Mt MAGNET DISTRICT, WESTERN AUSTRALIA

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LOCATION

Mt Magnet is located 560 km north-northeast of Perth, at about 28°03′S, 117°48′E in the KIRKALOCKA (SH50-3) 1:250 000 map sheet area. The Stellar and Quasar Au deposits, about 5 km apart, lie some 6 km to the west and southwest of Mt Magnet, within the Boorgardie Synform of the Murchison Province of the Yilgarn Craton (Figure 1). This summary is largely derived from Robertson *et al.* (1994).

PHYSICAL SETTING

Geology

The Mount Magnet greenstone belt, composed of ultramafic, mafic and felsic volcanic rocks, with subordinate sediments, banded iron-formation (BIF) and chert, is intruded by minor felsic and mafic rocks and surrounded by gneissic granitoids (Archibald, 1982). It has been complexly deformed into a major domal structure, with a steeply plunging synform, the Boorgardie Synform (Figure 1). Major faulting occurs on the eastern and western margins of the belt.

In the study area, the basement consists of talc-carbonate altered ultramafic flows of the Boorgardie Formation, cut by fine- to medium-grained felsic intrusives. The stratigraphically younger Sirdar Formation hosts the majority of exposed mineralisation in the Hill 50 Mine area and consists of banded iron-formations intercalated with mafic, ultramafic and felsic flows and tuffs (Thompson *et al*., 1990).

Geomorphology

The Mt Magnet district occurs in an area of subdued relief where drainage and associated sediments comprise about 75% of the landscape (Figure 2). To the north of the Quasar Au deposit, low rises and backslopes of breakaways are characterised by ferruginous saprolite and saprolite and in some areas bedrock. Banded iron-formation forms strike ridges to the northeast of Quasar. Regionally, the Boorgardie Formation is mostly obscured by a cover of Quaternary colluvium and alluvium, which is partly underlain by Tertiary palaeochannel sediments. The thickness of colluvial–alluvial cover is variable and generally thickens away from the enclosing BIF ridges. Weathered bedrock exposure in

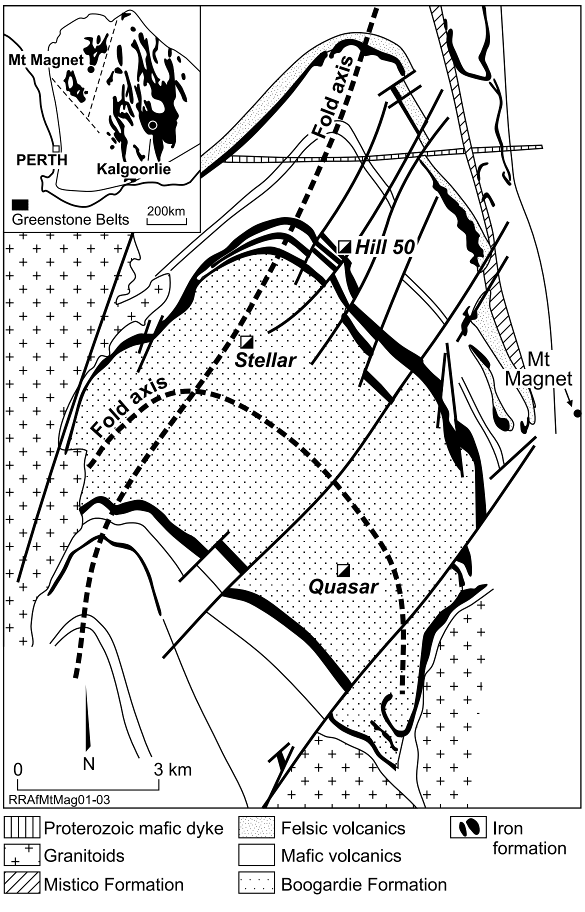

Figure 1. Geological map of the Mt Magnet area (after Thompson *et al*., 1990).

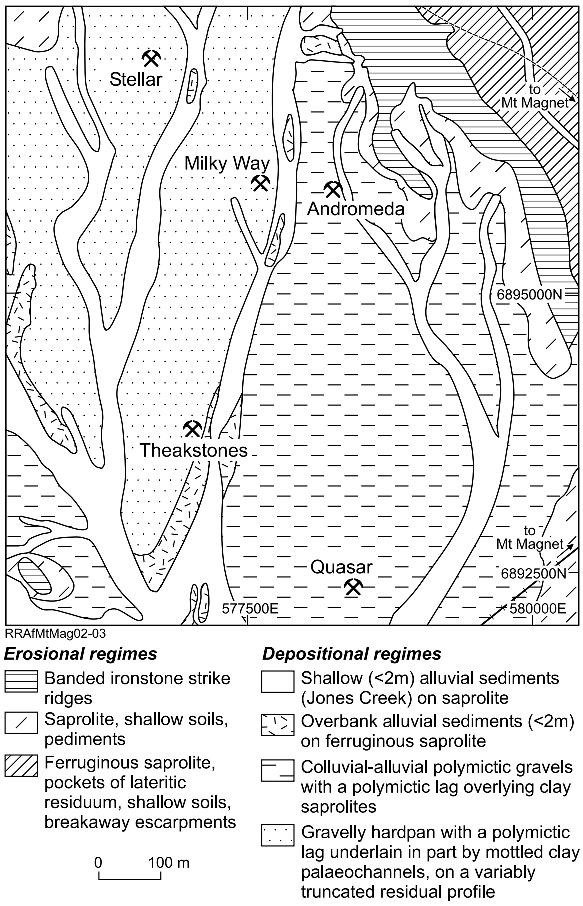

Figure 2. Simplified regolith–landform map of the Mt Magnet

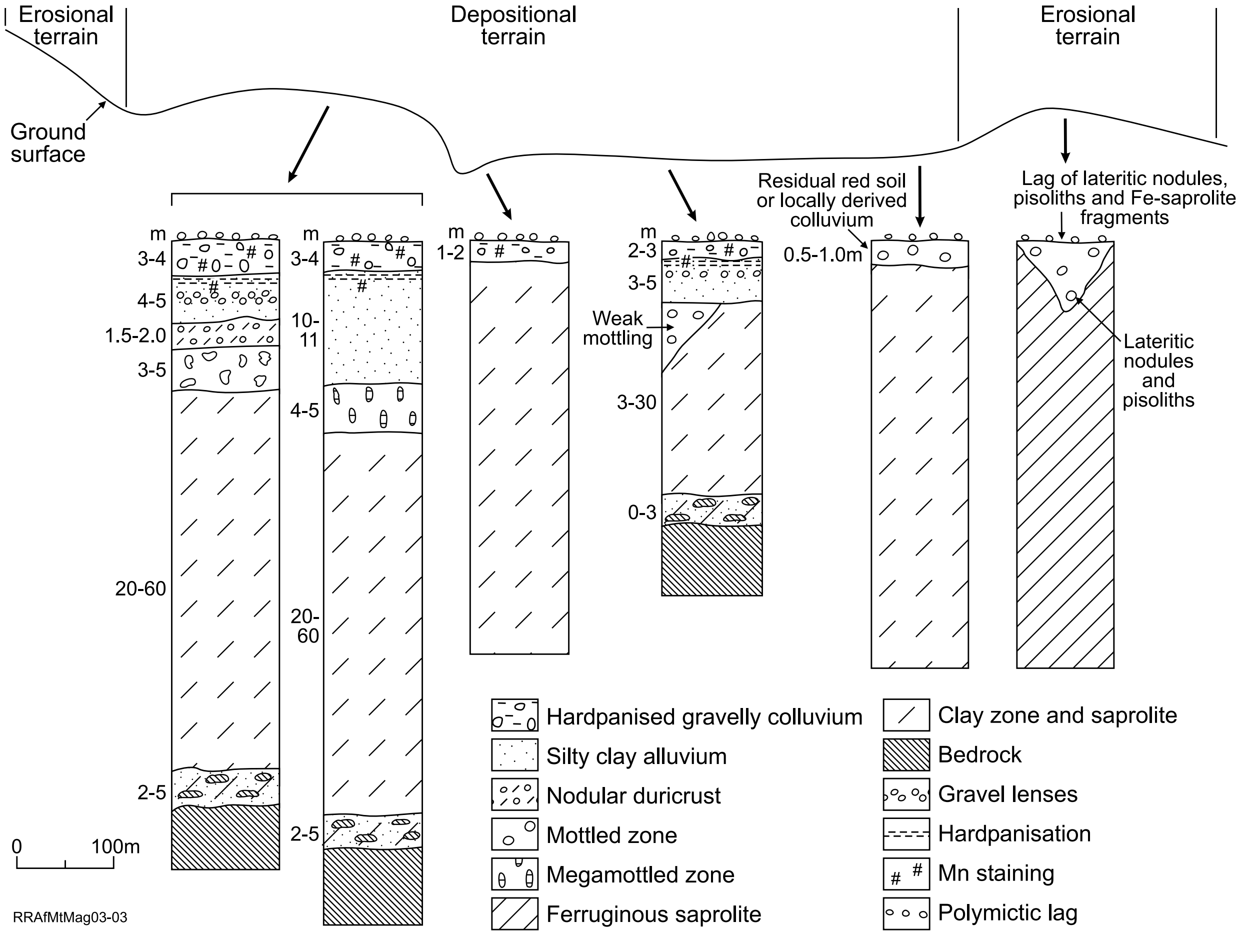

Figure 3. Generalised regolith–landform relationships for the mapped area.

the synform interior are restricted to the incised Jones Creek (Figure 2).

Climate and vegetation

The climate is semi-arid to arid with an average annual rainfall of 234 mm. The vegetation is dominated by mulga (Acacia spp.) and by various types of poverty bush and turpentine (Eremophila spp.), with isolated kurrajong trees on depositional surfaces.

REGOLITH–LANDFORM RELATIONSHIPS

Regolith–landform relationships were established by mapping the regolith of a 5 x 5 km area, encompassing both Quasar and Stellar Au deposits at 1:25 000 scale (Figures 2 and 3). The regolith stratigraphy and its characteristics were determined from drill cuttings and mine exposures and formed the basis for 3-D modelling of the regolith around both mines. Two main geomorphic regimes are identified within the mapped area. Erosional areas occupy about 25% of the area. These consist of ferruginous saprolite, saprolite, or fresh bedrock, now either exposed or concealed beneath modern soils or a veneer of locally derived sediments. They form areas of relief, some with outcropping BIF ridges. Pediments to the BIF ridges are gentle slopes, with red earths and a lag of coarse BIF fragments, vein quartz, lateritic nodules and ferruginous saprolite. Some BIF outcrops within these pediments. The erosional areas may be subdivided into:

(1) Outcropping, semi-continuous, BIF strike ridges, north of Stellar, which are deeply weathered.

(2) Truncated, saprolitic to ferruginous profiles that form generally concave slopes, flanking the ridges. These are covered by a thin, red, residual soil, mantled by a coarse lag of BIF and vein quartz. Bedrock commonly outcrops near the ridges but becomes progressively buried down slope, passing into a depositional regime.

(3) Breakaways occur on the northern margin of the enclosing BIF ridges in the northeast. Ferruginous saprolite and scattered patches of lateritic duricrust are exposed on the upper part and clay-rich, ferruginous saprolite on the lower breakaway surfaces. They are mantled by a thin, residual soil with BIF fragments from upslope. Tubular voids, up to a metre wide, filled with lateritic materials and probably representing relics of tree root structures, are widely distributed across the erosional surface.

Depositional areas (75% of the area) consist of locally to distally derived colluvium–alluvium that covers the lower slopes and form the plains (Figures 2 and 3). They mantle both duricrust-capped and variably truncated saprolitic profiles and are strewn with coarse polymictic lag. Concealed beneath are earlier palaeovalleys, filled with megamottled, clay-rich and ferruginous materials. There are four units within these depositional regimes (Figure 2):

(1) Active, modern, south-flowing, drainage sediments of Jones Creek that overlie hardpanised red–brown, silty clay, with interbedded gravel lenses, or exposed underlying basement.

(2) Overbank deposits, along major drainages with up to 2 metres of hardpanised cover, resting on ferruginous saprolite or a saprolitic substrate.

(3) Outwash colluvial–alluvial polymictic gravels (ferruginous pisoliths, nodules and lithic fragments in a red–brown, clay–silt matrix) form plains and are well exposed in the Quasar Pit. They occur down slope and are less than 8 m thick. The upper 5 m are commonly hardpanised to a variable depth. The sediments generally overlie saprolite on ultramafic rocks and clay zone on felsic rocks. The upper, ferruginous, duricrust zone is absent, with only scattered patches of weakly ferruginous saprolite occur. Near Quasar, infilled palaeochannels increase the total thickness of transported cover to 14 m; thin dolomitic horizons have developed in these palaeochannels.

(4) Thick, complex, transported cover, mainly west of Jones Creek, consisting of three main units — a basal, mottled, puggy clay, overlain by red–brown clays with lenses of ferruginous gravel, coarse gravel and an upper horizon of gravelly hardpan, 2-5 m thick. The upper 5 m of the profile is hardpanised and overlies either a full or partly truncated lateritic profile. The surface is strewn with a coarse, polymictic lag of ferruginous lithic fragments, maghemite-rich ferruginous gravels, ferruginous saprolite and vein quartz.

REGOLITH CHARACTERISATION AND PALAEOTOPGRAPHY

Stellar Pit

Prior to mining, the Stellar area had a lag-strewn surface on colluvium–alluvium, sloping gently (1:115) to the south. The regolith consists of a cover of colluvial–alluvial and palaeochannel sediments, thickening from 10 in the west to 22 m in the east, unconformably overlying bedrock weathered to a depth of up to 60 m (Figure 4). The thickness of colluvium–alluvium increases to the northwest. The colluvium–alluvium is composed of two sedimentary units: (1) a lower, red-brown, silty clay with coarse, gravelly lenses, rounded quartz pebbles and remnant trough bedding, and (2) an upper hardpan from 0–3 m depth, in the coarse gravel. Each unit consists of several facies.

The sediments of the palaeochannel are well exposed in the southeastern wall of Stellar Pit, are unconformable on the basement and extend to the east and southeast, reaching a maximum thickness of 18 m. The residual regolith surface, onto which the palaeochannel sediments were deposited, probably had a palaeohigh to the north and a localised palaeohigh in what is

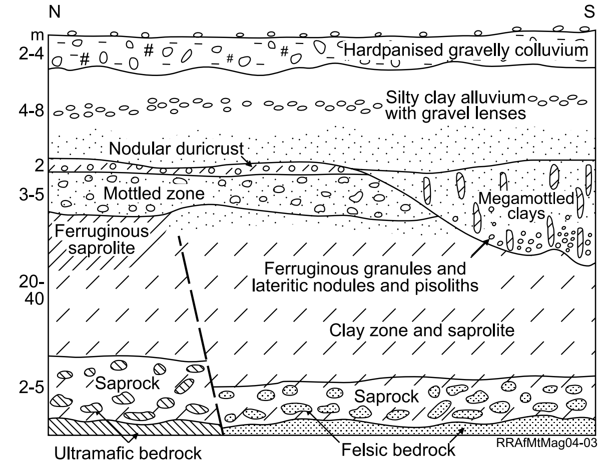

Figure 4. Regolith stratigraphy, Stellar Pit.

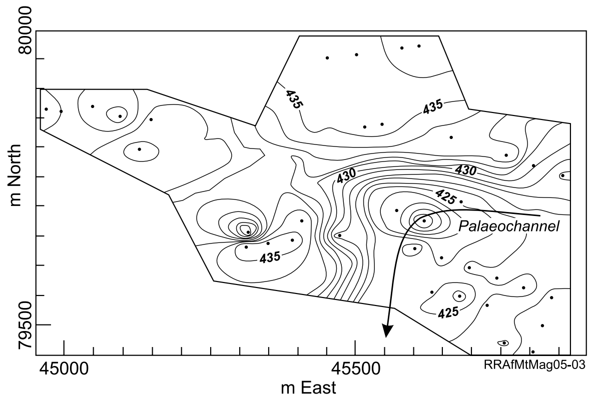

Figure 5. Contoured palaeotopogarphy of eroded basement at Stellar showing the deeply eroded and curved palaeochannel to the southeast. Local grid coordinates.

now, the southeast wall of the pit, although some modification of the landscape probably occurred prior to colluvium–alluvium deposition. The area east and southeast of the pit had been eroded into a curved channel (Figure 5), possibly with an entry point to the east and exit to the south. The northern and northwestern wall of the channel was steep (1:10) but the southeastern part sloped quite gently upward (1:75) to the southeast.

The sediments consist of a grey, plastic clay and minor sandy clay (smectite and kaolinite). Hematitic brown and yellow megamottles occur as vertically elongate aggregates up to 400 mm long. This megamottled horizon is typical of palaeochannel environments in the Yilgarn (Singer, 1979; Anand *et al*., 1993; Kern and Commander, 1993). Creamy, grey clays become more prominent with increasing depth and contain elongate, columnar cracking structures which expose roots, commonly sheathed in Fe-rich accumulations. An irregular zone of sepiolite masses occurs towards the top of the palaeochannel.

The residual profile appears to be essentially 'complete' but the upper, ferruginous horizon transgresses the unconformity between bedrock and palaeochannel. In the northwest, 1.5–2.0 m of duricrust forms the principal substrate to 10 m of colluvium-alluvium. A mottled zone, transitional between saprolite, ferruginous saprolite and duricrust is preferentially developed on ultramafic rocks. In the southeast, the colluvium–alluvium is separated from felsic saprolite by palaeochannel sediments in the southeast of the pit. The base of oxidation is variable but tends to be very deep, generally >60 m.

Quartz–tourmaline veins in the basement have weathered *in situ* to coarse, rounded cobbles that trace the original projection of the veins into the duricrust. Similar cobbles are widely dispersed in the upper parts of the duricrust, suggesting lateral transport by mass flow.

There is a nodular vermiform duricrust over ultramafic rocks whereas the felsic rocks have an indurated mottled clay with abundant lateritic nodules. Nodular duricrust consists of yellowish brown to reddish brown, goethite-rich nodules, set in a pale to yellowish brown, sandy matrix. Between the nodules, a network of pale kaolinite and quartz patches occurs. They have resulted from removal from the matrix. Irregular to ellipsoidal voids also occur in the matrix, some of which have earthy infill of kaolinite and quartz. There are no systematic differences in mineralogy between duricrust over felsic and ultramafic rocks.

In polished section, the matrix of the nodular duricrust both from felsic and ultramafic profiles has abundant angular grains of detrital quartz. The quartz grains vary widely from 20–200 µm, with a predominance at 50–100 µm. Many quartz grains show corrosion, solution, partial replacement and impregnation by hematite and goethite. Cores and cutans of some nodules contain quartz but others are quartz free. The Fe oxides are dominantly goethite, or a mixture of goethite and hematite. Some cutans have abundant detrital quartz and retain the fabric of the matrix.

The geochemical characteristics of the parent rock (e.g., Cr, Fe) diminishes from the bottom to the top of the profile but remains evident in the saprolite and mottled clay zones. However, in duricrust, Al, Si, Fe, Zr, Cr and Ni contents are very similar over both felsic and ultramafic rocks and suggest that the duricrust has developed in transported material.

Ferruginous granules separated from palaeochannel sediments are detrital and have an earthy to silvery, metallic lustre and a few have thin, earthy cutans. Some are magnetic, others are non-magnetic. They largely consist of hematite and maghemite, with small amounts of goethite, kaolinite and quartz. Ferruginous granules are comprised mainly of Fe_2O_3 (>62%), SiO_2 (10-12%) and Al_2O_3 (5-15%).

Quasar Pit

The pre-mining surface of the Quasar Pit area was nearly flat in the west with a very low, arcuate, approximately north-trending ridge in the centre and east. This surface was strewn with polymictic lag and was underlain by about 5 m of hardpanised colluvium–alluvium (Figure 6). The basement on which hardpansied colluvium–alluvium was deposited slopes to the south, suggesting that either the depression in which the palaeochannel sediments were deposited was incompletely filled

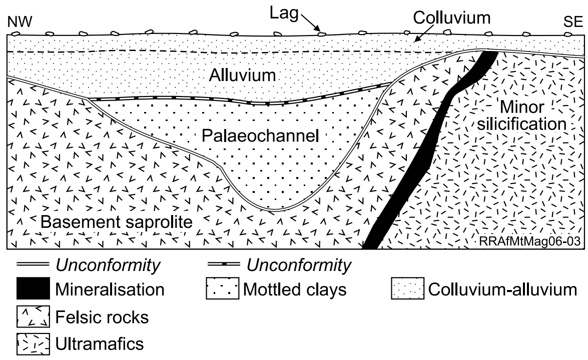

Figure 6. Regolith geology at Quasar showing an eroded basement, a palaeovalley infilled with mottled clays and cover of colluvium–alluvium.

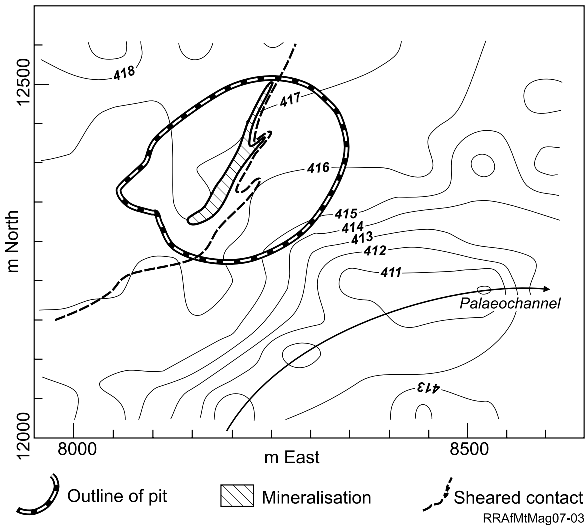

Figure 7. Contoured basement topography at Quasar with curved palaeovalley to the southeast. Local grid coordinates.

or this area was partly eroded after deposition of these sediments. The gradients, prior to deposition of the colluvium were gentle (1:80) and the thickness of the colluvium is quite consistent (4–8 m), in contrast to Stellar. Mechanical dispersion on the residual regolith, just prior to deposition of the colluvium, would generally have been to the south.

The colluvium–alluvium is largely composed of ferruginous nodules and pisoliths (with and without cutans), and fragments of quartz and ferruginous saprolite, in a silty clay matrix. The upper part of this transported cover consists of poorly sorted gravels with coarse, angular fragments of quartz and lithic material, typical of colluvium. At lower levels lateritic debris is dominant, and the transported cover becomes matrix dominated with associated manganese staining. Towards its base, the colluvium–alluvium contains coarse, poorly sorted gravelly lenses, consisting of rounded quartz pebbles and lateritic debris, indicating an alluvial environment.

The palaeochannel sediments are restricted to the southwest and were deposited in an arcuate channel (Figure 7) eroded into the basement; the flow direction was possibly to the southwest. The channel has a steeper gradient on its northern margin and a lesser gradient to the south, similar to Stellar, but it differs in that the sediments are generally only 3 m thick (locally to 6 m). The sediments consist of white kaolinitic clays with distinct layers of ferruginous gravels. No palaeochannel sediments were exposed in the Quasar pit.

The basement consists of weakly mottled, clay-rich, ultramafic saprolite; kaolinitic saprolite; silicified felsic porphyry. Some weak mottling also occurs in the clay-rich, felsic saprolite, where the base of oxidation steepens towards the structural contact. The weathering front on the ultramafic rocks is around 35 m depth, and on the felsic rocks it ranges from a few metres, to over 40 m near the shear zone.

REGOLITH–LANDSCAPE EVOLUTION

At Stellar, the composition of lower residual horizons (mottled zone and saprolite) are related to their parent rocks. However, in duricrust, Al, Si, Fe, Zr, Cr and Ni contents are very similar over both felsic and ultramafic rocks implying that it developed in transported material. Differing remnant fabrics in the lateritic nodules and pisoliths also indicate formation from mixed parent materials. These nodules and pisoliths were formed *in situ* in clay-rich parent materials. Thus, the petrographic and geochemical evidence suggest that the lateritic profiles at Stellar are polygenetic. From this it is suggested that:

(i) Deep weathering formed clay-rich saprolite above felsic and ultramafic bedrocks. Subsequent mass flow led to a mixed surface horizon that formed the parent material of much of the duricrust.

(ii) Ferruginisation during and after sedimentation developed nodules and pisoliths in this mixed, semi-residual to transported material, resulting in petrographic and geochemical homogenisation. The duricrust formed from vertical diffusion and lateral movement of Fe in groundwater, followed by precipitation of Fe oxides in the upper profile.

Thus, it is suggested that the duricrust at Stellar consists of allochthonous weathered material that was redistributed by water and later recemented.

At both Quasar and Stellar, the channel morphologies suggest meandering, fluvial channels, with deep incision and a steep bank on the outside, and a gentle slope and lesser incision (due to lower water velocities) on the inside. The characteristics of sediments indicate a complex history of deposition and subsequent modification by weathering. The kaolinite and quartz in these sediments were probably derived from the erosion of an existing regolith, suggesting that the landsurface may have been deeply weathered prior to the Eocene. The sediments contain detrital hematite–maghemite-rich ferruginous granules, transported with other clastic material, including quartz. The granules were presumably derived by erosion of an earlier, possibly pre-Eocene, lateritic profile that predates incision of the palaeochannel. The channel sediments and adjacent wall rocks were then further weathered, with megamottles forming in channel clays and hematitic and goethitic pisoliths and nodules forming on felsic and ultramafic rocks. The presence of smectite in the upper saprolite and duricrust and of sepiolite in the palaeochannel sediments and colluvium–alluvium suggest that weathering under conditions of restricted drainage. In contrast, kaolinite is formed under a strongly leaching, acidic environment.

The colluvium–alluvium has been derived from the dismantling of the older regolith and is rich in ferruginous nodules and pisoliths. Although some are possibly proximal to a lateritic source, most are polymictic (fragments of BIF, ferruginous saprolite, saprolite, saprock and lateritic debris) and distal. The silty–clay matrix is largely derived from saprolite. The lower parts are largely alluvial and the upper parts colluvial, probably dominated by sheet wash. The upper two to three metres of colluvial–alluvial sediments have been silicified, to a red–brown hardpan.

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