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# Pulau Perambut, an islet of goethite off Kedah, and its signficance

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**Abstract**. Pulau Perambut, an islet near the eastern end of Pulau Bunting off Kedah, is all goethite, which represents a lode trending 030. The goethite is derived from magnetite that had been earlier oxidised to hematite. The goethite is niobian and is believed to be owed to its occurrence in a region of columbite mineralisation. The occurrence of magnetite veins associated with quartz porphyry intrusions is suggested to be another possibility for the occurrence of the magnetic anomaly on the coast opposite Pulau Bunting.

**Abstrak**. Pulau Perambut, sebuah pulau kecil yang terletak di bahagian hujung Pulau Bunting di luar pesisir tanah besar Kedah, dibentukkan dengan goethit yang merupakan lod yang menjurus 030. Goethite itu didapati dari magnetit yang telah teroksida ke hematit sebelum perubahan ke goethite. Goethite itu mengandungi niobium dan dipercayai bahawa ini disebabkan kawasan kedapatan goethite itu adalah kawasan yang berpenmineralan kolumbit. Kedapatan tellerang-telerang magnetit yang berasosiasi dengan rejahan kuarza porfiri dicadangkan sebagai kemungkinan lain untuk kedapatan anomali magnet pada kawasan pantai bertentang Pulau Bunting.

## Introduction

Four small islands and a few islets exist off Gunung Jerai in Kedah, and the largest of them is Pulau Bunting, the most northerly of the islands (Figure 1). Adjacent to the eastern tip of Pulau Bunting is a small islet of bare rock, which is unnamed on the topographic map. We met a boatman from the nearby village of Kampong Sungai Limau who said the islet was called Pulau Perambut. The entire islet is dark goethite (α-FeOOH). We report here its occurrence and describe its chemistry; its economic and geological significance is also discussed.

### *Geological setting*

The Gunung Jerai area is underlain by the Cambrian Jerai formation that underlies the younger Ordovician – Silurian Sungai Patani formation [1], which was later reclassified as the Mahang formation [2]. The Jerai formation consists of schists, quartzites and calcareous rocks [1,3] that were intruded by hypabyssal quartz bodies during the Cambrian time, and they are interpreted to be coeval with the bedded acid tuff in the Cambrian Machinchang formation in Langkawi. The bedded early Palaeozoic rocks, together with the quartz porphyry bodies, were deformed and regionally metamorphosed to low grades during the mid Permian by the Patani Metamophic event [4,5]. The whole complex was intruded during the late Triassic by the Jerai granite that thermally metamorphosed the adjacent rocks up to the hornblende hornfels facies to result in the development of hornblende, diopside, garnet, biotite and sillimanite [6-10]. A well- developed thermal aureole has been mapped (Figure 1) [4].

The granite is associated with tin mineralization, particularly of the pegmatite type, in the southern part of the area near Semeling, which was once an important alluvial tin field. Associated with tin mineralization is columbite mineralization [1,9]. Possibly, iron mineralization in the area is associated with the Jerai granite intrusion [1,11]; however, a mapping and geomagnetic investigation showed that magnetite mineralization, which gave rise to magnetic anomalies in the aeromagnetic map of the area [12], is associated with the quartz porphyry intrusions [13]. There is as yet no report of the occurrence of iron ore on Pulau Perambut in previous reports on iron mineralization in the Jerai area [1,11].

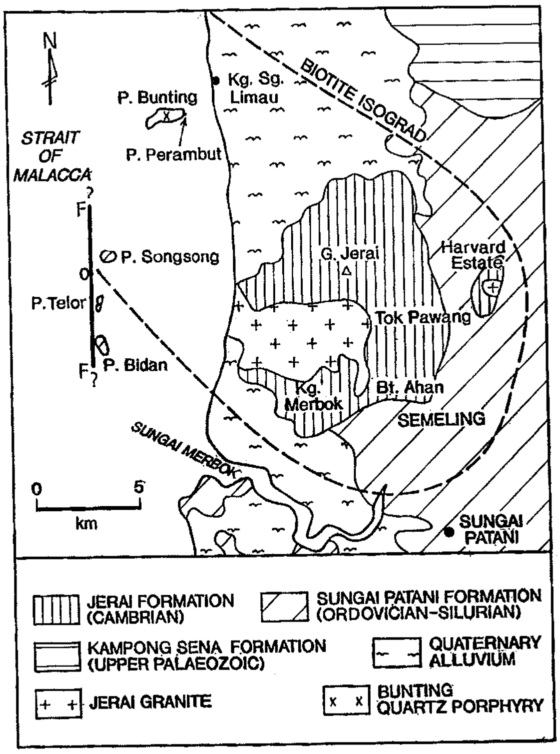


**Figure 1.** Geological map of the Gunung Jerai area. Biotite isograd demarcates the Jerai contact aureole. (P = Pulau, island; G = Gunung, mount; Sg = Sungai, river; Bt = Bukit, hill; Kg = Kampong, village, F = Fault).

*Occurrence*

The islet is made up of two pinnacled outcrops joined by a submerged curved sand bar. The outcrops stand about 2 m above low tide level, and they are largely submerged at high tide (Figure 2 and Figure 3). Both outcrops are entirely of goethite. Adjacent to these two outcrops are other smaller submerged outcrops that are visible through the clear sea water, and littered on the seafloor are many boulders of the goethite. The goethite occurrences form an elongated area about 100 m in length about 25 m in width. The elongation direction is 030°.

*Petrography*

The goethite is shiny, dark brown, scoured, smoothered and polished on the surface. It is concretionary at places with small concretions about 1 cm across. Sometimes, on the surface are seen masses of squat crystalline forms ranging from subhedral to euhedral cubic octahedral (Figure 4). The goethite is non-magnetic. In polished section, the material is largely goethite with isolated patches of hematite. Some of these hematite patches have a few sides reminescent of octahedral outlines. In addition, there are poorly reflecting pieces of quartz. There is no evidence of magnetite. The absence of magnetite was confirmed by X-ray diffraction, which registered only goethite and hematite reflections such as 4.19, 2.69A and 1.92° Å lines. From the presence of the octahedral crystal forms, magnetite was once present in the specimens collected. Both the hematite and grethite were derived from it.

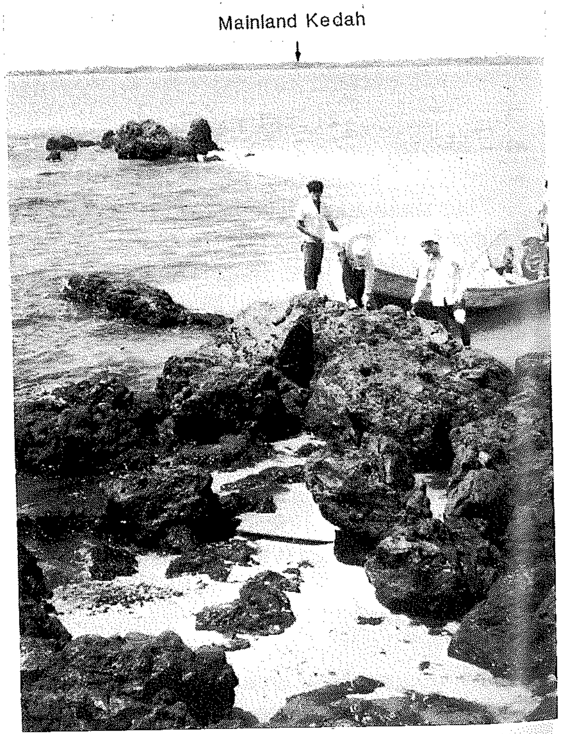


**Figure 2.** Pulau Perambut from northeast. Coastline in background is opposite (due east) of Pulau Bunting.

*Chemistry*

The chemical composition of the Perambut goethite is presented in Table 1. In addition to the elements analysed, a small amount of arsenic was found. The total iron in the Perambut goethite is lower than those of the iron ores from the Jerai area. The iron ores from the other areas were either hematite or magnetite, which have a a higher total iron than the hydrated Perambut goethite. As with the other ores from the Jerai area, the Perambut goethite is siliceous, and it is derived from included quartz, as noted in polished sections. An iron ore from Tok Pawang is reported to have unusually high arsenic (400 ppm) [1]; the Parambut goethite is similarly arsenic-bearing. The contents of aluminium oxide titanium dioxide and manganese in the Perambut goethite is within the range for magnetites reported in the literature. The copper content is also similar to those found in the iron ores from other parts of Peninsular Malaysia [11].

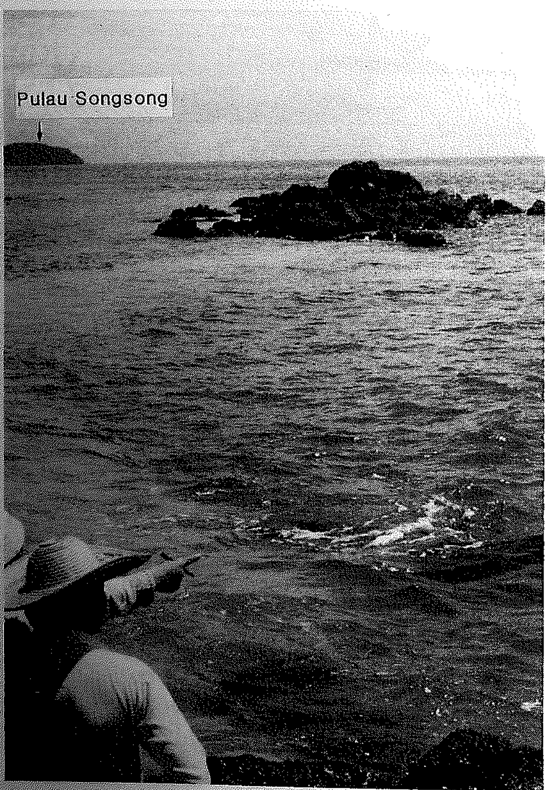


**Figure 3.** Pulau Perambut from southwest. Island in background is Pulau Songsong.

However, the composition of the Perambut goethite has some notable values. Zinc is usually not found in the iron ores of Peninsular Malaysia [11]; however, the Bunting iron ore was found to contain < 25 ppm zinc, which is lower than the 70 ppm in the Perambut goethite. Niobium, tantalum and yttrium are usually found in the Peninsular Malaysian iron ores either [11], so that the presence of these elements in the Perambut goethite is noteworthy. Niobium and tantalum are preferentially concentrated in rutile [14]; Nb-Ta rutile, struverite, occurs in the Jerai area [15]. A search was made for rutile in the polished section of the Perambut goethite did not turn up any rutile. As the niobium, tantalum and yttrium may exist in solid solution in the goethite (and hematite), the niobian goethite may be a result of the crust below being niobium rich, which is also reflected in the columbite mineralisation.

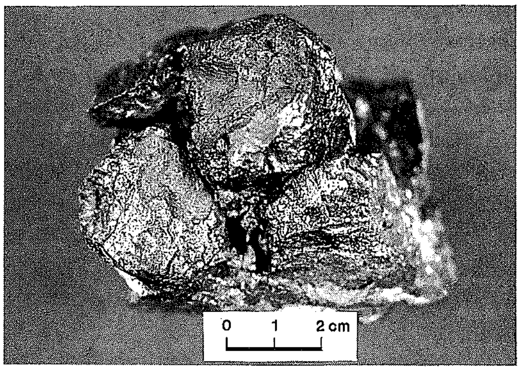


**Figure 4.** Handspecimen of Perambut goethite. Note octahedral habit.

The contents of calcium oxide and magnesium oxide in the Perambut goethite are somewhat difficult to rationalise. If the original magnetite is magnesian, then the magnesium oxide content may be explicable and some magnesium-rich magnetite have small amounts of calcium oxide but never higher than the magnesium oxide content content [16]. The Perambut goethite has more calcium oxide.

Since the early study of the scavenging properties of mineral particles by adsorption on the mineral surfaces [17], numerous studies have been made on the scavenging adsorption properties of goethite [18-26]. A study [19] of the surface chemistry of goethite in major iron seawater found that magnesium, followed by calcium, interacted with the goethite surface whereas sodium and potassium had negligible interaction to form surface complexes under the experimental conditions. An electron microprobe scan of sections of the goethite, which included the surficial rims, did not reveal any abnormal concentration of these minor elements in the goethite. These elements probably exist in solid solution in the goethite; possibly, as only the surface layer of the goethite participate in the scaverging [26, 27], they cannot be detected in the electron microprobe scan. The question of the higher concentration of calcium oxide over magnesium oxide remains unresolved.

## Discussion

In this section several aspects related to the Perambut goethite occurrence will be discussed.

*Trend and nature of the goethite body*

As there is no other rock beside the goethite in Pulau Perambut, whether the goethite body is concordant or discordant to the enclosing rocks in the Jerai metasediments cannot be determined. If the elongation direction of the goethite occurrence of 030° is indeed the strike of the body, then the 030° direction is one of the directions of veins, some of which are iron ore bearing, in the north Gunung Jerai area [1]. This coincidence may indicate that the Perambut goethite occurrence is part of a vein (or lode).

The geology and iron mineralisation of the adjacent island of Pulau Bunting has been studied; an unpublished survey [28] suggested that the disseminated iron oxide in the metasediments developed by remobilisation of magnetite along foliation planes arising from thermal metamorphism or from iron rich metasediments at depth. In addition, the absence of magnetite bodies of lode dimensions would support the interpretation rather than that the magnetite grains were a result of primary iron-rich solutions that accompanied the intrusions. The fortuitious exposure of the Perambut goethite, possibly part of a lode, would favour the other possibility that the iron mineralization was derived from iron-rich solutions from the quartz porphyry. This view has been expressed in a study of iron mineralization associated with quartz porphyry bodies in the Rest House area of Gunung Jerai [13].

*Location of Pulau Bunting and magnetic anomaly*

The results of an airborne magnetometer survey of parts of Kedah, including the Gunung Jerai area, have been published [29]. Only the mainland part of the Jerai area has been covered. An area of magnetic anomaly has been found on the mainland opposite Pulau Bunting (Figure 5). This anomaly, named Anomaly No. 8, has been interpreted as a deep-seated basic differentiate probably about 350 m below the surface.

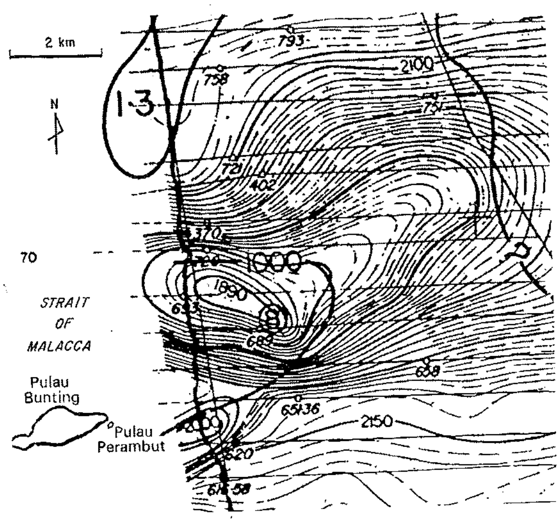


**Figure 5**. Magnetic anomaly No. 8 on the mainland opposite Pulau Bunting.

Magnetite-quartz veins exist in the quartz porphyry bodies of the area [13], and magnetite is abundant in the metasediments adjacent to the Bunting quartz porphyry [28] and magnetite lode (now the Perambut goethite). A buried quartz porphyry and associated magnetite under the area covered by Anomaly 8 could give rise to the magnetic anomaly pattern of Anomaly 8. A basic dyke now recrystallised by thermal metamorphism by the Jerai granite occurs in the river near the recreation centre of the Forestry Department [13]; possibly, a basic body lies under the anomaly [12]. However, basic igneous rocks are believed to be absent in the area [12].

*Development of the Perambut goethite*

The petrography and location of the Perambut goethite pose an interesting problem. There is evidence from the crystal form that the goethite had originally been magnetite that was later oxidised to hematite. However, the conversion of hematite to goethite at low temperatures has been a subject of debate and confusion [27]. Some studies suggest that hematite can develop directly to goethite in the presence of water [29-31]. Other studies claim that hematite does not convert directly to goethite but instead at below 100°C and 1 atm pressure, the iron is first dissolved and then reprecipitated as goethite [27, 32-35]. The latter appears to be the more popular view.

If goethite cannot develop directly from hematite, then there is little likelihood of the Perambut goethite having been developed after exposure as part of if is permanently under moving seawater and the part above the sea level is constantly lashed and washed over by waves. Reprecipitation on the hematite surface is unlikely.

Possibly, the hematite was dissolved and the goethite reprecipitated when the body was still buried but lying near to the surface. This will allow for the oxidising conditions necessary for the development of the goethite. A phraetic stituation with the body at the zone of a fluctuating water table would provide a suitable environment. This could be obtained if there is a broader and higher landmass incorporating the area of Pulau Perambut. Studies will have to be conducted to ascertain the last major fall in sea level during the last glacial event so as to understand the necessary landform.

*Name of the islet*

The word 'perambut' means 'hairy, fibrous or the lower end of a fishing line' [36]. The boatman from Kampong Sungai Limau, however, confirmed the meaning of 'hairy'. This being so, perhaps the name of the islet has been derived from one of the habits of goethite which is radially fibrous. This can be seen particularly in broken concretionary bodies of the goethite. An observant visitor could have noticed the radially fibrous habit of the goethite long ago and aptly named the islet as Pulau Perambut. In the opus of Malaysian place names [37], no island has been named after a mineral habit.

**Acknowledgments**

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**References**

1 Badford, E.F. (1972). *Mem. Geol. Survey Malaysia* **13**, 242 pp.
2 Burton, C.K. (1988). *J. S.E. Asian Earth Sci.* **1**: 93.
3 Khoo, T.T. (1984). *Warta Geologi* **10**: 1.
4 Khoo, T.T. (1984). *Bull. Geol. Soc. Malaysia* **17**: 79.
5 Khoo, T.T. and Tan, B.K. (1983). *Proc. Workshop on Stratigraphic Correlation of Thailand and Malaysia* **1**: 253.
6 Lye, Y.H. (1979). B.Sc. (Hons.) dissertation. University of Malaya.
7 Foo, W.Y. (1979). B.Sc. (Hons.) dissertation. University of Malaya.
8 Chow, K.T. (1980). B.Sc. (Hons.) dissertation. University of Malaya.
9 Awalludin Harun, (1982). B.Sc. Project Report. University of Malaya.
10 Salahudin Aminy Jamaluddin (1985). B.Sc. Project Report. University of Malaya.
11 Bean, J.H. (1969). *Geol. Survey Malaysia, Econ. Bull.* **2**: 194.
12 Agocs, W.B. and Paton, J.R. (1958). *Geol. Survey Malaysia Econ. Bull.* C-16.
13 Lim, B.K. (1980). B.Sc. Project Report. University of Malaya.
14 Bodinier, J.L., Merlet, C., Bedini, R.M., Simien, F., Remaidi, M., Garrido, C.J. (1966). *Geochim. Cosmochim Acta* **60**: 545.
15 Wan Fuad Hassan (1994). *J. S.E. Asian Earth Sci.* **10**: 11.

16 Deer, W.A., Howie, R.A. and Zussman, J. (1962). *Rock-forming minerals* **5**: 118.
17 Turekian, K.K. (1977). *Geochim Cosmochim Acta* **41**: 1139.
18 Balistrieri, L.S. and Murray, J.W. (1981). *Am. J. Sci.* **2281**: 788.
19 Balistrieri, L.S. and Murray, J.W. (1982). *Geochim. Cosmochim Acta* **46:** 1253.
20 His, C.D. and Langmuir, D. (1985). *Geochim Cosmochim, Acta* **49**: 1931.
21 Balistrieri, L.S. & Murray, J.W. (1987). *Geochim. Cosmochim Acta* **51**: 1151.
22 Zachara, J.W., Gassman, P.L., Smith, S.C. and Taylor, D. (1995). *Geochim Cosmochim Acta* **59**: 4449.
23 Gunneriusson, L. Lovgren, L. and Sjoberg, S. (1994). *Geochim Cosmochim Acta* **58**: 4973.
24 Zachara, J.M., Smith, S.C. and Kuzel, L.S. (1995). *Geochim Cosmochim Acta* **59**: 4825.
25 Ali, M.A. and Dzombak D.A. (1996). *Geochim Cosmochim Acta* **60**: 291.
26 Rustad, J.R. Felmy, A.R., and Hay B.P. (1996). *Geochim Cosmochim Acta* **60**: 1563.
27 Junta-Rosso, J.L. and Hochella, M.F. (1996). *Geochim Cosmochim Acta* **60**: 305.
28 Chung, S.K. (1959). *Geological investigation of Pulau Bunting* (unpublsihed). Geol. Survey Malaysia, 6 pp.
29 Onoda, G.Y. and de Bruyn, P.L. (1966). *Surf. Sci.* **4**: 48.
30 Bedarida, F. and Pedemonte, G.M. (1971). *Am. Mineral.* **56**: 1469.
31 Bedarida, F., Flamini, F., Grubessi, O., and Pedemonte, G.M. (1973). *Am. Mineral.* **58**: 794.
32 Smith, F.G. and Kidd, D.G. (1949). *Am. Mineral.* **36**: 403.
33 Berner, R.A. (1969). *Geochem. Cosmochim. Acta* **4**: 264.
34 Langmuir, D. (1971). *Am. J. Sci.* **271**: 247.
35 Swertmann, U. (1971). *Nature* **232**: 624.
36 Awang Sudjai Hairul (1977). *English-Malay and Malay-English Dictionary*. Times. 881 pp.
37 Singam, S.D.R. (1980) *Place names in Peninsular Malaysia.* Archipelago Publ. Kuala Lumpur, 155 pp.


**Table 1**. Composition of the Perambut goethite. Included are analyses of iron ore from the Jerai area [1, 11] for comparison. The Pulau Bunting ore is from heavy minerals panned from beach sand. In addition to the analyses shown the Perambut goethite contains CaO 0.7%, MgO 0.5%, $Na_2O$ 0.3%, Zn 0.2%, Nb 0.1%, Y 400 ppm, Ta < 100 ppm, Cu 70 ppm, K 150 ppm, Cr trace (nd = not determined; Nb, Y, Ta and $TiO_2$ by XRF, others by atomic absorption spectrometry, Si by qualitative analysis).

| Sample | Composition (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fe | Mn | $SiO_2$ | P | S | $Al_2O_3$ | $TiO_2$ | Sn |
| Perambut | 60.9 | 0.1 | 4 | nd | nd | 1.0 | 0.2 | nd |
| Bukit Ahan | 67.9 | nil | 2.6 | 0.0 | 0.0 | - | - | - |
| | 68.2 | 0.2 | 2.2 | 0.0 | 0.0 | - | - | - |
| | 59.1 | 0.2 | 2.5 | 0.0 | 0.0 | 6.0 | 0.1 | - |
| | 62.0 | 0.1 | 8.1 | 0.0 | 0.0 | 1.1 | 0.0 | - |
| Harvard Estate | 63.6 | - | 1.3 | 0.6 | 0.0 | - | - | - |
| Tok Pawang | 62.7 | - | 3.0 | trace | nil | 3.8 | 0.2 | nil |
| | 61.4 | - | 2.0 | 0.1 | 0.0 | 2.6 | 0.1 | nil |
| Kampong Merbok | 67.5 | - | 1.6 | 0.0 | 0.0 | 2.1 | 0.3 | nil |
| Pulau Bunting | 70.3 | 0.2 | 0.7 | - | - | 0.8 | 0.1 | nil |