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PAPERS

Cover Image : The cascade tufa at Otjikondavirongo, Kaokoland, Northern Namibia, showing the basal part of the tufa cliff, the actively accreting bryophyte curtain, the algae-filled pool at its base and the cave behind the curtain. The Herero place name signifies "Place beyond Places," with the sense of "The Outback", "The Back of Beyond" or "The Middle of Nowhere".

The Kalahari Group in the 400-m deep core borehole WW 203302, Northern Owambo Basin

R.McG. Miller [1], C. Lohe [2], S.T. Hasiotis [3], M. Quinger [2], R. Muyamba [4], R. Joseph [4] and A. Nguno [4]

[1]*Consulting Geologist, P.O. Box 11222, Windhoek, Namibia, <roymm36@mweb.com.na>*
[2]*Federal Institute for Geosciences and Natural Resources – BGR, Hannover, Germany*
[3]*Department of Geology, University of Kansas, Lawrence, USA*
[4]*Geological Survey, Windhoek, Namibia*

Key Words : Kalahari Group; Andoni Formation; Olukonda Formation; Owambo Basin; Cubango Megafan; bioturbation; seasonal climate; semi-arid; Tertiary; intermittent fluvial deposition; aeolian deposition; pedogenic calcrete; calcrete and dolocrete nodules; mud pellet clasts; reworked calcrete; aquifer; aquitard.

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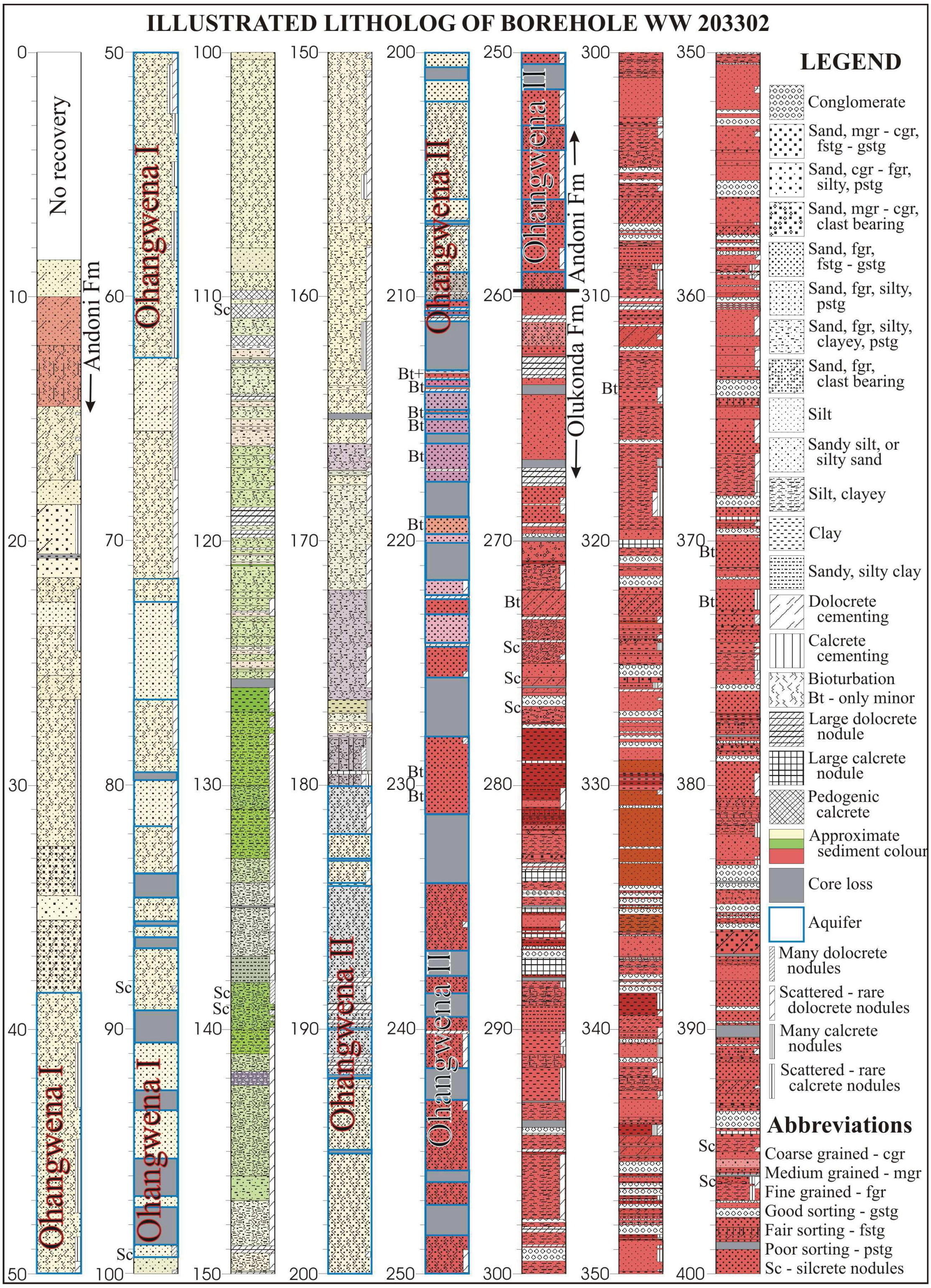
Submitted March, 2016

Extended Abstract: The borehole WW 203302 was drilled by the Federal Institute for Geosciences and Natural Resources (BGR) of Germany as part of the Ohangwena Groundwater Investigation Project in northern Namibia. It was completed early in 2015.

This is an incredible core. The total core loss was only 31.78 m (7.9%). It was 28.9 m (11.13%) in the Andoni Formation. Of this, more than half (18.4 m) was in the soft, water-saturated, totally unconsolidated Ohangwena I and II Aquifers. The core loss in the Olukonda Formation was 2.88 m (2.1%). The core reveals far more varied detail concerning sedimentology and post-depositional processes than any of the other boreholes have revealed. This report is based on the accompanying litholog of the borehole core. A graphic illustration of the litholog is presented below.

<u>Andoni Formation</u>

Sand is the primary component with quartz being by far the main mineral followed by feldspar (based on analyses of core boreholes WW 210216 and WW 201217) and then smectite clay. Well-rounded grains of probable aeolian origin form a significant component of the sands and were likely incorporated into the fluvial sediments from various sources. Occasional thin clay layers are present. There is evidence of bioturbation of wet sediment throughout almost the entire core from a depth of -11 m down to the last length of core logged. Palaeontological studies of the core boreholes WW 210216 and WW 201217 suggest that the environment was a grassland savannah (Fenner, 2010). The climate throughout deposition will have been seasonal and the lithology is suggestive of more humid and less humid periods. The latter culminated in very dry conditions with only limited annual summer rainfall towards the end of deposition of the aquitard between the Ohangwena I and II Aquifers (four stacked pedogenic calcretes/dolocretes), and in extreme aridity after deposition of the uppermost aquitard. Calcrete or dolocrete nodules of varying sizes occur throughout most of the section but can be noticeably absent or rare in the good aquifers. A few thin layers (≤ 1 m) of clustered nodules are suggestive of pedogenic calcrete horizons. Silcrete nodules are rare. The Perched (presumed), the Ohangwena I and the Ohangwena II Aquifers are present.



Graphic rendering of the core from borehole WW 203302

<u>Perched Aquifer : 0 m to -30 m</u>

The first 8.5 m of the borehole were not recovered but must include the Perched Aquifer which is described from 31 other boreholes in the area. This varies from 0 m to 30 m in thickness and averages 10-11 m. It consists primarily of medium- to fine-grained, moderately to well-sorted quartz sand. The upper 1-3 m are aeolian in origin and well-sorted. Below this the aeolian component is still significant. Sorting and grain size generally decrease downwards. Poorly sorted layers, often variably cemented by calcrete, occur in places between better sorted layers. Rainfall normally drains and disappears into the surface layers within about 24 hours of any heavy downpour.

Aquitard between the Perched and Ohangwena I Aquifers : -8.5 m to -38.5 m

This consists of calcrete- or dolocrete-cemented sand which is largely fine grained and poorly sorted. The sands were deposited during gradually waning rainfall as the whole of the African continent became progressively more arid. Thus, limited runoff was unable to produce well-sorted sands. Fluvial sediment accumulation would have been slow and ceased altogether between 4 and 3 million years ago as the climate became increasingly more arid (Miller, 2008; Miller *et al*. 2010). This is reflected in the upward increase in the proportion of well-rounded aeolian grains in the sands. The uppermost 3 m of the core is the most intensely cemented and probably represents a long-lived palaeosurface upon which the aeolian sheet sands and dunes of the Kalahari were deposited. The core is very hard down to -18.5 m. Below this, the cementing decreases and the core gradually becomes softer.

Ohangwena I Aquifer : -38.5 m to -99.3 m

This consists of very light yellow, moderately well-sorted to well-sorted, fine-grained sands. A 9 m thick section in the middle that is well-consolidated and cemented by calcrete and dolocrete divides the aquifer into upper and lower parts. The lower part is 28 m thick, is very uniform, well-sorted and water saturated. It is soft and totally unconsolidated. Drilling has significantly disturbed the core in this 28 m section and core loss within it was 7.7 m. The upper part of the aquifer is 24 m thick and is somewhat less well-sorted. These well-sorted sands suggest a much wetter climate with stronger runoff that was able to produce good sorting of the transported sands before they were deposited.

Aquitard between the Ohangwena I and Ohangwena II Aquifers : -99.3 m to -180 m

The sands in this section are fine-grained, poorly sorted and often clayey to very clayey. The primary colour of the sands, before modification by bioturbation, is very light yellow to very light greyish yellow down to -110.77 m, very light brown down to -126 m, light green to green down to -149.16 m, very light yellow or very light greyish yellow to -180 m. There are four clay layers, two from -126 to -127 m and from -137 to -138.05 m are green, one from -141.73 to -142.26 m is deep greyish purple, and one from -176.5 to -177.04 m is light olive. This succession was deposited during a period of lower rainfall during which lower volumes of runoff were unable to produce well-sorted sands. The rate of sediment accumulation would have been slower than for the aquifers. However, the sediments remained wet or even water-covered long enough for burrowing communities to establish themselves before the next layer of sediment was deposited. Water plants were also able to grow (Fenner, 2010). Over time, the climate slowly became significantly drier. Towards the end of deposition of the aquitard, the annual summer rainfall was limited and four stacked pedogenic calcretes/dolocretes developed just below the sediment surface. These occur between the depths of -109.77 m and -112.7 m. The uppermost of these four marks the point at which a biota that produced green burrows died out completely. The abundance of mainly green clay (smectite) suggests a source area dominated by weathered mafic rocks.

Ohangwena II Aquifer : -180 m to -259.73 m

This consists of very uniform, fine-grained, well-sorted sands. It is also totally unconsolidated, soft and has been disturbed by the drilling. Core loss was 7 m. In the upper 29 m the colour is very light yellow with light grey or light purple patches. The next 14 m are vari-coloured in shades of light yellow, light brown, purplish and rust red. Below -213 m the colour is rust red indicating an oxidised source and oxidising depositional and burial conditions. This aquifer is also presumed to have been deposited during a more humid period with higher and stronger runoff capable of producing well-sorted sands.

Olukonda Formation : -259.73 to -400 m

Red, consolidated, semi-consolidated or soft silt and sand dominate the Olukonda Formation. The sands are fine- to very fine-grained and range from being well-sorted (very few layers) to variably silty and/or clayey. The silts are rarely well-sorted and are normally variably clayey or sandy. Calcrete or dolocrete cementing occurs locally in both the sands and the silts, varies in intensity and is much more abundant in the Olukonda Formation than in the Andoni Formation. Calcrete and/or dolocrete nodules occur in places in varying concentrations but there are sections totally free of nodules and cement. Interbedded in many sections of the sands and silts are red clays and thin sandy conglomerate layers containing intrabasinal clasts of calcrete, dolocrete and clay pellets. The matrices of the conglomerates are invariably cemented by hard white calcrete (variably dolomitic) or variably calcareous dolocrete. The succession can be subdivided into sections dominated by specific lithologies or by interbeds of several sediment types. The well-sorted sands in the basal 30 m of the borehole are interbedded with poorly sorted sands and silts. They lack connectivity and, therefore, do not constitute an aquifer.

Post-depositional modification of the sediments

Bioturbation

Abundant dry-sediment bioturbation by burrowing biota followed fluvial deposition of layer upon thin layer of clay and well- to poorly sorted sands and silts. The evidence of bioturbation extends from a depth of -11 m to -195 m, the latter depth being 15 m into the top of the Ohangwena II Aquifer. Below this, with the exception of a burst of activity at 208 m, the evidence of bioturbation is rare and generally very faint. In the rest of the aquifer, delicate bioturbation structures could have been destroyed by stretching and compression of the disturbed core. In the Olukonda Formation, evidence of bioturbation remains rare and faint. Up to three periods of bioturbation can be recognised in the Andoni Formation. The first is often faint and subtle but is usually the most abundant. Colour of burrows varies from light yellow, light and darker green, light and dark purple, grey, light red and strong rust red. The last generation is the least abundant and is always a strong rust red in colour. In the dark purple and rust red burrows a *Cruziana*-type internal lamination is often present. A few roots and several calcified rhyzoliths occur. Locally, there is a jumbled mixture of sediments of different colours suggesting bioturbation by larger animals. Bioturbation was so intense that fine layering and bedding planes have been destroyed and coarse- to granule sized sand grains have become totally randomly scattered in unbedded clayey sands.

Carbonate cementation

Andoni Formation

Cementation by calcrete and dolocrete of the sands forming the first 3 m of the core is intense, is probably largely pedogenic in nature and signifies a long period (possibly as much as 1 million years) of a stable land surface. The intensity of this cementation slowly decreases downwards to -38.5 m. Below that only a few very short sections of the core, generally less than 1 m thick are hard and carbonate cemented. The four stacked pedogenic calcretes/dolocretes between -109 77 m and -112.7 m are also climate related.

Olukonda Formation

There is much more cementing of the Olukonda Formation by hard, white calcrete, dolomitic calcrete, dolocrete and calcareous dolocrete. The matrices of all the conglomerate layers are thoroughly cemented suggesting that these layers were permeable. Much of the laminated to very thinly bedded silt and sand is also cemented along the bedding again suggesting permeability of specific laminae or beds. This cementing is a diagenetic feature but it is unknown how long after deposition it took place.

Carbonate nodules

These are diagenetic features that formed long after deposition and generally deep within the sediment pile. They occur through most of the core, sometimes highly concentrated, sometimes scattered and sometimes rare. Sections of the core lack nodules altogether, particularly parts of the aquifers. The bulk of the nodules are hard, off-white calcareous dolocrete. Some are dolocrete and a few are calcrete. Some tiny white calcrete nodules are soft.

Silcrete nodules

These are rare.

Climate change summary

Well-rounded aeolian sand grains form a significant component of the sands throughout the core, having been incorporated into the fluvial sediments during flooding and sediment transport. A wealth of publications indicate that Kalahari deposition began when the climate became markedly seasonal about 70 Ma and subsequent to the high humidity of the mid Cretaceous (Miller, 2008, and references therein). Although seasonal, there were long-term cycles of higher and lower humidity. Thus, the Ohangwena II Aquifer was deposited during a more humid cycle with greater runoff during which surface flow was better able to sort the transported sediment load. The unsorted, clayey sediments of the aquitard between the Ohangwena I and II aquifers were deposited during an ensuing period with much less rainfall and runoff. This became steadily drier until there were long intervals of perhaps tens of thousands or even hundreds of thousands of years when there was no deposition and pedogenic calcretes/dolocretes could form just below the land surface. This saw the final demise of a biota that produced green burrows. A change back to more humid conditions saw higher runoff once again and deposition of the Ohangwena I Aquifer. Thereafter, drier conditions that followed saw deposition of the poorly sorted sediments of the upper aquitard. Deposition became ever slower and more sporadic as the climate became ever more arid until extreme aridity prevailed by about 4-3 Ma when the Arctic Ice Cap began to expand. The aeolian sheet sands and dunes of the Kalahari formed in the period between 3 Ma and 1 Ma (Miller, 2008, 2014; Miller *et al.* 2010).

Borehole WW 203302 location and statistics

Location of Borehole: 17.585983°S, 16.849619°E.
Collar elevation: 1130 mamsl.
Total Depth: 400 m.
Two Kalahari Group formations intersected, the Andoni and Olukonda formations

Andoni Formation: 0 m to -259.73 m
Ohangwena I Aquifer: -38.5 m to -99.3 m
Ohangwena II Aquifer: -181 m to -259.73 m
Olukonda Formation: -259.73 m to - 400 (Base of not reached)

Detailed Report

Introduction

WW 203302 is an incredible core. Of the 400 m of the almost totally unconsolidated fine-grained sand, there has been only a 7.87% (31.47 m) core loss. The core photographs of each metre of the core provide an excellent record and are extremely useful in the analysis of the core as one can refer to them repeatedly and one sees ever more information that was missed initially.

The borehole is located to the west of the central axis of the symmetrically shaped, 350-km long and 300-km wide, north-south orientated, sand-dominated Cubango Megafan (Fig. 1) deposited by the Palaeo-Cubango/Okavango River in an intracontinental basin under conditions of seasonal rainfall during the latter half of the Tertiary as the climate became progressively more semi-arid (Miller, 2008; Miller *et al*. 2010).

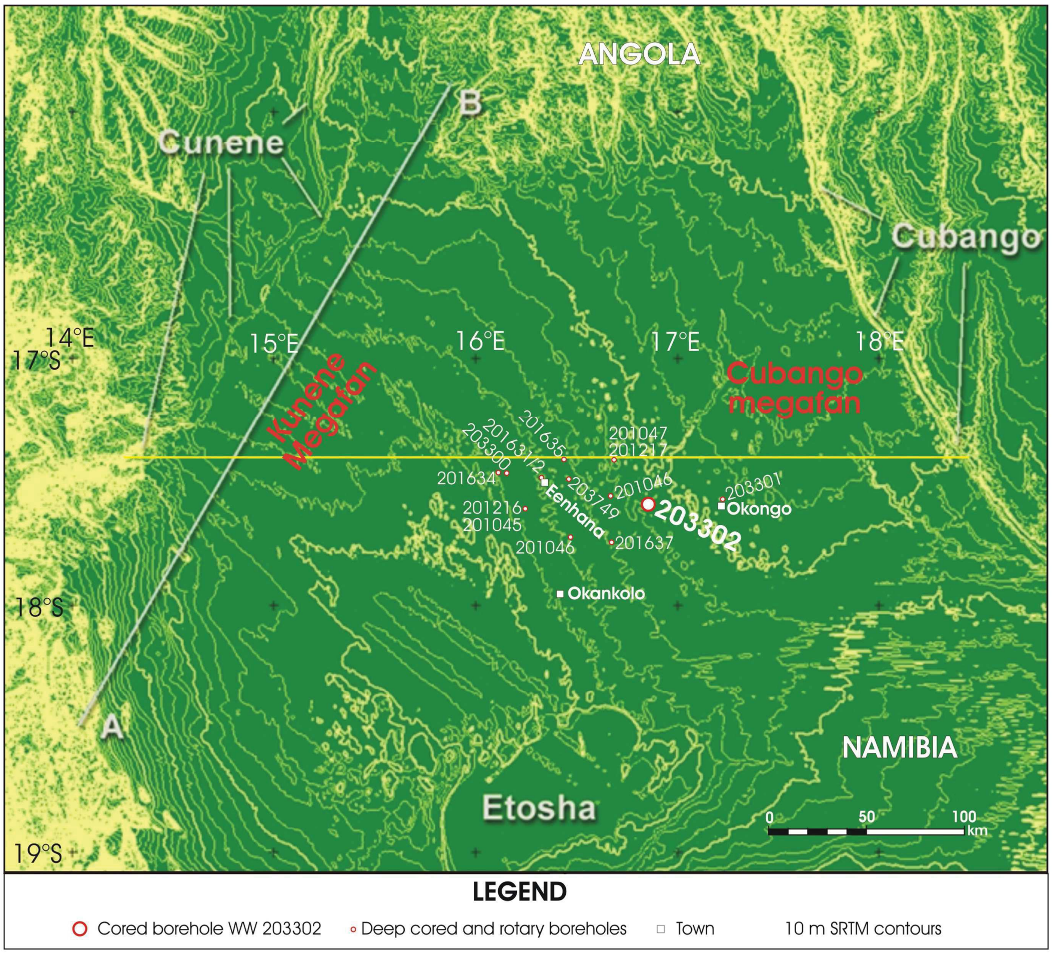


Figure 1. Location of core borehole WW203302 on the SRTM image (10 m contours) of the Cubango Megafan of northern Namibia. Megafan image modified from Miller (2008) and originally provided by Dr. Justin Wilkinson, Jacobs Engineering, Houston, USA. Present-day Cunene (Kunene in Namibia) and Cubango (Okavango) Rivers shown.

The megafan is at least 350 m thick. The highly saline Palaeolake Etosha, re-exposed in the present Etosha Pan (up to 13% NaCl in the deep pan clays) was the end point of the megafan. Fossils on the northwestern edge of Palaeolake Etosha indicate that megafan deposition ended about 4 million years ago (Miller *et al*. 2010). The red, east-west Kalahari dunes were deposited on the megafan between 3 and 1 million years ago when Africa became extremely arid as a result of expansion of the Arctic Ice Sheet (DeMenocal 1995, 2004, DeMenocal & Bloemendal, 1995, DeMenocal *et al*. 1993, references; Miller, 2014).

Previous rotary boreholes, and even the cored boreholes, provided only limited information about depositional conditions. This borehole was cored in order to obtain as good an understanding as possible of the two main aquifers in the megafan, the Ohangwena I (upper) and Ohangwena II (lower) Aquifers, and the depositional conditions under which they and the rest of the sediments in the megafan accumulated. This understanding, together with the flow testing of the borehole, is essential to ensure judicious utilisation of the aquifers and, in conjunction with geophysical definition of the aquifers, to guide step-out drilling to locate the regional extent of the aquifers and thereby to utilise the water contained therein. The near-surface aquifer, the Perched Aquifer, was not sampled but is described from other water boreholes in the area.

Critical to successful exploration for the regional extent of the aquifers is an understanding of where and how they were deposited within the megafan. Such megafans accumulate over millions of years. Deposition was not into a water body such as a delta on the edge of a continent but into an intracontinental basin with only local bodies of shallow, standing water that regularly dried up. Palaeolake Etosha, the end point of the megafan, was probably the most important of these. Such a symmetrical megafan is gradually built up by the main distributary channel slowly switching back and forth across the width of the megafan and depositing tongues of sediment. Consequently, individual tongues of sediment are not continuous across the entire megafan but are lensoid in form. Thus, it could be that lenses may differ significantly within and on either side of the megafan. Tongues of well-sorted sand are potential aquifers and are the targets sought. Thick bodies of well-sorted sands, such as the Ohangwena I and II Aquifers, suggest relatively long periods with a fairly humid climate and high run-off but whether such sands were deposited across the whole megafan can only be determined by drilling.

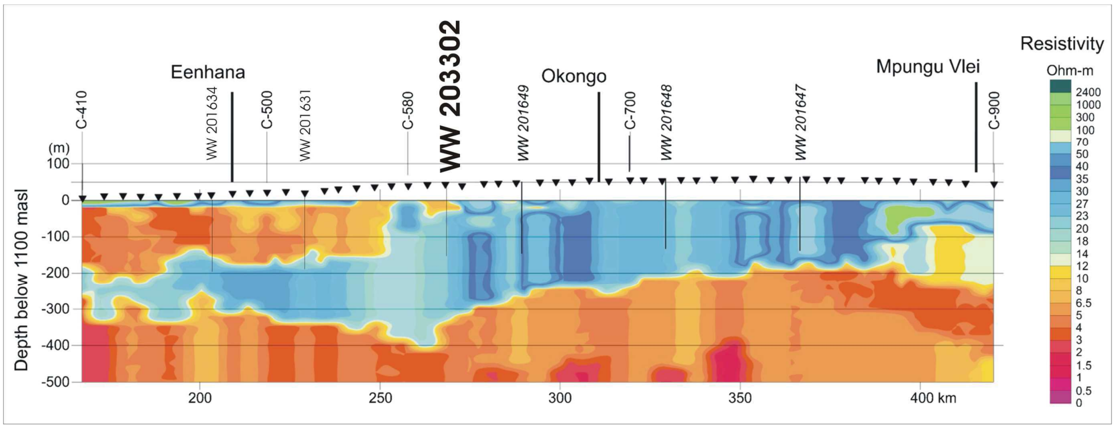


Figure 2. Interpretation of a 400 km long depth TEM profile across the Owambo Basin just south of the Namibian/Angola border; red – highly conductive saline pore water, blue – poorly conductive fresh pore water. Modified after Schildknecht (2012) and Lindenmaier *et al.* (2014).

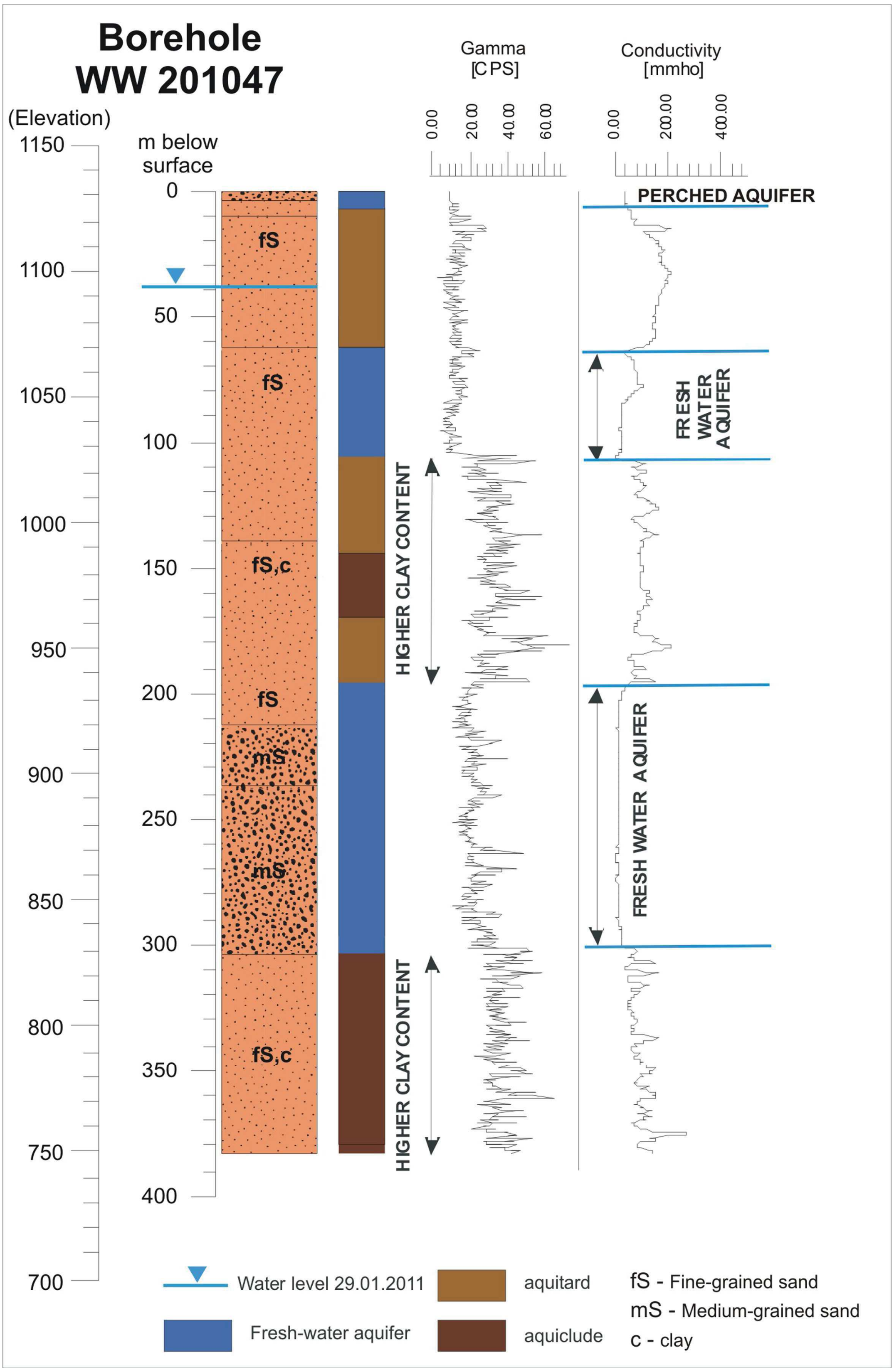


Figure 3. Downhole geophysical logs of rotary borehole WW 201047 illustrating the ability of such logs to distinguish mineralogy (gamma ray) and water quality (conductivity). Modified from Lindenmaier & Christelis (2012).

Deep-penetrating electrical sounding will detect such aquifers only if they carry fresh water bounded above and below by saline sediments. In other words, conductivity contrast is necessary for pre-drilling geophysics to locate fresh-water aquifers (poor conductivity) sandwiched between saline sediments (high conductivity). Such is the case in the western and southern extremities of the Ohangwena II Aquifer. In the same areas, the Ohangwena I Aquifer is saline (although not as saline as layers above and below it) and the geophysics did not detect it. Eastwards, the geophysics shows that the salinity disappears and water throughout almost the whole succession, even in the aquitards, has a low conductivity (i.e. is fresh) and the geophysics is unable to distinguish the permeable aquifers from the intervening impermeable zones (Fig. 2). Thus, drilling and careful logging of borehole samples remains the only way to delineate aquifers if the whole succession is saline or if the water in the whole succession is fresh. Consequently, drilling will be the only way to trace the fresh-water aquifers eastwards. Confirmation of exactly where the aquifers are is provided by down-hole geophysics using conductivity, gamma-ray and neutron logs. Conductivity survey is only effective if saline and fresh-water layers are present (western part of Ohangwena region). The gamma-ray log delineates clean, clay-free sands, i.e. aquifers, from less permeable, finer-grained, clayey layers (Fig. 3). The neutron log provides information on porosity and, hence, permeability. This down-hole geophysical data provides strong support for the lithological log of the core and often reveals information that is not obvious in the core and even less so in cuttings from rotary boreholes, particularly relating to correlation of specific horizons between boreholes, e.g. continuity or otherwise of clean sand horizons between boreholes. Figure 1 shows that all the deep boreholes drilled so far are west of the north-south axis of the Cubango Megafan. The power of such down-hole geophysical logs is well-illustrated by Lindenmaier *et al*. (2014) who made extensive use of such logs in their analysis of the deep rotary and cored boreholes into the aquifers in the Cubango Megafan to trace specific lithological horizons between boreholes. The geophysical properties of such horizons make them distinctive and recognisable even when their thicknesses change or when they occur at significantly varying depths. Lithological descriptions alone are usually not sufficient for such correlations as proportions of minor minerals, e.g. clays, are impossible to estimate accurately. The geophysical logs, in contrast, are very sensitive to intensity of natural radioactivity and to varying salinity of pore waters. Lindenmaier *et al*. (2014) point out that "more geophysical logs would greatly enhance the mapping" of the aquifers and aquitards.

Post-depositional processes have disturbed the sediments and sedimentary structures to such an extent that original bedding and cross-bedding is rarely detected. The first of these processes took place almost immediately after deposition, namely bioturbation by burrowing worms/crustaceans in wet sediment. In places, this has been intense. Penetration by plant roots followed later. Then followed intergranular cementation of specific horizons by calcrete or dolocrete. Formation of calcrete, dolocrete and rare silcrete nodules, which may or may not enclose sand grains, was the last of these processes but is likely to have taken place slowly, over a long period of time and in depth. In some sections, such nodules are enclosed in calcrete- or dolocrete-cemented sands.

Figure 4. Examples of a few very coarse grains randomly scattered through poorly sorted, clayey, fine- to medium-grained sand in borehole WW 201216: left sample -80.5 m depth; right sample -173.5 m depth; top to the left in each case.

Coarse sand grains and granules do not occur in individual beds but are randomly scattered through the sands, even in silty and clayey sands (Fig. 4). They should be concentrated in layers that were deposited by fast-flowing water but they are not. This scattering is difficult to explain in terms of sedimentary processes. It may be the result of disturbance and sediment churning by bioturbation but often bioturbation is not obvious where such scattered grains occur. Alternatively, such granules could be small silcrete nodules of diagenetic origin which grew under saline conditions as has been recorded in the Lower Roan arkosic sandstone of the Central African Copperbelt (pers. comm. Murray Hitzman, 2015). Consequently, several such granules from different stratigraphic levels have been collected for further analysis. Similarly, the rare, thin clay layers have been sampled for mineralogical studies, for determination of clay type and for detection of diagenetic minerals (analcime, pyrite, gypsum) in order to better understand how and if the post-depositional processes may have affected aquifer and water qualities.

With a southward slope of 0.00028 (0.017°) over a distance of 255 km (Miller *et al*. 2010), the Cubango Megafan has a surface gradient as low as the lowest gradient recorded for megafans (Stanistreet & McCarthy, 1993). Deposition of such a sand-dominated and clay-poor megafan under seasonal climatic conditions with an end point (Palaeolake Etosha) that was more often than not dry is difficult to explain sedimentologically. Clays are represented by a few thin layers and by some zones with minor to accessory amounts of interstitial clay (up to 20%). These form part of the aquitards. It is thus obvious that depositional conditions varied over time.

One key question is "When and where were well-sorted sands deposited?" These are the aquifers that need to be found and tested. Another question is "How are such aquifers fed and are they being recharged today?" Only systematic exploratory drilling will provide answers once enough data has been accumulated. Borehole WW 203302, with its excellent core recovery provides some answers and new, unexpected information, such as the extensive bioturbation over almost the entire length of the core and the interpretation thereof, which the rotary drilling never provided.

Andoni Formation: 0 m -259.73 m

Perched Aquifer

The Perched Aquifer in WW 203302 is within the upper 8.5 m of the borehole which was not sampled. This description is based on the logs of cuttings from many water boreholes in the Ohangwena region (31 boreholes, namely WW 200471 to WW 200486, WW 200646 to WW 200656, WW 201010, WW 201349, WW 201557). The Perched Aquifer is accessed by shallow hand-dug wells and sustains many households in the Owambo Basin of north central Namibia.

The aquifer ranges in thickness from 0 to 30 m but is on average 10-11 m thick. It is seldom absent (0 m), may only be 1-3 m thick (38% of above boreholes) or 6 m thick (19%). Only in 15% of the above boreholes is it more than 20 m thick. It consists of moderately to well-sorted, medium- to fine-grained, quartz-dominated sand with minor silt. The upper 1 to 3 m is a medium-grained aeolian sand and is the best sorted of all the layers. In general, the grain size decreases downwards and silt content increases concomitantly but the proportion of well-rounded, medium-grained aeolian clasts still remains high. Some holes have a poorly sorted layer with or without a clay component between 4 m and 7 m thick interbedded between better sorted layers. Such poorly sorted layers can also be highly calcareous due to a calcrete cement. The base of the aquifer is marked by a continuous succession of silty, poorly sorted sands that are often but not always carbonate cemented.

The upper 1 to 5 m is generally very light brown in colour, probably due to intermixed, degraded humus. Below this the colour is very light yellow or whitish where significantly calcareous. A reddish to orange ferruginous zone between 1 m and 5 m thick and typical of soil profiles occurs in some of the boreholes at depths varying from 2 m to 17 m. Rare, thin, greenish layers may also be present.

Rainfall normally drains and disappears into the surface layers within about 24 hours of any heavy downpour.

The aquitard between the Perched and Ohangwena I Aquifers

This extends from -8.5 m to -38.5 m and consists of poorly sorted and carbonate-cemented sands. It can be subdivided into upper and lower parts.

-8.5 m to -18.5 m

This consists of poorly sorted, fine-grained, very light yellow sand with a significant silt component and a variable, well-rounded, medium-grained, aeolian component down to a depth of -18.5 m. Coarse-grained clasts and granules occur scattered through these sands. Nowhere do such grains occur concentrated in specific layers. A few granules of quartz, feldspar and granite occur at -9 m. Two 2 cm thick layers of very light green clayey sand occur between -10 m and -11 m and a 2 cm thick, well-sorted, very light green sand layer occurs at a depth of -13.22 m. A post-depositional, patchy goethitic to hematitic colour pervades the sand from a depth of -9 m, becomes a more uniform light hematitic colour from -10 m to -14.5 m and then becomes patchy and fainter and is no longer present below -16.5 m. There are bleached, post-ferruginisation veins from -13.5 m to -14.5 m. This 10 m section of the core is hard and carbonate cemented; the cement is calcrete down to -9 m, then dolocrete to -11.5 m, calcrete to -14.5 m, then dolocrete to -18.5 m. The uppermost 3 m is very hard and intensely cemented. Below -11.5 m, the core becomes softer and less intensely cemented. Bioturbation burrows/channels occur in places from -11 m downwards (Figs 5, 6).

Figure 5. Poorly sorted, calcrete-cemented, fine-grained sand in which the pre-cementation bioturbation burrows/channels are still visible; scale divisions 1 cm; core section from -11.83 m to -12.22 m; top to the left in this and all subsequent figures.

-18.5 m to -38.5 m

This consists of very light yellow, moderately sorted, fine-grained and medium- to fine-grained sands which alternate in 1-2 m thick sections. Again scattered coarse-grained clasts and granules occur, some of which are up to 8 mm in diameter (-19.5 m to -20.5 m). Some of these larger grains are knobbly and may be diagenetic silcrete. 1 m thick sections of poorer sorting occur. Small fragments of a medium grey-brown clay occur scattered in the sand just below -20.5 m and suggest either bioturbation or rip-up clasts. The core is semi-consolidated, the cementing is not very intense and the cement is dolocrete throughout. The core becomes softer in the lower 2 m. Tiny nodules of soft, white calcrete and larger, hard nodules of white calcrete occur in places within this dolocrete-cemented core (Fig. 7).

Figure 6. Bioturbation channel with calcified margins and red sand core at -13.9 m in calcrete-cemented, fine-grained sand; bleached calcrete-rich vein; core section from -13.84 m to -14.07 m.

Figure 7. White calcrete nodule in poorly sorted, fine- to medium-grained sand weakly cemented by dolocrete, faint bioturbation burrows to the right of the nodule; core section from -21 m to -21.25 m.

Bioturbation burrows or channels occur in patches or throughout 1 m sections of the core from -11 m to the base of this section at -38.5 m. At least two periods of such bioturbation are recognised. The first is generally the most abundant, is faint, slightly darker yellow than the enclosing sands and occurs throughout (Fig. 7). The second is later, hematite stained, much less common and only occurs at a few levels (Fig. 8). White, calcite-bearing, rhyzolith-like features occur at -15.04 m and -33.55 m. A root occurs at -12.82 m. Hollow tubes occur at -0.85 m and -37.02 m.

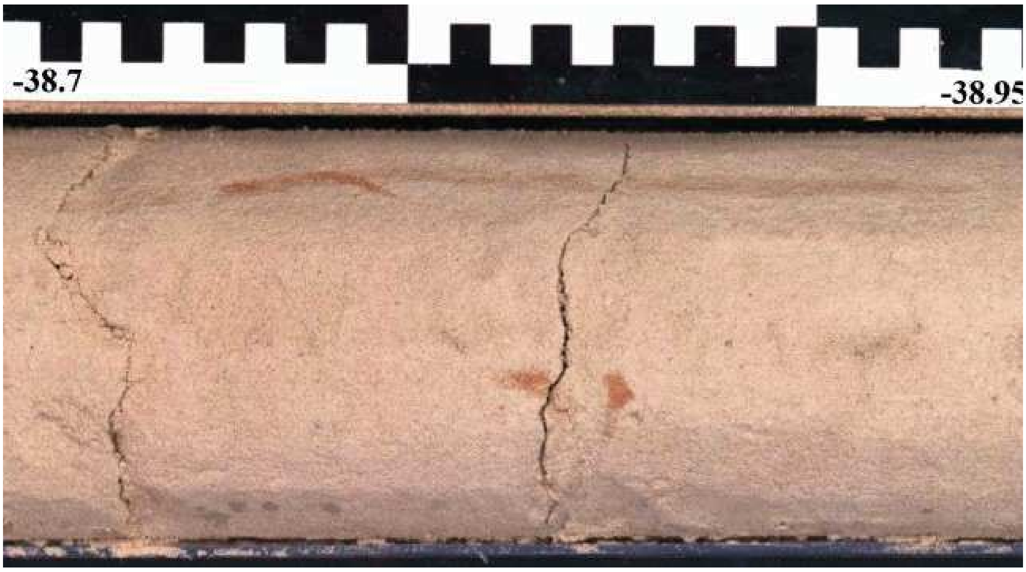


Figure 8. Top of the Ohangwena I Aquifer; moderately well-sorted fine-grained sand showing three periods of bioturbation. The first is by far the most abundant and is faintly visible down the centre of the core as very subtle, streaky colour variations, the second is slightly darker than the enclosing sands (long vertical burrow just below the scale), and the third is highly ferruginous (spots and burrow) and the least common of the features; core section from -38.7 m to -38.95 m.

Ohangwena I Aquifer

This extends from -38.5 m to -99.3 m and consists of two aquifer zones separated by a 9 m thick zone of cemented and probably impermeable sand.

-38.5 m to -62.5 m, core loss 6 cm

This consists primarily of soft, very light yellow, moderately well-sorted, fine-grained sand with minor medium-grained sand and very minor amounts of silt. Some 1-2 m thick sections have medium-grained sand as the main component. Most medium-grained clasts are well-rounded. The section is strikingly uniform. Some very light green, possibly slightly clayey sand spots and streaks (bioturbation?) occur between -43.72 m and -43.86 m.

A few hard white calcrete nodules of different sizes occur through this section with an occasional dolocrete or calcareous dolocrete nodule or calcareous dolocrete nodule with a calcrete margin here and there.

Bioturbation occurs throughout this section. Three phases of bioturbation can be recognised, e.g. between the depths of -38.7 m to -38.95 m (Fig. 8), where the first phase is very faint but abundant, the second is represented in the figure by a long, better defined, vertical channel (less common) and the third is red, ferruginous, the least abundant and overprints the two earlier phases (Fig. 8). A few long, thin, white, subvertical calcrete nodules(?) between -42.6 m and -44.6 m (Fig. 9.1) may be calcified rhyzoliths. Pieces of roots occur at -43 m and at -49.26 m. At a depth of -49.86 m there are two small white calcrete spots with a wide dark rim around them which may also be rhyzoliths (Fig. 9.2).

Figure 9.1. Possible calcified rhyzoliths in soft, fine-grained, moderately well-sorted sand of the Ohangwena I Aquifer; core section from -42.58 m to -43.02 m.

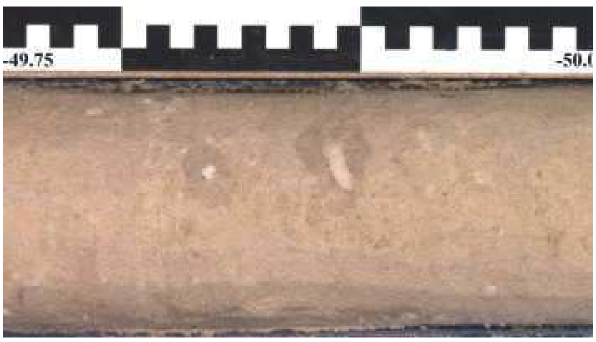


Figure 9.2. Small white calcrete spots. The enclosing sand has been darkened around the spots; core section from -49.75 m to -50.0 m.

-62.5 m to -71.5 m, core loss 2 cm

This section consists of the same fine-grained, moderately well-sorted, very light yellow sand but the sand is consolidated by calcrete cement for the first metre and then by dolocrete cement. Soft, less cemented or uncemented zones occur in places. Possible faint bedding occurs between -68.5 m and -69.5 m. Several hard, white, calcareous dolocrete nodules of various sizes occur scattered through the section with hard, white calcrete nodules from -67 m to -67.5 m. Faint bioturbation occurs through almost the entire section, being abundant and clear in the one individually recognisable layer between -67.02 m to -67.5 m, the bioturbation being abundant at the top and absent at the base (Fig. 10).

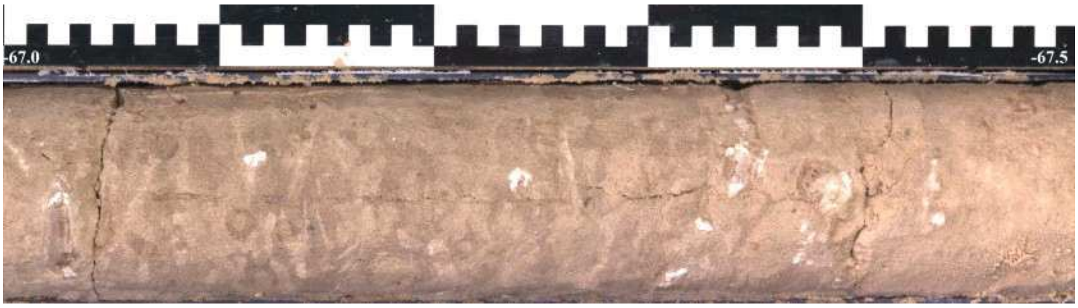


Figure 10. Distinct bioturbation of hard, fine-grained, moderately well-sorted, dolocrete-cemented sand, note zoning of some of the bioturbation channels; core section -67 m to -67.5 m.

<u>-71.5 m to -99.3 m, core loss 7.7 m</u>

The core was very wet and often disturbed where very soft for most of this section and there was some core loss (7.7 m) in places. This is still the same fine-grained, very light yellow sand. Sorting appears to have improved. This must be the main part of the Ohangwena I Aquifer. It appears to be a good aquifer and better than it was further west. The proportion of frosted, well-rounded aeolian grains is lower than higher up in the borehole but is, nevertheless, still significant. Many grains are shiny and typical of fluvial grains, again more so than higher up. A few small patches of semi-consolidated (slightly cemented?) core occur. A few hard, white, calcareous dolocrete nodules of different sizes are scattered through the core to -77.4 m. Thereafter the core is nodule-free to -88.2 m where a 30 cm wide zone of dark red and pink silcrete nodules occurs (Fig. 11). Below this, the core is again very soft, partly disturbed and nodule-free to -99.3 m. The basal 30 cm of this section is hard, cemented by dolocrete and contains brown, very fine-grained calcareous silcrete nodules. Bioturbation, if originally present, has been destroyed in the disturbed core but bioturbation channels or spots are detectable from -76.5 m to -93.3 m.

Figure 11. Dark red silcrete and light pink dolocrete nodules set in a hard, very light green matrix of fine-grained, clayey sand cemented by dolocrete; core section from -88.2 m to -88.5 m.

Aquitard between the Ohangwena I and Ohangwena II Aquifers

-99.3 m to -180 m

This 81 m thick section, although dominated by poorly sorted fine- to very fine-grained sands, is highly variable and highlights features that have been almost totally missed in the rotary boreholes and even in some of the older core boreholes. This section is far more typical of the variability of sediment supply over time under variable rainfall intensities, climatic conditions and switching back and forth of the main distributary channel system. It is also characterised by colour changes, the presence of some thin clay layers and layers of clustered carbonate nodules suggestive of pedogenic calcretes, the latter, in turn, suggestive of long periods of non-deposition lasting possibly as much as 100 000 years. The relatively uniform sub-sections of between approximately 1 m and 10 m thickness in this aquitard are described individually. There are two thinly bedded sections with beds less than 1 m in thickness of very variable lithology. These thinly bedded sections are presented bed by bed.

-99.3 m to -102.8 m, core loss 50 cm

This is a transition zone of increasingly poor sorting of soft, very light greyish yellow, fine- to very fine-grained sands. Medium-grained clasts are very minor. The core is disturbed in places. A 12 cm thick layer of clustered hard, white, calcareous dolocrete nodules (pedogenic in origin?) in dolocrete-cemented sand occurs at -100 m (Fig. 12). There are some lighter coloured zones which may be due to interstitial calcrete or dolocrete cement. There are faint signs of bioturbation in places.

Figure 12. 12 cm thick zone of clustered calcareous dolocrete nodules at -100 m, origin uncertain; core section -99.9 m to -100.1 m.

-102.8 m to -109.77 m, core loss 1.66 m

Poorly sorted, soft, very light greyish yellow, fine- to very fine-grained sand with increasing silt content downwards, possibly up to 20% silt. Medium-grained clasts are rare. There are some lighter coloured zones which may be due to interstitial calcrete or dolocrete cement but this whole section lack nodules. There are faint signs of bioturbation in places. From -109.14 m to -109.77 m the sand is cemented by calcrete which increases in proportion downwards; a 1 cm thick layer of tiny calcrete nodules occurs at -109.22 m. There was core loss of 1.66 m in the lower part of this section.

-109.77 m to -112.9 m

This section of highly variable sand consists of several thin layers of differing composition, colour and grain size and includes layers of nodular pedogenic calcrete. This section is a record of the demise of biota that caused light green bioturbation during a gradual but major climatic change to much drier conditions. There was no core loss so the litholog gives a good record of this section. NB: the colour change of the sand from the green and light green below to very light yellow or very light greyish yellow above -110.32 m.

The following detail documents this variability:

-109.77 m to -110.02 m:- Pedogenic calcrete (Fig. 13) densely clustered nodules, uppermost of four stacked pedogenic calcretes/dolocretes, matrix of the same above sand.
-110.02 m to -110.31 m:- The same sand as above, poorly sorted, soft, very light greyish yellow, fine- to very fine-grained with approximately 20% silt.
-110.31 m to -110.32 m:- Dark brown clay, subsequently highly dismembered, possibly by bioturbation (Fig. 14).
-110.32 m to -110.77 m:- Abundant, rather angular nodules of the third of the four stacked pedogenic layers of calcareous dolocrete, matrix of very light green, poorly sorted, fine- to very fine-grained, highly silty sand which is cemented by calcareous dolocrete. Between -110.54 m and -110.65 m the calcareous dolocrete fragments have irregularly shaped cores of dark brown silcrete, often with serrated margins (Figs 14, 15).
-110.77 m to -111 m:- Soft, fine-grained, poorly sorted, clayey, very light green sand; salty (?); four 1 cm thick interbeds of very light brown sand.
-111 m to -111.6 m:- Same sand, soft, fine-grained, poorly sorted, clayey, very light green, salty(?); faintly bioturbated.
-111.6 m to -112 m:- Second nodular pedogenic calcareous dolocrete layer, soft matrix of the same very light green, clayey sand; fewer nodules in the lower 15 cm (Fig. 16).
-112 m to -112.12 m:- Basal part of the above pedogenic dolocrete with fewer nodules and more of the very light green matrix sand (Fig. 17).
-112.12 m to -112.49 m:- Soft sand, fine-grained, poorly sorted, very light brown, a few scattered calcareous dolocrete nodules (Fig. 18).
-112.49 m to -112.9 m:- Soft clayey sand layer, fine-grained, poorly sorted, very light green and bioturbated to -112.58 m (Fig. 18) then follows within this layer a nodular pedogenic calcareous dolocrete from -112.58 m to -112.7 m (lowest of the four). The intensity of bioturbation gradually decreases below the calcrete and the original very light brown sand contains only scattered light green burrows (Fig. 18).

Figure 13. Clustered nodules of a 23 cm thick pedogenic calcrete, uppermost of the four stacked pedogenic calcrete/dolocrete layers; core section -109.7 m to -110.02 m.

Figure 14. The third of the four, stacked, nodular pedogenic calcareous dolocrete layers. The matrix between the nodules is a very light green, poorly sorted, fine- to very fine-grained, highly silty sand cemented by calcareous dolocrete; note (i) the irregularly shaped cores of dark brown silcrete in the dolocrete nodules in the middle part of the section, the silcrete being a replacement of the dolocrete, (ii) the thin disrupted layer of dark brown clay on top of the dolocrete (arrowed), and (iii) the very light green sand below the dolocrete; core section -110.3 m to -110.8 m.

Figure 15. Same section as Fig. 14 but showing more of the sands above and below the dolocrete. The sand below is very light green, the colour probably being due to very intense bioturbation of an originally very light brown sand (see later). The same very light green sand forms the matrix to the dolocrete fragments indicating that the dolocrete formed within the very light green sand, very likely just below the surface of the sand. The subsequent depositional episode probably washed away the cover of green sand above the dolocrete and deposited a very light greyish yellow sand (very light brown in the photograph) which was not subsequently bioturbated. This suggests either (i) a long break in sedimentation allowing the dolocrete to form, and/or (ii) a significant change in depositional conditions between deposition of the lower very light green layer and the upper very light yellow layer, (iii) or preferential carbonate deposition along the contact between the two differently coloured layers where the dark brown clay layer occurs; core section from -110.2 m to -110.84 m.

Figure 16. The second of the four stacked, nodular pedogenic calcareous dolocrete layers. It occurs below very light green (intensely bioturbated?), poorly sorted clayey sand. There are fewer nodules in the lower 15 cm of the dolocrete. The soft matrix of the dolocrete is of the same very light green, clayey sand. Thus, the pedogenic dolocrete formed within the very light green clayey sand; core section -111.55 m to -111.9 m. Fig. 17 occurs immediately below this dolocrete.

Figure 17. The lowermost 12 cm of the pedogenic dolocrete of Fig. 16. This contains fewer nodules and more of the very light green matrix sand and is typical of basal parts of pedogenic calcretes. The sand in the lower 8 cm of the figure is very light brown, soft, fine-grained and clearly different in colour from the matrix sand of the dolocrete; core section from -112.02 m to -112.18 m.

Figure 18. Core section from -112.35 m to -112.99 m. This is immediately below Fig. 17, and shows a bioturbated layer extending from -112.5 m to -112.9 m (marked by vertical bars). The very light brown sand at the base of Fig. 17 forms the top layer in this figure, i.e. to -112.5 m. A few scattered calcareous dolocrete nodules occur at the contact (-112.42 m to -112.48 m) between this sand and the underlying very light green clayey sand. The first of the four stacked, nodular pedogenic calcareous dolocrete layers (-112.57 m to -112.68 m) occurs within about 7 cm of the top of the light green intensely bioturbated sand. Below this the intensity of the bioturbation gradually decreases downwards to the very light brown sand of the basal part of the layer. The top of the next layer down is at -112.9 m.

-112.9 m to -115 m

Two layers of soft clayey sand, fine-grained, poorly sorted; the original very light greyish to brownish yellow colour is intensely overprinted by abundant very light green bioturbation (Fig. 18) to -114.5 m and then from -114.5 m to -115 m but with decreasing intensity of bioturbation downwards in both layers (Fig. 19). As in the above -109.77 m to -112.9 m section, deposition of very light brown sands swamps and prevents further biogenic activity in the underlying layer. However, after a while, this biogenic activity is able to re-establish itself so the tops of the very light brown layers become bioturbated by very light green bioturbation (Fig. 19). Here is one large, hard, very light tan, calcareous dolocrete nodule.

Figure 19. Core section from -114.4 m to -114.99 m; Intense very light green bioturbation of soft very light brown, fine-grained sand between -114.54 m and -114.7 m which then decreases in intensity downwards. Influx of a new sand layer above -114.54 m smothered the biogenic organisms shortly after they had caused some bioturbation of the basal part of the new sand layer (-114.5 m to -114.54 m). In this particular layer, bioturbation only reached to a depth of 45 cm below surface of the sediment, i.e. from -114.54 m to -114.99 m. However, in the core section immediately below this, the bioturbation reaches a depth of 2 m below the surface of the sediment, i.e. from -115 m to -117 m.

-115 m to -118.61 m

Six layers of soft clayey sand, fine-grained, poorly sorted, light green; so highly bioturbated by light green bioturbation that the original very light brown colour of the sand is almost but not quite totally obliterated in most of this section. The intensity of bioturbation decreases downwards in each layer.

-118.61 m to -120.32 m

Zone dominated by two large, hard calcareous dolocrete nodules containing very light tan, bioturbation-like channel fillings weakly cemented by calcareous dolocrete (Fig. 20). These channel fillings may have been bioturbation channels that were not as intensely cemented as the enclosing nodules. An 11 cm thick zone of the same very light green sand as above separates the nodules. The basal 32 cm of this section consists of the same light green clayey sand with several thin, horizontal, laminated, white to very light brown calcareous dolocrete veins.

Figure 20. Large, hard calcareous dolocrete nodules, the uppermost one (left) containing round, bioturbation-like burrows filled with sand weakly cemented by calcareous dolocrete. The burrows would have pre-dated the nodule and seem to have escaped the intense cementation of the rest of the nodule; core section from -119 m to -120 m.

-120.32 m to -122.07 m

Four layers of soft clayey sand, fine-grained, poorly sorted, with zones alternating in colour from light green to very light green and very light grey-brown; thin horizontal light green streaks in the lower half of the section and clear bioturbation from -121.7 m, decreasing in intensity below to -121.91 m. Possibly two periods of bioturbation, first very light green, second darker green. Possible faint horizontal bedding from -120.42 m to -120.69 m. Some thin layers of very light brown, medium- to fined-grained sand between -120.52 m and -120. 95 m. A 0.5 cm thick layer of green clay occurs at -120.95 m.

-122.07 m to -125.22 m

Eight layers of soft clayey sand, fine-grained, poorly sorted, very light yellow with two periods of bioturbation, light green then darker green; individual layers were bioturbated before the next layer was deposited (Fig. 21); there are some calcareous dolocrete nodules.

Figure 21. Core section from -122 m to -122.76 m. This core shows three separate sedimentary layers. Each was intensely bioturbated before the next layer was deposited. Each layer smothered the biota in the underlying layer but the biota were able to re-establish themselves in the new layer after a while. The intensity of bioturbation decreases downwards. The top of the first layer is at -122.64 m (layer thickness 0.46 m, -122.64 m to -123.1 m), the top of the next layer is at -122.06 m (layer thickness 0.58 m), and the section from -122.06 m to -122 m is the base of the 1.8 m thick bioturbated layer extending from -120.32 m to -122.06 m. Without the bioturbation, these three layers would probably have been identical to each other and, consequently, indistinguishable from each other. Thus, the bioturbation is showing that the time break between the deposition of individual layers was long enough to allow colonisation of the wet sediment. It also suggests that there are far more individual layers in the non-bioturbated sections of the core than visual logging of the core indicates. The lighter and darker green can be distinguished at -122.7 m and in the lower part of each bed where there has been less bioturbation.

-125.22 m to -126 m, core loss 38 cm

Three layers of soft clayey sand, fine-grained, poorly sorted, light green fading downward to very light brown; sand hard and dolocrete cemented from -125.37 m to -125.62 m; same two colours of bioturbation; light grass green bioturbation channels from -125.27 m to -125.37 m; some bioturbation channels filled with white, calcrete-cemented sand; some scattered dolocrete nodules.

-126 m to -127 m

Clay, green, slightly silty to sandy; irregular dolocrete nodules, patches and streaks.

-127 m to -127.9 m

One layer of soft clayey sand, fine-grained, poorly sorted, light green fading downward to very light brown; some scattered dolocrete nodules, several cm-thick layers of dolocrete in the basal 10 cm.

-127.9 m to -134.2 m, core loss 44 cm

Very clayey sand, fine-grained, poorly sorted, soft, light green; clusters of hard, small dolocrete or calcareous dolocrete nodules up to about 1-2 cm in diameter choke the core (Fig. 22); the matrix sand can be soft or hard and cemented by calcareous dolocrete. In parts of the core with fewer nodules, rare darker green patches suggest bioturbation. Some of the nodules have the shape of carbonate-cemented bioturbation channels.

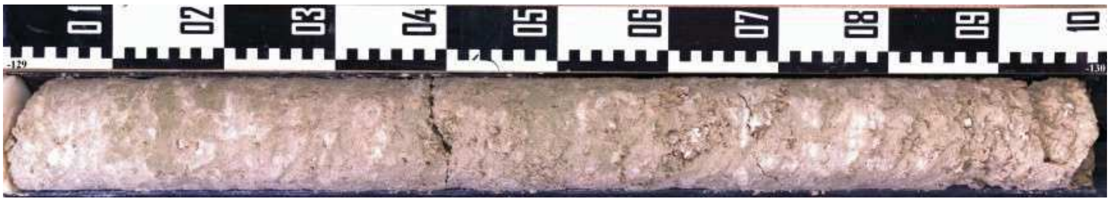


Figure 22. Soft, light green, very clayey, poorly sorted, fine-grained sand choked by smallish, hard dolocrete and calcareous dolocrete nodules; core section -129 m to -130 m.

-134.2 m to -137 m

Very clayey sand, fine-grained, poorly sorted, soft, light green to very light grey green; fewer but larger, hard, dolocrete or calcareous dolocrete nodules, some irregularly sub-vertically oriented; the matrix sand can be soft or hard and cemented by calcareous dolocrete.

-137m to -138.05 m

Clay, light green, sandy and silty; a few small calcareous dolocrete nodules; abundant light green bioturbation in very light brown sand in the lower 25 cm, several calcified rhyzoliths in lowest 15 cm.

-138.05 to -141.40 m

Very clayey sand, fine-grained, poorly sorted, soft, green becoming light green downwards; small irregularly shaped calcareous dolocrete nodules throughout but clustered in places; sand becomes whiter and lighter green and harder in the nodule clusters due to cementing of the sand by calcareous dolocrete, larger nodules between -140 m and -140.65 m; irregularly shaped silcrete nodules at -138.51 m and -139.1 m. Several thin white rhyzolith-like features filled with calcareous dolocrete (Fig. 23). Two red bioturbation burrows at the base of the section. Possible very faint horizontal bedding at -140.68 m and slightly angled bedding from -140.83 m to -140.93 m (Fig. 24).

Figure 23. Elongated, thin, white, randomly orientated, calcareous dolocrete nodules which may be rhyzoliths; core section -138.65 m to -138.9 m.

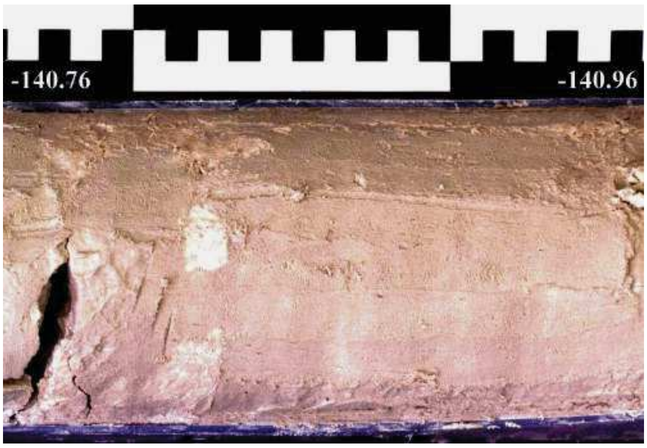


Figure 24. Faint layering (bedding?) forming an angle of about 10° to the core; core section -140.76 m to -140.96 m.

-141.40 m to -141.74 m

Same light green clayey sand as above but containing small patches of the underlying deep greyish purple clay. This section was probably the top of the clay but it has been intensely bioturbated. Bioturbation burrows filled with the overlying light green sand are so abundant that there is more sand than clay (Fig. 25).

Figure 25. Core section from -141.3 m to -141.8 m. The section from -141.4 m to -141.74 m is a zone of light green sand containing patches of faintly purplish clay. This appears to have been the top of the underlying deep greyish purple clay so intensely bioturbated that there is more light green sand (burrow fillings from overlying sand) than clay. There are two faintly reddish burrows above the mixed zone and two very hematitic burrows in the lower half of the mixed zone.

-141.73 m to –142.26 m

Clay, deep greyish purple; a few small calcareous dolocrete nodules; some faintly reddish, sand-filled bioturbation burrows.

-142.26 m to -142.40 m

Transition zone to underlying sand; downward decrease in clay content and intensity of the purple colour.

-142.40 m to -149.16 m, core loss 1.1 m

Very clayey sand, fine-grained, poorly sorted, soft, light green; clay content decreases downwards but sand remains clayey; local thin light purple zone; scattered, small, irregularly shaped calcareous dolocrete nodules to -145.8 m; almost nodule-free sand to -148.2 m then a several large nodules to -149.16 m. Bioturbation burrows present but not abundant and it is not possible to use bioturbation to define individual layers. Two periods of bioturbation recognisable in places, first light purple, second red but less abundant, rare zoned burrows, one calcified rhyzolith. NB : the colour change of the first period of bioturbation from very light green above to very light purple below about -148 m.

-149.16 m to -154.2 m

Sand, fine grained, soft, poorly sorted, low but variable clay content, very light yellow to very light greyish yellow; a 5 cm thick layer of poorly sorted light green sand at -149.9 m; a few scattered, white, hard, calcareous dolocrete nodules. The same two periods of bioturbation occur, the first is very faint purple and the most abundant, red is rare (Fig. 26). There are indistinct concentrations of the very faint purple bioturbation which may mark the tops parts of specific sedimentary layers but no layer has a sharply defined top as was the case with the green bioturbation. In such 'layers' the concentration of the bioturbation decreases downwards; some calcrete-filled rhyzoliths (Fig. 27). NB : the colour change of the sand from very light green above to very light yellow or very light greyish yellow below -149.16 m. Large calcareous dolocrete nodule at the point of colour change, possible deposited on a layer boundary.

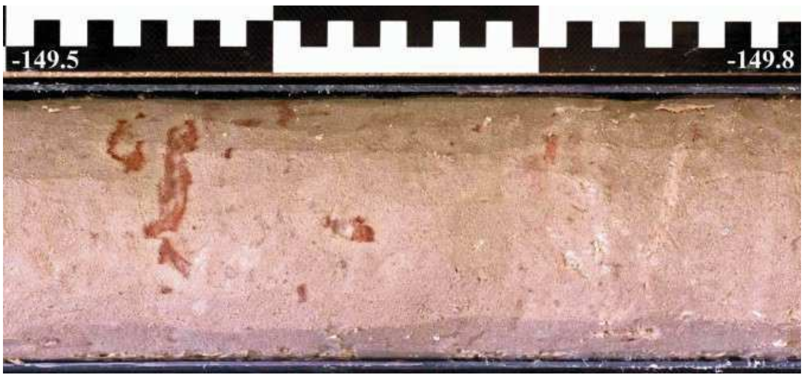


Figure 26. Very faint light purple first period bioturbation, less abundant, hematitic second period bioturbation; weakly calcified rhyzolith(?) to the right; core section -149.5 m to -149.8 m.

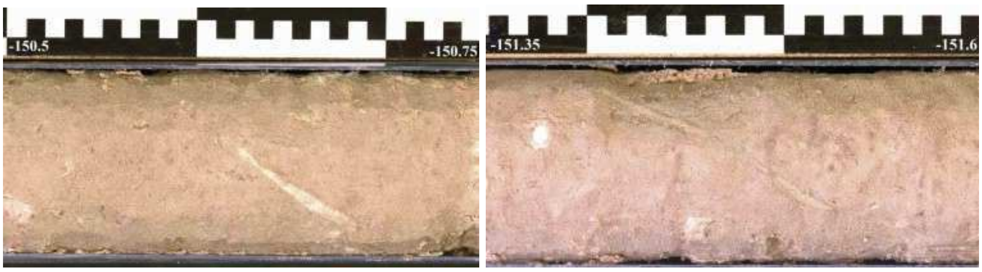


Figure 27. Left: Calcified rhyzolith; core section -150.5 m to -150.75 m. Right: Faint light purple bioturbation burrows; off-white, long, less calcified rhyzolith; core section -151.35 m to -151.6 m.

-154.2 m to -160.7 m

Same sand, fine grained, soft, poorly sorted, low but variable clay content, very light yellow to very light greyish yellow, tending to very light purplish where the first period of bioturbation is abundant. red burrows are more abundant than higher up in the core but are not as abundant as the light purple burrows. The top, very light purplish 70 cm of this section with fairly numerous red burrows is sharply and irregularly disrupted by very light yellow sand with almost no bioturbation (Fig. 28). Below this, both light purple and red burrows are very sharply defined (Figs 29-31), their concentration gradually decreases below -157.8 m. Internal, *Cruziana*-type laminations occur in both the purple and the red burrows (Figs 30, 31). Many of the burrows are zoned with dark margins and very light yellow sandy cores (Fig. 31). Zones of concentrated burrows grade downwards into zones with fewer burrows but it is uncertain whether such gradational zoning is representative of individual layers. There are variable concentrations of scattered, white, hard, calcareous dolocrete nodules.

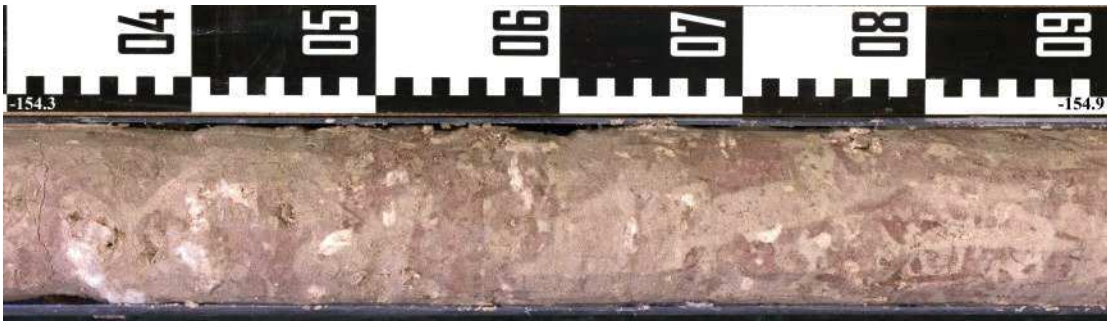


Figure 28. Light purple core broken up into sharp-edged patches by light yellow sand in which there is almost no bioturbation – is this disturbance by larger animals? The light purple colour is due to pervasive first period bioturbation. The second period bioturbation in the purple patches is red in colour and is less abundant; core section from -154.3 m to -154.9 m.

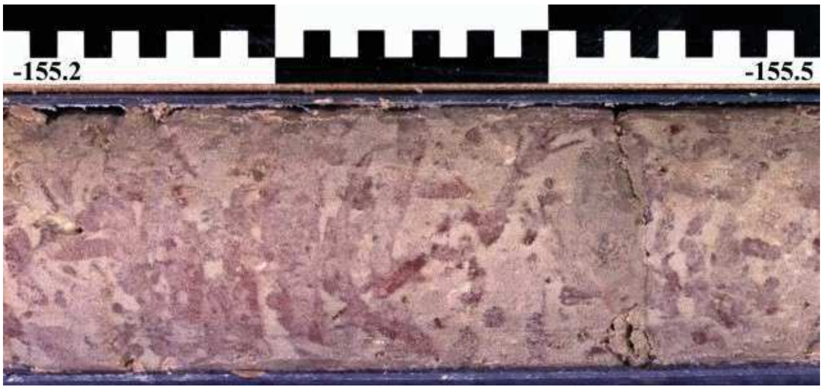


Figure 29. Broad and narrower light purple, first generation bioturbation burrows cut by less abundant, second generation red bioturbation burrows; core section from -155.2 m to -155.5 m.

Figure 30. Red, second period burrows with internal, *Cruziana*-type laminations; core section from -155.5 m to -155.75 m.

Figure 31. Light purple, first period burrows with internal, *Cruziana*-type laminations. Note zoning of many of the burrows, particularly the circular sections; core section from -156.3m to -156.6 m.

-160.7 m to -163 m

Same sand, fine grained, soft, poorly sorted, low but variable clay content, very light yellow to very light greyish yellow; more nodules, calcareous dolocrete larger, calcrete small; much less bioturbation, most faint, unusual structure at -162.64 m with thin red rim and same coloured sand inside and outside (Fig. 32).

Figure 32. Unusual bioturbation structure with thin red rim and the same coloured sand inside and outside the rim; core section from -162.55 m to -162.75 m.

-163 m to -166 m, core loss 21 cm

Sand, soft, fine-grained, moderately sorted, very light greyish yellow and light green layers, thin poorly sorted light green layer from -164.64 m to -164.79 m; fairly numerous small calcareous dolocrete nodules in the first metre, fewer below this; very minor red bioturbation; abundant, faint light purple bioturbation in the final metre with some white calcification of some burrows.

-166 m to -176.5 m, core loss 11 cm

Sand, fine-grained, variable clay content, soft, poorly sorted, very light yellow to very light greyish yellow; zones where the sand has a very light purple colour; very clayey and light purple from -166.55 m to -167.1 m; scattered clusters of calcareous dolocrete nodules to -168.1 m, very few to -172 m, abundant from -172 m to -173 m, then very few to -176.5 m; light purple bioturbation burrows fairly abundant through most of this section, red much less abundant, *Cruziana*-type laminations in some burrows.

-176.5 m to -180 m

This basal 3.5 m of the aquitard is highly variable. The following detail presents this variability.

-176.5 m to -177.04 m:- Clay, silty, light olive green, very calcareous, abundant calcrete nodules, small at both ends of this section, much larger in the central 19 cm.
-177.04 m to -177.42 m:- Sand, very fine grained, clayey, poorly sorted, very light olive, soft; many white calcrete nodules.
-177.42 m to -177.89 m:- Sand, fine grained, poorly sorted, very light yellow; patches of grey clay; some dolocrete nodules below -177.8 m; admixture of sand and clay patches due to bioturbation.
-177.89 m to -178.06 m:- Sand, very fine grained, clayey, poorly sorted, very light purplish grey, some vague very light yellow patches, soft; scattered calcrete nodules; light purple bioturbation, minor red bioturbation.
-178.06 m to -178.43 m:- Sand, very fine grained, clayey, poorly sorted, very light purplish grey, intense whitish calcrete cement, a few small, scattered, white calcrete nodules; bioturbation structures still preserved but not abundant.
-178.43 m to -179.32 m:- Sand, very fine grained, clayey, poorly sorted, very light purplish grey; abundant irregularly shaped calcrete and calcareous dolocrete nodules, both types rimmed by calcrete- and calcareous dolocrete-cemented sand; some red bioturbation.

-179.32 m to -180 m:- Sand, very fine grained, clayey, poorly sorted, very light purplish grey; fewer nodules but both large and small; one 15 cm diameter nodule at -179.5 m contains uncemented, sand-filled bioturbation channels; some bioturbation in the sand.

Ohangwena II Aquifer: -180 m to -244.3 m

-180 m to -187.65 m, core loss 7 cm

Sand, fine grained, very minor silt, well-sorted, soft, light grey or mottled very light grey to very light yellow or very light purple; a few scattered dolocrete nodules of different sizes in places, loose nodules between -184.14 m and -194.4 m – sand loss between these nodules; variably abundant light grey bioturbation channels (Fig. 33), much less common red bioturbation, local sand disturbance during bioturbation (Fig. 34). Individual layers from here on downwards are suggested by colour changes caused by bioturbation. Abundant grey bioturbation with a relatively sharp upper boundary forms the top of a layer. The grey bioturbation gradually decreases in abundance downwards to the base of the layer where the original light yellowish colour of the sand is more apparent (Fig. 33).

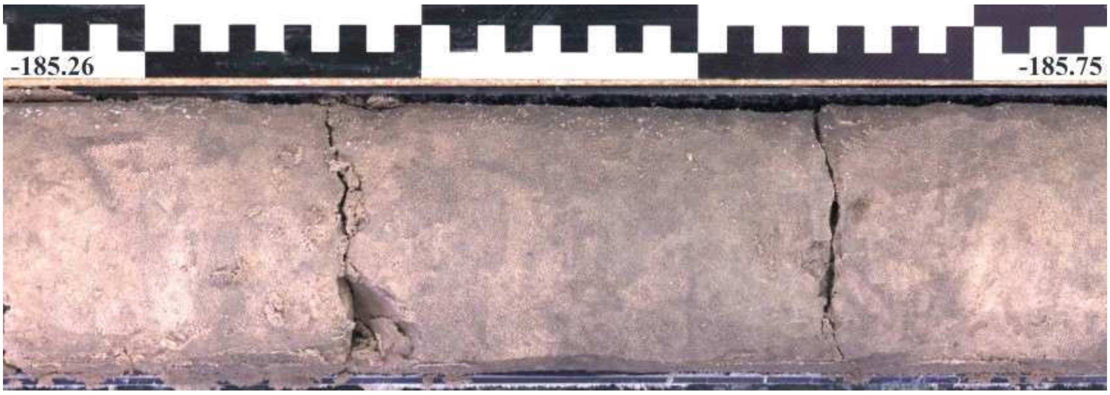


Figure 33. Core section from -185.25 m to -185.65 m: Light grey bioturbation burrows in the top of the Ohangwena II Aquifer; Top of grey bioturbated layer at -185.45 m, abundance of grey bioturbation burrows decreasing downwards to -186.65 m.

Figure 34. Core section from -181 m to -181.6 m, top of Ohangwena II Aquifer: There is a sharp sedimentary boundary at -181.04 m and a very light grey or purple tinge to the core below that. After the first very light purple and light red bioturbation, the sand was broken up into different sharp-edged coloured patches. Burrowing bioturbation then continued (see long, thin, vertical, slightly sinuous burrow or root channel between -181.3 m and -181.4 m). The dark red burrows seem to be the youngest, note the bleaching of the sand around them and the *Cruziana*-type lamination in the burrow at -181.54 m (diagenetic reduction of organic matter?).

-187.65 m to -192.36 m, core loss 19 cm

Same sand as above same colour variations, also light purple colour from -190 m; several large hard calcareous dolocrete nodules scattered through this section, most with a few sand-filled, bioturbation-like channels (Fig. 35); very light grey bioturbation burrows scattered through most of the sandy parts of this section, this very light grey colour changes to very light purple below -190 m (Fig. 36), rare red bioturbation. Individual layers can still be recognised.

Figure 35. Hard, white, calcareous dolocrete nodule enclosing uncemented, sand-filled bioturbation burrows(?). If these are burrows, they pre-dated the nodule; core section from -187.85 m to -188 m.

Figure 36. Scattered very light purple bioturbation burrows at the base of a layer; note the curved burrow at -190.93 m; core section from -190.75 m to -191 m.

-192.36 m to -208 m, core loss 0.81 m

Sand, fine grained, very minor silt, well-sorted, soft, very light yellow, core disturbed in places; i.e. same sand as above; no carbonate nodules except for a few tiny calcrete nodules between -202.5 m to -202.65 m, one large, hard, Fe-stained calcareous dolocrete nodule at -204.36 m and another from -206.8 m to -207.26 m; very light purple bioturbation in places and in different concentrations through this section; much less red bioturbation. Bioturbation is abundant from -193.98 m to -194.2 m (Fig. 37) and from -207.27 m to -207.62 m; no recognisable bioturbation where core is disturbed, i.e. between -200 m and -202 m. Some scat-

tered, very light purple patches speckled by numerous tiny dark purple spots between -195.6 m and -197.55 m (bioturbation?) (Fig. 38).
Bedding: Faint bedding at an angle of ~10° to the core axis from -194.24 m to -194.86 m,
Faint bedding at an angle of ~15° to the core axis from -194.7 m to -194.9 m (Fig. 39),
Faint horizontal bedding at -196.3 m, between -198 m and -199 m,
Two sets of bedding at different 10° angles to the core between -199 m and -200 m (Fig. 40),
Faint horizontal bedding between -203 m and -206 m.

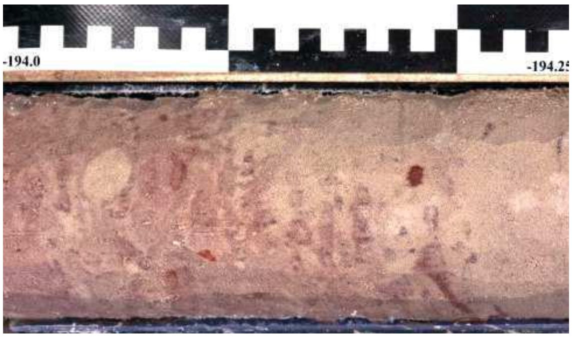


Figure 37. Abundant light purple burrows, fewer red burrows, base of layer at -194.2 m; core section from -194 m to -194.25 m.

Figure 38. Very light purple patches speckled by numerous tiny dark purple spots (bioturbation?). See also Fig. 41 for similar spots; core section from -196.3 m to -196.7 m.

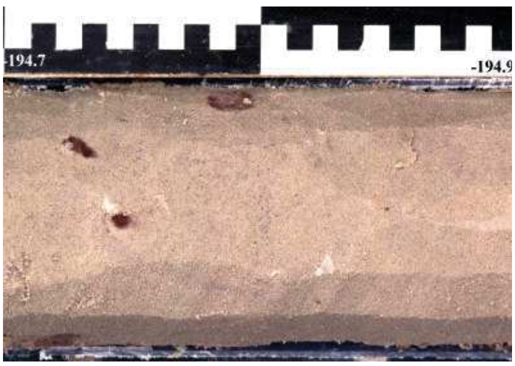


Figure 39. Faint laminated bedding at an angle of about 15° to the core; core section -194.7 m to -194.9 m.

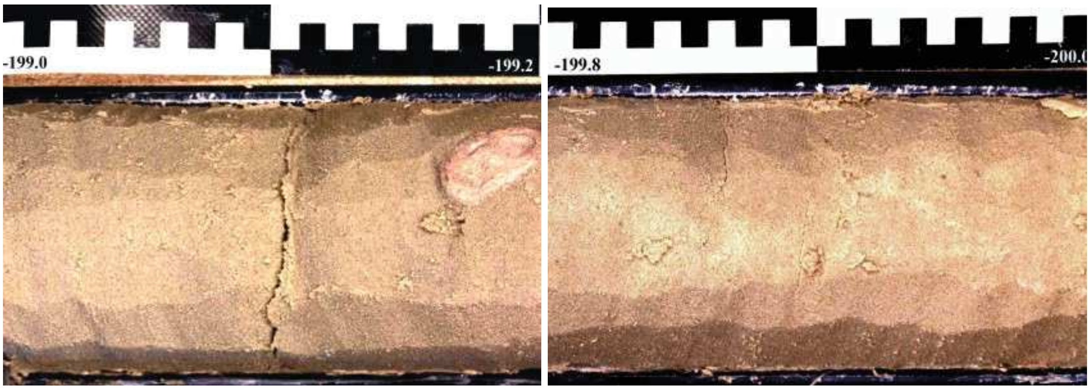


Figure 40. Faint cross bedding at different angles to the core in the upper and lower 20 cm of the core section -199 m to -200 m; Left - core section from -199 m to -199.2 m; Right – core section from -199.8 m to 200 m. Is this real or has the scanner produced this effect since the photographs are from each end of this metre-long section of core?

-208 m to -209 m

Sand, fine grained, very minor silt, well-sorted, soft, i.e. same sand as above; very light yellow, very light greyish yellow, purple staining from -208.54 m to -208.56 m, very red ferruginisation from -208.56 m to -208.66 m and 1 cm thick at -208.69 m; no carbonate nodules.

-209 m to -210.17 m

Sand, fine grained, very minor silt, well-sorted, soft, very light greyish brown to darker greyish brown, i.e. same sand as above but just a slight colour difference; 20 cm thick layer of finer grained, clayey, poorly sorted sand containing a large, white, hard, slightly calcareous dolocrete nodule with sand-filled cavities; some scattered, tiny purple spots between -209.5 m and -209.8 m (bioturbation?) (Fig. 41).

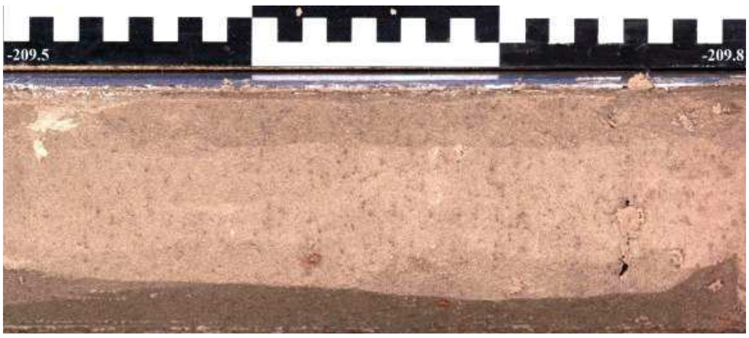


Figure 41. Scattered tiny purple spots, possible bioturbation. See also Fig. 38 for similar spots; core section from -209.5 m to -209.8 m.

-210.17 m to -215 m, core loss 1.7 m

First appearance of rust red sand (Fig. 42). Nine sand layers, mainly fine grained, very minor silt, well-sorted, soft, between intervening large, hard, white, dolocrete nodules with partly cemented, sand-filled, bioturbation-like cavities; of these nine sand layers, two are 29 cm thick, finer grained, poorly sorted, silty; colour variations between the sand layers are light greyish brown to darker greyish brown, rust red, light purplish brown (Fig. 43); several loose hard white dolocrete nodules from -210.74 m to -211.3 m – most core loss probably here; variable abundance of light purple bioturbation, less light red or red bioturbation.

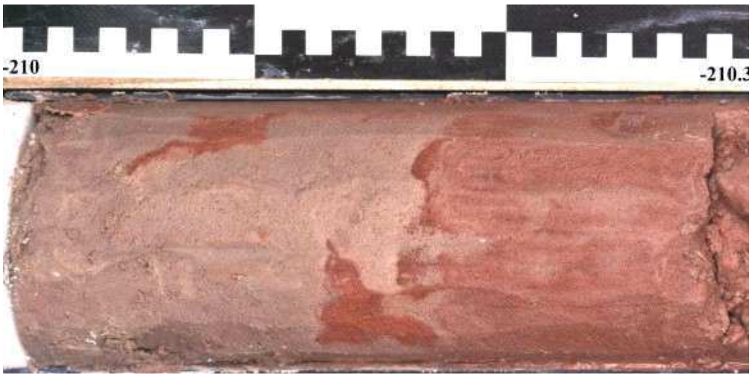


Figure 42. Uppermost layer of rust red sand at -210.17 m which is typical of the lower part of the Ohangwena II Aquifer; core section from -210 m to -210.3 m.

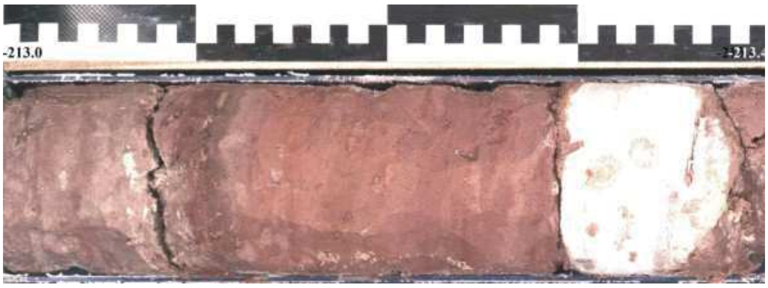


Figure 43. Layers of sand of different colours with intervening large, hard dolocrete nodules; core section from -213 m to -213.4 m.

-215 m to -219.7 m, core loss 1.8 m, no core from -217.6 m to 219 m

Sand, fine grained, very minor silt, well-sorted, soft, i.e. same sand as above, reddish purple brown; core disturbed in places; no nodules except form one large hard white dolocrete nodule from -217.05 m to 217.16 m; some unevenly distributed red bioturbation burrows.

-219.7 m to -224 m, core loss 1.5 m

Sand, fine grained to very fine grained, minor silt, fair to good sorting, soft, light purplish red and rust red, core disturbed in places; rare large hard white dolocrete nodules; bioturbation not obvious.

-224 m -244.3 m, core loss 8.45 m (from -225.8 m to -228 m & from -231.2 m to -234 m)

Sand, fine grained to very fine grained, minor silt, fair to good sorting, soft, rust red, occasional bedding planes visible between layers of different red intensities (Fig. 44), faint bedding in places, core disturbed in several places; rare hard white dolocrete nodules of different sizes; a few scattered red bioturbation spots below -229.4 m (Fig. 45).

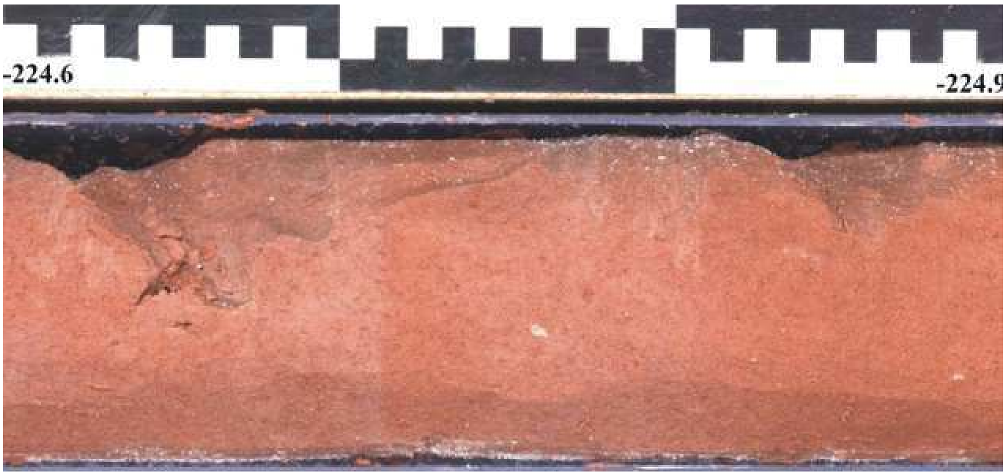


Figure 44. Beds of different red intensities; bedding planes at -224.71 m and -224.81 m with possibly cross bed at about 10° to the core between these two bedding planes; core section -224.6 m to -224.9 m.

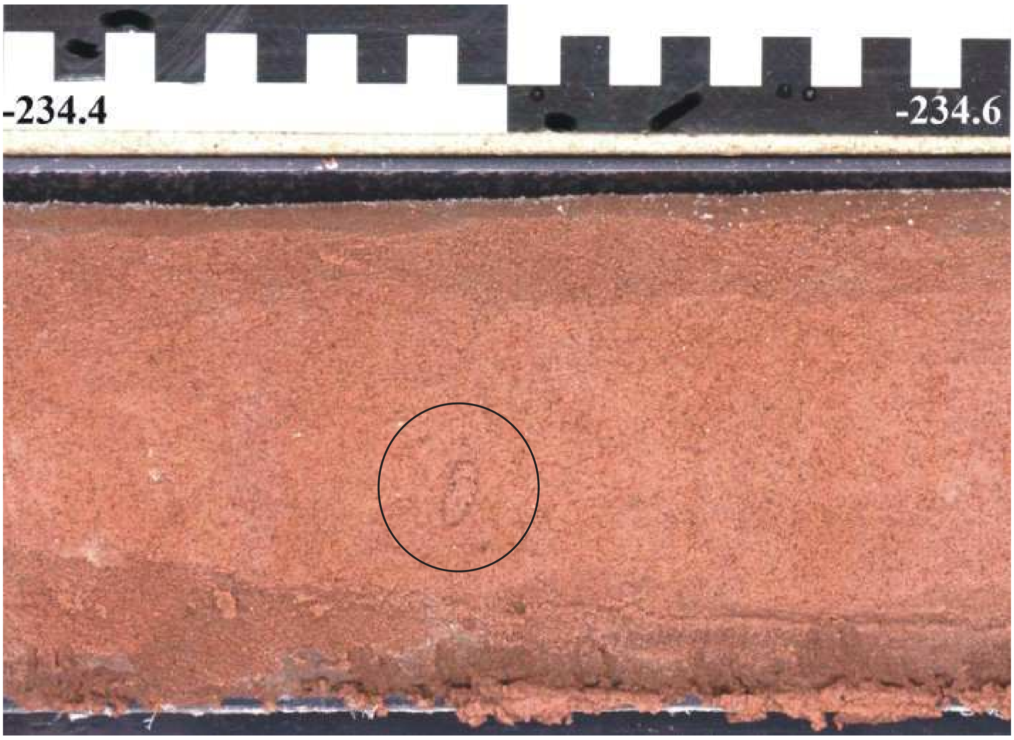


Figure 45. Rare bioturbation (?) structure that always occurs singly; core section from -234.4 m to -234.6 m.

-244.3 to -259.73 m, core loss 3.7 m

Bedding planes visible Sand, largely identical to above section; fine grained to very fine grained, more medium sized grains in the lower 5 m, minor silt locally, fair to good sorting, soft, rust red, occasional between layers of different red intensities (Fig. 44), core disturbed in several places; rare hard white dolocrete or calcareous dolocrete nodules of different sizes; a few scattered red bioturbation spots.

The Base of the Ohangwena II Aquifer at -259.73 m is taken to be the base of the Andoni Formation.

Olukonda Formation: -259.73 m – 400 m

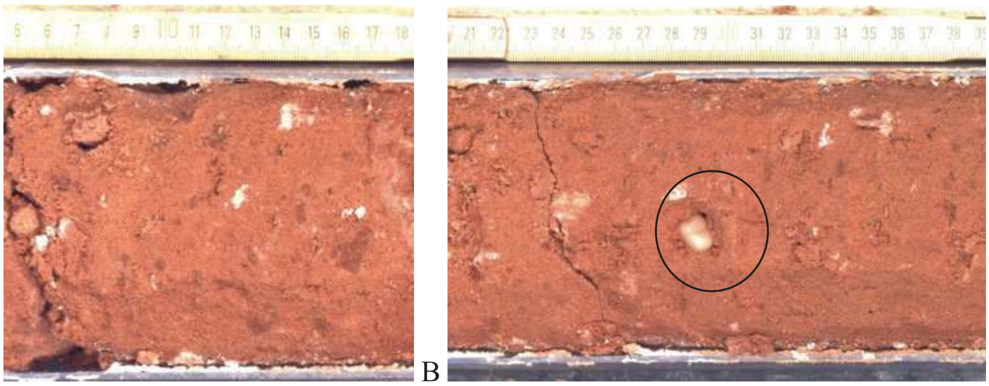
Stratigraphy below the Ohangwena II Aquifer the Olukonda Formation

Red, consolidated, semi-consolidated or soft silt and sand dominate the formation. The sands are fine- to very fine-grained and range from being well-sorted (very few layers) to variably silty and/or clayey. The silts are rarely well-sorted and are normally variably clayey or sandy. Calcrete or dolocrete cementing occurs locally in both sands and silts, varies in intensity and is far more abundant in the Olukonda Formation than in the Andoni Formation. Calcrete and/or dolocrete nodules occur in places in varying concentrations but there are sections totally free of nodules and cement. Interbedded in many sections of the sands and silts are red clays and thin sandy conglomerate layers containing intrabasinal clasts of calcrete, dolocrete and clay pellets. The matrices of the conglomerates are invariably cemented by hard white calcrete or dolocrete. The succession can be subdivided into sections dominated by specific lithologies or by interbeds of several sediment types.

-259.73 to -271.80 m: Sand, red, very fine-grained, silty

This consists predominantly of soft, red, poorly sorted, very fine-grained silty sand. Layers of red, fairly well- to well-sorted fine-grained to very fine-grained sand occur from -261 m to -262.35 m and from -267.72 m to -269.21 m. These have not been included in the Ohangwena II Aquifer because of the intervening poorly sorted sands. The red sand layer from -270 m to -270.8 m contains scattered clasts, these being quartz pebbles up to 1 cm in diameter (from a extrabasinal source?), some small fragments up to 1 cm diameter of dark red, intrabasinal, very clayey, very fine-grained sand to 0.25 cm across, and a few very small white clay fragments (Fig. 46 A and B). The uppermost of many thin, sandy conglomerate layers in the Olukonda Formation occurs between -269.71 m and -269.86 m (Fig. 47). This 15 cm thick layer contains small white calcrete clasts from sand size to ≤5 mm in diameter, a grey calcrete clast ±1 cm in diameter, and clay pellet clasts. Its matrix is cemented by a dense, hard, off-white calcareous dolocrete cement. Such dense dolocrete or calcrete cement is typical of almost all the underlying sandy conglomerate layers. With the exception of one conglomerate layer at a depth of -389.66 m to -389.72 m, all clasts are intrabasinal.

This section contains a few massive nodules of calcareous dolocrete between 10 cm and 90 cm thick as well as a few small scattered calcareous dolocrete nodules below -268 m.



A B

Figure 46. A: -270.05 m to -270.18 m; Dark red clasts of very clayey, very fine-grained sand and small fragments of white clay in soft, silty, poorly sorted, very fine-grained sand. B: -270.29 m; quartz pebble 1 cm in diameter (circled) in the same soft, silty, poorly sorted, very fine-grained sand.

Figure 47. -269.71 m to -269.86 m: Sandy conglomerate layer with intrabasinal clasts of white and grey calcrete and dark red clay. The matrix is cemented by hard white calcareous dolocrete.

-270.80 to -277.44 m: Sand, red, very fine-grained, silty, clayey

This is capped by a 9 cm thick, dark red clay containing streaks of very fine-grained unsorted sand. Below this, red very fine-grained, variably silty but clayey to very clayey sand predominates. From -273.27 m to -273.87 m is a mixed layer of uncertain origin (Fig. 48). From -276.3 m to -277 m there is a clast-bearing clayey, sandy conglomerate which is irregularly and patchily cemented by calcareous dolocrete and contains a few small scattered clasts of grey calcrete and more red clay. A few grey chert nodules, from granule size up to 1-2 cm diameter occur between -271 m and -277 m (Fig. 49). Uneven cementing by calcareous dolocrete has hardened parts of this otherwise soft sand.

Figure 48. From -273.45 m to -273.90 m is a mixed layer of soft, red, poorly sorted, very silty, very fine-grained sand containing irregular, darker patches of very similar but more clayey sand which may have been mixed during deposition (clasts of one in the other) or by bioturbation.

Figure 49. Grey chert nodule at -276.84 m in red, soft, very silty, very clayey, poorly sorted, very fine-grained sand. Sand above the nodule cemented by hard white calcrete.

-277.44 to -281.81 m: Clay, dark red, variably silty

This section consists of 10 layers of dark red clay and silty clay with minor interbedded red sand or silt. There is patchy calcrete cementing to -281.26 m, often along and enhancing bedding laminations of very thin beds (Fig. 50 A and B) and patchy massive dolocrete cementing below this.

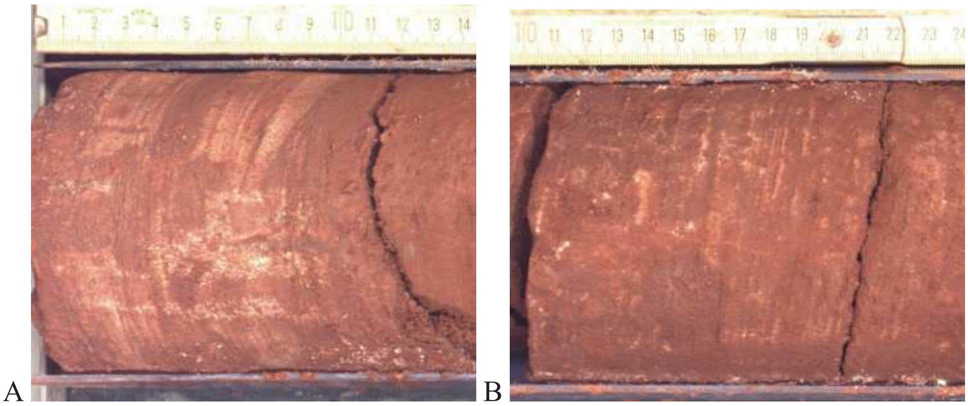


Figure 50. A: -279.0 m to -279.14 m, laminated clay cemented by hard white calcrete along and enhancing bedding laminae, ripple cross bedding laminae and very thin beds; B: -281.10 m to -281.24 m, very similar to A.

-281.81 to -285 m: Silt, clayey, red

This section consists mainly of red clayey silt with a coarse-grained, dolocrete-cemented sand layer with red clay clasts at the top (Fig. 51), a grit layer and two conglomeratic layers between 8 cm and 10 cm thick. The 20 cm thick grit layer between -282.80 m and -283 m is cemented by hard white slightly calcareous dolocrete. Some of the cement in the silt occurs in bedding-parallel bands. The two conglomerate layers contain small intrabasinal clasts of red clay and slightly calcareous dolocrete. Both conglomerate layers are cemented by hard white calcrete that is indistinctly layered parallel to and enhances bedding.

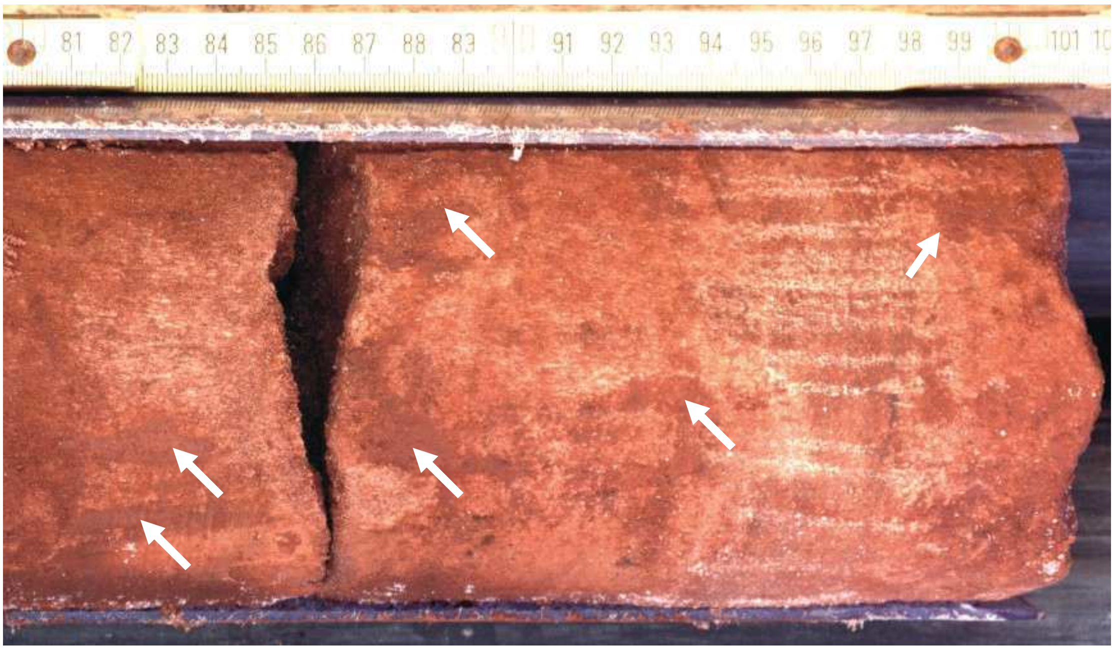


Figure 51. -281.80 m to -282.01 m: A coarse-grained sand layer containing red clay clasts (arrows). The layer is cemented by hard white slightly calcareous dolocrete. All medium- to coarse-grained sand layers and the coarse sandy matrix of conglomerate layers are invariably cemented by either calcrete or dolocrete and in some instances by both, one in the upper part, the other in the lower part.

-285 m to -287.76 m: Clay, silt, conglomerate and calcrete in alternating layers

There are five dark red, silty clay layers between 4 cm and 25 cm thick, three layers of massive hard white calcrete between 20 cm and 69 cm thick, two layers of soft to semi-consolidated, red, clayey silt between 13 cm and 52 cm thick, and two sandy, small-clast conglomerate layers between 10 cm and 47 cm thick. The latter have small intrabasinal clasts of white calcrete and larger clasts of red clay. The sandy matrix of both conglomerate layers is cemented by dense hard white calcrete. Each of the conglomerate and silt layers is capped by clay suggesting that the clay forms a quiet-water drape after currents had deposited the conglomerate and silt layers. One clay layer contains a few small irregularly shaped calcrete nodules.

-287.76 m to -291 m: Clay

There are 8 clay layers in this section that are silty and red to dark red in colour. Bedding laminae or very thin beds with local low-angle, ripple cross lamination (Fig. 52), enhanced by more silty laminae, occur between -288.28 m and -290 m. There is weak lamination-parallel cementing by calcrete or dolocrete that either enhances the laminae or is patchy. Some sections of the clay have only a calcrete cement whereas adjoining sections have only a dolocrete cement (Fig. 52). There are three vertical, rhyzolith-like calcrete nodules up to 25 cm long (Fig. 53) and in the basal metre, a few small dolocrete and calcrete nodules occur. Some of the nodules, both calcrete and dolocrete, are zoned with a black, dark grey or grey core and white rim.

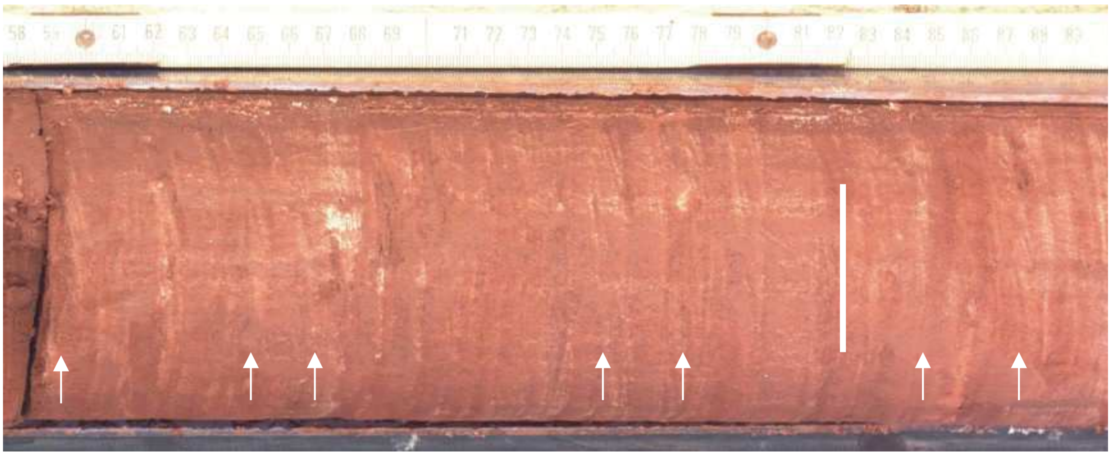


Figure 52. -288.58 m to -288.9 m: Red, laminated, silty clay with ripple cross lamination (arrowed). The bedding-parallel cementing enhances the laminations. The cement is dolocrete to -288.83 m and calcrete below this.

Figure 53. -290.7 m to -290.95 m: Long, vertical, rhyzolith-like calcrete nodule in red clay.

-291 m to -305.88 m: Silt

The main sediment type in this section is red, clayey to very clayey silt. Bedding laminae and/or very thin beds are well-developed down to -299 m. Below this, bedding laminae occur only sporadically until the last two metres where they become more abundant again. Most of the laminae are horizontal or form an angle of ≤5° to the core axis. A single 42 cm thick, cross-bedded unit with bedding forming an angle of ±20° to the core occurs from -291 m to -291.42 m (Fig. 54). Rarely, small clasts of red clay occur in a silt layer. The first metre of this section (-291 m to -292 m) is unevenly cemented by patchy calcrete. The rest of the silt is consolidated but lacks a pervasive carbonate cement. Instead, a few 1-10 cm thick, bedding-parallel bands of varying concentrations of hard white calcareous dolocrete or slightly dolomitic calcrete cements the silt in places thereby making laminae or beds more visible. Individual dolocrete or calcrete nodules in the silt are rare and are generally not larger than about 1 cm. A few of these are zoned with grey cores and white rims.

Figure 54. -291.0 m to -291.5 m: Single 42 cm thick cross-bedded unit of red clayey silt from -291.0 m to -291.42 m. The layering forms an angle of about 20° to the core. Horizontal bedding, the norm (cf Fig. 52), in the basal 9 cm of the photograph.

There are six interbeds of red clay between 1 cm and 137 cm thick, seven of sandy, small-pebble conglomerate between 2 cm and 55 cm thick and three 3-20 cm thick zones of bedding-parallel cementing of the sediment by calcareous dolocrete. The clay layers are red or dark red, silty or silt free. Some of the clay layers contain small nodules of calcrete and very calcareous to slightly calcareous dolocrete. Some of these nodules are zoned as described above. The conglomerate layers generally have a rather abundant sandy matrix which varies in grain size. Laminar bedding is visible where the sand is finer. Coarser sand generally occurs in thicker beds mostly not more than about 1 cm thick. Clasts can be abundant or scarce and scattered. All are intrabasinal and consist of white or grey calcrete up to 1.5 cm in size and smaller clasts of red clay, red silty clay or red clayey silt. Where only red clay clasts are present, they tend to be larger and up to 2 cm in size. The matrix sands are invariably intensely cemented by hard white slightly to highly calcareous dolocrete which may or may not obliterate the internal bedding.

-305.88 m to -308.89 m: Sand, clay, silt, conglomerate

This is a mixed succession of these sediment types: there are three layers of red, fine to very fine-grained, well- to poorly sorted sand or alternating sand and silt, between 6 cm and 112 cm thick, two of sandy, small-pebble conglomerate between 8 cm and 25 cm thick, one of red, very clayey silt 8 cm thick, and four of red clay or silty clay between 1 cm and 73 cm thick. There is local cross bedding. The sand layers are well-laminated with some whitish cementing by calcrete and dolocrete along and enhancing some of the laminae. Small red clay clasts occur in part of the silt layer. The conglomerate layers and one sand layer are directly overlain by clay layers in the nature of clay drapes. The conglomerate layers have only a few small clasts of white and grey calcrete accompanied by more abundant, smaller red clay clasts. Their sand matrix is densely cemented by calcareous dolocrete.

-308.89 m to -322.89 m: Silt, minor clay, conglomerate

Silt is the predominant sediment type in this section. The silt is red, fine-grained to very fine-grained, clayey to very clayey and consolidated to semi-consolidated. Fifteen silt layers between 5 cm and 137 cm thick are present. These are distinguished from each other by clay or sand content, or by proportions and type of enclosed nodules, or are separated from each other by other interbedded sediment types or by massive carbonate nodules/cement. The silts are only locally laminated but varying intensities of local, bedding-parallel calcrete and dolomitic calcrete cement enhance the bedding. Some layers are speckled by small cementation spots. Carbonate nodules occur only in a few of the silt layers in varying sizes and concentrations. There are six layers of red clay and silty clay between 5 cm and

63 cm thick, two of red, fine-grained sand between 5 cm and 35 cm thick, four of small-pebble conglomerate between 15 cm and 45 cm thick, and five of massive dolocrete, calcareous dolocrete or dolomitic calcrete between 5 cm and 35 cm thick. Some of the clay layers contain small zoned (as above) and unzoned calcareous dolocrete nodules.

The conglomerates all have an abundant coarse sand matrix and small intrabasinal clasts of white and grey calcrete and red clay and silty clay. The matrix in all layers is cemented by hard white calcrete that locally preserves the almost horizontal bedding.

-322.89 m to -326.81 m: Sand, clay, silt, conglomerate

This section consists of five red sand layers from 5 cm to 75 cm thick. Grain size is mainly very fine-grained but one layer is slightly coarser with fine sand. Sorting is fair to good despite a small silt component in the upper three layers. The fourth layer down is silty and poorly sorted and the fifth layer is well-laminated and densely cemented by lamination-parallel calcrete. Three of the sand layers are soft. Six clay layers from 10 cm to 31 cm thick are red to dark brown red in colour. Some are silty. One contains a 5 cm thick, laminated, cross bedded zone within which the bedding makes an angle of ±20° to the core axis. One clay layer contains two thin bedding-parallel bands of massive dolocrete. Other clay layers contain small scattered nodules of calcrete or dolocrete, both types of which can be zoned with grey cores and white margins. The single silt layer is red, well-sorted and soft. The single, 75 cm thick conglomerate layer (Fig. 55) has a very thinly bedded to laminated basal 20 cm with small clasts, a bedded middle section with abundant larger clasts of white calcrete up to 1 cm across, a few of grey calcrete and many of red clay up to 4 cm long. Long clay clasts lie flat in the bedding. The upper 13 cm has a few small calcrete clasts but the same larger clay clasts. The conglomerate is densely cemented by calcareous dolocrete.

Figure 55. Sandy conglomerate layer containing intrabasinal clasts. The matrix sand is cemented by calcareous dolocrete. A: -325.06 m to -325.2 m; upper part, a few small clasts of white calcrete, large red clay clasts. B: -325.3 m to -325.5 m; thinly bedded middle part, many white, a few grey calcrete clasts up to 2 cm in diameter, red clay clasts up to 4 cm long, latter flattened in the bedding. C: -325.6 m to -325.74 m; basal laminated part with a few small white calcrete and red clay clasts.

-326.81 m to -329.47 m: Silt, conglomerate

This section consists of seven red silt layers between 3 cm and 126 cm thick. The average thickness is 26 cm. Most silt layers are fairly well-sorted and soft but locally can be semi-consolidated to consolidated. Some layers contain a few red clay clasts (Fig. 56), an occasional dolocrete band, rare calcareous dolocrete nodules and local calcareous dolocrete that has cemented individual laminae or very thin beds thereby enhancing the bedding. Interbedded are five very sandy conglomerate layers ranging from 6 cm to 27 cm in thickness. The average thickness is 10 cm.

These conglomerate layers contain almost exclusively intrabasinal clasts of red clay and silty clay up to 1 cm in diameter. One layer contains a few small clasts of grey calcrete. The matrix sand of the four upper layers is densely cemented by calcrete, that of the lower two by calcareous dolocrete. The section includes one 19 cm thick layer of dark red silty clay that contains many dark nodules of calcrete and dolocrete.

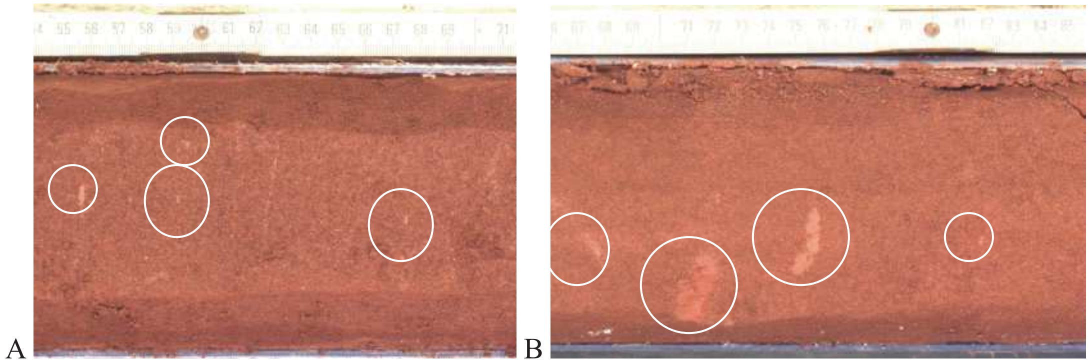


Figure 56. Red clay clasts in red silt (circled): A: -326.54 m to -326.71 m. B: -353.66 m to -353.85 m.

-329.47 m to -330.20 m: Clay

This section consists of six alternating layers of red, dark red brown or dark red clay between 3 cm and 17 cm thick. One layer has small, slightly calcareous black spots, another is partly cemented by calcareous dolocrete.

-330.20 m to -334.20 m: Silt, conglomerate

This section consists of five reddish brown, well-sorted, consolidated silt layers between 55 cm and 159 cm thick, averaging 59 cm. Laminated bedding is discernable from -331 m to -331.5 m. Interbedded are four sandy conglomerate layers between 3 cm and 10 cm thick, averaging 7 cm. Clast content varies from layer to layer but all are intrabasinal. The uppermost has white and grey calcrete clasts up to 2 cm in diameter and red clay clasts 5 mm across. The next layer down has clasts of red clay and reddish brown silt up to 1 cm in diameter. The third and fourth layers have clasts of white dolomitic calcrete and red clayey silt up to 1.5 cm in diameter and clasts of reddish brown clay up to 3 cm long lying flat in the bedding. These conglomerate layers are cemented either massively, patchily or along the bedding by hard white calcareous dolocrete or dolomitic calcrete.

-334.2 to -334.93 m: Conglomerate, clay

This section consists of three sandy conglomerate layers each with a red or red brown clay drape. The conglomerates range from 4 cm to 36 cm in thickness, averaging 16 cm. The clast suite in each is almost identical and consists of white dolomitic calcrete and red clayey silt up to 1.5 cm in diameter and clasts of reddish brown clay up to 3 cm long lying flat in the bedding. Each of these conglomerate layers is cemented by hard, white, bedding-parallel dolomitic calcrete that enhances the laminated bedding. The clay drapes range from 2 cm to 14 cm in thickness, averaging 6 cm (Fig. 57).

Figure 57. -334.45 m to -334.72 m. Two laminated to very thinly bedded, sandy conglomerate layers with a 2 cm thick clay layer that drapes the top of the lower conglomerate and separates the two conglomerates from each other. Both conglomerates contain small white calcrete clasts and red clay clasts, the larger of which are arrowed.

-334.93 to -338m: Silt, conglomerate

This section consists of eight red brown and red silt layers between 4 cm and 85 cm thick, averaging 31 cm. Most of the silt layers are very clayey and display laminar bedding. One that is only slightly clayey contains small clasts of red clay. Most of the laminated silt is semi-consolidated. Some laminae are almost pure clay. Unbedded portions of the silt are soft. Six interbedded sandy conglomerate layers range from 1 cm to 23 cm thick, average 9 cm. Scattered intrabasinal clasts of white calcrete and calcareous dolocrete are present and are up to 1 cm in diameter. Some of these clasts are zoned with grey cores and white rims (nodules?). Some clasts of red clayey silt and red clay are also present. The sandy matrix of each conglomerate layer is cemented by dolomitic calcrete or very calcareous dolocrete.

-338 m to -340.56 m: Clay, conglomerate

This section consists of ten stacked layers of red to dark red, locally laminated clay between 4 cm and 70 cm thick, averaging 21 cm in thickness. Some clay layers are silty, others are silt free. Some are variably calcareous and some have small white dolocrete and calcareous dolocrete nodules. One layer has thin, black, bedding-parallel streaks. Interbedded with the clay are three conglomerate layers between 14 cm and 29 cm thick, averaging 17 cm in thickness. The two upper layers contain abundant intrabasinal clasts of white calcrete and calcareous dolocrete up to 2 cm in diameter and much larger clasts of red clay, silty clay, and clayey silt. These two layers are cemented by hard white dolomitic calcrete. The lowest conglomerate layer has an abundant sandy matrix and fewer clasts. These are of rounded intrabasinal white calcrete and red clay up to 1.5 cm in diameter. The matrix sand is patchily cemented by white calcrete.

-340.56 m to -345.19 m: Silt, Clay

This succession consists of several red fining-upward depositional cycles of silt-clay in which the clay layer in all but two of the seven cycles is thin (4 cm, 5 cm, 2 cm, 7 cm and 1 cm) and in the nature of a clay drape. The two exceptions are 37 cm and 50 cm thick. There are nine silt layers ranging from 2 cm to 84 cm in thickness and averaging 37 cm. The silt is variably clayey and consolidated. Some silt layers contain a few small clasts of red clay. The silt is well-laminated where clayey or in layers and where a bedding-parallel cement of calcrete, dolocrete or calcareous dolocrete emphasises the laminations. Low-angle ripple cross-lamination is locally present. Some of the silt layers contain scattered calcrete and/or dolocrete nodules from 1 mm to 1.5 cm in diameter. The basal unit of one of the cycles is a red, fine-grained, laminated, 5 cm-thick sand that is cemented along the laminations by hard white slightly calcareous dolocrete. There is also one conglomerate layer 18 cm thick. It has an abundant coarse sand matrix and scattered intrabasinal clasts of white dolomitic calcrete and clayey silt up to 1.5 cm in diameter and of red brown clay up to 3 cm in diameter. The matrix is intensely cemented by hard white dolomitic calcrete that occurs along and enhances very thin bedding and laminae.

-345.19 m to -350.48 m: Clay, Silt, Conglomerate

This succession consists of 19 fining-upward depositional cycles of silt-clay, conglomerate-clay or, less frequently, conglomerate-silt-clay. Many of the clay layers are thin (1 cm - 8 cm) and are in the nature of quiet-water clay drapes. In total there are 17 clay layers between 1 cm and 22 cm thick, averaging 7.5 cm in thickness, 13 red silt layers between 1 cm and 94 cm thick, but 12 of them average 9 cm in thickness. There are 12 conglomerate layers that range from 2 cm and 50 cm in thickness, averaging 18 cm. The clay layers are usually significantly thinner than the directly underlying silt or conglomerate layer.

Most of the silt layers are laminated, some are clayey or sandy, but all are consolidated. A few are cemented by dolomitic calcrete or calcareous dolomite cement either massively, patchily or along bedding planes thereby emphasising the bedding lamination. A couple of the silt layers contain either scattered or numerous tiny calcrete nodules. One silt layer contains small, flat, angular calcrete clasts up to 1 cm long.

The clay layers are red, dark red or dark red brown in colour. One clay layer is silty, another contains a few small scattered calcrete nodules, and the lowermost clay layer contains a clast of calcrete and calcrete-cemented intrabasinal conglomerate up to 3 cm across.

All but one of the conglomerate layers have an abundant sandy matrix. The clast suite is from intrabasinal sources and varies in composition and size. Some layers have white calcrete or calcareous dolocrete clasts with maximum sizes of either 2 cm, 1.5 cm, 1 cm or 0.5 cm. All have red clay clasts which are small when the calcrete clasts are small but can be up to 5 cm and 7 cm long. The latter lie flat in the bedding. One conglomerate layer contains abundant white and grey calcrete clasts that fine upwards from 5 cm in diameter at the base to 1 cm across at the top (Fig. 59). The red clay clasts in this layer are less abundant and reach 3 cm in size. All conglomerate layers are cemented either by hard white calcrete, dolomitic calcrete or calcareous dolomite which can be massive, patchy or concentrated along laminae and thereby enhance the lamination.

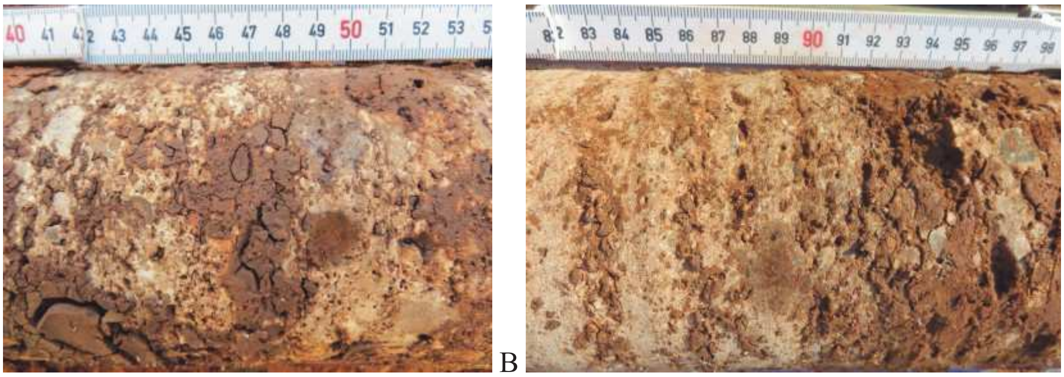


Figure 58. Intrabasinal red clay clasts in conglomerate layers, the sandy matrix of both layers being intensely cemented by dolomitic calcrete. A: -345.40 m to -345.54 m, large clasts of soft, red clay cracking up as it dries out, also clasts of grey and white calcrete; B: -352.82 m to -352.98 m, large red clay clasts at the base of the unit, thin layers of small red clay clasts higher up.

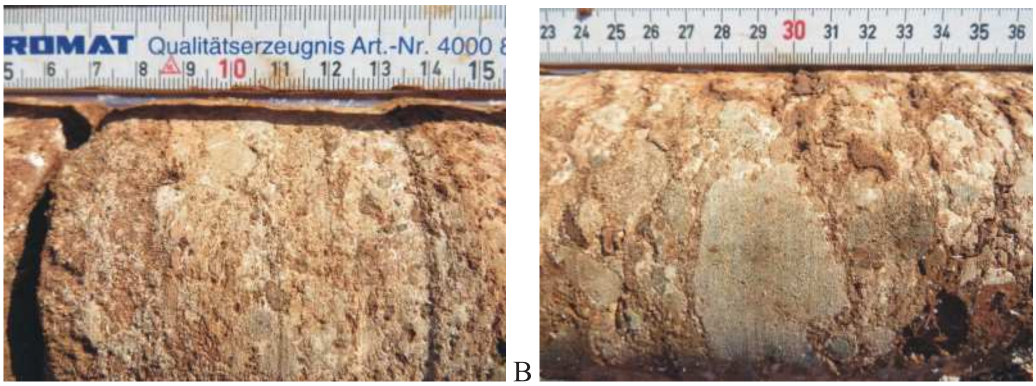


Figure 59. Upward-fining sandy conglomerate with numerous intrabasinal clasts of white and light grey calcrete and fewer clasts of dark red clay. The matrix is massively cemented by hard, white calcrete. A: Top, -348.05 m to 348.15 m; B: Base, -348.23 m to -348.36 m.

-350.48 to -354.78 m: Silt

This section contains 12 layers of red, almost nodule-free silt between 2 cm and 100 cm thick, averaging 31 cm in thickness. Some layers contain a fine-grained sand component, some are laminated, but all are consolidated. Two layers contain a few long, thin, flat, red clay clasts (Fig. 56). Locally there is bedding-parallel cementing by hard white calcrete that enhances the laminations. A 1 cm-thick layer of fine-grained sand is cemented by hard white dolomitic calcrete. Two upward-fining conglomerate layers occur in the section, 15 cm and 32 cm thick. White calcrete clasts are 1 cm in diameter at the base of each layer and fine up to 5 mm. Red clay clasts also fine upwards. There are layers of small red clay clasts in the lower of the two conglomerates (Fig. 58). The hard white dolomitic calcrete cement of both layers enhances the bedding lamination.

-354.78 m to -358.16 m: Sand

More sand occurs in this section. There are seven red sand layers from 1 cm to 59 cm in thickness and averaging 15 cm in thickness. Most are fine- to medium-grained, variably silty, soft, semi-consolidated or consolidated. One 3 cm-thick sand layer is well-sorted. Some of the sand layers contain small white clasts of calcrete or calcareous dolocrete or red clay. Some of the sand layers are patchily or densely cemented by hard white calcareous dolocrete. One 94 cm-thick layer consists of mixed patches of red fine- to medium-grained sand and red silt within which are many clasts of red clay between 5 cm and 2 mm in diameter (Fig. 60) as well as rare 1 cm-diameter clasts of white calcrete. The silt patches may also be clasts. There is one 15 cm-thick layer of red, slightly silty clay and one of sandy conglomerate 71 cm thick. The clay contains a few irregularly zoned calcrete nodules (black core, white rim) up to 1.5 cm in diameter. The conglomerate contains a few scattered intrabasinal white calcrete clasts up to 8 mm in diameter and scattered red clay clasts up to 8 cm long which are largely flat and lie parallel to the bedding. There is a variable intensity of hard white calcareous dolocrete cement in the upper part and dolomitic calcrete cement in the lower part. In places, cementing has taken place along laminae thereby enhancing laminae or very thin bedding.

Figure 60. -356.64 m to -356.87 m: Numerous clasts of red clay (paler red) in fine- to medium-grained red sand. Patchy cementing by hard, white calcrete.

-358.16 m to -364.15 m: Silt, conglomerate

This section contains 13 red, consolidated silt layers between 1 cm and 110 cm thick, averaging 33 cm. Most of the silt layers are sandy with fine- and medium-grained sand fractions. A few of the silt layers are slightly clayey or clayey. A few are fairly well-sorted without sand or clay. Laminated bedding is locally present. Patchy or bedding-parallel cementing by calcrete of calcareous dolocrete is present but not common. Instead, several sections in the silt are variably nodular with calcareous dolocrete and dolomitic calcrete nodules ranging in size from 2 mm to 5 cm (Fig. 61). Several of these are zoned as above. In places there are also long, narrow nodules up to 15 cm long either perpendicular or parallel to bedding (Fig. 62).

Figure 61. -358.8 m to -359 m: Scattered calcareous dolocrete and dolomitic calcrete nodules in red, clayey, consolidated silt; some nodules faintly zoned.

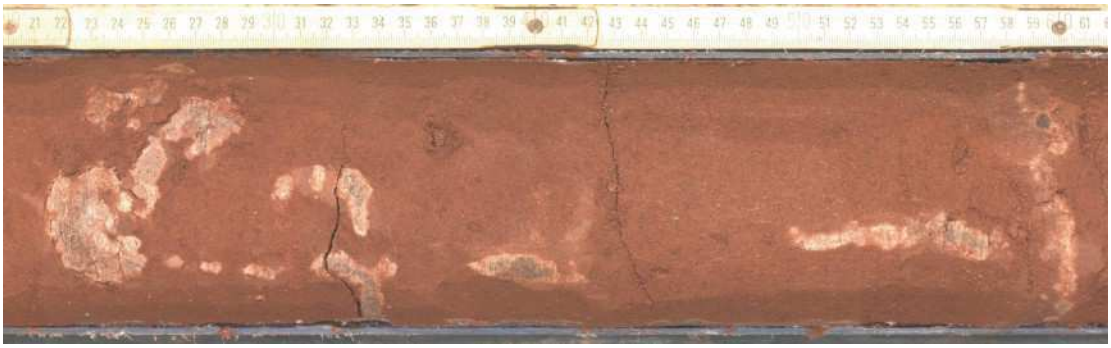


Figure 62. -361.2 m to -361.62 m: Unusual elongate, calcareous dolocrete nodules parallel and perpendicular (rhyzoliths?) to bedding in red, consolidated, slightly clayey silt; note zoning of nodules - grey cores, white rims.

There are seven sandy conglomerates layers ranging from 1 cm to 22 cm in thickness, averaging 8 cm thick. All have intrabasinal clasts of white or grey calcrete of calcareous dolocrete, up to 2.5 cm in diameter in the uppermost conglomerate layer but <5 mm across below this. Only the lowest conglomerate layer has red clay clasts up to 3 cm in diameter in addition to calcrete clasts. The hard white dolomitic calcrete or calcareous dolomite cement of the sandy matrix of the conglomerates can be massive, patchy or laminated parallel to bedding.

There are three red clay layers 1 cm, 3 cm and 22 cm thick. The thickest of these contains several black, knobbly, calcareous dolocrete and dolomitic calcrete nodules with thin white rims as above and up to 3 cm across (Fig. 63).

A 50 cm-long vertical streak 6 mm wide at -362.5 m may be a bioturbation burrow (Fig. 64).

Figure 63. -359.05 m to -359.20 m: Black, knobbly calcareous dolocrete and dolomitic calcrete nodules with thin white rims in red clay.

Figure 64. -362.15 m to -362.65 m: An intermittent, 6 mm-wide and 50 cm-long vertical streak that may be a bioturbation channel or burrow.

-364.15 m to -370 m: Silt, Sand, conglomerate

Within this section are nine red silt layers, eight red sand layers and three conglomerate layers. The silt layers range from 5 cm to 100 cm in thickness and average 40 cm. They vary from being sandy, slightly sandy (fine sand to very fine sand) to clayey. One slightly sandy layer has small red clay clasts. Silt layers in the upper part of the section are semi-consolidated to consolidated but the basal three are soft. The uppermost, 7 cm-thick silt layer is intensely cemented by nodular calcrete. Some layers are nodule free or almost so, but other layers contain varying concentrations of roundish to irregularly shaped calcareous dolocrete and dolomitic calcrete nodules from a few millimetres to 5 cm in size, some of which are zoned (Fig. 65).

The sand layers range from 1 cm to 79 cm in thickness and average 24 cm. Most are fine grained, silty and unsorted. Even silt free fine- to medium-grained sands are poorly sorted. Two layers contain small red clay clasts. The uppermost sand layer is hard due to patches of white calcrete cement. This layer also contains a rip-up clast of white, dolocrete-cemented, small-pebble conglomerate. All other sand layers are soft and, apart from one layer with thin horizontal nodules, are nodule free. Two massive calcrete nodules between 2 cm and 13 cm in diameter are present.

The three conglomerate layers are, from top to bottom, 15 cm, 44 cm and 27 cm thick. The uppermost layer has an abundant very sandy (fine sand) to clayey matrix with many intrabasinal clasts of red clay up to 3 cm in diameter and a few of white or grey calcrete, all patchily cemented by dolomitic calcrete. The second layer has an abundant matrix of medium- to coarse-grained sand with smaller clasts of white dolomitic calcrete and red clay reaching only 1 cm in size. This matrix is intensely cemented by hard, white, dolomitic calcrete. The lowest conglomerate layer fines upwards and contains intrabasinal clasts of subangular to rounded, dark grey to white, slightly to very calcareous dolocrete which are up to 5 cm across at the base and 1.5 cm across at the top. red clay clasts fine upwards from 8 cm at the base to <1 cm at the top. The 8 cm red clay clast at the base is enclosed in a thin veneer of white, coarse-grained, silty sand. The same sand fills cracks in the clast (Fig. 66). This demonstrates that this clast was a curled-up mud crack that had a white sand layer deposited over it and within cracks in it before it was ripped up by the next flood event and deposited as a clay pellet. All the red clay fragments in the conglomerates, sands and silts probably have the same origin.

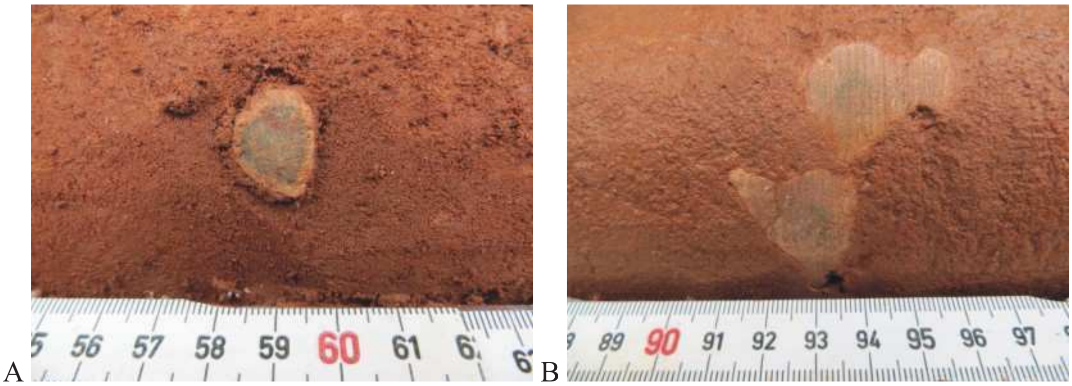


Figure 65. Core section from -366 m to -367 m: Zoned slightly calcareous dolocrete nodules in red, clayey silt. Note the contrasting widths of the white rims.

Figure 66. -369.7 m: Ripped up mud flake as a red clay clast in conglomerate. Note the white sand surrounding the clast and in the two cracks in the clast. This suggests that all red clay clasts in silts, sands and conglomerates are ripped up mud flakes from the tops of desiccated and mud cracked clay layers. This in turn suggests cycles of flooding followed by desiccation. Base of photograph 8.5 cm wide.

-370 m to -400 m: Sand

This section contains 63 layers of red sand from 1 cm to 107 cm thick, averaging 32 cm in thickness. There are 13 layers of red silt from 8 cm to 72 cm thick and averaging 33 cm in thickness. Thirteen layers of red, dark red or brown red clay range from 2 cm to 33 cm in thickness and average 10 cm in thickness. Sixteen layers of conglomerate range from 2 cm to 84 cm in thickness and average 22 cm in thickness. Two massive, hard, white calcrete nodules, 13 cm and 5 cm thick, occur near the base of the section.

A few of the clay layers are slightly silty but most of the layers contain neither sand nor silt and appear to be mainly clay drapes. Only one clay layer has nodules which are calcareous dolocrete. The clay layer between -381.19 m and -381.24 m contains sand-filled bioturbation burrows. The layer between -371.07 m and -371.19 m contains a clast of a nodular, polycyclical, very calcareous, pedogenic dolocrete. The underlying silt layer contains three similar clasts (Fig. 67). The silt layer between -387.23 m and -387.31 m contains similar pedogenic dolocrete clasts. The silt layers are either clayey or sandy and range from being soft to consolidated. The two silt layers between -394.36 m and -395.29 m contain a few dark grey or grey-green silcrete nodules up to 1.5 cm across. Calcrete and dolocrete nodules are rare and small in the silts.

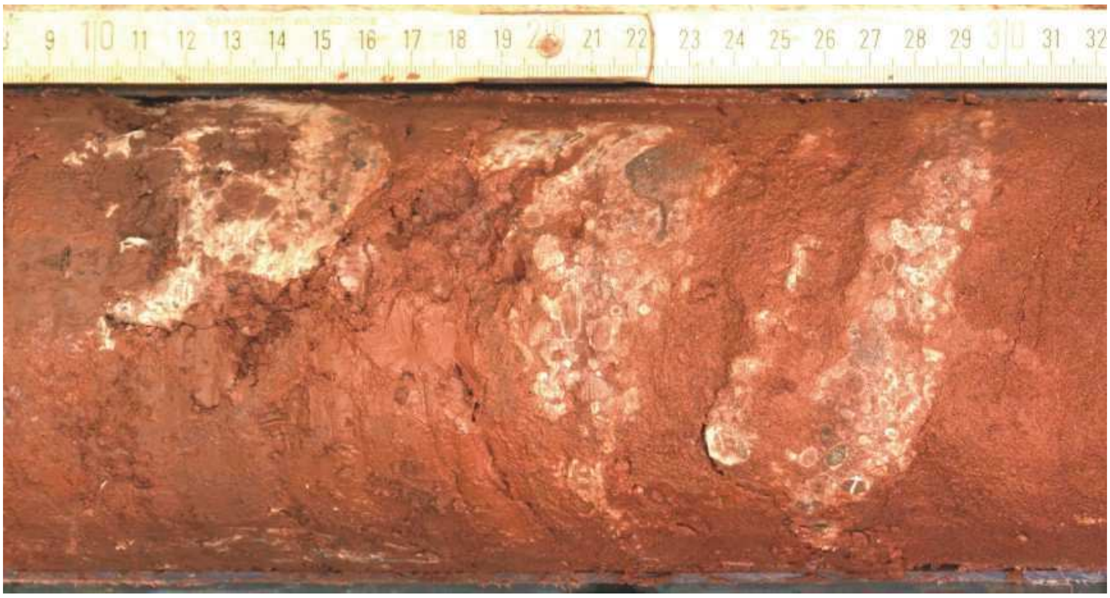


Figure 67. -371.08 m to -371.32 m: Four clasts of hard, white, very calcareous, polycyclical, nodular, pedogenic dolocrete. Note the white and grey nodules (latter with white rims) and the later intense white cement dolocrete enclosing the nodules. Upper clast in red clay, lower three clasts in red, slightly sandy, semi-consolidated silt. These clasts strongly suggest that pedogenic calcretes and dolocretes upstream were the source of the calcrete and dolocrete nodules in all the conglomerates.

The conglomerate layers have an abundant sandy matrix, normally medium to coarse-grained, but occasionally also clayey in layers with abundant red clay clasts. All layers contain intrabasinal clasts of white or grey calcrete of dolocrete and, all but one, clasts of red clay of varying abundance and size. The 6 cm-thick conglomerate layer from -389.66 m to -389.72 m contains extrabasinal clasts of red, fine-grained quartzite (Nosib Group?) and green weathered basalt up to 3 cm long (Fig. 68). All conglomerate layers are cemented, often along the bedding, by hard white calcrete or calcareous dolocrete. One layer is cemented by this calcrete in the upper half and by dolocrete in the lower half.

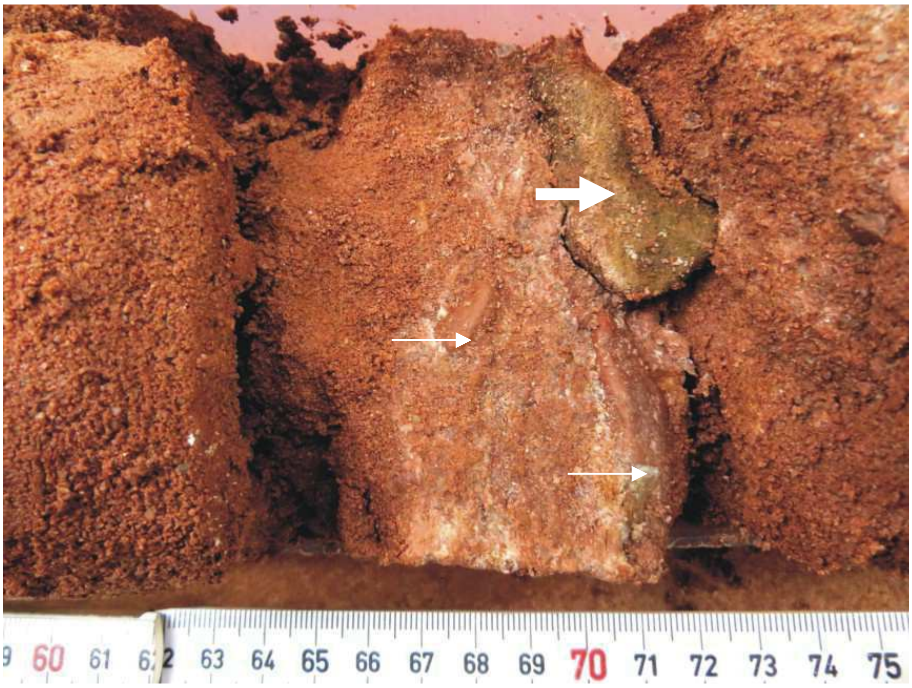


Figure 68. -389.7 m: Thin conglomerate layer with extrabasinal clasts of red, fine-grained quartzite (thin arrows) and green weathered basalt (?, thick arrow).

Calcrete and dolocrete nodules occur only in a few of the sand layers and can be abundant, scattered or rare and range from 1-2 mm in size to 5 cm.

The sand varies from fine grained, silty, clayey and poorly sorted through fine- to medium-grained, fairly well- to well-sorted sand to medium- to coarse-grained sand that is generally well-sorted. As the grain size increases to coarse-grained sand, so cementing by calcrete, dolomitic calcrete, dolocrete or calcareous dolocrete becomes more manifest and can be patchy, rather massive or bedding parallel, the latter enhancing bedding. Varying concentrations of small clasts of red clay occur in 18 of the sand layers. The layer from -390.61 m to -391 m contains a grey, fine-grained, extrabasinal quartzite pebble 1.5 cm in size. Unsorted sand layers with silt and clay fractions tend to be semi-consolidated to consolidated but not invariably. Well-sorted, fine-grained layers are almost invariably soft. There are rare features that may be ascribed to bioturbation (Fig. 69).

Figure 69. -372.4 m to -372.75 m: Faint, white, vertical bioturbation channel or burrow.

Of the 63 layers of sand, 32 are fairly well- to well-sorted, soft, uncemented and unconsolidated. However, there is very limited or no connectivity between many of these layers due to intervening layers of poorly sorted silty to clayey sands, cemented sand, silt, clay and cemented conglomerate as demonstrated in the following list of thicknesses. Thus, although individual layers are potential aquifers, the section as a whole is not an aquifer. The red clay clasts in some of the well-sorted sands suggest that the permeability of these layers may not be as good as those lacking such clasts.

107 cm - fairly well- to well-sorted sand.
88 cm - clay, silt, cemented conglomerate.
94 cm - fairly well- to well-sorted sand.
49 cm - cemented sand.
9 cm - fairly well- to well-sorted sand.
19 cm - cemented sand.
6 cm - fairly well- to well-sorted sand.
10 cm - cemented sand.
33 cm - fairly well- to well-sorted sand.
187 cm - clay, silt, poorly sorted sand, cemented conglomerate.
1 cm - fairly well- to well-sorted sand.
13 cm - cemented conglomerate.
89 cm - fairly well- to well-sorted sand.
43 cm - clay, silt.
8 cm - fairly well- to well-sorted sand.
5 cm - cemented sand.
22 cm - fairly well- to well-sorted sand.
7 cm - cemented sand.
10 cm - fairly well- to well-sorted sand.
26 cm - poorly sorted sand, cemented conglomerate.
20 cm - fairly well- to well-sorted sand.
9 cm - cemented sand, clay.
20 cm - fairly well- to well-sorted sand.
23 cm - cemented conglomerate.
205 cm - fairly well- to well-sorted sand.
414 cm - cemented sand, unsorted sand, silt, clay, cemented conglomerate.
2 cm - fairly well- to well-sorted sand.
9 cm - cemented conglomerate.
6 cm - fairly well- to well-sorted sand.
17 cm - unsorted sand, cemented conglomerate.
9 cm - fairly well- to well-sorted sand.
27 cm - cemented conglomerate.
11 cm - fairly well- to well-sorted sand.
189 cm - unsorted sand, cemented sand, silt.
106 cm - fairly well- to well-sorted sand.
15 cm - cemented conglomerate.
45 cm - fairly well- to well-sorted sand.
16 cm - cemented sand, cemented conglomerate.
28 cm - fairly well- to well-sorted sand.
2 cm - cemented conglomerate.
39 cm - fairly well- to well-sorted sand.
32 cm - cemented sand.
74 cm - fairly well- to well-sorted sand.
108 cm - cemented sand.
6 cm - fairly well- to well-sorted sand.
108 cm - clay, cemented conglomerate, calcrete.
7 cm - fairly well- to well-sorted sand.
325 cm - cemented sand, silty, clayey sand, silt, cemented conglomerate.
28 cm - fairly well- to well-sorted sand.
68 cm - cemented sand.
100 cm - fairly well- to well-sorted sand.

The base of the Olukonda Formation was not reached.
The base is the Beiseb Formation which is a conglomerate carring a variety of extrabasinal pebbles.

Interpretation and summary

<u>Andoni Formation</u>

<u>The Perched Aquifer, not sampled</u>

This was missed as core recovery began only at -8.5 m. From other boreholes in the area, the Perched Aquifer ranges from 0 m (seldom) to 30 m (seldom) in thickness. It has an average thickness of 10-11 m. The upper one to three metres consists of sorted, medium- to fine-grained aeolian sands into which heavy rains generally drain away within 24 hours. Downwards, the grain size becomes finer and sorting becomes progressively poorer although there is still a considerable proportion of well-rounded and frosted aeolian grains. Quartz grains dominate by far. A huge time gap appears to separate the sediments of the Perched Aquifer and the underlying aquitard (see below).

The aquitard between the Perched and Ohangwena I Aquifers: -8.5 m to -38.5 m

The sand in the aquitard is primarily fine-grained, poorly sorted and very light yellow. A 6 m thick section with somewhat better sorting occurs between -19.5 m and -25.5 m. Frosted medium-grained clasts of aeolian origin are still a significant component of the sand but their proportion appears to decrease downwards. These grains must have been incorporated into the megafan fluvial sediments from local aeolian systems of roughly the same age or from older, reworked aeolian sources. In places, a few coarse-grained clasts and even granules are scattered through the core (Fig. 4). Their random distribution does not seem to be a primary sedimentary feature and may be due to bioturbation. Quartz grains again dominate by far.

The upper three metres of the aquitard consist of very light yellow, poorly sorted, fine-grained sands that are hard and pervasively cemented by calcrete or dolocrete. This intense cementation of the upper three metres is typical of pedogenic calcretes which implies that the top of this aquitard was part of a stable land surface with less than a metre of sand/soil cover over the calcrete for tens of thousands or even hundreds of thousands of years. The 6 m ferruginous zone from -10 m to -16 m could represent part of a soil profile accompanying pedogenic calcrete development. The cementing will have destroyed porosity and renders the section impermeable.

Below the ferruginised zone, sand colour is very light yellow with a whitish tinge down to -26.5 m due to carbonate cementing. Cementing is significant down to about -18 m but gradually becomes less intense and the core slowly becomes progressively softer downwards. Below -26.5 m cementing is present but weaker than above. The core remains semi-consolidated down to -38.5 m, the base of this zone.

The Ohangwena I Aquifer: -38.5 m to -99.3 m

This is subdivided into three stratigraphic units, namely between -38.5 m and -62.5 m, between -62.5 m and -71.5 m, and between -71.5 m and -99.3 m, all dominated by quartz grains.

The uppermost section is a soft, strikingly uniform, very light yellow, moderately well-sorted, fine-grained, aquifer sand extending from -38.5 m to -62.5 m. Some 1-2 m thick layers of medium-grained, moderately well-sorted sand are also present.

The intermediate unit is 9 m thick and extends from -62.5 m to -71.5 m. It consists of the same fine-grained, moderately well-sorted, very light yellow sand. The difference is that the sand is consolidated by calcrete and dolocrete cements. Soft, less cemented or uncemented zones occur in places. The lateral extent of this unit is unknown as is its permeability. If laterally extensive and impermeable, it could form an aquitard between upper and lower parts of the Ohangwena I Aquifer.

The lower unit extending from -71.5 m to -99.3 m is a better aquifer than the top unit. It consists of the same fine-grained, very light yellow sand but sorting is better. Most of the unit is very soft, totally unconsolidated and water saturated. The core is significantly disturbed in many places and wash-outs have resulted in a total core loss over the length of this unit of 7.7 m. Movement of short, partly cemented sections and the odd hard dolocrete nodule may have contributed to difficulties during drilling and significant disturbance of the underlying soft sand. The loss of soft sand suggests there may a considerable water over-pressure in this section of the aquifer.

The aquitard between the Ohangwena I and II Aquifers: -99.3 m to -180 m

This aquitard is a basin-wide zone but there must be lateral variability through it. Within this borehole, the aquitard can be subdivided into specific stratigraphic units, namely between -99.3 m and -109.77 m, between -109.77 m and -112.9 m, between -112.9 m and -127 m, between -127 m and -138.05 m, between -138.05 m and -148 m, and between -148 m and -180 m. All sands are again dominated by quartz grains.

In the section from -99.3 m to -109.77 m, the very light yellow colour of the sand still prevails but zones of a very light brown colour are also present. The sand is fine grained and poorly sorted. This unit was deposited after a major environmental change from a more humid climate to a semi-arid climate and after a long period or series of periods of non-deposition. Evidence for this is provided by the underlying unit. This unit is very silty at the base (up to 20% silt) but slowly becomes less silty upwards suggesting a gradual approach to a wetter climate with more runoff and a progressively better sorting of the transported sediment through time. If this interpretation is correct, it would suggest that the overlying well-sorted sands of the Ohangwena I Aquifer reflect the culmination of this evolution to a more humid climate with more runoff and, consequently, better sorting of the transported sands.

The section from -109.77 m to -112.9 m, i.e. 10 m from the top of the aquitard, encompasses a major though gradual environmental change. Four nodular pedogenic calcretes or dolocretes that are spread through this section point to four long periods of non-deposition and stable land surfaces which enabled the pedogenic calcretes/dolocretes to form just below the sediment surface. For such pedogenic carbonates to form, the climate must have been seasonal and semi-arid with short, hot rainy seasons with rainfall averaging less than 550 mm annually and long dry periods between (Miller, 2008, and references therein). This climate change also saw the final demise of a long-lived biota that produced green burrows in newly deposited, wet sediment. Each of the three lower pedogenic carbonates occurs near the green bioturbated top of a layer and clearly post-dates the bioturbation (Fig. 18). Deposition only continued after the pedogenic carbonate had formed, probably tens of thousands of years later. Bioturbation of the new sedimentary layer then followed. The top of the last green bioturbated layer occurs at a depth of -110.77 m. The pedogenic carbonate capping this layer is 46 cm thick (Figs 14, 15). The top of the fourth and youngest of the pedogenic carbonates occurs at -109.77 m (Fig. 13) and is located at the base of the very light brown sands that were deposited at the very end of this semi-arid period. The ensuing climatic conditions were more humid because there are no pedogenic carbonates higher up in the succession. This also means much more rapid deposition and too short a time lapse between the deposition of individual layers to allow pedogenic carbonates to form.

The biota that caused a light green bioturbation of otherwise very light brown sands finally died out completely after the last green layer was deposited and during the formation of the third pedogenic carbonate. The demise of the biota was not immediate. It would have been gradual and would have started during the beginning of the gradual evolution to semi-arid conditions when the first pedogenic carbonate built up at the depth of -111.6 m to -112.15 m.

The section from -112.9 m to -126 m was initially a succession of very light brown, fine-grained, clayey sand layers. Each layer was intensely bioturbated before the next layer was deposited, the biota producing burrows that were filled with light green, clayey sand. The bioturbation was concentrated in the top 10-50 cm of layers and generally rendered this top portion entirely light green. The intensity of the bioturbation invariably decreased downwards so that the light green burrows are only scattered in the very light brown sand (Figs 17 - 21). Although the light green colour of the sands continues to a depth of -148 m, slightly darker green bioturbation burrows are rare.

Two similar pedogenic calcretes occur at a depth of between -130 m and -135 m in core borehole WW 201217 (collar elevation the same as this borehole) which is 42 m from the top of the aquitard between the Ohangwena I and II Aquifers and significantly deeper than in this borehole. The suggested explanation for this difference in elevation of the pedogenic calcretes in these two boreholes is that deposition of the aquitard was extremely slow and as the main depositional channel slowly switched back and forth across the megafan, pedogenic calcretes were able to form in those parts of the megafan where no deposition was taking place for extended periods of time.

The bulk of the remaining section of the aquitard from -126 m down to -180 m is fine grained, clayey to very clayey and poorly sorted. The clay is very likely to be smectite which swells when wet to fill pore spaces thereby reducing permeability almost to zero (Lindemaier, 2012). Nevertheless, the detailed descriptions of the core reveal a variety of depositional conditions and varying sediment compositions.

The 12 m thick section from -126 m to -138 m consists of 10 m of soft, green, fine-grained, very clayey sands that are choked with small, hard nodules of dolocrete or calcareous dolocrete (Fig. 22) sandwiched between two 1 m thick, green, non-calcareous clays. Although calcrete and dolocrete nodules occur in many places in the core, the intense choking by such nodules of this 10 m section is unique. The two bounding clay layers appear to have accumulated in a small, local and temporary quiet-water end-point or lake that may have been filled by gentle overflow from more active sediment transport channels. The intervening green, nodule-ridden, clayey sands accumulated under more active depositional conditions possibly during more active but, nevertheless, intermittent flooding of the lake. Although very clayey, this 10 m thick unit must have been highly calcareous initially. The growth of the nodules has largely destroyed any sedimentary structures and layering that may have been present so it is not easy to explain why this 10 m section is so carbonate rich. However, few bioturbation burrows, slightly darker green than the green sands, are preserved indicating that the sands were wet and soft for long enough to permit bioturbation. The abundance of carbonate may have had something to do with depositional conditions. For example, if the sands were deposited in very thin layers with long intervals between the deposition of each layer, growth of tiny pedogenic carbonate nodules could have been initiated under a seasonal, semi-arid climate (note the abundance of frosted, well-rounded quartz grains) with annual rains but only rare flooding and a long dry period. These tiny nodules would then become nucleation centres for later diagenetic enlargement. The clayey sand between the nodules is only cemented by the same dolocrete over a thickness of 2 m near the base of this 10 m unit. Nodule growth could be ascribed to there having been enough permeability to allow short-distance migration of carbonate to nodule nucleation points but only within this highly calcareous zone and certainly not from sediments above and below the two confining clay layers.

Between -138 m and -148 m, the green, fine-grained, poorly sorted sands are clayey but have variable clay contents. The green colour becomes light green downwards and is also light green where the sands are partially cemented by calcrete or dolocrete. A 50 cm thick, deep greyish purple clay extends from -141.73 m to -142.26 m (Fig. 25). The interstitial clays in the sands on either side of this clay are also purplish.

From -148 m to -180 m, the sands remain fine grained, poorly sorted and variably clayey but are very light yellow. Very light purple bioturbation pervades the core in places and imparts this colour to such places. There are also a few very thin light green layers. Some of the layers between -163 m and -166 m have slightly better sorting. A 50 cm thick layer of very light olive clay is present between -176.5

m and -177.04 m. The poorly sorted, clayey sand of this section rests with a sharp contact on the top of the Ohangwena II Aquifer. The basal two metres of this unit contains numerous, large and hard calcrete and dolocrete nodules which may indicate a preferential development of such nodules along contact zones between layers or units of contrasting lithologies.

The Ohangwena II Aquifer: -180 m to -259.73 m

As with the higher stratigraphic units, this is not a single stratigraphic unit but consists of at least two parts.

The upper 29 m of this aquifer down to -209 m consists of soft, totally unconsolidated, fine-grained, well-sorted, quartz sand that is mainly very light yellow in colour but has light grey or light purple patches resulting from bioturbation(?) (Figs 33, 36). The next metre is light greyish brown in colour and then the uppermost rust red sand layer appears at -210.27 m. For the next 14 m to -224 m, the colour of the sand varies from greyish brown to rust red, light purplish brown, purplish brown and light yellow. Below that the colour varies only slightly in shades of rust red to the base of the aquifer at -259.73 m (Figs 44, 45). As with the Ohangwena I Aquifer, the soft and totally unconsolidated sands of the Ohangwena II Aquifer are water saturated and, in places, have been disturbed by drilling. Core loss from -180 m to -259.73 m amounts to 10.7 m. The loss of soft sand suggests there must be a considerable water overpressure in this section of the aquifer.

As with the Ohangwena I Aquifer, the tremendous uniformity of the well-sorted aquifer sands of Ohangwena II must reflect specific climatic conditions that were very different from those that prevailed during deposition of the poorly sorted and often clayey sands of the aquitards. It is again suggested that the climate during deposition of these aquifer sands was humid resulting in far better winnowing of transported sands during much higher runoff.

The rust red colour of the lower sands is due to a hematite coating of individual sand grains. This is indicative of an oxidised source region and the maintenance of oxidising conditions in the sediment during deposition, burial and throughout deposition of the rest of the megafan succession. This rust red colour is inherited from the underlying Olukonda Formation which is rust red in colour throughout. The interbedding of rust red, light yellow and light brown layers in the 14 m section above the rust red section suggests that the light brown and yellow layers are from a different source or sources. Whether oxidising conditions within the overlying sediment changed after burial is uncertain but the purplish patches suggest bioturbation with some addition of organic matter to the sediment very soon after deposition. In the upper part of this aquifer in core borehole WW 201217, parts of the core released H_2S when tested for carbonate with dilute HCl. This clearly indicates some degree of reduction and possible colour change after burial.

Bioturbation features are far less common in the lower, red part of the aquifer and are not readily discernible.

Olukonda Formation

Red, consolidated, semi-consolidated and soft silt and sand dominate the formation. Silt comprises up to 40% of the formation, sand 30 %, conglomerate 16 %, clay 11.6 % and thick calcrete or dolocrete concretions 2.4 %.

The silts are rarely well-sorted and are normally variably clayey or sandy. Many silt layers contain a few, small, scattered clasts of red clay.

The sands are fine- to very fine-grained and range from being well-sorted to variably silty and/or clayey. Several sand layers also contain a few scattered clasts of red clay ranging from 2 mm to 2 cm in size. Towards the top of the formation, several sand layers are fairly well- to well-sorted suggesting a gradual transition to the Ohangwena II Aquifer but these are invariably interbedded with poorly sorted sands so have not been included in the aquifer.

Hard, white calcrete or dolocrete cementing occurs locally in both sands and silts and varies in intensity. It has been assumed that this cementing has taken place in the coarser grained, better sorted, more permeable base of layers but the cement obscures whether this is really the case. Calcrete and/or dolocrete nodules occur in places in varying concentrations but there are sections totally free of nodules and cement.

Interbedded in many sections of the sands and silts are thin sandy conglomerate layers containing intrabasinal clasts of calcrete, dolocrete and red clay pellets. The matrices of the conglomerates are invariably cemented by hard white calcrete, dolomitic calcrete, dolocrete or calcareous dolocrete.

The clays are red or dark red. Some are sandy or silty. They are rarely calcareous but a few contain calcrete or dolocrete nodules.

The succession can be subdivided into sections dominated by specific lithologies or by interbedding of several sediment types.

Over the 140.27 m of the Olukonda Formation there are 84 sandy, carbonate-cemented conglomerate beds ranging from 1 cm to 84 cm in thickness. Most, though not all, contain clasts of white or grey calcrete or dolocrete. All conglomerates contain red clay clasts. In some layers, all clasts are small (≤ 5 mm), in others the clast size is fairly uniform (±1 cm for calcrete or dolocrete clasts), in yet others the clast size fines upwards. Maximum size of carbonate clasts is 3 cm but clay clasts can be as large as 8 cm long and +1.5 cm thick. The large clay clasts almost invariably lie flat in the bedding. Except for the conglomerate at -389.7 m which contains extrabasinal clasts and the quartz pebbles in the sand layer between -270 m and -270.8 m, all clasts are intrabasinal and are derived from older Kalahari sources within the Kalahari Basin. The abundance of clay-bearing silt and sand layers and 113 layers of clay between 1cm and 105 cm thick suggest that this Kalahari source must have been clay rich. The average thickness of the clay layers is 18 cm but 57 of the layers are less than 10 cm in thickness.

The red clay clasts in the conglomerates and in some of the sand and silt layers provide a clue to depositional conditions. The key to the assertion that the clasts in the conglomerates must have been from intrabasinal sources are the red clay clasts. Often the clay layers form a thin capping to a layer of silt, sand or conglomerate much in the nature of a clay drape but there are also sections of stacked clay layers or isolated clay layers significantly thicker than the average. The clay layers would normally accumulate under quiet-water conditions in local shallow depressions or channels after fluvial transport of coarser grained sediments.

It is common in semi-arid environments with a seasonal climate and irregular thunder showers for desiccation to follow periodic runoff. Thus, mud cracks and mud flakes with curled up edges will develop on the top of clay layers. The next flood would pick these up and transport them as clasts or rip-up clasts. The sandy conglomerates with the hard clasts of calcrete and dolocrete must have been transported by relatively strong currents but the associated large clay clasts, often larger than the carbonate clasts, suggest short-distance transport in order to ensure their preservation. Large carbonate and clay clasts suggest proximal deposition whereas the small clasts suggest distal deposition but never a distance beyond which clay clasts would totally disintegrate. Small clay clasts also survived in many of the sand and silt layers. Thus, the clay clasts must be intrabasinal and from relatively proximal sources.

The calcrete and dolocrete clasts in the conglomerates are rounded to subangular. The large ones are generally rounded to sub-rounded. In a semi-arid environment with less the 550 mm of rain annually, pedogenic calcretes or dolocretes form within a few centimetres of the top of soil cover on flat to gently sloping land surfaces that have been stable for millennia (Goudie, 1983). Pedogenic calcretes normally have a thin, hard coalesced hardpan top and a much thicker nodular part in the soil profile underneath. The nodules can coalesce close to the hardpan top but below this they float as individual nodules in the enclosing soil. Erosion of such a pedogenic calcrete produces a few fragments of the hardpan top and innumerable loose nodules. The calcrete and dolocrete nodules in the conglomerate layers are believed to have been derived from actively eroding pedogenic calcretes and dolocretes upstream. Since no extrabasinal clasts occur in the conglomerates, the pedogenic carbonates are assumed to have been part of an older Kalahari profile being eroded further upstream. The fragments of hard, polycyclical, nodular, very calcareous pedogenic dolocrete at -372.2 m support the assumption that such pedogenic calcretes and dolocretes must be the source of the calcrete and dolocrete nodules in the conglomerates.

Post-depositional modification of the sediments

Bioturbation

Bioturbation produced the first and almost immediate modification of the sediments. This will have taken place immediately after deposition while the sediment was still wet and possibly even when there was still a shallow water cover and while active biota had access to oxygen. Thus, the bioturbation provides important information on depositional conditions.

Only 16% of the core is not bioturbated and half of this percentage is in the soft, highly disturbed sediment of the aquifers where delicate bioturbation structures could have been destroyed during squeezing and stretching of the core and as a result of core loss. Thus, the core reveals an incredible amount of bioturbation almost throughout the whole depositional sequence drilled. The shallowest bioturbation structures occur at a depth of -11 m and the deepest in the final 0.3 m of the core.

Up to three periods of bioturbation producing different coloured structures can be recognised. The earliest is often faint or subtle and recognisable only as small segments of different colour within the core (Figs 6, 7) or as faint elongated burrows (Fig. 8), or as a faint early bioturbation overprinted by later, better defined burrows, (Figs 6, 10, 21, 28-31, 33, 37). Colour of the early period of bioturbation changes down the length of the core from light yellow (Fig. 8) to very light green (Figs 17-21), to very light purple (Figs 25-31, 36), and locally light grey (Fig. 33) or light red (Fig. 37). The second period of bioturbation that overprints the first is generally the same colour as the first but simply a darker shade. The second period structures can also be light red or a strong rust red in colour where only two periods are recognised. Where three periods as present, the third period is always the strong rust red. Except for Figure 37, the light red and strong rust red structures are always the least abundant of all structures. In some cases, intense bioturbation becomes less intense downwards which appears to define individual sedimentary layers or at least the tops of individual layers (Figs 17-21, 33, 37). In that part of the core from -154.3 m to -160.7 m, all three generations, light purple, darker purple and rust red, are sharply defined and fairly evenly scattered without the typical concentration of layer tops (Figs 29-31). Nevertheless, the upper 4 m of this section have a greater concentration of structures than the lower 2 m. In this section, both the darker purple and the red burrows have internal, *Cruziana*-type laminations and many of the burrows are zoned with dark margins and light yellow centres.

The sediment must have remained wet long enough for one community to be replaced by another or for redox conditions in the sediment to change so that late structures differed in colour from the early ones.

Later bioturbation occurred after burial when roots penetrated to various depths in the soft sediment succession. Rhyzolith calcification must have been even later still.

In the upper, very light yellow part of the Ohangwena II Aquifer there is a considerable number of very light grey to faint purplish bioturbation features with rare red bioturbation features. These are still present where the sand colour gradually becomes darker. In the red sands, deeper red or zoned or whitish bioturbation features do occur but are much less common and less obvious.

In the Olukonda Formation, bioturbation is rare. Where present, it appears as lighter coloured sands in burrows in the red sediment. There may be rare calcified burrows or rhyzoliths (Figs 48, 53, 62, 64, 69).

Carbonate cementation

Andoni Formation

Cementation by calcrete and dolocrete of the poorly sorted, fine-grained sands of the first 3 m of the core below the presumed Parched Aquifer is intense, is probably largely pedogenic in nature and signifies a long period (possibly as much as 1 million years) of a stable land surface prior to deposition of the sands of the Perched Aquifer. The intensity of this cementation slowly decreases downwards to -38.5 m. Below that only a few very short sections of the core, generally less than 1 m thick are hard and carbonate cemented. A few short sections of the core are slightly calcareous. The light olive clay hosting calcrete nodules between -176.5 m and -177 m is highly calcareous but the other clays are non-calcareous.

The four stacked pedogenic calcretes/dolocretes between -109.77 m and -112.7 m are also climate-related as described above.

Olukonda Formation

There is much more cementing of the Olukonda Formation by hard, white calcrete, dolomitic calcrete, dolocrete and calcareous dolocrete. The matrices of all the conglomerate layers are thoroughly cemented (Figs 47, 51, 55, 57, 58, 59, 66, 68). This suggests that the matrices of these layers were permeable thus allowing carbonate-bearing solutions to permeate along these layers, gradually cementing them up. Much of the laminated to very thinly bedded silt and sand is also cemented but this has clearly taken place along the bedding (Figs 50, 52, 54), again suggesting permeability of specific laminae or beds. This cementing is a diagenetic feature but it is unknown how long after deposition it took place.

Carbonate nodules

The cementing of permeable layers is totally different from the growth of carbonate nodules which almost invariable grow as individuals and occur in impermeable clayey silt or sand or even clay. Carbonate nodules are diagenetic features that post-date other post-depositional changes to the sediment, i.e. the bioturbation, cementing of permeable layers. They probably develop long after burial. Hard and soft nodules in the same piece of core suggest at least two different growth periods. The nodules vary in size from tiny spots up to almost 0.5 m in diameter. They occur scattered through the core in varying abundances. Most are hard, off-white calcareous dolocrete, a few are dolocrete, and even fewer are calcrete. Some of the very small white calcrete nodules are soft. The highest concentrations of nodules are in the aquitards. There are variable abundances in the good aquifer sands. Many of the nodules in the Ohangwena II Aquifer are large. The following is a highly simplified list of the distribution of nodules through the core.

Andoni Formation

-16.5 m to -33.5 m: rare;
-33.5 m to -39.5 m: none;
-39.5 m to -62.3 m: rare; Top of Ohangwena I at -38.5 m;
-62.5 m to -68.5 m: slightly more;
-68.5 m to -77.5 m: rare
-77.5 m to -109.77 m: none to very rare; Base of Ohangwena I at -99.3 m;
-109.77 m to -112.7 m: none to very rare in the poorly sorted clayey sands between the pedogenic calcretes/ dolocretes;
-112.7 m to -118.6 m: very rare;
-118.6 m to -120.3 m: several large nodules;
-120 m to – 127 m: rare;
-127 m to -137 m: green, poorly sorted, fine-grained, very clayey sand choked with nodules;
-137 m to -139.4: rare;
-139.4 m to -155.2; scattered, large and small;
-155.2 m to -157.9 m: rare;
-157.9 m to -168.1 m: scattered, large and small;
-168.1m to -170.1 m: rare;
-170.1 m to -171 m: scattered;
-171 m to -172 m: none
-172 m to -176.5 m: a few;
-176.5 m to -181.8: many, mainly large; Top of Ohangwena II at -180 m;
-181.8 m to -183.85 m: rare;
-183.5 m to -184.4 m: a single large nodule;
-184.4 m to -187.65 m: none;
-186.65 m to -192.36 m: many, large;
-192.36 m to -210.45 m: none or very rare;
-210.45 m to -213.45 m: many, large;
-213.45 m to -217.05 m: none;
-217.45 m to -222.4 m: a few, large;
-222.4 m to -228.3 m: rare, large;
-228.3 m to -240.05 m: none;
-240.05 m to -241.9 m: a few, large and small;
-241.9 m to -249 m: none;
-249 m to -255.66 m: rare and small;
-255.66 m to -259.73 m: none; Base of Ohangwena II at 259.73 m;

Olukonda Formation (the list below only records post-sedimentation nodules in uncemented sands, silts and clays);

-259.73 m to -260 m: none;
-260 m to -263.35 m: four very massive nodules;
-263.35 m to –266.65 m: none;
-266.65 m to -269.72 m: a few, some massive, some scattered;
-269.65 m to -272 m: small & scattered, varying concentrations;
-272 m to -273.29 m: several zones of massive calcareous dolocrete cementing – nodules?;
-273.29 m to -277 m: none;
-277 m to -277.58 m: a few, small;
-277.58 m to -291.85m: patchy cementing in places, nodules very rare;
-291.85m to -293.7 m: none;
-293.7 m to -295.76 m: rare;
-295.76 m to -301.29 m: none;
-301.29 m to -303.54 m: scattered small nodules, varying concentrations;
-303.54 m to -307.7 m: rare;
-307.7 m to -309.13 m: a few, small, scattered;
-309.14 m to -313.03 m: none;
-313.3 m to -313.7 m: two small clusters of tiny nodules;
-313.7 m to -314.32 m: scattered small nodules;
-314.32 m to -316 m: rare;
-316 m to -317 m: scattered small elongate nodules;
-317 m to -323.1 m: a few, various sizes;
-323.1 m to -324.55 m: clay zones with nodules, many dark grey to black;
-324.55 m to -327.56 m: rare;
-327.56 m to -338.5 m: none or very rare and tiny;
-338.5 m to -340.38 m: small scattered nodules in some clay layers;
-340.38 pm to -350.12 m: some zones with clusters of small nodules;
-350.12 m to -358.85 m: rare;
-358.85 m to -359.4 m: higher concentration of small nodules;
-350.4 m to -361.20 m: rare;
-361.20 m to -363.18 m: knobbly larger nodules often elongated vertically or parallel to bedding;
-363.18 m to -364 m: rather dense clustering of small irregular nodules;
-364 m to -369.86 m: rare to widely scattered.
-369.86 m to -374.24 m: none;
-374.24 m to -375.32 m: zones of small clustered nodules;

-374.32 m to -381.55 m: rare to a few;
-381.55 m to -381.91 m: small scattered nodules;
-381.91 m to -387.73 m: rare;
-387.73 m to -395.85 m: none;
-395.85 m to -398.22 m: zones of small nodules;
-398.22 m to -400 m: none.

Drilling over the past few decades has shown that such nodules occur throughout the Kalahari succession in the Owambo Basin. They obviously form from through-flow of carbonate-bearing pore water in the sediment but the amount of through-flow that results in growth of nodules and the source of the carbonate are unknown. The 10 m thick, nodule-choked sand between -127 m and -137 m may provide an answer. This sand is green, fine grained, poorly sorted and very clay rich. It is sandwiched between two impervious, 1 m thick clays. These clays would have prevented flow of water from overlying or underlying sands into the nodular zone. Similarly, the sand matrix between the nodules is so poorly sorted and so clay rich that lateral flow through the sand would have been all but impossible. Studies of previous borehole cores, have shown that the green clay is smectite that swells and blocks porosity and permeability when wet (Lindenmaier, 2012). This all strongly suggests that the carbonate formed a significant component of this 10 m thick sand at the time of deposition. Once nucleation of nodules had begun, a chemical gradient permitted diffusion of carbonate molecules to such nucleation points. The distance between nodules may possibly be a measure of the distance over which diffusion could have taken place. This could also be an explanation for all isolated and oddly shaped carbonate nodules throughout the fine-grained, poorly sorted, poorly permeable to impermeable parts of the succession, i.e. limited lateral diffusion of greater or lesser amounts carbonate within sediments already containing some carbonate either as detrital grains or a weak, early carbonate cementing. The aquifers appear to have contained less carbonate. Here through-flow or long-distance diffusion may have been more important. Many of the nodules, though not all, in the aquifers are large suggesting growth over a long period of time with through-flow providing low concentrations of carbonate from distant sources. Nucleation points in the aquifers were, in general, far apart.

Silcrete nodules

These are rare. A layer of dark brown nodular silcrete occurs between the depths of -88.2 and -88.47 m (Fig. 11). Some occur as cores to nodules in the pedogenic calcrete between the depths of -110.54 m and -110.72 m. Two occur at -138.51 m.

Conditions of Deposition and Climate Change Summary

Andoni Formation

The start of deposition of the Andoni Formation records a major change from the largely clayey silts and sands of the Olukonda Formation to the well-sorted, uniforms sands of the Ohangwena II Aquifer, the unit forming the base of the Andoni Formation. This is suggestive of a wetter climate resulting in more runoff and better sorting of sediment at the borehole site.

Surprising has been the abundance of bioturbation by burrowing organisms. Some of this may have taken place while the sediment was still wet or even still submerged. But zoological bioturbation of dry sediment, with or without a vegetation cover, could have been just as extensive. The intensity of bioturbation decreases downwards in bioturbated layers. This reveals something about conditions soon after deposition of a layer but it does not indicate the time lapse between the deposition of individual layers.

From a study of diatoms, sponge spicules, phytoliths and authigenic minerals in the cores of core boreholes WW 201216 and WW 210217, Fenner (2010) (See also Lindenmaier, 2012) concluded that clay-rich sediments were deposited in a temporary, fresh-water, shallow lake (many borehole logs show that there were local, temporary, shallow water bodies, often isolated from each other, in which clay layers or very clay-rich sands were deposited) in the Cubango Megafan that slowly became slightly alkaline (diagnostic diatom) and then dried up completely so that the sediment became significantly saline with a high pH (authigenic analcime, clinoptilolite). Flooding and desiccation occurred repeatedly. Open water lasted long enough for aquatic plants to grow. Nevertheless, the climate was seasonal with flooding during the rainy season and a long dry interval between the summer rains. Under such conditions of repeated inundation and desiccation salt build up was inevitable (Miller, 2008; Miller *et al*. 2010) and sediment accumulation could not have been rapid. Abundant phytoliths of C4 grasses together with some from trees, shrubs and palms were washed in with the sediments. Thus, a savannah-type environment prevailed.

However, the sedimentary succession also indicates that within the prevailing seasonal climatic conditions, there were more humid periods with greater and stronger runoff, drier periods with weaker runoff and even hot, semi-arid periods during which pedogenic calcretes/dolocretes formed. During the first and relatively prolonged wetter period, the higher runoff produced the well-sorted sands of the Ohangwena II aquifer which were sourced from oxidised sources and deposited and buried under oxidising conditions. Reducing conditions may have prevailed in the top part of the aquifer after deposition. Then followed a long period of reduced rainfall when runoff was much more limited and produced only poorly sorted, variably clayey sands. Burrowing biota were able to establish themselves in the sediments deposited during this period. It was only towards the end of this period that there were long breaks of tens of thousands to possibly hundreds of thousands of years between the deposition of individual sedimentary layers. In this long time interval, pedogenic calcretes/dolocretes formed just below the surface of soil profiles. During the slow build up of such pedogenic calcretes/dolocretes, the average seasonal rain falling on the megafan sediments was less than 550 mm per annum (pedogenic calcretes do not form where annual rainfall is higher than this - Goudie, 1983; Miller, 2008, and references therein). There was then a slow increase in rainfall and higher and stronger runoff which finally deposited the well-sorted sands of the Ohangwena I Aquifer. After deposition of the lower part of the aquifer, the volume of runoff began to wane gradually and slowly the sorting of the aquifer sand began to become poorer until finally runoff was only strong enough to deposit the poorly sorted sand of the uppermost aquitard. Although well-rounded grains of apparent aeolian origin form a significant proportion of all sands and provide further support for a seasonal environment, this proportion appears to increase upwards in the upper aquitard. The whole of this aquitard is cemented by calcrete or dolocrete but the uppermost 3 m are the most intensely cemented. These 3 m point to a long very dry period but with enough seasonal rain for the carbonate cement to develop over time. The top of the carbonate-cemented sands must be a palaeo-surface. Miller (2008) and Miller *et al*. (2010) demonstrated that the deposition of fluviatile sediments in the Kalahari Group had ceased by 4 million years ago. This was when the Arctic Ice Cap began to expand and the whole of Africa became extremely arid (see DeMenocal references). The carbonate cementing at the top of the aquitard is the result of the build up to this aridity. It was also during this time that the unsorted sands of the Perched Aquifer were deposited. The aeolian sheet sands at the top of this aquifer and the Kalahari dunes formed thereafter during the most intensely arid intervals in the period between about 3 Ma and 1 Ma.

Olukonda Formation

The Olukonda Formation is red throughout. The colour has been inherited from an oxidised source area and is due to a coating of amorphous hematite on all grains. The oxidising conditions in the sediment were maintained during deposition and subsequently during burial. Evidence of bioturbation is rare and faint.

The conglomerates provide an indication of the frequency of stronger flooding events at the borehole locality caused either by periods of varying length of higher or lower seasonal rainfall or by migration of the main channel system back and forth across the megafan. The table below suggests an almost rhythmical alternation of periods of more frequent and less frequent flooding.

Frequency of conglomerate layers			
Section depths	Section thickness	Number of conglomerate layers	Frequency of conglomerate layers
From 259.73 m - 284.30 m	24.57m	2	1 layer every 12.29 m
From 284.30 m - 308.70 m	24.40m	13	1 layer every 1.88 m
From 308.70 m - 321.89 m	13.19 m	4	1 layer every 3.30 m
From 321.89 m - 338.51 m	16.62 m	21	1 layer every 0.79 m
From 338.51 m - 345.38 m	6.87 m	2	1 layer every 3.44 m
From 345.38 m - 350.48 m	5.10 m	12	1 layer every 0.43 m
From 350.48 m - 358.16 m	7.68 m	3	1 layer every 2.56 m
From 358.16 m - 364.15 m	5.99 m	8	1 layer every 0.75 m
From 364.15 m - 400.00 m	35.85 m	19	1 layer every 1.89 m

Conclusions

Both the Olukonda and Andoni Formations attest to intermittent fluvial depositional conditions under a seasonal, semi-arid environment often with complete desiccation of individual layers and long intervals of non deposition. The evidence for this in the red and largely fine-grained and unsorted Olukonda Formation is provided by the sandy, channelised conglomerate layers. The clasts in these layers are from proximal, intra-basinal sources, red clay pellets from the desiccated and mud-cracked clay drapes of previous floods, and dolocrete and calcrete nodules from the nodular zone of pedogenic calcrete. Many unsorted clayey silt layers that contain small fragments of the same red clay pellets suggest rapid, small-scale, limited volume flood events involving short-distance transport without the strength to effect sorting of the transported sediment or total destruction of the clay-pellet clasts.

Conditions during deposition of the Andoni Formation were more variable. Three aquifers are present in the formation, namely, the deep, well-developed and uniform Ohangwena II Aquifer, the shallower and lithologically variable Ohangwena I Aquifer, and the Perched Aquifer, the latter generally within approximately 10 m of surface. Aquitards separate the aquifers. Deposition of fine-grained, well sorted sands with well rounded sand grains of the Ohangwena II Aquifer at the base of the formation suggest higher rainfall and stronger and more regular depositional currents. The red colour of the lower part of the aquifer suggests inheritance from and reworking of the underlying Olukonda Formation but the well rounded sand grains suggest a different, possibly basin-margin, aeolian source. A colour change to grey towards the top of the aquifer and then pale grey to pale yellow above this characterises the Andoni Formation.

Post-depositional modification of the sediments takes the form of early post-depositional bioturbation and later calcrete cementation and growth of calcrete and dolocrete nodules. Bioturbation is rare in the Olukonda Formation but becomes significant towards the top of the Ohangwena II Aquifer. The significance of the bioturbation in this aquifer still needs careful analysis. The silty to clayey sands and the interbedded clay layers of the aquitard zones as well as the sands of the Ohangwena I Aquifer contain evidence of extensive bioturbation. The preserved burrows and channels are interpreted as having been produced in dry sediment. This again suggests intermittent fluvial depositional events punctuated by long periods of non deposition during which the individual sediment layers dried out. The biota responsible for the bioturbation so churned up the sediment that coarse-grained sand grains, which must initially have been deposited in layers in the sediment, are now totally randomly scattered through the otherwise clayey and silty sands. Rhyzoliths, present in places, indicate that a vegetation cover was able to establish itself between depositional events.

The carbonate cementing takes three forms: pedogenic calcretes or dolocretes, pervasive and uniformly textured calcrete or dolocrete cementing of individual permeable sedimentary layers, and growth of calcrete and dolocrete nodules between 1 mm and +30 cm in size. Such nodules are free standing and do not occur in association with carbonate cemented layers. Locally, there has been partial silica replacement of such nodules to form fine-grained chert. Rare chert nodules occur without associated carbonate. The pedogenic calcretes occur at depths of between 100 m and 112 m at the top of the aquitard between the Ohangwena I and II Aquifers and probably record a phase of significantly reduced rainfall with intervals between individual depositional events lasting 10s to 100s of thousands of years. Although seasonal rainfall will have prevailed, pedogenic calcretes need such intervals to form some 10 cm to 20 cm below ground level of a long-stable land surface. The pervasively cemented layers and the free-standing nodules are features that probably formed below the water table. How such cementing and nodular growth takes place and over what period of time is not well understood.

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Annex: Borehole WW 203032 Logged by Roy McG. Miller, June, November 2015

Litholog of Borehole WW 203302	Location: 17.585983°S, 16.849619°E,	Collar elevation: 1130 mamsl

Abbreviations

Lithology:

Aa, aa - as above
cgl – conglomerate; peb – pebble;
cs - coarse-grained sand; vcs - very coarse-grained sand;
mS - medium-grained sand, capital S denotes main component;
ms - medium-grained sand, small s denotes minor component;
fs - fine-grained sand; vfs - very fine-grained sand;
slt - silt; c - clay;
fgr - fine grained; mgr – medium grained; stg – sorting;
mS, fs, vfs, slt, c - components in decreasing order of abundance
cc - calcrete; dc - dolocrete; sc - silcrete;
calc - calcareous; dolic - dolomitic;
cmt - cement, cmted - cemented, cmting - cementing
abund - abundant, bdg - bedding; bt - bioturbation;
consol - consolidated; diam - diameter;
ferrug - ferruginous; gr - grained; irreg - irregular;
lam - laminations, laminated; nod - nodule;
sl - slightly; std - sorted; tr - trace; unstd - unsorted;
v - very; w - with; xbdg - cross-bedding
Ø - diameter, // - parallel

Abbreviations

Colour:

lt - light
dk - dark
blk - black
brn - brown
grn - green
gry - grey
purp - purple
rd - red
wht - white
y - yellow

Depth to m	Core recov-ery m	Core loss m	Core Description	Photo depth m	Sample, purpose Permea-bility in mDc	Bioturbation (bt)
			Sorting is somewhat difficult to assess and will only be more accurately determined with proper grain size analysis; the sand core is massive with no bedding unless otherwise indicated, bedding is defined by rare clay layers but internally the clay layers have no bedding. Colour of core in the scan photos is usually not correct, in some cases very wrong, in many cases the colour of the half next to the scale is close to correct but that half furthest away is different and wrong. Some scanned cores have been mis-numbered (e.g. 152-153 should be 151-152, 151-152 should be 152-153 - proof from digital camera photos). No scan photo of 173-174 m.			All sand-filled channels (burrows) ± 1 cm Ø unless otherwise indicated, some are thin 2 mm wide streaks - rare. Wood still in two features. Some filled with white cc or dc or with wht cc or dc margins - may be rhyzoliths. Most channels-fills can be distinguished by differences in colour and sand grain size to the enclosing sands
0-8.5	0		No core collected			
-9	0.5	0	Sand, fS, slt, ms, rare cs; unbedded, stg poor to variable; most ms & cs grains v well rounded from here downwards until otherwise recorded, v lt y, hard, soft cc cmt @ -8.6 m NB: no bedding planes seen throughout core except where thin layers of a different colour present, at contact to clay layers or where bedding is specifically mentioned			
-10	1	0	Sand, fS, ms, slt, cs, rare subangular to subrounded granules of qtz, feldspar, granite from 9-9.1 m, stg poor, most ms and cs grains well to v well rounded - this is the case to a depth of at least 75 m; hard, dc cmted; v lt y, patches y goethite and rd hematite cmt			
-11	1	0	Sand, fS, ms, slt; stg poor, hard, dc cmted; v lt y, more uniform reddish hematite colour; two v lt grn, softer layers of clayey sand at 10.64 m (2 cm thick) and 10.77 m (0-9 cm); v thin wht cross-cutting veinlets of dc			
-11.5	0.5	0	Sand, fS, ms, slt, rare cs grains; stg poor, hard, dc cmted, uniform reddish hematite colour, remnant patches of the original v lt y colour from 11.25-11.50 m			Faint bt from 11-11.21 m
-12.5	1	0	Sand, fS, ms, slt, scattered cs grains, stg poor, softer than above, cc cmted; uniform			Variously cc cemted bt from 11.86-12.21 m, this may be a single deposi-

			reddish hematite colour, remnant patches of the original v lt y colour, tiny filigree networks of Mn staining			tional layer with its top at 11.86 m
-13.5	1	0	As for 11.5-12.5 m, fewer cs grains. Well sorted v lt grn, fS layer from 13.22-13.24 m			Root bt @ 12.82 m. Faint bt channels in last 20 cm
-14.5	1	0	Sand, fS, slt, ms, scattered cs grains, rare granules, stg v poor, semi consolidated, cc cmted; ferruginised, remnant patches of the original v lt y colour; bleached postferruginisation veins at 13.75, 13.2, 13.97, 14.22, 14.32, 14.45 m		Granule @ 14.25 m for XRD	Red bt layer from 13.58-14.05 m, next layer down from 14.05-14.77 m(?); zoned channel at 13.80 m with wht margin of dc cmted fS & core of rd mS
-15.5	1	0	Sand, fS, slt, ms, scattered cs grains, rare granules, stg v poor, semi consol, dc cmted, v lt y; horizontal 1 mm thick wht clay layer at 15.17 m; 2 cm thick horizontal cc vein at 14.85 m; ferruginisation becoming patchy; Layer of pre-cmt nods from 14.77-14.93 m, i.e. at contact between two layers			Next bt layer down from 14.93- 15.76 m, good rhyzolith at 15.04 m
-16.5	1	0	Sand, aa, v lt y, semi-consol, weak dc cmt; ferruginisation decreasing downwards; possibly layer of pre-cmet nods from 15.76-15.88 m; next layer down starts at 15.88 m, base uncertain; horizontal cc vein at 15.9 m with thin bleached, carbonate-free margins		3 granules for XRD between 15.5 & 15.9 m	Red bt, good rd bt channels at 15.66 m & 16.04 m
-17.5	1	0	Sand, aa, becoming finer grained downwards, v lt y, semi-consol, weak dc cmt becoming softer & less consol downwards; some tiny wht cc nods, thin wht cc nod at 16.68 m		Granule for XRD at 16.68 m	Minor ferrug bt decreasing downwards
-18.5	1	0	Sand, fS, slt, ms, scattered cs grains, rare granules, less slt, stg sl better, v lt y, semi consol, dc cmted,		2 knobbly granules for XRD at 17.6 & 17.82 m	
-19.5	1	0	Sand, f-mS, minor slt, v rare cs grains, better stg, v lt y, semi consol, dc cmted; v rare tiny soft wht cc nods			
-20.5			Sand, f-mS, v minor slt, scattered cs grains & granules up to 0.8 cm Ø from 19.5-20.05 m becoming fewer and smaller downwards, fair stg of f-mS, v lt y, semi consol, dc cmted; a few tiny soft wht cc nods, flat cc nod at 19.85 m			Fragmented gry clay with wht bt channels from 20.55 m to 20.68 m. Faint bt in places
-21.5	1	0	Sand, f-mS, v minor slt, v rare cs grains, v lt y, stg fair, semi consol by dc cmt, small fragments of medium gry-brn clay from 20.5-20.69 m; vertical, 10 cm long cc nod at 21,10 m			Small fragments of medium gry-brn clay probably from a thin clay layer fragmented by bt; faint bt below this
-22.5	1	0	Sand, fS, ms, slt, sl finer than above metre, v rare cs grains, stg fair, v lt y, semi consol by dc cmt, Wht cc nod at 21.95 m, 2 v small soft wht cc nods below this			Faint bt throughout
-23.5	1	0	Sand aa; stg fair, v lt y, semi consol, 6 cm wht cc nod at 23.08 m			
-24.5	1	0	Sand, f-mS, minor silt, a few scattered cs and v cs grains from 23.5-23.8 m, stg fair, semi consol; v lt y, a few small wht cc nods			Sl darker y bt from 23.63-24.25 m
-25.5	1	0	Sand, fS, ms, v minor silt, rare cs grains, stg fair, semi consol, v lt y,		V cs grain at 24.9 m for XRD	Faint but scattered bt throughout
-26.5	1	0	Sand, fS, silt, ms, stg poorer, semi consol, v lt y			Some faint bt to 26.96 m
-27.5	1	0	Sand, from m-fS to f-mS, minor slt, v rare scattered cs grains, stg fair, semi consol but soft, v lt y, a few small hard wht cc nods, larger nod at 26.8 m			Some faint bt to 27.86 m
-28.5	1	0	Sand, similar to previous metre but more slt, stg poorer, soft, a few tiny soft wht cc spots, one hard 10 cm nod at 28.03 m			Faint bt scattered throughout
-29.5	1	0	Sand, fS, ms, v minor slt, rare scattered cs grains, stg fair, v lt y , soft?; 2 cm thick layer of many tiny wht soft cc nods at 29.12 m; rare 1-2 cm ferruginous spots			Faint bt from 27.5-28.17 m, ferrug spots may be bt

-30.5	1	0	Sand, v similar to previous metre;		V cs grains at 29.74 m for XRD	Rare v faint bt in places, 2 rd bt channels near base
-31.5	1	0	Sand, as for 28.5-29.5 m; some hard wht cc nods and v small soft cc nods			Open vertical cavity with v f gr & sl ferrug wall lining from 30.8-30.88 m
-32.5	1	0	Sand, as for 28.5-29.5 m; long hard irreg wht cc nod from 31.58-31.70 m			V faint, sl ferrug vertical bt channels at 31.62, 31.94, 32.22 & 32.45 m
-33.5	1	0	Sand, mS, fs, minor slt but more than above, v rare cs grains, stg fair-poor, semi consol, v lt y, a few small hard & soft wht cc nods			Faint bt at 33.32 m
-34.5	1	0	Sand, fS-mS, v minor slt, stg fair, v lt y, semi consol, scattered tiny soft wht cc nods, aggregate of small hard cc nods at 34.36 m			Long, thin bt tube filled with wht cc from 33.53-33.6 m, faint sl ferrug bt at 34.06-34.18 m, scattered faint bt
-35.5	1	0	Sand, fS-mS, fs fraction ranges to vfs, v minor slt, stg poor, soft, v lt y,			
-36.5	1	0	Sand, mS, fs, trace slt, v rare cs grains, stg fair, v lt y, semi consol but soft			~vertical bt burrow from 35.7-35.84 m, minor faint bt in places
-37.5	1	0	Sand aa, sl more slt			
-38.5	1	0	Sand aa but variable concentrations of main fraction from mS to fS, tr slt, v lt y			Hollow root tube at 37.02 m; faint bt from 37.9-38.06 m
-39.5	1	0	**TOP OF OHANGWENA I AQUIFER AT 38.5 m** Sand, fS, ms, v minor slt, stg fair, soft, v lt y, large wht hard cc nod at 39.30 m			3 phases of bt, 1st v faint, 2nd - long vertical sl ferrug burrow from 38.7-38.91 m, 3rd - rd ferrug burrow from 38.74-38.91 m
-40.5	1	0	Sand, aa but mainly fS, most ms grains still v well rounded, v lt y			Some scattered faint bt channels
-41.5	1	0	Sand, aa, 4 small, isolated hard wht cc nods			Thin hollow tube-like cavity at 40.96 m, faint bt at 41.2 m
-42.5	1	0	Sand aa, trace slt, cc nods aa			Faint bt at 42.22 m, thin cc streak at 42.30 m
-43.5	1	0	Sand aa, rare scattered cs grains			2 long thin cc nods at 42.62-42.76 m & 42.93-43.0 m (latter nodular) - possibly filling of bt channels or rhyzoliths; 1 rd bt burrow at 43 m; one 0.8 cm Ø wood of root with blk edge at 43 m
-44.5	1	0	Sand aa, mainly mS, some v lt grn, possibly sl clayey sand spots and streaks			Long thin irreg, knobbly cc nods (bt?) from 44.03-44.11 m & 43.72-43.86 m, v lt grn spots may be bt, faint bt in places
-45.5	1	0	Sand aa, mainly mS, some small cc nods			1 small reddish bt feature at 44.92 m
-46.5	1	0	Sand aa, trace slt, some hard cc nods			Single reddish bt features at 45.63, 45.8 m, 46.1 m, faint bt throughout
-47.5	1	0	Sand aa but mainly fS, less ms, v minor slt, stg fair, some cc nods			Subtle colour differences in v lt y suggest extensive bt throughout
-48.5	1	0	Sand aa, still v lt y			bt aa but v faint
-49.5	1	0	Sand aa, large cc nod at 49.13-49.2 m			bt from 49.23-49.28 m, wood of thin root at 49.24-49.28 m
-50.5	1	0	Sand aa, trace slt; a few hard wht dc nods			V lt olive bt spots with small wht cc cores
-51.5	1	0	Sand aa, some small cc & dc nods, 1 zoned calc dc nod with cc margin			Thin v lt gry bt channels from 51.0-51.45 m, faint bt throughout, 1 cc-cored spot aa
-52.5	1	0	Sand aa, v minor to trace slt, nods aa			Bt aa from 51.5-51.75 m, some Y-shaped channels; strange little bt channels with cs at 52.2 m
-53.5	1	0	Sand, fS, slt, v minor ms, fair stg; large hard cc nod at 52.99 m, 1 small hard cc nod		One large grain at 2.78 m for XRD	A few thin v lt gry channels in places through whole core, some Y shaped
-54.5	1	0	Sand aa, trace slt, stg fair, still v lt y			V faint y bt, some v lt gry bt throughout
-55.5	1	0	Sand aa, minor ms, trace slt, some cc nods		One silcrete (?) nod at 54.98 m for XRD	Faint bt in several places
-56.5	1	0	Sand aa			V faint y bt throughout
-57.5	0.96	1st 6 cm	Sand aa, some small hard cc nods, one flat clast of dk brn-gry clay at 57.72 m (rip-up clast (?)		Clay sample for XRD	Some v faint y bt
-58.5	1	0	Sand aa, zone of many small wht dc nods from 57.88-58.06 m, 2 hard wht cc nods			Faint bt in zone of small nods, some channels calcified, ditto at 58.4 m

-59.5	1	0	Sand aa			V faint y sand-filled bt channels at 59.4 m, thin v lt gry bt channels filled with clay-rich sand from 58.9-59.0 m; faint bt throughout
-60.5	1	0	Sand aa, a few scattered cs grains, soft			Some v lt y bt
-61.5	1	0	Sand aa, some hard cc nods			Some v lt y bt, some sl calcified
-62.5	1	0	Sand aa, some hard cc nods			Some v lt y bt
-63.5	1	0	Sand, fS, minor ms, minor to v minor slt, consol with some porosity-reducing cc cmt from 62.5-62.9 m, large hard calc dc nod from 62.9-62.96 m. Below this have softer fS with minor ms, trace slt, fair stg			
-64.5	1	0	Sand, fS, ms, trace slt, stg fair, hard with dc/salt cmt, many calc dc nods up to 4 cm Ø, particularly from 63.9-64.1 m			
-65.5	1	0	Sand aa, nods aa but sl fewer & up to 2 cm Ø			
-66.5	1	0	Sand aa, hard, consol, dc cmt, some calc dc nods			Some faint y bt
-67.5	1	0	Sand aa, hard and dc/salt (?) cmted to 67.4 m, softer in last 10 cm; a single sedimentary layer from 67.02-67.53 m with abund bt at top and none at base, a few hard calc dc nods to 67 m, hard cc nods below this	Bt at 67.1 m		Abund v lt y bt, v clear from 67.02-67.4 m;
-68.5	1	0	Sand aa, several calc dc nods			Faint v lt y bt from 67.5 m, best from 68-68.25 m, none below this
-69.5	0.98	68.50 - 68.52	Sand aa, several calc dc nods, v lt y, soft; faint bdg from 69.63-69.71 m			V faint bt
-70.5	1	0	Sand aa, sl softer but still well consol, several calc dc nods			V faint bt throughout, best from 70.0-70.2 m
-71.5	1	0	Sand aa, irreg shaped calc dc nods from 71.3-71.42 m	U-shaped channel at 71.1 m		V lt y bt throughout, U-shaped channel lying on it side at 71.1 m
-72.5	1	0	Sand aa, much softer, some wash out from drilling			V faint lt y bt
-73.5	1	0	Sand aa, softer and harder zones, some wash out from drilling, some calc dc nods, core v disturbed			
-74.5	1	0	Sand aa, much wash out from drilling, core v disturbed			
-75.5	1	0	Sand aa, patchy harder and softer parts, partial drilling wash out of softer parts, 1 calc dc nod, core v disturbed			
-76.5	1	0	Sand fS, vfs, v minor ms, trace to v minor slt, soft, sticky. Core v wet from 71-99.3 m.			
-77.5	1	0	Sand aa, soft, calc dc nods at 76.7 & 77.35 m, large dc nods at 76.85 m & 77.0 m			Faint bt at 77.3 m
-78.5	1	0	Sand, fS, ms, trace slt, fair-well sorted, soft, 1 small calc dc nod, core disturbed in places			Bt from 77.6-77.7 m
-79.5	1	0	Sand aa, more consol, proportion fluvial grains (shiny and not matt like aeolian grains) increasing			V faint v lt y bt, 1 sl ferrug channel at 79.2 m
-79.8	0	0.3	Core loss			
-81.7	1	0.9	Sand, fS, ms, trace slt, stg fair-good, soft, v lt y, 2 small calc dc nods, core disturbed in places			
-82.6	1	0.1 m gain	Sand aa, most grains shiny (fluvial), soft, v lt y, 4 small calc dc nods			V faint sl ferrug bt at ~82 m, rd bt spots at 87 cm
-84.6	1	1	Sand aa, soft, 2 large calc dc nods, one at 84.6 m, core a bit disturbed			Faint bt, rare small bt spots
-85.75	1	0.15	Sand aa, 1 cs grain, stg fair-good, soft			Faint sl ferrug bt from 84.72-84.87 m
-87.2	1	0.45	Sand aa, stg fair-good, still v lt y, soft			2 bt channels in top 20 cm
-88.2	1	0	Sand aa, stg fair-good, v lt y, soft			V lt brn bt channels from 87.8-88.2 m
-90.5	1	1.3	Sand aa, stg fair-good, still v lt y; sand soft; hard layer from 88.22-88.47 m of dk rd silcrete and lt pink dc nods all totally cmted by a v lt grn dc cmt	Hard layer of sc nods		Rare scattered bt below sc
-91.5	1	0	Sand aa, stg fair-good, still v lt y, soft, upper ½ of core disturbed			

-93.3	1	0.8	Sand aa, most grains shiny, stg fair-good, still v lt y, soft, core v disturbed below 1st 20 cm			Tiny rd bt spots in 1st 20 cm
-94.3	1	0	Sand aa, stg fair-good, still v lt y, soft, core v disturbed in 1st 40 cm			
-96.8	1	1.5	Sand aa, stg fair-good, still v lt y, soft, core v disturbed			
-99.3	1	1.5	Sand aa, stg fair-good, still v lt y, soft for upper 68 cm; then 12 cm of same sand hard and cmted by dc & enclosing large brn, v fgr calc dc nods (or sl calc sc nods); basal 18 cm same sand aa but mainly fS, more slt, most grains shiny; v lt y, soft **BASE OF OHANGWENA I AQUIFER AT 99.3 m**			
-100.3	1	0	Sand, fS-vfS, ms, more slt than above (10%??), stg - fair to poor, v v lt gry-y, soft; 12 cm thick zone of calc dc nods at 100 m			Possible v faint bt from 99.58-99.75 m
-101.3	1	0	Sand, same sand, same sorting, same colour, soft			Some faint bt from 100.58-101.02 m
-102.8	1	0.5	Sand aa, more vfs, soft			Some faint bt in places
-103.8	1	0	Sand, vfS, fs, slt (15%??), v minor ms, stg poor, soft			V faint bt in places
-104.8	1	0	Sand aa,			V faint bt in upper ½
-105.8	1	0	Sand aa			V faint bt in places
-108	0.54	1.66	Sand aa,			Rare faint bt
-109	1	0	Sand aa to 108.2 m then finer below, i.e. f-vfs, slt (15-20%??), rare ms grains, stg poor, v v lt gry-y			
-110	1	0	Sand aa with ± 20% slt to 109.14 m; cc cmted below that with increasing cmt to 109.77 m. Last 23 cm a nodular pedogenic cc; 1 cm thick layer of v small cc nods at 109.22 m	Pedo-genic cc		2 bt spots at 108.94 m
-111	1	0	Very variable. Sand aa with ± 20% slt to 110.32 m but weakly & variable cmted by cc; horizontal, 1 cm thick speckled layer of highly dismembered, possibly bioturbated, dk brn clay at 110.32 m; 110.33-110.77 m:- angular fragments of massive, probably pedogenic calc dc enclosed in v lt grn sand all cmted by calc dc; this occurs at the contact between v lt gry-y to v lt brn sands above and many layers of v lt brn sands below which have an intense vlt grn to lt grn bt in their upper parts, i.e. located at a major change in environmental and depositional conditions; within this section from 110.54-110.65 m the nods have dk brn cores of sc & rims of calc dc, such nods enclosed in the same v lt grn cmted sand; 110.77-111.0 m:- fS, clayey, v lt grn, salty, soft with 1 cm thick interbedded layers of v v lt brn fS at 110.77, 110.83, 110.91 & 111.0 m - possibly representing 3 separate very thin layers with v lt grn bioturbated tops and v lt brn, bioturbation-free bases (see layer descriptions below).		Sample of clay layer for XRD	See core description
-112	1	0	Sand, fS, clayey, v lt grn, salty, soft to 111.6 m; nodular pedogenic calc dc with matrix of the soft v lt grn clayey fS from 111.6-112 m			Bt channels filled with v v lt brn fS from 111-111.10 m, 2 long bt channels from 110.5-110.6 m
-113	1	0	Very variable. 112 -112.1 m:- Same sand aa, whitish, hard, cmted by calc dc, abund v lt grn bt channels; 112.1-112.51 m:- Sand, fS, soft, v v lt brn, a few scattered calc dc nods at 112.3 m, and from 112.42 m to 112.51 m at the contact between this layer and the underlying v lt grn layer; This section is the basal part of a single 1.51 m thick layer from 111 m to	Photo at 112.1 m		112-112.15 m:- Matrix may be bioturbated; 112.7-113.0 m:- Abund whitish bt channels, no acid reaction, highly disturbed by bt

			112.51 m with bioturbated top (v lt grn) and bioturbation free base (v v lt brn), the pedogenic dolocrete developed in the bio-turbated part possibly as much as 100 000 years after bioturbation; 112.51-112.9 m:- Sand, fS, clayey, soft, v lt grn, to 112.58 m, bioturbated; from 112.58 m to 112.7 m is a nodular pedogenic calc dc with it matrix of soft v lt grn clayey fS, i.e. pedogenesis followed bioturbation; v lt brn sand of the base of this layer from 112.51 m to 112.9 m; 112.9-113.0 m:- Sand, fS, clayey, soft, v lt grn; this is the intensely bt top 10 cm of the next layer down, a 1.64 m thick layer of v lt brn sand that has been intensely biotur-bated in the upper 1.1 m (see next two me-tre descriptions - base of layer at 114.54 m)			
-114	1	0	Sand, fS, clayey, soft, v lt grn; middle part of the 1.64 m thick layer;	Photo of bt		Highly disturbed by bt; 113.8-114 m, decreases in intensity downwards so the initial v lt brn colour of the sand be-comes more apparent
-115	1	0	Sand, fS, clayey, soft, v lt brn from 114.27-114.54 m, base of the 1.64 m thick layer recorded above; 114.54-115 m:- Next layer down is a 46 cm thick v lt brn sand, which is v lt grn & in-tensely bioturbated at the top but bt de-creases significantly in intensity down-wards to base of layer at 115 m; large v v lt tan calc dc nod from 114.0-114.27 m			114.47-115 m:- bt aa, decreasing in intensity downwards
-116	1	0	Three layers of v lt brn Sand, fS, clayey, soft, so intensely bioturbated to a lt grn colour that only the basal, slightly less in-tensely bioturbated part shows the original sand colour; top layer from 115 m to 115.32 m, next layer down 115.32 m to 115.46 m, next layer down from 115.46 m to 116.10 m;			Bt with whitish bt channels aa to 115.7 m
-117	1	0	Sand, fS, clayey, soft, lt grn from 116.1 m due to intense bt; 2-3 cm thick layer of small calc dc nods at 116.1 m which is the contact between two layers; next layer down from 116.1 m to 116.53 m, calc dc at contact to next layer down, next layer down from 116.53 m to 116.98 m, calc dc again at contact to underlying lay-er, i.e. from 116.9-116.98 m - this dc seems to extend up into the overlying bt channels for ±8 cm larger & long; thin calc dc nods from 116.52-116.68 m;			Bt with whitish bt channels aa for most of this core; note dc of 116.9-117 m extending upwards into overlying bt channels for ±8 cm
-118	1	0	Sand, fS, clayey, soft, lt grn due to bt, traces of original v lt brn colour; scattered calc dc nods from 117.76-117.9 m which may the contact zone between two layers; top of next layer down at 117.9 m			Bt channels throughout aa with some dc cementing of bt channels in lower 8 cm
-119	1	0	Sand, fS, clayey, soft, lt grn to 118.61 m, traces of the original v lt brn sand; base of this layer at 118.61 m; 118.61-119 m hard v v lt brn massive calc dc nod with numerous irregularly shaped, channel fillings of v lt tan sand less in-tensely cmted by calc dc;			Same intese bt aa in grn sand to 118.61 m
-120	1	0	Same calc dc continuous from 119-119.37 m; 119.37-119.48 m:- Sand, fS, clayey, soft, v lt grn; 119.48- 119.88 m:- Hard wht massive calc dc with few sandy v lt tan channel fillings weakly cmted by calc dc; 119.88-120.0 m:- Sand, fS, clayey, soft, lt grn; 3 thin calc dc layers			
-121	1	0	Sand, 120-120.32 m:- fS, clayey, soft, lt grn,			Rare small bt channels

			many horizontal laminated calc dc layers coloured wht to v v lt brn; 120.32-120.59 m:- Sand layer, fS, clayey, lt grn due to bt to 120.53 m, faint horizontal bdg(?) from 120.42-120.52 m, v lt brn (original colour) mS-fS sand from 120.53-120.59 m, base of this layer and no bt; 120.59-120.96 m:- next layer down, lt grn bt to 120.86 m, v lt brn below this; 120.96-121 m:- next layer down with 0.5 cm thick, disrupted layer of grn clay at 120.96 m			
-122	1	0	Sand, fS, slt, clay, v minor ms, rare cs grains, stg poor, soft, lt grn; many horizontal sl lighter fS layers that may be layering to 121.31 m; then same sand but with v v lt grn-y colour and only short thin subhorizontal lt grn streaks with occasional darker grn 1-2 cm bt(?) patches; Last 2 cm v lt y sand with darker grn bt. The vlt y colour may be the original colour, the lt grn may be due to a 1st period of v pervasive bt, & the later darker grn a 2nd period of bt. This may be a single layer with its top at 120.96 m and base at 122.07 m.		1 cs grain for XRD at 121.79 m	A bit of bt(?) to 121.7 m, more concentrated & obvious bt from 121.7-122 m. Note comment in lithology column
-123	1	0	Sand aa, fS, slt, clay, v minor ms, rare cs grains, stg poor, soft, v lt y with 2nd period darker grn bt to 122.07 m, this is the base of the 120.96 m to 122.09 m layer; 122.07-122.35 m:- next layer down, lt grn bt with abund darker grn bt decreasing in intensity downwards revealing the original v lt y sand; 122.35-122.64 m:- next layer down identical to above layers but calc dc nod just below the top at 122.39 m; 122.64-123.1 m:- next layer down, lt grn with abund darker grn bt to 122.80 m, then large calc dc nod 122.8-122.86 m, then same sand but v lt brn with no bt.	Photo bt net-work	1 cs grain for XRD at 122.5 m	Bt - lt grn may be due to a 1st period of v pervasive bt, & the later darker grn a 2nd period of bt, latter abund to 122.86 m, none below this
-124	1	0	Sand aa to 123.1 m, 123.1-123.3 m:- next layer down, mS-slt, clayey, stg poor, soft, bt aa but base also with abundant bt; 123.3-123.92 m:- next layer down aa, uniform lt grn with v subtle colour variations suggestive of v pervasive 1st period bt to -123.73 m, then a more y colour to the sand with the lt grn bt more patchy & more obvious as bt to 123.92 m; darker grn 2nd period bt rare; 123.92-124 m:- top of next layer down (extends to 124.3 m), a long thin wht bt channel at 123.97 m			See lithology for bt comments
-125	1	0	124-124.3 m:- continuation of last layer from above, Sand, mS-slt, clayey, stg poor, lt grn bt as in above layers, less abundant in basal 12 cm; 124.3-124.67 m:- sand and bt aa but much less bt than in overlying layers & only v lt grn, no bt below about 124.47 m, some scattered, thin, short dc nods through this layer 124.67-125 m:- 3-cm thick cluster of darker grn channels at the top, only scattered lt grn bt channels below this, none below 124.92 m, initial colour of sand v v lt brn (this non-bt sand extends to base of this layer at 125.22 m)			See lithology
-126	0.62	0.38	125-125.22 m:- Sand, fS, ms, slt, clay, trace cs grains, stg poor, soft, base of above layer; 125.22-125.27 m:- Sand aa, v v lt brn with v v lt grn bt channels & abund 2nd period		1 cs grain for XRD at 125.1 m	See lithology

			darker grn bt channels; 125.27-125.37 m:- Sand aa, same v v lt brn sand, sand soft to this point, intensely pervaded by lt grass grn bt channels with rare 2nd period darker grn bt channels; 125.37-125.62 m:- Sand aa, same v v lt brn sand, hard and dc cmted, so intensely pervaded by 2nd period darker grn bt channels than patches of sand of original colour are rare; some bt channels filled with wht cc cmted sand; large irreg calc dc nods at each end of this section; Core missing below 125.62 m.			
-127	1	0	Clay, sl silty, grn, hard, more sandy from 126.80-127 m; zone of irreg dc nods from 126.92-127 m, i.e. at contact to underlying layer (?); small irreg dc nods and patches & a few thin short horizontal and vertical dc streaks throughout the clay		Clay sample for XRD at 126.6 m	2 long bt channels intersecting at 90° at 126.86 m
-128	1	0	Sand, v clayey, ms, slt, stg poor, grn; clusters of dc nods from 127.20-127.33, 127.36-127.65 & 127.9-128 m; soft where no nods			
-129	1	0	Sand, fS, slt, v clayey, grn; abund small round calc dc nods from 128-128.34 m which may be filled bt channels, fewer and more irreg nods to 128.78 m, then cluster of irreg nods to 129 m, hard, cemted by calc dc			See lithology
-130	1	0	Sand, fS-vfS, slt, v clayey, v minor ms, stg poor, grn, soft; abund small to medium irreg shaped calc dc nods	Photo at 129.2 m		
-131	1	0	Sand aa to 130.15 m but fewer nods & with some darker grn bt channels; sand more clayey to 131 m, grn - lt grn, soft, with v abund small, mainly round calc dc nods			Some darker grn bt channels to 130.15 m
-132	1	0	Sand aa, fS-vfS, slt, v clayey, v minor ms, lt grn, soft; abund small to medium irreg shaped calc dc nods with hard nod clusters in places; fewer nods from 131.07-131.33 m			
-133	1	0	Sand aa, fS-vfS, slt, v clayey but variable clay content, v minor ms, grn, soft & hard in places; abund small to medium irreg shaped calc dc nods with hard nod clusters in places;			
-134	1	0	Sand aa, fS-vfS, slt, v clayey but variable clay content, v minor ms, lt grn, hard; abund small to medium irreg shaped calc dc nods with more hard nod clusters;			Darker grn 2nd period bt channels in the sand between the nods
-135	0.94	0.06	Sand aa to 134.21 m, then bigger irreg, vertically elongate calc dc nods more widely spaced in hard v lt grn to v lt gry-grn clayey sand to 134.84 m, then almost no nods			2 reddish bt channels at 134.9 m
-136	1	0	Sand aa, v lt grn to v lt gry-grn, sl darker grn from 135.3-135. m, possibly faint horizontal bdg to 135.09 m & from 135.78-135.96 m, soft below about 135.7 m, fewer and smaller nods, clayey sand variable calc			Faint reddish bt channels from 135.3-135.42 m, thin calcified rhyzolith at 135.42 m, some small round or elongate nods may be calcified bt channels
-137	1	0	Sand aa, v clayey possibly becoming more clayey downwards, non calc, sand soft, scattered irreg shaped calc dc nods of various sizes, ± 60% sand, 40% nods, no nods between 136.76 & 136.88 m			Possibly some v faint bt
-138	1	0	Clay, slt, fs, non calc; a few small calc dc nods	Photo rhyzolith at 137.91		Faint, abund bt channels in lower 20 cm, of lt grn bt in v lt brn sand or visa versa, several calcified rhyzoliths in lowest 10 cm
-139	1	0	Clay aa to 138.05 m; Sand, fS-vfS, slt, v clayey but variable clay content, v minor ms, rare cs grains at 138.13 m, stg poor, soft, grn but becomes	Photo sc nods at 138.51	Sample cs grains at 138.13 m for XRD	Wht, thin, rhyzolith-like features filled with calc dc at 138.30 (zoned), 138.37, 138.56, 138,71, 138.82 & 138.87 m

			whiter & lighter grn & harder where abundant calc dc nods due to matrix cementing; small irreg shaped, often longish calc dc nods throughout but zones of concentrated nods from 138.20-128.32 m, 138.64-138.92 m. 2 large wht irreg shaped sc nods at 138.51 m. no nods below 139.96 m	m		
-140	1	0	Sand, fS-vfS, slt, v clayey to 139.4 m, soft, grn; clay non calc; patches of calc dc nods from 139.4-139.6 m, 139.72-139.83 m, 139.88-140 m; 1 wht chert nod at 139.1 m			bt-sized patches of sandy clay and clayey sand probably due to bt
-141	1	0	Sand, fS-vfS, slt, v clayey, becomes much more clayey below 140.4 m, soft, grn becoming lt grn downwards; non calc to sl calc; a few scattered fairly large calc dc nods, 1 large nod at 140.5 m; possible v faint horizontal bdg at 140.68 m, and sl angled bdg from 140.83-140.93 m			
-142	1	0	141-141.40 m:- Sand aa, v clayey, lt grn, non to sl calc, soft, scattered irreg-shaped wht calc dc nods 141.40-141.73 m:- aa but with faint purplish more clay-rich patches; same calc dc nods 141.73-142 m:- Clay, deep gry-purp, one small calc dc nod near base	Photo gry-purp clay		141-141.40 m:- some sl reddish bt; 141.40-141.73 m:- mixed grn & purp clay due to bt, some 2nd period rd bt near base 141.73-142 m:- some faint reddish sand-filled bt channels, no deep red
-143	1	0	142-142.26 m:- Clay aa, deep gry-purp, small calc dc nods; 142.26-142.40 m:- Transition downwards to underlying lt grn sand through gradual decrease in clay content and decrease in purp colour; 142.40-143 m:- Sand, fS, slt, clay, lt grn, soft, non calc, a few small irreg-shaped calc dc nods; lt purp zone from 142.75-142.84 m, sand more clayey below this			142-142.26 m:- fewer of above bt channels; 142.40 m:- 2 rd bt channels
-144	1	0	Sand aa to 143 m, rare cs grains, clay content possibly decreasing downwards, much less clay below 143.57 m, soft, small irreg-shaped calc dc nods			Some faint reddish bt channels in basal 10 cm
-145	1	0	Sand, fS, slt, clay, lt grn, soft, non calc, a few small irreg-shaped calc dc nods;	Photo purp bt & wht bt at 144.65 - 144.70 m		A few 1st period lt purp bt channels scattered through core, fewer 2nd period rd bt channels; one cc-filled rhyzolith(?) at 144.65 m
-146	1	0	Sand aa; fewer nods			Faint 1st period lt purp scattered through core, clear rd 2nd period bt at 145.44 m, one zoned with rd rim, lt grn sand core
-147	1	0	Sand aa; fewer nods; scan photo of core wrong colour			No obvious bt
-148	0.9	147-148.1	Sand aa, rare ms & cs grains, v lt grn, soft; only 1 calc dc nod at 147.25 m	Photo long zoned bt channel at 147.52 m		A few faint lt purp bt channels scattered through core; long zoned lt purp channels with wht rim in middle part; 4 tiny widely spaced rd bt channels
-149	1	0	Sand aa, large calc dc nod with cavities at 148.3 m, large nod forms the last 15 cm of this core	Photo bt cluster at 148.53 m		Faint lt purp bt throughout, these channels clustered at 148.53 m
-150	1	0	Last nod of above core continues to 149.16 m; 149.16-149.89 m:- Sand, fS-vfS, slt, v minor clay, stg poor, v lt y (colour of scan photo of core wrong - see photo of bt), soft; rare calc dc nods 149.89-149.94 m:- Sand, fS, slt, clayey, stg	Photo lt purp & rd bt at 149.56 m		Faint lt purp bt throughout, rd bt in places in v lt y sand; wht bt channels at 149.74 m. Purp and rd bt in lt grn sand

			poor, lt grn; 149.94-150 m:- calc dc nod			
-151	1	0	Sand, fS-vfS, slt, v minor clay, stg poor, v lt y, soft, (colour of scan photo of core wrong - see photo of bt), soft, non calc; clusters of small calc dc nods from 150.06-150.24 m, 150.75-151 m, zoned calc dc nod at 150.47 m	Photo wht rhyzo-lith at 150.63 m		Abund v lt purp bt throughout, no rd bt, wht calc dc-filled rhyzoliths(?) at 150.27, 150.63 & 150.87 m
-152	1	0	Sand aa, a few round or irreg-shaped calc dc nods to 151.46 m	Bt photos at 151.46, 151.66, 151.83 m		Abund v lt purp bt throughout, later rd throughout but less abund; photos: 151.46 m 17 cm long whitish channel; 151.66 m - v lt purp & rd bt; 151.83 m - v lt purp, red, whitish bt (wht last)
-153	1	0	Sand aa, a few round or irreg-shaped calc dc nods			Abund v lt purp bt throughout, rd minor, often tiny
-154	1	0	Sand aa, a few round or irreg-shaped calc dc nods			Abund v lt purp bt throughout, rd v minor, from 153.76-154 m
-155	1	0	Sand aa, a few round or irreg-shaped calc dc nods. In this core one can see how intense v lt purp bt turns the v lt y sand to v lt purp, i.e. patches of v lt y sand and v lt purp sand			See lithology. 1st abund v lt purp bt, 2nd rd bt no so abund but good from 154.71-154.91 m, 3rd whitish bt at 154.29 (zoned), 154.38
-156	1	0	Sand aa, i.e. fS-vfS, silt, clay, stg poor, soft, v lt y original colour, v lt purp patches due to 1st bt; v few cc to calc dc nods. Bt v clear	10 Photo pano-rama of whole core		Bt v clear; 1st abund v lt-lt purp, *Cruzi-ana* banding at 155.5 m; 2nd rd bt less abund, some zoned with v lt y sand core, some *Cruziana* banding at 155.62-155.86 m, a fork-like splay of 3 thin rd streaks at 155.4 m
-157	1	0	Sand aa, soft, identical to above; a few small round or irreg-shaped calc dc nods from 156.74 m downwards	5 photos		Identical to above; some rd v thin, many of the round rd cross sections zoned with rd rim and v lt y sand core, *Cruzaina* banding common
-158	1	0	Sand aa, soft, identical to above, possibly more clay, initial sand colour before bt v lt y-gry; Layer of pedogenic-like calc dc nods from 157.92-158 m	Photo at 157.1 m, *Cruzi-ana*		Identical to above, bt structures not quite as concentrated
-159	1	0	Sand aa, possibly more clay; Photos at 158.34 m - nod cutting rd bt; 158.9 m - deep rd bt channel; scattered small irreg calc dc nods to 158.26 m; large knobbly calc dc nods from 158.26-158.84 m; v small scattered calc dc nods from 158.84-159 m	Photos at 158.34 & 158.9 m		Identical to above but still less concen-trated; see lithology
-160	1	0	Sand aa, less clay, small to tiny calc dc nods scattered through the core			Identical to previous metre
-161	1	0	Sand aa, small to tiny calc dc nods scattered through the core, then larger and more abund v calc dc nods below 160.75 m			Identical to previous metre to 160.75 m then no bt. 21 cm long rd bt channel centred at 160.6 m
-162	1	0	Sand aa, variable clay content; fairly numer-ous small scattered hard calc dc and soft cc nods			Aa but much less bt
-163	1	0	Sand aa, variable clay content; fairly numer-ous small scattered hard calc dc and soft cc nods	Photo large bt at 162.63 m		Few bt structures
-164	1	0	Sand, fS, minor slt, trace clay, stg fair, soft, v lt y - v lt gry-y, fairly numerous small scattered hard calc dc nods			Trace rd bt in upper ½, more bt in lower ½
-165	0.79	Last 21 cm	Sand aa to 164.64 m, stg fair, colour aa, soft; a few scattered calc dc nods; 164.64-164.79 m:- Sand, fS, vfs, v minor ms, slt, clayey, stg poor, lt grn, soft	Two photos of rd bt at 164.18 from above		Some v faint sl reddish bt, one deep rd bdg-parallel feature at 164.18 m - broad, flat, branched

				& on bdg plane		
-166	1	0	Sand, fS, slt, trace clay, stg fair, soft, lt grn of above to 165.10 m then v lt y, some scattered small hard calc dc nods. The abund lt purp bt gives a patchy lt purp tinge to the sand			Se lithology; abund but faint lt purp bt, minor rd bt; wht bt channel at 165.38 m
-167	1	0	Sand aa to 166.55 m, soft, calc dc nod at 166.03 m; 166.55-167 m:- fS, v clayey, stg poor, v lt purp, soft; abund wht hard calc dc nods from 166.23-166.55 m, small cluster of small calc dc nods at 166.87 m			Fairly abund v lt purp bt in upper sand with rare tiny rd bt spots; scattered bt with sand fill in clayey section
-168	1	0	167-167.1 m:- Sand, fS, v clayey, stg poor, v lt purp, soft; 2 long vertical calc dc nods; 167.1-167.30 m:- Sand, fS, clayey, clay content decreases downwards, v lt gry-grn, soft; 167.3-167.7 m:- Sand, fS, clayey, soft, v lt y, large irreg hard calc dc nods from 167.34-167.77 m; 167.7-169 m:- Sand, fS, vfs, slt, some clay, stg poor, soft, v lt gry-y, some wht calc dc nods			Some v lt purp bt, some lt rd bt in lowest 30 cm
-169	1	0	Sand aa, fS, vfs, slt, some clay, stg poor, soft, v lt gry-y, rare tiny calc dc nods	Photo rd bt at 168.68 m		Abund lt purp bt, rare rd bt; photo - 1st lt purp *Cruziana* laminae, 2nd rd *Cruziana* laminae, 3rd lighter rd cutting the red
-170	1	0	Sand aa, no nods			Abund lt purp bt, some scattered rd bt
-171	1	0	Sand aa, hard calc dc nods at 170.15 m, 170.45 m then scattered below 170.75 m			Abund lt purp bt down to 170.8 m, some scattered rd bt throughout
-172	0.89	1st 11 cm	Sand aa, large calc dc nod at 171.12 m, then rare small calc dc nods			Faint lt purp bt, a few scattered rd bt channels becoming a little more abun-dant below 171.87 m
-173	1	0	Sand aa to 172.04 m, then same sand but original colour almost totally overprinted by v lt gry-purp possibly due to intense 1st period bt but only scattered rd bt detecta-ble; many hard & soft wht cc nods often in clusters			See lithology
-174	1	0	Sand aa, v lt gry-purp, abund nods to 173.32 m then no nods			Same bt aa but with a few lt purp bt channels detectable, rd aa
-175	1	0	Sand aa, only a few small calc dc nods			Same bt aa
-176	1	0	Sand aa, a bit more of the original v lt y colour showing, still soft, only a few small calc dc nods to 175.5 m, more below this			Same bt aa
-177	1	0	Sand aa to 176.2 m then sand becomes pro-gressively more clayey to 176.5 m, soft; 176.5-177 m:- Clay, silty, lt olive colour, v calc, abund cc nods from v small up to 3 cm Ø			Same bt aa to 176.5 m, rare rd bt pre-served below this
-178	1	0	Clay aa to 177.04 m; 177.04- 177.42 m, Sand, vfS, v clayey, v lt olive, soft, many small & larger wht cc nods; 3 cm thick flat dc layer from 177.39-177.42 m; 177.42-177.89 m: Patches of gry clay in v lt y fS-vfS – this mixture due to intense bt of the clay such that all channels (v ill de-fined) filled with the sand, no rd bt; some dc nods below 177.8 m 177.89-178 m:- Sand, vfS, clayey, v lt purp-gry, some vague v lt y patches, soft	Two photos mixed sand & clay at 177.5 m		177.42-177.89 m: this mixed zone due to intense bt of the clay such that all chan-nels (v ill defined) filled with the sand, no rd bt; 177.89-179 m:- lt purp bt abund but not obvious, some rd bt
-179	1	0	178-178.06 m:- Sand aa, vfS, clayey, v lt purp-gry, some vague v lt y patches, soft, one rd bt; 178.06-178.43 m:- Sand aa, intense cc cmt within which are a few scattered small soft wht cc nods; bt still preserved; 178.43-179 m:- Sand aa, many cc and calc dc nods rimmed by cc & dc cmted sand; rare bt			See lithology

-180	1	0	179-179.32 m:- Sand aa, many cc and calc dc nods rimmed by cc & dc cmted sand; some rd bt; 179.32-180 m:- Sand aa but with fewer nods to 179.40 m & from 179.55-180 m; large hard cc nod from 179.40-179.55 m – this preserved uncalcretised bt channels; a little bt obvious in the sand			See lithology
-181	1	0	**TOP OF OHANGWENA II AQUIFER AT 180 m** Sand, fS, minor vfs, v minor slt, stg good, lt gry, soft, rare small dc nods, more below 180.75 m			Rare rd & wht bt
-182	1	0	Sand aa, colour faintly mottled from v lt y to v lt gry, a few small nods, more between 181.55 & 181.75 m	Photo at 181.5 m		V faint lt gry bt, rare rd bt with lt y alteration zone outside the rd (Photo at 181.5 m)
-183	1	0	Sand aa, v lt y colour more obvious, no nods. Individual layers from here on downwards suggested by colour changes caused by bt, grey bt with sharp upper boundary, grey decreasing in intensity downwards; single layer from 182.3 m to 183 m.			Abund v lt gry bt, no red
-184	0.93	1st 7 cm	Sand aa, colour aa, core v soft and disturbed, small dc nods at 183.5 m, large dc nods in last 10 cm.			Bt present but not clear, core v disturbed
-185	1	0	Sand, fS, slt, v clayey to 184.1 m, stg poor 184.1-184.4 m, Loose nods to no sand, suggest loss of sand, 184.4-185 m:- Sand, fS, minor vfs, v minor slt, stg good, most grains v well rounded, soft, v lt gry at top, original v lt y with less bt at base. This section is an individual layer.			Rare rd bt, possibly some light coloured bt in lower 30 cm
-186	1	0	Sand, fS, minor vfs, v minor slt, stg good, most of the grains v well rounded, v lt gry, more patches v lt y, soft, no nods. One layer from 184 m to 184.45 m, next layer down from 184.45 m to 186.29 m.			Abund v lt gry bt, rare rd bt
-187	1	0	Sand aa, no nods. Layer from 186.29 m to 186.45 m; next layer down from 186.45 m to 187 m.			Fairly abund v lt gry bt, no rd bt
-188	1	0	Sand aa, large calc dc nods from 187.62-187.75 m, 187.83-188 m. Layer from 187 m to 187.27 m, next layer down from 187.29 m to 188.53 m.	Photo nods with sand between		Some v lt gry bt, less rd bt, lowest dc nod has cavities like uncemented bt channels
-189	1	0	Sand aa, large calc dc nods from 188-188.2 m, 188.35-188.48 m, 188.89-189 m. Layer from 188.53 m to 190.13 m			Some v lt gry bt, less rd bt, top & middle dc nods have cavities like uncemented bt channels
-190	0.95	1st 5 cm	Sand aa, alternating with large hard sl calc dc nods, sand from 189.37-189.5 m, 189.72-189.78 m, 189.91-190.0 m; a few bt-like features in the nods that are sand filled or partly cmted by cc.			See lithology for nods Faint bt in the sand
-191	1	0	Sand aa, colour v lt y, v lt gry & lt purp, soft; v sl calc; dc nods at 190.1 & 190.42 m. Faint horizontal bedding from 190.13 m to 190.2 m. Layer from 190.13 m to 190.3 m; next layer down from 190.3 m to 191 m.	Photo faint purp bt, 190.7 m		Faint purp bt scattered throughout, rare rd bt
-192	0.86	Last 14 cm	Sand aa, alternating with large hard sl calc dc nods, sand from 191-191.16 m, 191.34-191.59 m			Scattered lt purp bt, rare rd bt; sand filled or weakly cmted bt-like cavities in nods
-193	1	0	Sand aa, v lt y, soft, calc dc nod with bt-like cavities from 192.29-192.36 m. Layer from 192.36 m to 193.36 m.			Scattered v lt purp bt, rare rd bt
-194	1	0	Sand aa, no nods below this unless mentioned. Layer from 193.36 m to 193.8 m; next layer down from 193.8 m to 193.98 m, next layer down from 193.98 m to 194.2 m.			Bt aa but less abund

-195	0.94	Last 6 cm	Sand aa, stg still good, soft, v faint bdg at an angle of ~10° to horizontal from 194.24-194.86 m	Two photos bdg		Much v lt purp bt, some rd to 194.22 m then no purp bt only rare rd bt
-196	0.93	1st 7 cm	Sand aa, same v lt y, stg good			2 rd bt at 195.14 m, no bt to 195.57 m, v lt purp bt below 195.57 m increasing in abund downwards, all small
-197	1	0	Sand aa, same v lt y, stg good, faint bdg to 196.30 m	Photo bdg		Minor v lt purp bt to 196.67 m, all small individuals, none below this
-198	1	0	Sand aa,	Photo faint bt		Zone of faint v lt purp to lt rd bt from197.26-197.45 m
-199			Sand aa, possibly faint bdg			No bt
-200	1	0	Sand aa, one 3 cm dc nod at 199.19 m; 2 sets of faint bedding at different 10° angles to horizontal /// \\\			One rd bt spot only
-201	0.6	Last 40 cm	Sand aa, no bdg			No bt
-202	0.86	1st 14 cm	Sand aa, no bdg			No bt
-203	1	0	Sand aa,			A few tiny lt purp bt spots
-204	1	0	Sand aa, possibly some v faint bdg			A few tiny lt purp bt spots
-205	1	0	Sand aa, some v faint bdg, large hard Fe-stained calc dc nod from 204.32-204.4 m			A few tiny lt purp bt spots, 2 rd bt next to the nod
-206	1	0	Sand aa, some v faint bdg,			A few tiny lt purp bt spots,
-207	0.9	Last 10 cm	Sand aa, possibly a sl increase in grain size downwards, v faint bdg, large hard Fe-stained calc dc nod from 206.8-206.9 m			No bt
-208	1	0	Sand aa, large hard partly Fe-stained calc dc nod from 207-207.27 m, another smaller calc dc nod at 207.75 m			Lt rd bt between the nods, abund from 207.27 m to 207.62 m, decreasing to 207.75 m, only 3 small rd spots below this
-209	1	0	Sand aa, v lt y but sl gry-y at top and bottom, purp staining from 208.54-208.56 m, v rd ferruginisation from 208.56-208.66 m and 1 cm thick at 208.69 m	Photo rd ferrug		Rare tiny purp spots 108.3-108.4 m, more below 108.7 m 2 small rd spots 108.44-108.5 m
-210	1	0	Sand aa, v lt gry-brn to 109.8 m; 109.8-110 m:- Sand, vfS, clayey, darker gry-brn; large hard wht sl calc dc nod with large sand-filled cavities from 109.9-109.9 m			Some lt purp bt at 109.05 m, tiny scattered specks of lt purp bt 109.46-109.8 m, some larger bt below 109.8 m
-213	1.3	1.7	210-210.17 m:- Sand, fS, minor vfs, v minor slt, stg good, lt gry-brn, soft, i.e. same well sorted sand aa; 210.17-210.44 m:- Sand, fS, minor vfs, v minor slt, stg good, rust red, soft; possibly some core loss here; 210.44-210.56 m:- large hard wht sl ferrug dc nod; 210.56-210.74 m:- same sand as 210.27 m; 210.74-211.3 m :- several loose hard wht dc nods - probably most core loss here			Minor rd bt in the top lt gry-brn sand; nods at bottom of core have uncemented or weakly cemted sand-filled bt-like cavities
-214	1	0	213-213.13 m:- Sand, fS-vfS, slt, some clay(?), stg poor, gry-brn, soft, 213.13-213.29 m:- Sand, fS-vfS, slt, some clay(?), stg poor, soft, rust red, 213.29-213.38 m:- dc nod with partly cmted sand-filled bt cavities, 213.38-213.67 m:- same sand as to 213.29 m, more purplish, soft; 213.67-213.77 m:- Sand, fS, well sorted, lt gry-brn & rust red, soft; 213.77-213.85 m: - dc nod 213.85-214 m: Sand, fS, well sorted, lt purp-brn, soft;			Abund lt purp bt to 213.13 m; See comment on nod Some rd bt below 213.85 m
-215	1	0	214-214.63 m:- Sand, fS, well sorted, lt purp-brn, soft; sl finer grained between 214.45 & 214.57 m; 214.63-214.76 m:- Sand, fS, well sorted, rust red, soft; 214.76-215 m:- Sand, fS, well sorted, lt purp-brn, soft;			214.76-215 m:- some clear rd bt

-216	0.6	0.4	Sand, fS, well sorted, redder purp-brn, soft;			Red bt from 215.1-215.17 m, at 215.42-215.5 m
-217	1	0	Sand, fS, well sorted, redder purp-brn aa, soft;			Red bt at 216.23, 216.39-216.52 & 216.9 m
-217.6	0.6	0	Sand, fS, well sorted, redder purp-brn aa becoming more lt y downwards, soft; dc nod from 217.05-217.16 m			
-219	0	1.4	No core			
-219.7	0.7	0	Sand, fS, well sorted, lt brn to ~219.38 m becoming progressively redder down-wards, soft; core disturbed			One rd bt channel
-222	0.8	1.5	Sand, fS, vfs, lt purp red, soft; some rounded dc nods, core disturbed			
-223	1	0	Sand, fS, vfs, stg fair-good, lt purp rd to 222.21 m, soft; 222.21-222.38 m:- dc nod with some sand-filled cavities, vertical at top; 222.38-223 m:- Sand, fS, vfs, rust red, soft; one deep y spot at 222.64 m			
-224.2	1	0	Sand, fS, vfs, stg fair-good, lt purp red, soft; core disturbed			
-225	0.8	0	Sand, fS, vfs, stg fair-good, rust red, some faint purp patches, soft; core disturbed; hard wht dc nod 224.2-224.3 m			
-225.8	0.8	0	Sand, fS, vfs, stg fair-good, rust red, soft; 1 dc nod at 225.53 m			
-228	2.2	2.2	No core			
-229	1	0	Sand aa, fS, vfs, stg fair-good, rust red, soft; dc nods from 228-228.3 m			
-229.4	0.4	0	Sand aa, fS, vfs, stg fair-good, rust red, soft; core v disturbed			
-230.4			Sand aa, fS, vfs, stg fair-good, rust red, soft; colour sl weaker in lower 25 cm of core; a few small whitish spots			1 rd bt at 229.66, 2 small zoned rd bt channels (dark rim, lighter core, pale wht sand outside rim) near base of core
-231.2	0.8		Sand aa, fS, vfs, stg fair-good, rust red, soft; core disturbed NB – core photo missing			2 rd zoned bt spots aa at 230.37 & 230.6 m
-234	2.8	2.8	No core			
-235.3	1.3	0	Sand aa, fS, vfs, stg fair-good, rust red, soft; 2 small dc nods at 235.69 m			Red zoned bt spots aa at 234.12, 234.49 & 234.63 m
-236.3	1	0	Sand aa, fS, vfs, stg fair-good, rust red, soft;			A few small rd zoned bt spots
-238.3	2	1	Sand aa, fS, vfs, stg fair-good, rust red, soft;			A few small rd zoned bt spots
-240	0.75	0.95	Sand aa, fS, vfs, stg fair-good, rust red, soft;			A few small rd zoned bt spots
-241	1	0	Sand aa, fS, vfs, stg fair-good, rust red, soft; 12 cm dc nod from 240.05-240.17 m, 4 small dc nods spaced through the rest of the core	Photo at 240.3 m		
-243.3	1	1.3	Sand aa, fS, vfs, stg fair-good, rust red, soft; 2 small dc nods			A few small rd zoned bt spots
-244.3	1	0	Sand aa, fS, vfs, stg fair-good, rust red, soft;			A few small rd zoned bt spots; a few pale bt burrows
-245.3	1	0	Sand aa, fS-vfs, tr slt, rare mgr grns, v uni-form, rust rd, no bdg	Photo faint bt		Some sl darker rd bt, v faint, rare small wht spots that may be bt
-246.8	1	0.5	Sand aa, no bdg			No rd bt, some small wht bt (?) spots
-249	1	1.2	Sand aa, 2 small calc dc nds			
-250	1	0	Sand aa, three 1-2 cm dc and calc dc nods	Photo faint bt		Faint rd bt, some wht bt spots
-252	1	1	Sand aa, several irreg 1-4 cm calc dc nods			
-253	1	0	Sand aa, four 2-4 cm calc dc nods			
-254	1	0	Sand aa,			Some faint wht and rd bt spots
-254.88	0.88	0	Sand aa, one small calc dc nod			
-256	1.12	0	Sand aa, but fS, almost mgr, coarser than above, still v well sorted, no bdg, same rust rd, almost all grns highly spherical and frosted, i.e. aeolian but deposited fluvially from a distal aeolian source, three 1-5 cm calc dc nods			
-257	1	0	Sand aa, some zones w sl smaller grn size, no nods			Rare small off wht bt spots
-259	1	1	Sand aa to 258.9 m, more mgr grns than above, most highly spherical and frosted; then to 259 m - fS, vfs, slt, rare mgr grns,			

			poorly sorted, still highly spherical and frosted, deeper rd			
-260	1	0	259-259.3 m - sand, fS, vfs, slt, rare mgr grns, poorly sorted; 259.3-259.73 m - fS-mS, well sorted, grns highly spherical and frosted, accessory blk heavy mineral grains, also v well rounded and frosted **BASE OF OHANGWENA II AQUIFER AT 259.73 m** 259.73-260 m - Sand, vfS, slt, poorly sorted, deeper rd;			Lighter rd bt burrow/layer(?) filled w well sorted fS at 259.89 m
-261	0.9	0.1	Sand, vfS, slt, poorly sorted, rd; soft, 3 cm thick fS lighter rd layer at 260.4 m			
-262	1	0	Sand, fS-vfS, fair sorting, lighter red, grns spherical, soft,			Rare deeper rd bt spots
-263	1	0	Sand, fS-vfS, well sorted to 262.35 m; soft, 262.35-262.43 m - Sand, deep rd, vfS, silty, poorly sorted, soft, 262.43-263 m - massive calc dc, some tiny spots ± 1 mm diam and a few larger patch-es of uncemented rd silty sand, almost no sand grains in the dc otherwise			
-264	0.6	0.4	263-263.34 m - massive calc dc aa 263.34-263.6 m - Sand, deep rd, vfS, silty, poorly sorted, no bdg 263.6-264 m - core loss			
-265	1	0	Sand, deep rd, vfS, silty, poorly sorted, no bdg, soft,			
-266	1	0	To 265.85 m: Sand, deep rd, v uniform, vfS, silty, poorly sorted, no bdg, soft, 265.85-266 m: Sand sl deeper rd, still finer gr, v poorly sorted, v uniform, no bdg, soft,			
-267	0.65	0.35	Sand aa, deeper rd, vfS, v poorly sorted, v uniform sand, no bdg, soft, 266.65-267 m: core loss			
-268	1	0	To 267.72 m: massive, unbedded sand-cementing calc dc, 267.72-268 m: Sand, fS-vfS, well sorted, rd, v uniform, no bdg			
-269	1	0	Sand aa, to 268.72 m, fS-vfS, well sorted, rd, v uniform, no bdg; soft, Sand, 268.72-269 m, vfS, fair sorting, rd, v uniform, no bdg; soft, calc dc cmting and small off wht calc dc nods from 268.24 m to 268.33 m, 6 cm diam calc dc nod at 268.5 m, some small scattered calc dc nods and cmting from 268.74-268.9 m			
-270	0.86	0.14	Sand, 269-269.21 m, same vfS aa, fair sort-ing, rd, v uniform, no bdg; soft, 21-41 cm: massive calc dc, 41-56 cm: Sand, vfS, silty, poor sorting, deep rd, v uniform, no bdg; soft, 56-71 cm: same sand, cmted by hard off wht calc dc, 71-86 cm: Cgl w some small wht cc clasts ≤5 mm, grey cc clast ±1 cm, clay pellet clasts in a v sandy matrix with abund tiny sand-size cc fragments densely cmted by hard off wht calc dc			
-271	1	0	Sand, vfS, to 0.80 cm, silty, v poor sorting, rd, no bdg, soft, clast bearing; a few ran-domly scattered qtz granules and qtz pebs up to 1 cm diam to 0.48 cm, one 1 cm di-am qtz peb at 27 cm, some small fragments up to 1 cm diam of dk rd v clayey v fgr sand to 0.25 cm, a few v small randomly scattered wht clay fragments to 0.48 cm, a few scattered c gr grns from 0.48 to 0.59 m; 80-89 cm: Clay dk rd w some streaks of v			

			fgr unsorted sand; 89 cm-271 m: Sand rd v fgr silty clayey unsorted.			
-272	1	0	Sand, vfS, silty, v clayey, a few rounded qtz or chert granules 4-8 mm Ø, rd, rare small wht calc dc nods; 04-12, 18-74, 78 cm -271 m - dc with some sand-filled cavities		4 granules for XRD	
-273	1	0	Sand aa, hard, intensely but sl unevenly cmted by calc dc; high contrast image shows v irreg mixing of lighter and dker rd sand - bt?; dc from 08-22 cm			Possible bt mixing of v irreg mixing of lighter and dker rd sand
-274	1	0	Sand aa to 27 cm; then patchy vfS, v slty, poorly std, soft rd sand & irreg patches of vfS, slty, v clayey, poorly std, dker rd sand, possibly mixed by bt; Small qtz/chert peb at 36 cm for XRD; cmting by calc dc from 87 cm-274 m; dc from 09- 15 cm	Photo dker rd bt (?) patch-es	Peb for XRD	Mixing by bt?
-275	1	0	Sand, vfS, v slty, v clayey, poorly std, soft, rd; uneven hardened patches of calc dc cmt; one 2 cm long silcrete nod at 33 cm; possibly some darker spots of bt			Dker rd bt spots?
-276	0.94	0.06	Sand aa, a few scattered angular silcrete nods with chert cmting extending into the enclosing rd sand; hard calc dc cmting from 58-94 cm 94 cm -276 m: core loss		Silcrete nods	
-277	1	0	Sand aa but hard intensely cmted by wht calc dc to 20 cm; scattered granules from 276-276.2 m; 20-30 cm: Sand aa, soft; 30-75 cm: Cgl? v sandy, rare small clasts of grey cc, a few larger clasts of rd clay, v irreg and patchily cmted by calc dc; 75 cm -277 m: Cgl or clast-bearing clayey sand; abund rd clay clasts in sandy matrix; chert nods at 78, 84 and 87 cm		Chert nod at 276.87 m for XRD	
-278	1	0	Sand aa that becomes finer gr more clayey and dker rd to 44 cm; 44-48 cm: Clay dk rd, calc, speckled by tiny wht cc spots; 48-66 cm: rd Sand, gritty studded w tighly clusted tiny clasts of wht cc and rd clay both up to 5 mm diam; patchily cmted by hard wht cc; 66 cm 278 m: Clay, slty, dk rd, v calc, wht cc cmting			
-279	0.92	0.08	Clay aa 92 cm 279 m: core loss			
-280	1	0	279 m - 10 cm: cc 10 cm -280 m: Clay aa, patches of wht cc cmt in places, v faint bdg lam throughout at angle of <5° to core			
-281	1	0	280 m - 61 cm: Clay aa, patches of hard wht cc cmting; 61-91 cm: Silt, well std, rd, soft 91 cm -281 m: Clay aa			
-282	1	0	281 m - 26 cm: Clay, slty, dk rd, v clear bdg lam, v calc; 26-35 cm: Clay dk rd; 35-48 cm: Clay, slty, dk rd; 48-60 cm: Clay, slty, dk rd, hard, sl calc dc cmting; 60-61 cm: Clay, dk rd; 61-79 cm: Sand, cmted by hard wht calc dc; 79-81 cm: Clay, dk rd; 81 cm -282 m: Sand, coarse, rd clay clasts, hard, wht, sl calc dc cmting;			
-283	1	0	282 m - 80 cm: Silt, clayey, rd, hard, sl calc dc cmting to 22 cm; hard wht calc dc from 22-28 cm; 80 cm -283 m: Grit, hard, speckled by wht, v sl calc dc cmt			

-284	1	0	283 m - 14 cm: Silt aa, v clayey, rd; 14-33 cm: v sl calc dc layered // to bdg; 33-37 cm: Silt, v clayey, rd; 37-44 cm: v sl calc dc layered // to bdg; 44-93 cm: sl dolic cc, v densely speckled; 1-2 cm thick dk rd clay layers at 56, 62 & 85 cm; 93 cm -284 m: Silt, v clayey, rd, hard;			
-285	0.90	0.10	284 m- 30 cm: Silt, v clayey, rd, hard, lam bdg at ±5° to core throughout; 30-40 cm: Cgl, granule (?)-sand matrix, small calc dc pebs, , rd clay pellet clasts, cmted by hard wht cc prefernetially in ±1 cm-thick bdg-// layers; 40-45 cm: massive hard wht cc; 45-47 cm: Silt, v clayey, rd; 47-55 cm: Cgl, small calc dc pebs, granules, clay pellet clasts, cmted by hard wht cc prefernetially in ±1 cm-thick bdg-// layers; 55-90 cm: Silt, sl clayey, rd, hard; hard wht cc nods near top and middle, fine wht speckling from 80-90 cm; 90 cm -285 m: core loss			
-286	1	0	285 m - 20 cm: cc; 20-27 cm: Clay, silty, dk rd; 27-79 cm: Silt, well sorted, rd, soft; 79-93 cm: Clay, silty, dk rd; 93 cm - 286 m: cc nods			
-287	1	0	286 m - 04 cm: Clay, silty, dk rd; 04-22 cm: cc, wht, hard, v speckled; 22-35 cm: silt, clayey, rd, semi-consol; 35-60 cm: Clay, silty, dker rd, some irreg cc nods; 60-70 cm; Cgl, v sandy matrix, small wht cc clasts and some larger rd clay clasts, matrix densely cmtd by cc; 70-75 cm: Clay, dk rd; 75 cm - 287 m: Cgl, v sandy, small wht cc clasts and some larger rd clay clasts, densely cmtd by cc;			
-288	0.84	0.16	287 m - 07 cm: same Cgl aa, densely cmtd by cc; 07-76 cm: cc, hard, wht, speckled; 76-78 cm: Clay, dk rd; 78-84 cm: Clay, silty, calc, rd; 84 cm - 288 m: core loss			
-289	1	0	288 m - 28 cm: Clay, silty, rd, scattered cc nods; 28-60 cm: Clay, silty, rd, cc cmtg of bdg lam; 60-83 cm: Clay, silty, rd, dc cmtg of bdg lam; 83 cm - 289 m: Clay, silty, rd, cc cmtg of bdg lam;	Photo xbdg lam		
-290	1	0	Clay, silty, rd, v thin bdg expressed as harder and softer layers that stand out on edge of core; patchy cc cmt in a few thin layers			
-291	1	0	Clay aa to 05 cm, 05 cm - 291 m: Clay, only sl silty, rd; a cc nod from 05-06 cm then a few scattered sl calc dc nods to 70 cm, then 3 long vertical rhyzolith-like cc concentration to 95 cm & rare zoned (blk or dk grey core, wht rim) cc nods <1 cm diam			
-292	1	0	Silt, - 57 cm, clayey, rd, poorly sorted, uneven cc cmtg to 46 cm, more intense cc cmtg to 57 cm; a single xbd unit to 42 cm; 57 cm - 292 m: Clay, silty, rd, some small cc nods	Photo xbdg, angle ±20°		
-293	0.94	0.06	Clay, silty, rd, 3 small cc nods at 40 cm, tiny cc nods from 86-94 cm; 94 cm - 293 m: core loss			
-294	0.70	0.30	Silt, clayey, rd, poorly sorted, faint horizon-			

			tal bdg throughout 30 cm core loss			
-295	1	0	294 m - 24 cm: Cgl, abund small intrabasinal clasts up to 5 mm diam of rd clayey silt and rd clay and cc, densely cmted by hard wht sl calc dc; coarse sandy matrix 24-30 cm: hard wht calc dc, faint layering // to bdg; 30-91 cm: Silt, clayey, rd, poorly sorted, consol, no cmt, some bdg lam at <5° to core, a few calc dc bands 1-10 cm long // to bdg; 91 cm - 295 m: hard wht calc dc.			
-296	1	0	295 m - 10 cm: Clay, dk rd, lower contact to underlying dc at 45° to core; 10-12 cm: Cgl, rd clay clasts, cmted by hard wht calc dc, layer at 45° to core; 12 cm - 296 m: Silt, v clayey, rd, poorly sorted, consol, much bdg lam at ~2° to core, some nods of v calc dc elongated in bdg			
-297	1	0	Silt, aa, v clayey, rd, poorly sorted, consol, much bdg lam, some tiny 2-4 mm diam calc dc nods strung out along bdg like strings of beads from 42-65 cm	Two photos of bdg		
-298	1	0	297 m - 75 cm: Silt, aa, v clayey, rd, poorly sorted, consol; strings of tiny calc dc nods aa to 05 cm; 5 mm-thick calc dc layer // bdg at 75 cm; 75-82 cm: Cgl, intrabasinal clasts 1-20 mm diam of rd clayey silt in hard wht v calc dc; 82 cm - 298 m: Silt, aa, v clayey, rd, poorly sorted, consol;			
-298.92	0.92	0	298 m - 10 cm: Silt, aa, v clayey, rd, poorly sorted, consol; 10-30 cm: hard wht v calc dc; 30-92 cm: Silt, aa, v clayey, rd, poorly sorted, consol; hard wht calc dc layer // to bdg from 82-88 cm			
-300	1.08	0	298.92 m - 299.47 m: Cgl, sand matrix, intrabasinal clasts of rd clay 1-8 mm diam, larger clasts flattened in bdg, matrix intensely cmted by hard wht sl dolic cc; 47-48 cm: thin rd Clay; 48 cm - 300 m: Silt, clayey, rd, poorly sorted, consol; 1.5 cm thick bdg-// layer of sl dolic cc at 82 cm			
-301	1	0	Silt, clayey, rd, poorly sorted, consol, sl less clayey below 36 cm; hard wht bdg-// sl dolic cc layers preserving bdg lam from 28-36 and 78-82 cm;			
-301.94	0.94	0	Silt, sl clayey, rd, poorly sorted, consol; clay content decreases sl downwards; 2 cm-thick wavey cc layer at 32 cm			
-303	1/06	0	301.94-302.63 m: Silt, aa, sl clayey, rd, poorly sorted, consol; irreg sl calc dc layer from 10-18 cm 63-89 cm: Clay, rd, sl calc, a few thin short elongate (up to 2 cm) subvertical sl calc dc nods to 83 cm, rest to 89 cm speckled by scattered small v calc dc nods up to 1 cm diam; 89-96 cm: Silt, v clayey, rd; 96 cm - 303 m: Clay, rd, a few small (up to 1 cm diam) zoned (blk core, wht rim) calc dc nods			
-304	1	0	303-303.09 m: Clay, rd; 09 cm - 304 m: Silt, clayey, rd, consol; irreg calc dc nods up to 8 mm diam near top then a few scattered small (up to 2 cm diam) calc dc nods down to 53 cm, some zoned w grey core, wht rim; thin calc dc bdg-// streaks at 67 cm			

-304.91	0.91	0	303-303.70 m: Silt aa, clayey, rd, consol; dk rd clay clasts in silt from 32- 35 cm; 70-91 cm: Cgl, dk rd clay clasts, sand matrix, cmted by hard wht dolic cc layered // to bdg lam		Cgl sampled from 72- 78 cm for TS to study cmted matrix	
-306	1.09	0	304.91-305.18 m: Silt, clayey, rd, consol; 18-21 cm: hard rd calc dc; 21-22 cm: Clay drape, rd; 22-26 cm: Cgl, intrabasinal rd clay clasts, cmted by hard wht calc dc; 26-35 cm: Silt, clayey, rd, consol; preferential cmting of specific v thin beds by calc dc - seen as a fine intermittent wht speckling along bed (photo); 35-88 cm: Silt, clayey, rd, consol; a 1-2 cm thick wavy bdg-// calc dc layer at 41 cm; 88 cm - 306 m: Sand, fS-vfs, well sorted, consol; bdg lam (photo)	Photo at 306.26 cm, prefer-en-tial cmtg of specif-ic beds; Photo of lam in fgr sand		
-307	1	0	Sand, vfS-fs, sl clayey, poorly sorted, rd, clear lam bdg throughout, single xbd unit to 53 cm; horizontal bdg 53- 56 cm; single xbd unit 56 cm -307 m (photos at top and middle of this unit)	Photo 1 - horiz and xbd bdg; 2 - lower xbd		
-307.93	0.93	0	307-307.32 cm: Cgl: intrabasinal small rd clay pellet clasts <5 cm diam & v dk gry cc clasts up to 2 cm diam, intensely cmtd by hard wht sl dolic cc; 32-33 cm: Clay, rd (drape?); 33-41 cm: Cgl: intrabasinal small rd clay pellet clasts, rare wht & gry cc clasts; 41-45 cm: Clay, rd (drape?); 45-70 cm: Cgl: intrabasinal small rd clay pellet clasts only; 70-83 cm: Silt, v clayey, rd, a few small 1-2 cm calc dc and dolic cc nods; 83-93 cm: Silt, v clayey, rd, a few small rd clay clasts.			
-309	1.07	0	73 cm: Clay, silty, rd, a few small scattered cc nods; 3 cm: Clay, rd, (drape?) 7 cm: Sand, vfS, well sorted, consol, abund tiny wht non-reactive speckles (wht clay?); 6 cm: Sand, silt, alternating v thin layers of rd poorly sorted silt and lighter rd poorly sorted vfS; 8 cm: Silt, v clayey, rd.			
-310	1	0	309 m -72 cm: Silt, clayey, rd, dense hard wht dolic cc cmting from 11-12, 51-58 and 69-72 cm; 72 cm - 310 m: Clay, rd			
-310.94	0.94	0	Clay, rd, massive wht hard dc layers from 07-19 and 29-53 cm, silty xbdg from 79-87 cm, one vert dc nod from 58-65 cm, short thin bdg-// cmting at 78 cm			
-312	1.06	0	16 cm: Clay, rd; 6 cm: calc dc, massive hard wht, with some bdg lam; 84 cm: Silt, clayey, rd, consol, some wht lam-// cmting by dolic cc from 32-43 (slight), 56-65 (denser), 72-79 (variable intensity), 91-94 cm (denser)			
-313	1	0	312 m - 04 cm: Silt aa, clayey, rd, consol; 04-19 cm: Cgl, abund mS-cS matrix, speckled texture, with coarse-sand size to granule size clasts of rd clay and two up to 1 cm diam, intensely cmted by hard wht cc;			

			19-24 cm: Silt aa, clayey, rd, consol; 24-42 cm: Silt aa, clayey, rd, consol, sl speckled by disseminated spots of cc cmting; 42-48 cm; Silt aa, clayey, rd, consol; 48-59 cm: Clay, silty, rd; 59 cm - 313 m: Silt, v clayey, rd, consol, some speckled calc dc cmting from 91-94 cm.			
-313.91	0.91	0.02	313 m - 72 cm: Silt aa, v clayey, rd, consol, some speckled low density cc cmt from 03-07 and 27-34 cm; 72-92 cm: Clay, silty, rd, some small up to 1 cm diam irreg-shaped sl calc dc nods, some zoned (dk gry core, wht rim)			Possible calcified bt burrow from 84-90 cm
-315	1.07	0	33 cm: Clay aa, silty, rd, with scattered zoned and unzoned irreg-shaped sl calc dc nods aa but 1-4 cm diam; 17 cm: Silt, fgr, sl clayey, rd, consol, small cc nods in top 4 cm; 5 cm: Clay, silty, rd (drape?); 52 cm (to 315 m): Silt, vfgr, clayey, rd, consol, some cc cmting in top 10 cm.			
-316	1	0	315 m - 85 cm: Silt aa, vfgr, clayey, rd, consol, sl coarser grained in basal 1.5 cm; 85 cm - 316 m: Cgl, small intrabasinal clasts of wht and dk gry cc and rd clay; patchy hard wht cc cmtg of the matrix			
-316.95	0.95	0	316 m - 62 cm: Silt, clayey, rd, consol; 95 cm: Silt, more clayey, rd, consol; whole core spotted by many small (1-10 mm) wht cc nods			
-318	1.05	0	Silt, clayey, rd, consol, sl decrease in clay content downwards, rare small 1 cm cc nods			
-319	1	0	Silt aa, clayey, rd, consol; more nods, some cc some calc dc, larger are irreg shaped, two 2-3 cm wide vertical nods 8 and 12 cm long from 09-17 cm and 68-80 cm			
-319.94	0.94	0	319 m - 54 cm: Silt, clayey, rd, semi consol, variable clay content, variable silt size - coarser to 22 cm, finer to 54 cm; 89 cm: Sand, vfS, silty, poorly sorted, rd; 94 cm: Sand, vfS, silty, poorly sorted, rd, patchily cmted by hard wht dolic cc			
-321	1.06	0	32 cm: Hard wht spotty dolic cc; 1 cm thick silt layer at 13 cm; 33 cm: Silt, clayey, rd, semi consol, sl less clay in top 10 cm; 28 cm: Cgl, a few small intrabasinal clasts of wht and grey cc, rd silty clay and clay in an abund coarse sand matrix intensely cmted by hard wht cc // to bdg (lam and v thin bdg); 13 cm: Silt, sandy (vfs), rd, consol,			
-322	1	0	321 m - 19 cm: Silt, clayey, rd, consol; 44 cm: Silt, better sorted, rd, semi consol to soft; 89 cm: Cgl, small intrabasinal clasts of rd clay, silty clay in coarse sand matric in-tensely and massively cmted by cc; 322 m: Sand, vfS, sl silty, fair sorting, rd, soft			
-322.96	0.96	0	322 m - 20 cm: Sand, vfS, sl silty, fair sort-ing, rd, soft; 95 cm: Sand aa, vfS, sl more silt, fair sort-ing, rd, partial cmting of 1-2 cm thick bdg-// layers by wht v calc dc giving a sl lighter colour to the layers			
-324	1.04	0	10 cm: Sand aa, vfS, sl silty, fair sorting, rd, densely cmted by wht hard v calc dc; 21 cm: Clay, rd, two massive 2 cm-thick dc layers;			

			10 cm: Clay, silty, dk brn rd, tiny dc nods in top 2 cm; 23 cm: Silt, fair sorting, rd, soft; 5 cm: Sand, vfs-fS, well sorted, rd, soft; 17 cm: Clay, rd; 18 cm to 324 m: Clay, silty, rd, several zoned dc nods gry core, wht rim; 2 cm-diam clast of blk clay at base.			
-325	1	0	324 m - 17 cm: Sand, cS, many small fragments of rd clay; intensely cmted along bdg planes to 07 cm, less intense cmtg to 17 cm; 48 cm: Clay, rd, many zoned (aa) cc nods; 68 cm: Clay, silty, rd, bdg at ±20° to core (xbdg) from 52-57 cm, basal contact at ±25° to core; 325 m: Sand, vfS, silty, poorly sorted, becoming sl coarser and better sorted downwards, soft			
-326	1	0	325 m - 06 cm: Silt, clayey, rd, soft; 58 cm: Cgl, abund small intrabasinal clasts up to 2 cm diam of wht cc, some gry cc and many rd clay clasts; v thinly bedded, dense calc dc cmt; small clasts in basal 20 cm and upper 13 cm; 81 cm: Sand(?), lam, intensely cmted by lam-// cc; 326 m: Clay, silty, rd, many dark cc and dc nods			
-326.96	0.96	0	326 m - 03 cm: Silt, poorly sorted, rd, soft; 10 cm: calc dc enhancing thin bedded to lam bdg; 326.96 m: Silt, sl clayey, poorly sorted, rd, soft to semi consol, sl more clay in top 25 cm, a few small rd clay clasts from 52- 56 cm and 86- 89 cm, single layers of dc nods at 48 and 94 cm			
-328	1.04	0	27 cm: Sand-Cgl, cS, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, intensely cc cmted; 13 cm: Silt, fairly well sorted, rd, soft; 5 cm: Sand-Cgl, cS, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, intensely cc cmted; 36 cm: Silt, fairly well sorted, rd, soft; 7 cm: Sand-Cgl, cS, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, a few gry cc clasts, intensely cc cmted; 9 cm: Silt, fairly well sorted, rd, soft, 3 cm-long rd clay clast at base; 8 cm: Sand-Cgl, cS, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, intensely cc cmted;			
-328.94	0.94	0	09 cm: Sand-Cgl, cS, dk rd brn, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, intensely calc dc cmted; 15 cm: Silt, fairly well sorted, consol; 21 cm: Sand-Cgl, cS, dk rd brn, a few small intrabasinal clasts up to 1 cm diam of rd clay and silty clay, intensely calc dc cmted; 328.94 m: Silt, fairly well sorted, consol, 1 cm-thick calc dc layer/vein inclined at ±20° to core at 30 cm, two tiny rd clay clasts at 33 cm.			
-330.03	1.03	0.03	53 cm: Silt, aa, rd brn, varying numbers of wht 1 mm diam calc dc specks, calc dc cmt in basal 8 cm; 3 cm: Clay, rd; 12 cm: Clay, dk brn, scattered 2-10 mm sl calc blk spots, clay v fragmented, core loss probably here; 17 cm: Clay, rd; 4 cm: Clay, dk brn;			

			14 cm to 330.03 m: Clay, dk rd brn,			
-331	1	0	330.03 m - 20 cm: Clay, rd, calc dc cmting from 12-16 cm; 85 cm: Silt, well sorted, rd brn, consol; wht speckled to 40; 91 cm: Cgl, cS matrix, intrabasinal clasts of wht and lt gry cc up to 2 cm diam and rd clay clasts up to 5 mm; intensely cmted by hard wht dolic cc; 331 m: Silt, well sorted, rd brn,			
-332	1	0	Silt, sl clayey, well sorted, rd brn, consol, bdg lam at 331.30 m and from 53- 62 cm			
-333	1	0	332 m - 50 cm: Silt, aa, well sorted, rd brn, consol; 60 cm: Sand-Cgl: cS, a few intrabasinal clasts up to 1 cm diam of rd clay and rd brn silt; cmted along bdg by hard wht calc dc; 333 m : Silt, aa, well sorted, rd brn, consol;			
-334	1	0	333 m - 15 cm: Silt, aa, well sorted, rd brn, consol; 18 cm: Cgl: intrabasinal calc dc clasts up to 1 cm diam, irreg cmted by calc dc; 334 m: Silt, aa, well sorted, rd brn, consol, 1 cm-thick streaky bdg-// calc dc bands at 31 and 80 cm, faint bdg lam from 86-96 cm.			
-335	1	0	334 m - 12 cm: Silt, aa, well sorted, rd brn, semi consol; 20 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht dolic cc and rd clayey silt up to 1.5 cm diam and of rd brn clay up to 3 cm diam, intensely cmted by hard off wht dolic cc along and enhancing v thin bdg and lam; 22 cm: Clay, silty, rd (drape); 58 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht dolic cc and clayey silt up to 1.5 cm diam and of rd brn clay up to 3 cm diam, intensely cmted by hard off wht dolic cc along and enhancing v thin bdg and lam; 62 cm: Clay, rd brn, (drape); 86 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht dolic cc and clayey silt up to 1.5 cm diam and of rd brn clay up to 3 cm diam, intensely cmted by hard off wht dolic cc along and enhancing v thin bdg and lam; 90 cm; Clay, rd brn (drape); 93 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht dolic cc and clayey silt up to 1.5 cm diam and of rd brn clay up to 3 cm diam, intensely cmted by hard off wht dolic cc along and enhancing v thin bdg and lam; 335 m: Silt, clayey, poorly sorted, rd brn, soft.	Three photos of cgl, 3rd of cut surface of cmted cgl		
-336	1	0	335 m - 04 cm: Silt, aa, clayey, poorly sorted, rd brn, soft. 25 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht dolic cc and clayey silt up to 1.5 cm diam and of rd brn clay up to 3 cm diam, intensely cmted by hard off wht dolic cc along and enhancing v thin bdg and lam; 336 m: Silt, v clayey, rd brn, redder below 90 cm, clear bdg lam throughout.			
-337	1	0	336 m - 10 cm: Silt, v clayey, rd, clear bdg lam throughout; 16 cm: Cgl, abund cS matrix, scattered intrabasinal clasts of wht cc and calc dc up to 1 cm diam, some clasts (nods?) zoned with gry core, wht rim, v uneven top and bottom surfaces to layer, cmted by hard wht v calc			

			dc; similar cmted layer <1 cm thick at 20 cm; 337 m: Silt, sl clayey, rd, rare small rd clay clasts below 53 cm, semi consol with narrow soft bands.			
-338	1	0	337 m - 04 cm: Silt, v clayey, rd, clear bdg lam throughout, some lam almost pure rd clay; 06 cm: Cgl aa; 16 cm: Silt, v clayey, rd, clear bdg lam throughout, some lam almost pure rd clay, consol where lam, soft where no lam; 17 cm: Cgl aa; 39 cm: Silt, v clayey, rd, clear bdg lam throughout, some lam almost pure rd clay, consol where lam, soft where no lam; 40 cm: Cgl aa; 73 cm: Silt, v clayey, rd, clear bdg lam throughout, some lam almost pure rd clay, consol where lam, soft where no lam; 96 cm: Cgl aa; 338 m: Silt, v clayey, rd, clear bdg lam throughout,			
-339	1	0	03 cm: Clay, rd; 18 cm: Cgl, cS matrix, abund intrabasinal clasts of wht cc and calc dc up to 2 cm diam and much larger clasts of rd clay, silty clay, clayey silt, cmted by hard wht dolic cc; 22 cm: Clay, rd; 51 cm: Cgl, cS matrix, abund intrabasinal clasts of wht cc and calc dc up to 2 cm diam and much larger clasts of rd clay, silty clay, clayey silt, cmted by hard wht dolic cc; 339 m: Clay, dk rd, some small irreg–shaped cc nods;			
-340	1	0	339 m - 41 cm: Clay, aa, dk rd, v thin bdg lam in places, a few tiny blk spots, a few v thin bkl bdg-// streaks; 340 m: Clay, rd, variably calc, some zoned dc nods aa from 44-54 cm.			
-341	1	0	340 m - 11 cm: Clay, aa, rd, variably calc, a few scattered small up to 1 cm diam wht dc and calc dc nods; 15 cm: Clay, lam, silty, rd; 21 cm: Clay, aa, rd, variably calc, a few scattered tiny wht dc and calc dc nods; 33 cm: Clay, lam, silty, rd; 38 cm: Clay, aa, rd, variably calc, a few scattered tiny wht dc and calc dc nods; 52 cm: Cgl, many wht cc clasts up to 1 cm diam, a few rd clay clasts up to 2 cm diam, cmted by wht hard cc; 56 cm: Clay, rd; 341 m: Silt, sl clayey, consol, speckled from 61-69 cm by many tiny unevenly distributed cc nods.			
-342	1	0	341 m - 15 cm: Silt, aa, sl clayey, soft, a few small rd clay clasts below 09 cm; 33 cm: Cgl, abund sandy silt w scattered rounded intrabasinal clasts of wht cc and rd clay up to 1.5 cm diam; patchy cc cmtg; 56 cm: Silt, rd, consol, uneven scattereing of cc nods up to 1.5 cm diam; 60 cm: Clay, rd, some wht cc nods; 92 cm: Silt, variably clayey, rd, lam, some low-angle lam xbdg; consol, some scattered small up to 1 cm diam cc and dc nods to 67 cm and below 75 cm; uneven wht cc cmtg between 67 and 75 cm; 97 cm: Clay, rd, some wht cc nods; 342 m: Silt, variably clayey, rd, consol.	Photo lam low-angle cross bedding at 91 cm		
-343	1	0	342 m - 49 cm: Silt, variably clayey, rd,			

			consol, variably cc cmted to 22 cm, clear lam to 22 cm, less clear to 42 cm, intensely dc cmted from 42-49 cm; 86 cm: Clay, rd, irreg patches of rd silt, a few small cc nods, some zoned aa to 70 cm, rare sl calc dc nods below this; 343 m: Silt, sl clayey, rd, consol.			
-344	1	0	343 m - 70 cm: Silt, aa, sl clayey, rd, consol, faint lam in places to 36 cm, well lam below this to 60 cm, clasts of rd clay from 65-70 cm, lenses of cmtg by calc dc at 34, 38 and from 56-60 cm; 72 cm: Clay, rd (drape?); 74 cm: Silt, lam, cmted by hard wht sl calc dc; 81 cm: Clay, rd, sl silty in basal 1 cm (drape?); 86 cm: Sand, fs?, cmted by hard wht sl calc dc that emphasises bdg; 344 m: Clay, dk rd brn, some sl calc dc nods to 93 cm, some cc nods below this.			
-345	1	0	36 cm: Clay, aa, dk rd brn, many cc and calc dc nods up to 2 cm diam, many zoned aa; 65 cm: Silt, rd, lam, consol, faint wht pervasive calc dc cmting along and emphasizing lam; 66 cm: Clay, rd; 345 m: Silt, rd, lam, consol, faint wht pervasive calc dc cmting along and emphasizing lam;	Two photos of cgl with wht, lt gry cc clasts and rd clay pellet clasts		
-346	1	0	345 m - 19 cm: Silt, aa, rd, lam, consol, faint wht pervasive calc dc cmting along and emphasizing lam; 20 cm: Clay, rd (drape?); 38 cm: Silt, rd, lam, consol, faint wht pervasive calc dc cmting along and emphasizing lam; 88 cm: Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, some of wht cc up to 1.5 cm diam, more of rd clay pellets up to 5 cm diam, matrix intensely cmted by hard wht dolic cc; 346 m: Clay, dk rd			
-347.02	1.02	0	346 m - 06 cm: Clay-pellet Cgl; abund cS matrix, intrabasinal clasts of rd clay pellets up to 5 cm diam, matrix intensely cmted by hard wht dolic cc; 22 cm: Silt, rd, lam, consol; 27 cm : Clay, dk rd (drape); 48 cm : Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, a few of wht cc up to 1 cm diam, more of rd clay pellets up to 7 cm diam, matrix intensely cmted by hard wht dolic cc; 51 cm: Clay, dk rd brn (drape?); 79 cm : Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, a few of wht cc up to 1 cm diam, more of rd clay pellets up to 7 cm diam, matrix intensely cmted by hard wht dolic cc; 84 cm: Clay, dk rd brn (drape?), some cc nods up to 1.5 cm diam; 87 cm: Silt, rd, lam, cmted dolic cc; 95 cm: Clay, dk rd brn (drape?); 99 cm : Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, a few of wht cc and rd clay pellets up to 1 cm diam, matrix intensely cmted by hard wht dolic cc; 347.02 m: Clay, dk rd brn			
-348	0.98	0	6 cm: Clay, dk rd brn; 33 cm: Clay-pellet Cgl; abund cS matrix, lam, intrabasinal clasts, a few of wht cc,			

			more of rd clay pellets up to 3 cm diam, cmted along lam by hard wht cc and calc dc; 1 cm: Clay rd (drape); 13 cm: Silt, lam, rd, some lam cmted by wht calc dc; 2 cm: Clay rd; 2 cm: Silt, lam, rd, consol, some lam cmted by wht calc dc; 8 cm: Clay, silty, rd; 8 cm: Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, a few of wht calc dc, more of rd clay pellets up to 5 cm diam, cmted by hard wht cc and calc dc; 16 cm: Clay, rd; 1 cm: Silt rd, consol, cmted; 5 cm: Clay-pellet Cgl; abund cS matrix, intrabasinal clasts, a few of wht calc dc and rd clay pellets up to 1 cm diam, cmted by hard wht cc and calc dc; 3 cm: Silt, sandy (vfs), rd, intensely cmted by calc dc,			
-349	1	0	348 m - 02 cm: Cgl, cS matrix, small cc clasts, tiny rd clay clasts, cmted by dolic cc; 06 cm: Silt, rd, small wht flat cc clasts up to 1 cm long, some wht dolic cc cmting around clasts ; 39 cm: Cgl, cs matrix, abund clasts of wht to lt gry cc that fine upwards from max of 5 cm at base to max of 1 cm diam at top, a few dk rd brn clay pellet clasts up to 2-3 cm diam, intense wht cc cmt; 52 cm: Clay, dk rd brn, some small wht cc nods; 62 cm: Silt, rd, many cc nods up to 1.5 cm diam; 69 cm: Clay, dk rd brn with 1 cm-thick rd upper and lower margins; 349 m: Silt, faintly lam, rd, consol, small wht cc nods up to 2 mm from 86-91 cm	Two photos of 39 cm-thick up-ward fining cgl, at 10 and 30 cm		
-350	1	0	349 m - 94 cm: Silt, sl clayey, rd, consol, 1 mm diam wht cc spots scattered to 48 cm and in the lower 8 cm; 95 cm: Clay, rd; 96 cm: Silt, rd, lam; 350 m: Clay, rd;			
-351	1	0	350 m - 05 cm : Cgl, sandy, clasts of wht cc up to 2 cm diam, rd clay clasts, wht calc dc cmt 16 cm: Clay, rd, fragments of sandy cgl and cc clasts up to 3 cm diam; 39 cm: Silt, clayey, lam, rd, consol; 43 cm: Silt, sandy, poorly sorted, speckled by scattered 1-2 mm diam dolic cc spots; 48 cm: Cgl, cs matrix, clasts of wht cc up to 5 mm diam and flat rd clay clasts up to 1 cm diam, dolic cc cmt, intense and wht from 45- 48 cm; 351 m: Silt, rd, consol, lam in top 4 cm.			
-352	1	0	Silt, rd, consol, small wht 1 mm cc spots from 41-44 cm, 2 calc dc nods at 52 cm			
-353	1	0	352 m - 37 cm: Silt, rd, lam, consol, one 1 cm-thick calc dc cmted layer at 22 cm; 52 cm: Cgl, abund ms matrix, small cc clasts, a few up to 1 cm diam at base, v few above this up to 3 mm diam, lam, lam-enhancing wht dolic cc cmt; 58 cm: Silt, lam, rd, consol; 59 cm: Sand, fS, cmted by wht dolic cc; 68 cm: Silt, lam, rd, consol; 353 m: Cgl, clasts and matrix fine upwards, wht cc clasts fine from 1 cm diam near base to v fine at top, large rd clay clasts	Photo of layers of small rd clay clasts at 352.85 m		

			from 91-97 cm, layers of much small rd clay clasts from 83-89 cm, fewer and smaller clay clasts upwards, lam in upper 5 cm, wht dolic cc cmt throughout			
-354	1	0	Silt, rd, consol, no dbg, rare rd clay clasts at 30, 49, 71 and 74 cm, four sl calc dc nods up to 1.5 cm diam from 25-44 cm	Photo rd clay clasts in rd silt		
-355	1	0	354 m - 11 cm: Silt, sandy, fs, rd, consol, irreg wht patches; 22 cm: Silt, rd, consol, irreg wht patches; 24 cm: Silt or fs, cc cmted; 42 cm: Silt, v fgr, rd, consol; 61 cm: Silt, sandy, fs, rd, consol, several long thin flat rd clay clasts lying // to bdg; 76 cm: Silt, rd, consol; 78 cm: Silt, sandy (fs), rd, consol; 79 cm: Sand, cmted by wht calc dc cmt; 355 m: Silt, v fgr, rd, consol;			
-356	1	0	355 m - 23 cm: Silt, v fgr, rd, consol; 94 cm: Cgl, abund cs matrix, a few scattered intrabasinal wht cc clasts up to 8 mm diam and scattered rd clay clasts up to 8 cm long, most flat and bdg //; variable intensity of hard wht calc dc cmt in upper part and dolic cc cmt in lower part, enhancing lam or v thin bdg in places; 97 cm: Sand, fS, rd, well sorted, soft; 356 m: Silt, rd, some small wht cc nods			
-357	1	0	356 m - 94 cm: Sand & silt, v mixed, uneven patches of rd fs-ms sand and rd silt, large (up to 5 cm) and v small (2 mm) rd clay clasts, rare 1 cm diam clasts of cc, consol, irreg wht cc-cmted zones // to bdg; 357 m: Silt, lighter rd			
-358	1	0	357 m - 05 cm: Sand, fS-mS, lt rd, soft; 64 cm: Sand, fS, variably silty, poorly sorted, rd, small clasts up to 3 mm diam of wht cc in lower 20 cm, all cmted by calc dc; 79 cm: Clay, sl silty, rd, some irreg zoned cc nods (blk core, wht rim) up to 1.5 cm diam from 69-76 cm; 88 cm: Sand, mS, a few small clasts of calc dc near base, v uneven cmting by dense wht hard calc dc cmt; 358 m: Sand, fS, variably silty, rd, soft to semi consol, rare small rd clay clasts up to 5 mm diam.			
-359	1	0	358 m - 16 cm: Sand, fS, variably silty, rd, semi consol; 28 cm: Cgl, abund cs matrix, intrabasinal calc dc clasts up to 2.5 cm diam, cmted by calc dc, irreg U and L contacts; 84 cm: Silt, rd, consol, no bdg, two zoned (gry core, wht rim) calc dc nods, one long vertical from 32-42 cm, the other at 42 cm; 97 cm: Silt, clayey, rd, consol, scattered calc dc and dolic cc nods; 359: Clay, rd.			
-360	1	0	359 m - 06 cm: Cgl, cc clasts up to 5 mm diam, unevenly cmted by hard wht dolic cc; 28 cm: Clay, rd, many knobbly, zoned (blk core, wht rim) calc dc and dolic cc nods up to 4 cm diam; 360 m: Silt, rd, lam, consol, scattered calc dc nods in upper 5 cm; 1 cm-thick cgl layer aa at 54 cm, cc nod at 68 cm, cc bdg-// cmting from 73-76 and 83-91 cm.			
-361	1	0	360 m - 22 cm: Cgl, lam, small wht calc dc clasts <1 cm diam, cmted by hard wht dolic cc;			

			26 cm: Silt, sandy (fs), rd, consol; 31 cm: Cgl, lam, small wht calc dc clasts <1 cm diam, cmted by hard wht dolic cc; 32 cm: Silt, sandy (fs), rd, consol; 34 cm: Cgl, lam, small wht calc dc clasts <1 cm diam, cmted by hard wht dolic cc; 38 cm: Silt, sandy (fs), rd, consol; 49 cm: Cgl, lam, small wht calc dc clasts <1 cm diam, cmted by hard wht dolic cc; 361 m: Silt, sl clayey, rd, consol, sl calc dc nods up to 3 cm diam in last 10 cm and one vertical 15 cm long and 2 cm wide			
-362	1	0	361 m - 59 cm: Silt, sl clayey, rd, faintly lam, consol, several knobbly irreg calc dc nods from1-5 cm diam round or elongate // to or perpendicular to bdg, longest vertical nod from 33- 53 cm; 60 cm: Cgl, small wht or dk gry calc dc clasts <1 cm diam, cmted by hard wht calc dc; 362 m: Silt, sl clayey, rd, consol, dense tiny wht speckles from 64-74 cm.			
-363	1	0	362 m - 03 cm: Silt, sl clayey, rd, consol; 40 cm: Silt, sandy (fs-ms), rd, consol, abund knobbly dolic cc nods 1-3 cm diam from 03-18 cm then fewer nods to 38 cm; 84 cm: Silt, rd, consol, a few calc dc nods, one vertical intermittent streak up to 6 mm wide of wht non-reactive silt from 15-64 cm; 363 m: Silt, sandy (fs-ms), rd, consol, tiny wht 1-2 mm cc nods from 89 cm-363 m.	Photo of wht verti-cal streak (bur-row?)		
-364	1	0	363 m - 04 cm: Silt, intensely cmted by hard wht calc dc; 24 cm: Silt, sandy (fs-ms), rd, consol, a few irreg patches cmted by wht cc; 25 cm: Clay, rd; 364 m: ‘Cgl’, abund v sandy (fs) to clayey matrix with many clasts of rd clay up to 3 cm diam and a few clasts of wht or grey cc, patchy cmting by dolic cc which increases in amount downwards	Photo rd clay clasts, rare small wht cc clast in the ‘cgl’		
-365	1	0	364 m - 15 cm: ‘Cgl’, aa, -; 44 cm: Sand, fS, silty, poorly sorted, rd, patchily cmted by cc cmt, one large frag-ment of a wht calc-dc-cmted small-clast cgl at 20 cm; 51 cm: Silt, sl sandy, intensely cmted by nodular cc; 365 m: Silt, sl sandy (vfs), rd, consol, nod-free, a few rd clay clasts in top 5 cm.			
-366	1	0	365 m - 50 cm: Silt, sandy (fs), variable concentrations of sand that increase in amount downwards, rd, semi consol, one long intermittent vertical sl calc dc nod up to 8 mm wide from 05-20 cm; 366 m: Sand, fS, silty, minor ms grains, poorly sorted, rd, soft, rare horizontal sl calc dc nods up to 8 cm long & <1 cm wide.			
-367	1	0	366 m - 29 cm: Sand, aa, fS, silty, minor ms grains, poorly sorted, rd, soft; 42 cm: Sand, fS, unsorted, rd, soft; 367 m: Silt, clayey, rd, consol, faint lam in upper 20 cm, a few irreg-shaped sl calc dc nods 1-5 cm diam, several zoned nods with bkl core, wht rim	Two photos of zoned nods		
-368	1	0	Silt, clayey, rd, consol, a few scattered sl calc dc nods up to 2 cm diam to 55 cm, some zoned, then a few dolic cc nods be-low this, some also zoned			
-369	1	0	368 m - 17 cm: Silt, clayey, rd, consol, one dc nod or clast at 07 cm showing small dk	Three photos		

			nods enclosed in wht dc cmt (photo); 61 cm: Cgl, abund ms-cs sand matrix with small intrabasinal clasts up to 1 cm diam of dolic cc and small clasts up to 1 cm of rd clay, most <5 mm, matrix intensely cmted by dolic cc; 369 m: Sand, fs, silty, and silt, sandy, rd, soft, poorly sorted, small rd clay clasts up to 8 mm diam above 80 cm and increasing in number upwards.			
-370	1	0	369 m - 13 cm: cc; 15 cm: Sand, fs-ms, poorly sorted, rd, soft; 39 cm: silt, sandy, rd, soft, scattered wht calc dc nods up to 1 cm diam, irreg patches of calc dc cmting; 49 cm: Sand, fs-ms, silty, poorly sorted, rd, soft, no nods; 76 cm: Cgl, sandy matrix, intrabasinal subangular to rounded, dk gry to wht sl to v calc dc clasts up to 5 cm at base, fining up to 1.5 cm at top, and rd clay clasts up to 8 cm at base fine upwards to ±1 cm or less, matrix intensely cmted by hard off wht v calc dc or dolic cc; the 8 cm diam rd clay clast at the base of this cgl has wht cgr silty sand attached to it above and below and in cracks in the clast, i.e. this sand was deposited on, between and underneath dry and curled up mud cracks of rd clay (photo); 81 cm: Silt, sandy (fs), rd, soft; 83 cm: cc, dolic, nodular; 84 cm: Sand, fS, silty, dirty wht, poorly sorted, soft, abund tiny 1-2 mm rd clay clasts at top; 370 m: Silt, sandy (vfs), silty, rd, soft.	Photo sand-en-closed rd mud-crack clast		
-371	1	0	**DEEP SUCCESSION FROM 370 TO 400 m OF LAYERS OF FAIRLY TO WELL-SORTED SAND BETWEEN IMPERVIOUS LAYERS: insufficient connectivity to be an aquifer** Sand, vfS, sl silty, fair sorting, accessory mica flakes, rd, semi consol, no nods, sl lighter laminae of coarser sand at 27 & 43 cm; 7 cm-long bt burrow below top lighter layer (photo)	Photo bt burrow filled with lighter rd sand		Photo bt burrow filled with lighter rd sand
-371.95	0.95	0	371 m -371.07 m: Sand, vfS, sl silty, fair sorting, accessory mica flakes, rd, semi consol, no nods; 19 cm: Clay, rd, encloses 8 cm long clast of nodular polycyclical v calc pedogenic dc; 47 cm: Silt, sl sandy (vfs), rd, semi consol, no nods, at top of this silt have 3 irregularly shaped clasts of nodular polycyclical v calc pedogenic dc (photo); 55 cm: Cgl, abund cs matrix, clasts of rd clay up to 3 mm diam, intensely cmted // to bdg by hard wht cc; 95 cm: Silt, cgr, rd, semi consol	Photo of 4 clasts of pedo-genic dc, 3 at top of silt, 1 in overly-ing clay		
-373	1.05	0	371.95 m -372.89 m: Sand, fS-vfS, sl silty, fair sorting, rd, soft, one bt burrow ±8 mm wide filled with wht well sorted f-m sand from 42-73 cm, 4 horizontally elongate dolic cc nods; 373 m: Sand, cs(?), rare small rd clay clasts, intensely cmted by hard wht cc			One bt burrow ±8 mm wide filled with wht well sorted f-m sand from 42-73 cm
-374	1	0	373 m -38 cm: Sand, fS-mS, some cgr grains, fair sorting, rd, consol, cmted by numerous nodule-like concentrations of v calc dc; 47 cm: Sand, fS-ms but finer than above, rd, soft, no nods; 66 cm: Sand, mS-cS, intensely cmted // to			

			bdg by hard wht cc; 72 cm: Sand, fS-vfs, rd, fair sorting, soft, no nods, a few small rd clay clasts; 82 cm: Sand, fS-mS, fair sorting, rd, soft, bdg-// cmting by hard wht dolic cc in coarser grained basal 4 cm; 374 m: Sand, fS-vfs, tr silt, fair sorting, rd, soft			
-375	1	0	15 cm: Sand, aa, fS-vfs, tr silt, fair sorting, rd, soft; 25 cm: Clay, sl silty, rd; 58 cm: Clay, sl silty, more silty in lower 10 cm, sl browner, a few tiny blk spots, some calc dc nods near top and bottom of which some are zoned (blk core/wht rim); 375 m: Silt, clayey, rd, consol, scattered calc dc nods from 67 cm (<1 cm) to 86 cm (up to 1.5 cm), some wht cc nods up to 1 cm below 86 cm			
-376	1	0	375 m -28 cm: Silt, clayey, rd, consol, uneven distribution of cc nods; 65 cm: Sand, fS, silt, ms, minor cs fraction, unsorted, rd, soft-semi consol, rare small dc nods, small rd clay clasts in basal 2 cm; 86 cm: Sand, fS, silty to clayey, poorly sorted, rd, many rd clay clasts up to 2 cm diam, numerous irreg-shaped calc dc nods up to 3 cm diam; 376 m: Cgl, intrabasinal wht cc and rd clay clasts up to 1 cm diam, matix sand intensely cmted by hard wht cc			
-377.03	1.03	0	376 -01 cm: Sand, mS-cS, rd, soft; 14 cm: Sand-Cgl, mS-cS, a few rd silt & rd clay clasts up to 1 cm diam, intensely cmted by hard wht cc; 377.03: Sand, fS-mS, fair sorting, rd, soft, no nods			
-377.97	0.94	0.05	5 cm: Clay, brn rd; 11 cm: Clay, rd, sl silty; 4 cm: Clay, brn rd; 2 cm: Clay, rd; 11 cm: Silt, v clayey, rd, faintly lam, consol; 10 cm: Silt, sandy (fs); 8 cm: Sand, mS-fS, well sorted, rd, soft, rare small rd clay clasts; 5 cm: Sand, aa, mS-fS, well sorted, rd, rd clay clasts, sl unevenly cmted by hard wht dolic cc; 22 cm: Sand, fS-mS, well sorted, rd, soft, rare small rd clay clasts, no nods; 7 cm: Sand, fS-mS, intensely cmted by hard wht dolic cc 10 cm: Sand, fS-mS, well sorted, rd, soft, rare small rd clay clasts, dislodged fragment of hard wht cc cmted fs-ms sand; 5 cm: core loss			
-378.95	0.98	0	10 cm: Sand, fS-mS, silty, poorly sorted, rd, semi consol, small rd clay clasts at base; 8 cm: Sand, fS-mS, silty, poorly sorted, rd, semi consol, more small rd clay clasts, one 1 cm-thick discontinuous layer of hard wht sl calc dc cmt; 8 cm: Sand-Cgl, mS-cS, rd clay clasts, intense hard wht dolic cc cmt; 5 cm: Sand, fS-mS, well sorted, rd, soft; 15 cm: Sand, mS-cS, rd, many rd clay clasts, soft-semi consol; 7 cm : Sand, mS-cS, rd, many rd clay clasts, intensely cmted by hard wht dc in top part and v calc dc in lower part; 2 cm: Clay, rd; 20 cm: Sand, fS, well sorted, rd, consol, no nods or cmt; 23 cm: Cgl, matrix mS-cS, intrabasinal clasts			

			of gry dolic cc up to 2 cm diam and a few small rd clay clasts <5 mm diam, matrix intensely and massively cmted by hard wht dolic cc			
-380.08	1.08	0	50 cm: Sand, fS, some ms grains, well sorted, sl lighter rd, local v thin whitish or redder bdg, soft; 58 cm: Sand, fS-vfS, some ms grains, rd, fair sorting, soft, rare sl calc dc nods up to 3 cm diam			
-381	0.92	0	51 cm: Sand, aa, fS-vfS, some ms grains, rd, fair sorting, soft, rare sl calc dc nods up to 3 cm diam to 45 cm; 41 cm: Sand, fs-vfS, rd, fair sorting, soft, rare circular bt channels filled with wht fS from 53-86 cm, sand bleached lighter rd around some of these channels			Bt circular channels filled with wht fS from 53-86 cm, sand bleached lighter rd around some of these channels
-382	1	0	381 m -05 cm: Sand, fs-vfS, rd, fair sorting, soft; 19 cm: Silt, clayey, rd, patchy wht cc cmting, 1 cm-thick layer of off wht fgr sand at 16 cm; 24 cm; Clay, rd, some sand-filled bt channels; 382 m: Sand, clayey, silty, unsorted, rd, consol, some sand-filled bt channels to 61 cm, scattered cc nods up to 3 cm diam from 54-91 cm			Sand-filled bt channels in clay and silt from 19-61 cm
-383.07	1.07	0	Sand, variable from f-vf silty sand to vf-f sand, variable sorting, rd, semi consol but soft from 50-59 cm, some cc nods up to 4 cm diam to 11 cm, cc cmted layer containing wht cc nods from 12-16 cm, rare nods below this			
-384	0.87	0.06	2 cm: Sand, vfS-fS, rd, semi consol; 16 cm: Sand, fS-mS, most grains highly spherical and frosted, fair sorting, abund hard wht nods of cc often coalesced; 69 cm: Cgl-sand, fS-mS as matix, numerous intrabasinal clasts of wht & gry cc up to 1 cm diam and rd clay up to 3 cm long, variable intensity of wht hard cc cmting emphasising bdg in places 6 cm core loss at end			
-385	1	0	384 m -25 cm: Cgl-sand, aa, fS-mS as matix, numerous intrabasinal clasts of wht & gry cc up to 1 cm diam and rd clay up to 3 cm long, variable intensity of wht hard cc cmting emphasising bdg in places; 29 cm: Clay, rd; 89 cm: Sand, fS-mS, silty, poorly sorted, sl clayey in upper 5 cm, most grains highly spherical and frosted, rd, soft, a few rd clay clasts, small irreg-shaped patches up to 3 cm across of whitish sand; 385 m: Cgl, fS-mS matrix, wht cc & rd clay clasts, cmted by hard wht cc			
-386	1	0	385 m -19 cm: Cgl, aa, mS-cS matrix, wht cc & rd clay clasts, cmted by hard wht cc; 21 cm: Sand, mS-cS, well sorted, most grains highly spherical and frosted, rd, soft; 30 cm: Cgl, aa, mS-cS matrix, wht cc & rd clay clasts, cmted by hard wht calc dc; 36 cm: Sand, mS-cS, well sorted, most grains highly spherical and frosted, rd, soft; 43 cm: Cgl, aa, mS-cS matrix, wht cc & rd clay clasts, cmted by hard wht calc dc; 53 cm: Sand, fS-mS, clayey, silty, unsorted, rd, soft; 62 cm: Sand, fS, rd, many rd clay clasts in lower half, many irreg patches of off wht			

			mgr sand from 59-62 cm, soft; 89 cm: Cgl, mS-cS matrix, small wht cc clasts up to 1 cm diam, intensely cmted by hard wht calc dc; 386 m: Sand, mS-cS, well sorted, most grains highly spherical and frosted, rd, soft;			
-387	0.89	0.11	Sand, mS-cS, sl clayey to 31 cm, fair to good sorting, rd, rd clay clasts to 31 cm, soft but cmted along bdg by hard wht sl calc dc from 00 05 cm, at 22 cm (only partly), from 31-34, 38-45, 46-58, 62-78 and 81-89 cm; 11 cm core loss to 387 m			
-388	1	0	387 m -16 cm: Sand, vfS-mS, sl silty, un-sorted, lighter rd, cmted by hard wht sl dol-ic cc that is concentrated along and em-pahsises alternating 1 cm-thick beds; 19 cm: Sand, vfS-mS, sl silty, unsorted, rd, consol; 23 cm: Sand, fS-mS, clayey, unsorted, rd, consol; 31 cm: Silt, v clayey, rd, 4 irreg clasts of nodular polyphase calc dc up to 8 cm long; 388 m: Silt, sl sandy, sl clayey, semi consol, hard with no obvious cmt from 48-58 cm			
-389	1	0	388 m -65 cm: Sand, variable from fs-ms, rare cgr grains, fair sorting, rd, soft, no nods, no bdg; 389 m: Sand, sl finer grained, sl harder, rd, no nods, no bdg			
-390	0.82	0.18	389 m -06 cm: Sand, fS-mS, some cgr grains, fair sorting, rd, soft; 21 cm: Cgl, rd ms matrix, a few small up to 1 cm diam clasts of wht and grey sl calc dc and rd clay, variably intensely cmted along and empahsising bdg by hard wht calc dc; 66 cm: Sand, varying zones of poorly sorted vfs-ms sand and fairly well sorted fs-ms sand, numerous cs grains throughout, rd, soft; 72 cm: Cgl, sandy, extrabasinal clasts of hard rd fgr quartzite and green weathered basalt(?) up to 5 cm long, massively cmted by hard wht calc dc; 82 cm: Sand, fs-cs, fair sorting, rd, bdg-// cmting by calc dc; 390 m: core loss	Photo Extra-basinal clasts		
-391	0.69	0.31	390 m -31 cm: core loss; 59 cm: Sand, fs-ms, variable amounts of cgr grains, fair sorting, rd, soft, rd clay clasts at 35, 37 cm; 61 cm: Cgl, sandy, small intrabasinal clasts of wht dc <1 cm diam, hard wht v calc dc cmt; 391 m: Sand, fs-ms, variable amounts of cgr grains, fair sorting, rd, soft, rd clay clast at 70 cm, fgr gry quartzite peb 1.5 cm in diam at 81 cm;			
-392	1	0	391 m -14 cm: Sand, fs-ms, many cgr grains, rd, soft; layers cmted by hard wht sl calc to calc dc from 391 m to 391.05 m; 20 cm: Sand, ms-cs, rd, soft; bdg-// layers cmted by hard wht sl calc to calc dc from 16- 18 cm; 32 cm: Sand, fs-ms, many cgr grains, rd, soft; layers cmted by hard wht sl calc to calc dc from 20-23, 26-32 cm; 392 m: Sand, fs-ms, scattered cgr grains, varying proportions of mgr grains, fair sorting, rd, soft;			
-393	1	0	392 m -06 cm: Sand, fs-ms, scattered cgr grains, fair sorting, rd, soft;			

			393 m: Sand, variable fs-ms sand and ms-cs sand, rd, soft; intermittent to continuous bdg-// layers of hard wht calc dc cmting at 09 cm, from 16-21, 22-24, 27-30, 37-47, 51-53 and 57-60 cm, loose calc dc nods up to 5 mm diam in soft sand from 33-36 cm;			
-394	1	0	393 m -14 cm: Sand, fs-cs, variably intense bdg-// cmt of hard wht cc; 20 cm: Sand, fS, well sorted, rd, soft; 35 cm: Clay, rd; 394 m: Cgl, fs-ms clayey sand matrix, many dk rd clay clasts, variably intensely cmted // to bdg by hard wht cc			
-395	1	0	394 m -03 cm: Cgl, aa, fs-ms clayey sand matrix, many dk rd clay clasts, intensely cmted by hard wht cc; 15 cm: Clay, dk rd; 28 cm: cc, sl dolic, dense, hard wht; 35 cm: Sand, mS-cs, well sorted, rd, soft; 36 cm: Sand, cmted by hard wht dc; 395 m: Silt, v fgr, clayey, rd, soft, a few small wht sl calc dc nods from 90 cm-395 m, 3 v dk gry silcrete nods up to 1.5 cm diam from 87-91 cm			
-396	0.95	0.05	395 m -29 cm: Silt, v sandy, rd, soft, a grn-gry 1.5 cm diam silcrete nod at 18 cm; 66 cm: Sand, fs-vfs, silty, unsorted, consol, sl lighter rd, patces of gry-rd colour; 84 cm: Sand, fs, silty, clayey, rd clay clasts at base, rd, semi consol; 90 cm: Sand, sl coarser than above, rd, soft to semi consol, irreg bdg-// cmting by hard wht calc dc; 95 cm: cc, massive; 396 m: core loss			
-397	1	0	396 m -31 cm: Sand, fs-ms, some cgr grains, silty, clayey, rd, consol to semi consol, soft near base, scattered wht cc nods and lt gry calc dc nods; 42 cm: Silt, sandy (f-mgr), v clayey, rd, semi consol; 397 m: Silt, sandy (f-mgr), v clayey, rd, consol, a few scattered cc nods from 1 mm to 2 cm diam, one long vertical calc dc nod from 36-52 cm that widens from 1 cm at base to 3 cm at top			
-398	1	0	397 m -08 cm: Cgl, rd silt matrix, rd clay clasts up to 1 cm diam at base and sl dolic cc clasts, cmted by hard wht cc; 33 cm: Silt, sl sandy, rd, consol; 70 cm: Cgl, abund sl to v calc dc clasts up to 6 cm long in a "matrix" of abund dk rd clay clasts; 72 cm: Clay, rd; 398 m: Sand, fs, variable ms fraction, rd, consol to 91 cm, sl coarser and semi consol below this			
-399	0.68	0.32	Sand, fs, variable proportions of mgr grains, sl silty, fair sorting, rd, soft, intermittent to continuous bdg-// cmting by hard wht cc from 09-13, 17-20, 29-34 & 40-41 cm then by calc dc from 43-45, 50-51 & 57-59 cm; Core loss of 32 cm at end of core			
-400	1	0	Sand, fs-ms, well sorted, rd, soft, no nods, no bdg.			
			End Of Hole at 400 m			