BIOTURBATION OF THE WEIPA BAUXITE

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The bauxite deposit at Weipa, in north Queensland, is a 2 to 6 m thick pisolithic bauxite overlying a lateritic weathering profile about 30 m deep. The Plateau is covered by open tropical Eucalypt woodland, dominated by Darwin Stringybark (*Eucalyptus tetradonta*), with minor Melville Island Bloodwood (*Corymbia nesophila*), Cooktown Ironwood (*Erythrophleum chlorostachys*), Nonda Plum (*Parinari nonda*) and Roth's Wattle (*Acacia rothii*), as well as native grasses and herbs. Prominent among the organisms living in the bauxite are several species of termites, including "cathedral", "magnetic" and "phallic" mound builders, and "tree termites". There is evidence that the larva of a weevil, or other soil-inhabiting beetle, is or was present in the bauxite. Weipa has a strong tropical monsoonal climate with clearly defined wet and dry seasons. Nearly 90% of the 1650 mm annual rainfall occurs from November to April. The annual rise and fall of the water table is of the order of 10 m.

The bauxite overlies two different substrates (Figure 1). On the Weipa Peninsula, Tertiary fluvial sands and clays of the Bulimba Formation form the substrate, whereas on the Andoom Peninsula the substrate is glauconitic marine sediments of the Normanton Formation, a part of the Rolling Downs Group. The major difference between the two regions is the presence of quartz at Weipa and its absence at Andoom.

The lateritic profile at Weipa follows the classic sequence from bedrock though saprock and saprolite to a plasmic (pallid or bleached) zone, up to a mottled zone having a ferruginous duricrust of variable cementation at its top. Above the duricrust is the lateritic gravel—the bauxite. The bauxite is entirely pisolithic and oolithic, with only sporadic cementation of these particles. Consequently the bauxite is loose and is free-flowing whenever a vertical edge is created. The base of the bauxite (top of the lateritic duricrust or iron-stone) coincides with the top of the wet season watertable. Soils over the bauxite are grey-brown sandy loams with a very thin A-horizon and a red-brown to yellow B-horizon. Locally there are yellow podsolic soils.

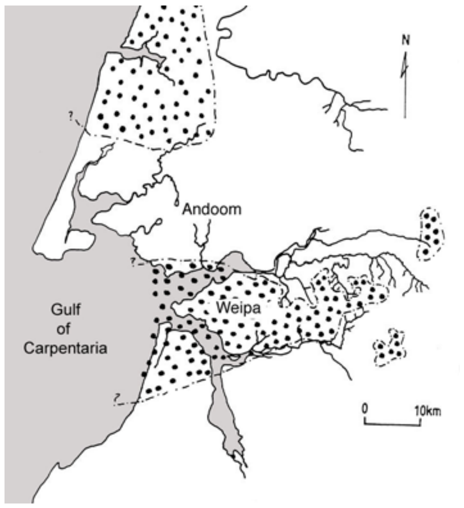

Figure 1: Distribution of Bulimba Formation (stippled) over Rolling Downs Group sediments (unshaded) at Weipa and Andoom (Zambelli 1991).

Geochemical analyses of the bauxite show that it is remarkably uniform throughout its thickness, and across each part of the deposit (Figure 2). This uniformity contrasts with the more normal character of a bauxitic profile, in which there is change from its base to the surface.

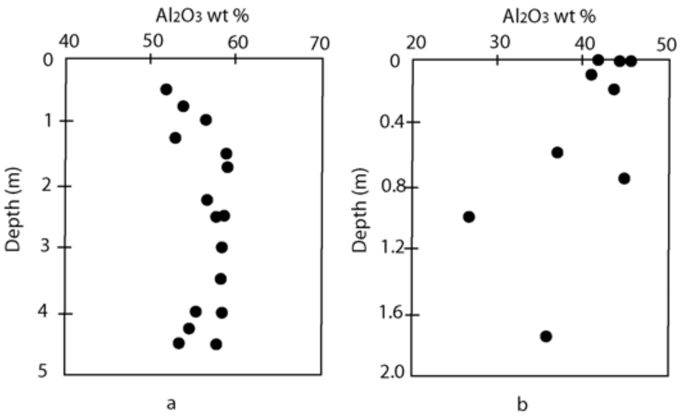

Figure 2a (left): Aluminium oxide concentration in 4 bauxite profiles at Weipa and Andoom. **Figure 2b (right):** Aluminium oxide concentration in 2 bauxite profiles over granite at Darling Ra., WA (data from Davy 1979).

Such uniformity can be explained by the displacement effects of root growth and tree-throw and by the falling of loose pisoliths under gravity into tubules left as roots decay. Burrows and tunnels made by large animals and by root-eating insects such as cicadas, weevils of the genus *Leptopius* and scarabs such as Christmas beetles *(Anoplognathus*), as well as ants

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and termites also allow movement of bauxite particles within the profile and lead to homogenization.

Although the bauxite is homogenous chemically, there is marked contrast in its magnetic character down-profile (Figure 3), and between the mineralogy of the bauxite and of the overlying soil (Table 1). The decrease in total magnetic susceptibility can be interpreted as a decrease in maghemite content, though even at the top there is too little for X-ray diffraction to detect reliably. Maghemite is formed in soil from goethite or hematite during bushfires by a reduction-oxidation process (Ketterings 2000). We conclude that heating at the surface, probably enhanced by burning roots, has created the maghemite. However, the lack of magnetic uniformity suggests that the bioturbation acts more slowly than does the mineralogical change.

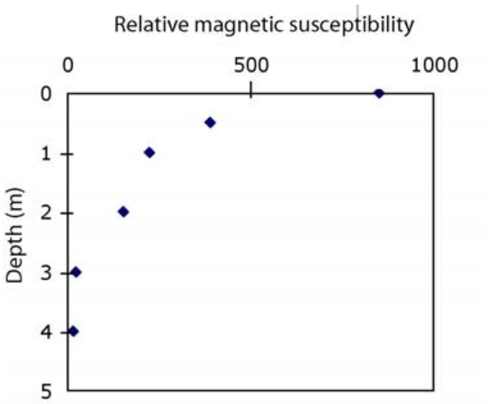

Figure 3: Variation of magnetic susceptibility with depth for larger pisoliths at the Jacaranda pit profile, Andoom.

Termites are abundant at Weipa. Their galleries are visible well into the mottled zone, and probably extend into the plasmic zone. By their activity, particles from below the bauxite are brought up, to be distributed across the landscape when the termite mounds and muds disintegrate. Table 1 shows also the composition of the wall of a "Cathedral" termite mound. There is more kaolinite in the termite mound than in the surrounding soil. On the gallery walls are numerous small bright white patches of almost pure kaolinite, with a little illite. Illite is not detected in the bauxite or mottled zone, but is quite abundant in the kaolinitic plasmic horizon. These white spots of clay appear to be particles of the plasmic zone brought up by termites. Incorporation of kaolinite into the "Cathedral" wall may act to strengthen the structure, and indeed may be a feature that allows "Cathedral" mounds to be built out of otherwise weak soil material. The sourcing of kaolinite from the plasmic zone via termite activity explains the increased kaolinite content in the soil and upper bauxite (Figure 4).

Table 1: Mineralogical composition (wt. %) of the upper parts of the Andoom Bauxite.

	Termite nest wall	Soil A-horizon	Soil B-horizon	Bauxite at 3 m
Gibbsite	9	6	10	68
Boehmite	27	24	28	17
Quartz	7	8	6	0
Anatase	2	2	2	2
Kaolinite	46	34	39	4
Hematite	4	8	7	9
PDM	0	17	12	0

PDM: Poorly Diffracting Material, largely alumina.

A third form of bioturbation may arise from the activity of larger burrowing insects such as beetle larvae. There are several kinds of larvae that live in the soil and eat plant roots. Some, such as the lawn scarab, and weevils of the genus *Leptopius*, form rotation ellipse-shaped pupal cases out of the soil material. On completion of their metamorphosis, they cut a hole near one end of their pupal case and then burrow up to the surface. In most places the pupal cases are too fragile to survive for long, but in some circumstances they become hardened. One well-known locality for such hardening is in the Bridgewater Formation on Eyre Peninsula in South Australia, where pupal cases are petrified by calcite. At Weipa rare, large nodules have been compared with pupal cases of *Leptopius duponti* (Tilley *et al.* 1977). Smaller ellipsoidal nodules are common, mostly in the upper parts of the bauxite, but in some places they occur throughout the bauxite (Figure 5).

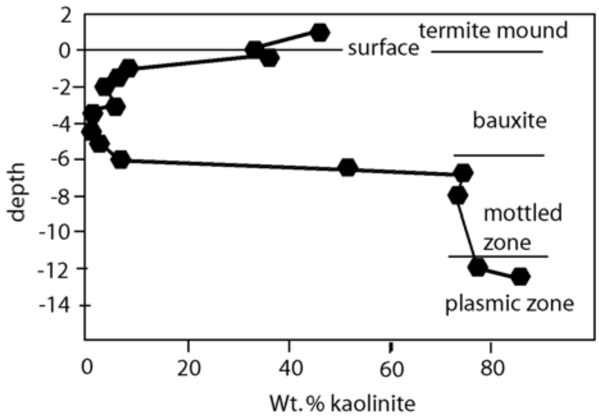

Figure 4: Kaolinite content through the plasmic, mottled and bauxite horizons, in soil at the surface and in a Cathedral termite nest wall.

A selection of the more symmetrical, rotation ellipse-shaped nodules reveals considerable similarity in their dimension, suggesting similar origins. (Table 2). They are tentatively identified as the pupal cases of a medium-sized beetle

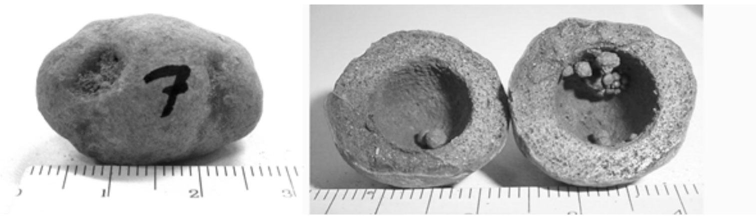

Figure 5: Nodule from the Weipa bauxite. Left, entire, showing aperture plugged by small particles. Right, sectioned, showing hollow interior and a few adventitious ooliths.

Table 2: Dimensions of rotation ellipse-shaped nodules.

	Nodule length	Nodule diameter	Cavity diam. (D)	Cavity length (L)	Cavity L/D
mean (19)	28.5	20.4	10.4	19	1.8
SD	3.3	2.4	0.7	2.6	0.3

Just how important these are in the evolution of the profile is not yet clear. Their cementation is quite strong, suggesting that they affect the local bauxite chemistry enough to solubilize components and subsequently become cemented, presumably by silica, alumina, hematite or goethite. Their presence may also allow some limits to be put on the age of the surrounding bauxite. At Elliston in South Australia the pupal cases are reported to be 40 to 100 ka.

There is nothing static, or "fossil" about the Weipa bauxite. It is in constant modification; from the top down by fire and gravity, from the bottom up by termite and other insect activity, and continually churned and stirred by roots and burrowing.

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