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Origin of iron carbonate layers in Tertiary coastal sediments of Central Kalimantan Province (Borneo), Indonesia

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ABSTRACT

Siderite layers, brown coals and quartzitic sands are an important part of the Tertiary section of the Rungan River Basin in Central Kalimantan Province, Indonesia. The siderite layers consist of grey, fine-grained, indurated rocks.

The depositional setting in Borneo during the Upper Tertiary was that of a large coastal lowland area with peat swamps and tropical giant podzols, much like the modern landscape. This environment seems to have been favourable for the formation of siderite. A relationship can be suggested between iron carbonate sedimentation and deferrification of onshore sedimentary continental formations through a pedological podzolization process. The iron was probably removed from the soils by 'black' waters which were rich in iron-complexing organic compounds. The iron carbonate was probably formed in tidal lagoons, in a brackish environment under reducing conditions.

The depositional setting shows that the origin of the iron in siderite layers must be sought laterally, probably hundreds of kilometres away, in bleached siliceous formations, associated with coal beds which are the former peat deposits. This mode of occurrence may have application to other sequences where such distinct lateral relationships are less obvious.

INTRODUCTION

Since 1979, Indonesian and ORSTOM scientists, within the framework of scientific cooperation between Indonesia and France, have produced soil maps covering large parts of Central Kalimantan Province (Brabant & Muller, 1981; ORSTOM & Dept Transmigrasi, 1981). Numerous observations and analyses are available for the post-Miocene sediments of the Central Kalimantan Coastal Plain (Sumartadipura, 1976).

The outcrops of these sediments reveal sandy layers, sometimes intercalated with gravels and clayey horizons, siderite, and coal beds. An analysis of the modern depositional setting of the coastal plain was carried out as a basis for interpreting the nature and formation of these outcrops. This paper outlines the characteristics of the main outcrops along the Rungan River (Fig. 1) and describes the present coastal landscape and geochemistry of units within it.

DESCRIPTION OF THE OUTCROPS

Siderite

The most conspicuous outcrops of bedded siderite are located on the Rungan River, between its confluence with the Manuhing River and the town of Tumbang Jutuh (Fig. 1). On this stretch, the Rungan River cuts its valley through post-Miocene sediments. Three main siderite outcrops can be observed within the river channel between July and November, when the water level of the river is low.

The siderite consists of a very hard rock, forming nearly continuous layers between 200 and 300 mm in thickness. The layers are so hard that they form small rapids in the river (Fig. 2). The rock has a very pale yellowish-grey colour which changes gradually into dark reddish-violet, especially after a week of air exposure. This change in colour is not just super-

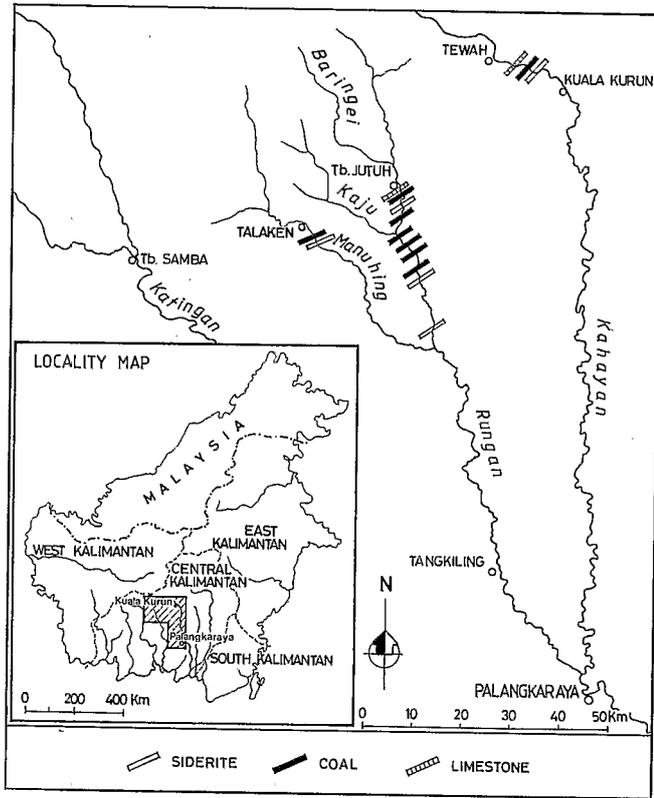


Fig. 1. Coal and siderite outcrops along the Rungan River, Borneo, Indonesia.



Fig. 2. Outcrop of siderite layers in the Rungan River, in Central Kalimantan (Borneo).

ficial; after two weeks a depth of 20 mm is affected, and after two months a 100 mm thick block becomes completely dark red up to the centre. This change in colour undoubtedly corresponds to an oxidation process. Submerged under the river water the siderite acquires only a very superficial yellow crust.

Clay beds

The indurated siderite layers are mainly underlain by fine soft bluish-grey clay. Frequently, organic matter in the form of leaves and other plant fragments can be observed in these clay layers. The overlying sediments above the siderite are silty with an upwards increasing amount of sand, and a minor amount of quartz gravels.

Coal beds

Between the second and third outcrop of siderite (Fig. 1), five coal beds can be observed. Coals have not been observed to directly overlie the siderite. The rank of the coal is brown coal and the total thickness reaches 800 mm (Fig. 3). Perfectly preserved tree trunks can be found within the coal layers, indicating a depositional environment of forest peat, similar to that described by Cecil *et al.* (1985) for the Central Appalachian Basin during the Carboniferous and comparable to the current peat belt in Kalimantan to the south (Fig. 4).

ANALYTICAL DATA

In its X-ray diffraction pattern, the siderite has all the characteristic reflections of iron carbonate (3.58, 2.79, 2.34 and 2.13 Å). Associated with the siderite is an interstratified montmorillonite–chlorite. In a normal state, the main peak for this phase is 12.8 Å, shifting after heating to 11.8 Å, and after glycerol treatment to 14.7 Å. Fine quartz, illite and disordered kaolinite are often associated with these minerals. The bluish-grey clay underlying the siderite contains the same montmorillonite–chlorite mineral, associated with disordered kaolinite, illite, and a small amount of quartz.

The rivers are transporting a different mineral suite today. In order of abundance, disordered kaolinite, quartz, illite and goethite dominate the riverine clay fraction in accordance with the dominant oxisol and ultisol cover of the island's interior. The clay mineral mixture associated with the siderite

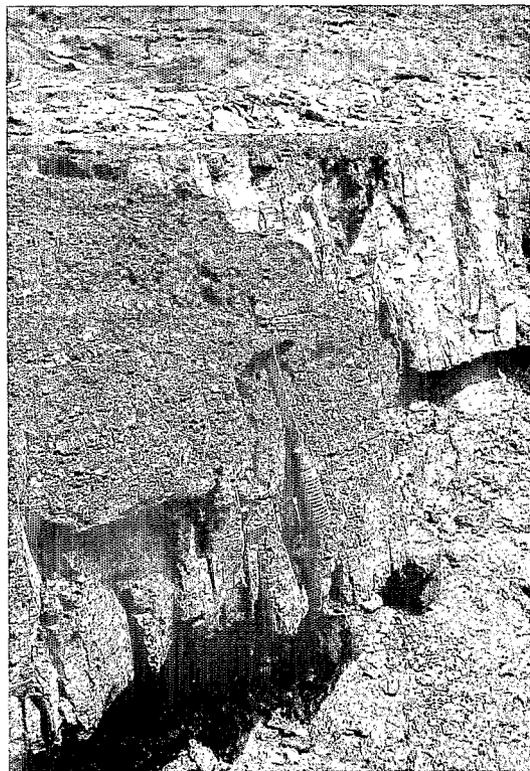


Fig. 3. Outcrop of Miocene coal on the Rungan River, in Central Kalimantan (Borneo).

instead appears to be more like that of coastal sedimentation under a periodic marine influence, mainly because of its montmorillonite–chlorite content, its bluish colour and reducing characteristics, and the absence of goethite and hematite.

An explanation for the genesis of the siderite is more problematic. A good approach to understand its deposition is to look at geochemical mechanisms of the modern coastal plain of the Indonesian Central Kalimantan Province.

THE MODERN COASTAL LANDSCAPE

Millions of hectares of poorly drained coastal plains of the Indonesian Islands are covered with peat. The peat zone of Kalimantan is situated in relation to the other landscape units in a well-defined sequence (Fig. 4): upslope from the peat is a wide zone of deferrified tropical giant podzols; further inland is a zone including coal and siderite; and at the centre of

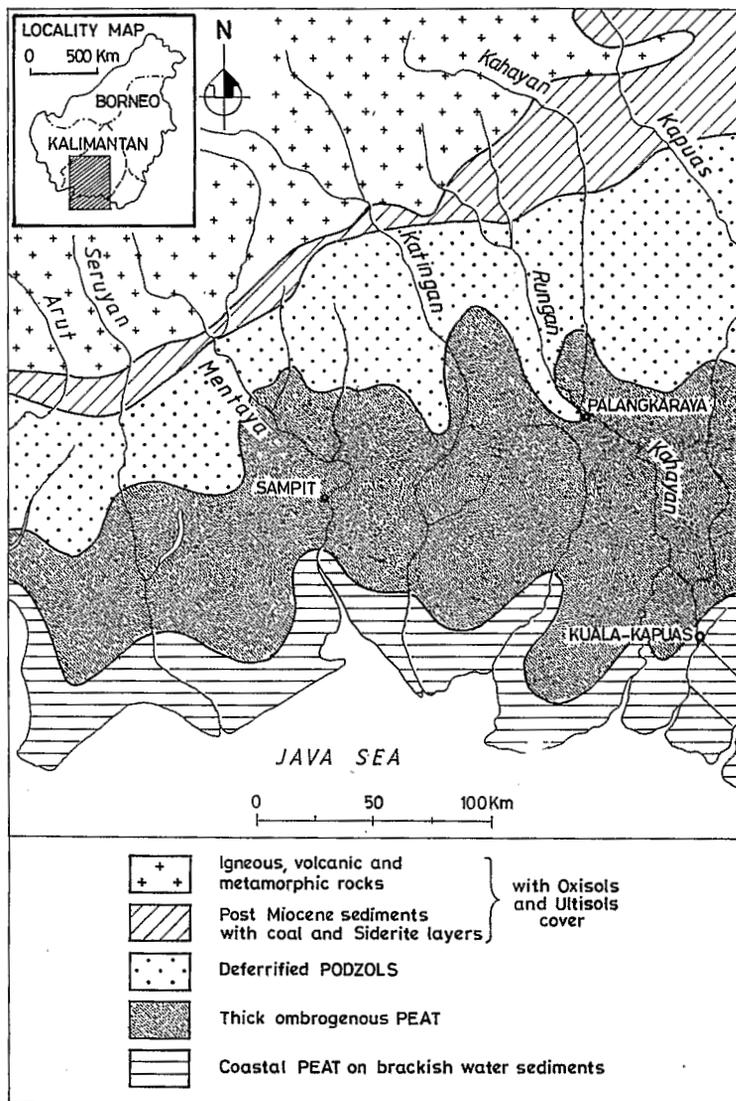


Fig. 4. Succession of soil types in Central Kalimantan Province.

the island is a vast oxisol landscape developed on crystalline and volcanic rocks. Towards the coastal area, thinner peats overlie predominantly clayey, brackish water sediments containing pyrite, montmorillonite-chlorite and sometimes siderite.

GEOCHEMISTRY OF MODERN COASTAL LANDSCAPE

The geochemistry of each of the landscape zones represented in Fig. 4 is different.

The oxisols

In the upstream units, the oxisol formation is controlled by two mechanisms: weathering and erosion. 1 Weathering destroys completely the minerals of the crystalline and volcanic rocks through a hydrolysis process. The less-soluble elements remain and form the characteristic minerals of the oxisols; mainly kaolinites, iron and aluminium oxides and hydroxides. Such processes have been well studied during the last 30 years by Bonifas (1959), Millot (1964), Delvigne (1965), Lelong (1967), Tardy (1969) and Sieffermann (1973). These authors have shown that

during hydrolysis, nearly two-thirds of the weathered rock is removed in soluble, ionic form. It is easy to forget this because the process is invisible. The hydrolysis of 3 parts of andesite gives only 1 part of soil and the remaining 2 parts disappear. Half of the dissolved rock is silica. In other words, for each quantity of soil we can see in Borneo, on the Matto Grosso Shield in Brazil, or in the Congo Basin, an equal amount of silica has been transported to the coastal zone of sedimentation.

2 Erosion affects all soils and removes the soil minerals formed during the weathering process in the form of suspensions in the rivers. In equatorial regions, the soils represent an equilibrium between the weathering and the erosion processes. This removal of 'soil minerals' can be seen and measured: it is the solid transport. These two mechanisms are represented on the right-hand side of Fig. 5.

The giant podzols

This unit occurs over thousands of square kilometres and forms a very flat landscape. The giant podzols can be morphologically compared with those of temperate climates, but differ from temperate podzols by the greater thickness of their horizons. They are characterized by a white quartz sand horizon, often more than 5 m thick, overlying an iron and aluminium hardpan, frequently more than 2 m thick.

The hardpan forms a nearly permanent water table with only lateral outflow.

Such podzols have been extensively reported during the last 30 years by Viera & Oliveira-Filho (1962), Altenmuller & Klinge (1964), Klinge (1967, 1969), Andriess (1969, 1970), Turenne (1970, 1975), Flexor *et al.* (1975) and Thompson (1986). The normal, undisturbed vegetation on such soils is forest.

At its southern limit, the giant podzols are overlain by ombrogenous thick peats as represented in Fig. 5. The great contrast in these soils, between the white quartz sand horizon and the iron and organic hardpan, is not caused by a change in depositional source materials or by facies changes resulting in different parent materials, but by thousands of years of clay mineral breakdown through rainwater percolation.

The giant podzols have been formed from fluvial sedimentary clayey sands, similar to those deposited by modern rivers, and composed mainly of quartz gravels and sands, kaolinites and iron hydroxides. The percolation of the equatorial rainwater through such sediments created the bleached horizon in which only quartz remains. If the past rainfall was comparable to the modern rainfall, a column of 50 km of rainwater has percolated slowly through these soils during the last 30 000 years.

The removal of the iron and aluminium through organic compounds has been described by Bruckert

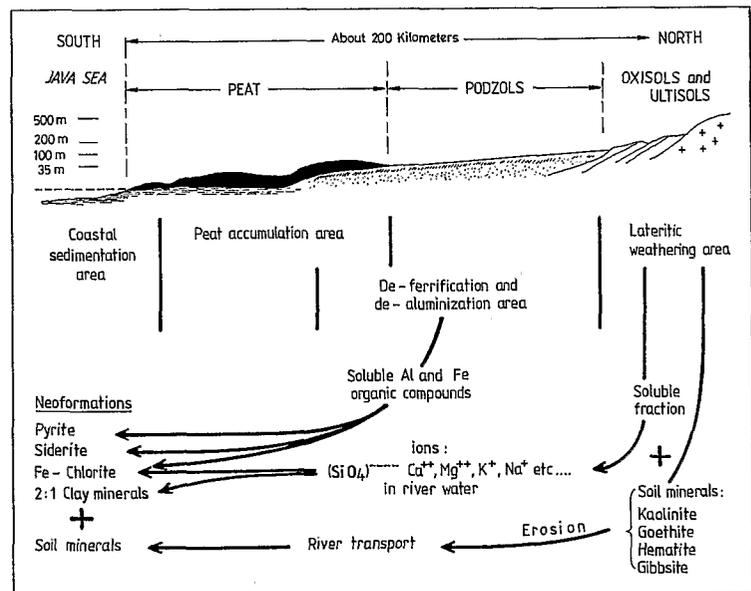


Fig. 5. Transfer of elements during weathering and genesis of new minerals in the coastal landscape of Kalimantan.

(1970), Razzaghe-Karimi (1974), and Turenne (1975). Tancredi *et al.* (1975) proposed that the iron removed from the soils was later available to make siderite and iron chlorite in Quaternary sediments of the Amazon Delta. Tancredi *et al.* therefore suggested a relationship between siderite formation and deferrification of white kaolin deposits, processes that fit the situation in Indonesia. A similar mechanism was proposed by Bubenicek (1970) for the iron chlorites and siderite of the important iron ore deposit of Lorraine (France). These processes are shown in the central part of Fig. 5.

The coastal sedimentation zone

The coastal sedimentation zone is characterized by its clay mineral suites.

1 Inherited clays and minerals arrive detritally from the inland environment; these are mainly disordered kaolinites, small amounts of quartz, and minor amounts of mica.

2 Clay mineral of 2:1 type; mainly interstratified montmorillonite—chlorite and iron-bearing clay minerals with chlorite X-ray characteristics. These 2:1 minerals can represent up to 30% of the clays of the coastal unit.

It should be emphasized that such 2:1 minerals are almost absent in the solid load of rivers draining tropical oxisol areas. A similar absence of such minerals was observed in South America in the solid transport of the tropical Xingu River (Gibbs, 1967). The most plausible explanation is that these 2:1 minerals of the coastal sedimentation zone are formed by aggradation of degraded clay particles coming from the inland units. The river water carries soluble silica derived from the inland soils where equatorial weathering occurs. This silica could contribute to the growth of small clay crystals in the sedimentation area, with incorporation of potassium and magnesium ions from seawater in the new structure. Such transformations by the aggradation of inherited clays related to the environment have been extensively reported by Dietz (1941), Grim *et al.* (1949), Grim & Johns (1954), Powers (1957, 1959), Nelson (1960) and Pinsak & Murray (1960).

3 Neoformed siderite and pyrite. The iron in these two minerals is undoubtedly derived from inland, either in the form of soluble iron—organic compounds or from the destruction of detrital goethite and hematite. Goethite and hematite disappear in the reducing brackish water environment of the coastal sedimentation zone, and their iron may contribute

to the genesis of the siderite and pyrite. Siderite may be the dominant mineral in reducing freshwaters (Postma, 1982; Giresse, 1987), whereas pyrite may be more frequent in seawater environments (Casagrande *et al.*, 1977; Postma, 1982).

The clays surrounding the siderite layers of the Rungan River suggest brackish water sedimentation, even though the salt has been washed away since the Tertiary. More field investigations have to be undertaken in order to understand the genesis of the siderite and pyrite.

There is little data available for iron carried by inland groundwater to the coastal area. However, the heavy clayey texture of the sediments, their topographic position which is less than 1 m above the mean sea level, the presence of salt which induces dispersion of clays and consequently the imperviousness of the clay layers, suggest that groundwater iron discharge may play a role only in short distance transport.

CONCLUSION

In the coastal area of Central Kalimantan Province, the fine sediments are a mixture of inherited detrital components and newly formed aggradational clays incorporating cations from the seawater. Within this clay mineral mixture, neoformed minerals such as siderite and pyrite are being produced.

This modern depositional setting can be directly applied to post-Miocene sediments in Central Kalimantan, in which indurated siderite layers are underlain by clays having a mineralogical composition much like those of the modern analogue. Deferrification of onshore sedimentary continental formations through the agency of pedological podzolization processes can be inferred from such features as bleached quartz sands and organic hardpans.

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