CHAPTER THREE: GEOLOGY OT THE PLATREEF ON NONNENWERTH

3.1 General

The farm Nonnenwerth 421 LR is located ca. 65 km north of Mokopane (Fig. 2.3). The area is generally covered by soil, thus little outcrop is present. The geology of the Platreef on Nonnenwerth 421 LR is known from boreholes drilled by Gencor and Pan Palladium, and from geophysical work. Two drill cores were investigated in this study. They were sampled by boreholes 2121 and 2199, located ca. 2 km apart (Fig. 3.1). Borehole 2121 was drilled to a depth of 342.85 m and borehole 2191 was drilled to a depth of 371.05 m. Both boreholes were collared (drilled) at an angle of 50^0 to the east, intersecting the Main Zone and the Platreef and terminating in granite gneiss floor rocks. The Platreef dips at approximately 40^0 in a westerly direction and is approximately 110 m meters thick. In the present work, it has been sub-divided into five sub-units that are mostly composed of medium to coarse-grained gabbronorite, norite and coarse-grained anorthosite which progressively become more leucocratic and coarser grained from the base upwards. Occasionally, pegmatoidal bands enriched in magnetite and phlogopite are developed. Two calc-silicate xenoliths, up to 25 m in thickness, are present.

The upper part of the intersected sequence, ca. 170 m, consists of homogenous medium-grained, unmineralized gabbronorite. Based on lithological and compositional grounds, this sequence is correlated with the Main Zone. The Platreef and the Main

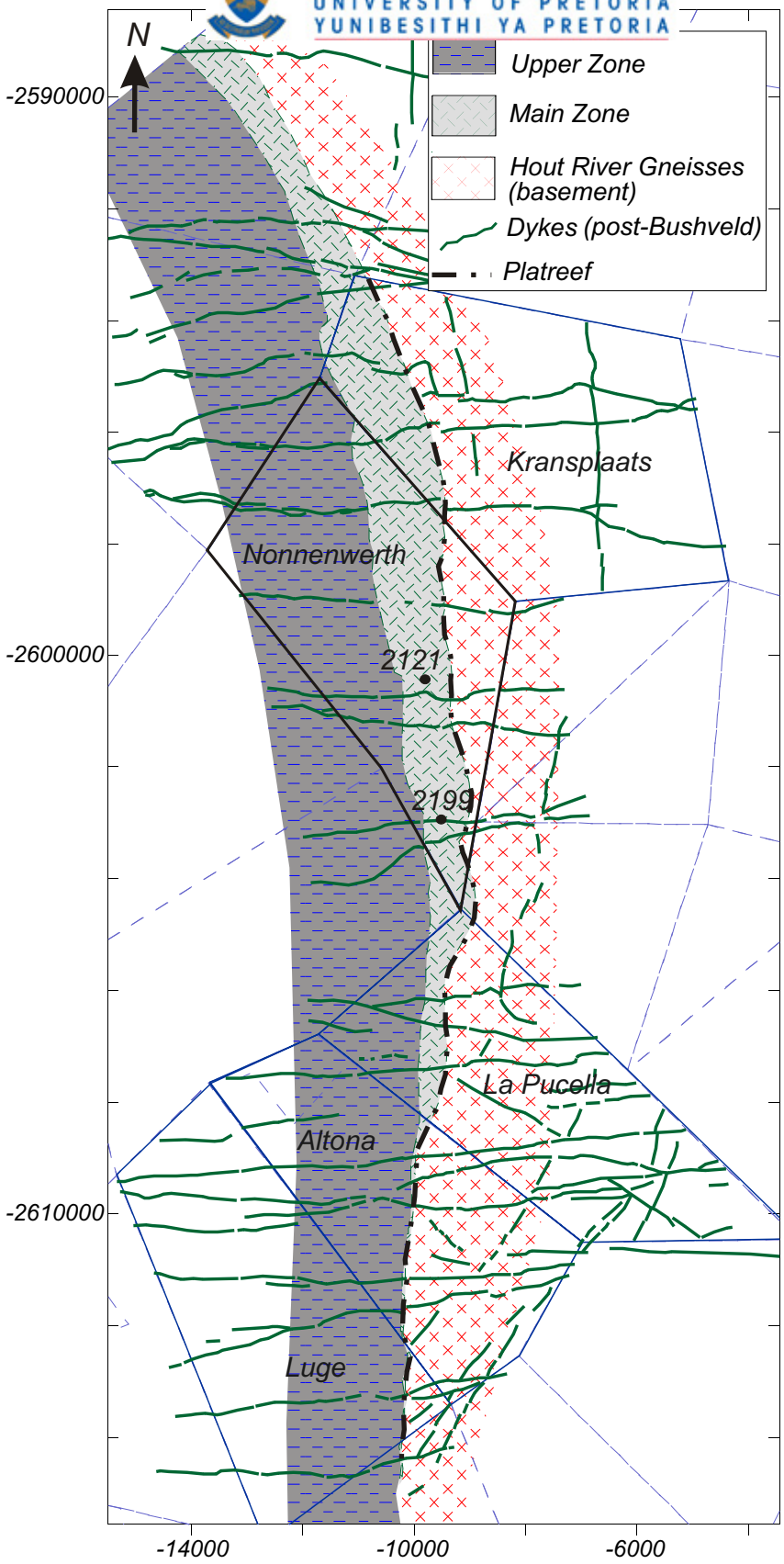

Fig. 3.1: Map of the northern sector of the Platreef (modified from www.panpalladium.com). Note the localities of boreholes 2121 and 2199.

Zone are separated by a dolomite xenolith that is ca. 25 m thick in borehole 2121 and 3 m in borehole 2199. A second dolomite xenolith or raft occurs within the Main Zone, at a depth of 51 – 65 m in borehole 2199 and 49 - 71.5 m in borehole 2121.

3.2 Borehole 2121

A simplified stratigraphic column of Borehole 2121 is given in Fig. 3.2. The footwall to the Platreef is composed of Archaean granite gneiss. This is a medium-grained, pinkish-grey, quartzo-feldspathic rock containing dark green, orthopyroxene-rich melanosomes that define rhythmic layering (Fig. 3.3). The contact between the granite gneiss and the overlying mafic rocks of the Rustenburg Layered Suite is sharp (Fig. 3.4).

3.2.1 Platreef

Sub-unit 1

The base of the Platreef is marked by a fine-grained norite, up to ca. 30 cm, possibly representing a chilled contact facies. This is overlain by a ca. 13.15 m thick, medium-grained melagabbronorite interlayered with several further layers (up to 20 cm) of fine- to medium-grained norite (Fig. 3.5 and 3.6). The contacts between the gabbronorite and norites are sharp (Fig. 3.5 and 3.6) possibly suggesting a hiatus between the intrusion of the norite and the gabbronorites. It is here acceptable that the distinction of layers from xenoliths in borehole intersections is difficult. However, from the two boreholes studied and further examination of more Platreef core from Nonnenwerth at Impala core shed in Springs, the norites seem to represent layers

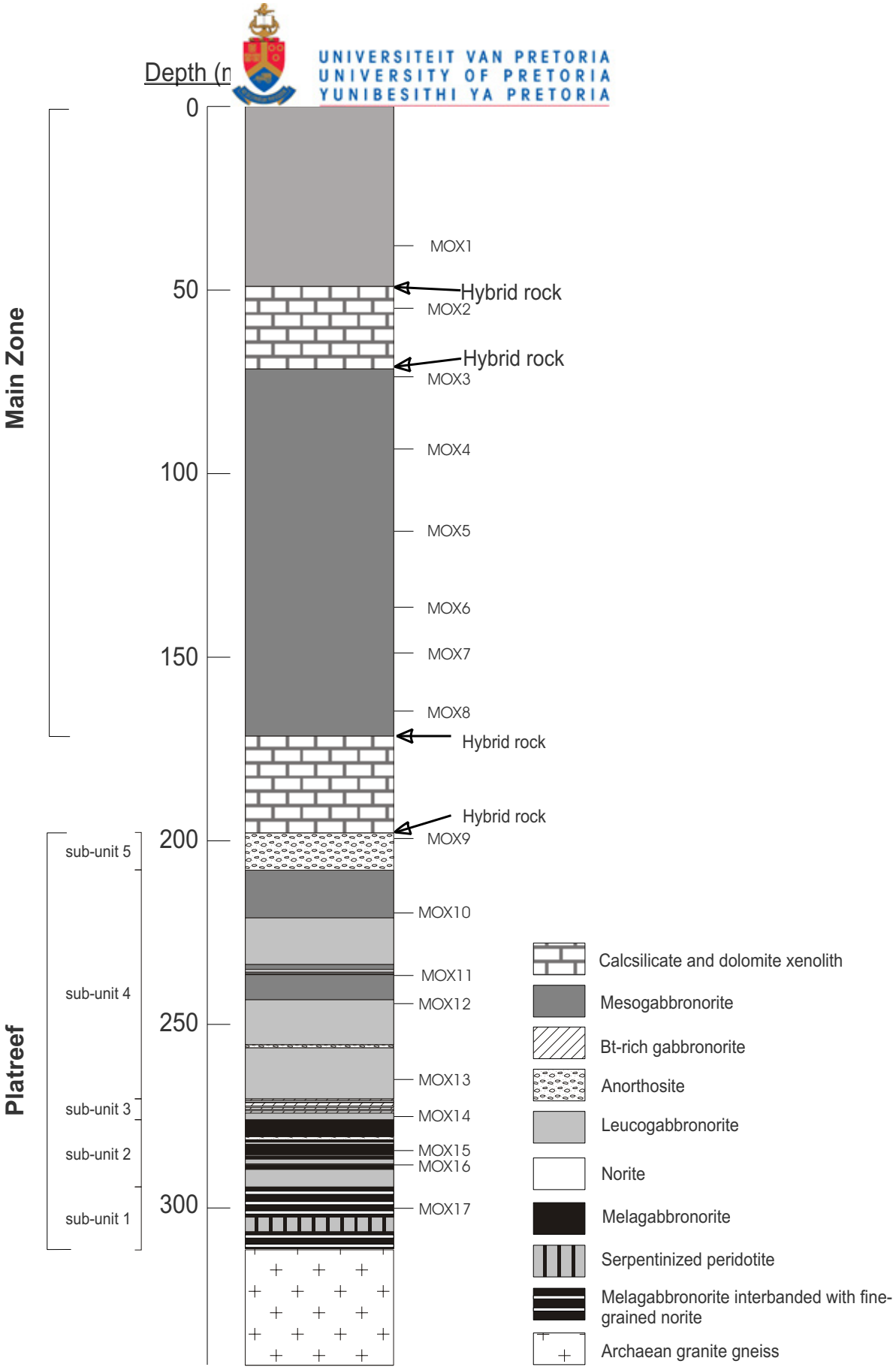

Fig. 3.2: Stratigraphic log of borehole 2121. Numbers on right side of log indicate samples that were analysed by XRF.

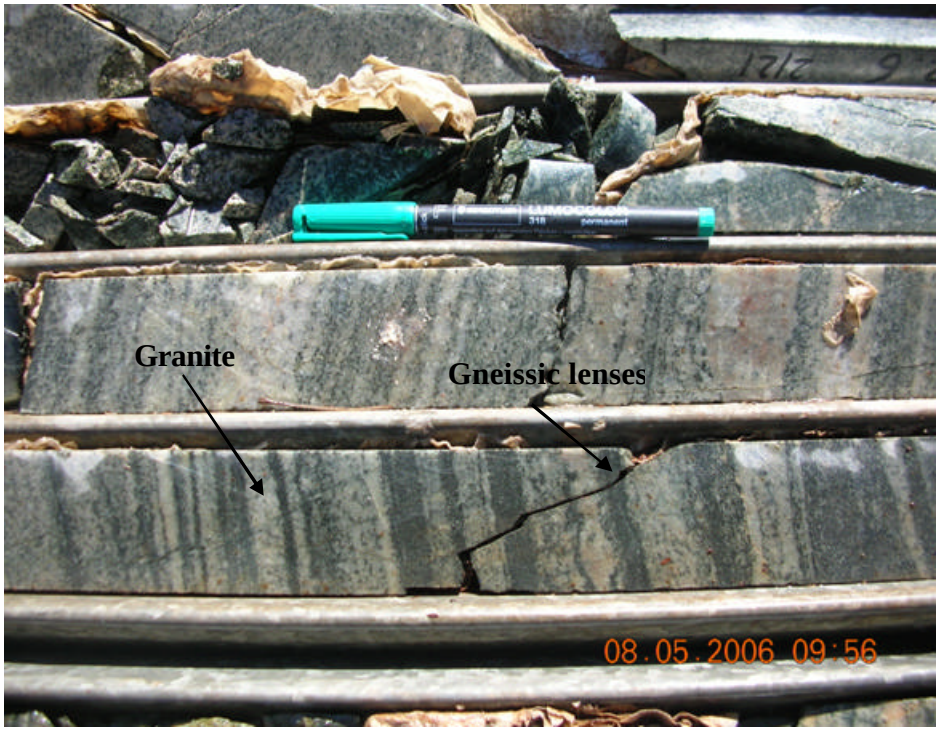

Fig. 3.3: Medium-grained, pinkish-grey granite gneiss containing dark green melanosomes that define rhythmic layering. 330m depth, borehole 2121. Pen is shown for scale.

Fig. 3.4: Sharp contact at 311.30m depth (indicated by stippled line) between granite gneiss (above) and fine-grained (chilled) norite (below). Pen is shown for scale. Borehole 2121.

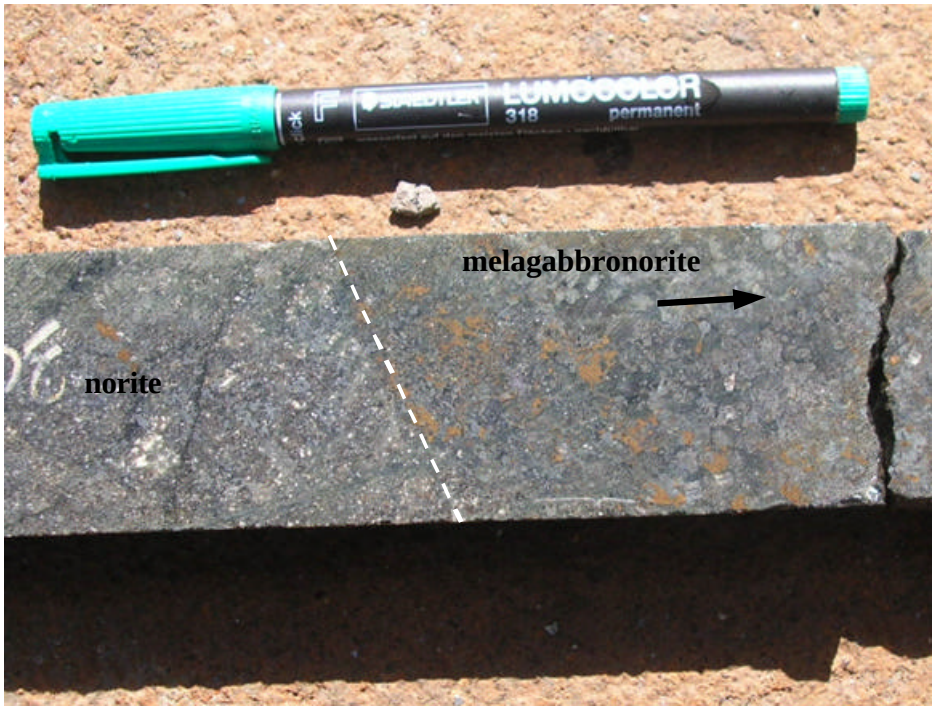

Fig. 3.5: Sharp contact (at 300.93m) between medium-grained, sulphide-bearing melagabbronorite and fine-grained, poorly mineralized to barren norite. Stippled line represents the contact. Arrow indicates stratigraphic up. Pen is shown for scale. Borehole 2121.

Fig. 3.6: Sharp contact (at 296.62 m and 296.50 m depth) between medium-grained, sulphide-bearing melagabbronorite and fine-grained, poorly mineralized to barren norite. Stippled lines represent the contact. Arrow indicates stratigraphic up. Pen is shown for scale. Borehole 2121.

Fig. 3.7: Medium-grained peridotite with serpentine veins at 305.50m depth, borehole 2121. Arrow indicates stratigraphic up. Pen is shown for scale.

rather than xenoliths. Within the succession is a pervasively serpentinised layer, ca. 3.6 m (Fig. 3.7). The composition of the rock, particularly its relatively low CaO (1.64 wt. %), high Fe_2O_3 (22.63 wt. %), Ni (2463 ppm) and Cr (3605 ppm) whole rock contents suggest that the rock is a serpentinized peridotites of igneous derivation. The contacts between the ultramafic rock and the gabbronorite-norite succession are sharp. The occurrence of this ultramafic rock is notable, as ultramafic rocks are less common in the northern portions of the northern lobe than in the southern to south-central portions of the northern lobe (Armitage *et al.*, 2002; Kinnaird, 2004). Holwell and McDonald (2006) report on the presence of several calc-silicate/dolomite xenoliths and serpentinites at Overysel where the floor rocks are Archean basement gneisses, but they do not mention any igneous ultramafic rocks. The contrast in

composition between the present ultramafic rock and its gabbronoritic host rocks could suggest that it represents a xenolith, but a similar ultramafic layer also occurs in borehole 2199, suggesting the rock represents an intrusion of primitive magma.

The melagabbronorite is composed of greenish brown to dark grey, anhedral and subhedral pyroxenes and mostly translucent feldspar crystals. The norite contains greenish to dark grey, anhedral and subhedral pyroxenes and white feldspar crystals giving the rock a “speckled” appearance. The white feldspars and the fine-grained nature clearly distinguish the norite from the melagabbronorite in hand specimen (Fig. 3.6). The feldspar to pyroxene ratio is approximately 30:70 in the melagabbronorite increasing to 50:50 in the norite. Phlogopite is an accessory phase in most samples from the melagabbronorite. The norite is poorly mineralized with generally < 0.1% sulphides, but in the medium-grained melagabbronorite sulphides locally reach up to 3 modal %. The sulphides occur as interstitial and net textured, intergrown grains of pyrrhotite, chalcopyrite and minor pentlandite.

Sub-unit 2

The contact between sub-unit 1 and 2 occurs at 294.35 m and is sharp. Sub-unit 2 is composed of repetitive sequences of interlayered medium to coarse-grained leucogabbronorite and fine to medium-grained melagabbronorite. The contacts between leucogabbronorite and melagabbronorite are sharp (Fig. 3.8). Sulphides (up to 2 modal %) occur as interstitial and net textured, intergrown grains of pyrrhotite, chalcopyrite and minor pentlandite in the melagabbronorite. No sulphides were identified in the leucogabbronorite. A fine-grained norite (from 288.30 to 288.00 m

and 282.05 to 281.42 m) and a coarse-grained anorthosite (from 281.42 to 280.62 m) (Fig. 3.9) occur with sharp contacts, within the interlayered leucogabbronorite and melagabbronorite sequence. The fine-grained norite is texturally similar to the ones described earlier and are not shown on the stratigraphic log. The anorthosite is composed of up to 1.5 cm wide, euhedral and subhedral, white and translucent feldspars intergrown with less than 10 % interstitial pyroxenes.

Sub-unit 3

Sub-unit 2 is overlain at a depth of 276.00 m by a sequence, ca. 5.70 m thick, of interlayered medium-grained leucogabbronorite and coarse-grained phlogopite-rich gabbronorite constituting sub-unit 3. The contacts between the lithologies are sharp (Fig. 3.10). Locally, pegmatoidal domains are developed in the phlogopite-rich melagabbronorite. The phlogopite-rich gabbronorite has dark green to grey, subhedral pyroxenes and white, anhedral to subhedral feldspar crystals. Phlogopite constitutes up to 5 modal % of the rock and sulphides less than 1 modal %. The sulphides occur as interstitial and net textured composite grains of pyrrhotite, chalcopyrite and minor pentlandite.

Sub-unit 4

At 270.30 m, sub-unit 3 is overlain with a sharp contact by coarse-grained, light grey leucogabbronorite of sub-unit 4 (Fig. 3.11). Pegmatoidal and medium-grained leucogabbronorite domains are locally developed. In the pegmatoidal domains, feldspar crystals may reach 3 cm in size. At 256.40 m, a coarse-grained anorthosite,

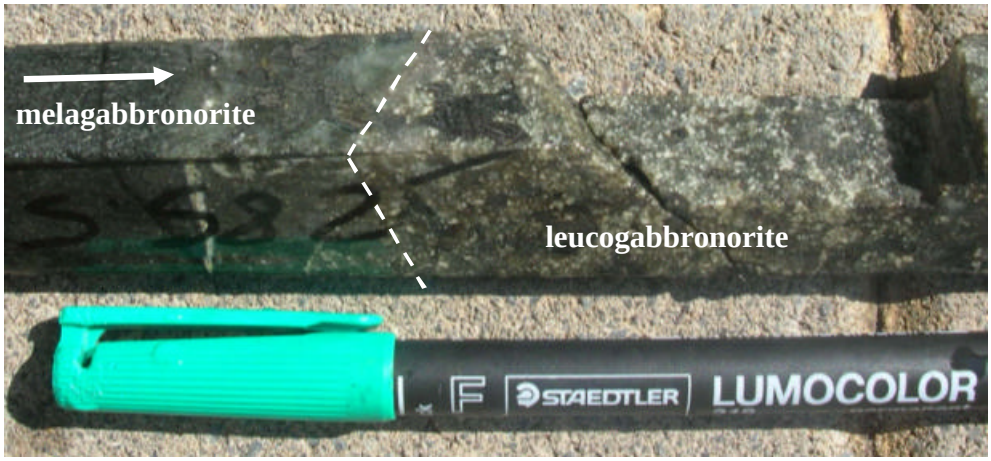

Fig. 3.8: Leucogabbronorite in contact (at 285.46m depth) with melagabbronorite. Arrow indicates stratigraphic up. Stippled line represents the contact. Pen is shown for scale. Borehole 2121.

Fig. 3.9: Anorthosite in contact (at 281.42m depth) with fine-grained melagabbronorite. Note the sharp contact between the two rock types. Arrow indicates stratigraphic up. Stippled line represents the contact. Pen is shown for scale. Borehole 2121.

Fig. 3.10: Phlogopite-rich gabbronorite in contact (at 274.15m depth) with leucogabbronorite. Note the sharp contact between the two rock types. Stippled line represents the contact. Arrow indicates stratigraphic up. Pen is shown for scale. Borehole 2121.

ca. 0.9 m, similar to the one described earlier occurs. From, 246.84 to 208.00 m, the coarse-grained leucogabbronorite is overlain by a sequence of medium to coarse-grained leucogabbronorite interlayered with coarse-grained, locally pegmatoidal mesogabbronorite. The feldspars in the rocks are pervasively altered, resulting in their white colour (Fig. 3.11). Pyroxenes are greenish to dark grey and anhedral or subhedral. The mesogabbronorite is composed of greenish brown to dark grey, anhedral and subhedral pyroxenes with mostly translucent feldspar crystals.

The mesogabbronorite has less than 2 % disseminated sulphides (Fig. 3.12) with the sulphide content increasing in pegmatoidal domains (up to 10 %). The sulphides consist of pyrrhotite and chalcopyrite in broadly equal proportions, with minor pentlandite. At 221.54 m, a melagabbronorite fragment/xenoliths, ca. 5 cm in size, occurs in leucogabbronorite (Fig. 3.13). This suggests that the leucogabbronorite intruded after the melagabbronorite.

Sub-unit 5

Sub-unit 5 consists of a coarse-grained mesocratic anorthosite, ca. 10.53 m, with a brownish grey colour. Euhedral white to translucent feldspars are intergrown with minor brownish-green anhedral pyroxenes. Disseminated pyrrhotite and chalcopyrite generally occur in abundances of <1 %, except for isolated patches where sulphides may reach up to 3 % of the rock.

The upper contact of the Platreef is marked by the occurrence of a calc-silicate xenolith, ca. 25.97 m (Fig. 3.14). The contact zone is marked by a, dark green to

Fig. 3.11: Coarse-grained leucogabbronorite. At 255.30m depth, borehole 2121. Pen included for scale.

Fig. 3.12: Medium-grained sulphide-bearing mesogabbronorite in medium-grained leucogabbronorite. 252.81m depth, borehole 2121. Arrow indicates stratigraphic up. Stippled lines represent the contact. Pen is shown for scale.

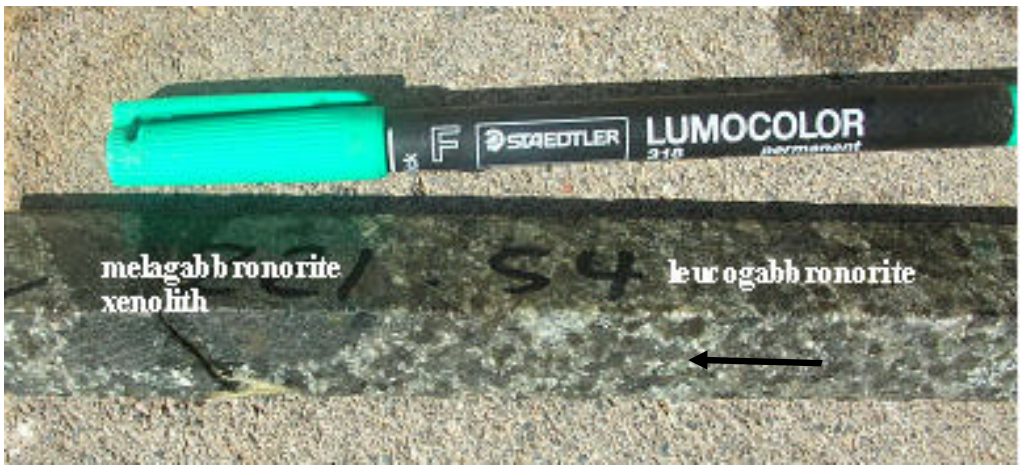

Fig. 3.13: Melagabbronorite xenolith in leucogabbronorite at 221.54m depth, borehole 2121. Arrow indicates stratigraphic up. Pen is shown for scale.

Fig. 3.14: Dolomite xenolith separating Platreef and Main Zone at 197.47m depth, borehole 2121. Pen is shown for scale.

black hybrid rock, ca. 1 m thick, consisting of gabbronorite and numerous small calc-silicate and dolomite fragments. The massive dolomite/calc-silicate xenolith is a leucocratic greyish green rock, with medium-grained, milky white to clear domains and patchy, fine-grained, greyish green clays (probably chlorite and kaolinite).

3.2.2 Main Zone

The Main Zone forms much of the upper portion of the drill core. It is underlain by a contact zone, ca. 1 m thick, that immediately overlies the calc-silicate xenolith. This contact zone consists of calc-silicate fragments in gabbronorite and is highly chloritised and serpentinised, suggesting increased hydrothermal activity. Disseminated sulphides associated with large magnetite crystals persist throughout this contact zone, but are absent in the xenolith proper.

The Main Zone consists of homogenous, medium-grained gabbronorite with a leucocratic base (Fig. 3.15a), except for numerous (5 - 50 cm) pyroxenite bands

particularly towards the top of the unit, and an interval of magnetite-bearing pegmatoidal mesogabbronorite a few metres above the basal contact. The latter rock contains patchy centimeter-scale feldspar-rich domains in coarse gabbronorite.

Magnetite (up to 1 cm) is interstitial to plagioclase and pyroxene (Fig. 3.15b). The bulk of the Main Zone gabbronorites are of medium grain size, with little or no sulphides and magnetite. Greyish-green to dark grey, medium-grained pyroxene occurs as subhedral to euhedral grains together with pale green to white, anhedral to subhedral, saussuritised feldspar. The pyroxene to feldspar ratio varies from 40:60 to55:45. The gabbronorite is cut by a quartz - epidote vein between 140.23 – 140.35 m. A light grey, gabbroic pegmatoid is developed at 71.47 m. It is composed of dark green, interstitial pyroxene grains up to 2 cm wide and light grey to pale green, subhedral saussuritised feldspar grains, up to 6 cm in size. The gabbroic pegmatoid grades into a 1.5 m leucogabbronorite overlain by a calc-silicate xenolith from 68.00 to 53.50 m. A dark green to black, “mottled” rock consisting of calc-silicate fragments in a gabbroic matrix is developed at the lower and upper contacts of the calc-silicate with the leucogabbronorite.

Close to the surface, the Main Zone is weathered and eventually gives way, at about 1.36 m depth, to red loamy soil. The weathered gabbronorite is of a khaki colour, and extremely friable with a 60 to 80% core recovery. Greenish brown, altered, subhe dral pyroxenes constitute 60% of the rock. Pale green to khaki feldspars occur as subhedral to euhedral grains and make up the rest of the rock.

Fig. 3.15a: leucocratic gabbronorite at the base of the Main Zone at 171.50m depth, borehole 2121. Stratigraphic up direction is towards the top of the page. Pen is shown for scale.

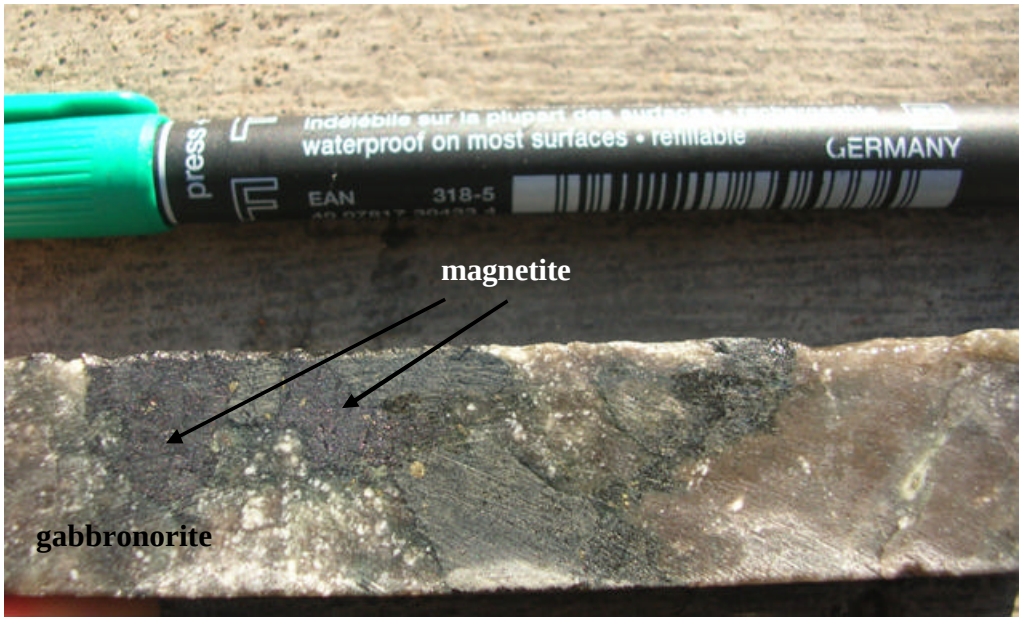

Fig. 3.15b: Coarse magnetite (at 161.60m depth) in Main Zone gabbronorite. Pen is shown for scale. Borehole 2121.

3.3 Borehole 2199

A simplified stratigraphic column of the sequence intersected by borehole 2199 is given in Fig. 3.16. As in borehole 2121, the Platreef is underlain by Archaean granite gneiss which has the same texture and appearance as the one described in borehole 2121 (Fig. 3.17). The stratigraphy of borehole 2199 is broadly similar to that of borehole 2121 despite differences in the thicknesses of correlatable units. Furthermore, sub-unit 5 is not developed in borehole 2199. Thus, sub-unit 1 consists of a basal fine-grained norite overlain by an interval of medium-grained melagabbronorite containing several further layers of fine-grained norite and containing a layer of pervasively serpentinised peridotite, ca. 4.50 m (from 342.50 to 338 m). Next is a sequence of interlayered medium to coarse-grained leucogabbronorite and medium-grained melagabbronorite with sharp contacts, also intruded by fine-grained norite (sub-unit 2). Two coarse-grained anorthosites, ca. 0.70 m and 3.4 m wide occur within the abovementioned sequence. The sequence is overlain by sub-unit 3 at ca. 204.20 m, composed of interlayered coarse-grained phlogopite-rich gabbronorite and medium-grained leucogabbronorite, with sharp contacts between the two rock types. Locally, pegmatoidal domains of the phlogopite-rich melagabbronorite are developed. Sub-unit 4, overlies sub-unit 3 with sharp contacts and consists of cycles of coarse to medium-grained mesogabbronorite interlayered with medium-grained leucogabbronorite. Note that the coarse-grained, leucogabbronorite that forms the base of sub-unit 4 in borehole 2121 is not developed here. Pegmatoidal domains in the leucogabbronorite with feldspar crystals up to 3 cm in size are locally developed.

The dolomite xenolith separating the Platreef and the Main Zone is 3 m thick, in contrast to the 26 m observed in borehole 2121. The Main Zone consists of similar medium-grained gabbronorite as in borehole 2121, and contains a further dolomite xenoliths, ca. 1.8 m, at a depth of 160.00 to 158.20 m.

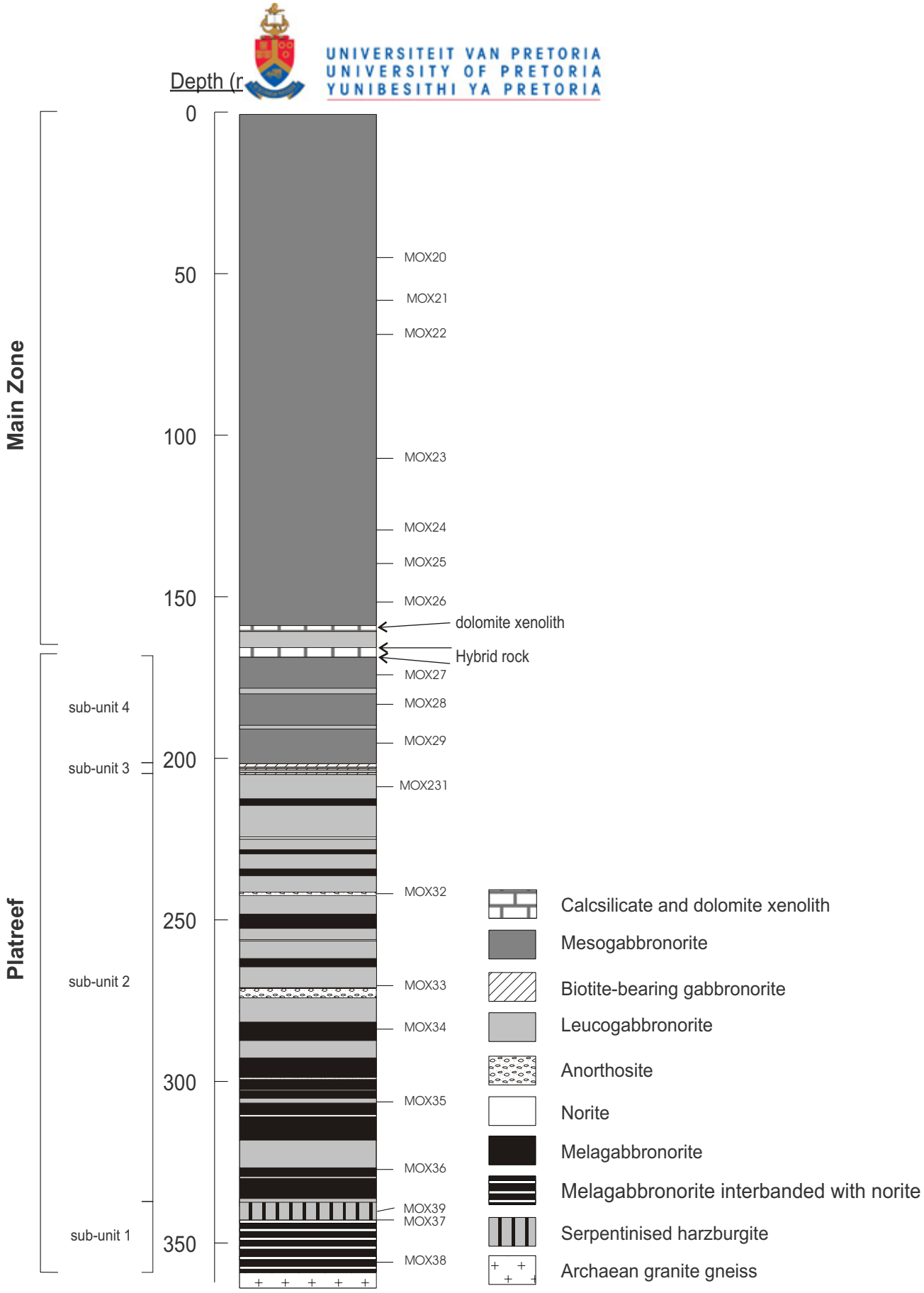

Fig. 3.16: Stratigraphic log of borehole 2199. Numbers on right side of log indicate samples that were analysed by XRF.

Fig. 3.17: Granite gneiss in sharp contact (at 359.00 m) with fine-grained (chilled) norite. Stippled line represents the contact. Pen included for scale. Borehole 2199.

CHAPTER FOUR: GEOLOGY OF THE PLATREEF ON TOWNLANDS

The farm Townlands hosts the town of Mokopane, formerly Potgietersrus (Fig. 4.1). A drillcore intersecting part of the Platreef has been investigated by Manyeruke (2003) and Manyeruke *et al.* (2005). Since the data generated during these studies will be compared to the data from Nonnenwerth, and since I have generated additional trace element data from Townlands during the present investigation, a short revision of the stratigraphy of the Platreef on Townlands is necessary. The examined drillcore comes from a borehole collared some 2 km to the NE of Mokopane. A simplified stratigraphic column of the Platreef and its floor rocks in the borehole is given in Fig. 4.2. At this locality, the floor rocks of the Platreef consist of hornfels, quartzite and calc-silicates probably belonging to the early Proterozoic Silverton Formation of the Pretoria Group, Transvaal Supergroup. The hornfels possibly formed by heating of the sedimentary floor rocks by hot Platreef magma. The sedimentary rocks are locally layered on a millimeter to centimeter scale with the layering defined by thin (1-2 mm), dark bands. They are intruded by numerous sill-like bodies of pyroxenites which show internal variation in grain size, from fine-grained margins to medium-grained central portions. The widths of the sills range from a few centimeters to several meters. The contacts between the pyroxenite sills and the sedimentary rocks are sharp and may be defined by thin (< 2 mm) reaction rims. Notably, no sills were observed within the Platreef. This may be a coincidence or could indicate that the sills are older than the Platreef. More information from other borehole intersections is necessary to constrain this question.

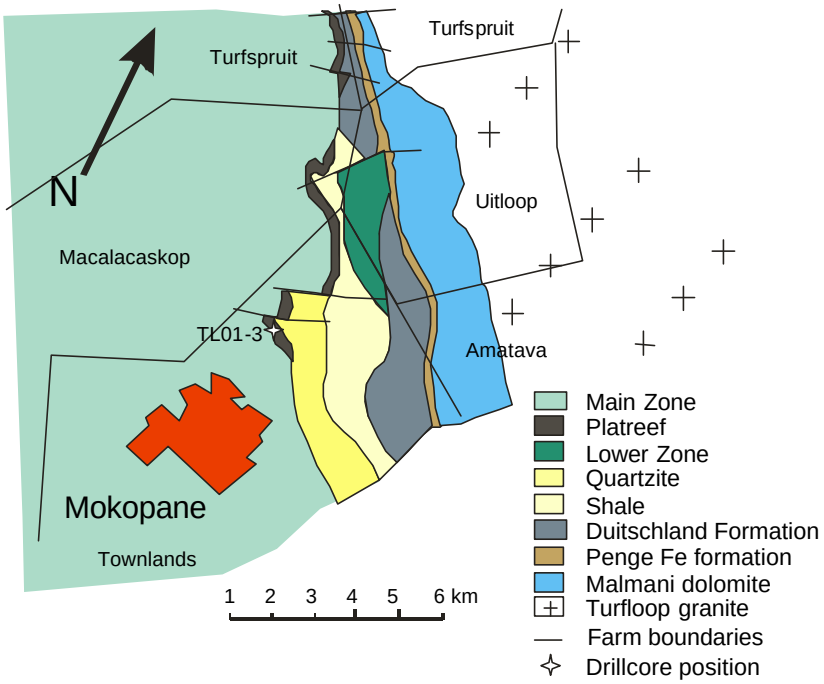

Fig. 4.1: Geological map of the Platreef on the farm Townlands and the location of borehole TL01-3. Map from Falconbridge Ventures of Africa (Pty) Ltd.

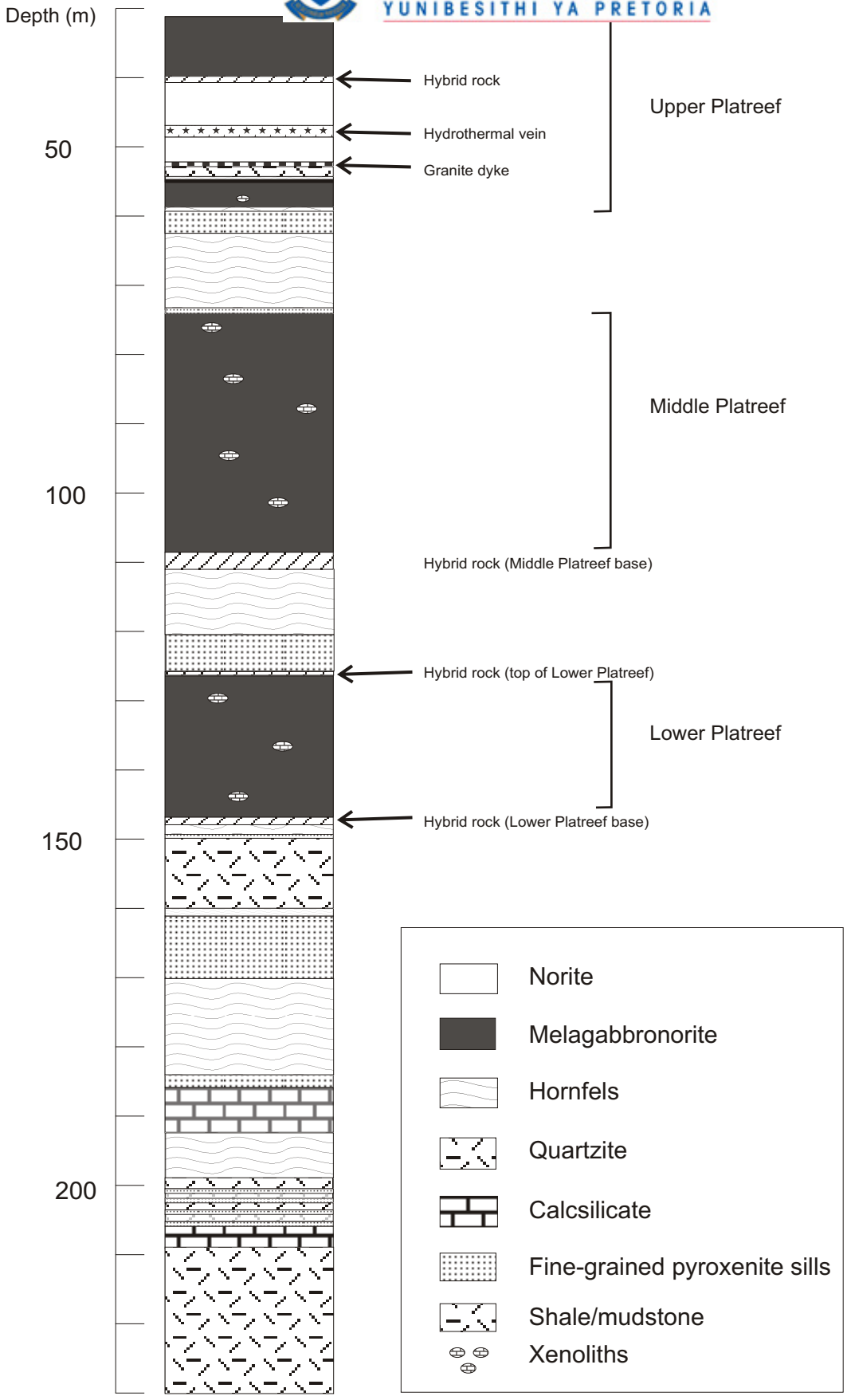

Fig. 4.2: Generalised stratigraphic column through the Platreef on the farm Townlands (from Manyeruke, 2003).

In general terms, the Platreef on Townlands consists of medium-grained gabbronorite and olivine melagabbronorite. Manyeruke (2003) distinguished three distinct units, a Lower, Middle and Upper Platreef (Fig. 4.2). The individual units are separated by thick (several 10s of meters) intervals consisting of hornfels and fine grained pyroxenite sills.

The Lower Platreef is noritic to gabbronoritic in composition, with minor pyroxenitic domains. The contact between the Lower Platreef and the quartzitic floor rocks is formed by a hybrid zone which consists of highly altered metasedimentary rocks apparently injected by medium grained, non-mineralized pyroxenite. Alternatively, the hybrid rock may represent pyroxenite containing a dense load of sedimentary xenoliths. A clear distinction between the two possibilities is not possible in the borehole core.

A ca ~18 m interlayer consisting of 1 m of hybrid rock, 6m of fine-grained pyroxenite overlain by ferruginous hornfels and ca 3 m of hybrid rock separates the Lower Platreef from the Middle Platreef. The hybrid rocks are similar in appearance to the ones described earlier. The fine-grained pyroxenite is interpreted to belong to the suite of sills described above. The Middle Platreef is approximately 35 m thick and consists mainly of a medium grained, olivine bearing, gabbronorite with a heterogeneous texture. Pegmatoidal patches are abundant and represent a local increase in modal proportion and grain size of feldspars intergrown with dark, altered olivine and greyish-green pyroxene. Coarse sulphides of up to 3 cm in size are preferably associated with the felsic pegmatoidal domains, whereas fine-grained

sulphides are found in the more even-textured gabbronorite. Xenoliths of metadolomite are not uncommon and are usually pervasively serpentinised. In the vicinity of the xenoliths, the igneous rocks show a progressive increase in the degree of serpentinisation and in modal olivine. Interaction between the xenoliths and the intrusive rocks is also evident by means of coarse-grained to pegmatoidal textures in the intrusives surrounding the xenoliths.

A hornfels interlayer, ca. 10 m (similar to the one between the Lower and Middle Platreef) overlain by a 3 m fine-grained pyroxenite sill barren of sulphide mineralization (59.55 – 62.83m) separates the Middle Platreef from the Upper Platreef. The lower and upper contacts of the sill are sharp and the Platreef rocks adjoining the contact are medium grained pyroxenites/gabbronorites, broadly similar in appearance to the Middle Platreef, but somewhat more melanocratic. As in the case of the Lower and Middle Platreef, there is no chilled margin developed at the contact of the Platreef with the hornfels. The pyroxenite/gabbronorite has about 12 % interstitial plagioclase in the upper portions decreasing to about 3 % in the lower portions. Sulphides are mainly present in the form of fine disseminations and irregular interstitial blebs of pyrrhotite and minor chalcopyrite. More massive sulphide patches (up to 3 cm) may also be developed locally. The Upper Platreef contains an intervening 13 m noritic package (41.44 to 54.62 m). The norite has a markedly different appearance to the Platreef pyroxenite/gabbronorite. It is medium grained and contains 50 – 60 % plagioclase and 40-50 % orthopyroxene. Minor (< 1 %) sulphides (chalcopyrite and pyrrhotite) occur as fine disseminations within the norite. The contact between the upper portion of the norite and the overlying

pyroxenite/gabbronorite of the Upper Platreef is defined by a ca 1.5 m fine-to medium grained hornfels layer grading into a hybrid zone similar to the ones at the contacts of the Lower and Middle Platreef. The hornfels is highly magnetic with magnetite reaching up to 50 modal %.