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The effect of mineralogical variation in the UG2 chromitite on recovery of platinum-  
group elements

by

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Platinum-group elements (PGEs) are recovered from UG2 chromitite by milling and flotation. The mechanisms involved during beneficiation of this type of ore are still poorly understood, partly because of its complex nature. Image-analysis techniques were used to characterise the mineralogy of UG2 chromitite from diverse geological environments, as well as the milling and flotation products derived from each of these ores.

Postmagmatic alteration of UG2 chromitite has a profound effect on the mineralogy, chemistry and recovery characteristics of the UG2 chromitite. Relatively unaltered UG2 chromitite consists predominantly of chromite and primary silicates, mostly bronzite and plagioclase with minor phlogopite, and small amounts of secondary silicates such as talc and chlorite. Trace quantities of base-metal sulphides, predominantly pentlandite, pyrrhotite and chalcopyrite  $\pm$  pyrite, generally occur at chromite-silicate grain boundaries. PGEs are present both as discrete PGE minerals, and, to a lesser extent, sub-microscopically in other phases, mostly palladium and rhodium in pentlandite.

The PGE mineral assemblage is characterised by sulphide minerals, mostly braggite, cooperite, nickeloan malanite and laurite, and is closely associated with the base-metal sulphides. Recovery of PGE minerals is strongly dependent on the degree of liberation, with liberated PGE minerals and PGE minerals associated with liberated

base-metal sulphides, the fastest-floating particles. PGE minerals report to flotation tailings predominantly as fine-grained inclusions in coarse silicate particles.

In places, the footwall rocks have been replaced by iron-rich ultrabasic pegmatoid. As a result of interaction with Fe- and Ti-rich fluids, the chromite grains in the UG2 chromitite have been enlarged due to sintering, and the PGE mineral assemblage replaced by one consisting predominantly of laurite, Pt-Fe alloy and other non-sulphide PGE minerals. The non-sulphide PGE mineral grains appear to be slower-floating than sulphide PGE minerals.

Low temperature hydrothermal alteration appears to have caused relatively widespread alteration of the UG2 chromitite in some areas, resulting in corrosion and redistribution of sulphide minerals, as well as the replacement of primary magmatic silicates by secondary silicates such as pumpellyite, epidote, prehnite, albite, talc, chlorite and quartz. Ore from such areas are characterised by a base-metal sulphide assemblage consisting predominantly of millerite, chalcopyrite, and pyrite. Base-metal sulphide and PGE minerals occur in fine-grained intergrowths with silicates, resulting in poor liberation. In the samples investigated, composite particles were often faster-floating than expected, at least partly due to the presence of naturally floatable talc.

The effect of faulting on the mineralogy of the UG2 chromitite probably depends on distance from the fault zone, and possibly also timing of faulting, and can cause cataclasis of the ore. Where cataclasis occurred, broken mineral grains are cemented by secondary, hydrous silicates. Liberation of base-metal sulphides and PGE minerals are poor, and recoveries consequently very low.

It was demonstrated that reasonable estimates of total PGE+Au recovery can be made from the mineralogical characteristics of UG2 chromitite ore. Based on the mineralogy of ore from a specific area, provision can be made for appropriate adjustments to metallurgical flowsheets.

## **Die effek van mineralogiese variasie in die UG2 chromitiet op herwinning van platinum-groep elemente**

deur

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Platinum-group elemente (PGE) word herwin uit die UG2 chromitiet deur middel van maling en flottasie. Die meganismes betrokke tydens opgradering van hierdie tipe erts word nog nie goed verstaan nie, deels as gevolg van die komplekse aard van die erts. Beeldanalise-tegnieke is ingespan om UG2 chromitiet vanaf verskillende geologiese omgewings te karakteriseer, asook die maal- en flottasieprodukte afkomstig uit elkeen van hierdie ertse.

Na-magmatiese verandering het dikwels 'n ingrypende effek op die chemie, mineralogie en herwinningseienskappe van die UG2 chromitiet. Relatief onveranderde UG2 chromitiet bestaan hoofsaaklik uit chromiet en primêre silikate, hoofsaaklik bronsiet en plagioklaas, met min flogopiet, en klein hoeveelhede sekondêre silikate soos talk en chloriet. Spoorhoeveelhede onedelmetaal-sulfiede, hoofsaaklik pentlandiet, pirrotiet en chalkopiriet  $\pm$ piriet, kom oor die algemeen gewoonlik voor langs chromiet-silikaat korrelgrense. PGE is teenwoordig beide as diskrete PGE mineraalkorrels, en, tot 'n mindere mate, submikroskopies, hoofsaaklik palladium en rhodium in pentlandiet.

Die PGE mineraal versameling bestaan sulfiedminerale, hoofsaaklik braggiet, cooperiet, nikkeldraende malaniet, en lauriet, en kom nou geassosieer met die onedelmetaal-sulfiede voor. Herwinning van PGE minerale hang grotendeels af van graad van bevryding, met bevryde PGE mineraalkorrels, en PGE minerale geassosieer met bevryde onedelmetaal-sulfiede die mees vinnigfloterende partikels. PGE

minerale in die flottasie uitskotte kom hoofsaaklik voor as fynkorrelrige insluitels in groot silikaatpartikels.

In sekere areas, is die vloergesteentes vervang deur ysterryke ultrabasiese pegmatoïed. As gevolg van die interaksie met Fe- en Ti-ryke vloeistowwe, is die chromietkorrels in die UG2 chromitiet vergroot deur 'n sinteringsproses, en die PGE mineraalversameling vervang deur een wat grootliks bestaan uit lauriet, Pt-Fe allooï, en ander nie-sulfied PGE minerale. Dit wil voorkom asof die nie-sulfied PGE minerale stadiger flotter as PGE sulfiedminerale.

Lae temperatuur hidrotermale verandering het in sekere gebiede relatief wydverspreide verandering van die UG2 chromitiet veroorsaak. Die resultaat is korrosie en herverspreiding van sulfiedminerale, asook die vervanging van primêre magmatiese silikaatminerale deur sekondêre silikaatminerale soos pumpelliet, epidoot, prehniet, talk, chloriet, kwarts en albiet. Hierdie monsters werk gekenmerk deur onedelmetaal-sulfiedversamelings wat bestaan hoofsaaklik uit milleriet, chalkopiriet en piriet. Onedelmetaal-sulfiede en PGE minerale kom fynvergroeid met silikate voor. Dit lei tot swak bevryding. In die monsters wat ondersoek is, is egter gevind dat saamgestelde partikels in hierdie monsters beter flotter as wat verwag is, deels as gevolg van die teenwoordigheid van natuurlik flotterende talk.

Die uitwerking van verskuiwings op die mineralogie van die UG2 chromitiet, hang waarskynlik af van die afstand vanaf die verskuiwingssone, en moontlik ook die stadium waarop die verskuiwing plaasgevind het, en kan kataklastiese teksture in die erts veroorsaak. Waar dit voorkom, is gebreekte mineraalpartikels deur sekondêre silikate gesementeer. Bevryding van onedelmetaal sulfiede en PGE minerale is gevolglik swak, en herwinning laag.

Totale PGE+Au herwinning kan redelik goed voorspel word uit die mineralogiese eienskappe van die UG2 chromitiet. Op grond van die mineralogie van erts afkomstig vanaf 'n spesifieke area, kan voorsiening gemaak word vir geskikte aanpassings aan metallurgiese vloekaarte.

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## CONTENTS

	<b>Page no.</b>
1. INTRODUCTION	1
1.1 Historical background	1
1.2 Reasons for undertaking this study	2
1.3 Previous work	4
1.4 Objectives	5
2. GEOLOGY AND REGIONAL SETTING	6
2.1 General	6
2.2 The Rustenburg Layered Suite	6
2.3 The UG2 chromitite layer	7
2.3.1 Undisturbed or normal UG2	9
2.3.2 UG2 with pegmatoid footwall	9
2.3.3 Iron-rich ultrabasic replacement pegmatoid	10
2.3.4 UG2 associated with pothole structures	11
2.3.5 Faulted and fractured UG2 chromitite	12
2.3.6 UG2 chromitite exposed to surface weathering	13
3. SAMPLING STRATEGY	14
3.1 Project outline	14
3.2 Sample collection	15
4. METHOD	19
4.1 Comminution	19
4.2 Froth flotation	19
4.2.1 General principles	19
4.2.2 Standard rate flotation tests	20
4.3 Chemical analysis procedures	24
4.4 Comparison of calculated and analysed feed grades	27
4.5 Mineralogical techniques	29
4.5.1 X-ray diffraction (XRD)	29
4.5.2 Preparation of polished sections	29

4.5.3 Optical microscopy	30
4.5.4 Scanning-electron microscopy (SEM) – Energy-dispersive X-ray spectrometry (EDS)	31
4.5.5 Electron-microprobe analysis	32
4.6 Image-analysis techniques	35
4.6.1 Introduction	35
4.6.2 Application of to UG2 feed and product samples – general principles	35
4.6.3 Modal analysis	46
4.6.4 Silicate and chromite grain-size distributions	49
4.6.5 Base-metal sulphide grain-size distribution and mode of occurrence	50
4.6.6 PGE mineral characterisation	51
5. RESULTS	66
5.1 Chemical composition	66
5.2 Mineralogy of crushed feed samples	77
5.2.1 Bulk modal analysis	77
5.2.2 Base-metal sulphide modal composition	77
5.2.3 Chromite textures and grain-size distributions	79
5.2.4 Other oxide phases	82
5.2.5 Silicate mineralogy	83
5.2.6 Base-metal sulphide mode of occurrence	88
5.2.7 Base-metal sulphide grain-size distribution	93
5.2.8 Modal distribution of PGE minerals	93
5.2.9 PGE mineral grain-size distribution	96
5.2.10 PGE mineral mode of occurrence	96
5.2.11 Chromite composition	98
5.2.12 Silicate compositions	99
5.2.13 Base-metal sulphide compositions	101
5.2.14 PGE mineral characteristics	107
5.3 Characterisation of milled feed samples	111
5.3.1 General	111



5.3.2	Chromite and silicate grain-size distribution	112
5.3.3	Base-metal sulphide	113
5.3.4	PGE minerals	113
5.4	Characterisation of flotation product samples	116
5.4.1	Chromite in flotation products	116
5.4.2	Silicate in flotation products	117
5.4.3	Base-metal sulphides in flotation products	120
5.4.4	Behaviour of PGE minerals during recovery	124
5.5	Milling behaviour	139
5.5.1	Milling curves	139
5.5.2	Screen analysis	139
5.6	Flotation behaviour	140
5.6.1	Mass recoveries	140
5.6.2	Cr <sub>2</sub> O <sub>3</sub> recoveries	140
5.6.3	Silicate gangue recoveries	141
5.6.4	Copper recoveries	141
5.6.5	Nickel recoveries	142
5.6.6	Total PGE+Au recoveries	144
5.6.7	Platinum, palladium and rhodium	145
6.	INTERPRETATION OF RESULTS	148
6.1	Identification of mineralogically and chemically different types of UG2 chromitite	148
6.2	PGE mass balance calculations	166
6.3	The effect of postmagmatic alteration processes on the UG2 chromitite.	169
6.3.1	Relatively unaltered UG2 chromitite	169
6.3.2	Sintered UG2 chromitite - the effect of Fe-rich ultrabasic replacement pegmatoid	171
6.3.3	Millerite-bearing UG2 chromitite - effects of low-temperature	172

hydrothermal alteration	
6.3.4 Cataclastic UG2 chromitite – the effect of faulting	174
6.3.5 Effect of pothole structures	174
6.4 Flotation behaviour of different types of UG2 chromitite	174
6.5 Interpretation of milling and flotation results	176
6.5.1 Factors affecting milling time	176
6.5.2 Mechanisms affecting gangue recovery	179
6.5.3 Base-metal sulphide and PGE mineral liberation	181
6.5.4 Flotation behaviour of base-metal sulphides	185
6.5.5 Flotation behaviour of PGE minerals	186
6.6 Prediction of PGE recovery based on mineralogical and chemical parameters	187
6.6.1 Relationship between flotation characteristics and selected mineralogical and chemical parameters in the ore prior to milling.	187
6.6.2 Predicting flotation parameters from crushed UG2 ore	201
6.6.3 Relationship between flotation characteristics and selected mineralogical parameters in milled ore.	211
6.6.4 Predicting flotation parameters from milled UG2 ore	215
6.6.5 Factors affecting the recovery of individual PGEs	217
7. DISCUSSION	221
7.1 Characterisation of PGE mineral-bearing particles	221
7.1.1 PGE minerals	221
7.1.2 Associated minerals	221
7.2 In situ trace-element analysis	222
7.2.1 Base-metal sulphide	222
7.2.2 Chromite	223
7.3 Effect of geological environment on mineralogy	223
7.4 Relating mineralogical characteristics to recovery	223
7.5 Concentrate grade	224

8.	SUMMARY AND CONCLUSIONS	225
8.1	Characterisation of UG2 ore and mineral processing products	225
8.2	Relating variations in mineralogy to geological environment	225
8.3	Factors affecting the flotation response of PGE mineral-bearing particles	227
8.4	Relating ore type to variations in flotation response	228
8.5	Relating the characteristics of PGE mineral-bearing particles to flotation parameters	229
8.6	Concluding remarks	229
9.	REFERENCES	231
APPENDIX A	Calculation of weighted mean atomic number ( $\bar{Z}$ ) and backscattered-electron coefficient ( $\bar{\eta}$ )	257
APPENDIX B	Ideal chemical formulae and densities of minerals in UG2 chromitite	258
APPENDIX C	Chromite grain-size measurements.	259
APPENDIX D	Electron microprobe analyses of selected chromite grains in samples A1, A4, B4 and C1.	262
APPENDIX E	SEM-EDS analyses of selected silicate grains reported as mass % oxide.	280
APPENDIX F	Electron-microprobe analyses of selected base-metal sulphide grains.	300
APPENDIX G	Electron-microprobe analyses of selected PGE mineral grains.	319
APPENDIX H	Mineralogical data for milled feed and flotation products.	324
APPENDIX I	Milling data	341
APPENDIX J	Flotation data	344
APPENDIX K	Multiple regression analysis results	379

## LIST OF ILLUSTRATIONS

	<b>Page no.</b>
<b>Figure 1</b> Geological sketchmap showing the distribution of the rocks of the Bushveld Complex.	7
<b>Figure 2</b> Stratigraphic succession of the Rustenburg Layered Suite.	8
<b>Figure 3</b> Cross section through a pothole structure in the UG2 ore.	12
<b>Figure 4</b> Outline of experimental treatment of 14 samples of UG2 ore.	14
<b>Figure 5</b> Lease boundaries of the main platinum-mining operations in the Western Bushveld Complex.	16
<b>Figure 6</b> Operator performing rate flotation tests.	21
<b>Figure 7</b> Time-recovery profile for Cu and PGE+Au from sample A1. The curves were fitted to the data using the modified Kelsall model.	24
<b>Figure 8</b> The Leica Cambridge morphochemical-analysis system	36
<b>Figure 9</b> Backscattered-electron image of UG2 ore	38
<b>Figure 10</b> Binary image of chromite	38
<b>Figure 11</b> Grey-level histogram of a backscattered-electron image of UG2 ore	40
<b>Figure 12</b> Grey-level histogram from grey level 116 to 255	40
<b>Figure 13</b> Graph of mean atomic number ( $\bar{z}$ ) against backscattered-electron coefficient ( $\eta$ ) for phases in UG2 flotation feed and products.	41
<b>Figure 14</b> Grey-level histogram of the image in Figure 9 before, and after grey image processing	42
<b>Figure 15</b> Examples of binary image processing tools used on UG2 ore	43
<b>Figure 16</b> % Relative error of the modal estimates of base-metal sulphide, chromite and silicate in crushed UG2.	47

<b>Figure 17</b>	% Relative error of the modal estimates of base-metal sulphide, chromite and silicate in milled UG2.	48
<b>Figure 18</b>	Effect of the number of polished sections of crushed UG2 measured, on % relative error in measured pentlandite and pyrite.	49
<b>Figure 19</b>	Flow diagram for automated PGE mineral search.	55
<b>Figure 20</b>	Flow diagram for semi-automated measurement and classification of PGE minerals.	57
<b>Figure 21</b>	The relationship between spatial resolution ( $\mu\text{m}$ per pixel) on a BSE image at different magnifications, and the number of fields of view required to cover area of a polished section.	58
<b>Figure 22</b>	Grain-size distribution of 4000 PGE mineral grains found in crushed UG2 chromitite.	59
<b>Figure 23</b>	Variation in $\Sigma(\text{Pt}+\text{Pd}+\text{Rh})$ calculated from the mineralogical composition depending on the number of PGE mineral grains recorded.	60
<b>Figure 24</b>	% Error in the calculated assay value at the 90% confidence limit associated with different numbers of PGE mineral grains.	61
<b>Figure 25</b>	Graphical representation of three PGE mineral-bearing particles illustrating the combined liberation index principle.	64
<b>Figure 26</b>	Volumetric proportions of base-metal sulphide minerals in fourteen samples of UG2 chromitite.	78
<b>Figure 27</b>	Chromite textures. Backscattered-electron image.	80
<b>Figure 28</b>	Sintered chromite grains with interstitial clinopyroxene and talc. Base-metal sulphides are pentlandite and chalcopyrite. Backscattered-electron image.	81
<b>Figure 29</b>	Cumulative chromite grain-size distributions of 14 samples	81

- based on area measurements on polished sections.
- Figure 30** Cataclastic chromite cemented by prehnite, quartz and chlorite. Bright grains are pentlandite. Backscattered-electron image. 82
- Figure 31** Complex oxide assemblage consisting of baddeleyite in the centre, rimmed by Zr-Ti-oxide, and rutile at the grain boundary of chromite and a fine-grained intergrowth of secondary hydrous silicates and sphene. Backscattered-electron image. 83
- Figure 32** Alteration of bronzite to talc along cleavage planes and grain boundaries. Backscattered-electron image. 86
- Figure 33** Resorbed grains of clinopyroxene and plagioclase (with dark chlorite veinlets) in amphibole (edenite). Backscattered-electron image. 86
- Figure 34** Zoned epidote crystal crosscutting pumpellyite rimmed by chlorite. Backscattered-electron image. 87
- Figure 35** Alteration of plagioclase to quartz, chlorite and sericite. Backscattered-electron image. 87
- Figure 36** UG2 chromitite consisting of rounded chromite grains in a matrix of plagioclase. Small base-metal sulphide grains occur at chromite - silicate grain boundaries. Backscattered-electron image. 89
- Figure 37** Pyrrhotite partially rimmed by pentlandite at a chromite – silicate grain boundary. A thin rim of prehnite separates sulphide from gangue. Backscattered-electron image. 89
- Figure 38** Pentlandite being replaced by pyrite along cleavage planes. Note the presence of a thin laurite parting at the grain boundary between chalcopyrite and pentlandite. Other PGE minerals present are braggite and malanite. Silicates are quartz and plagioclase. Backscattered-electron image. 90

<b>Figure 39</b>	Corroded base-metal sulphide grain consisting of millerite and siegenite in talc. Backscattered-electron image.	91
<b>Figure 40</b>	Corroded base-metal sulphide grain (chalcopyrite + millerite + pyrite) with zoned braggite. Silicates are orthopyroxene being altered to talc. Backscattered-electron image.	91
<b>Figure 41</b>	Corroded millerite grain associated with epidote. Other phases are phlogopite, albite and Ca-plagioclase. Backscattered-electron image.	92
<b>Figure 42</b>	“Skeletal chalcopyrite” associated with Ca-plagioclase, albite and pumpellyite. Backscattered-electron image.	92
<b>Figure 43</b>	Measured base-metal sulphide grain-size distributions in fourteen samples of crushed UG2 chromitite.	94
<b>Figure 44</b>	PGE mineral distribution in fourteen samples of UG2 chromitite.	95
<b>Figure 45</b>	PGE mineral grain-size distribution in fourteen crushed feed samples.	97
<b>Figure 46</b>	Mode of occurrence of PGE minerals in fourteen crushed samples of UG2 chromitite.	98
<b>Figure 47</b>	Composite sulphide grain consisting of pentlandite, chalcopyrite, millerite and pyrite with malanite (Pt-Rh-Cu-Ni-S) and Pd-Pb occurring at the grain boundary of chromite and bronzite being altered to talc.	106
<b>Figure 48</b>	Zoned Pt-Pd-S (more Pt-rich towards the rim) attached to Pt-Rh-Cu-Ni-S. Note the skeletal appearance of Pt-Rh-Cu-Ni-S at the grain edge. Associated sulphides are pentlandite and chalcopyrite. Some laurite inclusions are also visible. Backscattered-electron image.	108
<b>Figure 49</b>	Zoned Pt-Pd-sulphide (more Pt-rich towards the rim), laurite and malanite associated with a composite sulphide	109

- grain consisting of siegenite, millerite, pyrite and galena at the grain boundary of chromite and orthopyroxene being altered to talc. Small amounts of amphibole and pumpellyite are also present. Backscattered-electron image.
- Figure 50** Skeletal Pt-Rh-Cu-Ni-sulphide in pentlandite with pyrite at chromite -orthopyroxene→talc. Note the presence of braggite along the grain boundary of sulphide and crosscutting phlogopite. Backscattered-electron image. 109
- Figure 51** Pt-Rh-Fe alloy (brightest grains) associated with zoned laurite included in a composite chalcopyrite and pyrrhotite grain at the grain-boundary of silicate and chromite. Backscattered-electron image. 110
- Figure 52** Milled UG2 chromitite. Backscattered-electron image. 111
- Figure 53** Cataclastic UG2 milled to 80% <75µm. Backscattered-electron image. 112
- Figure 54** Mode of occurrence of PGE minerals in fourteen samples of UG2 chromitite milled to 80% <75µm. 114
- Figure 55** PGE mineral grain-size distribution of UG2 chromitite at <2mm and at 80% <75µm. 115
- Figure 56** Chromite grain size-distribution in flotation products of sample C1. 116
- Figure 57** Backscattered-electron image of a flotation concentrate sample. 117
- Figure 58** Coarse liberated chromite (chr) and silicate (sil) grains in flotation tailings. Backscattered-electron image. 118
- Figure 59** Silicate grain size-distribution in flotation products of sample C1. 118
- Figure 60** A comparison of time-recovery profiles for Fe-Mg-silicate, opx and talc, (blue) and Ca-Al-silicate, predominantly 119



- plagioclase, (red) in six samples.
- Figure 61** X-ray diffractogram from  $5^{\circ} 2\theta$  to  $15^{\circ} 2\theta$  for RC1 (rougher concentrate 1, 0-1 minutes), RC2 (rougher concentrate 2, 1-3 minutes) and RC3-5 (combined rougher concentrate 3, 4 and 5, 3-20 minutes) of sample C1. 120
- Figure 62** Base-metal sulphide grain-size distributions in composite flotation concentrates of samples A1, A3, A5, and B4. 121
- Figure 63** Base-metal sulphide liberation index in flotation concentrates of samples A1, A3, C1, C2, A4, A5 and B4. 122
- Figure 64** Millerite and chalcopyrite (bright grains) in flotation tailings with anorthite (an), pumpellyite (pu) and albite (alb). Backscattered-electron image. 123
- Figure 65** Relative proportions of chalcopyrite, pentlandite, pyrrhotite, pyrite and millerite in three flotation concentrates of samples from Areas A and B. 125
- Figure 66** Relative proportions of chalcopyrite, pentlandite, pyrrhotite, pyrite and millerite in three flotation concentrates of samples from Area C. 126
- Figure 67** Time-recovery profile for chalcopyrite (cpy), pyrite (py), pentlandite (pn), pyrrhotite (po) and millerite (mil) calculated from a composite of all the samples and assuming an ultimate sulphide recovery of 100%. 127
- Figure 68** Combined liberation index of PGE minerals (excluding laurite) in the combined flotation products of samples A1, A3, A4, A5, B4, C1 and C2. 127
- Figure 69** Mode of occurrence of PGE minerals (PGEM) in different flotation products based on combined data of seven samples. 128
- Figure 70** Liberated PGE mineral (bright grain in the centre of the image) in flotation concentrate. Backscattered-electron 129

	image.	
<b>Figure 71</b>	Liberated pentlandite grain with exsolved Pt-Rh-Cu-Ni-sulphide in flotation concentrate. Backscattered-electron image.	129
<b>Figure 72</b>	Braggite (br) grain attached to pentlandite (pn) with pyrite inclusions (slightly darker). Backscattered-electron image.	130
<b>Figure 73</b>	Grain-size distribution of liberated PGE mineral grains in the slow-, medium-, and fast-floating concentrate of samples.	133
<b>Figure 74</b>	Time-recovery curves for different PGE mineral phases. 'Other non-sulphide' refers to non-sulphide PGE minerals excluding Pt-Fe alloys.	134
<b>Figure 75</b>	Grain-size distributions of (Pt,Pd)-sulphide, (Pt,Rh,Cu,Ni)-sulphide, (Ru,Os,Ir)-sulphide and non-sulphide PGE minerals in UG2 chromitite.	137
<b>Figure 76</b>	Pt-Rh-sulpharsenide (bright grains) intergrown with epidote (ep), plagioclase (an) and pumpellyite (pu) in flotation tailings. Backscattered-electron image.	138
<b>Figure 77</b>	A comparison of the size distributions of PGE mineral-bearing particles with combined liberation index of <0.2 in the fast-, medium- and slow-floating concentrates and rougher tailings.	139
<b>Figure 78</b>	Milling curves for fourteen samples of UG2 chromitite	140
<b>Figure 79</b>	Cr <sub>2</sub> O <sub>3</sub> recoveries from sample A1 at 80% <75 μm, 65% <75μm and 30% <75μm.	141
<b>Figure 80</b>	Silicate recovery from fourteen UG2 chromitite samples milled to 80% <75 μm.	142
<b>Figure 81</b>	Time-recovery curves for copper from fourteen samples of UG2 chromitite milled to 80% <75μm.	143
<b>Figure 82</b>	Grade-recovery curves for copper for fourteen samples of	143

	UG2 chromitite milled to 80% <75µm.	
<b>Figure 83</b>	PGE+Au time-recovery curves for fourteen UG2 chromitite samples milled to 80% <75µm.	144
<b>Figure 84</b>	PGE+Au grade-recovery curves for fourteen UG2 chromitite samples milled to 80% <75µm.	145
<b>Figure 85</b>	Platinum time-recovery curves for fourteen UG2 chromitite samples milled to 80% <75µm.	146
<b>Figure 86</b>	Palladium time-recovery curves for fourteen UG2 chromitite samples milled to 80% <75µm.	146
<b>Figure 87</b>	Rhodium time-recovery curves for fourteen UG2 chromitite samples milled to 80% <75µm.	147
<b>Figure 88</b>	The distribution of selected chemical and mineralogical parameters between fourteen samples of UG2 chromitite.	149
<b>Figure 89</b>	Relationship between median chromite grain diameter (µm) and TiO <sub>2</sub> content for fourteen samples of UG2 chromitite.	158
<b>Figure 90</b>	Relationship between median chromite and base-metal sulphide (BMS) grain diameter.	159
<b>Figure 91</b>	Relationship between acid soluble copper and sulphur for fourteen samples of UG2 chromitite.	160
<b>Figure 92</b>	Relationship between nickel and sulphur for fourteen samples of UG2 chromitite.	160
<b>Figure 93</b>	Relationship between palladium and sulphur for fourteen samples of UG2 chromitite.	161
<b>Figure 94</b>	Relationship between palladium and copper for fourteen samples of UG2 chromitite.	161
<b>Figure 95</b>	Relationship between palladium and nickel for fourteen samples of UG2 chromitite.	162
<b>Figure 96</b>	Relationship between palladium and platinum for fourteen samples of UG2 chromitite.	163

<b>Figure 97</b>	Relationship between rhodium and palladium for fourteen samples of UG2 chromitite.	163
<b>Figure 98</b>	Relationship between rhodium and platinum for fourteen samples of UG2 chromitite.	164
<b>Figure 99</b>	Relationship between platinum and Cr <sub>2</sub> O <sub>3</sub> for fourteen samples of UG2 chromitite.	164
<b>Figure 100</b>	Relationship between rhodium and Cr <sub>2</sub> O <sub>3</sub> for fourteen samples of UG2 chromitite.	165
<b>Figure 101</b>	Relationship between palladium and Cr <sub>2</sub> O <sub>3</sub> for fourteen samples of UG2 chromitite.	165
<b>Figure 102</b>	Relationship between TiO <sub>2</sub> and Cr <sub>2</sub> O <sub>3</sub> for fourteen samples of UG2 chromitite.	166
<b>Figure 103</b>	Comparison of the flotation characteristics of fourteen samples of UG2 chromitite.	175
<b>Figure 104</b>	Relationship between Cr <sub>2</sub> O <sub>3</sub> content and time to reduce to 80% < 75µm in fourteen UG2 chromitite samples.	177
<b>Figure 105</b>	Relationship between chromite grain size (median equivalent circle diameter) and time to reduce to 80% < 75µm in fourteen UG2 chromitite samples.	177
<b>Figure 106</b>	% chromite recovery after 20 minutes flotation versus median chromite diameter in milled feed samples.	180
<b>Figure 107</b>	Relationship between actual and predicted base-metal sulphide liberation.	182
<b>Figure 108</b>	Relationship between % liberated PGE mineral at 80% < 75µm and the predicted PGE mineral liberation.	183
<b>Figure 109</b>	Effect of milling on base-metal sulphide (BMS) mineral median equivalent circle diameter (ECD).	184
<b>Figure 110</b>	Effect of milling on PGE mineral (PGEM) median equivalent circle diameter (ECD) based on % number of grains.	184

<b>Figure 111</b>	Relationship between mineralogical, chemical and flotation parameters.	194
<b>Figure 112</b>	Relationship between predicted PGE mineral liberation in flotation feed and % $R_f$ .	198
<b>Figure 113</b>	Relationship between predicted PGE mineral liberation in flotation feed and % $R_s$ .	199
<b>Figure 114</b>	Relationship between predicted PGE mineral liberation in flotation feed and % 100-U.	200
<b>Figure 115</b>	Comparison of observed and predicted values of $R_f$ based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio, amount of non-sulphide PGE mineral and PGE mineral grain diameter prior to milling.	204
<b>Figure 116</b>	Comparison of observed and predicted values of $R_f$ based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio and amount of non-sulphide PGE mineral.	205
<b>Figure 117</b>	Comparison of observed and predicted values of $R_f$ for samples from areas A and B based on predicted PGE mineral liberation, and amount of non-sulphide PGE mineral.	206
<b>Figure 118</b>	Comparison of observed and predicted values of $R_s$ based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio, amount of non-sulphide PGE mineral, PGEM grain diameter prior to milling, and chromite grain diameter prior to milling.	207
<b>Figure 119</b>	Comparison of observed and predicted values of $R_s$ based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio, amount of non-sulphide PGE mineral and PGEM grain diameter prior to	208

	milling.	
<b>Figure 120</b>	Comparison of observed and predicted values of $R_s$ based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio and amount of non-sulphide PGE mineral.	209
<b>Figure 121</b>	Comparison of observed and predicted values of 100-U based on predicted PGE mineral liberation, pentlandite/(pentlandite+millerite) ratio, base-metal sulphide grain size prior to milling.	210
<b>Figure 122</b>	Relationship between PGE mineral liberation in the milled flotation feed and % $R_f$ .	212
<b>Figure 123</b>	Relationship between PGE mineral liberation in milled flotation feed and % $R_s$ .	213
<b>Figure 124</b>	Relationship between PGE mineral liberation in milled flotation feed and % non-floatable fraction.	213
<b>Figure 125</b>	Comparison of observed and predicted values of $R_f$ based on PGE mineral liberation and amount of non-sulphide PGE mineral.	217
<b>Figure 126</b>	Comparison of observed and predicted values of $R_f$ based on PGE mineral liberation, amount of non-sulphide PGE mineral, base-metal sulphide liberation, pentlandite/(pentlandite+millerite) ratio, and median PGE mineral grain diameter before crushing.	218
<b>Figure 127</b>	Comparison of observed and predicted values of $R_s$ based on PGE mineral liberation, amount of non-sulphide PGE mineral and PGE mineral and chromite grain diameter prior to milling.	219

## LIST OF TABLES

	<b>Page no.</b>
<b>Table 3.1</b> Sample description.	17
<b>Table 4.1</b> Reagent additions and contact times.	21
<b>Table 4.2</b> Mass recoveries to rougher concentrate after 1, 3, 8 15 and 20 minutes of flotation for eighteen 1 kilogram subsamples of sample A1. Upper and lower confidence limits around the average were calculated for sets of six individual tests at the 95% confidence level using resampling statistics.	23
<b>Table 4.3</b> Model parameters of three replicate tests for PGE+Au and 90% confidence interval using the Student t-distribution	24
<b>Table 4.4</b> Chemical analysis techniques.	25
<b>Table 4.5</b> Analytical error calculated at the 95% confidence level for S, acid soluble Cu, total Ni , acid soluble Ni, PGE+Au (Pt+Pd+Rh+Au), Pt, Pd and Rh, over different ranges of concentration levels.	26
<b>Table 4.6</b> Analytical error calculated at the 95% confidence level for Cr, Fe, Mg, Al, Si, Ca and Ti (expressed as oxides) over different ranges of concentration levels.	27
<b>Table 4.7</b> A comparison of calculated and analysed PGE+Au, Pt, Pd and Rh feed grades for three subsamples of sample A1.	28
<b>Table 4.8</b> Elements (expressed as oxides) analysed for and standards used during quantitative EDS analysis of silicate minerals.	31
<b>Table 4.9</b> Detection limits (D.L.) (99% confidence level) and precision (95% confidence level) for oxides analysed.	32
<b>Table 4.10</b> Analytical reproducibility of S, Fe, Cu, Co and Ni in pyrrhotite, pentlandite, chalcopyrite, pyrite, millerite and siegenite calculated at the 95% confidence level from	34

duplicate analyses.

<b>Table 4.11</b>	Detection limits of Ru, Rh, Pd and Pt in ppm in pyrrhotite, pyrite, chalcopyrite, pentlandite and millerite calculated at the 99% confidence level.	34
<b>Table 4.12</b>	Mean atomic number ( $\bar{z}$ ), backscattered-electron coefficient ( $\eta$ ) and measured mean grey level (m.g.l.) of commonly found phases present in UG2 ore and product samples.	39
<b>Table 4.13</b>	Modal proportions of PGE minerals in sample A1 and the error associated with a sample of 200 grains.	62
<b>Table 4.14</b>	Mode of occurrence of PGE minerals in sample A1 crushed to <2mm and the precision associated with a sample of 200 grains.	63
<b>Table 4.15</b>	Mode of occurrence of PGE minerals in sample A1 milled to 80% <75 $\mu$ m and the precision associated with a sample of 200 grains.	63
<b>Table 4.16</b>	Combined liberation index of PGE minerals in sample A1 at 80% <75 $\mu$ m, and precision associated with a sample of 200 grains.	65
<b>Table 4.17</b>	Median grain diameter of PGE minerals in sample A1 at <2mm and 80%<75 $\mu$ m.	65
<b>Table 5.1</b>	Chemical, mineralogical, milling and flotation characteristics of fourteen samples of UG2 chromitite.	67
<b>Table 5.2</b>	Relative amounts of silicate minerals based on qualitative observations using optical and scanning-electron microscopy, as well as XRD analysis.	85
<b>Table 5.3</b>	Average chromite compositions of UG2 chromitite from samples A1, A4, C1 and B4.	100
<b>Table 5.4</b>	Average compositions of chalcopyrite in samples A1, B1 and C1 determined by electron-microprobe analysis.	102



<b>Table 5.5</b>	Average electron-microprobe analyses of pyrrhotite from samples A1 and B4.	103
<b>Table 5.6</b>	Average compositions of pyrite in samples A1, B4, C1, C2 determined by electron-microprobe analysis.	104
<b>Table 5.7</b>	Average compositions of millerite in samples C1 and C2 determined by electron-microprobe analysis.	105
<b>Table 5.8</b>	Average compositions of pentlandite in samples A1, B4 and C1 determined by electron-microprobe analysis.	107
<b>Table 5.9</b>	A comparison of acid soluble and total nickel values in two samples before and after rod milling.	112
<b>Table 5.10</b>	A comparison of grain-size distributions of PGE minerals in a composite of fourteen samples of UG2 feed crushed to <2mm and 80%<75µm.	116
<b>Table 5.11</b>	Combined liberated index distribution in the flotation concentrates (RC1, 0 to 1 minutes, RC2, 1 to 3 minutes, and RC3-5, 3 to 20 minutes) and tailings of selected samples.	131
<b>Table 5.12</b>	PGE mineral (excluding laurite) mode of occurrence in flotation products of samples A1, A3, C2, A5, C1, A4 and B4.	132
<b>Table 5.13</b>	Median grain diameter based on area % results of liberated PGE mineral grains in flotation products of seven samples.	134
<b>Table 5.14</b>	Flotation behaviour of different PGE minerals.	135
<b>Table 5.15</b>	% liberated PGE minerals as a fraction of (% liberated PGE mineral + PGE mineral associated with liberated base-metal sulphide) in the flotation concentrates of selected samples.	136
<b>Table 5.16</b>	Mode of occurrence of PGE minerals in particles with a combined liberation index of <0.2 in a composite of the flotation products of seven samples.	138
<b>Table 6.1</b>	Members and descriptive statistics for the mineralogical,	152

	chemical and flotation characteristics of each cluster.	
<b>Table 6.2</b>	Pearson correlation matrix for selected mineralogical and chemical parameters in fourteen samples of UG2 chromitite.	157
<b>Table 6.3</b>	A comparison of the PGE values in sample A1 calculated from the modal analysis with chemical assay values.	168
<b>Table 6.4</b>	Pearson correlation matrix for time in minutes to mill to 80% < 75 μm, Cr <sub>2</sub> O <sub>3</sub> content of the feed sample, chromite median grain diameter prior to milling, chromite median grain diameter after milling, silicate median grain diameter after milling, % chromite recovery after 1 minute, % chromite recovery after 20 minutes, % silicate recovery after 1 minute, % silicate recovery after 20 minutes.	178
<b>Table 6.5</b>	Correlation matrix of selected mineralogical and chemical parameters against R <sub>f</sub> , R <sub>s</sub> , 100-U, k <sub>f</sub> and k <sub>s</sub> .	189
<b>Table 6.6</b>	Regression summary for dependent variable R <sub>f</sub> with four independent variables. Fourteen samples.	204
<b>Table 6.7</b>	Regression summary for dependent variable R <sub>f</sub> with three independent variables. Fourteen samples.	205
<b>Table 6.8</b>	Regression summary for dependent variable R <sub>f</sub> with two independent variables. Samples from area C excluded.	206
<b>Table 6.9</b>	Regression summary for dependent variable R <sub>s</sub>	207
<b>Table 6.10</b>	Regression summary for dependent variable R <sub>s</sub> for four independent variables and excluding sample A5.	208
<b>Table 6.11</b>	Regression summary for dependent variable R <sub>s</sub> for three independent variables and excluding sample A5.	209
<b>Table 6.12</b>	Regression summary for dependent variable 100-U	210
<b>Table 6.13</b>	Regression summary for R <sub>f</sub> with PGE mineral degree of liberation and amount of non-sulphide PGE mineral as independent parameters.	216

- Table 6.14** Regression summary for  $R_f$  with PGE mineral degree of liberation, % non-sulphide PGE mineral, PGE mineral grain diameter before crushing, base-metal sulphide degree of liberation and pentlandite/(pentlandite+millerite) ratio as independent variables. 218
- Table 6.15** Regression summary for  $R_s$  based on PGE mineral liberation, amount of non-sulphide PGE mineral and PGE mineral and chromite grain diameter prior to milling. 219

## LIST OF ABBREVIATIONS

SEM – scanning-electron microscopy

EDS – energy-dispersive X-ray spectroscopy

IA – image analysis

XRD – X-ray diffraction

PGE – platinum-group element

PGEM – platinum-group mineral. This abbreviation was used rather than the more commonly accepted PGM to avoid confusion, as PGM is also used to indicate platinum-group metal.

BMS – base-metal sulphide

ECD – equivalent circle diameter

GB – grain boundary

Mintek – Council for Mineral Technology