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OCCURRENCE OF STONE-LINES IN TIN-BEARING AREAS IN BELITUNG, INDONESIA, AND RONDÔNIA, BRAZIL

BY

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Summary. – The stone-line or carpedolith is defined in terms of the residual weathering profile as formed in a humid tropical climate. It occurs in the upper part of the unstructured saprolite zone, which overlies the structured saprolite. The stone-line is composed of weathering resistant components from the parent rock ; it takes on the shape of a thin continuous blanket through superficial mass movement in a humid tropical climate. It is also enriched in weathering resistant economic minerals occurring in the parent rock. Sampling the carpedolith may be a simple, cheap and effective way to establish the presence or absence of economic minerals that, if present, may be enriched in the lag gravels of the fluvial valley.

Résumé. – *Présence de stone-lines dans les régions stannifères de Belitung (Indonésie) et de Rondônia (Brésil).* – La stone-line ou carpédolithe est définie comme une partie du profil d'altération résiduel sous un climat tropical humide. Elle apparaît à la partie supérieure du saprolite dépourvu de structure. Elle est composée d'éléments résistant à l'altération. Elle se présente sous forme d'une fine nappe continue par suite des mouvements de glissement des dépôts superficiels sous un climat tropical humide. Elle présente un enrichissement en minéraux d'intérêt économique par rapport à la roche-mère. Échantillonner la stone-line peut être un moyen simple, bon marché et efficace d'établir la présence éventuelle de ces minéraux qui, lorsque c'est le cas, se présentent avec des teneurs plus élevées encore dans les graviers fluviatiles.

Samenvatting. – *Voorkomen van stone-lines in tinhoudende gebieden in Belitung, Indonesië, en Rondônia, Brazilië.* – De "steenlijn" of carpedoliet is gedefinieerd als onderdeel van het residuaire verweringsprofiel zoals gevormd in een vochtig tropisch klimaat. De carpedoliet bevindt zich in het bovenste deel van de ongestructureerde saproliet zone. Hij bestaat uit verweringsresistente bestanddelen van het moedergesteente ; hij neemt de vorm aan van een ononderbroken deken of karpet door de horizontale dalafwaarts gerichte beweging van de bodem in een vochtig tropisch klimaat. De carpedoliet is ook aangerijkt in verweringsresistente economische mineralen, die in het moedergesteente voorkomen. Bemonstering van de carpedoliet kan een eenvoudige, goedkope en doeltreffende methode zijn om de aanwezigheid

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van economische mineralen in het moedergesteente aan te tonen, welke in dat geval ook aangerijkt zullen zijn in het bodemgrind van de rivierdalen.

The stone-line or carpedolith is a powerful instrument, given by nature, to facilitate the exploration for residual and fluvial placer deposits.

Following SHARPE (1938) and the Glossary of Geology (BATES & JACKSON 1980), the following definition may serve : a stone-line is a thin layer in the residual weathering profile (in cross-section a line) which is composed of angular to subangular weathering resistant rock fragments, and parallels a sloping topographic surface. It lies a short distance above the structurally undisturbed weathered parent rock (saprolite) at a depth of up to a few metres below the surface.

Figure 1 illustrates the characteristic features of a stone-line, which are largely independent of the type of parent rock, either of granitoid intrusive or of sedimentary derivation. The stone-line may occur below a surface vegetation varying from a 50 m high tropical forest to a low and stunted tropical savannah bush.

The figure is based on observations, made in 1952 in Belitung Island, of the wall of a trench dug to study the behaviour of a 10 cm thick, massive and fine-grained cassiterite vein (the heavy vein dipping against the surface slope in the figure). The parent rock here is a sedimentary succession of quartzite and shale of Permian age. The features in the figure have been confirmed by observations elsewhere in Belitung Island in areas with a granitic parent rock (ALEVA 1956, 1973, 1985) and in Rondônia, Brazil, also over a granitic parent rock, during the Sixties and Seventies.

Stone-lines are of typical occurrence in tropical climates, where the parent rock weathering is mainly of a chemical nature : feldspar and mafic minerals are chemically weathered to hydrous sheet silicate minerals (kaolinite, etc.), the alkali and earth-alkali elements and a large amount of silica and iron are removed in solution. As a result there is a considerable decrease in rock volume and the upper part of the weathering mantle becomes mainly composed of quartz and other weathering resistant minerals, as fine grained kaolinite is also mainly removed in particulate form.

The changes in structure and volume of the upper part of the weathering zone are best analysed by studying quartz veins – preferably those that contain other weathering resistant minerals such as cassiterite, topaz, etc. As indicated in Fig. 1, the structurally unchanged saprolite is overlain by a zone that is mineralogically similar to the saprolite, but its original structure is destroyed. Quartz veins begin to bend over and the granitic parent rock structures fade away in an irregular mixture of quartz grains and a kaolinite matrix.

This zone of unstructured saprolite is a zone of structural collapse, or rather shrinkage, as the process is a very slow one. This shrinkage can best be studied by observing the changes in position of quartz veins with opposite original dips. Veins that dip against the dip direction of the surface slope just bend down and are taken up into the stone-line ; veins that dip with the dip direction of the surface slope, but at larger angles (see the cassiterite-quartz vein in Fig. 1), first bend down more or less parallel to the surface slope direction – as could be expected from the shrinkage mechanism – but higher up in the zone they make a hairpin turn into a dip downslope the surface slope.

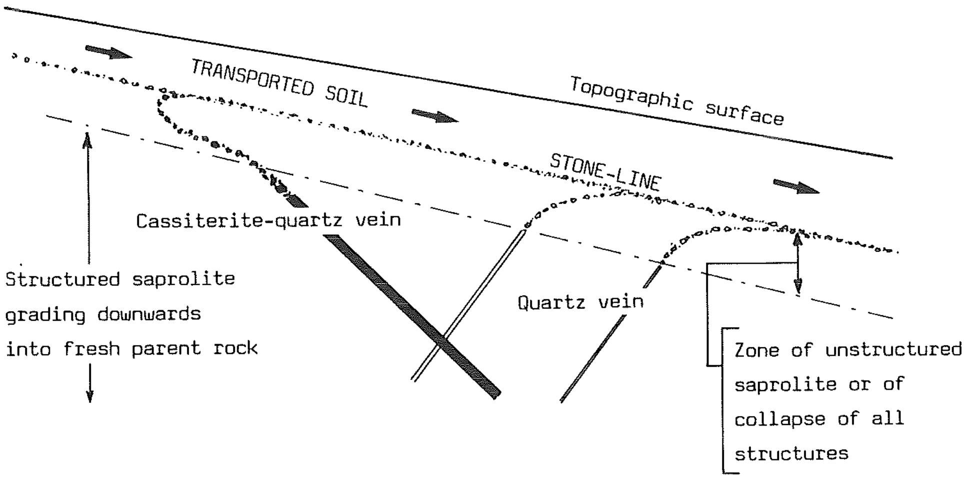

Fig. 1. – The stone-line or carpedolith in section, with its observed relation to quartz(-cassiterite) veins in Belitung Island (Indonesia), Rondônia (Brazil) and elsewhere. The thickness of the soil and the unstructured saprolite zone varies but is mostly in the dm to m range.

This last feature is the result of material transport, which occurs at the top of the unstructured saprolite zone. The narrow zone of maximum transport contains the carpedolith (in section seen as a line of stones or stone-line), a layer of weathering resistant rock fragments and minerals derived from the underlying, chemically weathered parent rock.

Above the stone-line is a horizon of transported soil, mostly clayey and sandy in nature. Over a granitic parent rock, the soil horizon contains only about half the amount of kaolinite that is found in the saprolite ; the quartz grains are of a little smaller diameter than in the parent rock. The top layer of the soil is characterized by a considerably larger average grain size of the quartz, as continued solution in the soil (increased presence of humic acids) removes the smaller quartz grains (ALEVA 1956).

The main process involved in the formation of these stone-lines or carpedoliths, is chemical weathering and the ensuing removal of elements in solution and fine clayey particles in particulate form. Indeed, stone-lines are indicative of humid tropical climates, present or past.

Mass transport – or tropical solifluction – is the other characteristic process required for carpedolith formation. In Belitung island it could be established that at least 40 m lowering of the surface has taken place since the start of the latest period of residual weathering and denudation (ALEVA 1983). In Rondônia, Brazil, mass transport can almost be seen happening. The soil horizon everywhere is moving towards the lowest places, i.e. the present-day, largely dendritic drainage system (Fig. 2).

In Rondônia, it can be observed that the present-day rainfall is insufficient to remove all the soil that is dumped into the valleys by mass transport. Drilling for fluvial cassiterite placer deposits proved the existence of an older landscape with wide and deep valleys, now partly filled up by mass movement of soil from the nearby interfluves. A younger drainage pattern largely follows this older valley system but its erosional and transporting capability has been insufficient to clean out the older valley fill completely, resulting in a variety of intricate valley cross-section patterns.

As shown above, the formation of carpedoliths can be explained by the process of chemical weathering and gravity movement. There is no need to involve boring animals, such as termites. In addition, in the areas studied termite hills etc. were all but absent.

Carpedoliths and laterite horizons belong to different domains ; they are generally not observed in the same area, as the stone-lines require a certain surface slope to be formed whereas laterite horizons require a stationary profile, i.e. as little slope as possible. Where they occur together, they are of different age, the one succeeding the other. Lateritization after stone-line formation will fossilize the stone-line and all movement will cease. Destruction of a laterite horizon by changing climate may lead to the laterite components taking part in the mass movement along the slope. Through laminar flow in the mass flow horizon, the resistant laterite concretions may gravitate to the bottom of the mass flow horizon and so contribute to the stone-line. Both situations have been observed in nature.

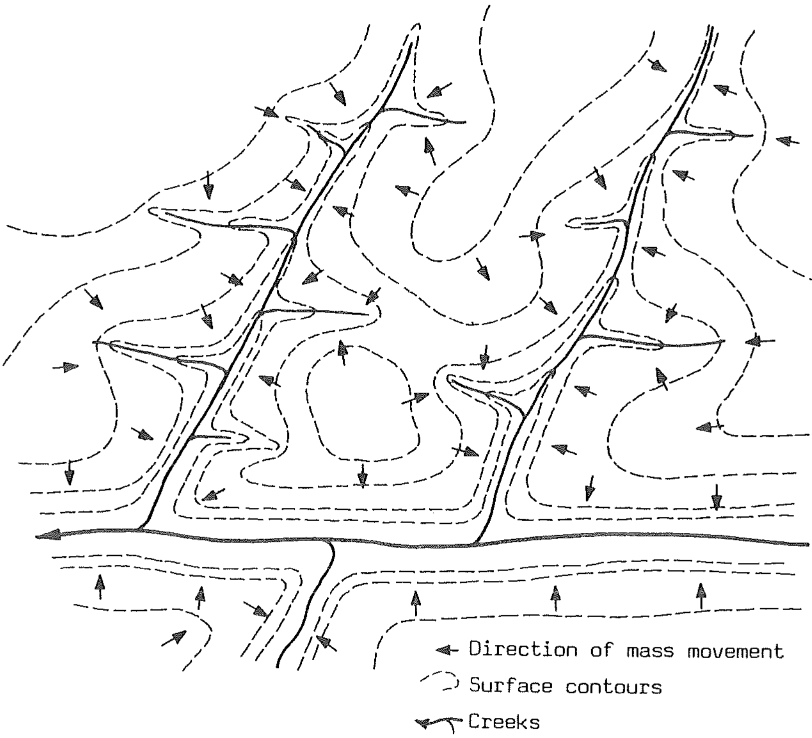

Fig. 2. – The transportation pattern of mass movement in humid tropical landscapes, indicated on a synthetic topographical map with contours in the order of 5-10 m interval.

Exploration for fluvial placer deposits (tin as cassiterite, also diamonds) requires sampling of the valley bottoms of past and present valley floors. The lognormal distribution of values in these placers, requires a minimum of 25 sample spots (in the case of cassiterite, and in a geologically and geomorphologically homogeneous valley floor area) to determine with economically acceptable certainty the presence of an ore-grade deposit.

Sampling has generally to be done by drilling, and in active valleys in tropical areas this is a time consuming and expensive task. The areal occurrence of the stone-line, (preference for using the term carpedolith now becomes clear) and the value distribution within it, permits the prospector to drill shallow holes with an auger (or dig shallow pits by hand) on the flat interfluve areas between the drainage channels. Any cassiterite found makes it probable that the valley contains cassiterite, fluvially concentrated in the drainage channels, which has been brought into that valley by mass movement of the weathering mantle, from just below the carpedolith up to the soil.

The practice developed in Beliting Island, and also employed in Rondônia, is simple. There are two methods :

(i) Little is known about the geology and structure of the area, which is the general case where the parent rock is an intrusive igneous rock. In accordance with the flow direction of the mass transport, shallow auger holes are drilled at regular interval along more or less straight lines parallel to, but 50-100 m upslope from, the present-day valley edges. The required depth of the holes, and the most economical distance between holes, has to be experimentally determined through a small pilot study (preferably in an area with known mineralized veins). The drilling samples are panned for heavy minerals, and a grain count of the economically interesting minerals will quickly indicate if the slope drilled has been transporting this mineral into the valley. If so, the valley itself must be drilled, if not then move to the next valley.

(ii) In a sedimentary terrain with known strike and dip directions, the lines to be drilled can be situated in such a way that these drilling lines will intersect the strike of any bedding features at an angle near to 90°. Drilling lines are now located with a geometry that maximizes their efficiency in locating the primary source of economic minerals, as well as the place where these enter the carpedolith. This is a combination of lines parallel to the present-day valleys and perpendicular to the strike of the formation. Drilling lines parallel to the general strike direction could run parallel to mineralized features, and thus could either over-estimate the amount of economic minerals present, or miss them completely.

Experience in Indonesia and Brazil has shown that carpedolith prospecting is a powerful, simple and inexpensive exploration method, which is able to find even very small primary sources of economic minerals. It must be realized that the economic value can only be determined by sampling the valley, where additional fluvial enrichment must have taken place.

In certain places no carpedolith can be found. This may indicate that the parent rock in question does not contain any material able to produce the relatively coarse, weathering resistant rock fragments that constitute the carpedolith. This has been observed in Rondônia, Brazil, where certain phases of the granitic intrusions were completely devoid of any quartz veins. The established absence of a carpedolith is also an important result of the first prospecting activity, as the absence of quartz veins in an intrusive mass may indicate that economic minerals will also be scarce, as they are generally related to quartz veins. The absence of coarse, weathering-resistant material in the fluvial valley will prevent, or at least considerably diminish, the capability of the river to enrich any heavy economic minerals brought by fluvial action (ALEVA 1985).

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