasu Formation to 1.9% in the Setul Formation (Table 2). The organic carbon content of the Mahang Formation is relatively low compared to inorganic carbon. It is probably due to the metamorphism, which transforms the organic carbon into graphite.

DEPOSITIONAL ENVIRONMENT

The chert in the Setul Formation is located in the Lower Detrital Member, which occurs between the Lower Limestone Member and the Upper Setul Limestone Member. This type of association is commonly found in the upper continental shelf, which is affected by the fluctuation of sea-level. A vertical succession from shallow marine limestone to chert sequence and back to limestone sequence represents a subsidence association (Jones and Murchey, 1986). The chert sequence was deposited in an environment deeper than that of the limestone. The sea-level was low during the deposition of the Lower Setul Member and increased during the deposition of the chert sequence (The Lower Detrital Member) and then subsided during the deposition of Upper Limestone Member.

The Mahang chert is a silty black laminated chert interbedded with mainly shale and minor sandstone. Some chert layers are argillaceous; some shale layers are siliceous. The shale and chert are black and contain carbonaceous material and minute pyrite crystals. This rock association can be considered as chert/shale association (Karl, 1989). The rock association is also known as a continental margin chert association (Jones and Murchey, 1986). The chert/shale association represents a basin environment along continental margin. The high Al_2O_3 content in the Mahang Formation reflects the depositional environment was located very close to a continent.

The occurrence of radiolarian chert and carbonaceous material in the Mahang and the Setul Formations suggests the high plankton productivity, which was related to the influx of nutrients and silica rich material as a result of continental weathering. The Mahang Formation contains pyrite and organic carbon, which was deposited in a euxinic condition (Burton, 1988). The chert of the Mahang Formation was deposited in an isolated basin under anoxic condition. This condition was commonly prevailed during the Silurian period where the climate was warm (greenhouse condition). During this period, the bottom currents were sluggish.

The chert of the Kubang Pasu formation is found at the base of the formation. The chert is overlain by interbedded sandstone and mudstone and finally passes to thickly bedded sandstone at the top. This rock association represents the continental margin chert association (Jones and Murchey, 1986). The occurrence of carbonaceous material in chert also suggests that there was a high plankton productivity, which related to upwelling of nutrient rich deep-water masses near the continental shelf. The upwelling of deep-water masses was very active during the ice-house condition which was prevailed during late Devonian to late Permian (Fig. 4). A similar Early Carboniferous chert deposition related to cold deep circulation was reported from south France and north Spain (Raymond and Letheirs, 1990).

The change in lithology from chert to interbedded sandstone and mudstone indicates that the chert was deposited in a calm marine environment with less supply of terrigenous material during the Early Carboniferous. The deposition of clastic material on the chert sequence indicates the influx of more clastic material transported by turbidity currents, which diluted the chert.

Geochemical data from the chert samples of the Setul, Mahang and Kubang Pasu Formations plotted on the Fe_2O_3/TiO_2 vs. $Al_2O_3/(Al_2O_3 + Fe_2O_3)$ discrimination diagram of Murray (1994) show most of the points are located in the field of older upper continental crust (Fig. 5). It means that the depositional basin of those rock formations were located on a continental shelf area. The absence of volcanic material indicates a passive margin. The Setul Formation was deposited in slightly shallower environment compared to the Mahang Formation.

Similar siliceous facies was reported from Visean phtanite Ardennes massif, Belgium and France (Demanet, 1938) and Devonian Domanik-type rocks in Russia (Ormiston, 1993). The Domanik rocks are major source rocks of the Pripjat, Timan-Pechora and Volga-Ural regions, in Russia. Both phtanite and domanic types rocks were

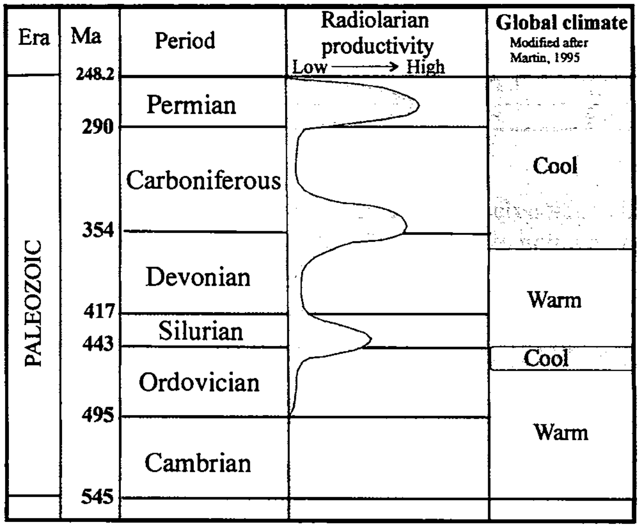

Figure 4. Radiolarian productivity based on the occurrence of chert in Peninsular Malaysia and global paleoclimate during the Paleozoic.

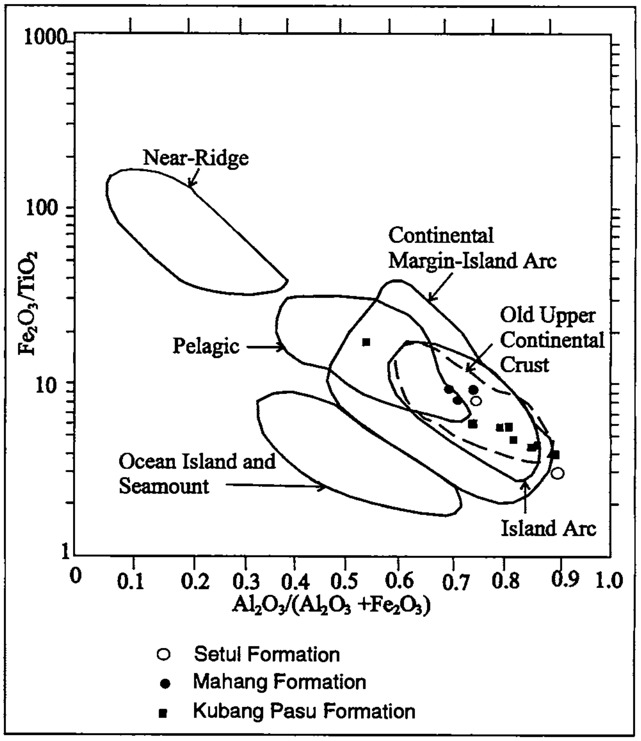

Figure 5. Geochemical data of the chert plotted on the Fe_2O_3/TiO_2 vs. $Al_2O_3/(Al_2O_3+Fe_2O_3)$ discrimination diagram of Murray (1994).

deposited in shallow marine environment (Crasquin, 1983; Vishnevskaya, 1993).

BASIN EVOLUTION

The Cambrian sedimentary rocks consist of the Machinchang Formation, and Jerai Formation. The Machinchang Formation was deposited in a wave-dominated delta (Lee, 1983). The presence of cross bedded sandstone in the Jerai Formation outcrops at Kampung Sri Perigi, Yan, Kedah, suggests that the Jerai Formation was also deposited in a similar deltaic environment (Che Aziz *et al.*, 1991).

During the Ordovician and Silurian the sea level rose, and followed by the deposition of the Setul Limestone on a shallow shelf environment (Langkawi and Perlis). In Kedah, the Mahang basin was developed due to block faulting on the continental shelf and an isolated basin was developed. The Mahang Formation was deposited in a relatively deeper marine environment compared to that of the Setul Formation (Fig. 6). Burton (1988) suggested that the Mahang Formation was deposited in a euxinic condition. The euxinic condition is commonly found in an isolated basin where the water circulation was sluggish. This event is usually related to the period of warm climate.

The Setul Formation is unconformably overlain by the Singa Formation, in Langkawi islands but in Perlis the formation is conformably overlain by the Kubang Pasu formation, which exposed at Kampung Binjai and Guar Jentik. Both the Singa and Kubang Pasu formations were deposited in shallow marine environment. In Kedah, the deep marine Mahang Formation passes up to the Kubang Pasu Formation, which was also deposited in a deeper water environment.

CONCLUSION

Black radiolarian chert forms a minor part of the Setul, Mahang, and Kubang Pasu formations. The lithologic association and the geochemical data of the chert are very important for interpreting the depositional environment. The black chert rock association and the geochemical data indicate that those formations were deposited in an isolated basin on a continental margin environment. The deposition of the black radiolarian chert was related to the high plankton productivity. The high productivity of chert from the Setul and Mahang Formations was likely related to the influx of nutrient and silica rich material from the continent during the Silurian. The development of chert in the Kubang Pasu Formation during Early Carboniferous was attributed to the upwelling of nutrient-rich bottom water masses. The radiolarian fossils in those formations were deposited in shallower marine environment and not deposited in a deep oceanic environment. The basin development started during the Cambrian with the deltaic Jerai and the Machinchang Formations and was followed by the deposition of the Setul and Mahang Formations, which are overlain by the Singa and Kubang Pasu Formations. The Mahang and Kubang Pasu Formations were deposited in a deepening isolated basin on the continental shelf.

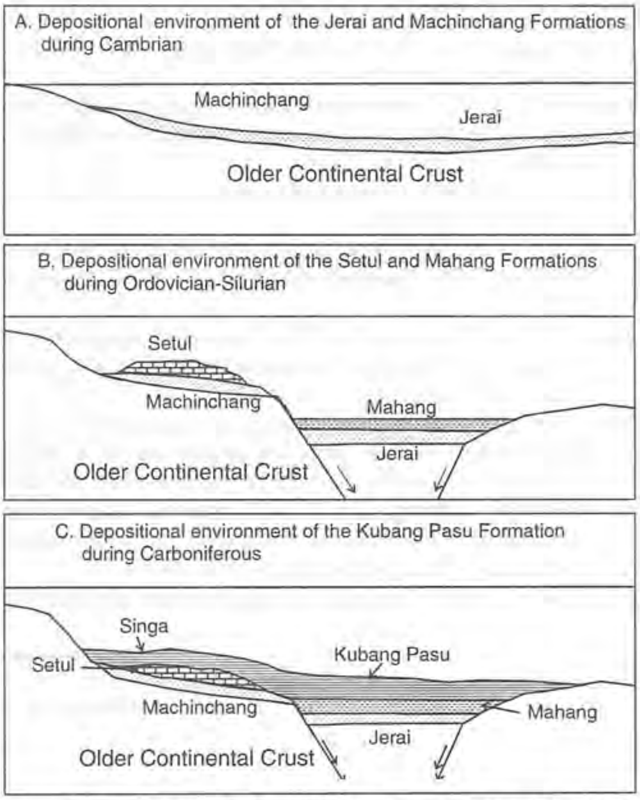

Figure 6. Evolution of depositional environments of the black chert bearing rock formations.

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