

Tropical weathering, denudation and mineral accumulation

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Introduction

During the Fifties, the mechanism of weathering and of eluvial and fluvial mineral (cassiterite) concentration was the central research topic for the geologists working on Belitung (formerly Billiton) Island, Indonesia. The 'Billiton Issue' of *Geologie en Mijnbouw* (Vol. 39, 1960) contained two relevant papers, one written by Krol (1960) and the other by Van Overeem (1960). The related stone lines have been discussed by Aleva (1983, 1989).

By chance I encountered an interesting, unpublished contribution to this subject, while perusing an old file of routine monthly reports of the Geological Department of the G.M.B. (Billiton Mining Corporation), the mining company at that time working the cassiterite deposits. In that report, dated 22-3-1956, Dr A.E. Escher described, without much comments, a Banka type drill hole – and a control pit beside it – accompanied by quantitative mineral analyses.

Geological setting and sampling

The section described is in the island of Belitung (Billiton), Indonesia, to the south of the river Cerucuk (formerly spelled Tjurutjuk), near the place where this river drains into the Gaspar Straits (South China Sea). The sampling spot is on a 2000 m wide, flat and low divide, with drainage to the West (the

sea) and toward the East (a bend of the river Cerucuk). The local basement is of granitic nature, 216 ± 2 Ma old (Priem et al. 1975) and forms an outlier of the large Tandjong Pandan granite massif. It is surrounded on three sites by the Triassic sedimentary formations that make up about three-fifth of the island, and contain several other large and many smaller granite massifs.

The local configuration of granitic and sedimentary basement is such that the sampling spot represents an outlier of the large granite massif which has been deroofed relatively recently, i.e. during the present phase of erosion and denudation.

The section, described by Escher (1956), has been sampled by drilling, while control samples were taken from the wall of a pit dug beside the drillhole; both types of samples give comparable results. Samples A, B and C (see Fig. 1) represent the in situ weathered granite (saprolite, composed of clayey kaolinite and the more weathering resistant minerals quartz, cassiterite, monazite and zircon); samples D, E, F and G are composed of relatively coarse sand with a considerable kaolinitic clay content, representing the weathered sedimentary basement. Sample H represents the humic top soil.

At the laboratory of the Geological Department, grain size analyses, through sieving, were made of each of the samples, and their heavy mineral contents were determined: mainly cassiterite, monazite and zircon. The opaque minerals, mainly ilme-

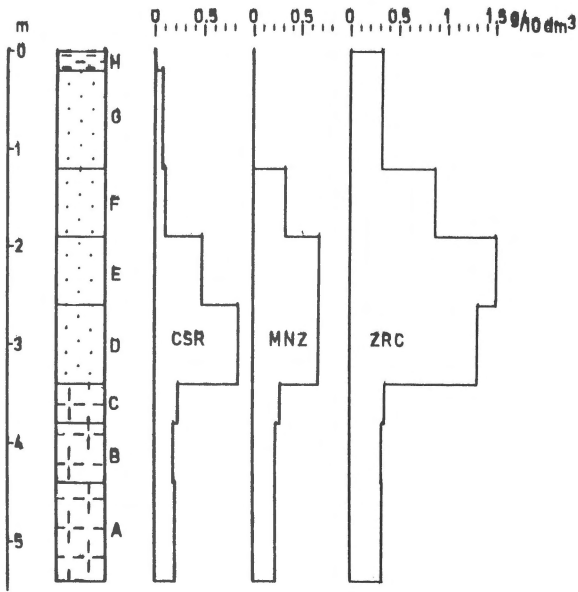


Fig. 1. Section through the upper 5.5 m of the weathering mantle over a granitic basement. The groundwater level – at the time of the sampling – was at 1.2 m below surface (bottom of sample G). The sand (stippled) down to about this level was whitish, that immediately below it dark and iron-rich. The sand in the samples D and E was yellow in colour.

The samples A, B and C represent the normal, kaolinitic, *in situ* weathering product of granitic basement rocks (marked by open crosses): an unconsolidated mixture of kaolinitic clay and coarse sand, and of a whitish colour. This material is locally called 'structured kong', as most of the structural and textural features of the parent granite are still completely discernible. The samples D and E represent a mixture of unconsolidated granitic weathering material without relict textures and structures – mainly angular quartz grains – and the rounded quartz grains of the weathered, sedimentary country rock with its accessory, rounded zircon grains.

The three histograms illustrate the amounts of the heavy minerals cassiterite (CSR), monazite (MNZ) and zircon (ZRC) present, quantified as the heavy mineral content, in gram, obtained from 10 cubic decimetre of sample.

For discussion see text.

nite, were not further investigated. The quantity of the three heavy minerals in the successive samples is given in Fig. 1 (as gram per 10 cubic decimetres).

The mineral analyses provide the following facts:

- i) Cassiterite occurs in all samples, with considerable enrichment in the samples D and E just above the granite-sedimentary country rock contact. In the uppermost samples F and G the cassiterite content is only a fraction of that

found in the samples A, B and C, which are composed of granitic kong (the Chinese term for the generally completely weathered basement, as found in the tin mines of Indonesia and Malaysia).

- ii) Monazite occurs in the granitic weathering product (saprolite) and is enriched in the samples directly overlying the kong, but it is absent in the samples higher-up. The grain sizes of cassiterite and monazite do not change throughout the profile.
- iii) Zircon is present in all samples, with a strong enrichment above the granite-sedimentary bedrock contact. Zircon in the granitic weathering products (samples A, B and C) is angular and idiomorphic in shape (i.e. granite derived). In the higher samples the proportion of well rounded zircon grains increases rapidly; these are derived from the sedimentary country rock, which is known to contain abundant, well rounded zircon.
- iv) Quartz grains < 0.480 mm in diameter are angular in all samples; smaller grains in samples F and G are rounded. Lower down only grains < 0.157 mm are rounded.
- v) The grain sizes of quartz in the upper layers are on the average of larger diameter than those lower down in the profile (see also Aleva 1956b).
- vi) The grain size distribution of quartz in the lower samples is indicative of a granitic origin (Aleva 1956a).

Interpretation

The Permo-Triassic sandstone of the country rock is known to contain much finely grained zircon in well rounded grains. Cassiterite may occur in the country rock as local mineralizations in thin gash veins; disseminated cassiterite in the sedimentary country rock is of unusual occurrence.

Intensive weathering under a humid, tropical climate produced a thick mantle of saprolite (quartz, heavy minerals and clayey kaolinite) and a surface horizon in which mainly quartz is accumulated (probably largely through the physical pro-

cess of elutriation, whereby the clay-sized kaolinite was removed from the system (Aleva 1956b).

This layer of physical accumulation (lag deposit) appears to be about three metres thick in this example (Fig. 1); it is also marked by the accumulation of cassiterite and monazite, both of igneous origin, and of zircon of both igneous and sedimentary origin.

The relatively small thickness of the total accumulation zone is presumably related to the topographic position of the sample site, being on the culmination of a low and flat divide, from which the weathering mantle continuously mass-moves down-slope, both to the West and to the East, (a process also known as tropical solifluction, shrinkage or collapse) and whereby lines may be formed (Aleva 1983, 1989). Elsewhere in Belitung Island, I observed that in places where the divide slopes a little steeper, the culminations are marked by small outcrops of fresh rock or by groups of large granite boulders.

The section clearly shows the heavy mineral concentration just above the saprolite (samples A, B and C, still containing the full structural and textural characteristics of the granite). The fine grains of the heavy minerals indicate that the accumulated minerals derived from disseminated accessory minerals in the granite. However, the processes at work are the same that might have produced a 'kultit' or eluvial deposit, provided that the local granite basement had contained primary, coarsely grained tin mineralization of a disseminated or gash vein nature. Accumulation can be considered to be driven mainly by gravity. The influence of in particular termites can be disregarded, as these are all but absent in the local forests.

The section of Fig. 1 shows another interesting feature: the variable rate in accumulation of the heavy minerals with increasing vertical distance from the granite contact. It seems to be related to the density difference between the minerals in question: cassiterite 7.0, monazite 5.1 and zircon 4.6. The greater vertical extent of monazite enrichment compared with that of cassiterite could be related to the higher density of the latter.

The abundance of zircon must be related to the presence of zircon in both the granite (angular, idiomorphic grains) and the sedimentary country

rock (fully rounded grains). It should not be surprising that the specific density of the various minerals comes into play in the denudation process, as denudation is transport, or movement under the influence of gravity, which acts on the individual mineral grains. In the moving mass of mineral grains, the heaviest grains have the better chance to quickly reach a lower position.

It must be concluded that the denudation is a process of mass movement, driven by gravity, of a layer of considerable thickness (several metres at least). Along the lower boundary of this layer the heavier mineral grains accumulate – in other places often visible as a stone line. Along the upper boundary of the layer the lightest and finest material is preferentially removed during and shortly after heavy rain storms, resulting in a sandy toplayer.

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