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Environment of placer gold deposits in northern Pahang

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Abstract: Deposition of placer gold in northern Pahang began contemporaneously with the deposition of the Tertiary Bed within subsiding basins. The Tertiary Bed is characterized by subbituminous coal seams in which some fine gold are present as mineral matter. Further downwarping, solution of limestone bedrock, and rising of sea level, the subsiding basins were aggraded by Old Alluvium. The disposition of the basins, on a relatively flat terrain adjacent to the towering Gunung Berentin, in which the host rocks of gold occur, provides the necessary topographic contrast which is essential for the separation of gold, other heavy minerals, and gravels and cobbles from the stream load. The gravel-cobble layer of the Old Alluvium contains pay streaks of gold. The Young Alluvium has only traces of gold.

INTRODUCTION

Though tin-mining has been and perhaps may continue to be one of the major mining industries in Peninsular Malaysia, exploration and mining for gold are on the increase these days, particularly with the high gold price. Though gold has often been won as a by-product from several tin placers (e.g. Bidor), the major gold producing areas are located in the Central Belt of the peninsula (Hosking, 1973). Most of the small to medium scale mine operators recover gold from alluvial deposits, adopting the techniques commonly used in tin-mining, viz., hydraulic jets, sluices and pans. This paper discusses the geology and the depositional environment of placer gold occurring in the Merapoh basin which is situated in north Pahang within the Central Belt of the peninsula.

GENERAL GEOLOGY

The Merapoh basin, accessible from the Gua Musang-Kuala Lipis highway and situated about 7 km south of the Kelantan-Pahang boundary, is characterized by relatively flat topography occasionally punctuated by some precipitous limestone hills. The rocks exposed in the mine pits as well as in their vicinity are limestone interbedded with some shale, mudstone, sandstone and tuff. These rocks which are mildly folded, belong to the Gua Musang Formation of Permian-Triassic age (Yin, 1965 a, b). The latter, in part, possibly overlies the deformed Paleozoic Berentin Complex which outcrops as a north-south trending mountainous range (Gunung Berentin) west of Merapoh. A fault occurring at the apron of the Gunung Berentin, separates the Gua Musang Formation from the Berentin Complex. The latter consists mainly of metatuff and schist, occasionally traversed by quartz dikes and veins. Hutchison (1973) however suggested

Presented at GSM Annual Geological Conference 1989 that other rock types could also be present in the Berentin Complex. The Gua Musang Formation at Merapoh is overlain unconformably by Tertiary sediment which in turn, is overlain by Quaternary alluvium. The geology of the area is illustrated in Fig. 1 and a cross-section of Merapoh basin is schematically illustrated in Fig. 2.

GEOLOGY OF THE MERAPOH BASIN

The bedrocks exposed in the mine pits operated by KMK Gold Mine, consist predominantly of limestone interbedded with some tuff amd shale, all of which belong to the mildly deformed Gua Musang Formation. The limestone which is largely dolomitic in composition, consists of clasts of varying sizes forming randomly disposed calcilutite, microsparite and occasional recrystallized coarse-grained calcite. Bedding in the limestone is often indistinct though occasionally is revealed by carbonaceous laminations. Fossils particularly pelecypods, ammonoids and crinoids are not uncommon in some of the limestone beds. These fossils, some of which had been identified by Hada (1966), Ichikawa and Yin (1966), and Tamura (1968), suggest a Permian-Triassic age for the Gua Musang Formation. The shale and tuff members are generally thinly bedded amd less massive compared to the limestone. The shale, some of which are calcareous, is well laminated and has colours varying from grey to black. The tuff which is white in colour, consists mainly of clay minerals, indicating that it had undergone alteration. Relatively unaltered tuff exposed elsewhere, however, has trachytic to andesitic composition.

Unconformably overlying the limestone is a sequence of sedimentary rocks interbedded with coal seams. These rocks are best observed in places where the limestone has not undergone solution. The base of the sequence consists of a thin layer of bituminous siltstone of less than 10 cm thick, followed by a coal seam of about 2 m thick. Above the latter is a layer of structureless clay of about 0.5 m thick. Occasionally, a thin layer of carbonaceous shale of less than 5 cm thick occurs between the coal seam and the structureless clay layer. In another pit (situated about 0.5 km west of the main pit just mentioned), a smaller coal seam of about 12 cm thick occurs above and parallel to the coal seam just described. Here, a thin layer of carbonaceous shale seperates the two coal seams. The stratigraphy and lithology of these coal-bearing sedimentary rocks are almost similar to some of the Tertiary Beds which are only known to occur in several low-lying areas on the western belt of Peninsular Malaysia (Stauffer, 1973). The geographical distribution of the Tertiary Beds can perhaps be extended to include other areas, particularly the Merapoh basin. The coal-bearing sequence described in this paper is hence referred to as the Merapoh Tertiary Bed.

The dark brown to black coal in the Merapoh Tertiary Bed, is usually soft, friable and has a dull luster. Inferring from microscopic studies and data obtained from proximate analyses, the Merapoh coal can be classified, using the

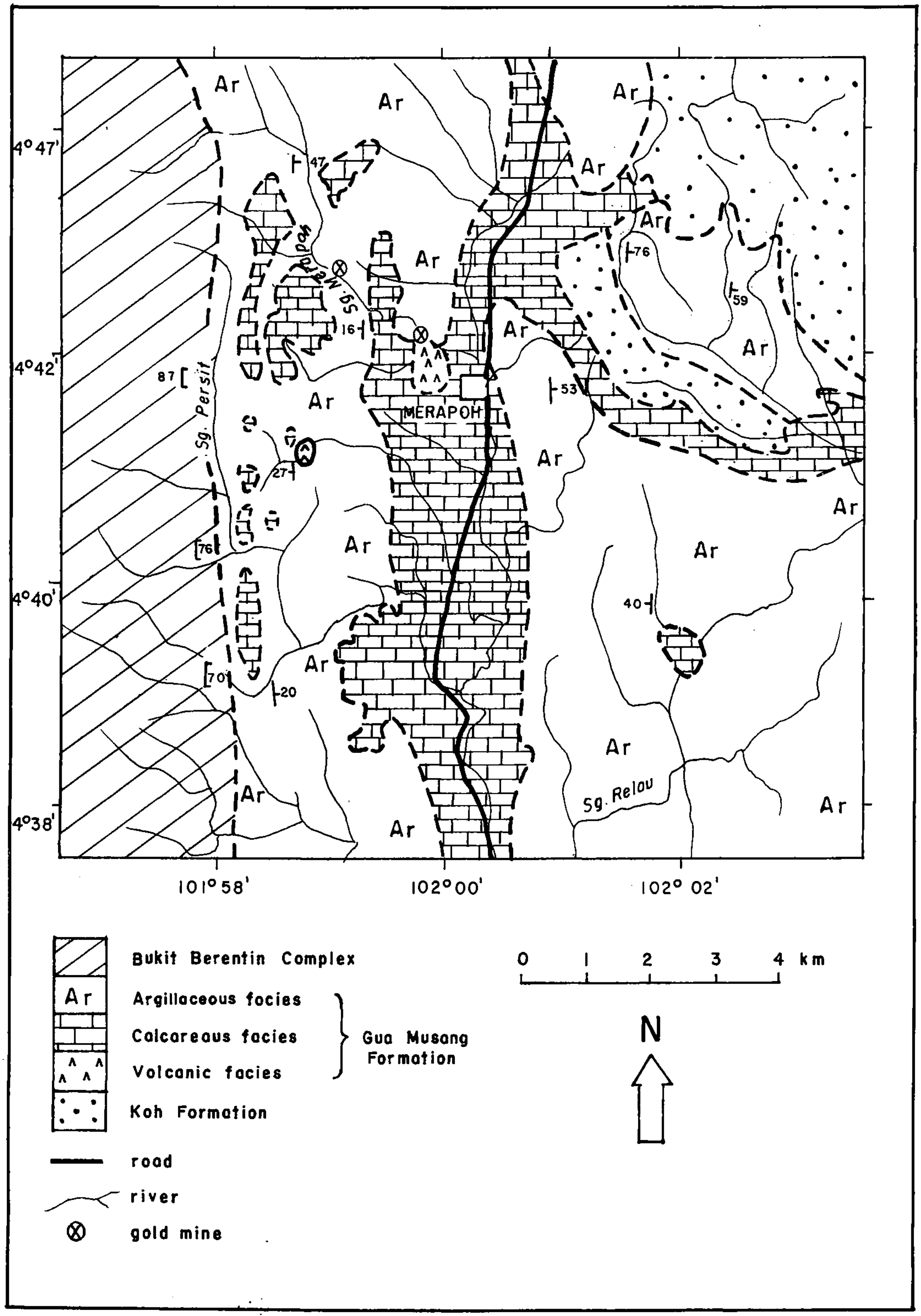

Figure 1: General geology of Northern Pahang.

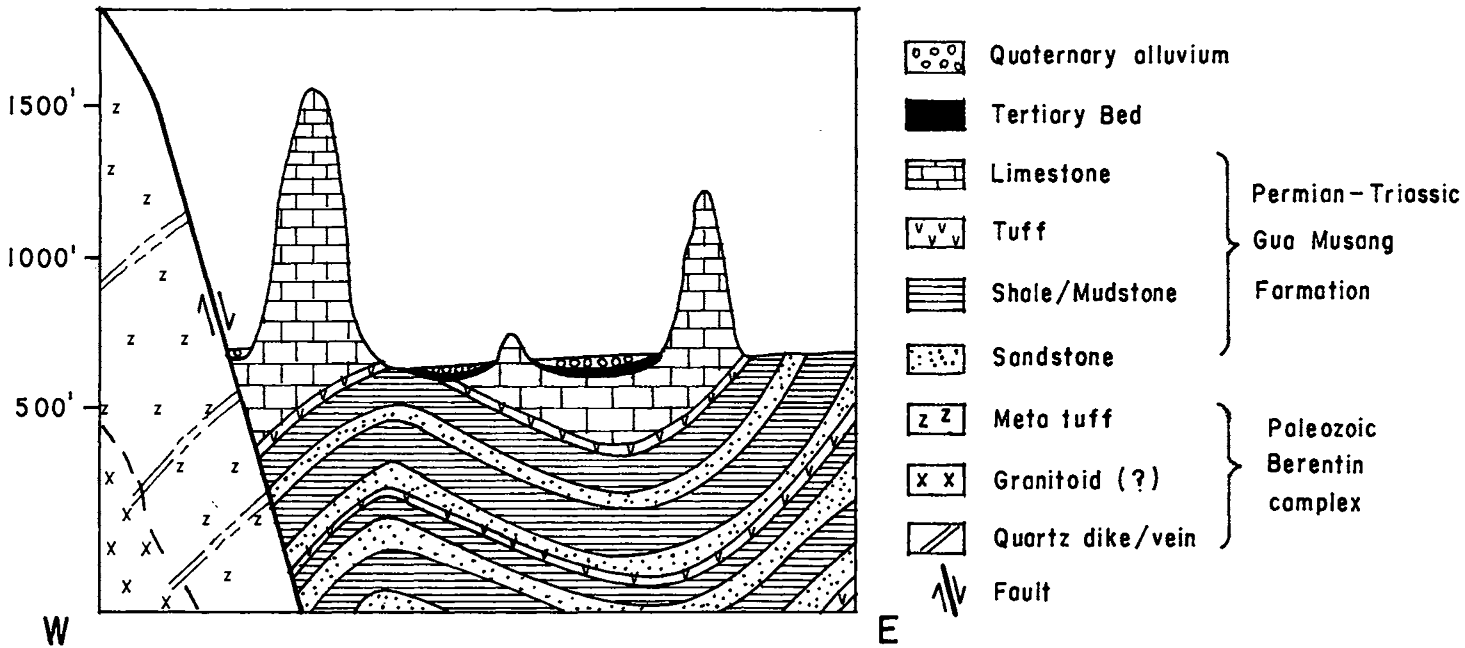

Figure 2: Schematic cross-section of the geology of the Merapoh basin.

method proposed by Stach *et al.* (1975), as bimacerate durain coal with a rank of either subbituminous coal C (ASTM terminology) or braunkohl (German terminology). A detail description including the composition and maceral content of the coal deposit will be presented elsewhere (in preparation).

At most places where the limestone bedrock expresses karst topography, the Merapoh Tertiary Bed slumped into the sink holes in which blocks of coal intermixed chaotically with clay, siltstone, shale and alluvial deposits.

The Merapoh Tertiary Bed is overlain unconformably by alluvial deposits. Immediately overlying the Tertiary Bed is a relatively thick layer of gravels and cobbles whose interstices are filled with subordinate amount of clay, silt and sand. Within this layer are occasional lenses of clay, peat and partly lignitised wood fragments. Most of the gravels and cobbles have lithologies of metatuff amd quartz; with some of limestone, shale, sandstone, mudstone amd tuff. Generally, the coarse materials are subangular to subrounded, with gravels having a median value of about 30 mm, while the cobbles up to about 100 mm. From the clastic composition, the gravel-cobble layer is very poorly sorted, with values of sorting (σ) ranging from 1.5 to 3.0. The gravel-cobble layer, in some instances, grades into stiff clay band of less than 0.5 m thick which appears at the top of the sequence. Such depositional sequence is less apparent in places where both the Merapoh Tertiary Bed and the alluvium had slumped into the limestone sink holes. The thickness of this alluvium is highly variable, ranging from less than 0.5 m to about 10 m, depending on the outline of the karst topography. The heavy minerals which are present in the finer grained matrix filling the interstices of the gravels and cobbles, are mainly pyrite, ilmenite, zircon and gold. Gold as well as other heavy minerals accumulate to anomalous concentrations, forming pay streaks in the gravel-cobble layer. This gold-bearing alluvial deposit is referred subsequently in this paper as the Old Alluvium since its characteristics are almost similar to those of the Old Alluvium described by Walker (1956), Sivam (1969), and Newell (1971).

Immediately overlying the Old Alluvium, as well as on flood plains, river terraces, and at many places over eroded surfaces of lowland earlier-formed rocks, is a layer of unconsolidated graded sediments consisting of mainly of sand and silt and subordinate clay with occasional gravels, peat and unlignitised wood fragments. Primary sedimentary structures such as cross-bedding, lenticular bedding, channel and clast imbrication in the gravels are common. Unlike the Old Alluvium, this deposit is not disturbed by slumping, but instead usually shows simple graded sequence from gravel at base, through sand to finer materials at top. In addition, the deposit having median values up to 15 mm, are poorly sorted with values of sorting (σ) ranging from 0 to 2.0. The heavy minerals present are pyrite, ilmenite, zircon and gold. This younger alluvial deposit is referred as Young Alluvium since its characteristics are almost similar to those

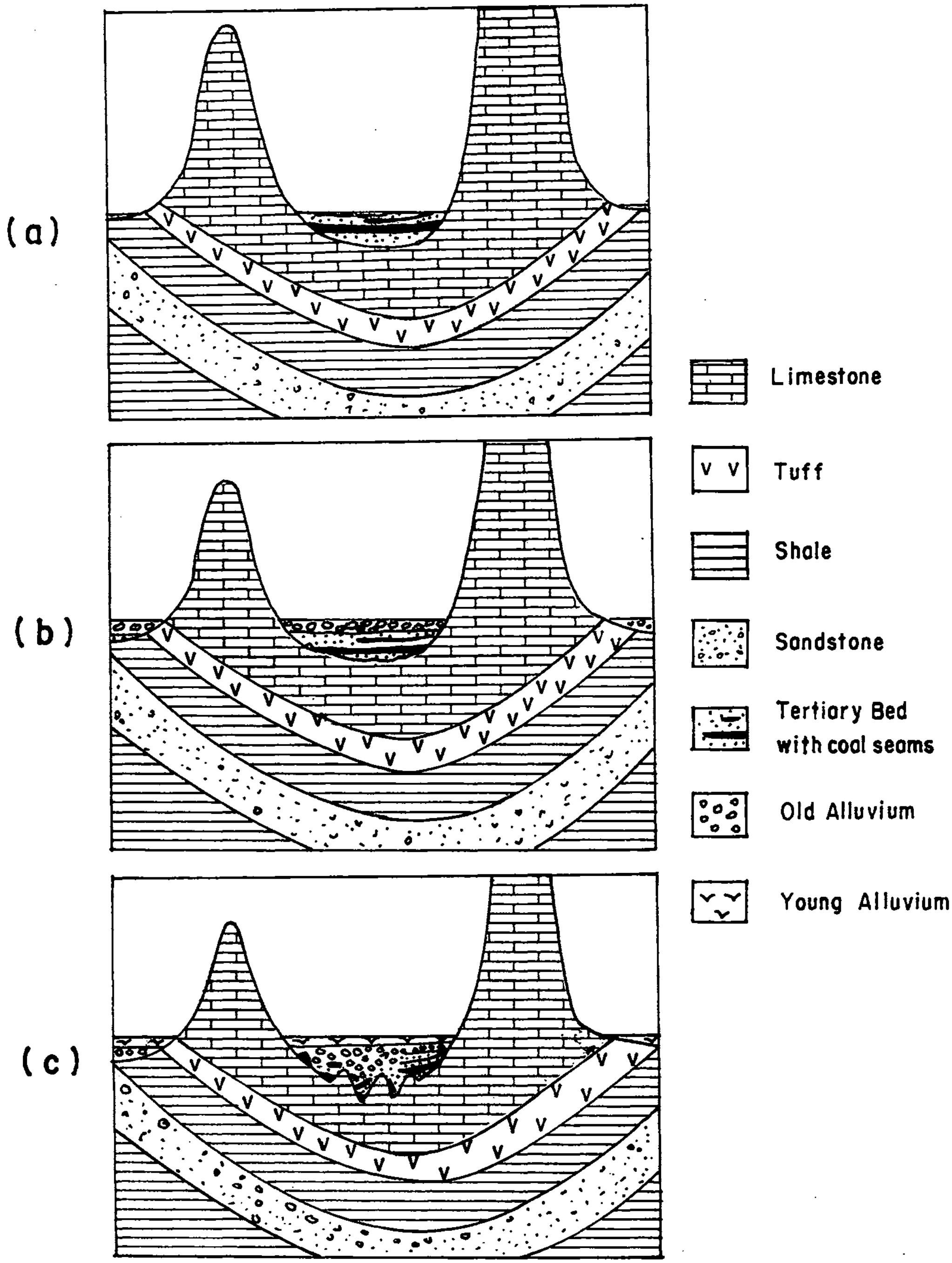

Figure 3: Evolution of the Merapoh basin. (a) Deposition of coal-bearing Tertiary Bed in subsiding basin, (b) deposition of gold-bearing Old Alluvium in down-warped Tertiary basin where part of the limestone bedrock had partly undergone solution, (c) deposition of Young Alluvium over slumped Old Alluvium and collapsed Tertiary Bed.

of the Young Alluvium described by Walker (1956), Sivam (1969) and Newell (1971).

The evolution of the Merapoh basin is summarized schematically in Fig. 3.

PLACER GOLD

Gold was liberated from various host rocks, viz., quartz dikes and veins, and metatuff of the Berentin Complex, through processes of weathering and erosion. In the headwaters of the drainage system, which were within the towering Berentin Complex, gold as well as other minerals were transported downstream by fast-moving water. On the foothills of the Berentin Complex where there is a sudden change in the topographic gradient, the velocities of the loaded streams decreased abruptly, favouring gold and other heavy minerals to be deposited. Though placer gold is present in the Tertiary and Quaternary sediments, only the gravel-cobble layer of the Old Alluvium contain pay streaks of gold. Using the fire assay method, the gold content present in samples of the Tertiary Bed, Old Alluvium and Young Alluvium are shown in Table 1. Although the analytical data do not give a true pattern of gold distribution in the entire Merapoh basin, they reflect that gold is markly concentrated in the gravel-cobble layer of the Old Alluvium which has gold content as high as 179 mg/m^3, while the Tertiary Bed and the Young Alluvium have gold values of less than 2 mg/m^3. The gold content in various rock types present in the Berentin Complex and the Gua Musang Formation will be presented elsewhere (in preparation).

Table 1 : Gold assay values in the sediments of the Merapoh basin

Sample	Description	Depth (m)	Au (mg/m^3)
Young Alluvium	silty clay layer	0.3	<1.0
	silty sand layer	0.6	1.5
Old Alluvium	clay band	1.1	26.0
	gravel-cobble layer	2.5	105.0
	gravel-cobble layer	8.0	179.0
Tertiary Bed	shale	11.1	<1.0
	upper coal seam	11.5	1.8
	lower coal seam	12.8	<1.0

The placer gold is generally in the form of dust with sizes ranging from about 0.005 to about 1.0 mm in diameter. Though coarser gold grains have been encountered during mining operation, they are exceeding rare (KMK pers. comm.). Most of the gold dust appear as subangular to subrounded flattened discs, with some having irregular shapes. The average fineness of the gold recovered is about 960 (KMK, pers. comm.).

ENVIRONMENT OF PLACER GOLD DEPOSITION

Since some gold dust were present as mineral matter in the coal seams, it can be expected that initial placer gold deposition occurred contemporaneously with development of the coal-bearing basin. The latter can be assumed not to have sunk at a constant rate, but instead had undergone periods of slow subsidence alternating with periods of more rapid sinking. During periods of slow subsidence, the basin became shallower due to continual deposition of sediments derived from erosion of neighbouring areas of positive topography. Such condition favoured the growth of swamp, marsh or bog. Dead plant materials which accumulated and entombed on the bottom of the swamp, were subsequently converted to peat through microbiological reaction.

Peat accumulation continued until the rate of subsidence of the basin increased again. Rapid sinking of the basin resulted not only in the submergence of the swamp but also in the infilling of the basin with sediments. The buried peat was slowly altered (coalification) to coal under water-logged reducing conditions. The reducing environment is indicated by the presence of minute framboidal pyrites occurring among the macerals.

The changing rates of basin subsidences account for the presence of multiple coal seams. From the presence of two successive parallel coal seams observed in the Merapoh basins, it can be inferred that there were at least two periods of slow subsidence intervened by periods of rapid sinking. The subsidence of the basin was probably caused by epeirogenetic down-warping which was the prominent tectonism operating during the Tertiary times (Stauffer, 1973).

The presence of distinct macerals in the coal reflects that the latter was derived form coalification of plant materials (humic) rather than from aquatic oozes or sludges (sapropelic). The maceral composition of the coal indicates that the pre-existing plant materials were derived mainly from woody and herbaceous plants as well as from some spore-bearing plants. The likely paleoenvironment is that of a tropical forest swamp dominated by angiosperms and to a lesser extent gymnosperms. From petrographic study and proximate analyses, the bimacerate coal can be ranked either as braunkohle (German terminology) or as subbituminous coal C (ASTM terminology). Such low grade coal is usually present in most of the Tertiary coal measures in the world (Kummel, 1961). Ratanasthien (1986) reported similar coal deposits present in Cenozoic basins in various parts of Thailand.

The Old Alluvium occurs at elevations of about 200 m above the present sea level. The origin of this high-level alluvial deposit is probably related to the Tertiary high sea level. Based on various evidences, sea level changes through geologic times have been documented by Biswas (1973), Tjia (1970), and Vail and

Mitchum (1979). Prior to the rising of the sea level, exposed parts of the low-lying Gua Musang Formation and the coal-bearing Tertiary basins were downcut by stream erosion, as well as downwarped by epeirogenesis , forming river valleys, lakes and basins. With the rising of the sea level, these geomorphologic features were subsequently aggraded by alluvium. The change in topography in the down-warped coal-bearing basins would cause a slack in stream velocity, and this would result in the deposition and accumulation of gold, other heavy minerals together with gravel and cobble-dominated sediments forming the Old Alluvium.

During high sea level stand, and owing to high water table, part of the limestone which forms the basement rock for the Tertiary Bed and the overlying Old Alluvium, dissolved forming sink holes into which part of the Tertiary Bed and the Old Alluvium collapsed. The solution of limestone could not have occurred prior or during the formation of the Tertiary Bed as most of the peat would have been oxidized and destroyed at high water table. Hence, it could be inferred that the high sea level change occurred after the Merapoh Tertiary Bed had been formed. If significant topographic changes were solely due to the solution of the limestone, then the occurrence of the Old Alluvium in the Merapoh area would have been more widespread, and not confined to the Tertiary basins. Regional downwarping together with localized solution of the limestone bedrock would produce significant topographic changes favouring the deposition of the gold-bearing Old Alluvium. The high sea level stand probably corresponds to the present elevation of the Old Alluvium which is at about 200 m above the present sea level.

In most areas of matured topography, the unconsolidated graded Young Alluvium forms an unconformable blanket over the older formations, including the Old Alluvium. The unconformity between the Old Alluvium and the Young Alluvium suggests that the latter represents a period of sedimentation following a period of erosion of part of the Old Alluvium. The various primary sedimentary structures present in the Young Alluvium indicate that the latter is of fluviatile origin, related to the existing drainage system. Transport direction inferred from clast imbrications is dominantly south-east, following the drainage trend of the present day Sungai Merapoh. Sedimentation of the Young Alluvium, continuing with the modern river deposition, probably began during the latest inter-glacial period of sea level stand which is at or near the present sea level. Erosion of part of the Old Alluvium, and to some extent the gold-bearing metatuff, liberated some gold and other heavy minerals which were then deposited together with the sediments of the Young Alluvium. The paucity of gold in the Young Alluvium could be due to little or no changes in topographic gradient, water-flow velocity or both, all of which are necessary in concentrating gold into a workable placer deposit.

CONCLUSION

Weathering and erosion of the gold-bearing host rocks, viz., the quartz veins and dikes, and metatuff of the Berentin Complex, contribute to the formation of placer gold in the Merapoh basin. Deposition of placer gold began contemporaneously with the deposition of the coal-bearing Tertiary Bed within subsiding basins. The Tertiary Bed contains subbituminous coal seams in which some fine gold are present as mineral matter. These basins which occur on a relatively flat terrain striking against the towering Gunung Berentin provide the necessary topographic contrast which is essential for the separation and deposition of gold and other heavy minerals. The Tertiary basins were deepened by regional downwarping as well as by localized solution of limestone bedrock. With enhanced topographic contrast and rising of sea level, the basins were aggraded by gold-bearing Old Alluvium. The gravel-cobble layer of the latter has the highest placer gold content, forming pay streaks. The Young Alluvium which is formed under present conditions and occur above the older sediments and along river valleys, contain only traces of gold.

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