Geological Society of Malaysia Bulletin 52
June 2006 p.129-135

Gold Mineralization And Zonation In The State Of Kelantan

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Abstract: Gold mineralization in Kelantan is mainly distributed in the central part of the state, bounded by Stong Igneous Complex and Senting Granite on the west, Kemahang Granite in the north and Boundary Range Granite in the east. The gold mineralization is more common in Triassic sedimentary rocks followed by Permian metasedimentary rocks. The oldest Silurian-Ordovician metasedimentary rocks only contain some insignificant gold mineralization, whilst the youngest Cretaceous-Jurassic sedimentary rocks are devoid of gold mineralization. Basically, the gold mineralization are identified as volcanogenic massive sulphides, skarns and hydrothermal quartz vein deposits. Six types of hydrothermal quartz veins can be observed, viz. low sulphide quartz veins, high sulphide quartz veins, quartz veins in sheared granite zones, quartz veins at the boundary of sedimentary rocks, structurally controlled quartz veins in volcanic-sedimentary rocks and metamorphic segregation quartz veins. The main factors contributing succession of gold mineralization are source rocks, heating chamber as well as depositional structures. The principal source rocks are Permian-Triassic volcanic rocks that are associated with sedimentary rocks. The heating chamber that induced the hydrothermal fluids is the granitoind bodies that intruded under the volcanic-sedimentary rocks, whilst the structures which allow the infiltration and deposition of gold are shear zones and fault zones originating from depth. Based on the type of ore deposits, geochemical data and geological setting, the study area can be divided into five zones, namely gold zone (hydrothermal veins), gold-base metal zone (volcanic exhalative), gold-silver-mercury zone (hydrothermal veins), base metal-gold zone (massive sulphides) and silver-lead-zinc zone (skarn and massive sulphides).

INTRODUCTION

Kelantan State has a long established gold mining history. Practically all the gold mining activities are concentrated in the central region of the state. The Geological Survey Department of Malaysia (GSM) has reviewed all available geological, geochemical, geophysical, prospecting and mining data obtained in 1987, 1994 and 1995. A total of 30 prospective gold (1,161 km2) sectors were delineated through an integrated evaluation of geochemical, geological and mining information (Teoh et al. 1987). Basically, most of the gold mines are working on placer deposits; they contribute approximately 10 % of the annual gold production of Malaysia.

GEOLOGICAL BACKGROUND

The regional geology of Kelantan consists of a central zone of sedimentary and metasedimentary rocks bordered on the west and east by granites of the Main Range and Boundary Range respectively. Within the central zone, there are windows of granitic intrusives, the more prominent of these being the Ulu Lalat (Senting) batholith, the Stong Igneous Complex and the Kemahang pluton. These belts of granite and country rocks have a north-south trend and are essentially the northern continuation of the regional geology of north Pahang. In west and central Kelantan, the belts continue northward into south Thailand but in the east the Boundary Range granite is overlain by the coastal alluvial flat of Sungai Kelantan.

The oldest rocks in the state are of Lower Paleozoic age, outcropping as a northerly-trending belt bordering the foothills of the Main Range and extending eastward up to Sungai Nenggiri. They are mainly metapelites with lesser volcanic fragmentals and minor arenaceous and calcareous intercalations. Rare occurrences of amphibolite and serpentinite have been recorded (MacDonald, 1967).

Predominantly Permian volcanic-sedimentary rocks occur extensively on the eastern side of, and overlying uncomformbly, the Lower Paleozoic sequence in south-west Kelantan. The Taku Schist, the age of which is still doubtful but definitely pre-Triassic, dominates central-north Kelantan.

Triassic rocks are confined mainly to central and south Kelantan. These rocks are mainly argillo-arenaceous sediments with intercalated volcanics and limestone. Several inliers of Permian rocks crop out through this veneer of Triassic sediments (MacDonald, 1967).

The youngest rocks are the Jurassic-Cretaceous continental rocks which overlie the Boundary Range Granite and Triassic sediments in the Gunung Gagau area at the common state boundary between Kelantan, Terengganu and Pahang and to the west in the Gunung Perlis and Gunung Pemumpu areas. This sequence consists of conglomerate overlain by sandstone with

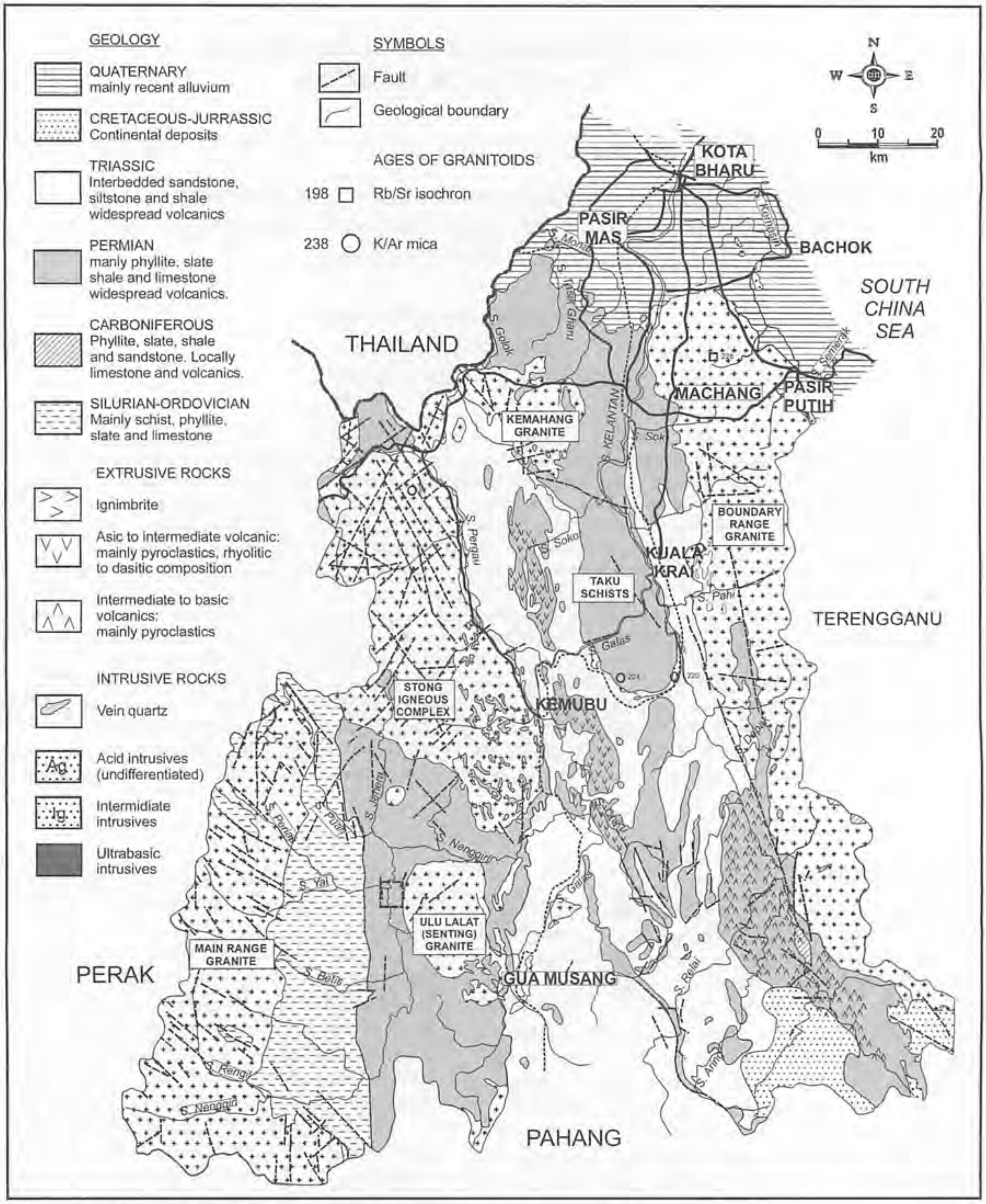

Figure 1: General geological map of Kelantan (after Teoh *et al.*, 1897).

sporadic volcanic intercalations (Rishworth, 1974). The geological map for the state of Kelantan is as shown in Figure 1.

GOLD DISTRIBUTION PATTERN

Based on the geochemical results, geological setting, structural geology and geophysical information obtained from previous works (Chu et al. (1980), Chu (1983), Chu et al.(1983), Teoh et al. (1987), and Geological Survey Malaysia (1982)), it can be concluded that most of the gold mineralization is concentrated in the central part of the state mainly in the Triassic and Permian metasedimentary rocks, which are well associated with volcanic rocks. On the other hand, the younger and the older sedimentary rocks in the state contain insignificant amounts of gold mineralization. The intrusive rocks show some sign of gold mineralization. The Senting Granite, Stong Igneous Complex and Kemahang Granite normally carry some gold mineralization in the shear zones. Quartz veins are well-developed along these shear zones and cut through the sheared granitoid. These types of deposits can be seen in Katok Batu Mine and Batu Melintang. The eastern granitoid bodies (Boundary Range Granite) intruded in the eastern site of Kelantan and normally cause the formation of skarn along contact zones. This type of gold deposit can be seen in Sungai Sok, Sungai Depak and Sungai Mangkok. The geophysical data indicate that the gold mineralization zones occur within the medium to high magnetic area, where there is no indication of basic intrusives (Geological Survey Malaysia, 1982. The vein type deposits are usually shown by low magnetic and low radiometric areas. Structural studies show that there are two sets of faults controlling the gold mineralization. The first set trending NE-SW and is relatively dominant, and the second set trends N-S and is less significant.

NATURE AND ORIGIN OF GOLD MINERALIZATION

Six types of hydrothermal veins together with volcanogenic massive sulphides and skarn deposits are observed. The description of each type is presented below.

Mesothermal Lode Gold

The mesothermal lode gold deposits are distributed all over the state, in association with other types of gold deposits, such as massive sulphides and skarn deposits. There are several types of mesothermal veins based on their nature of occurrence, origin and depositional environment. The factorx required for the formation of mesothermal veins are sources, heating bodies and deposition structures. The source of gold is mainly from volcanic rocks that were extensively extruded during the deposition of Triassic and Permian sediments. In addition, massive sulphide deposit is also found in Ulu Sokor, where the gold also originated from volcanic exhalatives during Permian to Triassic volcanic activities. The skarn gold found in Sungai Sok and Sungai Depak is also derived from the volcanic rocks that are intercalated with Permian metasediments. There are another two types of gold origin that probably also play an important role in Kelantan, namely limestone-hosted gold and igneous dyke gold. The igneous dykes in the Sungai Teleming area, carry a high amount of sulphide minerals, such as pyrite, arsenopyrite and chalcopyrite. Although the concentration of gold detected is lower than 0.03 ppm in the dyke, some other undiscovered dykes probably may carry some valuable mineralization (Goh, 2005).

Six types of hydrothermal quartz veins can be recognized in the state of Kelantan, namely:

- low sulphide quartz veins
- high sulphide quartz veins
- quartz veins in sheared granite zones
- quartz vein at the boundary of sedimentary rocks
- structurally controlled quartz veins in volcanic-s edimentary rocks
- metamorphic segregation quartz veins

Low sulphide quartz veins

The low sulphide quartz veins can be found in the sedimentary, metasedimentary, volcanic-sedimentary, massive sulphides and skarn deposits. The low content of sulphide minerals in these quartz veins is prominent because of the distance traveled. The volcanic layers are probably located at the distal end of hydrothermal veins, where most of hydrothermal fluids are relatively cool and less soluble for gold and other sulphide minerals. Thus, these types of quartz veins can only absorb small amounts of sulphides and gold, which are relatively low in their deposition temperature. These low sulphides quartz veins are commonly found in the gold zone and gold-silver-mercury zone, and can be found in Batu Melintang, Sungai Bertam and Katok Batu mine.

High sulphide quartz veins

The high sulphide quartz veins normally occur in the volcanic-sedimentary rocks, where the volcanic layers are close to the heating magma. The high solubility hydrothermal fluids at the early stage of infiltration are able to absorb most of the sulphide minerals as well as gold. These high sulphide hydrothermal veins are replaced by late phase quartz and form the high sulphide quartz veins. The ore samples in the Pulai gold field are the strong evidence of this type of mineralization veins. Other areas that contain abundance of these high sulphides quartz veins are Sungai Teleming, Sungai Ketil, Gua Setir and those hydrothermal veins associated with massive sulphides and skarn deposits.

Quartz veins in sheared granite zones

Some of the hydrothermal veins are controlled by structure caused by granite intrusiosn. During the intrusive stage, low temperature contact metamorphism will form the shear zones around the intrusive bodies. The quartz veins, normally low in sulphides, infiltrate through these sheared zones and some cross-cut the volcanic-sedimentary rocks. The quartz veins infill the fractures, cracks and bedding of the sedimentary rocks. Some of the hydrothermal veins probably originate from deeper levels. The hydrothermal solutions travel upwards along the granitoid shear zones to the surface. This type of hydrothermal veins is observed at the margins of granitoids at Katok Batu, Panggong Lalat and Panggong Besar mine.

Quartz veins at the boundary of sedimentary rocks

In certain places of Kelantan, structural features and granitoid bodies are not available. Thus, the hydrothermal solutions will travel along the bedding of sedimentary rocks and infiltrate along the boundaries of sedimentary-metasedimentary, sedimentary-volcanic rocks and metasedimentary-volcanic rocks. This type of quartz veins can be found along the boundary of Permian metasedimentary rocks and Triassic sedimentary rocks, such as the borderline in Sungai Kenik and along Sungai Besir-Sungai Perias-Sungai Berok. This type of quartz veins are more commonly found along the foliation of metasedimentary rocks rather than the bedding planes of the sedimentary rocks.

Structurally controlled quartz veins in volcanic-sedimentary rocks

Some of the quartz veins are controlled by structures. The structures that are usually infilled by the hydrothermal veins are fault zones and shear zones that originate depth.

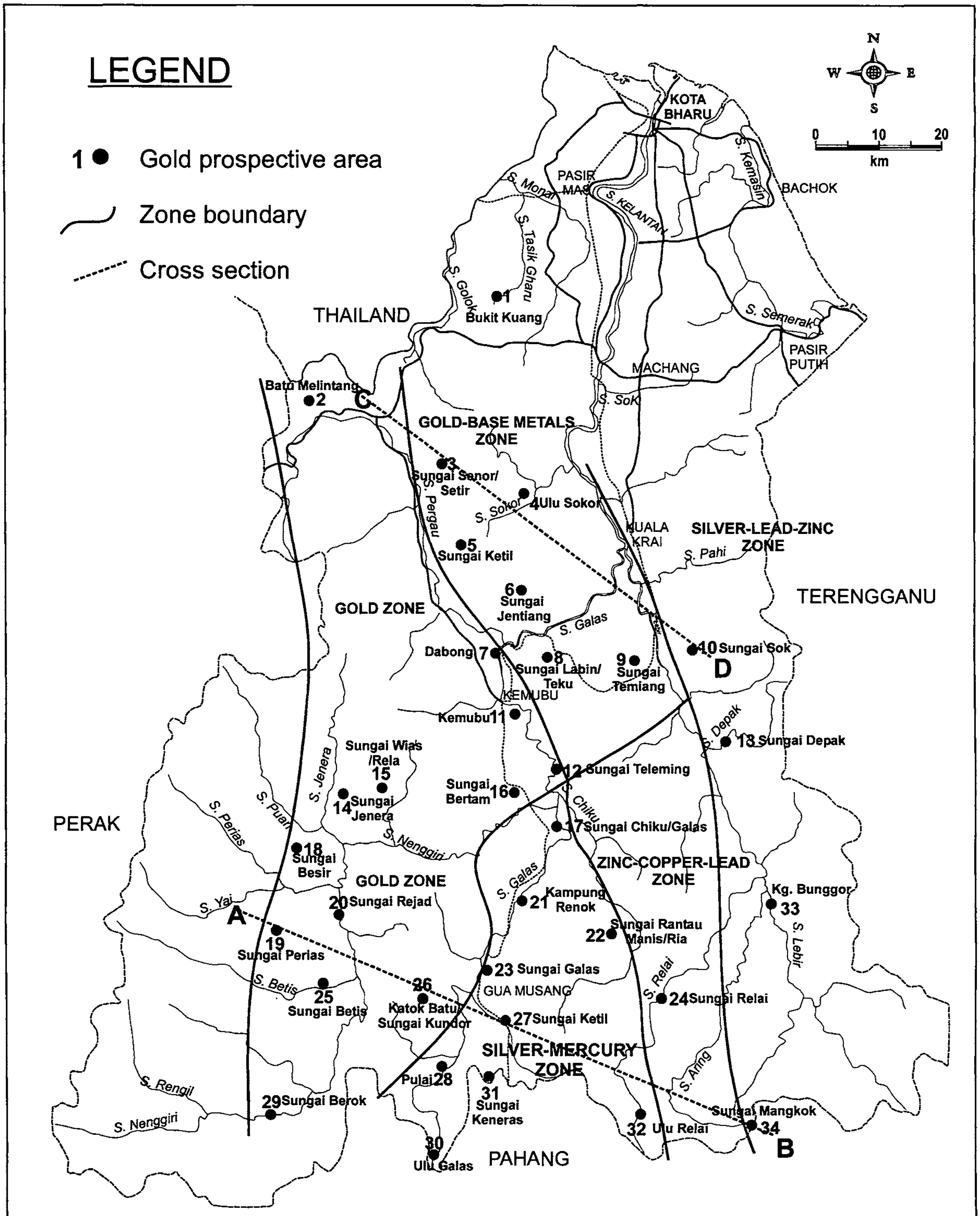

Figure 2: Location map of 34 gold fields in Kelantan (after Teoh *et al.*, 1987) and the distribution of mineralization zones.

Hydrothermal fluids will infiltrate through the volcanic rocks and then absorb the gold and sulphides when traveling along the weak zones of the lithosphere. These types of quartz veins are usually bigger in size and carry greater amounts of gold. The gold mineralizations that are found in Sungai Setir and Sungai Ketil are the ideal examples of structurally controlled quartz veins, where they are deposited along the sheared zones of sedimentary-volcanic rocks.

Metamorphic segregation quartz veins

During the metamorphic process, high temperature segregation will squeeze out the gold and low temperature

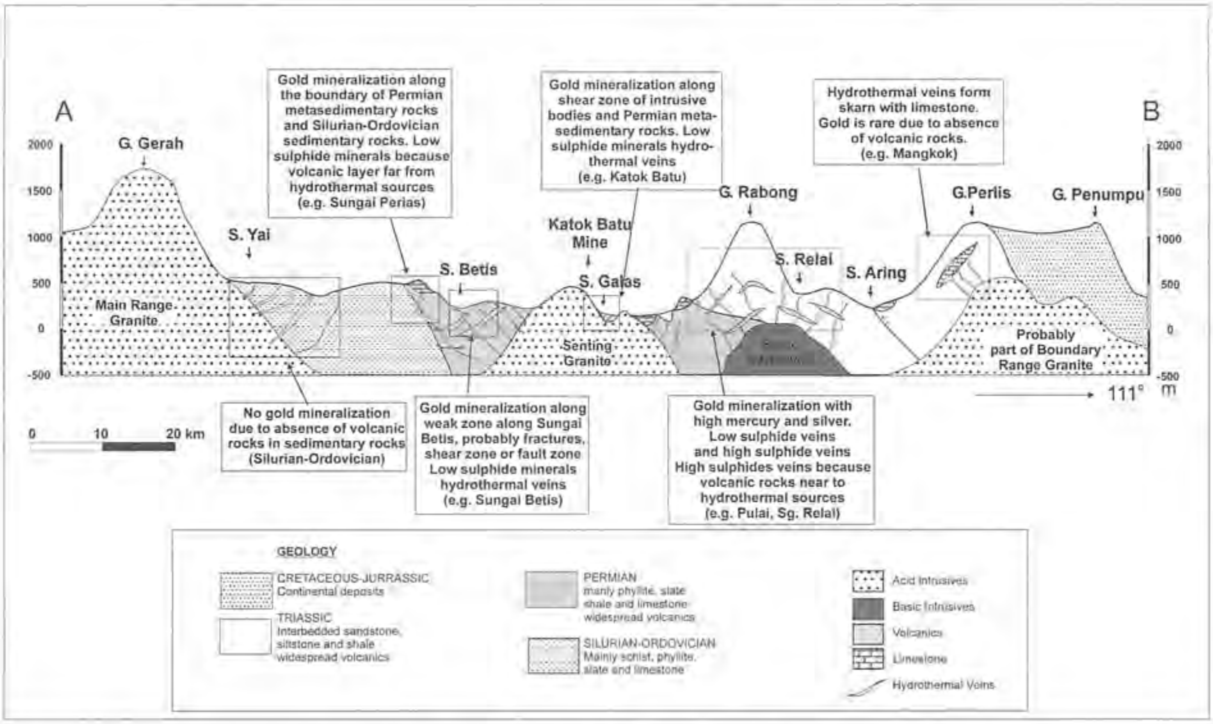

Figure 3: Gold mineralization model for cross section A-B, at southern Kelantan.

sulphides from the metamorphic rocks. This type of vein normally infills along the foliation, cracks and fractures of the schists and phyllite. The indicator of this vein is the existence of rutile, which is always associated with gold in the heavy concentrate. The best outcrop that can be observed in Kelantan is in Sungai Kenik, where metamorphic segregation quartz veins occur together with younger quartz veins that infilled foliations, cracks and fractures along the boundary between Permian metasedimentary and Triassic sedimentary rocks.

Volcanogenic Massive Sulphides Deposits

The volcanogenic massive sulphide deposits are formed at or near discharge vents of hydrothermal systems on the sea floor. The hydrothermal system accepts a sea water convection cell driven by the heat of a cooling subvolcanic igneous body with metals being leached from surrounding rocks through which the hydrothermal fluids circulate (Anthony, 1993). The discharge of these hydrothermal fluids is focused along fault or fracture systems. Triassic sedimentary structures in the massive component of the deposits may result from mechanical reworking and downslope transportation of sulphide ores after initial deposition (MacDonald, 1967 and Teoh et al, 1987). The typical volcanogenic massive sulphides deposits are such as Ulu Sokor in Kelantan as well as Tasik Chini (Bukit Ketaya and Chini 1) in Pahang.

Skarn Deposits

The hydrothermal fluids derived from the Boundary Range Granite infiltrate into the sedimentary rocks as well as limestone. The impermeable layers will form hornfels and in permeable layers close to limestone will form skarn deposits, replaced by massive sulphides veins. This type of deposit usually has not highly prospective for gold. However, when it is connected to the porphyry copper type, gold deposit will be significant, as shown by the Ertsberg-Grasberg superlarge deposit in East Indonesia (Hefton et al, 1995).

THE DELINEATION OF MINERALIZATION ZONES

Based on the geochemical and geophysical results, geological setting as well as nature and origin of gold, six gold mineralization zones are shown in Figure 2. Two cross are shown in Figures 3 and 4. Figure 3 shows the cross section from Sungai Perias to Sungai Betis, Katok Batu, Sungai Relai and Sungai Mangkok (Goh, 2005). There are 4 types of hydrothermal veins and a skarn deposit can be observed along the cross section A-B. The other cross section C-D is located in northern Kelantan, from Batu Melintang to Ulu Sokor and Sungai Sok, showing the hydrothermal veins, massive sulphide and skarn deposits (Figure 4).

Gold Zone (Hydrothermal Veins)

The gold zone is located on the western side of central Kelantan starting from Batu Melintang in northern Kelantan to Sungai Wias/Rela, Sungai Bertam and Katok Batu in southern Kelantan. Gold anomalies in this zone are not associated with any other metals and most of them are hydrothermal veins. The hydrothermal veins that exist in this zone are low sulphides quartz veins, occurring along the boundary between granitoid bodies and sedimentary rocks as well as sedimentary and metasedimentary rocks. The low sulphide hydrothermal veins can be found everywhere in this zone. Quartz veins that are formed along the shear zones of granitoid bodies can be seen at Batu Melintang, Panggong Lalat, Panggong Besar and Katok Batu. Quartz veins deposited along the boundary of sedimentary and metasedimentary rocks are continuous from Sungai Besir, Sungai Perias and Sungai Berok.

The sulphide mineral content in quartz veins is influenced by the location of the volcanic rocks (source rock). If the volcanic rocks are located proximal to hydrothermal veins, the high solubility fluids will be able to dissolve high amounts of gold and sulphide minerals from the volcanic rocks. The hydrothermal veins that are formed by these fluids will usually carry high amounts of sulphide minerals. On the other hand, if the volcanic rocks are located distal to hydrothermal veins, the solubility of the fluids will decrease, only dissolving small amounts of gold and some low temperature sulphide minerals such as galena and arsenopyrite. This type of quartz vein is normally low in sulphide content, and the gold is only associated with minor amounts of sulphide minerals.

Gold-Base Metals Zone (Volcanic Exhalative)

The gold-base metals zone is located in the northern part of central Kelantan, from Sungai Senor/Gua Setir gold field to Ulu Sokor gold field and is less significant towards the south. However, the entire zone shows high anomalies of Au, Pb, Cu and Zn in stream sediments.

Gold-Silver-Mercury Zone (Hydrothermal Veins)

The gold-silver-mercury zone is located in the southern part of central Kelantan covering the catchment area of Sungai Galas from the confluence of Sungai Chiku/Sungai Galas to upstream Sungai Galas. The high mercury and silver content in this zone is probably due to basic intrusions that are located 700 m below surface. Geophysical result from Geological Survey of Malaysia (1982) indicated that the batholith is located 700 m underneath the Sungai Galas gold district. Rankama and Sahama (1950) reported that the mercury content in basic rocks is higher than in acid intrusives, as low as 0.064 g/ton in acidic intrusives to 0.1 g/ton in gabbro. Therefore, the heated magma that induces the mobilization of hydrothermal fluids is probably from basic rocks that released significant amounts of mercury and silver into the hydrothermal veins.

According to Rankama and Sahama (1950), the young volcanic sediments, particularly in connection with zones of tectonic movements, where hot springs are found in fracture zones, may contain mercury as readily soluble sulphides. The occurrence of plenty of hot springs in the Gua Musang area is a good indication that the gold-silver-mercury zone is located within the tectonic movement zone. Mercury is also obtained from some gold veins being carried partly as telluride and partly as gold amalgam.

The gold deposits that are present in this zone are mainly hydrothermal veins, including low sulphide and high sulphide quartz veins, quartz veins in sheared granitoid and structurally controlled quartz veins. Basically, the sulphide mineral content is low and localized.

Base Metals-Gold Zone (Massive Sulphides)

The delineation of this zone is mainly based on the geochemical result from Chu et al. (1980), Chu (1983) and Teoh et al. (1987), where the dominant anomalies are Pb, Cu and Zn with minor amounts of Au. This zone is located between the skarn zone and the gold-silver mercury zone in the southern part of Kelantan. The geochemical patterns are almost similar with gold-base metal zone, the only difference is the absence of gold anomaly.

Silver Lead Zinc Zone (Skarn and Massive Sulphides)

The silver-lead-zinc zone is located in the eastern side of central Kelantan, extending from Sungai Sok to Sungai Depak and Sungai Mangkok in southern Kelantan. This skarn zone only occurs on the eastern side of Kelantan, where it is formed by contact metamorphism with the Boundary Range Granite. However, no skarn deposits or contact metamorphic aureole are found on the

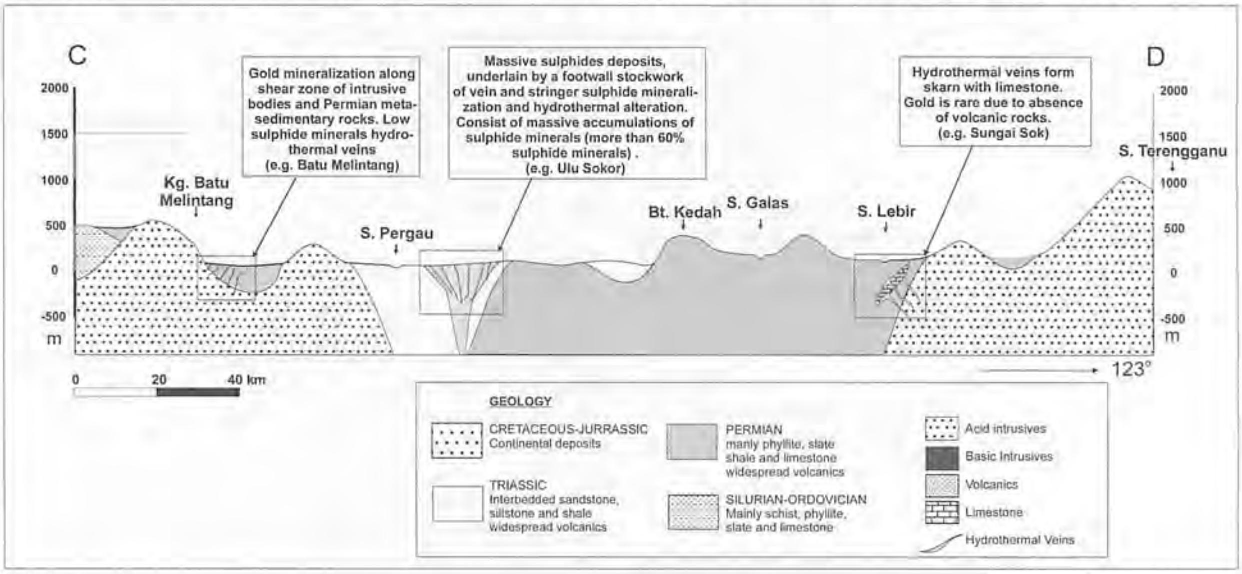

Figure 4: Gold mineralization model for cross section C-D, at northern Kelantan.

western granitoid such as Stong Complex Granite, Senting Granite as well as Kemahang Granite. Since limestone is present on both sides of central Kelantan, the absence of skarn deposits on the west is probably due to the relatively low pressure and low temperature of the intrusion.

CONCLUSION

The gold mineralization pattern in the state of Kelantan is well delineated in five zones. It basically varies from hydrothermal types on the west to massive sulphides types in the central and skarn type in the east. This trend is continuous further south to Pahang as well as Johor. A comprehensive study of these mineralization zones should be carried out in these states.

ACKNOWLEDGMENTS

The first author (Goh Swee Heng) is grateful to the University of Malaya for permission to use data from his Ph.D thesis for this paper. We wish to acknowledge Dr. Yeap Ee Beng, Mr. Mohd Rozi Umor and Mr. Osama Twaiq for their advice and support on this research.

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