

The use of PGE and base metal grades and ratios to determine the stratigraphic location of samples at Ngezi Mine, Great Dyke, Zimbabwe

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The main sulphide zone (MSZ) of the Great Dyke is cryptic and without obvious stratigraphic markers.

Although there are trends in the dimensions of the PGE and base metal profiles across the Hartley Complex, the profiles are invariant within a particular mining area.

Ratios derived from these profiles are used to interpret diamond drill cores drilled ahead of underground development. Detailed logging of oriented core shows the exact position and attitude of intersected faults. Metal ratios are used to estimate fault throw to within 25 cm. It is possible to draw detailed sections showing the extent of ground disturbance well ahead of mining. The method has been confirmed by mining and by drilling inclined holes through the fault blocks.

Keywords: main sulphide zone, Hartley Complex, Great Dyke, Zimbabwe, platinum, Palladium, Nickel.

Introduction

The Great Dyke is a layered mafic-ultramafic intrusion that transects the Zimbabwean Archaean Craton in a north-north-east trending direction. The Dyke is highly elongate, slightly sinuous, 550 km long, with a maximum width of 12 km.

The Dyke developed as a series of initially discrete magma chamber compartments, which joined up as the chambers filled¹. The Dyke is divided into two major successions, a lower ultramafic sequence dominated by cyclic repetitions of dunite, harzburgite and bronzitite (pyroxenite), and an upper mafic sequence consisting mainly of gabbro and gabbro-norite. The chambers coalesced towards the top of the ultramafic sequence. The main layer of platinum group element (PGE) and base metal mineralization known as the Main Sulphide Zone (MSZ) is found high up the ultramafic sequence some 20 to 40 m below the base of the mafic sequence. It is believed that the MSZ was originally a continuous layer over most of the length of the Dyke. Erosion has subsequently removed much of the mafic sequence and the MSZ, leaving four remnants known from south to north as the Wedza, Shurugwi, Hartley and Musengezi complexes.

Metal profiles

This paper deals with the metal profiles within the Hartley Complex of the Great Dyke where the MSZ is preserved as a continuous zone stretching 90 km from Lake Manyame in the north to Ngezi Dam in the south. The Hartley Complex straddles two sub-chambers, Darwendale and Sebakwe, but as these coalesced before the crystallization of the MSZ, the MSZ can be considered as one continuous unit within the Hartley Complex.

The MSZ in the Hartley Complex has a double plunging synformal structure resembling a flattened canoe. The structure dips towards the centre at approximately 2 degrees

along its axis and by up to 20 degrees at its margins. The maximum vertical depth is approximately 1250 m. This structure is believed to be primarily of magmatic origin but the synformal shape has been accentuated by subsequent subsidence of the dense ultramafic layers between the lighter wall rocks¹.

Orthopyroxenite (bronzitite) of the upper pyroxenite layer, P1, encloses the MSZ, which lies several metres below a two-pyroxene layer (websterite) and several tens of metres below the top of the ultramafic sequence. Two sub-zones are recognized within the MSZ: an upper base metal sub-zone associated with approximately 5 per cent sulphide mineralization and a lower PGE sub-zone where the sulphide content drops sharply to less than 1 per cent.

Obertur³ showed that the species of sulphides, arsenides and bismuthotelluridites vary vertically within the sub-zones. These systematic variations give rise to remarkably consistent metal profiles across the MSZ.

Figure 1 shows a typical grade profile from Ngezi Mine. From the base of the PGE sub-zone moving upwards, palladium increases to its peak of 2 ppm about 1.25 m below the peak platinum value of 3.4 ppm. Platinum has a subsidiary peak that coincides with the palladium peak and vice versa. The platinum profile is noticeably skewed, rising from the base containing 0.25 ppm platinum over 4 m to the peak and then tailing off back to 0.25 ppm platinum over 0.75 m above the platinum peak. Nickel rises from approximately 1000 ppm at the palladium peak to a peak nickel value of 2 750 ppm just above the platinum peak. Nickel values remain elevated for several metres above the nickel peak and there is a subsidiary nickel peak 1 m above the main peak.

Across the Hartley Complex, the shape of the metal profiles, their skewness and relative positions of the subsidiary peaks, is remarkably consistent. The dimensions of the profiles do, however, vary considerably as shown in Figure 2. At Ngezi in the south and Darwendale in the

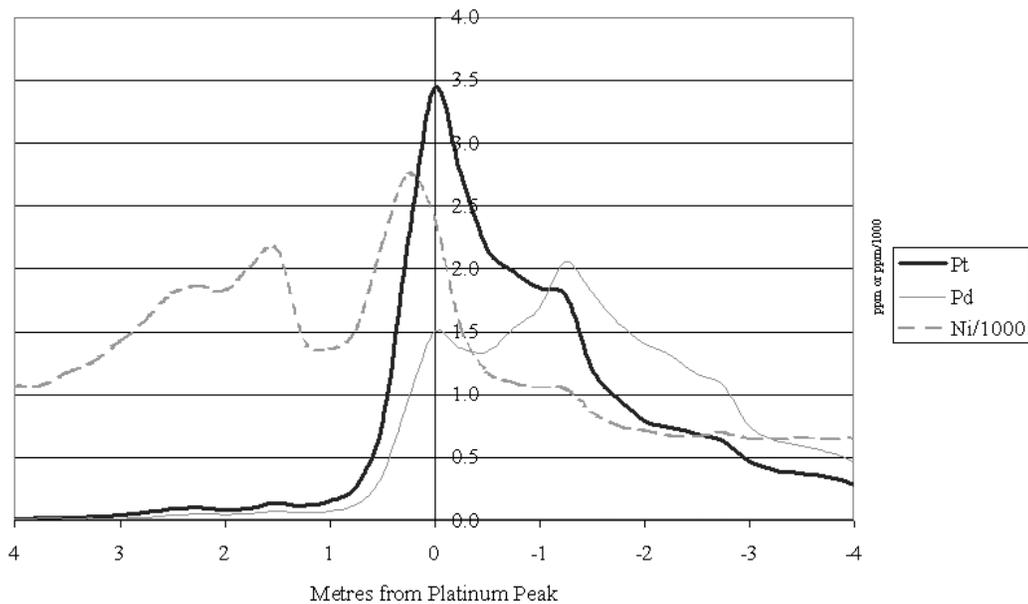


Figure 1. Typical grade profile across the MSZ at Ngezi Mine

north, the profiles are relatively flat and wide. Along the margins, the profiles are much narrower, while the peak values are significantly higher. For example, at Hartley the profile is compressed into 2 m and the peaks are twice the Ngezi levels.

There are also distinct transverse trends. The MSZ has been drilled across its full width in the Ngezi North area and the profiles get steadily higher in grade and narrower in width from east to west. At Hartley there is a similar trend and the few holes along the eastern margin opposite Hartley have a wider, lower grade profile than Hartley. There is insufficient drilling so far to confirm that the wider profiles seen in the axial zones to the north (Darwendale) and south (Ngezi) are also found at depth in the keel of the synform.

The transverse trends of the metal profiles are consistent with the textural and stratigraphic variations that have been documented¹. In particular, stratigraphic layers including the MSZ are thinner in the margins compared with the axis. This thinning coincides with a decrease in metal profile widths and with the decreased separation of the component peaks.

The asymmetry of the metal profiles across the Dyke (wider and lower grade in the east) are also mirrored by asymmetric dips, layer thicknesses and textures. The layering and profiles may have been primarily asymmetric, with the eastern side originally wider than the western side. Alternatively, the axis of an originally symmetric synformal structure has been rotated¹ and erosion has removed more of the eastern margin than the western margin. At Ngezi North the axis of the structure, as shown by the distance from the MSZ to the top of the ultramafic sequence, lies off centre towards the eastern margin suggesting a rotated axis.

A small number of drill intersections are disrupted by barren bronzitite pegmatoid. In these intersections the profile is displaced by the pegmatoid rather than being removed by it, as illustrated in Figure 3. This may point to an intrusive introduction of or the late crystallization of the pegmatoid, but it could also be explained by a delay or a disruption in the metal profile lay down due to the presence or development of the pegmatoid.

Identification of stratigraphic position at Ngezi

Although there are variations in the profile dimensions across the Hartley Complex, the profile is consistent within one mining area such as Ngezi Underground. This means that every intersection within the 2 km by 3 km area has a very similar profile. Knowledge of the profile of a given area can therefore be put to practical use.

Profiles are particularly useful because the MSZ is not marked by an obvious marker horizon. The MSZ is marked by relatively subtle changes in sulphide content within monotonous bronzitite. There is a sharp decrease in sulphide percentage from 5 per cent sulphides down to less than 1 per cent across the base of the base metal sub zone. This sharp decrease, base of MSZ (BMSZ) coincides with the platinum peak and is used as a marker to guide sampling and mining. This base of the sulphides takes careful observation to distinguish and is especially difficult to distinguish underground and on altered planes. Experienced technicians only manage to identify it successfully 85 per cent of the time. There are no obvious marker horizons and the stratigraphy either side of the MSZ does not change until websterite is encountered about 5 m into the hangingwall.

In the absence of a distinct stratigraphy in underground faces and drill holes, the profiles and ratios derived from assays are used to determine where on the profile a particular sample is located. In the underground mine at Ngezi, near-horizontal pilot holes are drilled to 100 m ahead of development. A combination of the careful logging of oriented core and the metal ratios allows the position and the throws of faults to be estimated well before the mine reaches them.

Absolute metal values alone do not give much assistance because it is not clear which side of the peak a value comes from. The use of ratios removes this ambiguity.

In the base metal sub-zone the Ni/Pt ratio decreases as the BMSZ is approached, while in the PGE sub-zone the Ni/Pt

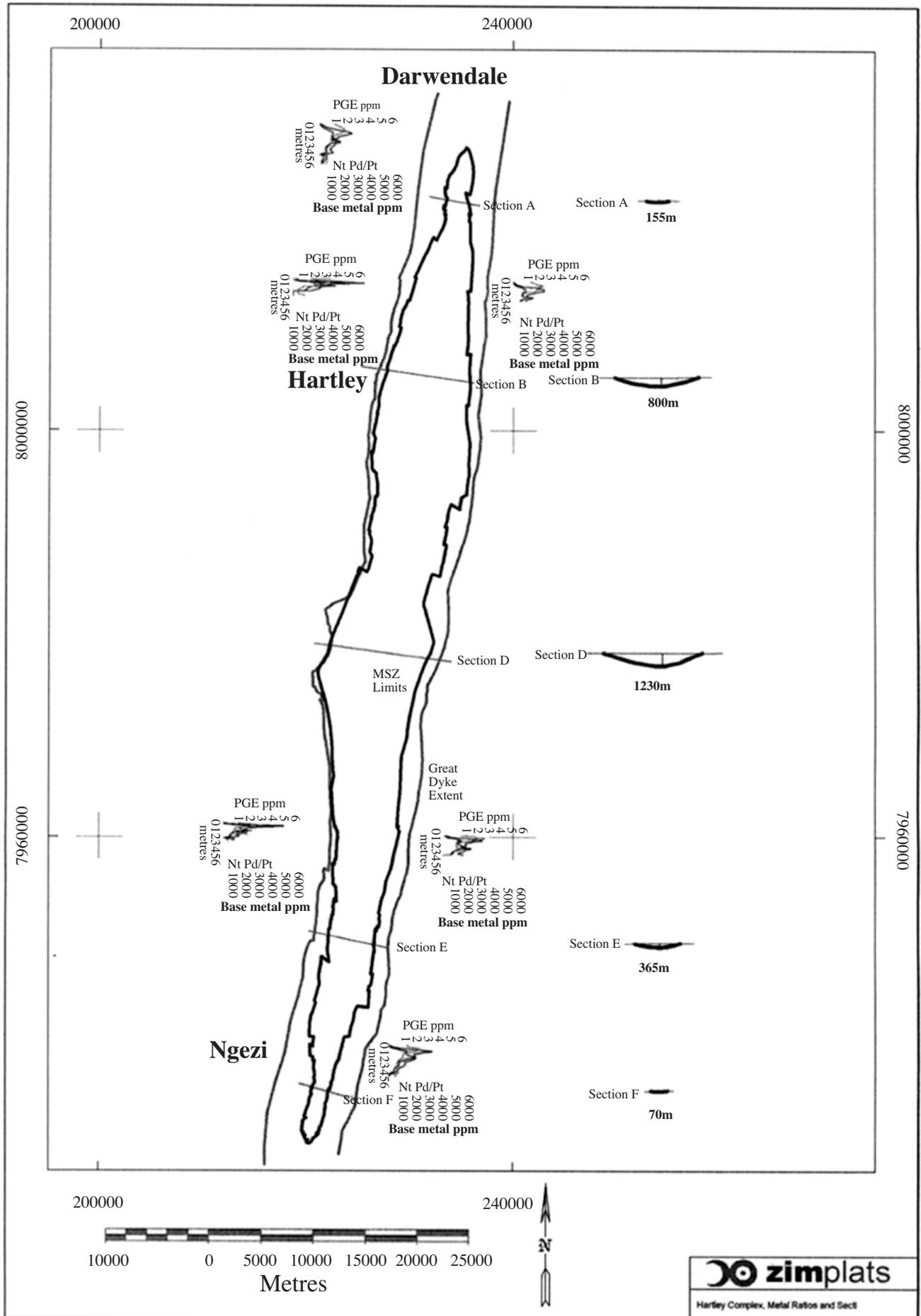


Figure 2. Variations in MSZ grade profiles across the Hartley Complex of the Great Dyke

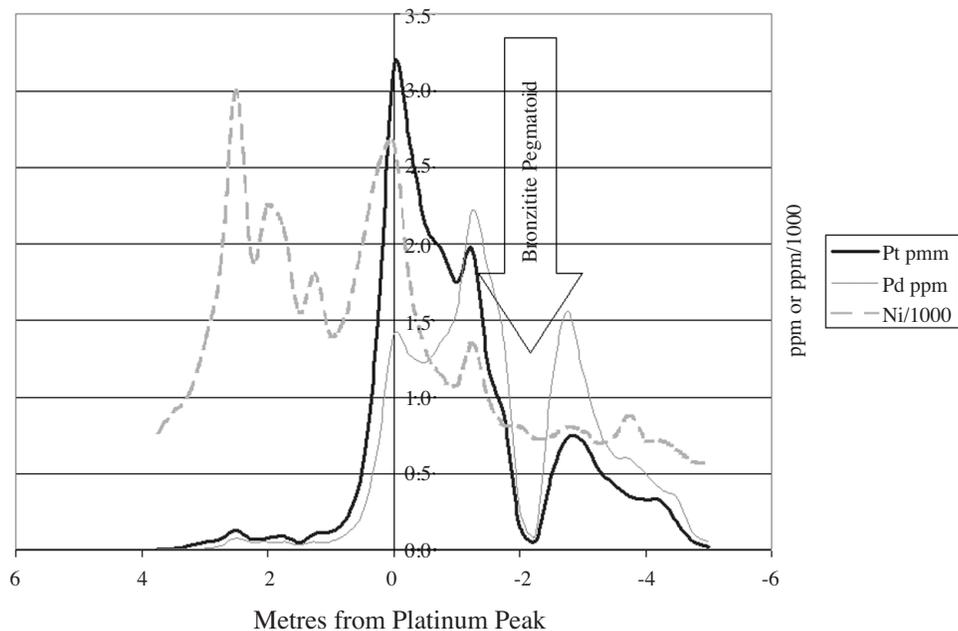


Figure 3. Effect of bronzite on the grade profile

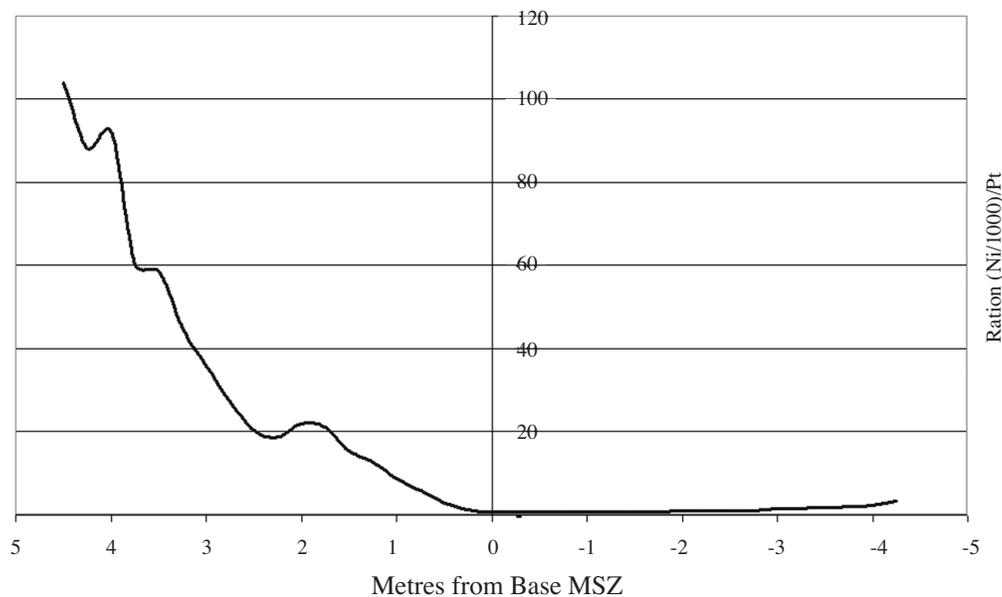


Figure 4. Ni/Pt ratios relative to the base of the MSZ

ratio changes little and is low due to the low levels of nickel. The Ni/Pt ratio shown in Figure 4 is therefore a useful guide to the relative position of a sample in the hangingwall of the BMSZ. In the PGE sub-zone, palladium has its peak stratigraphically below the platinum peak so the Pd/Pt ratio increases as the sample moves further into the footwall of the BMSZ, as shown in Figure 5. The combination of these two ratios allows meaningful positioning of a given sample within 2.25 m above and 3 m below the BMSZ. The absolute metal values and the extent of visible sulphides in the core are used as a guide to check the ratio indication.

Drilling and data collection

Diamond drill holes are collared parallel to the reef ahead

of advance. Holes are drilled in BQ core size and oriented after every 3 m run. An orientation spear is used in all intact core zones. Orientation is not possible where core is broken and unconsolidated.

All holes are carefully logged using the orientation to re-align all core pieces and collect strike and dip data on all structures and intrusive bodies. A structural log and a lithological log are produced.

The entire hole is sampled at 1 m sample lengths and assayed locally for Pt, Pd and Ni. Where a hole is inclined, the sample length is adjusted to collect a 0.25 m cut in the vertical plane. Samples on 14S6-1 (+10°) were cut to 1.4 m lengths.

Figures 6 to 8 show the assay profiles on three holes and the correlation between elemental ratios, the BMSZ and structures.

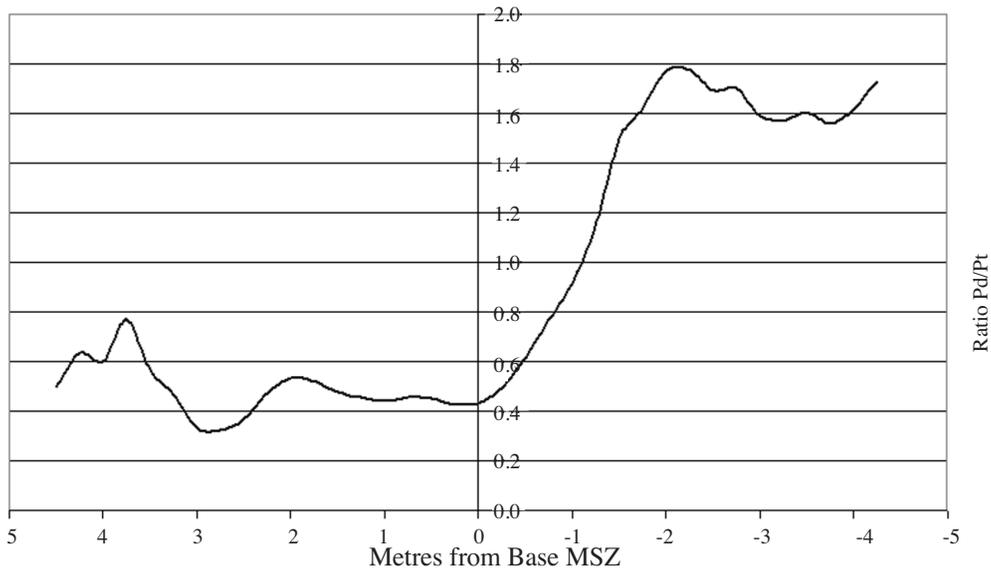


Figure 5. Pd/Pt ratios relative to the base of the MSZ

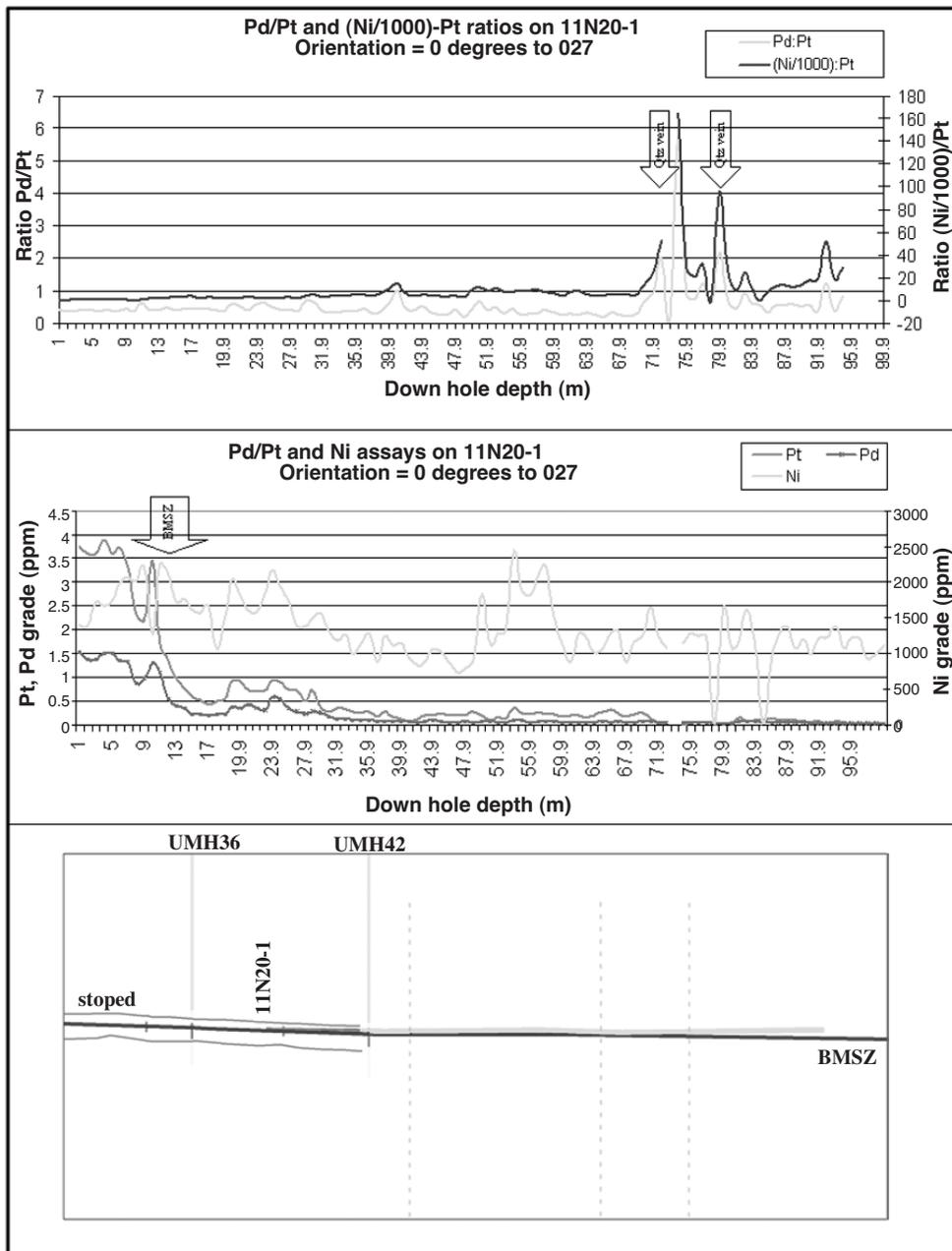


Figure 6 Sections along hole 11N20-1

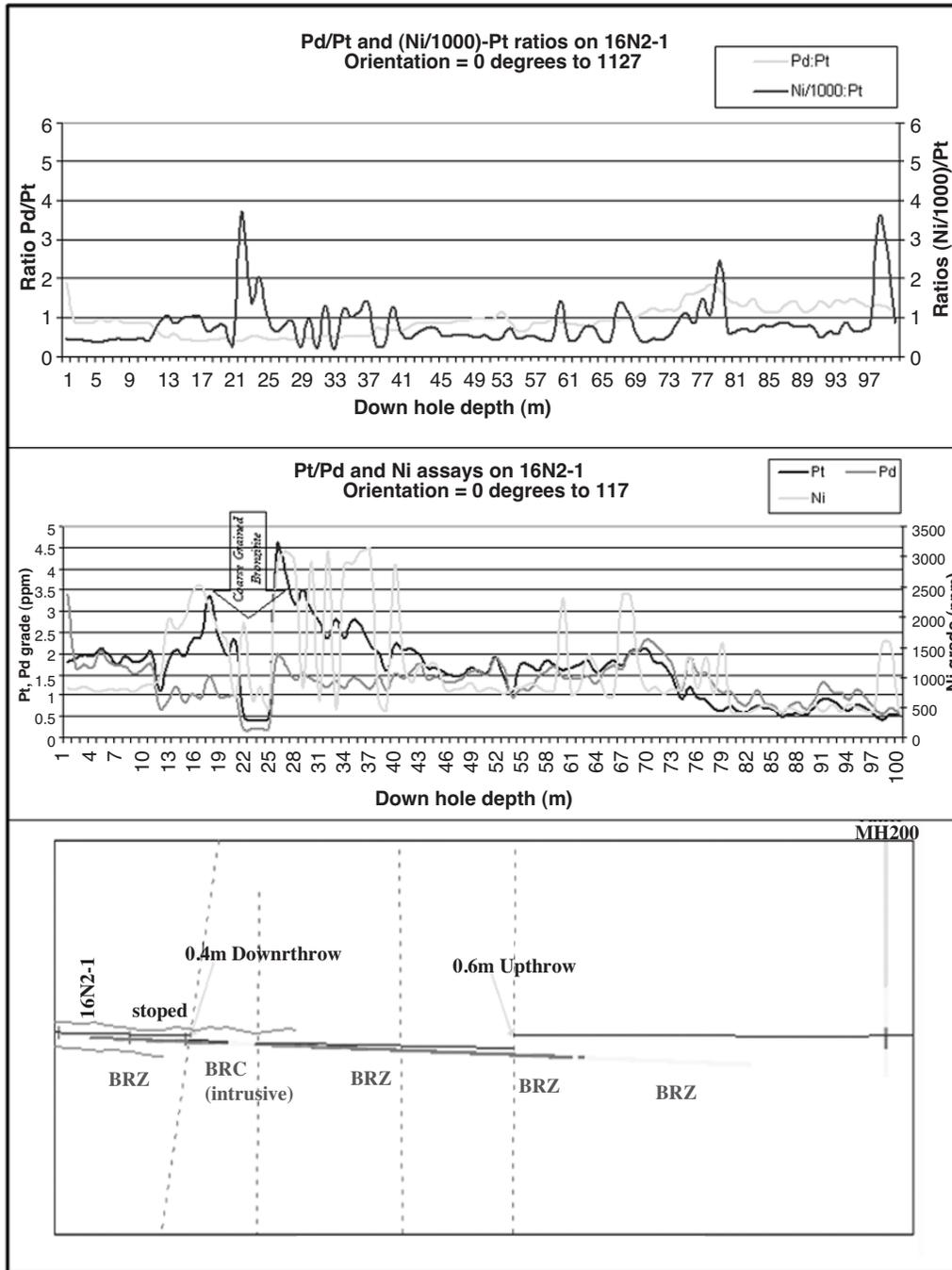


Figure 7 Sections along hole 16N2-1

Mining has since taken place along all these holes and fault prediction to date has been 100%, though strike and dip data were not as reliable due to the broken nature of the core around displacement zones.

Surface diamond drilling holes have been used in the past to predict faulting, though, due to the wide spaced drilling grid, fault localization has been poor. For example, when vertical holes are drilled on a 250 m pattern, a fault is only located to within 250 m. Very close spaced vertical drilling is required to obtain the exact location of a fault

Underground grade control channels, which are cut at 6 m intervals, show a good correlation with the BMSZ position as predicted by the horizontal holes both along strike and down dip. Wavy faults that may cut across the hole at several positions, however, may cause some confusion as these may be logged and interpreted as separate distinct faults.

Horizontal holes intersected all the significant structures that mining encountered and with orientation and down-hole surveys, the measurement of displacements can be confidently predicted.

Horizontal drilling is cost effective because all drilling is done 'on reef' so that each metre produces information that will guide mining. Surface drilling, by comparison, involves drilling through mostly waste and only provides information on the position of the MSZ at one intercept position.

Diamond drilling can be monitored as drilling progresses and down hole surveys conducted before hole completion. The main advantage of this is that data interpretation is ongoing and any hole can be stopped once information retrieved is deemed to be unreliable due to borehole diversion or large-scale faulting/dislocations.

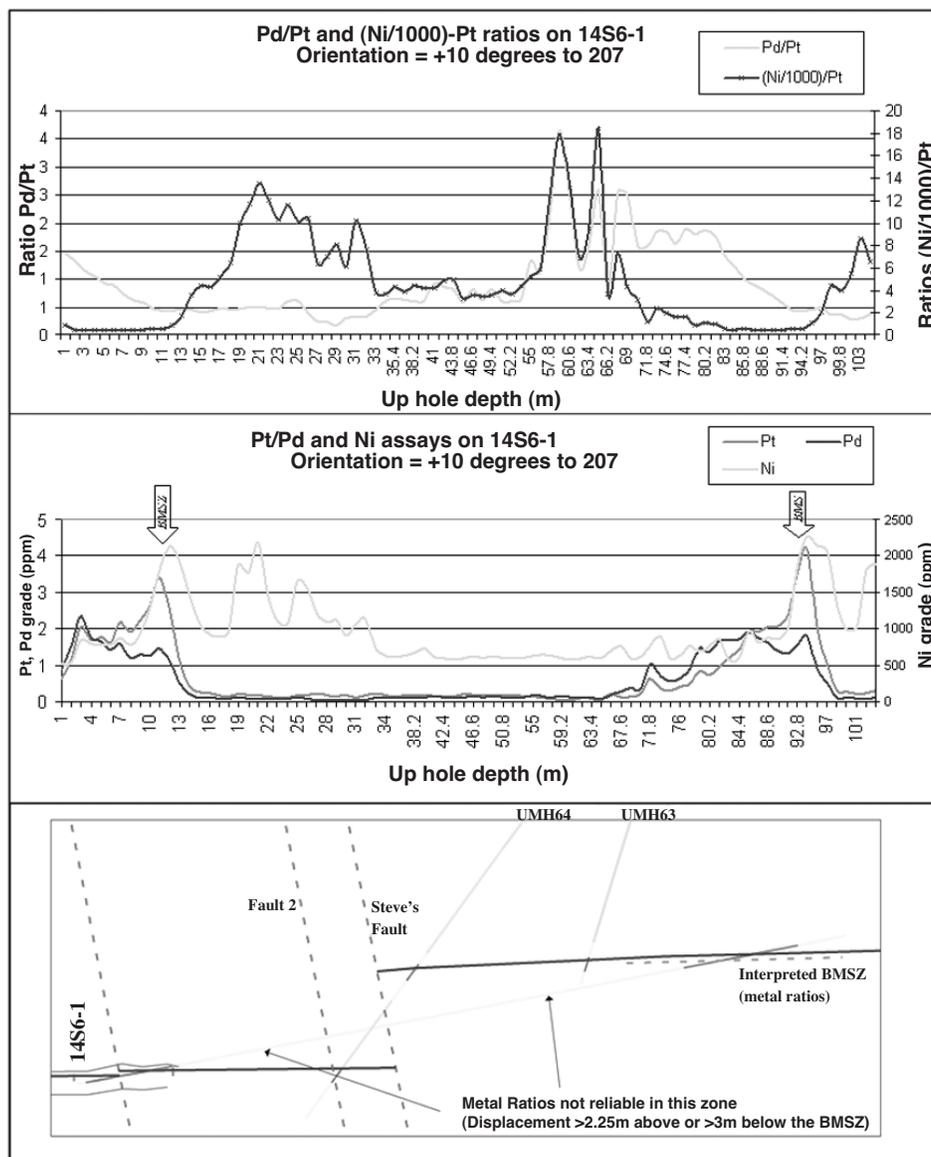


Figure 8 Sections along hole 14S6-1

Conclusion

The use of near layer parallel holes drilled from underground has been developed to give useful advance information ahead of mining. The information collected from horizontal holes is critical in predicting ground conditions and fault throws at Ngezi Underground Mine.

In future, long directional holes drilled from surface are planned so that even before portal development starts it will be possible to drill along the centre line of a decline or major roadway to determine the best angle of approach. If vertical surface holes were used, a large number of close spaced holes would be required to obtain the same information.

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