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FIFTH INTERNATIONAL ARCHEAN SYMPOSIUM: HANDBOOK FOR ARCHEAN DRILLCORE AT THE GSWA CORE LIBRARY

compiled by

MJ VAN KRANENDONK

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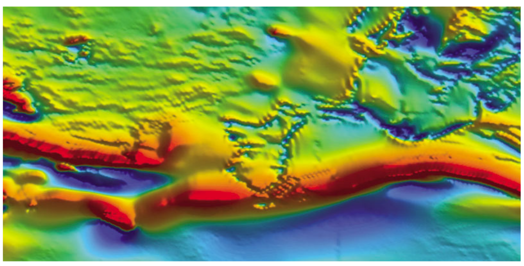


Geological Survey of Western Australia

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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Perth 2010

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Introduction

This handbook provides information regarding parts of six diamond drillcores laid out for view as part of the Fifth International Archean Symposium. The drillcores are all from the permanent collection stored in the core archive facilities of the Geological Survey of Western Australia at Perth and Kalgoorlie.

Table 1: Drillcores on view, listed from oldest to youngest.

Name	*Age (Ma)*	*Depth*	*Location (MGA)*	*Tectonic unit*	*Group*	*Formation*
PDP2b	3480	84–109.6 m	50K, 752249E 7656267N	Pilbara Craton	Warrawoona	Dresser Fm.
ABDP1	3470	0–264 m	50K, 783129E 7652790N	Pilbara Craton	Warrawoona	Duffer Fm.
ABDP6	2775	10–300 m	50K, 592706E 7689733N	Fortescue Basin	Fortescue	Mount Roe Basalt
PDP1	2720	0–104 m	51K, 231277E 7641811N	Fortescue Basin	Fortescue	Tumbiana Fm.
AMMD021	2710	50–135 m	51J, 303349E 6851170N	Yilgarn Craton		'Kambalda komatiite'
Witt47A	2495–2463	568–659 ft	50K, 627020E 7529707N	Hamersley Basin	Hamersley	Brockman Iron Fm. (Joffre Mbr)

PDP2b: Stromatolitic chert of the Dresser Formation, Pilbara Craton

The PDP2b drillcore transects the lower stromatolitic chert of the 3.48 Ga Dresser Formation in the North Pole Dome of the Pilbara Craton. It was drilled to explore for convincing signs of early life and to identify in fresh material from below the effects of surficial weathering, the protoliths of stromatolitic cherts and wrinkly laminated black and red-weathering material interpreted as microbial mats (Fig. 1).

Figure 1: *Outcrop view of wrinkly laminated microbial mat and domical stromatolites of the Dresser Formation.*

A detailed log of the core is presented in Figure 2. Highlights include:

- Bedded micritic carbonate and jaspilitic chert at 84.0 m depth (Figs 3, 4)
- Pyrite-replaced stromatolites at 85.65 m and 88.5 m depths (Figs 5, 6)
- Green carbonate, barite-containing sandstone, and secondary barite crystals at 87.2 m depth (Fig. 7)
- Downward-radiating barite crystal splays at 88.3 m depth.

The geology and detailed relationships between depositional and replacive hydrothermal components of the drillcore is described within the regional context by Van Kranendonk et al. (2008). Philippot et al. (2007) described detailed S-isotopic studies of pyrite and barite from the core, highlighting a microbial role in precipitation of microscopic pyrite in barite growth zones. Tessalina et al. (2010) obtained an Sm-Nd isochron of 3.49 ± 0.10 Ga and an ε_{Nd} value of −3.3 ± 1.0 for the rocks at this site, which was used to infer contamination by a Hadean basaltic protocrust.

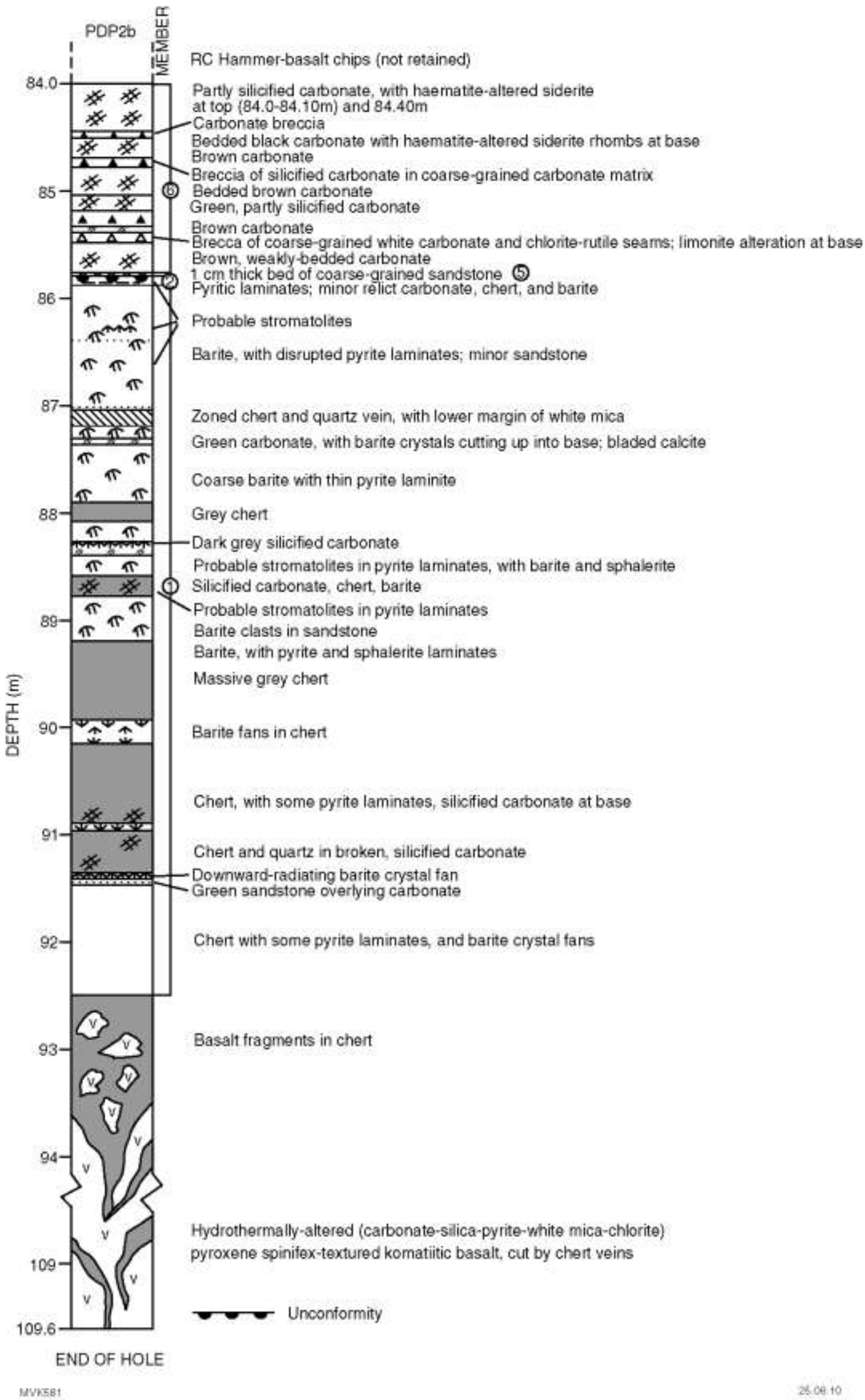

Figure 2: *Stratigraphic log of drillhole PDP2b (from Van Kranendonk et al., 2008)*

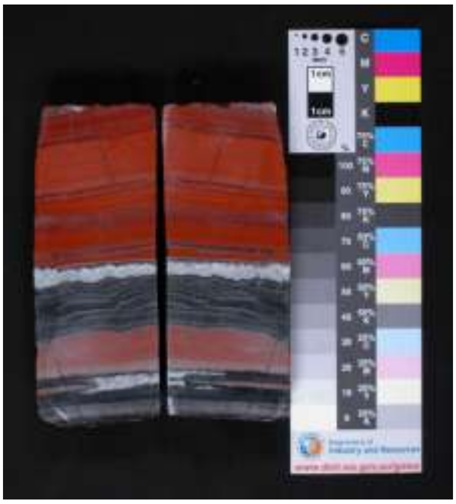

Figure 3: *Bedded jaspilitic chert and micritic carbonate, from the top of PDP2b.*

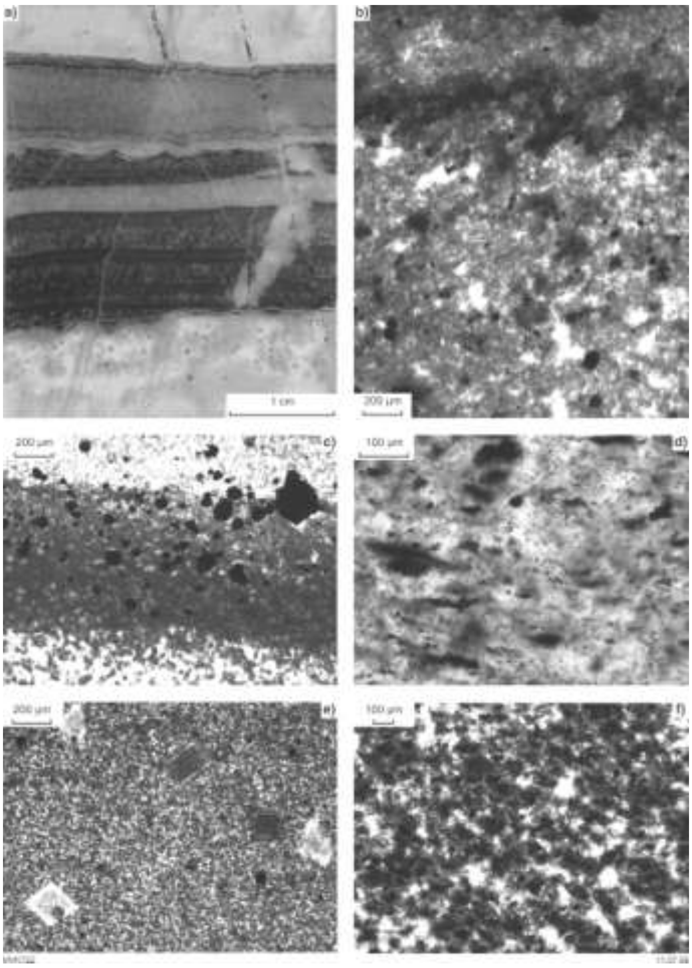

Figure 4: *Thin section features of bedded carbonate rocks of member 6: a) Whole thin section view of bedded micritic carbonate, showing fine-scale bedding defined by variations in texture and thin seams of dark matter along stylolitic bedding contacts. Note the four types of cross-cutting veins: 1) coarse carbonate veins parallel to bedding, 2) silica veins with euhedral carbonate rhombs that have jaspilitic cores, 3) quartz-chlorite-pyrite veins, 4) quartz veins (92.5 m in PDP2c); b) plane polarised light thin section closeup of a), showing stylolitic bedding plane between carbonate beds with different textures; c) plane polarised light thin section view of bedded carbonate quite thoroughly replaced by diagenetic pyrite (92.7 m in PDP2c); d) plane polarised light thin section view of irregular clots of carbonaceous material in bedded carbonate (93.5 m in PDP2c); e) cross polarised light thin section view of silicified carbonate, with diagenetic dolomite rhombs and pyrite crystals (92.7 m in PDP2c); f) plane polarised light thin section view of partly silicified carbonate, showing recrystallization texture of packed, zoned subhedral carbonate rhombs (sparry carbonate) that have dark cores and light rims.*

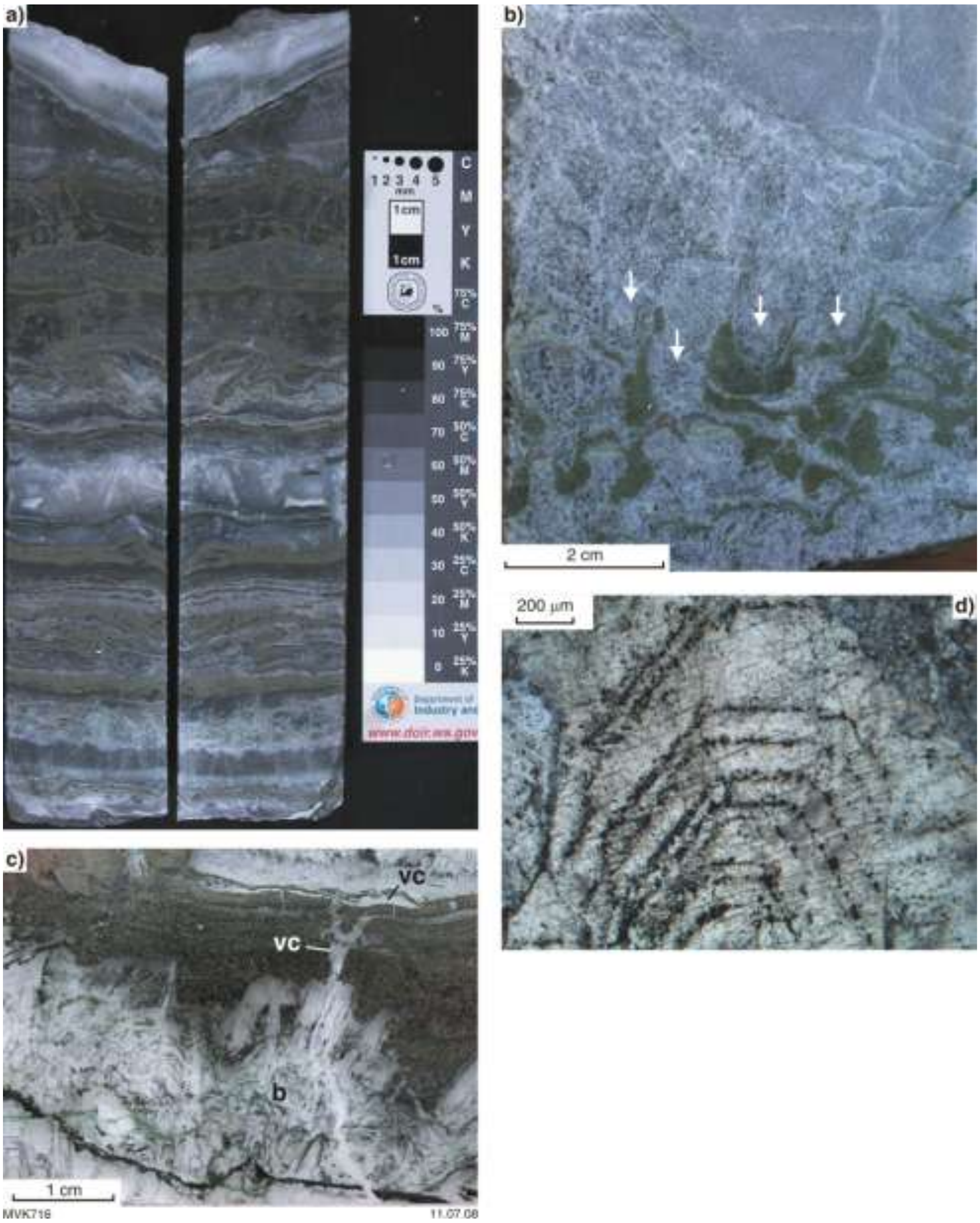

Figure 5: *Features of pyritic laminates and barite from member 1 in drillcore: a) section of core (88.4–88.6 m in PDP2b), showing the repeated, alternating nature of barite crystals and pyrite laminates in member 1 and soft sediment deformation of pyrite laminates. Note the variety of styles of the pyritic laminates, including flat laminates on carbonate at base, irregular laminates partway up, laminates with stromatolitic forms near the top, and flat laminates at the top; b) section of drillcore showing upward-radiating and downward-radiating sets of barite crystals intrusive into pyritic laminates (from 88.9 m depth in PDP2b); c) plane light, whole thin section view of carbonate and pyrite laminates cut by barite crystals: note the progressive excision of layering by lower barite from right to left, the well-developed pyritic growth zones in lower barite (b), and thin, subhorizontal layers of chert-barite in pyritic laminates that are fed by a crosscutting silica vein (vc); d) pyrite growth zones in barite crystal (88.4 m depth in PDP2b) (from Van Kranendonk et al., 2008).*

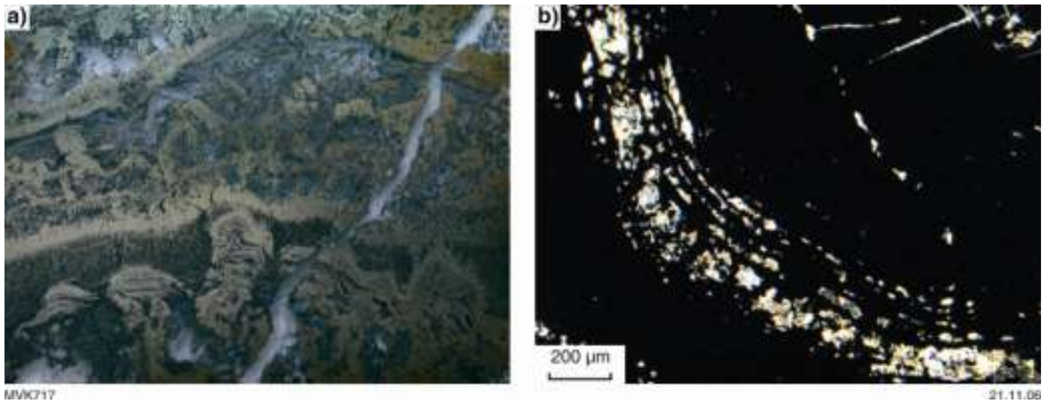

Figure 6: *a) whole thin section view of pyrite-replaced columnar stromatolites (88.7 m in PDP2b) (width of view ~5 cm); b) cross-polarised thin section views of relict carbonate in replacive pyritic laminates (from 95.35 m in PDP2c): note the thin, crosscutting veins of pyrite across the carbonate, indicating pyrite replacement of carbonate rather than carbonate replacement of pyrite (from Van Kranendonk et al., 2008)*

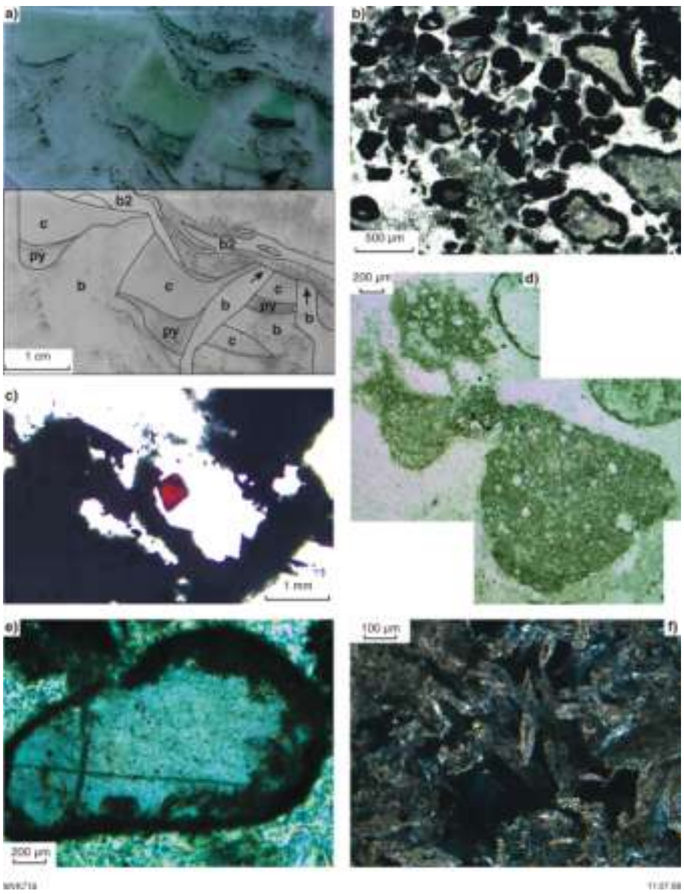

***Figure** 7: a) whole thin section view, and interpreted line drawing, of bedded carbonate (c) that has been replaced by pyrite (py) and cut by barite crystals (b), with local sphalerite rims (s), prior to deposition of overlying sandstone (dotted pattern). Note the bedding-subparallel veins of barite (b2) in the overlying sandstone (96.6 m in PDP2c, as shown in Figure 7c) and also the eroded barite crystal tops that cut the pyrite-replaced carbonate (heavy arrows in line drawing); b) plane polarised thin section view of the sandstone from the top of Figure 9a), showing carbonate-replaced sand grains rimmed by pyrite; c) plane polarised thin section view of the sandstone from the top of Figure 9a), showing euhedral detrital hematite crystal surrounded by replacement pyrite; d) plane polarised thin section view of intermediate volcanic clast in sandstone from 88.8 m in PDP2b; e) plane polarised thin section view of carbonate-altered barite clast in sandstone from 88.8 m in PDP2b; f) cross-polarised thin section view of bladed carbonate texture in chert from 87.3 m depth in PDP2b (from Van Kranendonk et al., 2008)*

ABDP1: Felsic volcaniclastic rocks and jaspilitic chert of the 3.47 Ga Duffer Formation, Pilbara Craton

The ABDP1 drillcore was drilled through the Marble Bar Chert Member of the c. 3.47 Ga Duffer Formation, in order to see whether the jaspilitic chert that is so prominent at the surface (Fig. 8) was preserved at depths below the effects of recent surficial weathering and if so, whether or not the Archean atmosphere may have been at least partly oxidized (Hoashi et al., 2009). The core was drilled from the stratigraphic base upwards, on account of the bedding being overturned at this locality.

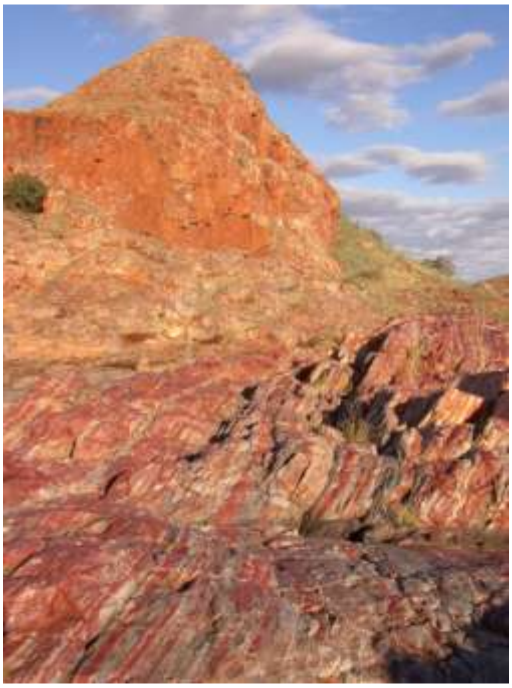

Figure 8: *Sunset view of 'The Marble Bar'.*

Highlights of the core (Fig. 9) include well-preserved felsic volcaniclastics of the Duffer Formation (11–78 m depth), komatiitic basalt with fine pyroxene spinifex texture (90–109 m), jaspilitic chert (142–188 m) and the voluminous hydrothermal chert breccias the cut through the succession. Notice also that Hylogger analysis of the core indicates extensive kaolinite alteration, and one zone of pyrophyllite (Fig. 10).

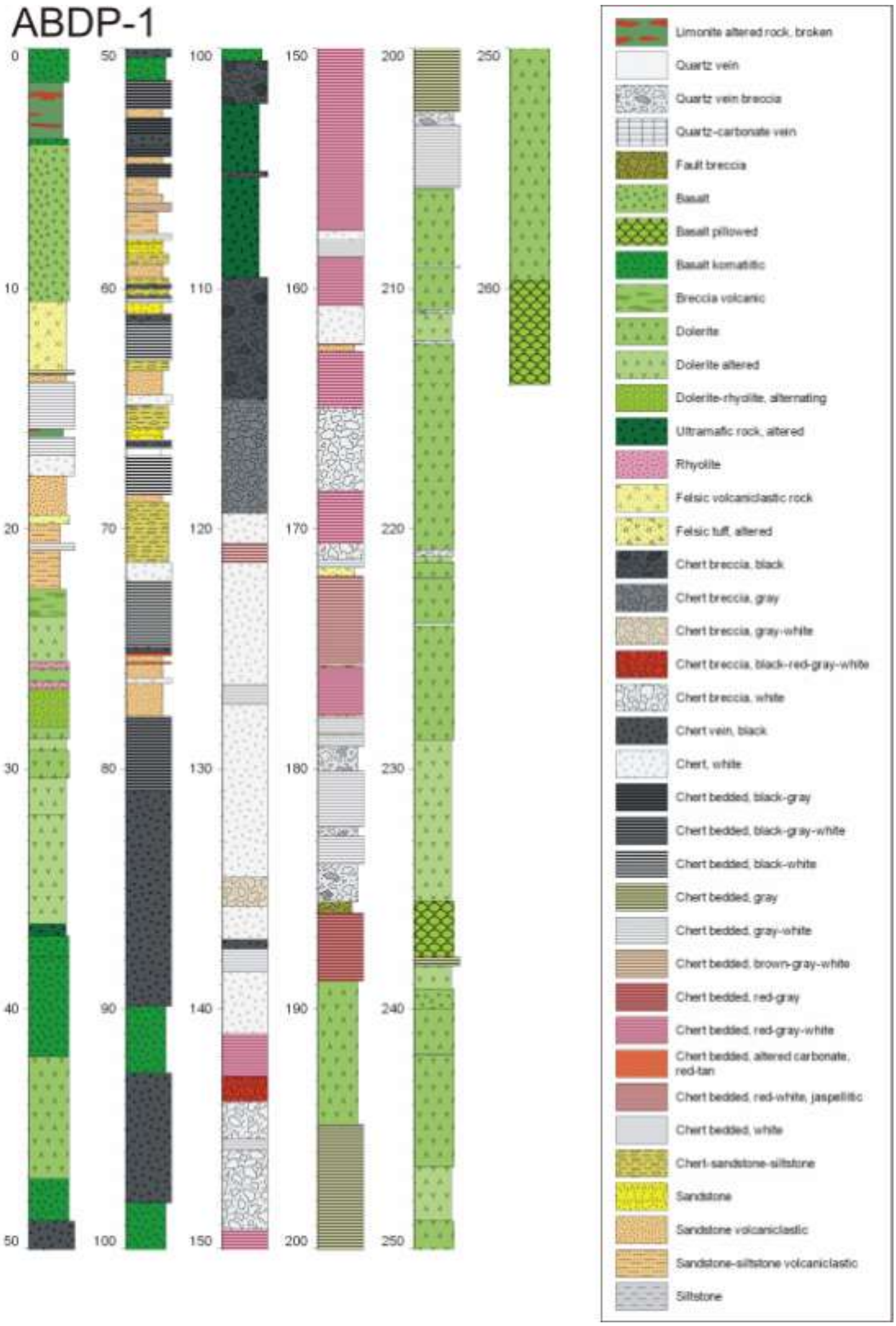

Figure 9: *Core log of the ABDP1 drillcore (by MJ Van Kranendonk and A Lepland)*

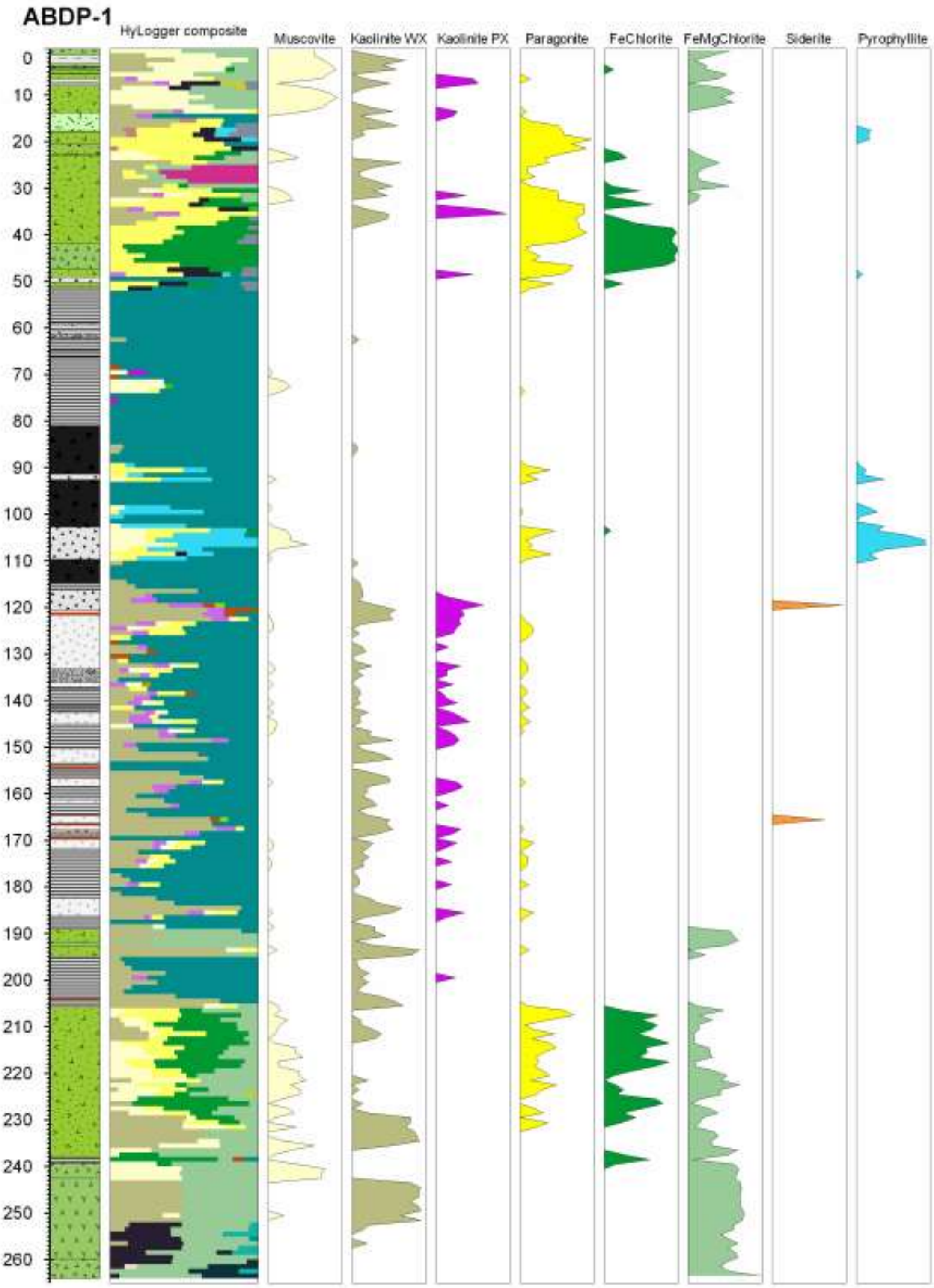

Figure 10: *Hylogger results of the ABDP1 drillcore (analysis by L Hancock, plot constructed by A Lepland)*

ABDP6: A c. 2.78 Ga 'paleosol' in the Mount Roe Basalt, Fortescue Group

ABDP6 drillcore (Fig. 11) was drilled through the upper of two prominent horizons of highly altered basalt within an outlier of the c. 2775 Ma Mount Roe Basalt, at the base of the Fortescue Group, near Whim Creek. These horizons have been interpreted to represent Archean paleosols, formed under a reducing Archean atmosphere (Macfarlane et al., 1994; Rye et al., 1995; Yang et al., 2002).

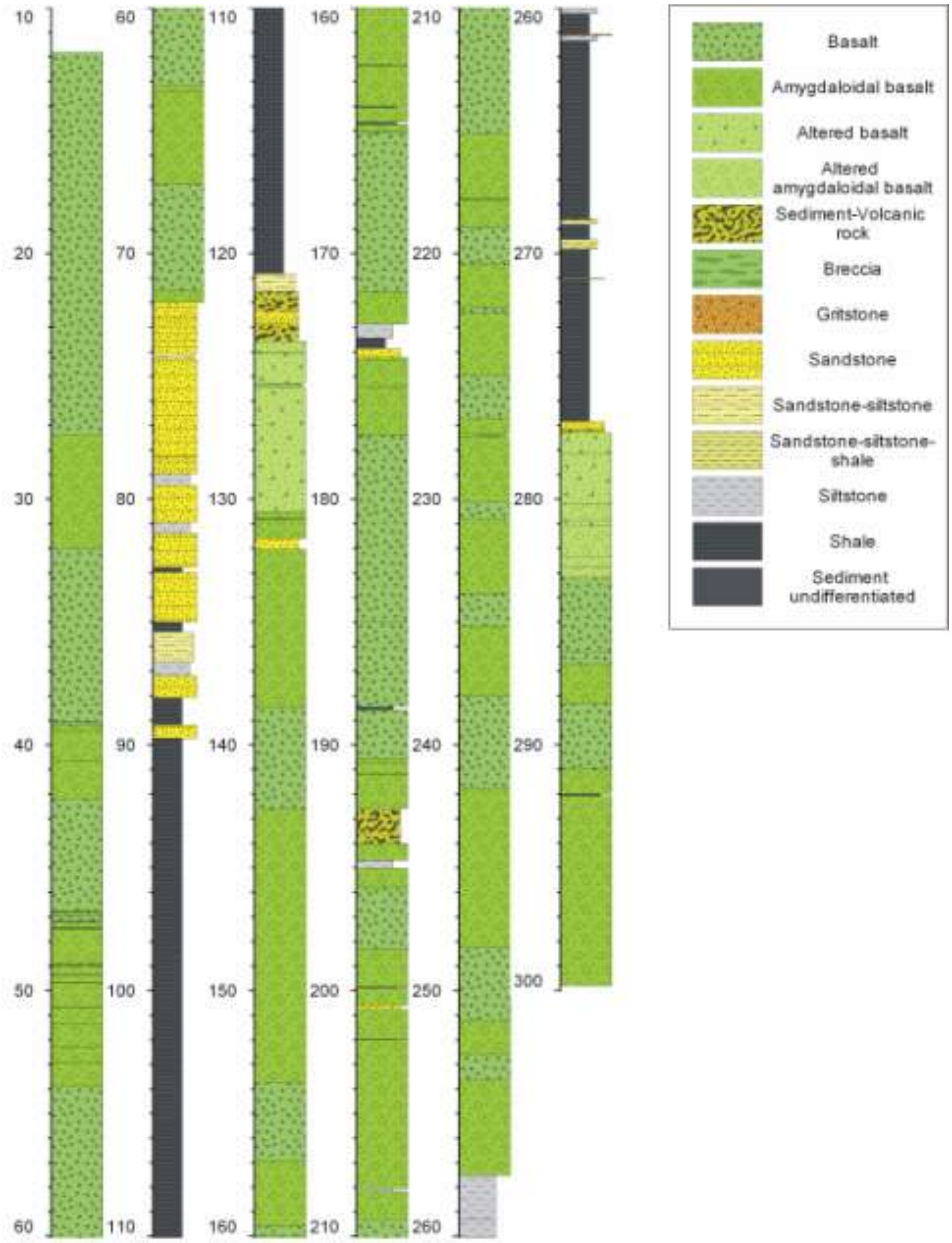

Figure 11: *Core log of the ABDP6 drillcore (by MJ Van Kranendonk and A Lepland)*

Well-preserved textures in the core include amygdaloidal basalt (143 m), bedded felsic volcaniclastic sandstone (82 m), and sandstone with detrital pyrrhotite (261 m). But the highlight of the core is the relationship between highly sericite-altered basalt and adjacent sedimentary rocks at between 121–124 m and 255–285 m depth. In particular, pieces of highly altered basalt of the underlying flow occur as irregular-shaped clasts with ragged flame-textured apophyses in shale (Fig. 12a). And in the top of the highly altered basalt below the shale, amygdales and fractures are filled by what appears to be remobilised, silicified shale (Fig. 12b). Most significantly, however, the alteration previously identified as being characteristic of a paleosol in the underlying basalt is also developed at the base of the overlying basalt, with a symmetrical distribution of alteration mineralogy developed away from the basalt-sediment contact both above and below (Fig. 13).

These are neither the textures nor relationships expected for a paleosol. Rather, it appears as if both the overlying and underlying basalts have been affected by hydrothermal alteration, with fluids sourced from the intervening sedimentary rocks, after deposition. A more complicated interpretation is that at least some of what have been interpreted as flows actually represent very shallow hybrid flow-sills, similar to those recently described from the continental margin off Norway (Miles and Cartwright, 2010), with peperite contacts against pre-existing shale. Indeed, this is consistent with observations of soft sediment deformation and dewatering structures along the ‘paleosol’-sediment contact (Macfarlane et al., 1994).

Figure 12. *Examples of basalt-sediment relationships in ABDP6: a) Highly altered basalt clast in shale, with ragged-textured margins; b) Fractured, highly altered basalt infilled with remobilised shale.*

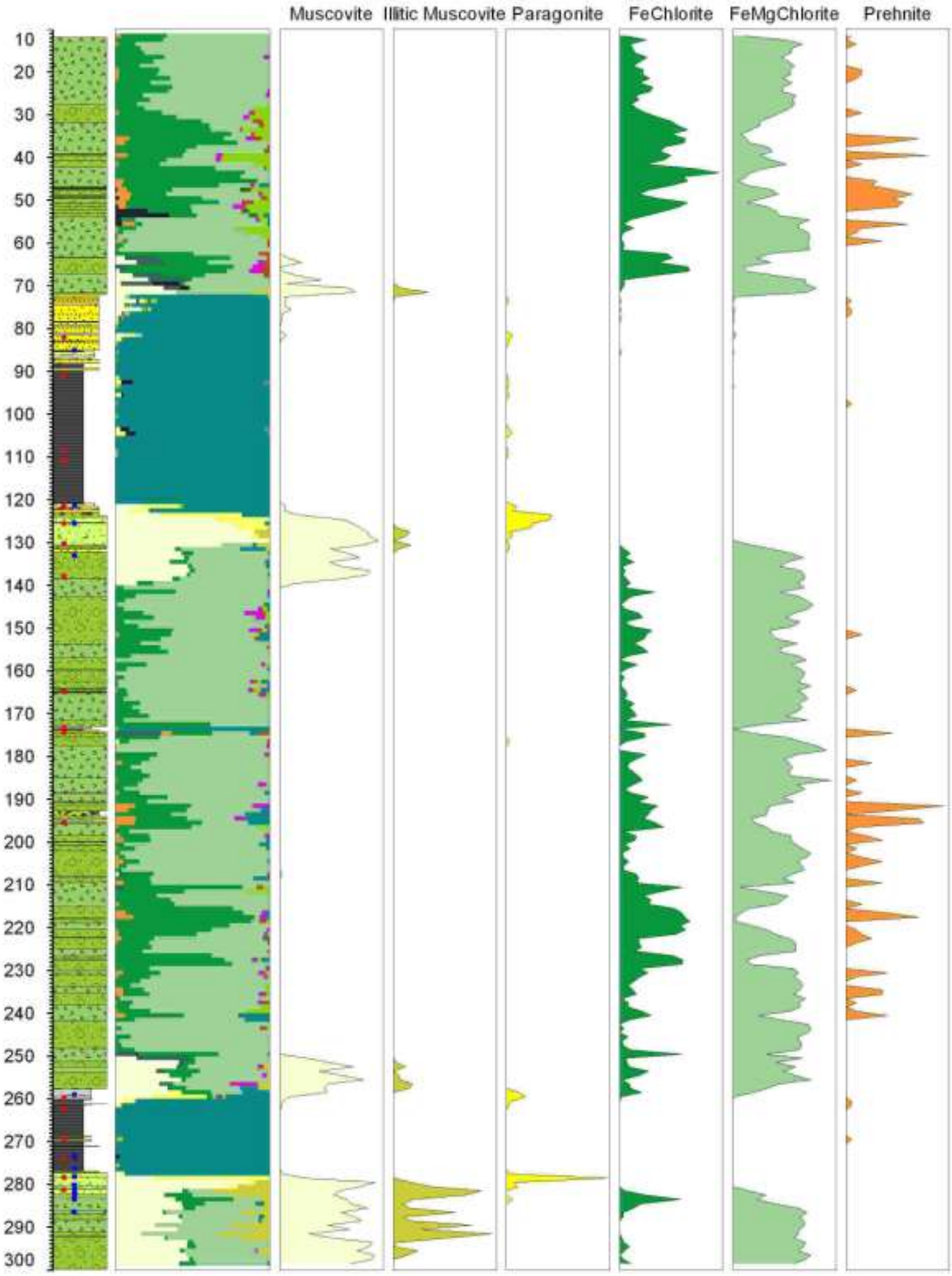

Figure 13: *Hylogger plot of ABDP6 drillcore (analysis by L Hancock, plot by A Lepland)*

PDP1: Stromatolitic carbonate of the 2.72 Ga Tumbiana Formation, Fortescue Group

The PDP1 drillcore was drilled through the c. 2.72 Ga Tumbiana Formation in order to obtain fresh material from below the effects of surficial weathering and investigate whether definitive signs of early life were preserved in these rocks. Tumbiana stromatolites were found to contain abundant microstructural evidence of microbial activity, as well as calcite-infilled open pore space structures that closely resemble gas-filled pockets resulting from bacterial decay (fenestral fabric). At the nanoscale, even more convincing evidence of microbial activity was uncovered in the form of organic globule clusters and aragonite nanocrystals within thin layers of the stromatolites, a combination that is remarkably similar to the organo-mineral building blocks of modern stromatolites (Lepot et al., 2008). Detailed analysis of organic matter in Tumbiana drillcore indicate the presence of both organic sulfur-rich material, as encapsulated microbial cells, as well as sulfur-poor material interpreted to represent fossil extracellular polymer substances, or recondensed kerogen (Lepot et al., 2009). The presence of sulphate-reducing bacteria has been inferred from these data.

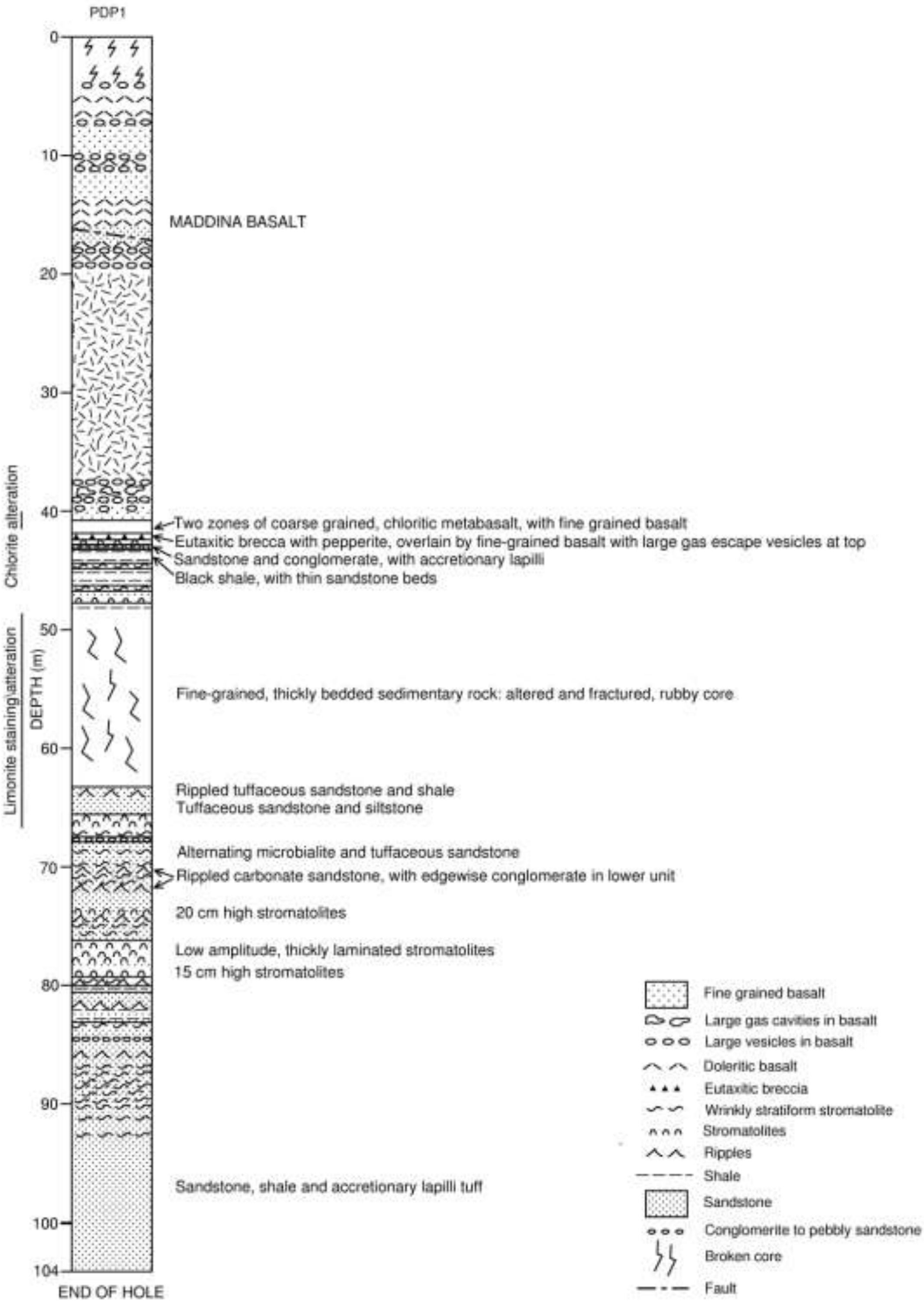

Figure 14: *Core log for the PDP1 drillcore*

AMMD021: Olivine spinifex-textured komatiite at Mount Clifford

Drillcore AMMD021, from Australian Mines Ltd's Marriott's Project, intersects a thick unit of mineralized (Ni-sulphides) serpentinized peridotite within the Mount Clifford area of the Kalgoorlie Terrane, Eastern Goldfields Superterrane, Yilgarn Craton. Regional geochronological considerations suggest that this unit probably forms part of the c. 2705 ± 5 Ma 'Kambalda Komatiite' (Kositicin et al., 2008), although a variety of types and compositions of ultramafic units have been defined, including thick sills (Fiorentini et al., 2010).

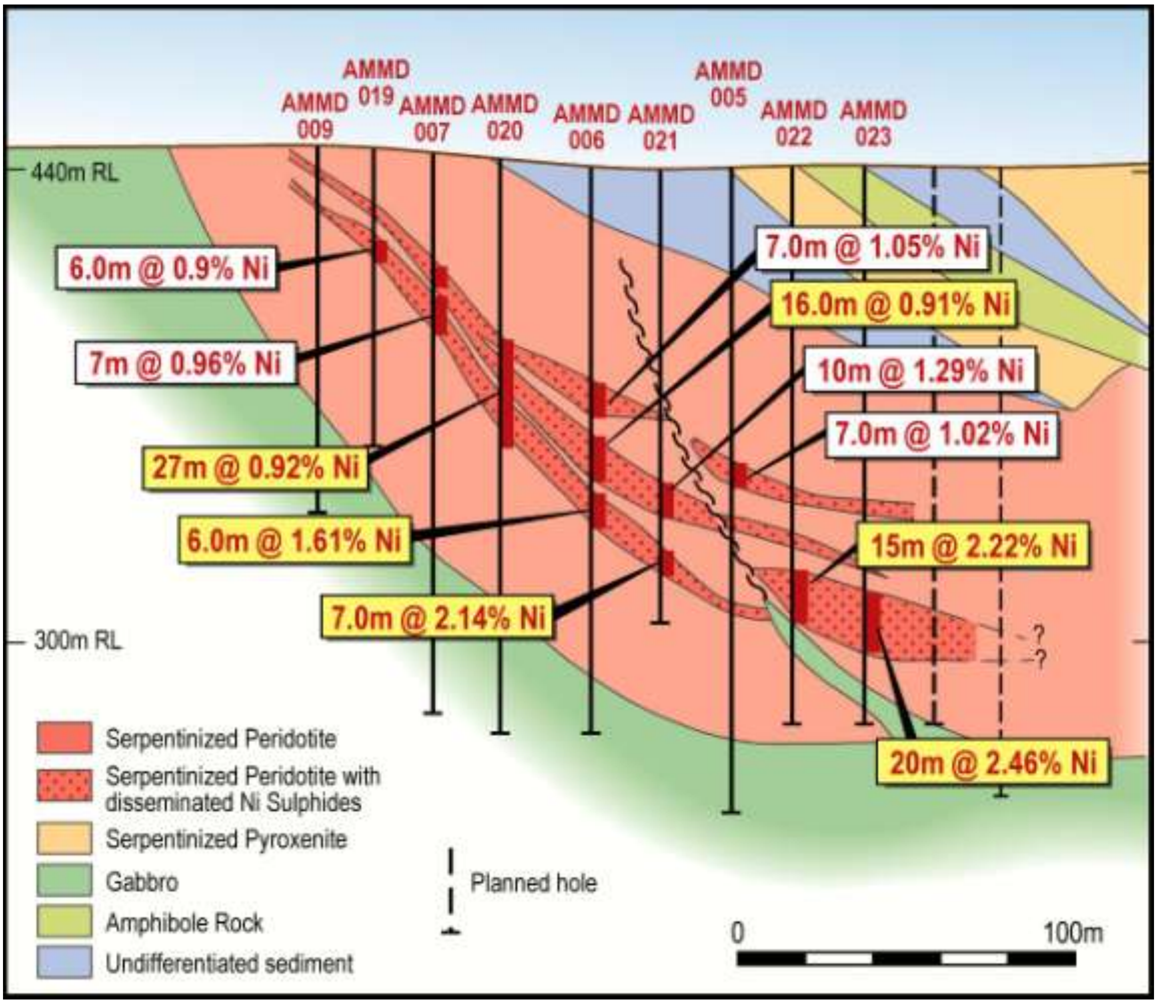

Figure 15: *Geological cross-section of the Marriott's project, showing location of drillhole AMMD021 (from Australian Mines Ltd website)*

Witt47A: ca. 2.46 Ga Joffre Member of the Brockman Iron Formation, Hamersley Group

Drillcore Wittenoom 47A is one of two parallel holes drilled through the Brockman Iron Formation of the Hamersley Group and used by Trendall and Blockley (1970) to define the type section for the Dales Gorge Member. The part of the hole on display intersects part of the overlying, c. 2.46 Ga, Joffre and Whaleback Shale Members of the Brockman Iron Formation (Trendall et al., 2004). In the drillcore, it is possible to see the Microbanding and Mesobanding that is a characteristic of the iron formations. The Joffre Member commonly contains ~30 wt % Fe, but mined ore is generally much higher, concentrated by the effects of younger hydrothermal processes (2.4 Ga, 2.2 Ga, and 2.14 Ga: Rasmussen et al., 2005) that accompanied orogeny.

References

Fiorentini, M, Beresford, SW, Rosengren, N, Barley, ME, and McCuaig, TC 2010, Contrasting komatiite belts, associated Ni–Cu–(PGE) deposit styles and assimilation histories: Australian Journal of Earth Sciences, v. 57, p. 543–566.

Hoashi, M, Bevacqua, DC, Otake, T, Watanabe, Y, Hickman, AH, Utsunomiya, S and Ohmoto, H 2009, Primary haematite formation in an oxygenated sea 3.46 billion years ago: Nature Geoscience, v. 2, p. 301–306.

Kositcin, N, Brown, SJA, Barley, ME, Krapež, B, Cassidy, KF and Champion, DC 2008, SHRIMP U-Pb zircon age constraints on the Late Archaean tectonostratigraphic architecture of the Eastern Goldfields Superterrane, Yilgarn Craton, Western Australia: Precambrian Research, v. 161, p. 5–33.

Lepot, K, Benzerara, K, Brown, Jr, GE and Philippot, P 2008, Microbially influenced formation of 2,724-million-year-old stromatolites: Nature Geoscience, v. 1, p. 118–121.

Lepot, K, Benzerara, K, Rividi, N, Cotte, M, Brown, Jr, GE and Philippot, P 2009, Organic matter heterogeneities on 2.72 Ga stromatolites: Alteration versus preservation by sulfur incorporation: Geochimica et Cosmochimica Acta, v. 73, p. 6579–6599.

Macfarlane, AW, Danielson, A and Holland, HD 1994, Geology and major and trace element chemistry of late Archean weathering profiles in the Fortescue Group, Western Australia: implications for atmospheric PO_2: Precambrian Research, v. 65, p. 297–317.

Miles, A and Cartwright, J 2010, Hybrid flow sills: A new mode of igneous sheet intrusion: Geology, v. 38, p. 343–346.

Philippot, P, Van Zuilen, M, Lepot, K, Thomazo, C, Farquhar, J and Van Kranendonk, M 2007, Early Archean microorganisms preferred elemental sulphur, not sulphate: Science, v. 317, p. 1534–1537.

Rasmussen, B, Fletcher, IR and Sheppard, S 2005, Isotopic dating of a low-grade metamorphic front during orogenesis: Geology, v. 33, p. 773–776.

Rye, R, Kuo, PH and Holland, HD 1995, Atmospheric carbon dioxide concentrations before 2.2 billion years ago: Nature, v. 378, p. 603–605.

Tessalina, SG, Bourdon, B, Van Kranendonk, M, Birck, J-L and Philippot, P 2010, Influence of Hadean crust evident in basalts and cherts from the Pilbara Craton: Nature Geoscience, v. 3, p. 214–217.

Trendall, AF and Blockley, JG 1970, The iron formations of the Precambrian Hamersley Group, Western Australia: Geological Survey of Western Australia, Bulletin 119, 366p.

Trendall, AF, Compston, W, Nelson, DR, deLaeter, JR and Bennett, VC 2004, SHRIMP zircon ages constraining the depositional chronology of the Hamersley Group, Western Australia: Australian Journal of Earth Sciences, v. 51, p. 621–644.

Van Kranendonk, MJ, Philippot, P, Lepot, K, Bodorkos, S and Pirajno, F 2008, Geological setting of Earth's oldest fossils in the c. 3.5 Ga Dresser Formation, Pilbara Craton, Western Australia: Precambrian Research, v. 167, p. 93–124.

Yang, W, Holland, HD and Rye, R 2002, Evidence for low or no oxygen in the late Archean atmosphere from the 2.76 Ga Mt. Roe #2 paleosol, Western Australia: Part 3: Geochimica et Cosmochimica Acta, v. 66, p. 3707–3718.

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