Alluvial Tin Mining on Bangka Island

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Regional Geology and Alluvial Tin formation

The South East Asian Tin Belt accounts for more than 70% of the tin mined this century (Bachelor, 1973). The 3,000 km belt extends from Burma and Thailand in the north, through West Malaysia and down into the Indonesian Islands of Bangka and Belitung in the southeast.

Stanniferous biotite granites provide the source rocks for the alluvial deposits that form as a result of pneumatolytic, hydrothermal and pyrometasomatic processes on the upper portions of the plutons (Bachelor, 1973). Originally emplaced at a depth of approximately 4 km, the granites were uplifted during the late Mesozoic (Ko, 1983).

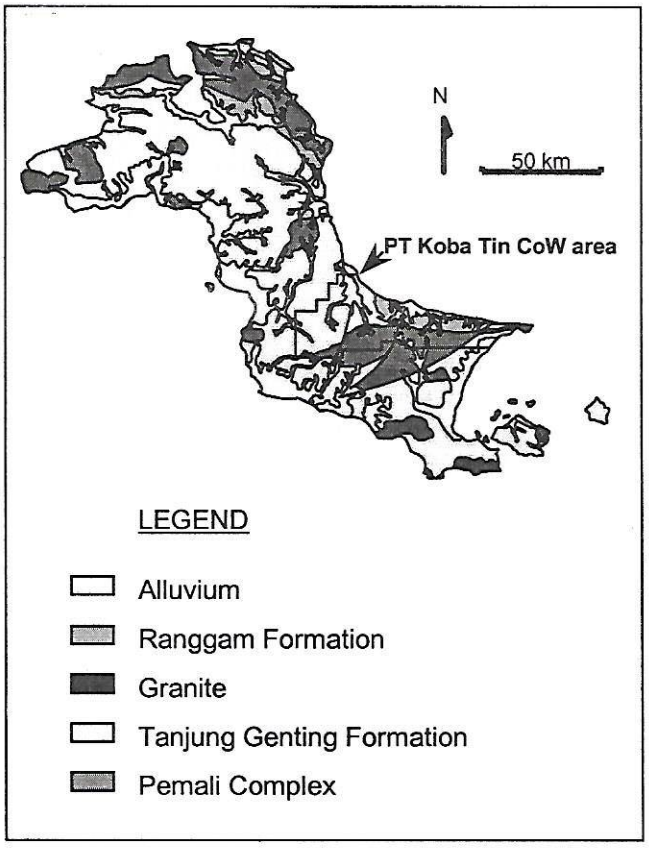


Fig 1: Geological map of Bangka (source: GRDC) in relation with the study area

In the time between the uplifting of the granites and the first glacial period of the Pleistocene, moderately high temperatures and an arid, dry climate typified the region. Chemical weathering in these conditions cause feldspars, micas and silicate minerals in the granites to break down into kaolin. This resulted in the more resistant minerals such as quartz, zircon, tourmaline and cassiterite to be freed from their surrounding groundmass and form elluvial deposits within the kaolin matrix. Soil creep of the elluvial deposits allowed the formation of colluvial deposits downslope into pre-existing valleys and depressions.
Cassiterite, tourmaline, larger quartz fragments and other heavier minerals slowly gravity sunk to the bottom of the weathered unit and collected where the bedrock was firm or unable to be penetrated. This process enriched the heavy minerals such as cassiterite and also allowed the resultant overlying lighter material to be more quickly transported down the gradient through soil creep, periodic stream activity and sheet flooding. Removal of the lighter materials enriched the overall grade of the remaining deposit. The lighter material is eventually deposited on the lower coastal plains.

During the Pleistocene, the first glacial cycle caused the sea level to fall and rainfall to increase. A tropical climate evolved and definite streams developed on the now larger landmass, often along the trend of older channels. Stream energy increased and the older elluvial and colluvial deposits are reworked and deposited downstream to form deposits known as Kaksas.
Rising sea levels and temperatures accompanied the Great Interglacial period in the middle Pleistocene. This period saw the return of chemical weathering as the dominant erosion process and it is thought that most of the elluvial and colluvial deposits formed during this time. Episodic rises and falls of the sea level during the next phase of the glacial period allowed great masses of material to be eroded. The scenario of chemical weathering of the granites developing elluvial deposits and subsequent mechanical working of the weathered material to downstream areas repeated with each glacial cycle. As the sea level rose, the barren material originally taken from the top of the elluvial and colluvial deposits redeposit in the recently submerged drainage channels until a flat surface or peneplain is attained.

During periods of low sea level, depositing of the heavier fraction through mechanical processes formed Kaksa type deposits in the upstream areas of the drainage system where tidal redeposition had not covered the bedrock. Downstream, mincan type deposits formed on top of the peneplained barren marine and terrestrial material.

In the Upper Pleistocene, towards the end of earth's glaciation period, the sea level steadily rose to current levels and all the lower lying placers were progressively filled by marine and terrestrial overburden. The end of the glaciation period (about 11,000 years ago) saw vegetation grow strongly, and the resulting organic debris accumulated as humic clays within low lying coastal swamps, covering the older clays and sands and forming the present day surface.

Mine Geology

The Koba Tin leases are located on the southeastern corner of Bangka Island. For exploration purposes, the lease is subdivided into its eleven valley or drainage systems, with all containing economic placer mineralisation.

Tin mineralization on the lease is sourced from the Pading Pluton. Topographically, the pluton forms the east-west striking Pading range, overlooking the low-lying plains that host the alluvial mineralization to the north. The Granite is Late Jurassic to early Triassic in age and is classified as an 'S' type granite with quartz, K-feldspar, albite, biotite, ilmenite, flourine, tourmaline, allanite, zircon and monzanite being some of the constituents in the mass. Hornblende is absent and the granite is medium to coarse grained and moderately deformed. The pluton intruded into the Triassic sediments of the Tanjung Genting Formation. These sediments cover most of the island and are comprised of shallow marine sands, clays and localised limestones.

The sedimentary sequence on Koba Tin's lease is dominated by the Ranggam group. This group was deposited during the glacial cycles of the Pleistocene and contains the economic tin horizons. The sequence is comprised of deposits derived from mass flows, swamps developed in floodplain areas, braided streams, floodplains, beach sands and shallow marine environs3. Variations in the type of facies deposited result from changing sea level, climate, topography of the landmass and energy levels in the transport medium.

Phyllite, schist and minor quartzite of the Pemali Complex are located near the intrusive granite. These metasedimentary rocks are thought to be Permian – Triassic in age, forming during early tectonic activity (Ko, 1983).
Overlying the older sequences is Quaternary alluvial cover, typically comprising of clays, muds and sands from river, swamp and coastal depositional environments.

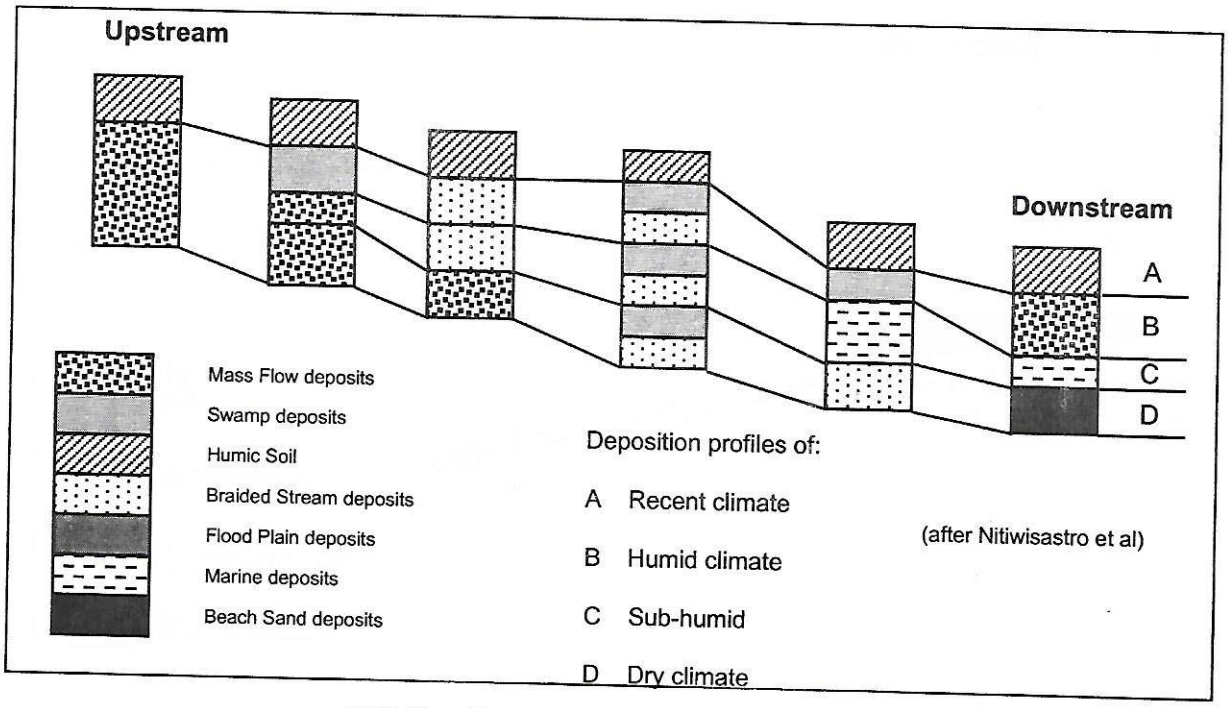


Fig 2: Depositional profile variations on Bangka Island

Structurally, the dominant features on the lease are the NE-SW strike-slip faults and the 'nick-point'. The dextral strike-slip faults post date the granite, and are thought to be of Miocene age, that is, before the Pleistocene depositions. Subsidence of the Koba block, which was in a tension zone, resulted from the strike-slip activity and the area was progressively infilled with sediments. The 'nick-point' is a term for the observed marked fall in the depth of the basement. It is thought that this feature relates to a thrust fault (possibly forming an old cliff face). The 'nick point' strikes east-west, parallel to the current coastline and often marks the commencement of the mincan tin layer, economically the most significant unit in the leases.

Heavy minerals found as accessories to tin in the alluvials and extracted in the mining processes are monzanite, zircon and xenotime (YPO4). Other minerals found in the mineralised layers are tourmaline, pyrite, hematite, siderite and ilmenite.

Drilling Methods

The study area is mature and the majority of mine lease exploration work has been completed. Several extensions to existing placers and some lower priority targets still remain to be confirmed.
Drilling is usually carried out by the Banka Bore method. This manual method of drilling is common to all alluvial tin areas in Indonesia and Malaysia. The drill is comprised of lengths of HQ casing with a platform fitted to the top casing. Drillers standing on the platform provide downward force and a crew on the ground rotate the pipe using poles and a simple leverage system. This method drives the casing into the ground. Inside the casing a sampling shoe is 'pumped' to collect the sediment inside the casing. The base of the sampling shoe has a one-way clack valve to prevent material inside the shoe from escaping back down the casing. Samples are usually collected every 0.5 to 1.0 meter. Once the sample is recovered, its volume, color and lithology are recorded. It is then panned or 'dulanged' into a field concentrate before being taken to the Koba Complex and dressed to +95% SnO2. The resultant sample is measured in terms of kg-SnO2 per cubic meter.
Other exploration drilling techniques include Air Core and Reverse Circulation via mechanical methods.

Reserves and Resources

At the end of 1999, reserves total 65,600 tonnes Sn at an average grade of 0.43 kgSn/m3 and reported resources amount to 7,583 tonnes Sn at an average grade of 0.42 kgSn/m3. The cut-off grade for gravel pump mining is 0.45 kgSn/m3 and for the dredges it is 0.28 kgSn/m3. These cut-off grades are based on a long-term real price of US$6,000/tonne Sn.

Resource estimations are compiled using classical polygonal methods with upper cut grades applied. These estimations are then reconciled back to production histories and a Mine Recovery factor (MRF) is applied to the classical estimation to produce the Reserve estimation. The MRF usually ranges between 0.8 and 2.0, with the mean adjustment being approximately 1.2. An MRF below 1.0 indicates over-estimation of the resource, whilst the more common case of an MRF above 1.0 indicates under-estimation.

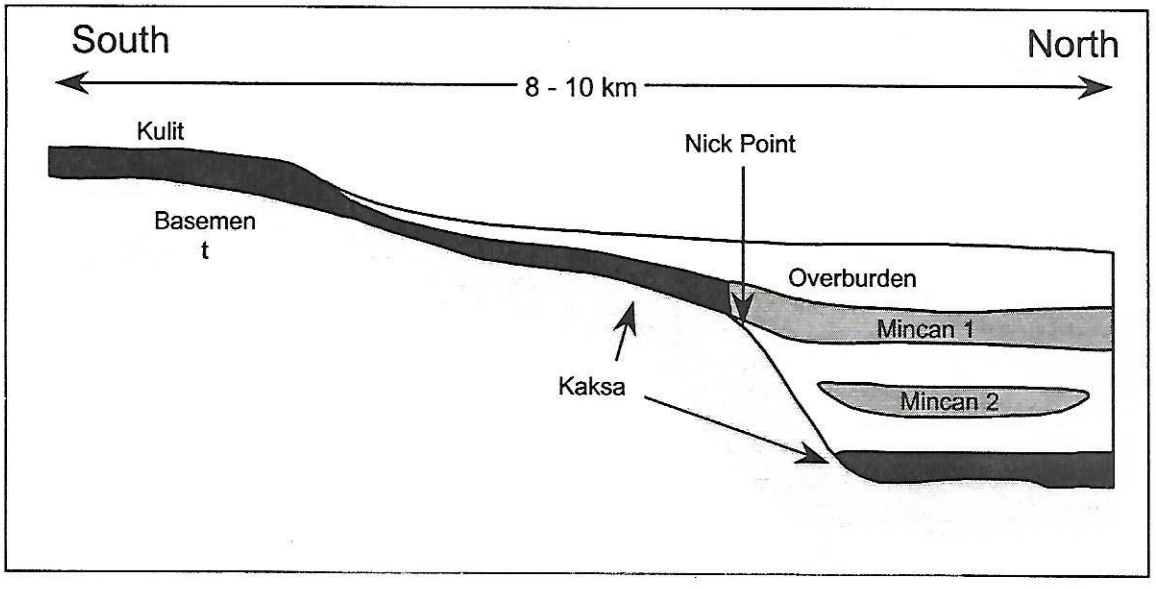


Fig 3: Idealized cross-section showing the three main types of orebodies.

Sedimentology for Safe Mine Practices

An important Mine Planning issue is the prediction of safe bench angles in the gravel pump mines. One mine currently in the process of being planned is Nibung 7.
In the Nibung Valley system, four alluvial units are generally found in the stratigraphic column. They are locally named Sand unit 2, Humic Clay unit 2, Sand unit 1 and Humic clay unit 1. The economic wash layer is contained in the lower sand unit (Sand unit 2), whilst the other lithologies are classified as overburden. Both the upper Humic clay and Sand units are found throughout the entire area, but the lower Humic clay units' occurrence is localised. Being dependant on deposition processes, the thickness of the Humic clay and Sand units is variable and can range from 0 to 12m.

Humic clays present mine planning difficulties as the unit is prone to slumping. An exposed working face will be more probable to slump as the amount of Humic clay present increases. In circumstances where thick Humic clays are present, mine and dam slope angles are calculated with emphasis being placed on the Humic clays as well as the water table level. Mine Planners calculate slope angles using soil characteristics such as porosity, cohesiveness, friction angles, overburden stress ratios and Specific Gravity as defining parameters. Using criterion such as these, the calculated bench slope for Nibung 7 was calculated to be 20o. This angle will give a stability factor of 1.3, or 30% above the calculated angle of failure for these rock types.
The angle of the constructed wall is a balance of safety and economics. The lower the bench slope, the safer it is; however, a flatter slope increases the amount of material needed, the size of the wall 'footprint' and the cost as well as a sterilising a larger amount of tin bearing wash. Correct geological information and interpretation are key factors in determining the most economic and safest bench system at the lease area.

References

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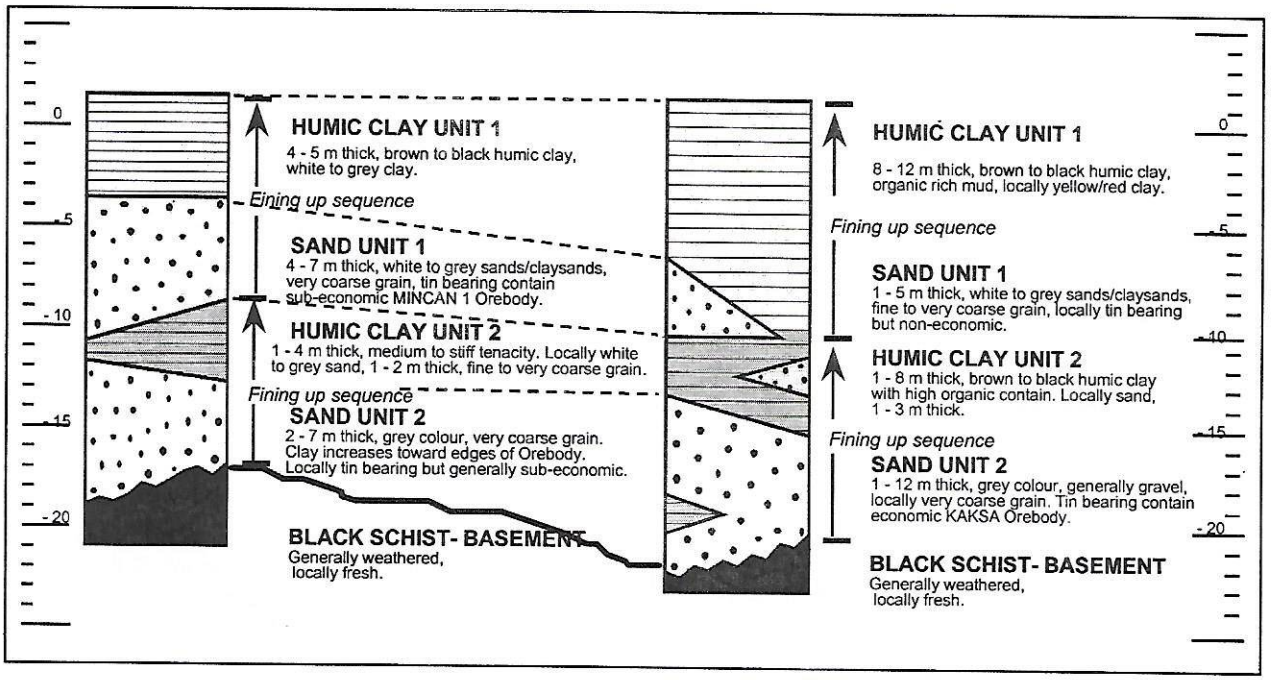


Fig 4: Generalized stratigraphy of the Nibung 7 area