All pisolithic bauxite deposits are transported – Really?

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Introduction

The literature attributes the majority of the pisolithic bauxite formation to the *in-situ* weathering of an Al-rich rock; granite, basalt, arkose etc is. On the face of it this supposition makes good sense because geologists know that alumina is immobile in weathering environments, TiO_2, common in bauxites, is also immobile, while SiO_2, FeO, and the alkalis are all readily mobile (e.g. Wilson 2004) and therefore removed leaving Al_2O_3 and TiO_2 with greater or lesser amounts of SiO_2 and Fe_2O_2 is bauxite if the Al/Fe ratio is high enough.

Most bauxite deposits are one of two types; pisolithic or massive. The former are by far the more common (e.g. Weipa, Mitchell Plateau, Southern Highlands of NSW), but in some deposits both occur (e.g. Darling Range) and totally massive deposits are not very common (e.g. intra-basaltic bauxite on the Monaro). All bauxite deposits sit over a 'lateritic'' profile formed in local country rock. The profile may be extremely thick (10's m, e.g. Weipa) to very thin (< 1 m) (e.g. Monaro Basalt) or, if the concept of a complete 'lateritic' profile is accepted, a truncated one. The mottled zone of the "laterite" rarely contains pisoliths but irregularly to semi-spherically shaped glaebules of Fe-oxyhydroxides that are widely space in a coloured or pale plasma.

Most pisolithic bauxites occur as a mass of pisoliths between 2 and 8 mm in diameter which are for the most part well packed. Occasional nodules (>10 mm) occur as lenses, stringers or scattered through the pisoliths. The pisolithic material may be set in a fine-grained matrix or be open.

Geochemically most bauxite deposits show some relationship to their underlying country rock, (e.g. Sadleir & Gilkes 1974, Taylor & Ruxton 1987). Naturally all contain significant Al_2O_3 and Fe_2O_3 with more or less TiO_2 and SiO_2.

With the exception of karstic bauxite deposits most occur in relatively high landscape positions capping hills and plateaux and/or draping their flanks.

Although this summary is brief it does point to many similarities between pisolithic bauxite deposits in Australia and elsewhere. At Weipa Taylor & Eggleton (2008) have shown deposits of the type described above are transported pisolith deposits over 'lateritic' weathering profiles. Some time ago Ollier & Galloway (1990) posited that all or most 'lateritic' weathering profiles had within them an unconformity where the upper ferruginous cap was a transported capping to the remainder of the profile. Many other authors have written of this (e.g. Anand and Paine 2002). This postulate has however not received much mileage in consideration of the origin of 'laterite' profiles not in bauxite formation.

Bauxite deposits of the Southern Highlands of N.S.W.

Jaquet (1901), Raggatt (1939), Owen (1954), Campbell (1992), Ruxton and Taylor (1992), and Taylor and Ruxton (1997) have all described various parts of the bauxite deposits of the Southern Highlands of New South Wales. Additionally several companies have held EL's over the deposits and described their findings in Reports to the NSW Government and on the web (e.g. Penrose PLA).

From the best field and available drilling data we have, all the bauxite deposits in the Southern Highlands are associated with Palaeogene basalts which occur scattered across much of the region. Many overlie, at least in part, deeply weathered basalt, but many also overlie deeply weathered Palaeozoic or Mesozoic rocks and Palaeogene quartzose and clay-rich-sediments. The pisolithic bauxites overlie deeply weathered rocks/sediments in which lateritic weathering profiles are the norm but on basalt complete lateritic profiles are not common;pallid zones are thin or absent (Brown *et al.* 1994).

The bulk of the bauxite deposits are composed of a mass of pisoliths varying in size from about 3 mm to 8 mm and contain nodules as well. At many sites these are cemented by gibbsite stained by more or less by iron oxyhydroxide, particularly near the surface and where the cement is not too dense a matrix of fine material including ooliths and other fine-grained debris can be observed. These deposits frequently show a rude bedding, often picked out by a stratum of nodules. At one site (Fire Tower) cross bedding is visible in several places. At several localities a sharp irregular boundary between the mottled zone and the pisoliths is observed and this we interoperate to be an unconformity.

The pisoliths that make up these deposits have a very similar fabric to those described by Taylor & Eggleton (2008). They are made up of a core that may comprise as much as 90% or as little as 60% of the pisolith. Cores are composed of ooliths and/or broken pisolith grains and matrix in a sub-spherical mass; many cores are composed of PDM of varying colour and shape, from broken fragments of larger PDM grains to sub-spherical abraded grains that vary in colour from cream to black; and much less commonly earthy fine-grained red-brown coloured mass, again sub-spherical in shape. The pisolith cores are invariably cracked concentrically or radially. Apart from PDM cores, others are composed of gibbsite, Fe-oxyhydroxides, maghemite, quartz, Ti-minerals. PDM cores may also contain fine-grained quartz. There is no noticeable differentiation of pisoliths with different core material through individual deposits, so, for example, PDM-cored pisoliths occur in about equally proportions vertically and horizontally through the deposit.

PDM-cored pisoliths are abundant throughout the deposit as are bauxite nodules composed of PDM, hematite and maghemite (Eggleton & Taylor, previous talk)

Pisolith cortices vary in number and thickness. There may be as few as two cortices to as many as 10, with 5-6 being the norm. Each cortical layer may be continuous around the whole pisolith or continuous lenticular, or incomplete and in places fill depressions in the earlier cortex or core. Commonly sharp cross-cutting discontinuities cutting across cortices indicate erosion during cortication. The cortices are invariably composed of gibbsite and Fe-oxyhydroxides with minor quartz and Ti-minerals.

The geochemistry of the bauxites is similar in respect of major elements with between 30 and 60% Al_2O_3, 20 and 50 % Fe_2O_3, 1 and 10% SiO_2 and 0.5 and 4% TiO_2 which is typical of most pisolithic bauxites deposits. More interestingly geochemical evidence points to the basalts as the parent material of the bauxites. They contain Al, Ti, V and Cr in similar proportions to the content of these elements in the basalt, though 3-4 times more.

From SEM examination the matrix between the pisoliths is predominantly composed of ooliths with minor quartz grains and much fine ilmenite or pseudorutile. As in the pisoliths, many of the quartz grains in the matrix are etched and/or altered to gibbsite. Voids are commonly lined with gibbsite . Some of the quartz grains are well rounded, but most are angular and etched. The isotropic clay-sized particles and ooliths are themselves aggregated into larger masses with yellow-brown coloured very fine-grained materials

The pisoliths and ooliths are in most places set in a matrix of gibbsite, bearing packed ooliths as well as etched quartz grains, ilmenite or pseudorutile, spinel fragments and rare zircon. Many but by no means all show concentric arrangements of the FeTi-oxide particles and some show more extensive zoning. Some contain a core of a single etched quartz grain. The ooliths are of different composition from the matrix, having more Fe overall and many small Fe/Ti-rich particles within them.

Discussion

So what does all this mean? If one accepts the geochemical evidence alone, then the pisolithic bauxite deposits obviously form from the basalt on the Southern Highlands. This, of course, does not mean they are *in situ*, just that the materials making up the bauxite came from weathered basalt. The other data we present show clearly that the bauxite deposits and their component fabric elements (pisoliths, ooliths, nodules) are transported accumulations of bauxite. The magnetic PDM-rich pisoliths and nodules throughout the bauxite profile provide telling evidence for transport. The PDM is formed at or very near the surface (Eggleton and Taylor, this volume) but are now mixed through the deposits. Logically then the materials form in weathered basalt and are then transported and accumulated in a lower landscape position. As the bauxite accumulates it forms an erosion resistant feature in the valley and over the years landscape inversion leaves it atop small mesas.

This is a second example we have reported, of pisolithic bauxites occurring unconformably above (stratigraphically) the materials from which they formed. As we showed in our introduction this seems a far more common situation than that they simply form the uppermost part of an *in situ* 'lateritic' profile. It goes a long way to justifying the unconformity in 'lateritc' profiles posited by Ollier and Galloway (1990) and also explains the pisolithic bauxites on slopes and valley bottoms in the Darling Range bauxite, but some are *in situ*, and the valley-fills of pisolith bauxite at Gove. We contend the situations we describe is more common than has been recognised to date.

References

Anand R. R.& Paine M. 2002 Regolith geology of the Yilgarn Craton, Western Australia: implications for exploration. Australian Journal of Earth Sciences 49 3 – 162

Brown, M.C., McQueen, K.G. & Taylor, G. (1994) A core through the Monaro Basalt: Bega (BMR) No 7. Australian Journal of Earth Sciences, 41, 71-72.

Campbell I. (1992) Lateritic bauxite deposits of the Moss Vale-Wingello district of N.S.W. Unpublished Honours Thesis, University of Technology Sydney, 87 pp plus appendices and map. (currently held in the N.S.W. Geological Survey Library).

Eggleton, R.A. & Taylor, G. (eds) (2008) Weipa Bauxite, Northern Australia . Australian Journal of Earth Sciences Supplement, 55 103 pp

Ollier, C. D. & Galloway, R. W. (1990) The laterite profile, ferricrete and unconformity. Catena, 17, 97-109.

Owen, H, B. (1954) Bauxite in Australia. Australian bureau of Mineral resources, Geology and Geophysics, Bulletin 24. 234pp.

Penrose PLA 3774 and Wingello PLA 7279, (2009) http://www.australianbauxite.com.au/tenements/windellemabungonia.html

Raggatt, H.G. (1939) Ferruginous Bauxite Deposits of the Moss Vale District. Report. Of the New South Wales Department of Mines, Unpublished.

Ruxton, B. P. & Taylor, G. (1982) The Cainozoic geology of the Middle Shoalhaven Plain. Journal of the Geological Society of Australia, 29, 239-246.

Sadleir, S.B. & Gilkes, R. J. 1974 Development of bauxite in relation to parent material near Jarrahdale. Western Australia Journal of the Geological Society of Australia, 23, 333-344.

Taylor, G. & Eggleton, R.A. (2008) Genesis of pisoliths and of the Weipa Bauxite deposit, northern Queensland. Australian Journal of Earth Sciences, 55 Suppliment, S87-S103.

Taylor, G. & Ruxton, B. P. (1987) A duricrust catena in south-east Australia. Zeitschrift fur Geomorphologie, 31, 385-410.

Wilson, M.J. 2004 Weathering of the primary rock-forming minerals: process, producys and rates. Clay Minerals, 39, 233-266.