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Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia

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1. Introduction

Malaysia had already established itself as one of the important gold producer long before the development of the great gold-fields such as in South Africa, Australia and USSR (Chu & Singh, 1986; Becher, 1983; Santokh Singh, 1977). Prior to the Portuguese conquest of Malacca in 1511, the country was known as the “Aurea Chesonese” or “Golden Peninsular”. Malaysia has a long history of widespread small-scale gold mining throughout the country, especially in the Central Belt of Peninsular Malaysia and highly potential region for gold mining industry.

The Central “Gold” Belt is a 20km wide, a major N-S trend of gold mining districts that shows the important role of hydrothermal fluids in the development of gold in Peninsular Malaysia, especially in the North Pahang and Kelantan area (Ariffin & Hewson, 2007; Yeap, 1993; Lee et al. 1986; Proctor, 1972; Richardson, 1939).

The majority of the gold production apparently came from the states of Pahang and Kelantan within the Central Belt (Fig. 1). A study of literatures covering the geology of the Central Belt goldfield shows the important role of hydrothermal fluids in the formation of gold deposits (Yeap, 1993; Lee et al. , 1982 , 1986; Alexander, 1949; Proctor, 1972; Richardson, 1939, 1950; Scrivenor, 1931, 1928, 1911). In Kelantan which is located in the north, gold mineralization typically associated with hydrothermal quartz vein system, skarn and volcanogenic massive sulphides (Teoh, et al., 1987; Chu & Singh, 1986; Chu, 1983). The regional geochemical survey for gold, carried out by Mineral and Geosciences Department of Malaysia over the Central Belt in North Pahang and Kelantan, has defined a 20-km-wide, north-south-trending gold mineralization in the Raub-Kuala Medang-Lipis-Merapoh area in Pahang, including Ulu Sokor-Sungai Sok-Katok Batu-Pulai in Kelantan (Figs 1 and 2). Gold mineralization in the Central Gold Belt is generally categorized as a low mesothermal lode gold deposit due to its tectonic and geological setting.

2. Gold mining history and prospects in Central Belt

During the British reign between 1880s and 1940s, major gold production generally came from the state of Pahang, Kelantan and Negeri Sembilan within Central Gold Belt .During this booming period Raub, Selinsing, Kechau-Tui, Katok Batu, Penjom and Batu Bersawah goldfields (Fig. 2) were the important underground lode gold mines. Between 1889 and 1960

some 30 tonnes of gold was mined from underground working from the historic Raub Australian Gold Mine (RAGM) and some 1100kg (over 1 million oz) of gold was extracted mainly from underground works at Bukit Koman, Raub goldfield (Richardson, 1939). As quoted from Free Press Mercantile news (F.M.S Gold Mining, 1903 in The Straits Times, 17 June 1904, Page 10) indicated that some 1,421 ounces of gold was extracted from 7,000 tons of treated tailing at Selinsing goldfield. Treatment of the tailings using heap leach extraction produced 6,624 oz of gold between 2003 and 2005. Whilst, the small Kechau-Tui goldfield where the gold is recovered from a shaft sunk to the depth of 30m which cutting the lode at this depth produced merely 48.5 oz from 1440 tons treated ore, whilst, Batu Bersawah gold mine, which is located at the southern part of the Central Belt, contributed some 180kg of gold between 1890 and 1910 through operation by the Batu Bersawah Gold Mining Company ore (The Straits Times, 5 May 1905 (page 6). In the last 15 years of active evaluation of gold mineralization and development activities at the former Raub Gold mine-Tersang-Tenggelan-Chenua belt have witnessed a few new modern and bigger scale; open pit gold mined have been developed. In Raub, Selinsing, Kerchau-Tui, Pulai, Rubber hill, Buffalo Reef, and Tersang are among the old alluvial mining goldfields which are actively being revisited for the existent of low grade bulk-mineable gold deposits. Most of these newly discovered goldfields are located in the heart of Central Gold Belt.

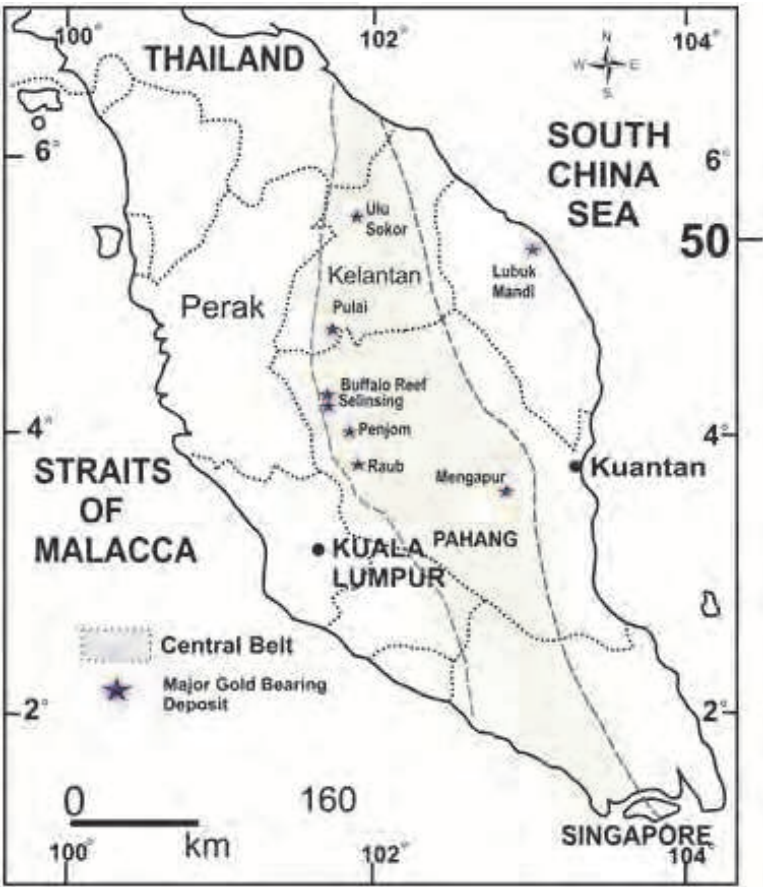


Fig. 1. Central mineral gold belt of Peninsular Malaysia with major gold bearing deposits.

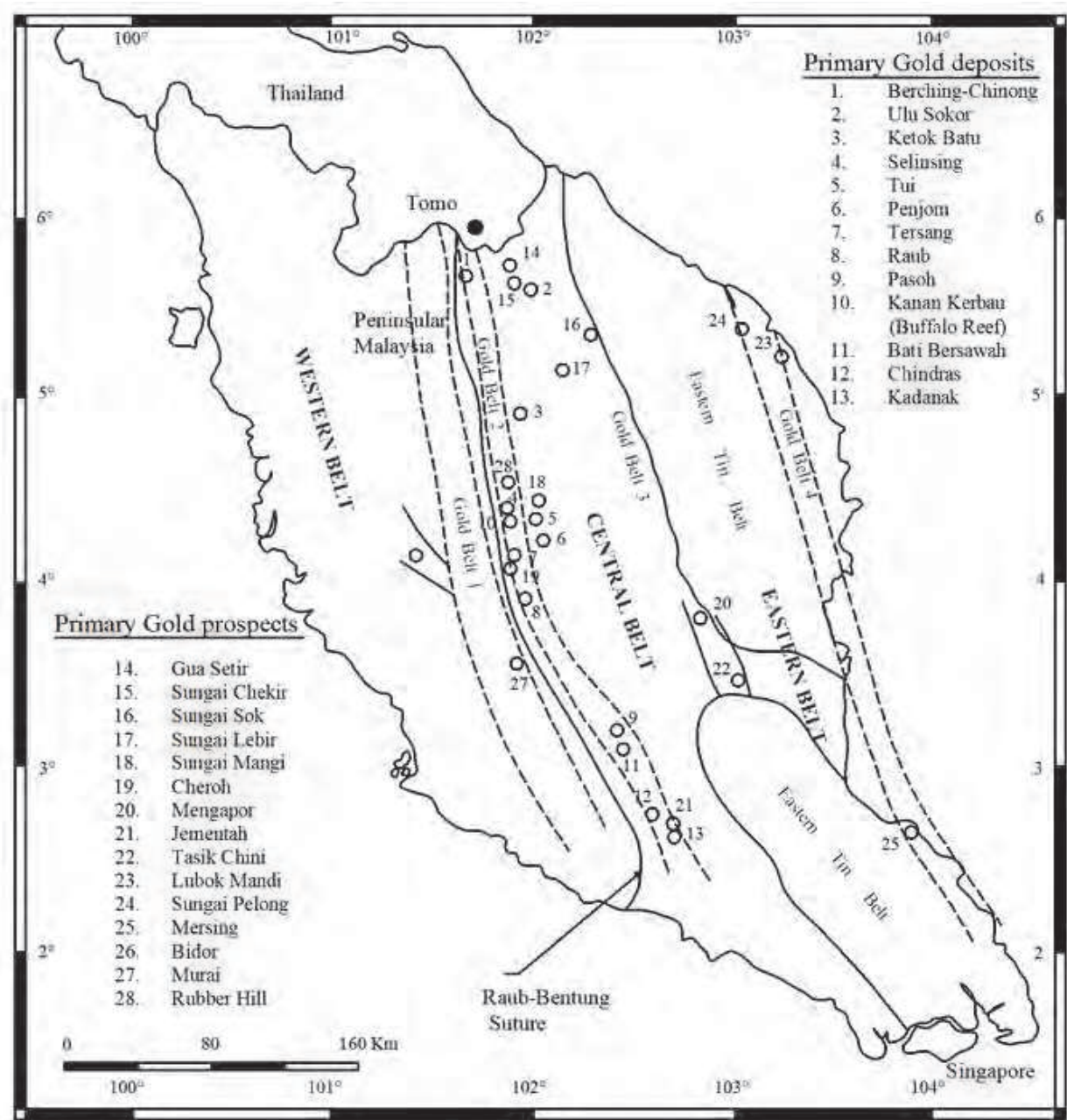


Fig. 2. Peninsular Malaysia showing mineral belts and primary gold occurrences (after Ariffin & Hewson, 2007 and Yeap, 1993)

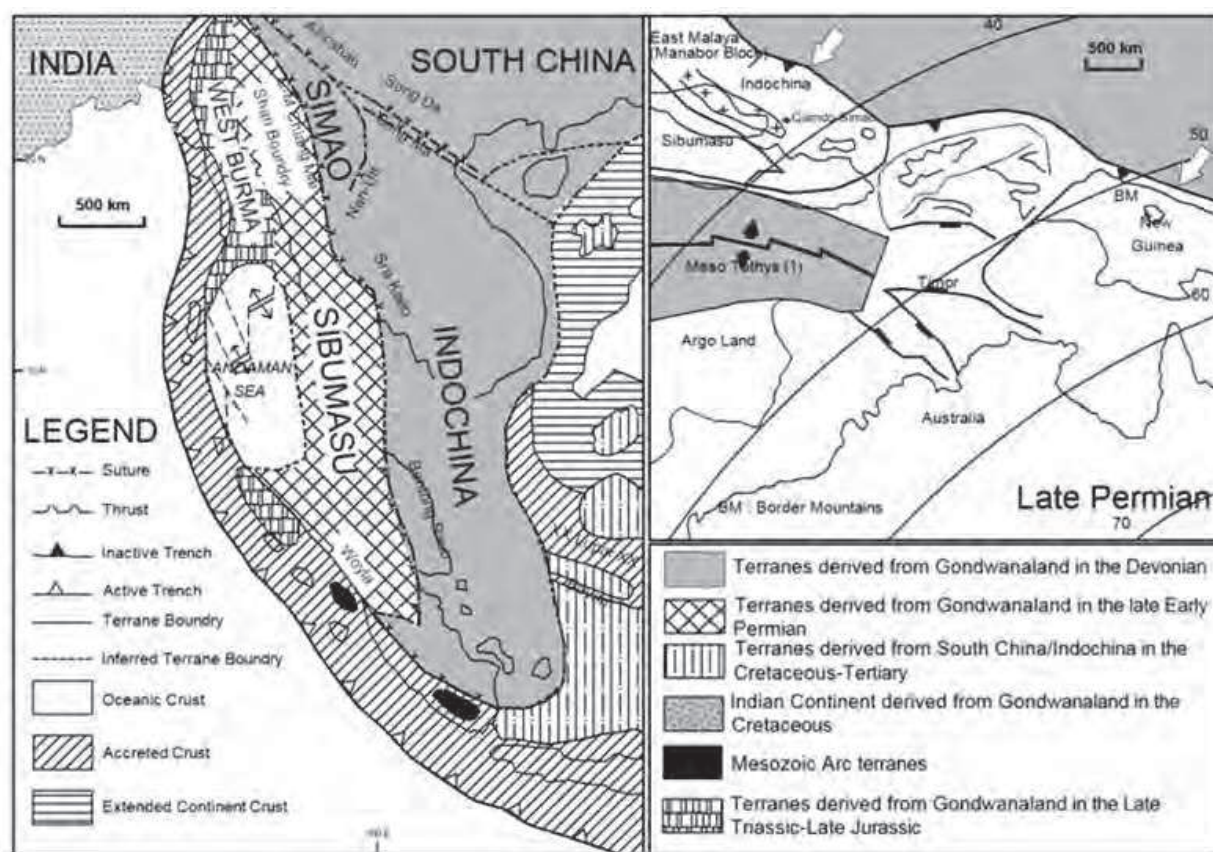


Fig. 3. Distribution of continental blocks, fragments, terranes and principle sutures of Southeast Asia, and palaeogeography during the Late Permian to show the position of Sibumasu (Shan-Thai), east Malaya/Indochina and Raub-Bentong Suture (modified after Metalfe, 2002).

Some 40 000 oz of gold were produced in Kelantan between 1906 and 1912 (Chu & Singh, 1986). In 1970-1980s, gold was produced for a short period from the now defunct Katok Batu, Panggong Lalat and Panggong Besar mines in Gua Musang area. Katok Batu is the only lode mine in Kelantan that produced 102 tahils or 4530gm (1 tahl = 37.8gm) of gold in 1934. In late 1903, Pahang and Negeri Sembilan produced 12 400 and 2 664 ounces of gold, respectively with the total amount of 15 070 ounces. Widespread alluvial gold occurrences have been long recognized in Pahang and Kelantan where there is a total in excess of one million ounces of gold has been recovered after this period. Over hundred prospecting permit/mining leases were issued for gold exploration in Pahang especially within Kuala Lipis-Raub districts to about 39 companies, mainly for alluvial gold mining mainly before 1990s.

Renewed interest in intensive exploration and mining for gold within the Central Belt has come into being since 1985 after the collapse of tin price. Its attraction lies in the good possibilities of finding the existence of a sizeable tonnage of low grade gold deposits, amenable to exploration by low cost, modern techniques of bulk mining (open-pit) with heap leaching and CIP/CIL (Carbon in Pulp/CIL Carbon in Leach) treatments. Many pre-world War II abandoned small scale alluvial and alluvial gold mining spots which were worked intermittently and have been targeted for re-evaluation since 1990.

The Penjom Gold Mine is the first, largest and the modern open pit gold mine that uses modern extraction methods and processing in Malaysia since its operation in 1996 (3.99 million tonnes, grading 3.78 g/t Au (484100 ounces of gold)) (Flindell, 2003).

Table 1 gives the Malaysia’s production of raw gold between 2006 and 2009, indicated over 90% of gold production is originated from Pahang (Penjom gold mine since 1996, Avocet Mining PLC), and recently from Selinsing gold mine (Monument Mining Limited), and Raub Gold Mine (Peninsular Gold Limited). Between this period, Pahang contributed over 12 million grams of gold, especially from Penjom and Selinsing open pit gold mine.

State	2006		2007		2008		2009	
	Grams	Mines	Grams	Mines	Grams	Mines	Grams	Mines
Pahang	3,415,446	6	2,832,489	6	2,449,961	4	2,771,770	6
Kelantan	78,189	3	80,151	5	37,159	3	49,844	4
Terengganu	-	-	-	-	2,876	3	32,553	2
Johor	3,606	1	-	-	-	-	-	-
Total	3,497,241	10	2,912,640	11	2,489,996	10	2,794,167	12

Table 1. Malaysia’s Production of Raw Gold 2006-2009
Source: Department of Mineral and Geoscience Malaysia, Mineral Year Book 2009

3. Tectonic setting

Peninsular Malaysia is a part of the east Eurasian Plate and tectonically located to the north of currently active subduction arc zones of the Sunda arc. Gold discovery distinctly in this region is always associated with Tertiary volcanic and hydrothermal activities, and appears to be very broadly related to tectonic boundaries in this region (Fig. 3).

The Malay Peninsular may be divided into two tectono-stratigraphic terranes which form part of the Sunda shelf, namely the East Malay (Eurasian plate-Indochina) and Sibumasu (Shan-Thai) terranes respectively. The Eurasian Terrane (Manabor block) has been interpreted as Permo-Triassic island arc system which never been far separated from Shan-Thai block. Stratigraphic, palaeontological and palaeomagnetic evidences suggest a possible origin of these terranes by the rifting of the north-east margin of the ancient Gondwanaland landmass in the Late Permian to Latey Triassic that responsible for the formation of the Central Belt and the Raub-Bentong Suture (Cocks et al., 2005; Metcalfe, 2002, 2000, 1988; Campi et al., 2002; Spiller and Metcalfe, 1995; Schwartz et al., 1995; Mitchell, 1977; Yeap, 1993; Tan, 1996, 1984; Tjia, 1989,1987; Khoo and Tan, 1983; Kobayashi and Toriyama, 1970).

Fig. 4 shows the conceptual cross-section that illustrating the formation of Central Belt to the east of Bentung Suture line as accretionary complex (Metcalf, 2000). Thus a thin and irregular strip of continental lithosphere and island arc sequence developed in front of it. These detachments later collided with the accreting Asian landmass and fused along the Raub-Bentong Suture. Peninsular Malaysia to the east of the suture belongs to Cathaysia.

A collision structure overprint has generated major N-S or NW-SW trending left slip fault and dilational Riedal and subsidiary shears and numerous splays associated with these fault (Hewson and Crips, 1992; Tjia and Zaitun, 1985). The Raub-Bentong Suture is a deep rooted 13km wide tectonic zone that runs generally in the N-S direction from Tomo in Thai Peninsular (Fig. 2) along the east side margin of the Main Range to the Malacca-Johore border (Cocks et al., 2005; Metcalfe, 2002, 2000, 1992, 1988; Yeap, 1993; Tan, 1996; Tjia, 1989). This N-S zone is located some 20km to the west of Penjom gold deposit and next to the Selinsing gold mine. This zone is characterized with the presence of schist, cherts with small

serpentine bodies, argillite, olistostrome and *mélange* (Metcalf, 2000; Tjia, 1987). It is also a zone of parallel steeply dipping N-S faults with several periods of reactivation. The “Gold belt” lies in the East Malay/Indochina Block (Fig. 4), subdivided into Eastern Belt and Central Belt.

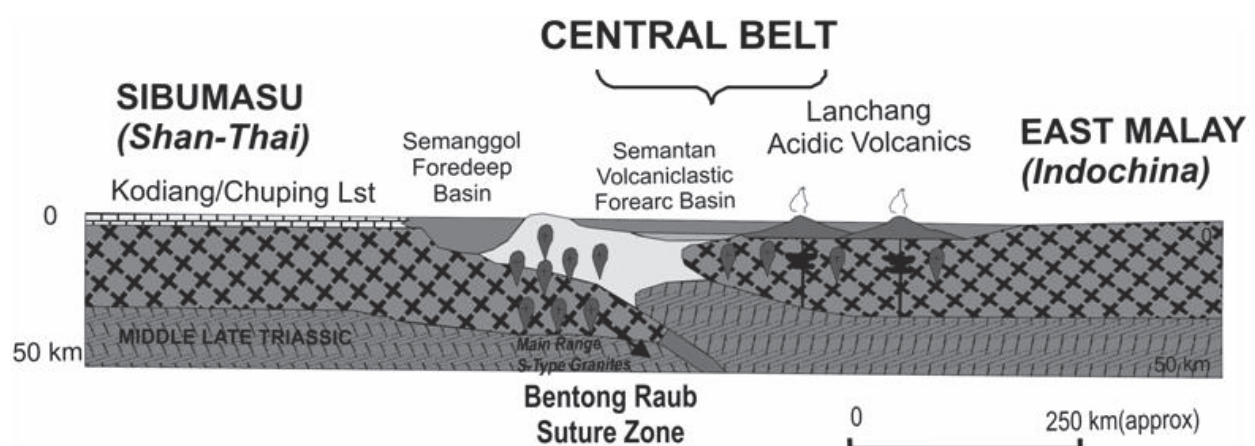


Fig. 4. Conceptual cross-section during Middle-Late Triassic illustrating the formation of Central Belt to the east of Bentung-Raub Suture line as accretionary complex modified after Metcalfe, 2000).

4. Regional geology

The Central Belt consists mainly of Permo-Triassic, a low-grade metasediments, deep to shallow marine clastic sediments and limestone with abundant intermediate to acid volcanics and volcanoclastics, deposited in paleo-arc basin (Metcalf, 2002; Leman, 1994; Richardson, 1939; Gobbet and Hutchison, 1973; Proctor, 1972).

Acid and intermediate intrusive rocks were emplaced east and parallel to Raub-Bentong Suture (Figs. 4 and 5). Batholiths in the Eastern Belt are smaller than those of Sibumasu, but are, in comparison, compositionally expanded. The Jurassic-Late Cretaceous batholiths, dominantly monzogranitic suite are of I-type affinity and carry both precious metal and base metal mineralizations.

Magmatism in the Central Belt is markedly less common and consists of an alkali series ranging from gabbro-diorite (157 Ma) monzonite (163 Ma) to quartz syenite (127 Ma), and a later calc-alkali series of granodiorites and granites (Yong et al., 2004; Mohd Rozi and Syed Sheikh Almashoor, 2000; Khoo and Tan, 1983; Jaafar Ahmad, 1979; Bignell and Snelling 1977; Hutchison, 1977). The Central Belt granitoids (slab break-off), which lie critically close to the Raub-Bentong Suture line have very high large ion lithophile (LIL) elements, that is, Ba and Sr, nearly to 1000 times rock/mantles and classified as mantle plume type magmatism (Azman et al., 2006; Mustafa Kamal and Azman, 2003). Fig 5 shows the general geology of the Central Belt along the major N-S trend goldfields in Kelantan and North Pahang. Seting granite, Stong igneous complex and Mahang Granite are the major granite intrusives in Kelantan. The Benom Plutonic Complex (Early Jurassic) which comprises Bukit Lima, Bukit Tujuh and Damar granite are the major shoshonitic granitoid in central Pahang (Fig 6), characterized by high K₂O content.

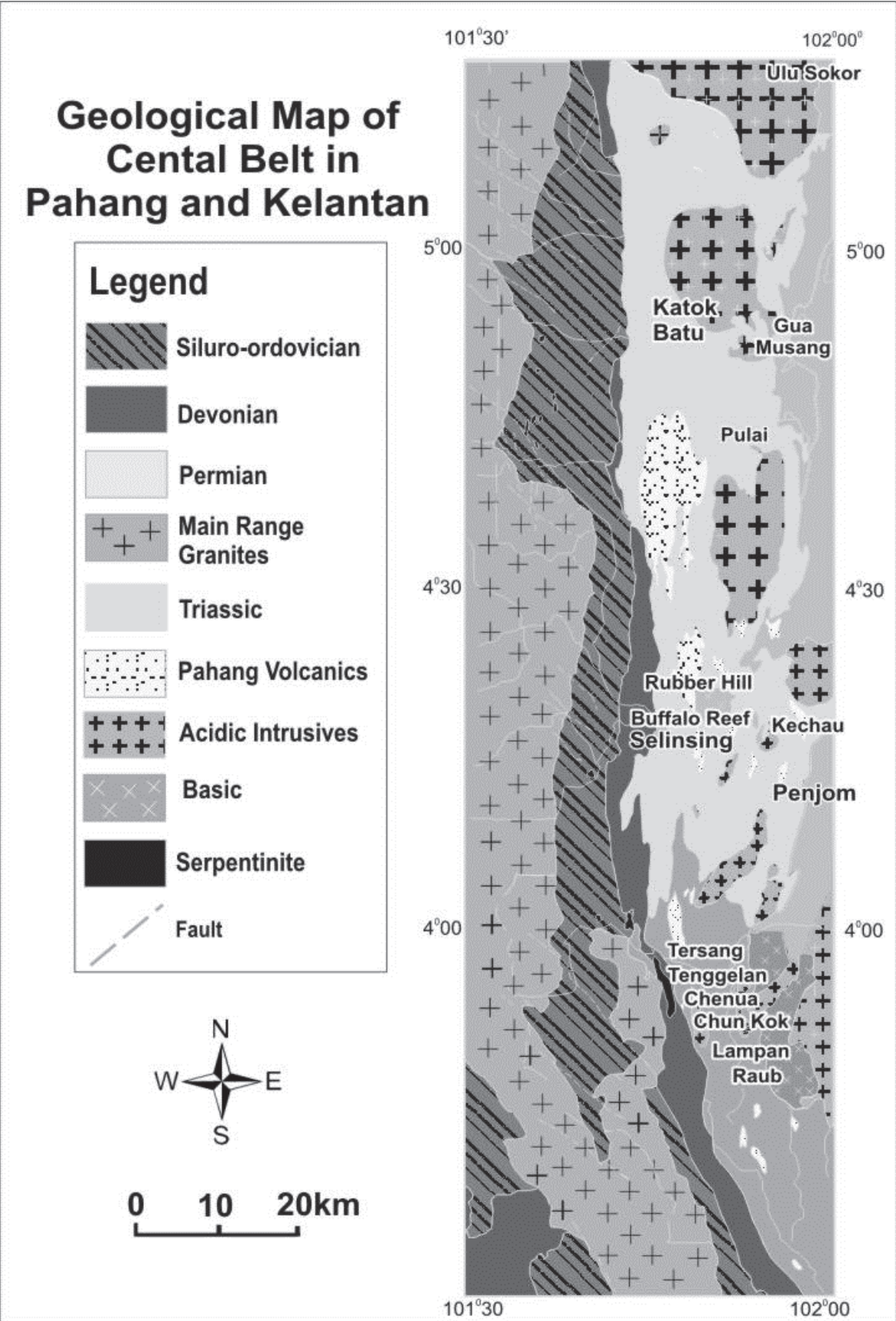


Fig. 5. Geological map of Central Belt in northern Pahang and South Kelantan

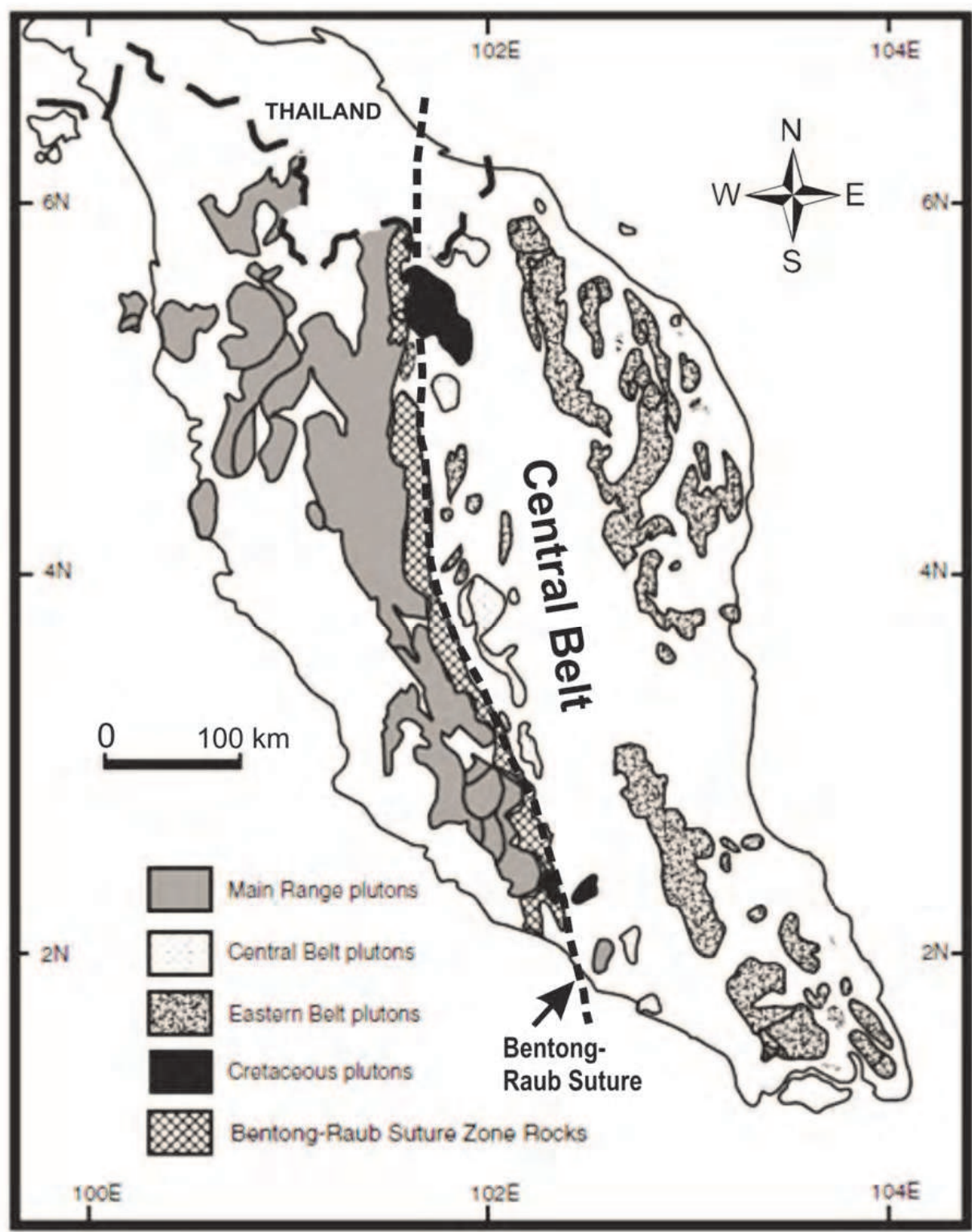


Fig. 6. Granitoids of Peninsular Malaysia shown in relation to the Bentong-Raub suture zone (modified after Metcalfe et al., 2000; Cobbing et al., 1992)

5. Gold mineralization in Central Belt

Mineralization in Central Belt is dominated by gold. Most of the gold is mined from quartz lode and stokwork deposits that are much associated with the accretionary prism along the terrain boundary known as the Raub-Bentong Suture. Mineralization took place within a low grade Permo-Triassic island arc system composed of meta-(sedimentary) and volcanic rocks accompanied by extensive deformation (brittle-ductile and shearing zone), metamorphism, and magmatic events that created the favorable environment for source and trap for the gold mineralization.

Most of the gold mineralization took place within a low-grade meta-sedimentary-volcanic terrain formed during the collision of the Sibumasu block underneath the East Malaya (Indochina) block through the Permian to late Triassic. Fig. 7 shows the typical representation of crustal environments of orogenic gold deposits in term of depth of formation and structural setting within attracted terrain that illustrated the resemblance to Central Belt gold formation (Groves et al., 1998).

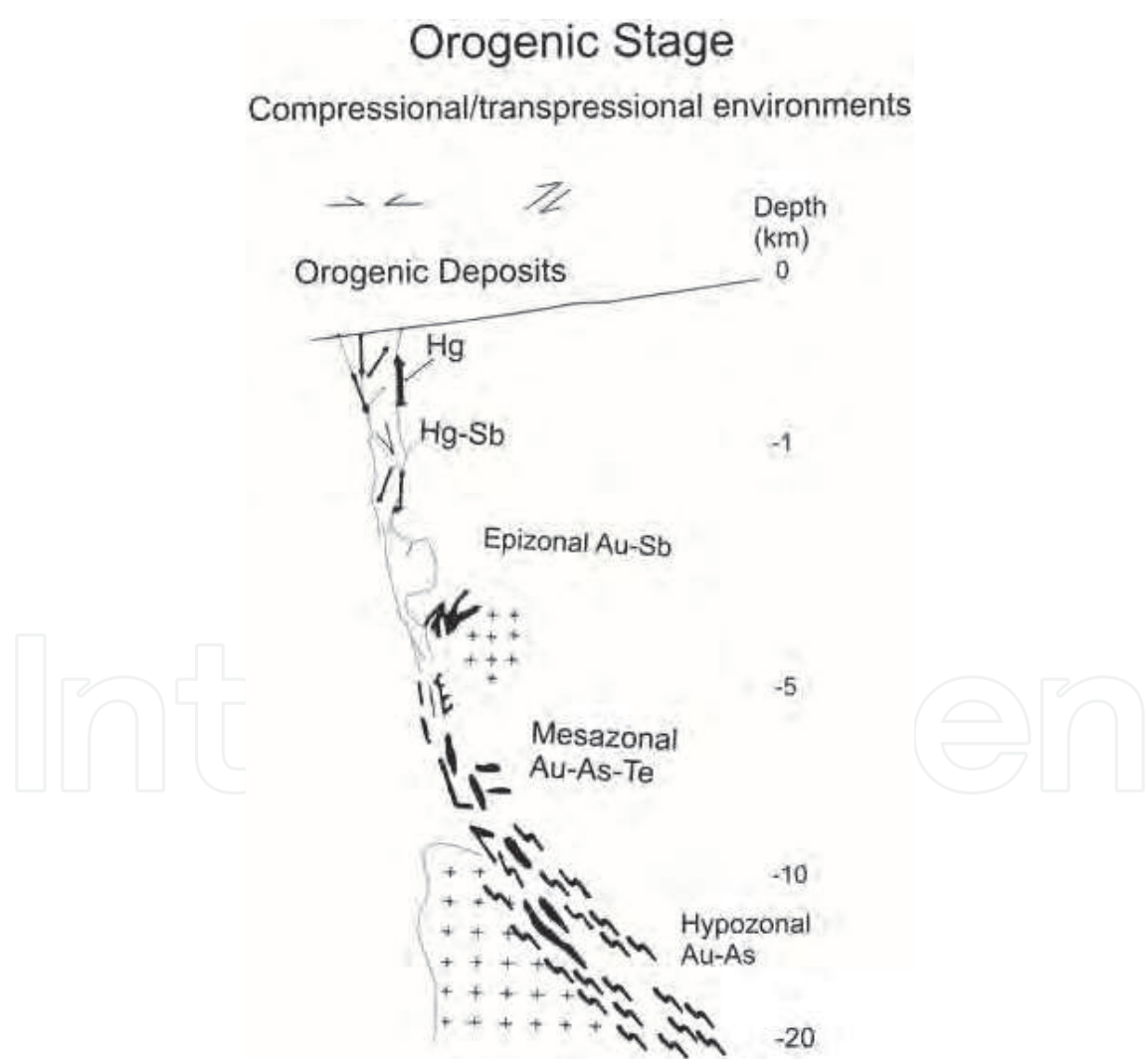


Fig. 7. Schematic representation of crustal environments of orogenic gold deposits in term of depth of formation and structural setting within accreted Terrance (modified after Groves et al., 1998)

Several mines being worked extensively were alluvial deposits developed on vein stockworks in altered, brecciated and sheared intrusive or adjacent country rocks (Scrivenor, 1911). Attraction lies on the good possibilities of the existence of sizeable tonnage of low-grade gold deposit. The old Raub gold mine lies within the western side of the Central Belt, whereas the Mengapur copper-gold porphyry skarn prospect on the north-eastern side (Figs. 1 and 2). Both deposits carry significant gold mineralization. Therefore, this Central Belt is well-known as “The Gold Belt”. As signified in Fig. 2, major primary gold mineralization patterns within Central Belt can be grouped into two types: type I (gold belt 2) and type II (gold belt 3), respectively.

The type I deposits consist of significantly large quartz reefs/lodes and parallel swarms of vein, traversing metasediments and granite. This type I mineralization belt is also identified as the gold geochemical zone (Lee et al., 1986, 1982). The mineralization is confined within brittle – ductile shear or brecciated zones. This gold belt is located immediately to the east of the Main Range granite and Raub – Bentong line (Yeap, 1993). Two major goldfields within the type I belt are the Buffalo reef (Kanan Kerbau) and further south, the Selinsing gold mine and the Tersang alluvial goldfields. Enhanced level and occurrences of stibnite and scheelite are common characteristics of the Buffalo reef, Selinsing and Raub goldfields, whereas ilmenite and cassiterite occurrence is considerable at the Tersang goldfield (Kamar Shah & Khairun Azizi, 1995; Pereira, 1993; Pereira et al., 1993).

However, elevated As and Sb are considered a common trend of these goldfields. Type II, which is located immediately to the east of the type I deposits, exhibits a broader variety of gold mineralization, bounded to gold disseminated within a stockwork of quartz veins affiliated with intrusive bodies and volcanogenic exhalative sulphides within a shear zone system. Dilated quartz veins and Au-Ag-bearing skarn carry significant amount of sulfides (Sinjeng, 1993). The type II belt is also designated as the silver zone (Lee et al., 1986). Ulu Sokor goldfield which is located in Gold belt 3 was geochemically delineated as Gold-base metals mineralization zone (Teoh, 1987; Goh et al., 2006). Table 2 presents common elemental or geochemical composition of common epizonal (Au-Sb) and Mesazonal (Au-As-Te) types of orogenic gold formation in the Central Gold Belt from Rubber hill prospects, Buffalo Reef, Tersang goldfield and Raub gold mine (Bukit Koman).

Sample no	Unit	K001	K002	K003	K004	K005	K006	K007	K008	K009	K010	K011	K012
Location	Rubber Hill - Trenching samples					Bufflao Reef	Selinsing Quartz vein	Buffalo Reef	Bufflao Reef	L.S Chong Pulai, Tersang	Bkt. Koman Quartz	Buffalo Reef Breccia	Rubber Hill
Description		(Red-Brown)	(Yellow-Brown)	(Yellow-Brown)	(Red-Brown)	(Brown-Yelow)	(Redish-Yellow)	(Dark Black)	(Grey)	(Greyish-Brown)	Shale (Grey)	(Brown-Yelow)	(Gold-Bearing)
Element													
Gold (Au)	ppm	0.01	0.11	0.01	0.07	145	0.07	4.44	0.11	0.03	1.18	2.5	363
Silver (Ag)	ppm	—	—	—	—	6	—	5.5	2	—	4	2	57
Antimony (Sb)	ppm	—	10	—	—	—	30	—	—	—	—	—	6
Antimony (Sb) % (w/w)		—	—	—	—	—	—	10	0.13	—	—	—	—
Lead (Pb)	ppm	—	27	—	—	—	—	—	—	10	—	—	150
Zinc (Zn)	ppm	—	180	—	—	—	—	—	—	2	—	—	29
Copper (Cu)	ppm	—	64	—	—	—	—	—	—	14	—	—	16
Arsenic (As)	ppm	—	570	—	—	—	—	—	—	—	—	—	425
Note : Soil and quartz vein samples from severals deposit/prospects													

Table 2. Geochemical composition of selected grab and trenching samples represent gold deposits and prospects from Northern Pahang.

Gold belt 4 (Lubok Mandi-Mersing Belt) is located in the eastern part of Peninsular Malaysia and it is juxtaposed with the Eastern Tin Belt. The Lubok Mandi gold deposit is an 8-km gold-quartz lode hosted in weakly metamorphosed and folded slate, phyllite and meta-

arenites. In the Mersing area the primary gold mineralization was observed as several discontinuous, approximately 350° striking, gold-quartz veins cutting strongly folded meta-argillites and arenites (Yeap, 1993).

6. Major goldfields, mines and prospect in Central Belt

Pahang and Kelantan were the first promulgated to be attractive and favorable economically for attracting foreign investment for systematic gold exploration in the states by the granting of prospecting licenses of designated concession blocks and consequently mining leases for systematic and modern techniques of gold ventures. The total production of gold bullion from Pahang for the period 1889 to 1985 is reported to be at least 36 tonnes. At present, 88% of the total production in Peninsular Malaysia is from Pahang state.

Penjom, Raub, Selising and Buffalo reef are the currently active gold mines in Pahang. At present, the Penjom Gold Mine is the highest production of gold in Malaysia with concentration about 6.0g/ton in Central Belt. The Penjom gold deposit lies within the western margin of Central Belt (Gold belt 3). Other less important gold bearing deposits are Mengapur, Tersang, Rubber Hill (Pahang) and Batu Bersawah in Negeri Sembilan. Ulu Sokor and Pulau are the only active gold mining and exploration projects in Kelantan, and mostly restricted to alluvial deposit.

6.1 Penjom gold mine

The geology of the Penjom gold deposit is dominated with widespread occurrences of marine clastic sediments, intermediate to acid volcanics, and subordinate rhyolitic lava sequences. Its is belongs to so-called Padang Tengku Formation of the , a Raub-group rock assemblage and the Pahang Volcanic series. This volcanoclastic and sedimentary association is intruded by a few shallow dipping sheets of tonalite unit as narrow sills and minor dykes of quartz porphyries and running almost parallel to the main mineralized shear zone. Tonalite is a major igneous intrusion complex within the area. The Raub-Bentong Suture has accommodated considerable strike-slip movement (Fig. 8). Structural analysis has indicated a regular geometrical pattern of repeated district scale fault trends (Kelau fault) which can be observed within most the goldfields in the Central Belt (Tjia & Zaitun, 1985).

Mineralization at the Penjom gold deposit is structurally controlled and erratic laterally and vertically. The Penjom thrust is the dominant feature controlling the distribution of ore at Penjom and generally strikes NE (35°) and dips to the southeast (30°-40°). Considerable shear stresses along the Penjom thrust have remobilized much of the carbon within the shale sequence to form a graphitic “alteration” zone. This, together with sheared and milled rock (fault gouge materials), makes the Penjom thrust an impermeable zone (Ariffin & Hewson, 2007; Flindell, 2005; Mustaffa Kamal, et al., 2003; Sonny et al., 2001; Kidd, 1998; Kamar Shah, 1995; Kamar Shah et al., 1995; Hewson & Crips, 1992). Major gold mineralization took place within the footwall of this thrust (Figs. 9 & 10).

Both the veining and massive ores can be subdivided on the basis of their mineral constitution into (1) gold-galena-tetrahedrite-tellurides (especially altaite) ore, (2) gold-arsenopyrite-pyrite ore, and (3) pyrite. At Penjom, the ore systems display permeability controlled or governed by lithology, structure and breccias and changes in wall rock alteration (quartz, carbonate, sericite, chlorite, fuchsite and clay). Gold mineralization was believed to form at the homogenization temperature higher than 270°C of hydrothermal fluid which is typical for mesothermal vein deposits (Ariffin & Hewson, 2007; Wan Fuad and Heru Sigit, 2003, 2001; Kamar Shah, 1995; Herrington, 1992).

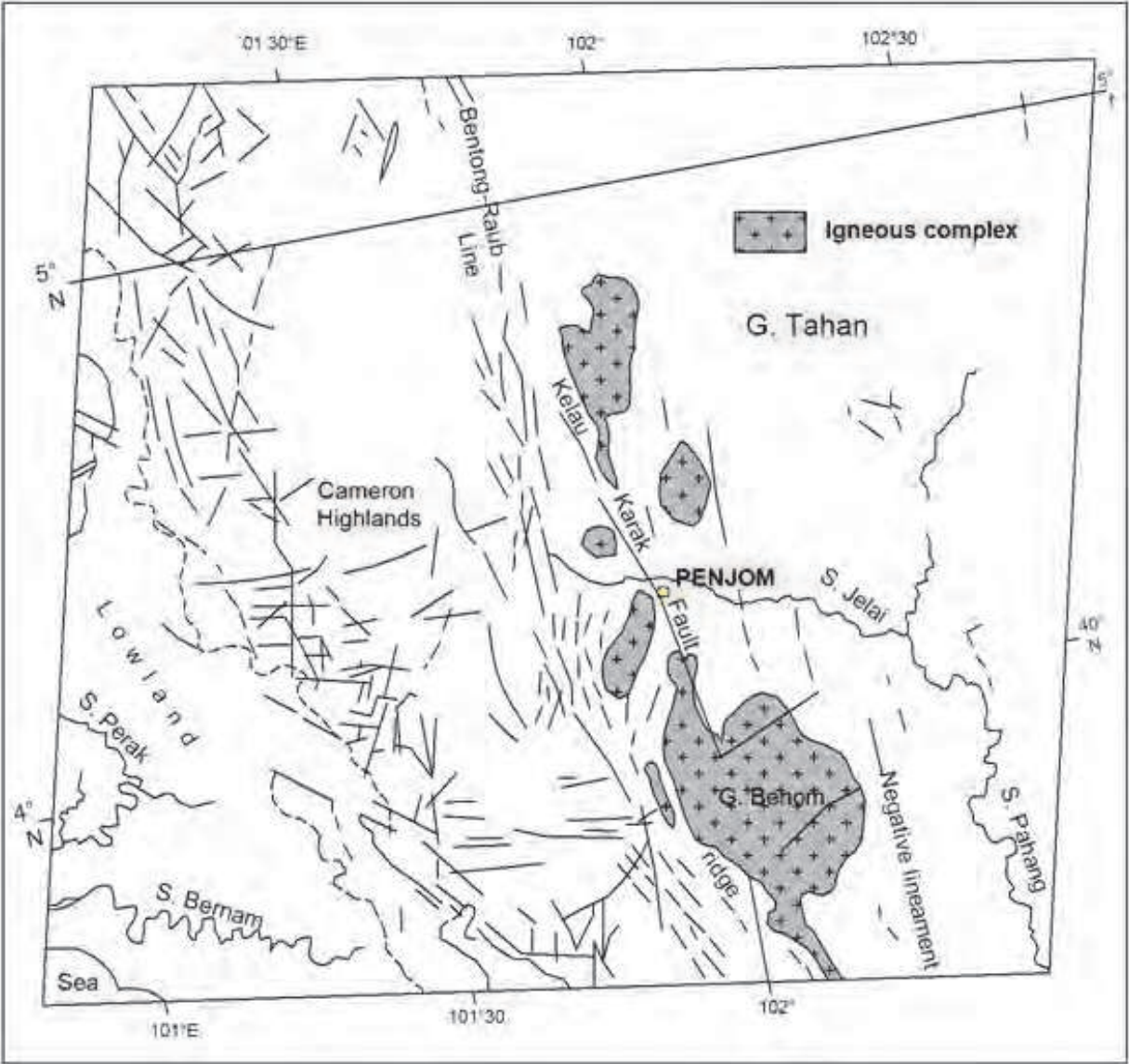


Fig. 8. Regular geometrical pattern of repeated district scale fault trends and numerous splays running along the Central Gold Belt with major granitoid emplacement (after Tjia and Zaitun, 1985).

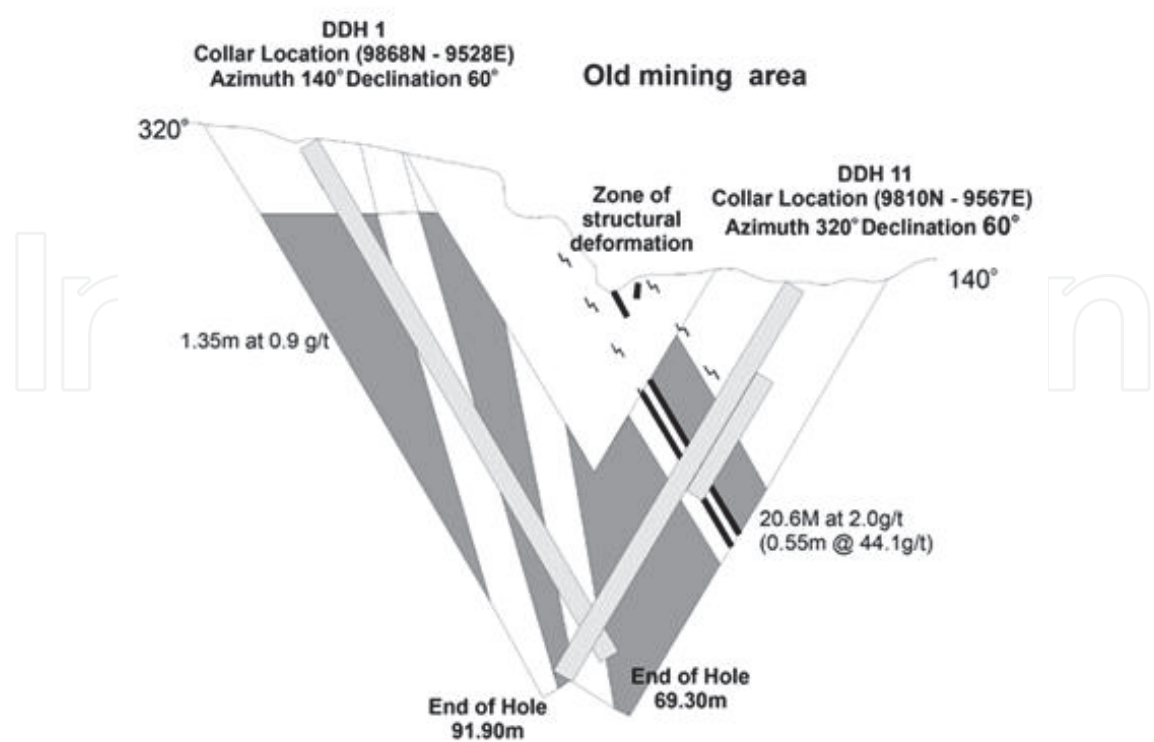


Fig. 9. An example of exploratory drillholes (DDH 1 and DDH 11) that cut the significant mineralization section within the Penjom trust (shear zone) (Kamar Shah, 2007)

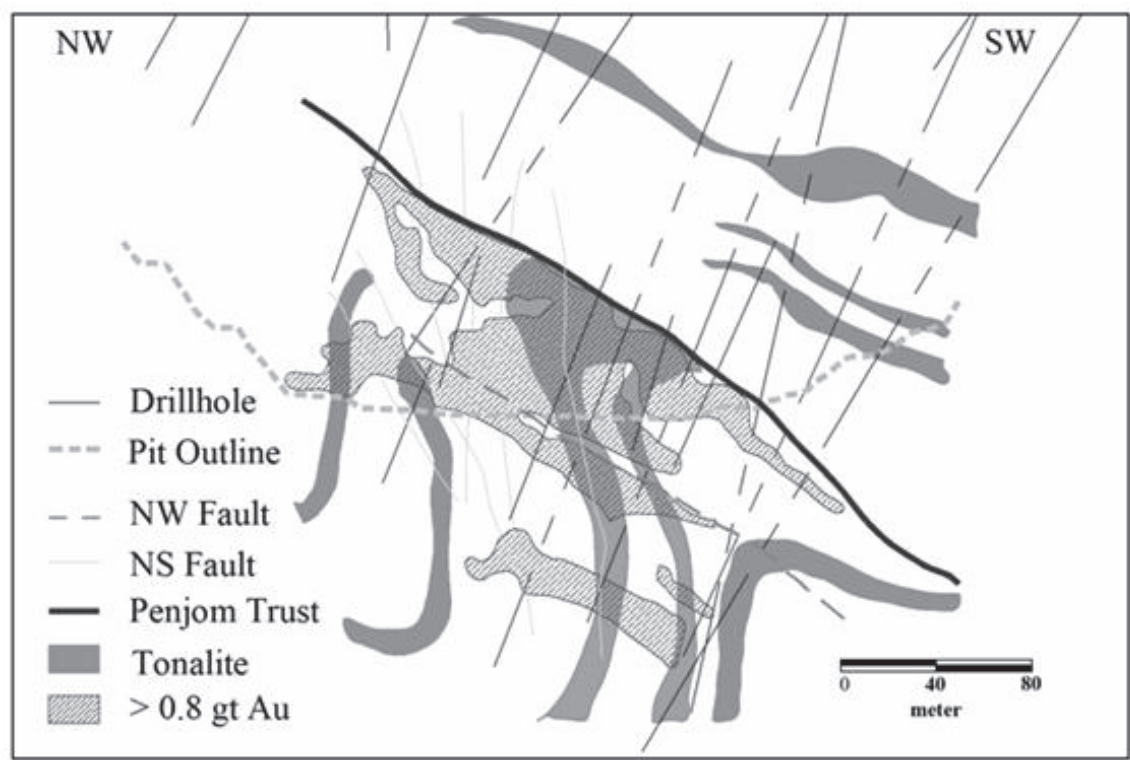


Fig. 10. Cross-section across the Penjom ore body running through the centre of the main deposit (Ariffin & Hewson, 2007; Flindell, 2003).

Multi-elemental distribution patterns with respect to the depth, litho-geochemistry and structural features of the Penjom gold deposit such as from DDH-3 and DDH-11 (Fig. 9) show that most of the gold-rich samples are proportionally elevated in arsenic. Ag, As, Te, Sb, and Bi except Hg as shown in DDH-3 (Table 3 and Fig. 11) and DDH-11(Fig. 11 bottom) are most elevated in segments associated with sulphide-gold mineralization. Gold has a marked affinity for Te and Bi and less for Sb. Two of the analyzed mineralized samples hosted within tuff of DDH-11, which are characterized by fault gouge materials have shown compelling occurrence of As (80 000 ppm), Au (18 - 47 ppm), Ag (4-8 ppm) and Te (8.5 ppm). Based on the elemental relationships, the Penjom gold deposit can be classified as an Au-Cu-Ag-Pb deposit.

Site No	Field description	BH No	Top Depth	Bottom Depth	Au	Ni	Co	Ag	Mo	Cu	Pb	Zn	Fe	Mn	As	Sn	W	Hg	Sb	Bi	Ba	Cr	Se	Te
1127	tuff	3	43.00	43.10	0.001	14	8	0.10	3.4	27	3	63	3.4	290	5.0	5	2.0	0.02	1	6	101	24		
1128	agglom, siderite alteration	3	45.00	45.30	0.001	11	13	0.20	3.4	24	5	54	3.8	1560	10.0	5	2.0	0.02	1	4	173	24	0.1	0.5
1129	agglom, siderite alteration	3	52.00	52.35	0.001	15	26	0.20	3.2	31	4	134	8.1	5480	15.0	5	2.0	0.02	2	5	352	24	0.1	0.7
1130	agglom, siderite alteration	3	54.40	54.50	0.001	15	21	0.30	2.8	10	5	121	7.9	5040	15.0	5	2.0	0.02	1	6	261	25		
1131	tuff, foliated	3	58.85	59.25	0.001	16	14	0.05	2.0	10	2	58	3.5	362	25.0	5	8.0	0.02	1	4	109	19		
1132	agglom, rubble with q.vein	3	67.00	67.50	57.463	22	31	34.00	14.2	300	185	136	13.0	1910	10.0	5	16.0	0.08	2	25	149	49	0.5	2.9
1121	tuff	3	91.65	92.20	0.001	2	4	0.05	2.9	5	11	51	1.7	584	3.0	5	2.0	0.06	1	7	561	33	0.1	0.3
1122	silic/cherty zone within tuff	3	103.00	103.40	0.008	6	2	0.10	4.8	20	14	21	0.9	361	15.0	5	2.0	0.02	1	5	197	83	0.1	0.1
1123	tuff with 1% euhedral pyrite	3	105.60	105.85	0.007	6	5	0.05	3.9	17	9	59	1.5	1580	10.0	5	2.0	0.02	5	4	668	35		
1124	calc, tuff, banded	3	106.60	106.80	0.048	6	6	0.20	2.9	9	13	40	1.9	1390	25.0	5	24.0	0.02	7	4	358	22	0.1	0.7
1125	tuff, silica	3	108.00	108.15	1.378	7	3	1.00	3.4	64	36	45	1.5	650	20.0	5	2.0	0.02	6	7	182	50	0.2	0.3
1126	tuff, silica	3	109.80	110.10	0.003	2	2	0.30	3.7	11	6	36	1.5	652	5.0	5	2.0	0.02	1	4	97	21	0.1	0.2

Table 3. Results of multi-element analyses data from DDH 3 of Penjom gold deposit from the early exploration stage (1990-1992; after Kamar Shah, 1995)

Ores from the Penjom deposit can be broadly divided into four groups, namely vein, dissemination, massive and fragmental. Sulphide minerals mainly arsenopyrite and pyrite are dominant constituents embedded in quartz-carbonate veins. There are widespread occurrences of pyrite, arsenopyrite, sphalerite, galena, chalcopyrite, molybdenite, tetrahedrite and tellurides (Fig. 12). The gangue minerals are commonly associated with gold mineralization include quartz, feldspars, carbonates (calcite, ankerite, dolomite, siderite and minrecordite), epidote, manganite, graphite and muscovite (sericite), talc, chlorites, fuchsite, goethite, limonite, fluorite, carbonaceous matter, pyrolusite and kaolinite. They basically coincide with the formation of polymetallic gold-silver ore that is transitional to higher crustal level carbonate-base metal class.

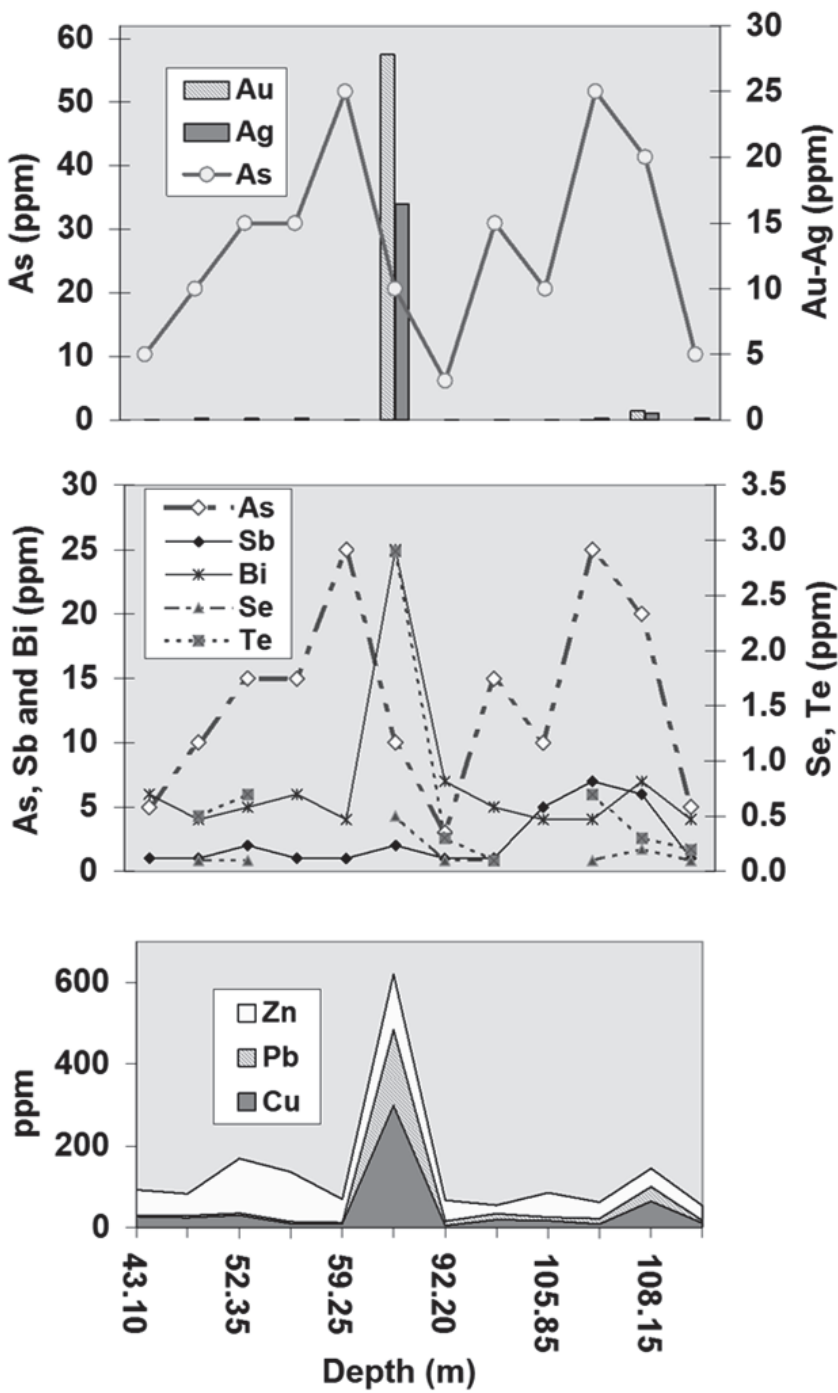
6.2 Selinsing goldfield

This is an active goldfield located in NW Pahang, Peninsular Malaysia. Mining at Selinsing commenced prior to 1888 and has operated intermittently through to 1966 (Johnston, 1998). Underground and open cut mining, together with tailings treatment, has produced an estimated 85,000 ounces of gold during this period.

Lithology of the area consists of low-grade metamorphosed sedimentary and volcanic rocks of Gua Musang Formation of Late Permo-Triassic age (Figures 5 & 13). Wall rock alteration in Selinsing Gold mine shows a direct relation with hydrothermal solution, structures, formation of quartz veins and gold mineralization.

The Selinsing deposit occurs along the north striking Raub Bentong Suture. The deposit is hosted by a series of auriferous quartz veins and stockworks of quartz veinlets in a package of sheared calcareous epiclastic sediments. The gold mineralisation occurs in quartz veins

that cut the host rocks and wall rocks with intensive alteration that are related to the N-S and NE-SW lateral faults and shear zones (Mohd Basril et al., 2009). Gold mineralization at Selinsing is associated with high grade quartz veining and accompanied by strong sericitization and silicification within a major shear zone. Formations of quartz veins are mainly related to the right lateral faults. Minerals often associated with gold mineralization are pyrite, arsenopyrite, chalcopyrite, tetrahedrite and sphalerite (Wan Fuad et al., 2008; Ariffin & Hewson, 2007; Pereira, 1993; Pereira, et al., 1993).



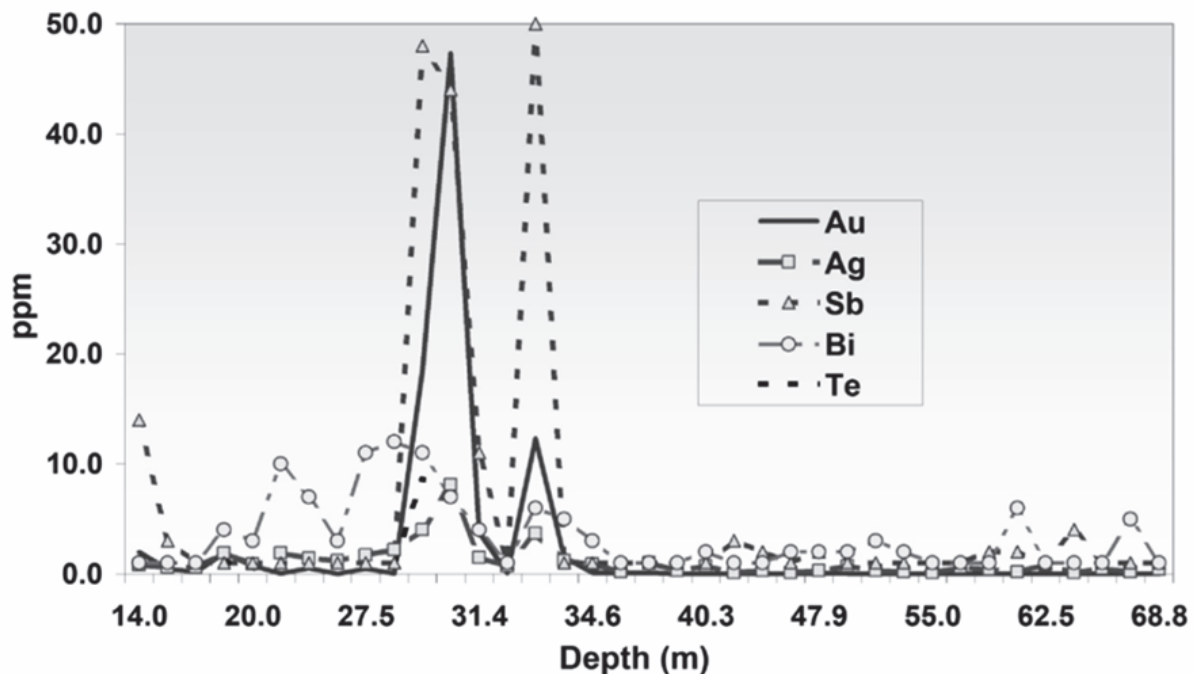


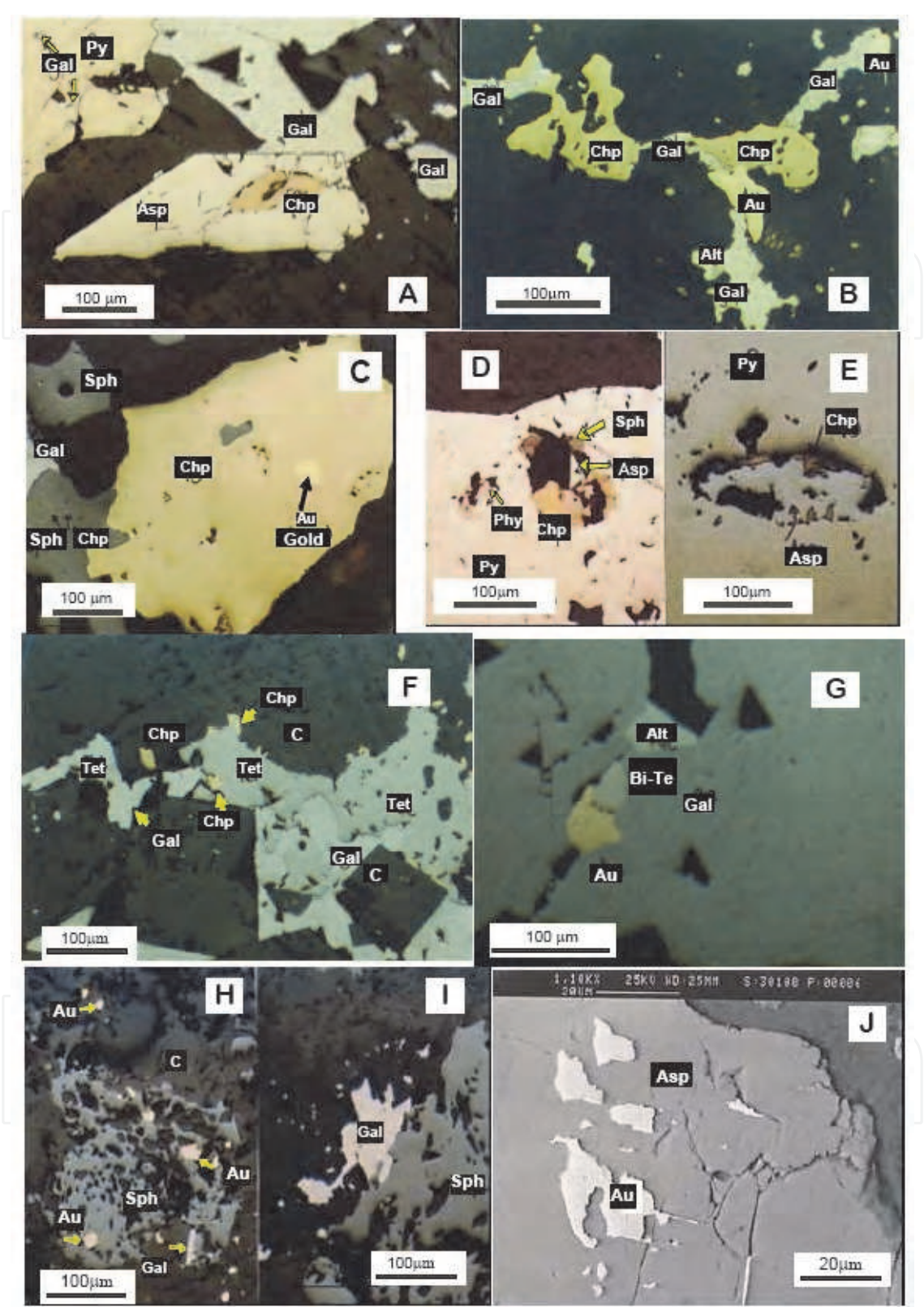
Fig. 11. Multi-elemental distribution patterns against the depth of the Penjom gold mineralization rock formation from DDH-3 and DDH-11 (after Ariffin & Hewson, 2007 and Kamar Shah, 2007).

Brecciation and cataclasite within shear zone are very prominent and show sensible relationship with mineralization. The host rocks of the deposit consist of a series of argillaceous and arenaceous of likely epiclastic origin, which have undergone low temperature regional metamorphism. This metamorphism has had little effect on their original mineralogy or texture. The ore samples show epigenetic gold and sulphide mineralisation in quartz veins with no direct relationship to the sediments hosting the quartz veins.

6.3 Buffalo Reef

The Buffalo Reef prospect lies close to the eastern flank of the Raub-Bentong Suture and main range granitic intrusions which also share the similar structural styles with Selinsing gold mine that located just to the north (Fig. 13). Gold mineralization is hosted by widespread occurrence of low regional grade metamorphism (greenschist to locally amphibolite facies) of marine clastic sediment, consist chiefly of pale to dark grey phyllitic carbonaceous and calcareous shale, lesser amounts of tuffaceous rocks, limestone and fine-grained schistose sandstone of Permian and subordinate of Devonian conglomerate. The conglomerate unit is belonging to Bentong group, whilst the Permian sedimentary rock formation is to the Raub Groups, respectively.

Gold mineralization is mainly confined to the marine clastic rock sequence, which is generally striking in N-NW direction and dipping towards east between 65° and 70° (Kamar Shah et al., 1995; Pereira, 1993). Some irregular and fractured quartz-carbonate veining also occurs throughout. Quartz veins are found mostly parallel to the bedding. The most significant feature with respect to gold mineralization is N-S aligned shear zone in the Raub Group. Significant gold mineralization often confined to the N-S trending sheared zone composed of metamorphosed, brecciated and hydrothermally altered calcareous graphitic shale with minor interbedded fine-grained sandstone and tuffaceous rocks.



(a) Chalcopyrite (Chp) is seen occupying a pit in subhedral arsenopyrite (Asp). Galena (Gal) is seen occupying tiny pits in pyrite (Py) and replacing both sulfides, (b) Carbonate matrix of quartz – carbonate vein shows fractures infilled by chalcopyrite (Chp), while altaite (Alt) and galena (Gal) are intergrown, replacing chalcopyrite (Chp) with the occurrences of tiny electrum,

(c) Chalcopyrite (Chp) is being replaced by sphalerite (Sph), which in turn is replaced by galena (Gal). An inclusion of submicroscopic gold (15 μm) embedded in chalcopyrite is also visible, (d,e) Arsenopyrite (Asp), chalcopyrite (Chp), sphalerite (Sph) and pyrrhotite (Phy) occupying fractures and pits in pyrite, (f) Jagged tetrahedrite (Tet), which is being replaced by galena (Gal), and chalcopyrite (Chp) occupied the interstices in the calcite (C) of quartz – carbonate vein, (g) Electrum (Au) is seen associated with light brownish grey bismuth – telluride BiTe(Pb)- tetradymite and altaite(Alt) enclosed in massive galena (Gal), (h) Sphalerite intergrown with galena and gold blebs locally within the quartz – carbonate vein (C-calcite), (i) irregular shaped sphalerite (Sph) intergrown with (Gal), and (j) Back-scattered electron image shows gold (Au) infilling the interstitial spaces and fractures of arsenopyrite (Asp).

Fig. 12. Photomicrographs of ore minerals in the Penjom deposit (after Ariffin & Hewson, 2007).

From north to the south of the prospects, in the north section, the gold mineralization are characterized by structurally bounded of steeply dipping quartz lode within complex dilated and silicified zone with dimension of 100m wide and 360m long. Two main NW Redial shear structures that composed of 40m wide x 300m long quartz lode and another narrower 500m long, east dipping extension lode in the central section. In the south, shear-parallel lode structure with 550m long and 70m wide are the main mineralization features of the area that is open to the south (Snowden, 2008; Pereira, 1993).

6.4 Raub gold deposit

The Raub deposit lies along the same Raub-Bentong suture 50 km south of Selinsing and Buffalo Reef goldfields. Raub Gold mine (RAGM) which is located within Bukit Koman vicinity comprises mainly interbedded sedimentary and metasedimentary rock strata flanked by the Kajang's granite porphyry of Triassic age which is exposed 5.5 km to the west of the mine. The sedimentary formation consist mainly of interbedded carbonaceous, silicified or calcareous types of grey to black shales, limestone, marble, and tuff which have experienced low grade metamorphism and belong to Raub Group of carbonaceous age (Gunn et al, 1993; Richardson, 1939). The shale is almost pyritic throughout and generally striking northwards and mainly steeply dipping eastwards. The rock often isoclinally folded, with compression, tension and oblique faults. Hard and occasionally jointed quartzite is the major metasedimentary rock that occupies an N-S orientation hill.

The Raub mine has been the site of extensive historic gold mining, as well as limited modern operations and currently hosts a proven reserve of 202,000 ounces in 8.6 million tonnes of tailings (Snowden, 2008; Howe, 2004). Between 1889 and 1961 approximately 400kg which accounted for 85% of gold annual output in Pahang was from Raub, until recently some 32 tonnes (1Moz) at grade 4.2g/t of gold have been mined. The Raub gold deposit is hosted in a 6 km long vertical mesothermal quartz-carbonate veins system. Recent investigation, In addition a further 218,000 ounces of gold has been identified to date in an area known as the East Lode oxides, comprising 136,000 ounces in the measured and indicated categories and 82,000 ounces inferred (per the JORC standard). The target is delineated to contain over 1 million ounces of gold resources. Lampan is another adjacent prospect located to the NW of Raub gold mine.

Gold mineralization is mainly discovered occupying the two 300m apart of N-S trending fault zones. Gold ores mostly extracted from steeply-inclined faulted and folded zone and

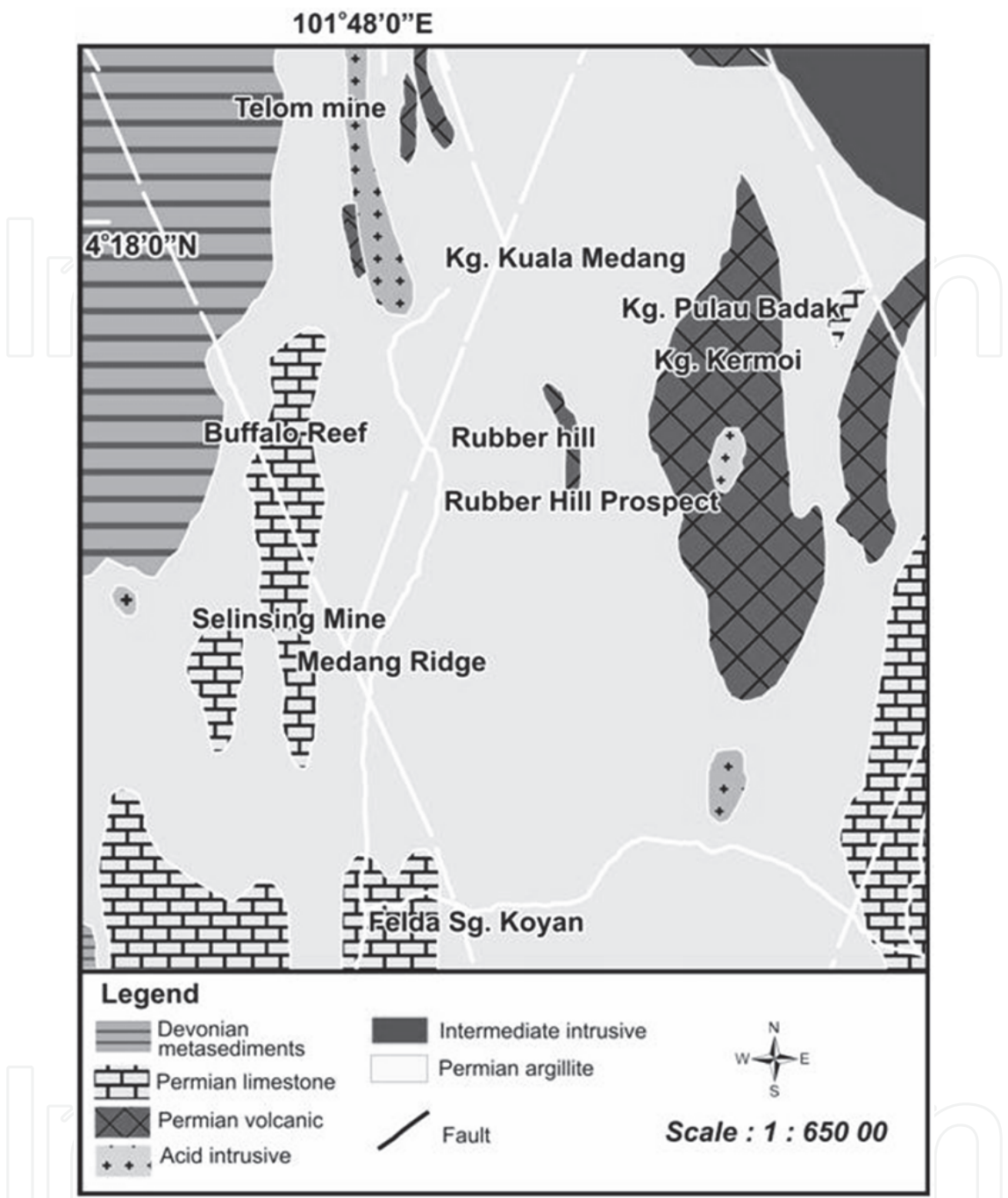


Fig. 13. Geological map of Selinsing gold mine and some prospects in the State of Pahang

lodes that occupying the central part of folded structure and proximity. Most of the underground working, alluvial and open cast mining efforts in the area are centred at the easternmost of the two fault zones along an area over 5km N-S to maximum 335m depth. Complexes quartz-carbonate veining stockworks has resulted intensive gold mineralization within cross-cutting, fissures and brecciated and silicified textures with high tenor in narrow zones of 2m wide. Sporadically from high-grade ore-shoots that featuring complex discontinuity and branching vein system. Gold fines is more than 981.16 with average Au (96-99%), Ag (1.44-1.91), As (0.04-0.12%), Hg (0.14-0.22) and Te (< 0.07%) (Henny et al., 1995).

6.5 Tersang Zone

Tersang is located about 20km north of Raub and along the same regional mineralized strike. The N-S trending Tersang gold deposit consists of a large and extensive outcropping quartz veins stockworks cutting within the 2km elongated of hydrothermally altered pyritised aplite-rhyolitic dyke as well as the metasediments. Hydrothermal alteration is shown by silicification, disseminated pyrite and arsenopyrite in the felsites with eminent sericitisation. The thickness of quartz veins varying from 1-20 cm and can up to 1 m in width at 80°/60° to the south. It is currently hosts an inferred gold resource of 528,000 tailings (Snowden, 2008; Howe, 2004). Assay results of stream sediment have return as high as 410 ppb Au and Sb anomaly. Other nearby prospects within the Tersang zone is Tenggelan, Chenua and Chun Kok in the south.

6.6 Kechau-Tui

Gold mineralization at old Kechau Tui (Ajmal mine), Kuala Lipis, Pahang is characterized by the quartz veins transecting the Permian limestone Bedrocks of Gua Musang Formation (Wan Fuad, 2008; Cheang, 1988). The veins are generally steeply dipping at about 70° to the west along N-S and NE-SW trending faulted and sheared zones, occurred as isolated or multiple parallel of a few cm to 20-30cm wide vein system.

The primary gold mineralization in the area seems to be related to the igneous intrusion of the area emplaced during Triassic-Jurassic period. To the north is a small pluton, named Bukit Tujuh granite and to the north-east is the Bukit Damar pluton. Gold mineralization in the Mine is significantly different from that of Penjom and Bukit Mandi (Wan Fuad & Heru Sigit, 2008, 2002; Gunn, 1993) as it contains less arsenopyrite and pyrite. The gold bearing veins are sulphide-poor. There are two type of mineralized veins in this deposit, viz i) sulphide rich, gold poor quartz veins and ii) sulphide poor gold bearing quartz veins. The main gold mineralization occurs in N-S trending sulphide-poor veins. Mineralogically, the later, consist mainly of late tetrahedrite, galena and traces of chalcopyrite and sphalerite. Gold is found as tiny free gold and isolated specks within these milky white quartz veins, away from main galena mass, and also as fine gold specks in the tetrahedrite. The gold was deposited earlier stage, and later, together with tetrahedrite. Wall-rock alteration is hardly visible. At the vein quartz-limestone contact, there is a narrow transition zone where the white colour is gradually changed to grey colour of limestone, and often near the contact it consist mainly of dolomite, followed by quartz and calcite.

6.7 Mengapur deposit

The Mengapur Copper mine in Maran, Pahang is a typical Cu-Fe of gold-bearing distal skarn deposit located in the Central Mineralization Belt. The study shows the ore deposit at Mengapur is a contact-metasomatic type associated with Triassic granodiorite. It is confined mainly to the extensive contact-metasomatic skarn aureole formed within the Permian calcareous metasediments and volcanic surrounding the Botak granite intrusion. The skarn rocks comprise a spectrum of garnet and pyroxene-rich types with the gold mineralization preferentially concentrated in the pyroxene-rich types varieties. Quartz-veins stockwork are common within the skarn and hosts for vein-type mineralization. The dominant metallic mineral assemblages of the skarn deposit are pyrrhotite, magnetite, chalcopyrite and arsenopyrite. In the veins the assemblage is more varied and includes pyrite, chalcopyrite, pyrrhotite, chalcocite, covellite, digenite, galena, sphalerite, molybdenite, bismuth,

arsenopyrite, stibnite, boulangerite, schellite and gold. Gold occurs as fine to medium grains, infilling fractures and fissures in pyrite and arsenopyrite, and also intergrown or enclosed by galena. Minute gold grains 5 to 10 micron infilled the interstices of intermediate quartz associated with fine carbonaceous stylolitic streaks and fragments of phyllite (Sinjeng, 1993). Formed at the homogeneous temperature of 169.2 to 313.7°C (NaCl wt% 2.4-8.0%) at shallow depth (Goh et al., 2003).

7. Potential of gold in Kelantan

Detailed accounts on gold mineralization in Kelantan was discussed by Goh et al. (2006); Chu & Singh (1986), Chu (1983 & 1980). In Kelantan, basically, most of the gold mines are working on placer deposits; they contribute approximately 10% of the annual gold production of Malaysia. Gold mineralization in Kelantan is mainly distributed in the central part of the state, bounded by Stong Igneous Complex and Seting Granite on the west, Kemahang granite in the north and Boundry Range granite in the east. Gold was mined from early times in the Pulai Districts, Galas, Pergau, Lebir and Kelantan River. Significant gold mineralizations mainly occur in sedimentary-metasedimentary rock of Perm-Triassic age. Gold mineralization typically associated with hydrothermal quartz vein system, skarn and volcanogenic massive sulphides. The main factors contributing succession of gold mineralization are source rocks, heating chamber as well as depositional structure.

The principle source rocks are Permian-Triassic volcanic rocks that are associated with sedimentary rocks (Fig. 14). The heating chamber that induced the hydrothermal fluids is the granitoid bodies that intruded under the volcanic-sedimentary rock, whilst structures which allow the infiltration and deposition of gold are sheared and faulted zones originating from depth.

Based on the type of ore deposits, geochemical data, and geological setting, the study area can be divided in to five mineralization zones (Goh et al., 2006; Teoh et al., 1987). Namely, hydrothermal vein gold mineralization zone, gold-base metal associated with volcanic exhalative zone, gold-silver-mercury zone (hydrothermal veins). Available data suggests that in Kelantan primary gold mineralization is associated with Ag-Au quartz veins, Massive sulphide bodies, pyritiferous and carbonaceous metasediments, skarn-type mineralization, and sulphide-bearing volcanic and volcanoclastic rocks. The most significant Ag-Au massive pyritic Pb-Zn sulphide bodies remaining are those at Ulu Sokor. These oxidised bodies show supergene gold enrichment, with the oxidised zones displaying a higher gold tenor than primary sulphides. Much of the gold in the primary sulphides is locked in pyrite (Batcher, 1994; Chu & Singh, 1986).

The intrusive rocks show some sign of gold mineralization. Gold mineralization is also occurs in shear zones in granite (Schroeder & Cameron, 1996) and not really significant (Batchelor, 1994; Chu 1983; Chu et al., 1980). 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, Pulai and Batu Melintang (Goh et al., 2006).

So far most of gold in Pulai were from placer type. The Pulai fluviatile gold placer deposit stretches along 17 km of the upper reaches of Sungai Galas. The valley alluvium ranges up to 1200 m wide and averages 6.2 m in thickness. Malaysia Mining Corporation had proved-up sizeable reserves following drilling and bulk testing during 1979-1983 (Batchelor, 1994). Six types of hydrothermal quartz veins can be recognized in the state of Kelantan, namely:

- a. low sulphide quartz veins
- b. high sulphide quartz veins
- c. quartz veins in sheared granite zones
- d. quartz vein at the boundary of sedimentary rocks
- e. structurally controlled quartz veins in volcanics
- f. sedimentary rocks
- g. metamorphic segregation quartz veins, as shown in Fig. 15.

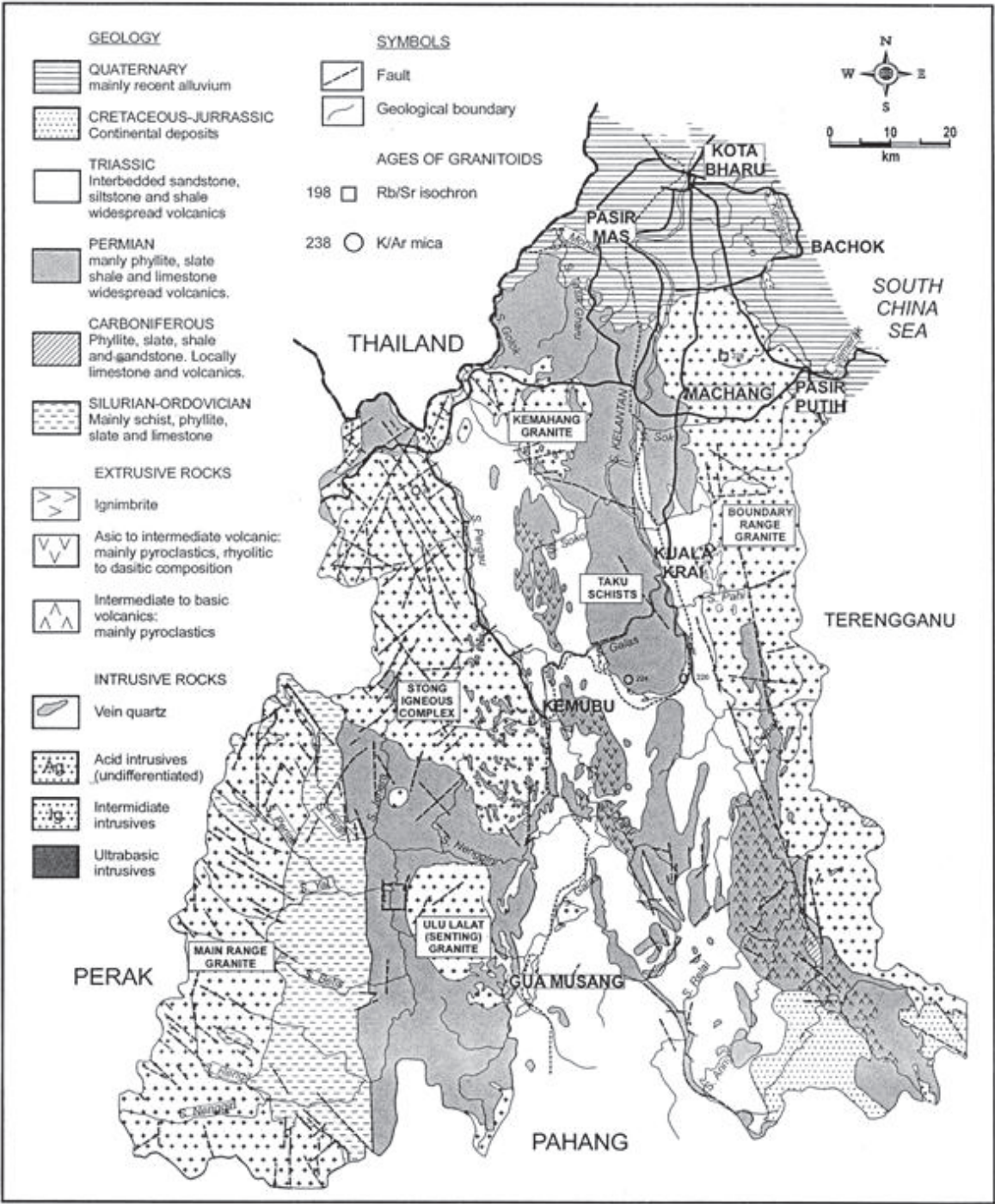


Fig. 14. General Geological map of Kelantan (after Teoh et. al., 1987; Goh et al., 2006)

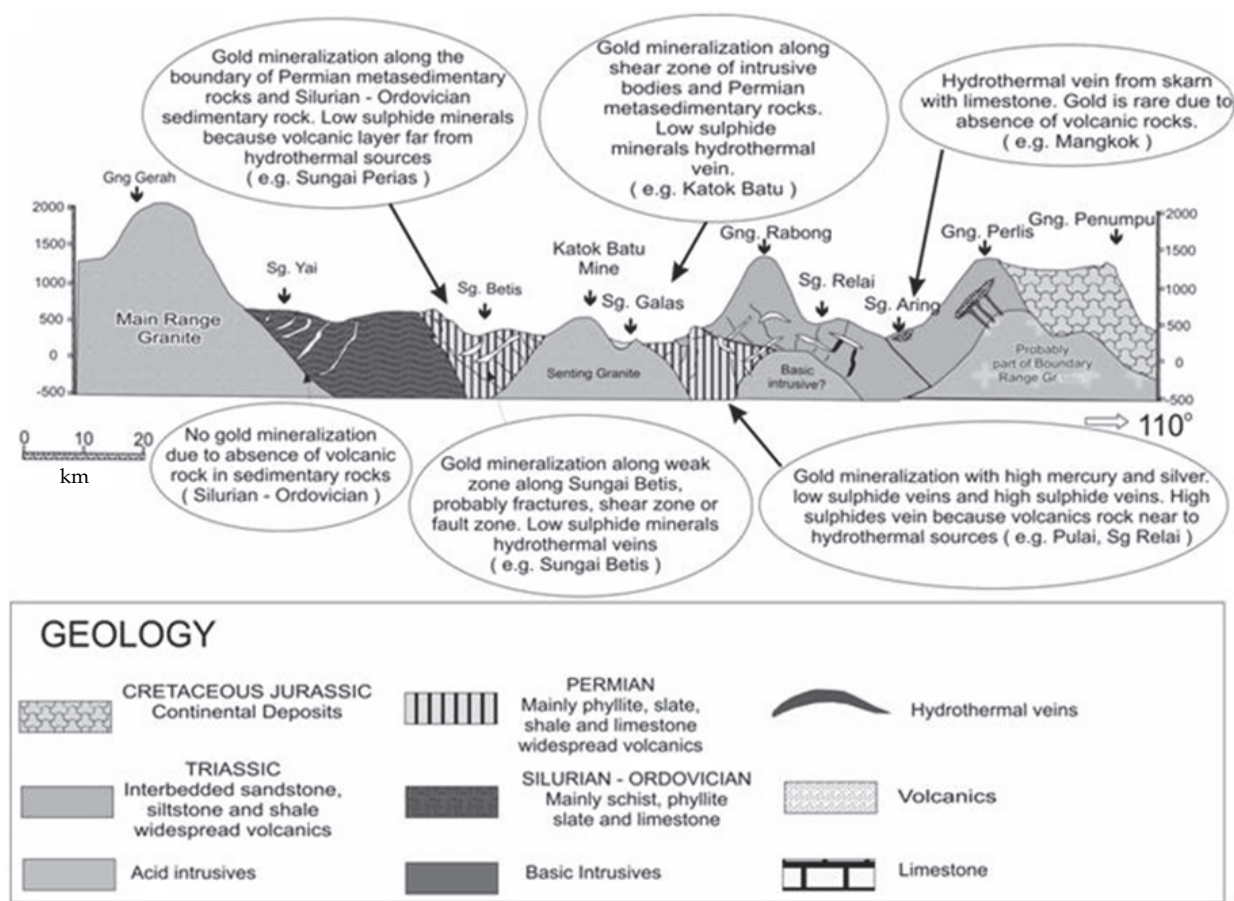


Fig. 15. Gold mineralization model across Main Range granite on the west to Sungai Relai, in the south-eastern corner of Kelantan (after Goh et al., 2006)

8. Potential of gold mineralization in Eastern Belt

The first significant discovery of primary gold of phanerozoic mesothermal lode gold mineralization type in the east coast of Peninsular Malaysia, within the Eastern Tin-gold belt is from Lubuk Mandi, near Rusila in Terangganu. As stated by Yeap (2000, 1993), most of the potential gold occurrences and deposits are located within Gold belt 3 and 4. Both Lubuk Mandi and Sungai Pelong (Bukit Panji) golfields are Gold Belt 4 (Fig. 2). Geology of the Eastern Tin-gold belt are predominantly consists of Carbon to Permian metasedimentary rock sequence (interbedded phyllite, and minor meta-arenite) with subordinate of volcanic which later intruded by the Late Permian to early Triassic granitoids. Interbedded siltstone and meta-sandstone are the younger, Jurassic-Cretaceous age, rock formation overlying a few areas.

A few new gold prospects have been recognized for follow-up study in the northern part of Terangganu during exploration programs carried-out by the Department of Mineral and Geosciences between 1991 and 2005. Following this programme, Sungai Tapah, Sungai Setiu, Sungai Pelong and Sungai Pelagat were identified as potential targets for integrated follow-up and detailed appraisal (Mohamad Sari, et al., 2005). Preliminary appraisal of geochemical data indicated several drainage basins within this area are gold and tin enrichment, where illegal gold panning activities was perceived. In Sungai Tapah 2m wide

quartz vein, striking N-S within N-S shear zone, cutting the graphitic phyllite and slate bedrock of the area were observed with assay result of 3.6ppm.

8.1 Lubuk Mandi deposit

The mineralization occurs in the structurally control, deformed and brecciated carbonaceous metasediment and main quartz veins ($345^{\circ}/80^{\circ}$) within of N-S trending brittle deformation zone of 5 to 10m wide. The quartz veins belonging to more than one generation are widespread throughout the sedimentary sequence, folded, discontinuous, strained, and complexes in nature, always concordant to the fabric of host rock and often extending less than 1m.

The country rocks generally comprise low-grade, chloritic alteration metasediments of Carbonaceous age, mainly grey to black laminated phyllite and shale unit with subordinate siltstone and sandstone of Sungai Perlis Beds, and generally dipping steeply at about $80-85^{\circ}$ to the east. Post-date mineralization, up to 4m wide dolerite dyke is the only igneous intrusive encountered, undeformed and free of quartz-vein (Gunn et al., 2000). Mineralization took place at 196.2°C homogenization temperature (salinity 4.2wt.) at a depth of 156m at 16kbar pressure (Wan Fuad & Heru Sigit, 2003).

Free gold (5 to $400\mu\text{m}$) was observed to occur close to and within streaks and clasts of graphitic shale and phyllite, incorporated into the veins and where stylolitic texture is developed (Gunn et al., 1993). Gold was deposited after the introduction of the most abundant pyrite and arsenopyrite and almost contemporaneously with sphalerite and galena including traces amount of schellite, cassiterite, hematite and other secondary iron. Elevated gold abundance in the veins is accompanied by enhancement of As and Pb, and to a lesser extent, of Ag, Zn, Bi, W, Mo, Cu, Te and Se. Based on the elemental relationships, the Lubuk Mandi gold deposit can be classified as a Au-Cu deposit.

8.2 Mersing

Mersing is located on the eastern coast of Peninsular Malaysia (eastern gold tin belt), in Johor. Gold has been reported in two distinct settings in the area, quartz veins in the Permo-Carboniferous shale sequences and placer type overlying Jurassic conglomerates that contain $\text{Ag} < 2\%$. The results show mesothermal sediment-hosted quartz-vein is a major type of gold mineralization indicated by the presence of pyrite, arsenopyrite and galena which is the common type in many other parts of Malaysia. Other minor components are ultramafic/mafic rock type and red-bed type unconformity (palaeo-placer) related mineralization. EPMA analysis on these alluvial gold grains indicated the samples often contain, maximum 0.18% Hg, 0.12% As, 0.08% Te and occasionally Se in Tiemannite (Styles et al., 1994).

9. Conclusion

Gold mineralization in the Central Gold Belt is generally categorized as a low mesothermal lode gold deposit due to its tectonic and geological setting. Most of the gold mineralization took place within a low-grade meta-sedimentary-volcanic terrain formed during the collision of the Sibumasu block underneath the East Malaya (Indochina) block through the Permian to late Triassic. Gold mineralization in Central Belt is much associated with the accretionary prism along the North-south trending terrain boundary known as the Raub-

Bentong Suture. A collision structure overprint has generated major N-S or NW-SW trending left slip fault; and dilational Riedel and subsidiary shears and numerous splays associated with these faults. These structures have of great consequence in hosting many mesothermal quartz lodes within the Central Belt.

Mineralization took place within a low grade Permo-Triassic island arc system composed of meta-(sedimentary- green facies and occasionally upgraded to amphibolite facies) and volcanic rocks accompanied by extensive deformation (brittle-ductile and shearing zone), metamorphism, and magmatic events that created the favorable environment for source and trap for the gold mineralization. In many occasion, the most significant feature with respect to gold mineralization in Central Belt is a north-south aligned shear zone in carbonaceous metasedimentary rock sequences. Significant gold mineralization often confined to the north-south trending sheared zone composed of metamorphosed, brecciated and hydrothermally altered calcareous graphitic shale with minor interbedded fine-grained sandstone and tuffaceous rocks. The gold mineralization in Central Belt is regarded as high grade quartz-carbonate-gold type related to a phyllic propylitic alteration of granite intrusion complex that intrudes weakly metamorphosed green schist facies sedimentary strata. In many deposits, ore systems display permeability controlled or governed by lithology, structure and breccias and changes in wall-rock alteration.

Arsenopyrite, pyrite, galena and sphalerite are the common sulphides. Signs of mineralization such as extensive wall-rock alteration that gave rise to carbonate and alkali metasomatism are evident such as conspicuous occurrence of sericitization, fuchsite, potassic albitization, chloritization as well as sulphidation. In Kelantan and Mengapur, gold mineralization typically associated with hydrothermal quartz vein system including as skarn and volcanogenic massive sulphides. Most of the gold-rich samples are proportionally elevated in arsenic. Ag, As, Te, Sb, and Bi except Hg are evident in segments associated with sulphide-gold mineralization. Gold has a marked affinity for Te and Bi and less for Sb except at Buffalo Reef. Other signatures conspicuously associated with gold included Ba, Mo, Co, Ni, W and Se. Based on elemental analyses epizonal (Au-Sb) and mesazonal (Au-As-Te) types of orogenic gold (Carline type) formation is favorable in Central Gold Belt (Groves et al., 1998).

In general, these deposits often characterized by a potassic radiometric anomaly (Nor'aini Surip, et al., 2003) and often accommodated within tightly folded sedimentary rock, associated with tonalitic intrusion and various scales of thrust faults, and appeared running parallel to the Raub Bentong Suture and nearby, district scale, splays. Mineralization often hosted within structurally control sheared thrust and veins within fold axes, bedded thrust associated mineralization type, stockworks in felsite, and finally steep, cross-cutting fractures. Mineralization of gold was believed to be formed at the homogenization temperature higher than 270-280°C hydrothermal fluid which is typical in epizonal and mesothermal lode and quartz veining within the metamorphogenic deformational terrain.

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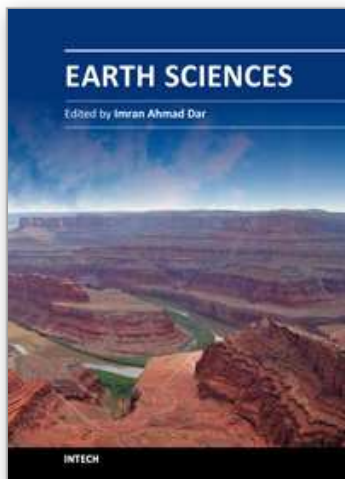
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