ISCOR
flat steel

ISCOR VANDERBIJLPARK STEEL

ENVIRONMENTAL MASTER PLAN

SPECIALIST REPORT

GEOLOGY

VOLUME 1 OF 2

BY

JASPER MÜLLER ASSOCIATES

SERIES IV
DOCUMENT IVS/SR/028
DECEMBER 2002

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Draft for discussion
CONFIDENTIAL
Research for IVS

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FINAL

ISCOR VANDERBIJLPARK STEEL

MASTER PLAN SPECIALIST REPORT

IVS/SR/028

GEOLOGY

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EXECUTIVE SUMMARY

This report is one in a series of specialist Base Line Studies Reports compiled in fulfilment of the terms of reference for the compilation of an Environmental Master Plan for Iscor Vanderbijlpark Steel (IVS).

Although this report represents a stand-alone document, the results generated during this study will be integrated into the Environmental Management and/or Environmental Monitoring actions proposed in the IVS Master Plan.

This Geology base line report is somewhat different from other Master Plan specialist studies, in that geology does not represent a threatened environmental component in terms of possible IVS impacts. However, the geology does play important roles in at least two of the transport media responsible for impact migration/propagation. Pathways related to both soils and ground water are geology dependant.

Different levels of detail were generated during the geological study and compilation of the descriptions, to support the level of detail required for the different zones/areas. In addition to a description of the regional geology of the larger study area, descriptions of local geological conditions were compiled for Master Plan Zones, to support regulatory requirements, impact and risk assessments and selection and conceptualization of possible management measures.

The following actions were performed during this study:

- All available published and unpublished geological information relevant to the site was gathered and reviewed, and consultations were held with certain individuals on selected matters.
- A basic air photo interpretation, using the available aireal photographs, was performed for the Works Area in an attempt to delineate lineaments and structural futures.
- Different phases of geophysical investigations were performed to investigate the lithological and structural distribution within the area.
- The Council for Geoscience also performed a Seismic Hazard Assessment for the area.
- Information obtained from the drilling of a large number of boreholes in 2001, was collated, computerized and interpreted.
- Extensive use was made of GIS and other visualization technologies for the compilation of the geological descriptions.

Although not part of a typical geological description, miscellaneous sub-surface issues related to undermined areas, earth tremors, rehabilitated open-cast mining, potential for future mining and sinkholes and surface subsidence, were also addressed, as they are a requirement of the "Minimum Requirements" process of DWAF, for the compilation of Permit Application Reports related to solid waste disposal.

In this regard the following conclusions are relevant:

- No area within the study area is undermined.

- According to the Seismic Hazard maps for Southern Africa, a probability of 10% exists that a horizontal Peak Ground Acceleration of between 100 cm/s^2 and 200 cm/s^2 (0,1 *g* to 0.2 *g*) will be exceeded at least once every 50 *years* at the Vanderbijlpark Steel Works. It should be noted that this is only a basic hazard assessment and is by no means complete – such a study may only be undertaken after a statistical evaluation of all the earthquake occurrences in the study area. Furthermore the blasting in South Africa's coal mining areas, some of which are close to Vanderbijlpark, was neglected in this study.

- Open-cast mining activities in the study area relate predominantly to coal mining, with additional clay and gravel quarry activities. It can therefore be stated that no current or rehabilitated open-cast mines occur within, or in close proximity (<1000 *m*) to the Study Area. The extent of gravel excavations within the Kiewiet footprint area, is rated as insignificant in terms of this assessment.

- The potential for future mining within a 1000 *m* radius of the study area, is insignificant. The economically mine-able coal seams mined north and south of the Vaal River, east of Vereeniging town, is not present within the study area.

- Due to the fact that no undermining has occurred on the site, and due to the lithological succession underlying the site (geo-technical stable units of the Transvaal Sequence), sinkholes and surface subsidence will not occur within the study area.

The regional geology for the area, which of course also relates to the local geology, comprise of formations belonging to the Transvaal System. Ascending the lithostratigraphic chronological order, the area is underlain by the following:

- Chuniespoort Group - Malmanie Subgroup- Dolomite, chert and remnants of chert breccia of the Rooihoogte Formation - exposures indicated some 2,75 *km* east of the IVS Work's eastern boundary. Dolomite of the Malmanie Sub-group is known as the host rock of South Africa's major secondary aquifers.

- Pretoria Group - Timeball Hill Formation - Ferruginous shale, hornfels, ferruginous quartzite.

- Pretoria Group - Hekpoort Formation - Andesite, agglomerate, tuff.

- Pretoria Group - Strubenkop Formation - Ferruginous shale, quartzite.

- Pretoria Group - Daspoort Formation - Quartzite and shale, ferruginous in places - exposures are indicated to arch concavely around IVS's Evaporation Ponds Dams 1 to 4, and the Maturation Ponds 1 to 3, the arch being to the east, basically striking north-south to some 400 *m* south of the Maturation Ponds.

- Pretoria Group - Silverton Formation - Shale with inter-bedded quartzite, hornfels, limestone.

- Marico Diabase Suite - The Marico Diabase Suite, which is probably related to an early intrusive phase of the Bushveld Complex. Informally and collectively referred to as Transvaal diabase, these rocks are intrusive into all horizons of the Transvaal Sequence, mainly on the southern side of the Bushveld Complex and more particularly on the south-eastern side.

- Prominent detrital deposits, consisting of gravels in a sandy or clayey matrix, are found along the Vaal River valley between Prieska and Potchefstroom, with isolated deposits found as far east as Standerton. Shallow deposits occur up to 30 *km* from, and as much as 120 *m* higher than the current river bed. Gravel consist of chert, quartzite, red jaspis, banded iron stone, lidianite, quartz, chalcedony, and bantams.

- Deep gravel deposits, representing gravel filled paleo-canals, occur close to the current river bed but can also be found much further afield and much higher. The Droogeveld canal south of the confluence between the Vaal and Harts Rivers, is a good example of such a canal.

- Gravel deposits are indicated on the geological sheet for the area, to occur on Rietkuil 551 IQ, the Steelvalley Agricultural Holdings and within the IVS property itself.

- Residual soils which developed on the sedimentary rocks. As a general observation it may be stated that residual soils formed from the Pretoria sedimentary strata, are shallow, often less than 2 *m* thick, and that they commonly consist entirely of inert minerals.

- Residual soils which developed on the andesites.

- Residual soils which developed on the Transvaal Diabase.

- Aeolian sand. Occurrences indicated on the geological sheet for the Vanderbijlpark area, seem to be restricted to the banks of the Vaal River, mainly the southern banks.

- Alluvium. Occurrences are indicated along the Rietspruit to the west of the works, the Leeuwspruit east of the Works and the Vaal River to the far south.

The main structural features present in the area, relate to faults and dolerite dykes:

- A major fault transects the area with a horizontal displacement of ~ 2 *km*. The Daspoort Formation exposures, around Vanderbijlpark Steel's Evaporation Ponds Dams 1 to 4, and Maturation Ponds 1 to 3, to some 400 *m* south of the Maturation Ponds, is displaced by a near vertical "sinistral wrench" fault displacing the strata in access of 2 *km* to the south-east and outside of the IVS property.

- From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of the property, the arch being to the north-west.

- The larger study area is bounded in the north and the south by two major east-west orientated dolerite dykes, inferred from the 1 *km* line spacing, regional aeromagnetic coverage of South Africa, and indicated on the geological sheet for the area as lineaments, or possible dykes, that can be traced over distances in excess of 40 *km*.

The formations exposed within the IVS property north of the displacement fault zone, is indicated to dip 14 *degrees* to the west, in the opposite direction of the arch, and perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, roughly in the same direction of the arch, perpendicular to the strike.

Rock sampling for analyses has not been part of the Master Plan Study scope of work. The geochemistry of the sedimentary rock of the Pretoria Group shows evidence of complex source terrains, with predominantly granitic and sedimentary sources, as well as, possibly, ultra-mafic sources. The geochemical signature of the Pretoria Group sediments is indicative of a divergent margin tectonic setting (intra-cratonic sag, failed rift/aulacogen or passive margin).

Geological impact assessments are not per se indicated as a requirement for any of the above, as the activities within the greater IVS area, relate primarily to waste and effluent management, and not mining.

An Integrated Impact Statement of **Insignificant** (Does not require further assessment/discussion) is applicable to the area.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the statement of **Management Objectives**.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the discussion of **Available Management Options**.

As no Environmental Management Measures for **geology** are required, no funds have to be allocated for on-going geological impact management.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for a geological monitoring system.

Respectfully submitted

Jasper L. Muller (PrSciNat) (Senior Partner : Managing and Consulting)	Riaan Grobbelaar (PrSciNat) (Associate : Geohydrology)

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1. INTRODUCTION

This report is one in a series of specialist Base Line Studies Reports compiled in fulfilment of the terms of reference for the compilation of an Environmental Master Plan for Iscor Vanderbijlpark Steel (IVS).

Although this report represents a stand-alone document, the results generated during this study will be integrated into the Environmental Management and/or Environmental Monitoring actions proposed in the IVS Master Plan.

This Geology base line report is somewhat different from other Master Plan specialist studies, in that geology does not represent a threatened environmental component in terms of possible IVS impacts. However, the geology does play important roles in at least two of the transport media responsible for impact migration/propagation. Pathways related to both soils and ground water are geology dependant.

The geological study and report, was designed to give fulfilment with several Regulatory Processes (Minimum Requirements, EIA etc.), both in terms of study/report material content and report format.

2. APPROACH AND METHODOLOGY

2.1 THE INVESTIGATING TEAM

The following JMA personnel were involved in compiling the geological descriptions:

Jasper L. Muller (PrSciNat)	M.Sc. (Geohydrology)
Louis J. Botha (PrSciNat)	M.Sc. (Geohydrology)
Jaco J. van der Berg (PrSciNat)	M.Sc. (Geohydrology)
Riaan Grobbelaar (PrSciNat)	M.Sc. (Geohydrology)
Louis J. van der Walt (PrSciNatTnl)	National Diploma (Geology)
Cas J. H. Erasmus	Senior Geotechnician with JMA

2.2 EXTENT AND DETAIL OF INVESTIGATION

Different levels of detail were generated during the geological study and compilation of the descriptions, to support the level of detail required for the different zones/areas. In addition to a description of the regional geology of the larger study area, descriptions of local geological conditions were compiled for Master Plan Zones, to support regulatory requirements, impact and risk assessments and selection and conceptualization of possible management measures.

2.3 LIAISON WITH AUTHORITIES

DWAF and DACEL are represented on the IVS Master Plan Steering Committee.

3. SCOPE AND TERMS OF REFERENCE

The primary aim of this report is to provide sufficiently quantitative geological base line information required for environmental management purposes at Iscor Vanderbijlpark - Steel (IVS) and was compiled by JASPER MÜLLER ASSOCIATES (JMA) as a Specialist Base Line Study Report in support of the IVS Environmental Master Plan.

The exact requirements for the geological descriptions may differ from site to site within the larger Works Area, dependant mainly on the statutory processes which have to be supported during license/permit applications for the different sites/areas.

Furthermore it should be noted that in addition to the required base line description, the geological descriptions given should also support impact assessment where necessary, if not primarily for geology, then definitely for related environmental components such as soils and ground water.

Subject to what was stated directly above, the terms of reference for this geological description can be summarized as follows:

- Compile regional geological description.
- Compile local geological descriptions which will support regulatory information requirements, as well as technical support requirements for management measure selection and implementation, for the different Master Plan Management Areas.

4. ACTIONS PERFORMED

The following actions were performed in order to fulfil the stated terms of reference:

- All available published and unpublished geological information relevant to the site was gathered and reviewed, and consultations were held with certain individuals on selected matters.

  Published References:

  The following publications were used extensively during compilation of the regional geological description:

  - Bosh, P (*1997*). Geological map of the 2627 DB Vereeniging sheet. Publication of the Council for Geoscience.
  - Duval, J.S. (*1983*). Composite colour images of aerial gamma-ray data. Geophysics 48, p72-73.
  - Fernandez, L.M. and Du Plessis, A. (*1992*). Seismic Hazard maps for Southern Africa. Geological Survey, Pretoria, South Africa.
  - Hofgaard, J. (*1997*). A new processing technique for airborne gamma-ray spectrometer data (noise adjusted singular value decomposition). In Am Nucl. Soc. Sixth topical meeting on Emergency Preparedness and Response, pages 22-25, San Francisco, April 1997.

- Kamentsky, F.V., Novikkov, P.V. and Timofee, V.M. (*1995*). O vozmozhnosti fiziches-kogo modelirovaniya elektromagninogo polya v provodyatschei polarizuyu-tscheisya srede. Izevestiya AN RAN: seriya Fizika Zemli, 5: 46-54 (*in Russian*)
- South African Committee for Stratigraphy (**SACS**) (*1980*). Stratigraphy of South Africa. Part 1(Comp. L. E. Kent). Litho-stratigraphy of the Republics of South Africa, Namibia and the Republics of Bophuthatswana, Transkei and Venda: Handb. Geol. Surv. S. Afr.8
- Truswell, J. F. (*1977*). The Geological Evolution of South Africa.
- Zadorozhnaya, V. And Bessonov, A. (*2001*). The IP effect as indicator of hydrocarbon pollution in groundwater. Abstract. XXVI General Assembly, European Geophysical Society, Nice.

Personal Communication:

Dr E.H. Stettler and Mr Stefan Laubscher from the Council for Geoscience (CGS) were consulted extensively with respect to the geological description of the Vanderbijlpark area.

Unpublished Reports:

Reports reviewed discuss the geology in varying degrees of detail The regional geology for the greater IVS study area is well understood. However, some of the later reports clearly indicate the requirement for detailed localized geological knowledge (weathering status, fracture intersections and stratigraphic traps). In addition to the publications listed above, the following reports containing geological information for the site, were perused:

- Report on the influence of evaporation and maturation dams on the groundwater regime at the Vanderbijlpark Works - (SRK). [PT.2938/2]
- Ground Water Contamination Problem - North West Corner of the Vanderbijlpark Works - (SRK). [MI.5039]
- Ground Water Flow Modelling of the influence of the evaporation dams and TETP canal on groundwater levels adjacent to the Iscor Vanderbijlpark Steel Works - Phase I Geohydrological Investigation (Geohydrological Services - IMCS)
- Integration of Mass Transport and Groundwater Flow Modelling Data around the Vanderbijlpark Steel Works - Geohydrological Investigation (Geohydrological Services - IMCS).
- Ground Water Management Measures for Containment of the Sub-surface tar spill (M. Simonic - Hydromedia Solutions).
- Permeability Investigation of Materials from Kiewiet Disposal Landfill - Iscor Vanderbijlpark Works (Geotechnical Services - IMCS).

• A basic air photo interpretation, using the available aireal photographs, was performed for the Works Area in an attempt to delineate lineaments and structural futures.

- Different phases of geophysical investigations were performed to investigate the lithological and structural distribution within the area.

    - Airborne survey whereby magnetic, gamma-ray radiometric, near-infra-red spectrometric and elevation data was collected - Council for Geoscience - report attached in **APPENDIX I**.
    - A ground survey where gravity data and seismic reflection data was collected - Council for Geoscience - report attached in **APPENDIX I**.
    - Experimental time domain electromagnetic (TD EM) technique was used to determine whether the Non-Aqueous Phase Liquids (NAPL) presence at shallow depth (0-40m) provides a measurable Induced Polarization (IP) effect - Council for Geoscience - report attached in **APPENDIX I** .
    - Several ground magnetic, EM and gravity surveys were performed to delineate regional structural geological features such as faults and dykes in localized areas, prior to, and during siting of a number of ground water monitoring boreholes within the IVS perimeter as well as in areas around the site - Council for Geoscience and JMA. Locality maps and results are attached in **APPENDIX II** and **APPENDIX III**.

- The Council for Geoscience also performed a Seismic Hazard Assessment for the area. A map showing earthquakes with a magnitude larger than M_L 4.7 in the area, as well as a list listing earthquakes with a magnitude of M_L 4.7 and larger, are attached in **APPENDIX II**.

- Information obtained from the drilling of a large number of boreholes in 2001, was collated and interpreted. The following list gives actions performed relating to the drilling program:

    - The status of existing boreholes was verified during the first action - gather existing info - boreholes that were found to be serviceable, were included into the Monitoring System.
    - GIS base maps needed for reporting and monitoring, were compiled.
    - Planning of field investigation was done.
    - Borehole siting was performed. Siting was optimized to make use of existing serviceable boreholes.
    - The boreholes were drilled in pairs of one deep (35 *m*) and one shallow borehole (5*m*).
    - Continuous geohydrological profiling was performed during drilling.
    - EC profiling of water columns in boreholes was performed after a 2-3 weeks stabilization period, after which sampling horizons were selected.
    - The boreholes were surveyed for Y-coordinates, X-coordinates and elevation.
    - All data collected was computerized and verified in an Aquabase database.
    - Geological information generated during other recent studies in the area, was also assimilated into the data base.

- Once in the data base, geological reports and profile plots were generated.

The following information generated is attached in **APPENDIX IV**:

- Maps indicating borehole localities.
- Site Information Reports containing information on borehole locality, borehole construction (depth, diameter, casing), aquifer characteristics, geology and ground water levels.
- Borehole Construction and Geological Logs.

- Extensive use was made of GIS and other visualization technologies for the compilation of the geological descriptions. Various maps and geological cross sections are attached in **APPENDIX V** (regional geology) and **APPENDIX VI** (local geology).

5. MISCELLANEOUS SUB-SURFACE ISSUES

Although not part of a typical geological description, the following aspects will be addressed shortly as it is a requirement of the "Minimum Requirements" process of DWAF, for the compilation of Permit Application Reports related to solid waste disposal.

5.1 UNDERMINED AREAS

No area within the study area is undermined and therefore no delineation and examination to establish the effect on the ground water flows and potential subsidence is necessary. It can be stated that no undermining has occurred within, underneath or even in close proximity (< 1000 *m*) to the Study Area.

5.2 EARTH TREMORS

An event search up to December 2000 was undertaken using the South African Earthquake Databank. The study area is defined as 28° 30'S to 25° 30'S and 26° 00' E to 29° 00' E. **FIGURE II-2** attached in **APPENDIX II**, shows a map of the area indicating the earthquakes with magnitudes larger than or equal to M_L=4,7. **DATASET II-2, APPENDIX II** lists all earthquakes of magnitude 4,7 and larger from the South African earthquakes databank, up to December 2000.

All these large earthquakes are associated with South Africa's gold mining areas. Hence, the largest hazard comes from the mine-induced seismicity, whereas the hazard for natural, tectonic earthquakes is low.

The Council for Geoscience (formerly known as the Geological Survey of South Africa) started producing seismological bulletins in 1971. Hence, large earthquakes almost certainly occurred before 1971 but were not reported. The following is a statement made by the Council for Geoscience:

"According to the Seismic Hazard maps for Southern Africa, a probability of 10% exists that a horizontal Peak Ground Acceleration of between 100 cm/s^2 and 200 cm/s^2 (0,1 *g* to 0.2 *g*) will be exceeded at least once every 50 *years* at the Vanderbijlpark Steel Works.

Note the following:

- This is only a basic hazard assessment and is by no means complete – such a study may only be undertaken after a statistical evaluation of all the earthquake occurrences in the study area.

- The blasting in South Africa's coal mining areas, some of which are close to Vanderbijlpark, is neglected in this study."

The possibility that near surface conditions, under unfavorable conditions, may amplify the seismic waves and thus increase the seismic hazard to the IVS, is not considered here.

5.3 REHABILITATED OPEN-CAST MINES

Open-cast mining activities in the study area relate predominantly to coal mining, with additional clay and gravel quarry activities. It can therefore be stated that no current or rehabilitated open-cast mines occur within, or in close proximity (<1000 *m*) to the Study Area.

The extent of gravel excavations within the Kiewiet footprint area, is rated as insignificant in terms of this assessment.

5.4 POTENTIAL FOR FUTURE MINING

The potential for future mining within a 1000 *m* radius of the study area, is insignificant. The economically mine-able coal seams mined north and south of the Vaal River, east of Vereeniging town, is not present within the study area.

5.5 SINKHOLES AND SURFACE SUBSIDENCE

Due to the fact that no undermining has occurred on the site, and due to the lithological succession underlying the site (geo-technical stable units of the Transvaal Sequence), sinkholes and surface subsidence will not occur within the study area.

6. DESCRIPTION OF THE CURRENT SITE GEOLOGY

A wealth of geological information is available for the Vanderbijlpark area. In addition to the published geological maps and memoirs for the region, local geological information was obtained from the available geohydrological study reports as well as from information generated during the recent (monitoring borehole) drilling program.

Information generated for the geological descriptions, are attached in **APPENDIX V** (regional geology) and **APPENDIX VI** (local geology). APPENDIX VI comprise geological cross sections as well as a geological map for each of the Master Plan Zones.

6.1 REGIONAL GEOLOGY

The regional geology will be discussed at the hand of the regional geological map attached as **FIGURE V-1** in **APPENDIX V**. This map represents a JMA compilation of the regional/local geology based on inter alia the formal published 1:250000 geological map for the area, supplemented with local geological information generated during the Master Plan geophysical surveys and borehole drilling program. This map has been verified provisionally with inputs from the Council for Geoscience.

6.1.1 Lithology

The Transvaal System is exposed in three individual basins, in the northern Cape, in the central Transvaal, roughly around the Bushveld Complex and in the Potchefstroom Synclinorium.

The Potchefstroom Synclinorium is situated in the southern Transvaal and arches concavely south of Johannesburg, past Potchefstroom, until it disappears under the Karoo deposits on the other side of the Vaal River.

Sedimentary/Igneous rocks

Ascending the lithostratigraphic chronological order, the area is underlain by the following:

- Chuniespoort Group - Malmanie Subgroup- Dolomite, chert and remnants of chert breccia of the Rooihoogte Formation - exposures indicated some 2,75 *km* east of the IVS Work's eastern boundary. Dolomite of the Malmanie Sub-group is known as the host rock of South Africa's major secondary aquifers.

- Pretoria Group - Timeball Hill Formation - Ferruginous shale, hornfels, ferruginous quartzite.

- Pretoria Group - Hekpoort Formation - Andesite, agglomerate, tuff.

- Pretoria Group - Strubenkop Formation - Ferruginous shale, quartzite.
- Pretoria Group - Daspoort Formation - Quartzite and shale, ferruginous in places - exposures are indicated to arch concavely around IVS's Evaporation Ponds Dams 1 to 4, and the Maturation Ponds 1 to 3, the arch being to the east, basically striking north-south to some 400 *m* south of the Maturation Ponds.

- Pretoria Group - Silverton Formation - Shale with inter-bedded quartzite, hornfels, limestone.

Intrusive rocks

The following rocks occur intrusively in the sedimentary/igneous formations:

- Marico Diabase Suite - The Marico Diabase Suite, which is probably related to an early intrusive phase of the Bushveld Complex, comprises three distinct lithological types:

    - Maruleng Diabase: dolerite dykes and sills, often of noritic composition.
    - Lydenburg Diabase: hornblende-bearing dolerite dykes and sills often of gabbroic composition.
    - Wanhoop Diorite: dioritic dykes of calc-alkaline affinity.

    Informally and collectively referred to as Transvaal diabase, these rocks are intrusive into all horizons of the Transvaal Sequence, mainly on the southern side of the Bushveld Complex and more particularly on the south-eastern side. The Maruleng Diabase sills are largely confined to the margin of the Bushveld Complex, while the Lydenburg Diabase occurs farther out. The diabase sills vary in thickness from 1 *m* to over 300 *m*. They are particularly prolific in the strata of the Pretoria Group where intrusion of the thicker sills occurred, characteristically at the contact between shales and quartzites and often over long distances of strike.

Gravel (diamondiferous in places)

- Prominent detrital deposits, consisting of gravels in a sandy or clayey matrix, are found along the Vaal River valley between Prieska and Potchefstroom, with isolated deposits found as far east as Standerton. Shallow deposits occur up to 30 *km* from, and as much as 120 *m* higher than the current river bed. Gravel consist of chert, quartzite, red jaspis, banded iron stone, lidianite, quartz, chalcedony, and bantams. A red matrix are normally associated with the shallow gravels and not with the deeper gravel horizon.

- Deep gravel deposits, representing gravel filled paleo-canals, occur close to the current river bed but can also be found much further afield and much higher. The Droogeveld canal south of the confluence between the Vaal and Harts Rivers, is a good example of such a canal.

- Gravel deposits are indicated on the geological sheet for the area, to occur on Rietkuil 551 IQ, the Steelvalley Agricultural Holdings and within the IVS property itself.

Soil cover

Soil cover comprise the following:

- Residual soils which developed on the sedimentary rocks. As a general observation it may be stated that residual soils formed from the Pretoria sedimentary strata, are shallow, often less than 2 *m* thick, and that they commonly consist entirely of inert minerals. It is true also of most occurrences of shale, particularly where these have given rise to residual soils which are red or yellow in color. X-ray analyses of such residual and weathered shales show very little variation in the mineral content, the main constituents being quartz, kaolinite, hydrous mica and mica with sub-ordinate feldspar and iron oxides and sometimes chlorite (Loubser, 1967).

- Residual soils which developed on the andesites. The Hekpoort Andesites of the Transvaal Sequence occur within Thornthwaite's sub-humid warm, to humid warm climatic regions, where Weinert's climatic N-value is less than 5. Chemical decomposition is the dominant mode of weathering and this produces residual soils which are commonly expansive. The bulk of the soil profile, both red and yellow zones, contain active clays. The red soils are more active than the yellow ones lower in the profile, in spite of the fact that the red soils represent a more advanced stage in the weathering sequence. This is clearly due to the progressive decrease in clay content with depth below the surface. Thus the color change from red to yellow soil cannot be taken as the boundary between potentially expansive and non-expansive soils, it merely represents a transition from dehydrated to hydrated iron oxides. An interesting feature about the Hekpoort Andesite is the extreme variability in depth, and in the degree of decomposition over relatively short distances, controlled by joint spacing.

- Residual soils which developed on the Transvaal Diabase. As occurrences of the Transvaal diabase are confined to the warm and relatively humid climatic zones, i.e. Thornthwaite's sub-humid warm, to humid warm climatic regions (Schulze, 1958), or Weinert's climatic N-value range of 5 to less than 2 (Weinert, 1964), chemical decomposition is usually far advanced and residual soils thus relatively deep.
  The similarity between the development of the soil profile and the engineering characteristics of these residual soils and those developed on the older Hekpoort Andesite of the Pretoria Group is remarkably close.

  The sequence of development of secondary minerals has also been shown to be the same for soils derived from these two different parent materials under similar climatic and topographic environments (Van der Merwe, 1964a).

As can be seen on the geological sheet for the area, the Transvaal Sequence is disguised underneath a soil cover over a large area between Vereeniging and Potchefstroom.

- Aeolian sand. Occurrences indicated on the geological sheet for the Vanderbijlpark area, seem to be restricted to the banks of the Vaal River, mainly the southern banks.

- Alluvium. Occurrences are indicated along the Rietspruit to the west of the works, the Leeuwspruit east of the Works and the Vaal River to the far south.

6.1.2 Regional Geological Contacts

The Iscor Vanderbijlpark Steel property is located on Transvaal Sequence strata exposed in the Potchefstroom Synclinorium.

The Transvaal Sequence strata underlying the greater Vanderbijlpark Steel area, described at the hand of the mapped Daspoort Formation exposures, strikes concavely, arching in a north-south direction around IVS's Evaporation Ponds Dams 1 to 4, and Maturation Ponds, to some 400 *m* south of the Maturation Ponds, the arch being to the east.

6.1.3 Faults

A major fault transects the area with a horizontal displacement of ~ 2 *km*. The Daspoort Formation exposures, around Vanderbijlpark Steel's Evaporation Ponds Dams 1 to 4, and Maturation Ponds 1 to 3, to some 400 *m* south of the Maturation Ponds, is displaced by a near vertical "sinistral wrench" fault displacing the strata in access of 2 *km* to the south-east and outside of the IVS property.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of the property, the arch being to the north-west.

6.1.4 Dykes

The larger study area is bounded in the north and the south by two major east-west orientated dolerite dykes, inferred from the 1 *km* line spacing, regional aeromagnetic coverage of South Africa, and indicated on the geological sheet for the area as lineaments, or possible dykes, that can be traced over distances in excess of 40 *km*.

The northern dyke, from west to east, cuts through the R568's interchange with the N1 Johannesburg highway, some 600 *m* north of the Louisrus smallholdings, through the Linkholm smallholdings, approximately 400 *m* north of the Steelvalley smallholdings, through the southern portion of IVS's Evaporation Ponds Dams 1 to 4, just north of the Existing Waste Dump, through the southern portion of the Kiewiet area, through the suburb Steel Park and the Malmanie Subgroup dolomite and chert exposures indicated some 2,75 *km* east of the IVS property's eastern boundary, and onwards to the east. This dyke has been displaced in several places, including a displacement in the vicinity of the R553, some 400 *m* north of the Steelvalley smallholdings.

The southern dyke, from west to east, cuts through the Vanderbijlpark airfield some 1,4 *km* south of the Rosashof smallholdings, through the Vanderbijlpark North suburb, some 2,2 *km* south of the IVS property, onwards to the east. Several displacements of the dyke are indicated along its strike.

6.1.5 Strata Dip

The formations exposed within the IVS property north of the displacement fault zone, is indicated to dip 14 *degrees* to the west, in the opposite direction of the arch, and perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, roughly in the same direction of the arch, perpendicular to the strike.

6.1.6 Geo-chemistry

Rock sampling for analyses has not been part of the Master Plan Study scope of work. The geochemistry of the sedimentary rock of the Pretoria Group shows evidence of complex source terrains, with predominantly granitic and sedimentary sources, as well as, possibly, ultra-mafic sources. The geochemical signature of the Pretoria Group sediments is indicative of a divergent margin tectonic setting (intra-cratonic sag, failed rift/aulacogen or passive margin).

DATASET V-1, APPENDIX V gives geochemistry data extracts obtained from Geological Publications and a published thesis, indicating the geochemistry of the Pretoria Group and Chuniespoort Group of the Transvaal Sequence.

Generally, two distinct groups of shales can be differentiated geochemically and mineralogically, i.e. high-Al shales with a predominant kaolinite-mica mineral assemblage, and high-Mg-Ca-Na shales with a plagioclase mineral assemblage. The high-Al shales dominate the succession from the base of the Pretoria Group up to the Daspoort Formation, the high-Mg-Ca-Na shales occur mainly in the Silverton and post-Magaliesberg Formations.

The Pretoria Group shales is enriched in Al, Th, Cr and Sc, and depleted in Mn, Na, Ca, Sr and some base metals, compared to average shale estimates. The Pretoria Group sandstone is enriched in Cr, Ni and Fe and depleted in Ca, Na, Ti and K, compared to average sandstone estimates.

Transport fractionation seems to have influenced the evolving pattern to a certain degree. The syndepositional palaeocolimate is thought to have been humid-hot, at least for the middel part of the Pretoria group (Hekpoort to Daspoort Formations).

The basal part of the Pretoria Group has a similar geochemical pattern (i.e. points to a similar climate), but the possible introduction of reworked and redeposited weathering profiles, related to the depositional hiatus between the Chuniespoort and Pretoria Groups, must be considered in any interpretation.

6.2 LOCAL GEOLOGY : CONSOLIDATED RESIDUE MANAGEMENT FACILITY (CRMF)

The local geology for the **CRMF**, will be discussed at the hand of **FIGURE VI-1**, **FIGURE VI-2**, **FIGURE VI-3**, **FIGURE VI-4** and **FIGURE VI-9** in **APPENDIX VI**. The geological logs for the following monitoring boreholes used in the geologic site characterization for the CRMF, are attached in **DATA SET VI-1**, **APPENDIX IV**:

IVB-D2; IVB-D3; IVB-D4; IVB-D5; IVB-D6; IVB-D7; IVB-D17; IVB-D18; IVB-D19; IVB-D20; IVB-D42; IVB-D45; IVB-D46; IVB-D47; IVB-D52; IVB-D53; IVB-D54; IVB-D55; IVB-D56; IVB-D57; IVB-D58; IVB-D59; IVB-D60; IVB-D61; IVB-D62; IVB-D65; IVB-D66; IVB-D67; IVB-D71; IVB-D72; IVB-D74; IVB-D75; IVB-D124; IVB-D125; IVB-D150; IVB-D153.

The CRMF area is almost entirely underlain by the Silverton Formation of the Pretoria Group in the Transvaal Sequence. A small part of the eastern boundary includes the Daspoort Formation and the Strubenkop Formation. Intrusive into all horizons of the Transvaal Sequence, the *Transvaal diabase* is observed in a number of the monitoring boreholes drilled within the CRMF's boundary. The thickness of these intersection varies from borehole to borehole.

The CRMF, as can be seen in geological cross sections *WE1*, *WE2* and *WE3* attached as **FIGURE VI-2**, **FIGURE VI-3** and **FIGURE VI-4** in **APPENDIX VI**, is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), with intrusive diabase. **FIGURE VI-1** shows the localities of the cross section lines on a map, also indicating the localities of the boreholes included in the cross sections.

6.2.1 Stratigraphy and Lithology

The local geology underlying the CRMF consist mainly of the shale and intrusive diabase.

This is best represented by the geology penetrated in monitoring boreholes IVB-D7, IVB-D19, IVB-D66 and IVB-D104. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D7

0*m*	-	2*m*	Overburden: black.
2*m*	-	18*m*	Diabase: greyish brown, weathered.
18*m*	-	25*m*	Diabase: brownish, grey, fractured, broken.
25*m*	-	26*m*	Water strike (2,0 *l/s*)
25*m*	-	26*m*	Diabase: brownish, grey, fractured, broken.
26*m*	-	36*m*	Diabase: grey, fresh, solid.

Lithology IVB-D19

0*m*	-	2*m*	Clay: brown.
2*m*	-	8*m*	Clay: reddish, brown.
8*m*	-	13*m*	Clay: yellowish, brown.
13*m*	-	17*m*	Diabase: brown, weathered.
17*m*	-	18*m*	Diabase: greyish, brown, fractured, broken.
18*m*	-	19*m*	Water strike (0,3 *l/s*)
19*m*	-	20*m*	Diabase: greyish, brown, fractured, broken.
20*m*	-	35*m*	Diabase: dark, grey, fresh, solid.

Lithology IVB-D66

0*m*	-	4*m*	Rubble.
4*m*	-	17*m*	Clay: greyish, brown.
17*m*	-	21*m*	Diabase: greyish, brown, weathered.
21*m*	-	24*m*	Diabase: dark, grey, fresh.

Lithology IVB-D104

0*m*	-	2*m*	Soil: black.
2*m*	-	5*m*	Soil: dark, brown.
5*m*	-	13*m*	Clay: yellowish, brown.
13*m*	-	16*m*	Shale: brown, weathered.
16*m*	-	18*m*	Shale: brown, weathered.
18*m*	-	20*m*	Shale: brownish, grey, fractured
20*m*	-	21*m*	Water strike (0,4 l/s)
20*m*	-	22*m*	Shale: brownish, grey, fractured.
22*m*	-	31*m*	Shale: light, grey, fresh.

It should be noted that the geology underlying the CRMF, mainly consist of the Silverton formation - Pretoria Group.

The general weathering profile constitutes of a soil profile that varies in depth between 0,00 *m* and 32,00 *m*, with an average depth below surface of ± 8,44 *m*. This is followed by weathered rock varying in depth between 4,00 *m* and 36,00 *m*, with an average depth below surface of ± 20,47 *m*, which gradually change to fractured rock varying in depth between 12,00 *m* and 43,00 *m*, with an average depth below surface of ± 26,14 *m*, before changing to fresh hard rock.

6.2.2 Tectonics, Lineaments and Structures

Two major regional structures namely the Fault and the northern Dolerite Dyke forms part of the local geological description of the CRMF area.

Fault

A major fault transects the area with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike, slip fault. Due to the scarcity of outcrop in the region, determination of the precise location of the fault is not possible just from geological observations alone. The location of the fault shown on **FIGURE VI-9** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort Formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of the property, the arch being to the north-west.

The formations exposed within the IVS property, north of the fault zone, are indicated to dip 14 *degrees* to the west, perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property, past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, perpendicular to the strike.

Several monitoring boreholes were drilled on the fault zone to verify the location and extent of the fault. A total number of five boreholes were drilled on the fault. IVB-D153 was drilled into the fault zone within the CRMF zone. All the boreholes were sited using resistivity and gravity methods.

All five of the boreholes intended to investigate the fault, successfully penetrated the fault zone.

Dykes

Only one major east-west striking dyke occurs locally in the area. This dyke transects the CRMF area from east to north-west. Six monitoring boreholes were drilled on the dyke to verify the location, dip and extent of the dyke in the study area. All the boreholes were sited using the magnetic geophysical technique. This dyke is approximately 80 *m* thick and its orientation dip is near vertical. Weathering and fracturing depths are average to above average along the dyke, but not necessarily as a consequence of its presence.

6.3 LOCAL GEOLOGY : CONSOLIDATED PLANT AREA (CPA)

The local geology of the **CPA**, will be discussed at the hand of **FIGURE VI-10**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization, are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D1; IVB-D11; IVB-D12; IVB-D13; IVB-D14; IVB-D15; IVB-D16; IVB-D29; IVB-D30; IVB-D31; IVB-D32; IVB-D33; IVB-D34; IVB-D35; IVB-D36; IVB-D37; IVB-D38; IVB-D39; IVB-D40; IVB-D41; IVB-D44; IVB-D48; IVB-D49; IVB-D50; IVB-D51; IVB-D73; IVB-D76; IVB-D84; IVB-D86; IVB-D89; IVB-D100; IVB-D110; IVB-D111; IVB-D112; IVB-D113; IVB-D114; IVB-D138; IVB-D142; IVB-D143; IVB-D144; IVB-D145; IVB-D146; IVB-D148; IVB-D149

As can be seen in geological cross sections *WE3, WE4 and WE5* attached as **FIGURE VI-4**, **FIGURE VI-5** and **FIGURE VI-6** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), with intrusive diabase. **FIGURE VI-1** shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.3.1 Stratigraphy and Lithology

The local geology underlying the CPA consist entirely of shale of the Silverton Formation. Gravels in a sandy or clayey matrix, are found in localized areas to the eastern and north-eastern side of the CPA.

The local geology is best represented by the geology penetrated in monitoring boreholes IVB-D15, IVB-D44 and IVB-D90. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D15

0*m*	-	2*m*	Overburden: reddish, brown.
2*m*	-	5*m*	Gravel: brown.
5*m*	-	9*m*	Clay: reddish, brown.
9*m*	-	17*m*	Clay: yellowish, brown.
17*m*	-	19*m*	Diabase: brownish, grey, fractured.
19*m*	-	35*m*	Diabase: dark, grey, fresh, solid.

Lithology IVB-D44

0*m*	-	1*m*	Overburden: dark, brown.
1*m*	-	3*m*	Clay: grey, brown.
3*m*	-	5*m*	Clay: dark, brown.
5*m*	-	8*m*	Clay: greyish, brown.
8*m*	-	9*m*	Shale: light, grey weathered, sandy.
9*m*	-	12*m*	Shale: olive brown, weathered.
12*m*	-	14*m*	Shale: brown, weathered.
14*m*	-	18*m*	Shale: light, brown.
18*m*	-	30*m*	Shale: dark, grey, fresh.
30*m*	-	34*m*	Shale: dark, brown, weathered.
34*m*	-	36*m*	Shale: black, carbonaceous.
36*m*	-	37*m*	Shale: dark, grey, sandy.
37*m*	-	40*m*	Water strike (0,13 *l/s*)
37*m*	-	40*m*	Shale: dark, grey, fractured, sandy
40*m*	-	42*m*	Shale: dark, grey.

Lithology IVB-D77

0*m*	-	3*m*	Soil: dark, brown.
3*m*	-	7*m*	Soil: brown.
7*m*	-	12*m*	Shale: light, brown, weathered.
12*m*	-	14*m*	Shale: brown, weathered.
14*m*	-	24*m*	Shale: brownish, grey, fractured.
24*m*	-	35*m*	Shale: light, grey, fresh.

The general weathering profile constitutes of a soil profile that varies between 1,00 *m* and 26,00 *m* in depth, with an average depth of ± 7,66 *m* below surface. This is followed by weathered rock varying in depth between 3,00 *m* and 36,00 *m*, with an average depth below surface of ± 17,60 *m*, which gradually change to fractured rock varying in depth between 8,00 *m* and 40,00 *m* below surface, with an average depth below surface of ± 22,41 *m*, before changing to fresh hard rock.

6.3.2 Tectonics, Lineaments and Structures

One major regional structure namely the Fault, forms part of the local geological description of the Consolidated Plant Area.

Fault

A major fault transects the area with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike slip fault. Due to the scarcity of outcrop in the region determination of the precise location of the fault is not possible just from geological observations alone and the location of the fault shown on **FIGURE VI-10** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone, seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort Formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of the property, the arch being to the north-west.

The formations exposed within the IVS property north of the fault zone, is indicated to dip 14 *degrees* to the west, perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property, past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, perpendicular to the strike.

Several monitoring boreholes were drilled on the fault zone to verify the location and extent of the fault. A total number of five boreholes were drilled to investigate the fault. IVB-D100 was drilled into the fault zone within the Consolidated Plant Area. All the boreholes were sited using resistivity and gravity methods.

6.4 LOCAL GEOLOGY : SOUTHERN SLAG PROCESSING AREA - SOUTH WEST (SSPA-SW)

The local geology of the **SSPA-SW**, will be done at the hand of **FIGURE VI-11**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization, are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D63; IVB-D131.

As can be seen in geological cross section *WE5* attached as **FIGURE VI-6** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), and intrusive diabase. **FIGURE VI-1**, **APPENDIX VI**, shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.4.1 Stratigraphy and Lithology

The local geology underlying the **SSPA-SW** consists mainly of shale of the Silverton Formation and intrusive diabase.

This geology is best represented by the geology penetrated in monitoring boreholes IVB-D63 and IVB-D131. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D63

0*m*	-	2*m*	Soil: brown, clayey.
2*m*	-	7*m*	Soil: Olive, brown, clayey.
7*m*	-	14*m*	Diabase: Brownish, grey, weathered, very.
14*m*	-	18*m*	Diabase:, greyish, brown, weathered.
18*m*	-	29*m*	Diabase:
29*m*	-	30*m*	Water Strike 1.39 *l/s*.
29*m*	-	30*m*	Diabase: Dark, grey, fractured.
30*m*	-	37*m*	Diabase: Dark, grey, fresh.

Lithology IVB-D131

0*m*	-	2*m*	Soil: Dark, brown, clayey.
2*m*	-	5*m*	Shale: orange, green.
5*m*	-	11*m*	Diabase; Weathered.
15*m*	-	16*m*	WaterStrike 0.14 *l/s*.
11*m*	-	18*m*	Diabase: fractured.

The general weathering profile constitutes of a soil profile that varies in depth between 2,00 *m* and 7,00 *m*, with an average depth below surface of ± 4,50 *m*. This is followed by weathered rock varying in depth between 11,00 *m* and 18,00 *m*, with an average depth of ± 14,50 *m*, which gradually change to fractured rock varying in depth between 18,00 *m* and 30,00 *m*, with an average depth of ± 20,00 *m*, before changing to fresh hard rock.

6.4.2 Tectonics, Lineaments and Structures

No major regional structures form part of the local geological description of the Southern Slag Processing Area - South West.

6.5 LOCAL GEOLOGY : SOUTHERN SLAG PROCESSING AREA - SOUTH EAST (SSPA-SE)

The local geology of the Southern Slag Processing Area - South East **(SSPA-SE)**, will be discussed at the hand of **FIGURE VI-12**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization, are attached as **DATA SET IV-1**, in **APPENDIX IV**:

IVB-D91; IVB-D92; IVB-D132; IVB-D133.

As can be seen in geological cross section *WE5* attached as **FIGURE VI-6** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), the Daspoort Formation (Pretoria Group - quartzite and shale), as well as intrusive diabase. **FIGURE VI-1**, **APPENDIX VI**, shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.5.1 Stratigraphy and Lithology

The local geology underlying the **SSPA-SE** consist mainly of shale of the Silverton Formation and intrusive diabase. The geology underlying this area in the south eastern corner of the IVS site, also includes the quartzite and shale from the Daspoort Formation.

This is best represented by the geology penetrated in monitoring boreholes IVB-D91 and IVB-D133. In these boreholes, the following lithologies were penetrated:

<u>Lithology IVB-D92</u>

0*m*	-	1*m*	Soil: reddish, brown.
1*m*	-	2*m*	Boulders: brown.
2*m*	-	3*m*	Soil: reddish, brown.
3*m*	-	13*m*	Shale: light, brown, weathered.
13*m*	-	16*m*	Shale: brownish, grey, fractured.
16*m*	-	18*m*	Shale: light, grey, fractured
18*m*	-	25*m*	Shale: light, grey, fresh.
25*m*	-	27*m*	Shale: light, grey, fractured.
27*m*	-	30*m*	Diabase: bluish, grey, fractured.
30*m*	-	35*m*	Diabase: bluish, grey, fresh.

<u>Lithology IVB-D133</u>

0*m*	-	6*m*	Clay: greenish, brown.
6*m*	-	8*m*	Quartzite: brownish, white, fractured.
8*m*	-	10*m*	Shale: orange, red, interbedded shale and silt stone.
10*m*	-	18*m*	Quartzite: pinkish, white.
18*m*	-	42*m*	Quartzite: pinkish, white.

The general weathering profile constitutes of a soil profile that varies in depth between 3,00 *m* and 20,00 *m*, with an average depth of ± 8,00 *m*. This is followed by weathered rock varying in depth below surface of between 13,00 *m* and 24,00 *m*, with an average depth of ± 18,33 *m* which gradually change to fractured rock varying in depth below surface of between 18,00 *m* and 30,00 *m*, with an average depth of ± 26,00 *m*, before changing to fresh hard rock.

6.5.2 Tectonics, Lineaments and Structures

No major regional structures forms part of the local geological description of the Slag Processing Area as such. However, the area in the extreme south-eastern corner is compromised by the regional fault.

Fault

A major fault transects the geology underlying the Vanderbijlpark Steel Works property with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike slip fault. Due to the scarcity of outcrop in the region determination of the precise location of the fault is not possible just from geological observations alone and the location of the fault shown on **FIGURE VI-12** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort formation took place. The displaced Daspoort Formation arches back from outside the IVS property, and the fault zone, past the south-eastern corner of property, the arch being to the north-west.

The formations exposed within the Vanderbijlpark Steel Works property north of the fault zone is indicated to dip 14 *degrees* to the west, perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property, past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, also perpendicular to the strike.

6.6 LOCAL GEOLOGY : KIEWIET AREA (KA)

The discussion of the local geology of the area, is based on a wealth of quantitative geological information. The local geology for the Kiewiet Area **(KA)** will be discussed at the hand of **FIGURE VI-13**, **APPENDIX VI**, whilst the geological logs for the following boreholes used in the geologic site characterization are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D21; IVB-D22; IVB-D23; IVB-D24; IVB-D25; IVB-D26; IVB-D27; IVB-D28; IVB-D70; IVB-D79; IVB-D82; IVB-D83; IVB-D84; IVB-D85; IVB-D94; IVB-D126; IVB-D127; IVB-D128; IVB-D129; IVB-D130; IVB-D154; IVB-D155.

The Kiewiet Area as can be seen in the geological cross sections *WE1* and *WE 2*, attached as **FIGURE VI-2** and **FIGURE VI-3** in **APPENDIX VI**, is complex and comprise of the Hekpoort andesite, the Strubenkop shale and quartzite, the Daspoort quartzite and shale and the Silverton Formation shale with inter-bedded quartzite, hornfels, limestone and volcanic tuff, intruded by Transvaal diabase sills.

These geological units have a north - south strike and dip 14 *degrees* to the west, perpendicular to the strike. Quaternary deposits of alluvium and gravel is also present in places. **FIGURE VI-1**, **APPENDIX VI** shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.6.1 Stratigraphy and Lithology

The geology underlying the Kiewiet area, represent different geological formations, namely the Hekpoort Formation (andesite, agglomerate and tuff), the Strubenkop Formation (shale and quartzite), and the Daspoort Formation (quartzite and shale), all part of the Pretoria Group.

This geology is best represented by the formations penetrated in monitoring boreholes IVB-D26, IVB-D25, IVB-D23 and IVB-D83. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D23

0*m*	-	2*m*	Soil: dark, brown.
2*m*	-	3*m*	Boulders and Clay: brown.
3*m*	-	7*m*	Soil: reddish, brown.
7*m*	-	19*m*	Soil: light, brown.
19*m*	-	25*m*	Lava: greyish, brown, weathered, broken.
25*m*	-	35*m*	Lava: dark, grey, fresh, solid.

Lithology IVB-D25

0*m*	-	3*m*	Soil: reddish, brown.
3*m*	-	5*m*	Boulders and Clay: light, brown.
5*m*	-	16*m*	Shale: light, brown, weathered.
16*m*	-	19*m*	Shale: grey, fractured, broken.
18.5*m*	-	19*m*	Water strike (0,2 *l/s*)
19*m*	-	35*m*	Shale: purple, fresh, solid.

Lithology IVB-D26

0*m*	-	1*m*	Soil: reddish, brown.
1*m*	-	4*m*	Quartzite: light, brown, weathered.
4*m*	-	7*m*	Quartzite: light, brown, fractured, broken.
7*m*	-	7*m*	Water strike (1,0 *l/s*).
7*m*	-	8*m*	Quartzite: light, brown, fractured, broken.
8*m*	-	13*m*	Quartzite: grey, fresh, solid.
13*m*	-	26*m*	Quartzite: reddish, brown, weathered, fresh.
26*m*	-	35*m*	Shale: light, grey, fresh, solid.

Lithology IVB-D83

0*m*	-	2*m*	Soil: reddish, brown.
2*m*	-	6*m*	Soil: dark brown.
6*m*	-	13*m*	Soil: light, yellow.
13*m*	-	18*m*	Lava: brown, weathered.
18*m*	-	19*m*	Water strike (3 *l/s*)
18*m*	-	27*m*	Lava: dark, grey, fractured.
27*m*	-	35*m*	Lava: light, grey, fresh, solid.

The straddling locality of the Kiewiet Area in relation to these local geological contacts, should be noted:

- Hekpoort Formation - andesite, agglomerate, tuff.
- Strubenkop Formation - ferruginous shale, quartzite.
- Daspoort Formation - quartzite and shale, ferruginous in places - exposures are indicated to arch concavely around IVS's Evaporation Ponds Dams 1 to 4, and the Maturation Ponds Dams 1 to 3, the arch being to the east, basically striking north-south to some 400 *m* south of the Maturation Ponds.

In addition to the above, quaternary deposits of gravel is also present within the indicated footprint of the Kiewiet Area. This was confirmed during the drilling of boreholes IVB-D23 and IVB-D25.

The general weathering profile constitutes of a soil profile that varies in depth between 1,00 *m* and 22,00 *m*, with an average depth of ± 9,24 *m*. The soil profile varies from east to west with the deepest soil profile on the Hekpoort Formation (andesite/lava), with thicknesses varying between 10 *m* and 20 *m*. For the remainder of the Kiewiet Area, localized deeper soil profiles are present, while the majority of the boreholes have soil thickness of between 1 *m* and 10 *m*. This is followed by weathered rock varying in depth below surface of between 8,00 *m* and 31,00 *m*, with an average depth of ± 21,33 *m*, which gradually change to fractured rock varying in depth between 16,00 *m* and 24,00 *m*, with an average depth below surface of ± 25,52 *m*, before changing to fresh hard rock.

6.6.2 Tectonics, Lineaments and Structures

Two major regional structures namely the Fault and the Dolerite dyke forms part of the local geology of the area.

Fault

A major fault transects to the south of the Kiewiet Area with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike slip fault. Due to the scarcity of outcrop in the region, determination of the precise location of the fault is not possible just from geological observations alone and the location of the fault shown on **FIGURE VI-13** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

Dykes

Only one major east-west striking dyke occurs locally in the area. This dyke transects the Kiewiet Area from east to north-west. Six monitoring boreholes were drilled on the dyke to verify the location, dip and extent of the dyke in the study area. Two of these monitoring boreholes (IVB-D154 and IVB-D155) falls within the footprint of the Kiewiet Area. The boreholes were sited using different geophysical techniques.

This dyke is approximately 80 *m* thick and its orientation dip is near vertical. Weathering and fracturing depths are average to above average along the dyke, but not necessarily as a consequence of its presence.

6.7 LOCAL GEOLOGY : OPEN VELD AREA - CENTRAL (OVA-C)

The local geology of the Open Veld Area - Central **(OVA-C)**, will be discussed at the hand of **FIGURE VI-14**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D8; IVB-D9; IVB-D10; IVB-D151.

The Open Veld Area - Central is located in the center of the IVS site, between the CRMF, the Kiewiet Area and the Consolidated Plant Area.

6.7.1 Stratigraphy and Lithology

The local geology underlying the **OVA-C** comprise three different geological formations, also including a regional fault that transects the area. The geology consist of shale of the Silverton Formation, quartzite of the Daspoort Formation and shale/quartzite of the Strubenkop Formation.

This geology is best represented by the formations penetrated in monitoring boreholes IVB-D8, IVB-D9 and IVB-D10. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D8

0*m*	-	4*m*	Overburden: dark, brown.
4*m*	-	6*m*	Soil: light, brown.
6*m*	-	20*m*	Soil: light, yellow.
20*m*	-	24*m*	Diabase: greyish, brown, weathered.
24*m*	-	25*m*	Diabase: brownish, grey, fractured.
25*m*	-	26*m*	Water strike (0,4 *l/s*)
25*m*	-	28*m*	Diabase: brownish, grey, fractured.
28*m*	-	35*m*	Diabase: dark, grey, fresh.

Lithology IVB-D9

0*m*	-	1*m*	Overburden: dark, black.
1*m*	-	3*m*	Gravel: brown.
3*m*	-	20*m*	Clay: yellowish, brown.
20*m*	-	25*m*	Diabase: greyish, brown, weathered, fractured.
21*m*	-	22*m*	Water strike (0,3 *l/s*)
25*m*	-	35*m*	Diabase: dark, grey, fresh, solid.

Lithology IVB-D10

0*m*	-	1*m*	Overburden: dark, brown.
1*m*	-	8*m*	Shale: dark, brown, weathered.
8*m*	-	22*m*	Shale: light, brown, fractured.
22*m*	-	32*m*	Shale: light, grey, fresh, solid.
32*m*	-	33*m*	Water strike (0,6 *l/s*)
32*m*	-	35*m*	Shale: light, grey, fresh, solid.

The general weathering profile constitutes of a soil profile that varies in depth between 1,00 *m* and 20,00 *m*, with an average depth below surface of ± 13,75 *m*. This is followed by weathered rock varying in depth between 8,00 *m* and 25,00 *m*, with an average depth of ± 19,25 *m*, which gradually change to fractured rock varying in depth below surface of between 22,00 *m* and 32,00 *m*, with an average depth of ± 26,75 *m*, before changing to fresh hard rock.

6.7.2 Tectonics, Lineaments and Structures

One major regional structure namely the Fault, forms part of the local geology of the **OVA-C**.

Fault

A major fault transects the area with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike slip fault. Due to the scarcity of outcrop in the region, determining the precise location of the fault is not possible just from geological observations alone and the location of the fault shown on **FIGURE VI-14** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort Formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of property, the arch being to the north-west.

The formations exposed within the IVS property north of the fault zone, are indicated to dip 14 *degrees* to the west, perpendicular to the strike.

The displaced formations south of the fault zone, that arch back from the fault zone outside the IVS property, past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, also perpendicular to the strike.

Several monitoring boreholes were drilled on the fault zone to verify the location and extent of the fault. A total number of five boreholes were drilled on the fault. IVB-D151 was drilled into the fault zone within the **OVA-C**. The boreholes were sited using resistivity and gravity methods.

6.8 LOCAL GEOLOGY : PARK AREA - SOUTH WEST (PA-SW)

The local geology of the Park Area - South West **(PA-SW)**, will be discussed at the hand of **FIGURE VI-15**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization, are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D43; IVB-D77; IVB-D78; IVB-D90.

As can be seen in geological cross section *WE5* attached as **FIGURE VI-6** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), with intrusive diabase. **FIGURE VI-1**, **APPENDIX VI** shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.8.1 Stratigraphy and Lithology

The local geology underlying the **PA-SW** consist mainly of shale of the Silverton Formation.

This geology is best represented by the formations penetrated in monitoring boreholes IVB-D78 and IVB-D90. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D78

0*m*	-	1*m*	Soil: reddish, brown.
1*m*	-	3*m*	Soil: brown.
3*m*	-	5*m*	Soil: light, brown.
5*m*	-	14*m*	Diabase: brown, weathered.
14*m*	-	17*m*	Diabase: dark, brown, weathered..
17*m*	-	20*m*	Diabase: brownish, grey, fractured.
20*m*	-	24*m*	Diabase: dark, grey, fresh.
24*m*	-	25*m*	Quartzite: light, grey, fresh.(Water Strike - 2 *l/s*)
25*m*	-	30*m*	Diabase: dark, grey, fresh.

Lithology IVB-D90

0*m*	-	2*m*	Soil: black.
2*m*	-	8*m*	Shale: yellowish, brown, weathered.
8*m*	-	10*m*	Shale: light, grey, weathered.
10*m*	-	21*m*	Shale: light, grey, fractured.
21*m*	-	30*m*	Shale: greyish, black, laminated.
30*m*	-	35*m*	Shale: greyish, black, carbonaceous.

The general weathering profile constitutes of a soil profile that varies in depth below surface, between 2,00 *m* and 7,00 *m*, with an average depth of ± 5,00 *m*. This is followed by weathered rock varying in depth between 10,00 *m* and 17,00 *m*, with an average depth of ± 14,50 *m*, which gradually change to fractured rock varying in depth between 20,00 *m* and 24,00 *m*, with an average depth below surface of ± 22,25 *m*, before changing to fresh hard rock.

6.8.2 Tectonics, Lineaments and Structures

In addition to the aireal photo interpretation (which yielded no meaningful results), the geophysical investigation performed for the site, prior to the drilling program, did not show any geological structures in this area.

6.9 LOCAL GEOLOGY : OPEN VELD AREA - SOUTH EAST (OVA-SE)

The local geology of the Open Veld Area - South East **(OVA-SE)**, will be discussed at the hand of **FIGURE VI-16 - APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization, are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D64; IVB-D87; IVB-D88; IVB-D134; IVB-D135; IVB-D136; IVB-D139.

As can be seen in geological cross sections *WE4 and WE5*, attached as **FIGURE VI-5** and **FIGURE VI-6** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), with intrusive diabase. The southern part of this area is underlain by the Daspoort Formation (Pretoria Group) - quartzite and shale. **FIGURE VI-1**,

6.10 LOCAL GEOLOGY : AREA SURROUNDING IVS WORKS

The area included in this zone represents a buffer zone around the IVS Works perimeter, as indicated on **FIGURE VI-17**, **APPENDIX VI**. The local geology of this area, will be discussed at the hand of **FIGURE VI-17**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization are attached in **DATA SET IV-1**, **APPENDIX IV**:

IVB-D69; IVB-D68; IVB-D95; IVB-D96; IVB-D97; IVB-D98; IVB-D99; IVB-D102; IVB-D103; IVB-D105; IVB-D106; IVB-D107; IVB-D108; IVB-D109; IVB-D115; IVB-D116; IVB-D118; IVB-D119; IVB-D120; IVB-D121; IVB-D123; IVB-D147; IVB-D156; IVB-D157; IVB-D158; IVB-D159; IVB-D160; IVB-D161; IVB-D162; IVB-D163; IVB-D164; IVB-D165; IVB-D166; IVB-D167; IVB-D168; IVB-D169; IVB-D170; IVB-D171; IVB-D172; IVB-D173; IVB-D174; IVB-D175; IVB-D176; IVB-D177.

As can be seen in geological cross sections *WE1* through *WE5*, attached as **FIGURE VI-2**, **FIGURE VI-3**, **FIGURE VI-4**, **FIGURE VI-5** and **FIGURE VI-6** in **APPENDIX VI**, the area is underlain by all the geological formations described in the regional geology (SECTION 6.1 of this report). The geology comprises of the Hekpoort andesite, the Strubenkop shale and quartzite, the Daspoort quartzite and shale and the Silverton Formation shale with inter-bedded quartzite, hornfels, limestone and volcanic tuff, intruded by Transvaal diabase sills. Quaternary deposits of alluvium and gravel are also present in places. **FIGURE VI-1**, **APPENDIX VI**, shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.10.1 Stratigraphy and Lithology

The local geology underlying the **Area Surrounding the IVS Works**, comprise of the Hekpoort Formation andesite, the Strubenkop Formation shale and quartzite, the Daspoort Formation quartzite and shale and the Silverton Formation shale with inter-bedded quartzite, hornfels, limestone and volcanic tuff, intruded by Transvaal diabase sills. Quaternary deposits of alluvium and gravel are also present in places.

Refer to the borehole logs in **DATA SET IV-1**, **APPENDIX IV** to view the different geological units penetrated during the drilling program for this zone. Boreholes IVB-D69, IVB-D102 and IVB-D163 are examples of the formations penetrated in monitoring boreholes. In these boreholes, the following lithologies were penetrated:

APPENDIX VI, shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.9.1 Stratigraphy and Lithology

The local geology underlying the **OVA-SE**, consists mainly of shale of the Silverton Formation as well as the Daspoort Formation. Alluvium and gravels in a sandy or clayey matrix, are found in localized areas.

This geology is best represented by the formations penetrated in monitoring boreholes IVB-D87, IVB-D134 and IVB-D139. In these boreholes, the following lithologies were penetrated:

Lithology IVB-D87

0*m*	-	2*m*	Clay: brown.
2*m*	-	4*m*	Shale: light, yellow, weathered.
4*m*	-	9*m*	Diabase: yellowish, brown, weathered.
9*m*	-	19*m*	Diabase: brownish, grey, fractured.
19*m*	-	23*m*	Diabase: light, grey, fractured.
23*m*	-	35*m*	Diabase: dark, grey, fresh.

Lithology IVB-D134

0*m*	-	1*m*	Soil: brown.
1*m*	-	18*m*	Quartzite: light.

Lithology IVB-D139

0*m*	-	1*m*	Soil: brownish, red.
1*m*	-	6*m*	Clay: dark, brown.
6*m*	-	11*m*	Clay: light, brown.
11*m*	-	27*m*	Diabase: brownish, grey, weathered.
27*m*	-	37*m*	Diabase: dark, grey, fractured.
37*m*	-	40*m*	Diabase: grey, fresh,.

The general weathering profile constitutes of a soil profile that varies in depth below surface of between 1,00 *m* and 11,00 *m*, with an average depth of ± 4,17 *m*. This is followed by weathered rock varying in depth between 9,00 *m* and 32,00 *m*, with an average depth below surface of ± 19,83 *m* which gradually change to fractured rock varying in depth between 13,00 *m* and 37,00 *m*, with an average depth below surface of ± 24,00 *m*, before changing to fresh hard rock.

6.9.2 Tectonics, Lineaments and Structures

No major regional structures form part of the local geological description of the **OVA-SE**.

Lithology IVB-D69

0*m*	-	2*m*	Sand: Brown, clayey, loose, topsoil.
2*m*	-	5*m*	Silt: Light yellow, clayey.
5*m*	-	19*m*	Diabase: Yellow, weathered, very.
19*m*	-	25*m*	Shale: Light, grey fractured
19*m*	-	25*m*	Water Strike 1.5 *l/s*.
25*m*	-	31*m*	Shale: Dark, grey fresh.

Lithology IVB-D102

0*m*	-	2*m*	Soil: Dark, brown.
2*m*	-	3*m*	Boulders: Brown.
3*m*	-	11*m*	Shale: Yellowish, brown, weathered, very.
11*m*	-	14*m*	Shale: Light, brown, weathered, very fine to fine grained.
14*m*	-	16*m*	Diabase: Brown, weathered, medium grained.
16*m*	-	17*m*	Diabase: Greyish, brown, weathered, medium grained.
17*m*	-	22*m*	Diabase: Brownish, grey, fractured, medium grained.
22*m*	-	35*m*	Diabase: Dark, grey, fresh, medium grained.

Lithology IVB-D163

0*m*	-	2*m*	Soil: Reddish, brown.
2*m*	-	11*m*	Clay: Yellowish, brown.
11*m*	-	13*m*	Lava: Greyish, brown, weathered.
17*m*	-	18*m*	Water Strike 0.8 *l/s*.
13*m*	-	18*m*	Lava: Grey, broken.
18*m*	-	31*m*	Lava: Greyish, green, solid.

6.10.2 Tectonics, Lineaments and Structures

Two major regional structures namely the regional Fault and the northern Dolerite dyke form part of the local geological description of the Area Surrounding the IVS Works.

Fault

A major fault transects the area with a horizontal displacement of greater than 2 *km*. It is a left lateral, strike slip fault. Due to the scarcity of outcrop in the region, determination of the precise location of the fault is not possible just from geological observations alone and the location of the fault shown on **FIGURE VI-17** in **APPENDIX VI**, is based on available geological data as well as extensive geophysical work performed.

From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the

Daspoort formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of property, the arch being to the north-west.

The formations exposed within the IVS property north of the fault zone, is indicated to dip 14 *degrees* to the west, perpendicular to the strike.

The displaced formations south of the fault zone, that arch back from the fault zone outside the IVS property, past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, also perpendicular to the strike.

Several monitoring boreholes were drilled on the fault zone to verify the location and extent of the fault. A total number of five boreholes were drilled on the fault. IVB-D152 and IVB-D164 were drilled into the fault zone within the Area Surrounding the IVS Works. All the boreholes were sited using resistivity and gravity methods.

Dykes

Only one major east-west striking dyke occurs locally in the area. This dyke transects the IVS works and surrounding area, from east to north-west. Six monitoring boreholes were drilled on the dyke to verify the location, dip and extent of the dyke in the study area. All the boreholes were sited using the magnetic geophysical technique. Four of these monitoring boreholes drilled in the Area Surrounding the IVS Works, were targeted specifically for the dyke.

This dyke is approximately 80 *m* thick and its orientation dip is near vertical. Weathering and fracturing depths are average to above average along the dyke, but not necessarily as a consequence of its presence.

6.11 LOCAL GEOLOGY : RIETKUILSPRUIT AREA

The local geology of the **Rietkuilspruit Area**, will be discussed at the hand of **FIGURE VI-18**, **APPENDIX VI**, whilst the geological logs for the following monitoring boreholes used in the geologic site characterization are attached as **DATA SET IV-2** in **APPENDIX IV**:

IVS-5; IVS-11; IVS-12; IVS-17; IVS-18; IVS-27; IVS-28 and IVS-29.

The area pertaining to this discussion, is located between the IVS-Rietspruit Canal in the south and the Rietkuilspruit stream to the north, from where the canal discharges into the Rietkuilspruit stream in the west, up to the earth dam, some 2 *km* upstream to the east. As can be seen in geological cross sections *WE6* and *WE7* attached as **FIGURE VI-7** and **FIGURE VI-8** in **APPENDIX VI**, the area is mainly underlain by the Silverton Formation (shale with interbedded quartzite, hornfels, limestone), with intrusive diabase. **FIGURE VI-1** shows the cross section lines on a map, also indicating the physical localities of the boreholes included in the cross sections.

6.11.1 Stratigraphy and Lithology

The local geology underlying the **Rietkuilspruit Area** consists mainly of shale of the Silverton Formation. Alluvium and gravels in a sandy or clayey matrix, are found in areas flanking the Rietkuilspruit stream.

This geology is best represented by the formations penetrated in monitoring boreholes IVS-5 and IVS-18. In these boreholes, the following lithologies were penetrated:

Lithology IVS-5

0*m*	-	0,5*m*	Soil: dark brown, clayey.
0,5*m*	-	3*m*	Ferricrete: reddish brown, weathered, very, clayey.
3*m*	-	4*m*	Shale: purple, brown, weathered, very clayey.
4*m*	-	10*m*	Shale: yellowish brown, weathered, very clayey.
10*m*	-	13*m*	Slate: olive brown, weathered.
14*m*	-	15*m*	Water Strike 0.3 *l/s*.
13*m*	-	15*m*	Slate: greyish brown, fractured, very.
15*m*	-	19*m*	Slate: greyish brown, fractured.
18*m*	-	19*m*	Water Strike 0.3 *l/s*.
19*m*	-	20*m*	Slate: brownish grey, fractured, slightly fresh.
20*m*	-	21*m*	Diabase: brownish grey, fractured, fresh.
21*m*	-	23*m*	Diabase: brownish grey, fresh, slightly fractured.
23*m*	-	25*m*	Diabase: grey, fresh, siliceous.
25*m*	-	31*m*	Diabase: grey, fresh.

Lithology IVS-18

0*m*	-	1*m*	Soil: reddish brown, gravel-bearing.
1*m*	-	2*m*	Shale: brown, weathered, sandy.
2*m*	-	5*m*	Shale: brown, weathered, sandy.
5*m*	-	7*m*	Diabase: brown, weathered.
7*m*	-	10*m*	Diabase: greenish brown, weathered.
10*m*	-	12*m*	Diabase: greyish brown, weathered.
12*m*	-	14*m*	Diabase: green-grey, weathered, slightly fractured.
14*m*	-	16*m*	Slate: grey, fresh, slightly fractured.
16*m*	-	17*m*	Slate: grey, fresh, slightly fractured.
17*m*	-	31*m*	Slate: grey, fresh, hard, fine grained.

The general weathering profile constitutes of a soil profile that varies in depth below surface of between 0,00 *m* and 5,00 *m*, with an average depth of ± 2,83 *m*. This is followed by weathered rock varying in depth between 4,00 *m* and 16,00 *m*, with an average depth below surface of ± 10,11 *m* which gradually change to fractured rock varying in depth between 17,00 *m* and 28,00 *m*, with an average depth below surface of ± 22,17 *m*, before changing to fresh hard rock.

6.11.2 Tectonics, Lineaments and Structures

No major regional structures form part of the local geological description of the **Rietkuilspruit Area**.

Smaller lineaments inferred from the 1 *km* line spacing, regional aero-magnetic coverage of South Africa, in the vicinity of the Lamont Park and Rosashof small holdings, followed up by ground magnetic and EM34 geophysical traversing and percussion drilling, proved these smaller inferred lineaments not to be dolerite dykes. Investigative boreholes drilled on EM34 anomalies coinciding with some of these lineaments, intersected carbonaceous shale. The localities of both the inferred lineaments and geophysical traverse lines in this area, are indicated on **FIGURE III-1, APPENDIX III**. The magnetic and EM34 results/graphs are attached as **DATA SET III-1** and **DATA SET III-2, APPENDIX III**.

7. GEOLOGICAL IMPACT ASSESSMENT

The main objectives of this geological report are to generate the necessary geological base line information which may be required to support Permit/License Applications and/or other Environmental Documentation (EIA, etc.), which may from time to time be required for IVS.

Currently geological base line information is required to support the following:

- Waste Disposal Permit Applications.
- EIA's.
- Section 21 Water License Application.

Geological impact assessments are not per se indicated as a requirement for any of the above, as the activities within the greater IVS area, relate primarily to waste and effluent management, and not mining.

The base line information will, however, undoubtedly be used for related impact assessments for soils and ground water.

Having stated all the above, a synoptic discussion on the geological impacts will nevertheless be given, only if to serve the purpose of putting the whole matter into perspective.

7.1 IDENTIFICATION OF IMPACTING ACTIVITIES

The only activities within the greater IVS area which can be classified as having an impact on the geology relate to:

- Foundation excavations for buildings and large structures.
- Cut and Fill operations to prepare suitable construction terraces for buildings, blending yards and dumps.
- Scraping of dam basins.
- Excavation of borrow pits.

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7.2 IMPACT MANIFESTATION MECHANISM

Significant geological impacts, as they might relate to mining activities, usually comprise the excavation and disturbances of geological material to large depths, which could result in hydro-geochemical alteration within the disturbed area, or to structural disturbances introduced into overlying strata as a result of underground mining.

As a worst case, structural instabilities can result in surface subsidence and/or earth tremors.

It is quite obvious that the activities listed for the greater IVS area, do not fall into any of these categories.

7.3 IMPACT ASSESSMENT

An environmental impact assessment is inherently a prediction of eventualities which could possibly/probably occur in future, based on an interpretation or assessment of data/information available at the time of compilation of such an assessment. It therefore contains inherent uncertainties in terms of the:

- Nature of impact.
- Time of impact.
- Extent of impact.
- Duration of impact.
- Intensity of impact.
- Probability of impact.
- Mitigation of impact(s).
- Determination of specific impacts.

In order to address the above in a qualitative/quantitative manner, the following assessment protocol will be used:

Nature of impact	:	Description of impact of industrial operations on the receiving environment, with emphasis on what is being affected and how.
Time	:	During which phase(s) the impact will occur, i.e., Construction, Operational, Decommissioning or Post-closure phases.
Extent	:	Will the impact be limited to the site, the immediate surroundings, the regional setting or nation wide.

Duration	:	Short term	-	0 - 5 *years*.
	:	Medium term	-	5 - 15 *years*.
	:	Long term	-	Total operational phase.
	:	Permanent	-	Duration indefinite.
Intensity	:	None	-	No impact whatsoever.
	:	Low	-	Negligible to no impact.
	:	Medium	-	The environment is changed, but natural and social functions continue, albeit in a modified way.
	:	High	-	The natural, cultural or social functions or processes are altered to the extent that it will temporarily or permanently cease.
Probability	:	Improbable	-	Very Low Probability
	:	Probable	-	Distinct possibility that the impact might occur.
	:	Highly Probability	-	Most likely that the impact might occur.
	:	Definite	-	Where the impact will occur regardless of any prevention measures.
Integrated Impact Statement	:	Insignificant	-	Does not require further assessment/discussion.
	:	Low	-	No mitigation measures needed.
	:	Medium	-	Where it will have an influence, unless it is mitigated. Possible influence on decisions to go ahead with the project.
	:	High	-	Where it definitely will have an influence, unless it is mitigated. Definite influence on decisions to go ahead with the project.

Subject to the above, the following **Geology** impact assessment summary is submitted:

Nature of impact	:	Shallow excavations and cut/fill operations for dam basin and dump footprint development, foundations and building terrace preparation, essentially in the overburden and unconsolidated horizons.
Time	:	Will occur during the construction and operation phases.

Extent	:	Limited to the facility site/footprint/basin.		
Duration	:	Permanent	-	Duration indefinite.
Intensity	:	Low	-	Negligible to no impact.
Probability	:	Definite	-	Where the impact will occur regardless of any prevention measures.
Integrated Impact Statement	:	Insignificant	-	Does not require further assessment/discussion.

8. MANAGEMENT OBJECTIVES

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the statement of **Management Objectives**.

9. AVAILABLE MANAGEMENT OPTIONS

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the discussion of **Available Management Options**.

10. COST ESTIMATES

As no Environmental Management Measures for **geology** are required, no funds have to be allocated for on-going geological impact management.

11. GEOLOGICAL MONITORING SYSTEM

The **Integrated Impact Statement** of **Insignificant** negates the requirement for a geological monitoring system.

12. SUMMARY AND CONCLUSIONS

This report is one in a series of specialist Base Line Studies Reports compiled in fulfilment of the terms of reference for the compilation of an Environmental Master Plan for Iscor Vanderbijlpark Steel (IVS).

Although this report represents a stand-alone document, the results generated during this study will be integrated into the Environmental Management and/or Environmental Monitoring actions proposed in the IVS Master Plan.

This Geology base line report is somewhat different from other Master Plan specialist studies, in that geology does not represent a threatened environmental component in terms of possible IVS impacts. However, the geology does play important roles in at least two of the transport media responsible for impact migration/propagation. Pathways related to both soils and ground water are geology dependant.

Different levels of detail were generated during the geological study and compilation of the descriptions, to support the level of detail required for the different zones/areas. In addition to a description of the regional geology of the larger study area, descriptions of local geological conditions were compiled for Master Plan Zones, to support regulatory requirements, impact and risk assessments and selection and conceptualization of possible management measures.

The following actions were performed during this study:

- All available published and unpublished geological information relevant to the site was gathered and reviewed, and consultations were held with certain individuals on selected matters.
- A basic air photo interpretation, using the available aireal photographs, was performed for the Works Area in an attempt to delineate lineaments and structural futures.
- Different phases of geophysical investigations were performed to investigate the lithological and structural distribution within the area.
- The Council for Geoscience also performed a Seismic Hazard Assessment for the area.
- Information obtained from the drilling of a large number of boreholes in 2001, was collated, computerized and interpreted.
- Extensive use was made of GIS and other visualization technologies for the compilation of the geological descriptions.

Although not part of a typical geological description, miscellaneous sub-surface issues related to undermined areas, earth tremors, rehabilitated open-cast mining, potential for future mining and sinkholes and surface subsidence, were also addressed, as they are a requirement of the "Minimum Requirements" process of DWAF, for the compilation of Permit Application Reports related to solid waste disposal.

In this regard the following conclusions are relevant:

- No area within the study area is undermined.
- According to the Seismic Hazard maps for Southern Africa, a probability of 10% exists that a horizontal Peak Ground Acceleration of between 100 cm/s^2 and 200 cm/s^2 (0,1 g to 0.2 g) will be exceeded at least once every 50 *years* at the Vanderbijlpark Steel Works. It should be noted that this is only a basic hazard assessment and is by no means complete – such a study may only be undertaken after a statistical evaluation of all the earthquake occurrences in the study area. Furthermore the blasting in South Africa's coal mining areas, some of which are close to Vanderbijlpark, was neglected in this study.
- Open-cast mining activities in the study area relate predominantly to coal mining, with additional clay and gravel quarry activities. It can therefore be stated that no

current or rehabilitated open-cast mines occur within, or in close proximity (<1000 *m*) to the Study Area. The extent of gravel excavations within the Kiewiet footprint area, is rated as insignificant in terms of this assessment.

- The potential for future mining within a 1000 *m* radius of the study area, is insignificant. The economically mine-able coal seams mined north and south of the Vaal River, east of Vereeniging town, is not present within the study area.

- Due to the fact that no undermining has occurred on the site, and due to the lithological succession underlying the site (geo-technical stable units of the Transvaal Sequence), sinkholes and surface subsidence will not occur within the study area.

The regional geology for the area, which of course also relates to the local geology, comprise of formations belonging to the Transvaal System. Ascending the lithostratigraphic chronological order, the area is underlain by the following:

- Chuniespoort Group - Malmanie Subgroup- Dolomite, chert and remnants of chert breccia of the Rooihoogte Formation - exposures indicated some 2,75 *km* east of the IVS Work's eastern boundary. Dolomite of the Malmanie Sub-group is known as the host rock of South Africa's major secondary aquifers.

- Pretoria Group - Timeball Hill Formation - Ferruginous shale, hornfels, ferruginous quartzite.

- Pretoria Group - Hekpoort Formation - Andesite, agglomerate, tuff.

- Pretoria Group - Strubenkop Formation - Ferruginous shale, quartzite.

- Pretoria Group - Daspoort Formation - Quartzite and shale, ferruginous in places - exposures are indicated to arch concavely around IVS's Evaporation Ponds Dams 1 to 4, and the Maturation Ponds 1 to 3, the arch being to the east, basically striking north-south to some 400 *m* south of the Maturation Ponds.

- Pretoria Group - Silverton Formation - Shale with inter-bedded quartzite, hornfels, limestone.

- Marico Diabase Suite - The Marico Diabase Suite, which is probably related to an early intrusive phase of the Bushveld Complex. Informally and collectively referred to as Transvaal diabase, these rocks are intrusive into all horizons of the Transvaal Sequence, mainly on the southern side of the Bushveld Complex and more particularly on the south-eastern side.

- Prominent detrital deposits, consisting of gravels in a sandy or clayey matrix, are found along the Vaal River valley between Prieska and Potchefstroom, with isolated deposits found as far east as Standerton. Shallow deposits occur up to 30 *km* from, and as much as 120 *m* higher than the current river bed. Gravel consist of chert, quartzite, red jaspis, banded iron stone, lidianite, quartz, chalcedony, and bantams.

- Deep gravel deposits, representing gravel filled paleo-canals, occur close to the current river bed but can also be found much further afield and much higher. The Droogeveld canal south of the confluence between the Vaal and Harts Rivers, is a good example of such a canal.

- Gravel deposits are indicated on the geological sheet for the area, to occur on Rietkuil 551 IQ, the Steelvalley Agricultural Holdings and within the IVS property itself.

- Residual soils which developed on the sedimentary rocks. As a general observation it may be stated that residual soils formed from the Pretoria sedimentary strata, are shallow, often less than 2 *m* thick, and that they commonly consist entirely of inert minerals.

- Residual soils which developed on the andesites.

- Residual soils which developed on the Transvaal Diabase.

- Aeolian sand. Occurrences indicated on the geological sheet for the Vanderbijlpark area, seem to be restricted to the banks of the Vaal River, mainly the southern banks.

- Alluvium. Occurrences are indicated along the Rietspruit to the west of the works, the Leeuwspruit east of the Works and the Vaal River to the far south.

The main structural features present in the area, relate to faults and dolerite dykes:

- A major fault transects the area with a horizontal displacement of ~ 2 *km*. The Daspoort Formation exposures, around Vanderbijlpark Steel's Evaporation Ponds Dams 1 to 4, and Maturation Ponds 1 to 3, to some 400 *m* south of the Maturation Ponds, is displaced by a near vertical "sinistral wrench" fault displacing the strata in access of 2 *km* to the south-east and outside of the IVS property.

- From the gravimetric work done by the Council for Geoscience, the strata north of the fault zone seem to be pivoted upwards in the south-east, the hinge being to the north-west, roughly from where the displacement of the Daspoort formation took place. The displaced Daspoort Formation arches back from outside the IVS property and the fault zone, past the south-eastern corner of the property, the arch being to the north-west.

- The larger study area is bounded in the north and the south by two major east-west orientated dolerite dykes, inferred from the 1 *km* line spacing, regional aeromagnetic coverage of South Africa, and indicated on the geological sheet for the area as lineaments, or possible dykes, that can be traced over distances in excess of 40 *km*.

The formations exposed within the IVS property north of the displacement fault zone, is indicated to dip 14 *degrees* to the west, in the opposite direction of the arch, and perpendicular to the strike.

The displaced formations south of the fault zone, that arches back from the fault zone outside the IVS property past the south-eastern corner of the property, is indicated to dip between 9 *degrees* and 16 *degrees* to the north-west, roughly in the same direction of the arch, perpendicular to the strike.

Rock sampling for analyses has not been part of the Master Plan Study scope of work. The geochemistry of the sedimentary rock of the Pretoria Group shows evidence of complex source terrains, with predominantly granitic and sedimentary sources, as well as, possibly, ultra-mafic sources. The geochemical signature of the Pretoria Group sediments is indicative of a divergent margin tectonic setting (intra-cratonic sag, failed rift/aulacogen or passive margin).

Geological impact assessments are not per se indicated as a requirement for any of the above, as the activities within the greater IVS area, relate primarily to waste and effluent management, and not mining.

An Integrated Impact Statement of **Insignificant** (Does not require further assessment/discussion) is applicable to the area.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the statement of **Management Objectives**.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for the discussion of **Available Management Options**.

As no Environmental Management Measures for **geology** are required, no funds have to be allocated for on-going geological impact management.

The **Integrated Impact Statement** of **Insignificant** negates the requirement for a geological monitoring system.

APPENDIX I

GEOPHYSICAL REPORT COMPILED BY THE COUNCIL FOR GEOSCIENCE
(Volume 1 & Volume 2)

A GEOPHYSICAL INVESTIGATION OF THE AREA SURROUNDING THE VANDERBILJPARK STEEL MILL

VOLUME 1 – TEXT

BY:

E.H. STETTLER

REPORT NUMBER: 2001-0238

CONTENTS

VOLUME 1

1. INTRODUCTION

At the request of Jasper Müller & Associates a geophysical survey was undertaken by the Council for Geoscience (CGS) on the property of the ISCOR Steelworks at Vanderbijlpark and the immediate surrounding area. The purpose of the survey was to determine from the available geological and collected geophysical information an improved understanding of the 3-dimensional geology of the area. This would facilitate the location and cleanup of past Dense Non-Aqueous Phase Liquid (DNAPL) spills, specifically tar, a waste product of the steel making process. Unfortunately the exact locations of spillage were not recorded in the past. Due to the shallow water table some of the DNAPL occurrences may occur below the water table and soluble components of the coal tars could be present in the ground water.

The geophysical data set collected consisted of 3 parts namely, an airborne survey whereby magnetic, gamma-ray radiometric, near-infra-red spectrometric and elevation data were collected; a ground survey where gravity data and reflection seismic data were collected and lastly an experiment whereby the time domain EM technique was used to determine whether the DNAPL presence at shallow depth (0-40m) provides a measurable Induced Polarization (IP) effect.

This report describes all the techniques used and data collected and ends with a three dimensional geological model that describes the upper crust best considering the present constraints that can be placed on the geophysical data. The drilling results available to the author have been incorporated in the geophysical models to constrain the results.

Bruce Beckett, Louis Berrington, Jaco Smit, Dirk Beukes, Raimund Stettler and the airborne team of CGS undertook all the data collection. Dr Valerya Zadoroshnya interpreted the time domain electromagnetic data.

This report together with all the figures and fundamental images and data sets are also available on CD at the back of this report. The report consists of two volumes, of which Volume I contains all the text and Volume II all the figures and appendices.

2. SURVEY AREA

All figures referenced in this report, are found in Appendix A.

The overall region considered in this investigation is shown in Figure 1. The area is located in the central part of the 2627DB Vereeniging 1:50 000 topographical map. It is bounded by the following LO co-ordinates in LO 27:

Corner descriptor	X co-ordinate	Y co-ordinate	Latitude	Longitude
A	-2942910.	-73289.	26 35' 47.9"	27 44' 8.7"
B	-2942910.	-89356.	26 35' 47.9"	27 53' 49.3"
C	-2951951.	-89356.	26 40' 38.3"	27 53' 49.3"
D	-2951951.	-73289.	26 40' 38.3"	27 44' 8.7"

The airborne geophysical and ground geophysical surveys covered areas with slightly different boundaries and these boundaries were governed by financial constraints. Both these boundaries fall within the co-ordinates given above.

Important to note is that the IVS plant resides on a topographic high and on Figure 1, are the perennial and non-perennial streams that drain the IVS plant to the east and west, are also shown. An additional man made canal drains the IVS plant to the west.

Figure 2(a) is a recent aerial photo of the steelworks and surroundings as provided by ISCOR. The photo is rectified and the N1 together with the on-and-off-ramps can be seen in the northwestern part of the image. The existing waste dump and the steel mill occur in the central part of the photo. It also depicts the considerable amount of man made structures in the area. Electricity power lines crisscross the area in great numbers as well as electrified railway lines. Attention is drawn to these features since they have a negative influence on the data quality of magnetic, electrical and electromagnetic geophysical techniques. The white square on Figure 2(a) is the area covered by the airborne geophysical survey.

Figure 2(b) is an extract of the more important landmarks on the aerial photo and highlights the infrastructure. This map will be used as an overlay to facilitate the orientation and discussion of other data sets in the report.

The visualization software used here makes use of a right handed Cartesian co-ordinate system. To change the South African LO 27 based X and Y co-ordinates to a right handed Cartesian system the X co-ordinate becomes Y and the co-ordinates are multiplied by -1.0. These transformed co-ordinates are shown on the figures in this report.

3. GEOLOGY AND PEDOLOGY

Figures 3(a) and (b) show the outline of the steelworks in relation to the geology as recently updated by the Council for Geoscience (Bosch, 1999). Figure 3(c) gives the stratigraphy in the area. The ISCOR Steelworks is mostly situated on the Silverton Formation of the Pretoria Group, which is fortunate since it consists mostly of shale and is normally an aquiclude. The eastern part of the factory overlies the Daspoort, Strubenkop and Hekpoort Formations of the Pretoria Group, Transvaal Sequence. Apart from the Hekpoort Formation which consists of andesitic lava the other formations are made up of mostly shale and quartzite with minor chert. The shales and quartzites of the Timeball Hill Formation and dolomite of the Chuniespoort Group only outcrop east of the Steelworks. The geological map has been simplified east of the steel works where the amount of detail is not so important. Here the three units of the Timeball Hill Formation have not been differentiated.

A major fault transects the area with a horizontal displacement of ~2km. It is a left lateral strike slip fault. Due to the scarcity of outcrop in the region the precise location of the fault is not possible just from geological observations alone and the location of the fault on Figures 3(a) and (b) is by inference but also using the available geophysical data.

It should be noted that the area is mostly covered by overburden and that the geological boundaries as indicated in Figures 3(a) and (b) are interpreted boundaries (Pieter Bosch, Pers. Comm., 2001).

Figure 3(b) was prepared as a vector file that is used as an over– or underlay to facilitate the orientation of geophysical phenomena discussed in the report.

Figure 4 is a soil map and the outline of the ISCOR property is indicated on the map. Since the DNAPL material will probably in time migrate downward and follow the solid bedrock contour, the soil map is important to indicate where past and present river courses existed. The depth to bedrock is expected to increase over the palaeo and present river channels bringing buried DNAPL material that migrated to these deeper bedrock parts in contact with the ground water level. The proximity of the DNAPL occurrences to these old river courses is therefore important.

4. <u>GEOPHYSICS</u>

4.1 AIRBORNE

Airborne geophysical data was collected to determine the more exact location of dykes in the area that could act as pollution pathways. Since it was expected that the Timeball Hill Formation is slightly magnetic its exact location could be determined from the air and thus constrain the geology map. It was also expected that diabase sheets intruded into the Transvaal Sequence could be mapped. Possible faults in the Timeball Hill Formation could be extrapolated into the rest of the area.

Gamma-ray spectrometer data was collected because slag is somewhat radioactive with an elevated Th and U count and could be important in delineating past localities of pollutants. Potassium rich halos have been reported in the literature to be sometimes associated with hydrocarbon occurrences. Although it is realized that the geological conditions and processes by which they were formed are totally different from the DNAPL occurrences it was worth the experiment to determine if some change in radiometric parameters was apparent. Furthermore the recorded K, U, and Th contributions could place further constraints on the geology map.

The near-infra-red (NIR) data was collected to further improve the geology map. Recording the spectra of NIR absorptions and emissions of rock below the aircraft can be used to identify rock types. NIR spectra over tar polluted areas could have a different signature.

The Council for Geoscience has its own airborne geophysical capability and conducted the airborne data collection with a Jabiru ultra light aircraft. The survey specifications are as follows:

Line spacing: 50 m
Tie-line spacing: 600 m
Line direction: North-South
Tie-line direction: East - West
Magnetic sampling distance along line: ~3 m
Gamma-ray spectrometer sampling distance along line: ~30 m
Near-infra-red spectrometer sampling distance along line: ~30 m
Near-infra-red sampling bandwidth: 0.3 to 1.6 μm
Aircraft flying height: 50 m
Aircraft surface velocity: 120 km/h

The absolute accuracy of the magnetic values is within 1nT and the positional accuracy of each collected data point is within 3m.

The instrument and aircraft specifications are given in APPENDIX B. The collected geophysical data was processed in the normal way. For the magnetic data this entailed subtracting the magnetic base station recordings that are recorded as a function of GPS time from the magnetic data recorded by the aircraft as a function of position and GPS time. The resultant data is corrected for aircraft orientation after which tie-line leveling is performed to remove the daily variations.

The spectrometer data recordings consist of individual gamma-ray spectra recorded every second (~30m) in the energy range between .5 and 6.0 KeV over 512 channels. The individual spectra is corrected for channel drift during flight and then a process called Noise Adjusted Singular Value Decomposition (NASVD) (Hofgaard, 1997) is performed on the collected spectra to remove noise from the spectra. Gamma-rays colliding with air molecules cause them to lose energy and due to this process called Compton scattering high energy cosmic gamma-rays fall into the energy ranges of Th, U, K and therefore contribute to those channels. In the same way Th contributes to the U and K windows and U to the K window. A process called stripping removes these false contributions. After the further compensation for the altitude effect, estimates of K in percentage of rock volume, and U and Th as parts per million, result.

The near-infra-red (NIR) spectrometer data is processed in a similar way as the radiometric data since individual spectra in the wavelength range 0.3 to 1.6 micron are also recorded every second (~30m) below the aircraft. The footprint of the NIR spectrometer is about 25m at a flying height of 50m, but due to the buffeting of the aircraft is not always directly below the aircraft.

The laser altimeter on the aircraft just provides the distance between the aircraft and the surface of the earth within a centimeter. This is achieved by recording the time difference between the laser light leaving the altimeter and the reflection from the ground reaching the altimeter. However, certain phenomena on the ground such as grass or heat waves can scatter the light. In areas with trees the laser altimeter will record the distance to the tree canopy. Subtracting the laser altimeter recordings from the GPS height of the aircraft above sea level and leveling the data afterwards provides the digital elevation model which in absolute terms is as accurate as the recorded GPS height of the aircraft, ie within 3m of the true height. The relative rate of change of the elevation is, however, much better and is within a cm.

4.1.1 Magnetics

Figure 5 depicts the total field magnetic data set, sun shaded from the north. Magnetic highs are coloured red and magnetic lows (valley's), blue. Most of the features on the map originate from artificial sources and especially the electrified railway lines have a large effect. The magnetic signature of the Timeball Hill Formation is unfortunately very subdued and its boundaries are indistinct from the noise. However, the existence of a number of possible east-west striking dykes that were postulated from the previous magnetic 1 km line spacing survey were disproved and only one major east-west striking dyke exists in the area. This dyke is displaced by a north-northwest striking fault. This fault is considered a part of the left lateral fault to the south-east as already mentioned under geology. The fault extends underneath the waste dump north of the steel mill. Small horizontal shifts in the magnetic anomaly pattern along the dyke may be an indication that smaller faults could still be present along the dyke. They are considered of academic importance in this study as they are far removed from the areas where known DNAPL pools occur. Figure 6 displays a qualitative interpretation of the magnetic data overlain on the colour coded magnetic image and the aerial photograph. The effects caused by the infrastructure in the area are also given on Figure 6.

4.1.2 Gamma-ray Spectrometry

Figures 7 to 10 respectively displays the Potassium, Uranium, Thorium and total count, radiometric data sets with the infrastructure of the area overlain on the maps. Areas with high radio element concentrations are coloured red. Water retards gamma-rays completely and the deep blue colours indicate where water occurred on the surface when the airborne survey was flown as would be the case for the water ponds on the ISCOR steel mill property. To combine the information from the individual K, U and Th data sets, a combined ternary map of K, U, Th appears in Figure 11. An overlay of the geology onto the ternary radiometric map is shown in Figure 12.

Radiometric data has virtually no depth penetration (maximum 0.5m) and the results reflect changes in radio element composition at or very near the surface. The most prominent anomalies on all three radio element maps are due to the waste dump that contains slag with a slightly elevated K, U and Th concentration. The maximum radioactive element concentrations are 8 percent K, 21 ppm U and 38 ppm Th. Compare this to average concentrations of 3.8 per cent K, 2.8 ppm U and 4.6 ppm Th for SA rocks.

The town of Vanderbijlpark to the south of the steel plant has possibly also been built with material from the waste dump (slag used as concrete and mortar aggregate) because an elevated radio element concentration exists over the town. An alternative is that the prevailing wind has blown furnace dust onto the town over a long period of time.

Other linear features with elevated radio element concentrations are the major roads and railway lines because foreign material was used along railway lines as ballast or road metal.

Figure 11 represents a ternary map presentation after Duval (1982) that is used to highlight areas where a positive or negative correlation exists between the K, U and Th element concentrations. The magenta, cyan and yellow colour scheme is used in this instance that represents K, U and Th respectively. A positive correlation between all three elements will produce a black colour and the absence of radio elements a white colour. An elevated concentration of K will produce a magenta hue and Th and U together a green hue. Again the waste dump and the town of Vanderbijlpark stand out as black areas flecked with occasional green. Other elevated areas are a K rich region in the north western and western regions of the study area that are possibly due to undisturbed old river gravel near the surface and man made structures in the eastern part. Slightly elevated K–rich magenta hues define a combination of possibly old river gravel and the modern canal extending from the steel mill to the Rietspruit flowing north-south along the western perimeter of the study area.

DNAPL occurrences by themselves are not gamma-ray emitters and as such would not be expected to show up on the radiometric data. However, as already mentioned Potassium concentration halos are known from the literature to occur above some oil occurrences. Figure 11 indicates an increased amount of small isolated localities with a deeper magenta and therefore higher Potassium concentration bordering on and extending westwards from the existing waste dump. A radiometric pattern reminiscent of a 'halo' is specifically visible on the south western edge of the existing waste dump as well as on the southwestern extremity of the southernmost water pond as indicated in Figure 12. Both these areas coincide with areas where DNAPL pools have been identified, as will be shown later in the report.

Figure 12 indicates that apart from the Timeball Hill Formation the overburden has unfortunately been too much disturbed by farming (adding fertilizer) and other man made activities to allow the delineation of the underlying geology. Unfortunately the radiometric data in this instance was not as useful as was anticipated, to define the boundaries of the different geological units, but at least a bench mark data set is available should a dispute ever arise over the radioactivity of the waste dumps.

4.1.3 Topography and Digital Terrain Model

Figure 13 is a detailed elevation map (digital terrain model) as determined by subtracting the GPS elevation from the onboard laser altimeter result. The results are unfiltered and the high frequency noise pattern on the data is due to small surface disturbances such as trees and man made objects. The most outstanding features that can be identified are the drainage pattern. The steel mill is topographically elevated and three tributaries of the Rietspruit (of which one is a man made canal) in the west and the Leeuwspruit in the east drain the steel works.

4.1.4 Near Infra Red Spectrometry

Figures 14, 15 and 16 depict three near infra red (NIR) images representing 1.0 to 1.2, 1.2 to 1.4 and 1.4 to 1.6 micron while Figure 17 depicts a ternary map of the three selected windows from the near infra red spectrometer. The light strength recorded as a function of frequency is in Lumen. Figure 17 represents also a qualitative interpretation of the data. Near-infra-red spectrometry similar to gamma-ray spectrometry has no depth penetration and all features visible are located at or very near to the surface.

The use of near infra red spectra are becoming increasingly popular to map geology and depending on the range of the spectrometer the presence of certain minerals or even rock types can be identified from the collected data. The NIR spectrometer used here is still in a pre-commercial stage where data is collected routinely to obtain experience in the processing of the data and its interpretation.

Momentarily it is not possible to isolate different mineral species in an automated form but the individual spectra can be investigated as a function of position to infer the presence of certain mineral species.

DNAPL occurrences have no known distinctive NIR reflective or absorptive spectra but again the data was collected to see if an unusual behavior could be detected in the area where DNAPL pools are suspected. In the area of interest the contribution of vegetation overshadows all the other effects due to geology and farm boundaries and other man made effects dominate on Figures 14 to 16. A visual comparison between the ternary NIR image and the overlain geology on Figure 17 show very little correlation.

4.2 GRAVITY SURVEY

The gravity technique is used to distinguish between different rock types on the basis of their density. Figure 18 depicts the distribution of gravity observation stations that were collected in the area in relation to the Bouguer anomaly map and the infrastructure. A total of 150 measurements were made. The measurements were converted to Bouguer anomaly values in the usual way. Elevations were determined by GPS and the accuracy of the data improved by post processing of base station information. The positional accuracy of the gravity measurements is within 1m and the elevations after post processing are within 1.5m. As usual the red colours signify gravity highs and the blue colours gravity lows.

Figure 19 depicts a colour coded contour map of the Bouguer anomaly values. The gravity highs are due to the presence of the dolomite of the Chuniespoort Group which outcrops in the northeastern part of the survey area. The local high over the area called townships (south east of the steel mill on Figure 18) is due to the left lateral strike fault bringing dolomite nearer to the surface underneath the townships area.

An arbitrary regional or background gravity field was chosen and represents a heavily filtered representation of the Bouguer field as shown in Figure 20. The regional field was chosen such that when removed from the Bouguer anomaly values the resulting residual gravity field accentuates the shallow geological entities (in the immediate 3km from surface). Figure 21 depicts the residual gravity field overlain on the infrastructure map.

The residual gravity field indicates that the dolomite in the eastern part of the area under investigation reaches its maximum thickness under the Karoo Sequence cover. Going west it dips and is overlain by the rest of the Transvaal sequence. In the area south east of the steel mill coinciding with the Boipatong Township the local gravity high indicates the dolomite being moved upwards as would be expected from the left lateral strike faulting. Significant is the gravity low that is roughly centered on the left lateral strike fault and underlies most of the steel mill and the waste dump north of the steel mill. Modelling described later indicates the low to be caused by the combined effect of the fault and a thicker overburden.

A further band of gravity highs occurs further west with the highest local peak occurring under the ISCOR steelworks. The possible cause of this high is unknown. Further south west a gravity low develops again and this low is the result of an increase in overburden thickness. A qualitative interpretation of the gravity data is given in Figure 22.

Of great interest is the depth at which the dolomite is expected below the area where the DNAPL pools have been identified. If the dolomite would occur near the surface soluble components of the DNAPL presence could move into this primary aquifer with serious consequences for water quality in the dolomite. Five east west profiles were chosen and geological models were calculated along them to determine the behaviour of the dolomite at depth. Please note that profile 2 runs semi-parallel to the major dyke and cuts the dyke two times. No evidence of the fault having displaced the Transvaal Sequence vertically in a major way is visible in the gravity data.

Starting from north to south, on profile one shown in Figure 24, a horizontal regional field was chosen at –131.0 mgal that is different from the one shown in Figure 20 because now the residual field is expected to represent the full thickness of the Transvaal Sequence. The previous regional field was chosen to highlight shallow features. According to the model in Figure 24 the dolomite is expected here to occur at the surface north east of the steel mill but then dipping down to be 2000m below the surface northwest of the steel mill and would not be affected by the DNAPL pools. The densities used in the model are also given on Figure 24.

Figure 25 depicts the second profile that crosses the major dyke in the area two times. The regional field is again a horizontal line taken now at –131.2 mgal. The dolomite again outcrops east of the steel mill and according to the best fitting model, become shallower at a depth of 1700m. The small variations in the gravity field have been modelled as being due to variations in the thickness of the weathered surface layer. Profile 2 transects the absolute northern extremity where DNAPL pools are expected and at a depth of 1700m below surface absolutely no pollution of this aquifer is expected. The fault's position is indicated on Figure 25 but according to the model it has not affected the Transvaal in a major way, vertically. The undulations in the gravity field could be explained by variations in overburden thickness, but could also be due to slight displacements in the Transvaal Sequence.

Figure 26 shows the third chosen profile and the regional field now lies at –131.4 mgal. West of the slag dump the dolomite is expected at about 1200m below surface and considering all the impervious layers above the dolomite such as the

Silverton Shale Formation and the Hekpoort Andesite Formation no effect on the dolomite is expected. The profile intersects the expected fault where it crosses the dyke and the dolomite is thicker, east of the dyke.

Moving further south, profile 4 depicts the dolomite to occur at 1000m below surface in Figure 27, for a regional field chosen at the Bouguer anomaly value of –131.4 mgal, with an upward (vertical) displacement of approximately 400m east of the fault. The Daspoort and Strubenkop Formations underlie most of the town of Vanderbijlpark and according to the calculated model as shown in Figure 28, the Hekpoort Formation is expected to thicken substantially.

One drawback of this potential field modelling is that if the regional field is chosen incorrectly, the whole model will be incorrect and the dolomite could be at a deeper or shallower level. A second geophysical technique is needed to overcome this ambiguity and the technique chosen was the reflection seismic technique.

5. REFLECTION SEISMIC SURVEY

Apart from the ground penetrating radar technique, the seismic reflection technique has the highest resolution of all geophysical techniques. It is, however, very labour intensive to apply and therefore expensive. Reflection seismics work best for a layered earth and layers with different seismic velocities (velocity at which a shock wave is propagated) will show up as reflectors, where the reflector will be the boundary between 2 layers with differing seismic velocities. There is a positive correlation between seismic velocity and density and therefore it is expected that the dolomite, which is much denser than any of the other units in the Transvaal Sequence, will give a strong reflector. The depth to this reflector can be determined much more accurately and the gravity regional field can be adjusted to allow the gravity model to concur with the seismic result.

Figure 29 shows the location of the seismic reflection line with a northwest strike and starting just west of Dam 10. The length of the line was 1500m and a 10m geophone separation was used. With a 48 geophone spread, a 24-fold coverage was achieved and the source was detonated midpoint of the spread. The source was a self constructed 12 bore Betsy Gun, shooting rim fire blanks manufactured by Swartklip (Denel). This source allows data to be recorded down to more than 1 second two way time.

The data was processed in the normal way by performing sorting of the reflections into bins on which the normal move out correction is applied. Static corrections are then applied that correct for variations in overburden thickness. Stacking the data together and performing cross correlations, the CDP brute stack, as shown in Figure 30, is achieved.

Migration of the data should be the next step, but great difficulty was experienced in the migration process. The data set is very sensitive to the migration velocities and is either under or over migrated. It is suspected that this is due to incorrect static corrections that were applied. Therefore the CDP brute stack was used to determine the depth to the strongest reflector which is considered to be due to the dolomite, and to interpret the seismic section.

The most obvious reflection occurs at a depth of 0.6 sec (two way time) and at an average velocity of 4000m/s this results in a depth of 1200m below surface for the dolomite. This fits very well with the result obtained from the gravity data (also 1200m) and there was no need to adjust the regional field up or down.

The CDP brute stack is given in Figure 30 and the interpretation of the brute stack in Figure 31.

6. <u>TIME DOMAIN ELECTROMAGNETICS</u>

Although the direct detection of hydrocarbon pollution does not strictly constitute a part of Phase I (creating a geological reference model), an experiment was conducted with the time domain electromagnetic technique to verify whether it is possible.

It has been recognized recently (especially in the Russian literature: Kamenetsky et.al, 1995; Zadorozhnaya and Bessonov, 2001) that rocks with an electrical chargeability cause a so-called Induced Polarization effect on time domain electromagnetic sounding curves. This so-called IP phenomena can be due to either a membrane effect caused by clay, which gives a positive anomaly to the sounding, and an osmosis effect that adds a negative anomaly to the layered earth effect. To establish what is to be expected, a theoretical model is first established where layers are identified by their resistivity, thickness, decay constant and percentage IP effect. The exact mathematics for this modelling is still under development, but with the help of Dr. Zadorozhnaya and Prof. Kamenetsky, the expansion of the electromagnetic theory was possible where the inclusion of previously neglected displacement currents can now be accommodated.

It must be emphasized that the time domain electromagnetic technique is much more susceptible to man made noise than the frequency domain technique, because the earth response is measured when the primary current has been switched off. Thus any interference from electrical cables or electrical fences will either add or reduce the measured amplitude in specific windows. Such behaviour may also be taken as being caused by an IP effect. For this reason the survey area was not extended to inside the steel mill property.

6.1 THEORETICAL MODEL FOR HYDROCARBON PRESENCE

Borehole information has indicated that to describe the earth electrically in general, a 4 layer earth model has to be considered. This consists of a surface layer of soil, clay consisting of decomposed Silverton shale or well decomposed Hekpoort andesite, partly decomposed shale or andesite and solid shale/andesite. The depth to solid shale/andesite varies between 2 to as much as 35m.

For calculating theoretical models, the result is plotted as a function of depth against longitudinal conductance $S\tau$, which is more appropriate for the electromagnetic technique than apparent resistivity. In Figure 32 the theoretical response of a four layer earth with suitable parameters chosen, based on field measurements at Vanderbijlpark, is shown. The 2 layers that cause the IP effects were taken to occur at a depth of 28m to 46m below surface. The following parameters were chosen to calculate a theoretical IP effect:

a) Resistivity ρ:	22.3, 24.0, 50.0, 225;
b) Layer thickness H:	28.0, 18.0, 2.5, 12.0;
c) Decay constant τ:	- , 0.15, 0.21, 0.03 [µsec];
d) IP effect η:	- , 0.15; 0.11, 0.03

In Figure 32 the IP effect which causes a distortion of the $S\tau$ curves is demonstrated. The data set to the left shows the results for the central loop sounding for a loop size of 100m by 100m. The smooth response that just rises and then stays constant as a function of depth is the model without the IP effect. The data set on the right is for an off-center position where the sounding position is 25m from the center. Again the smooth response that just rises and then remains constant is the model without the IP effect. Both models show the IP effect but it is more pronounced for the central loop sounding.

From the theoretical response it thus is possible to identify the IP effect in the sounding curve but what is more difficult to establish in field measurements, is whether we are dealing with the membrane effect that can be caused by just clay, or the osmosis effect.

6.2 RESULTS AT VANDERBIJL STEELWORKS

To test the above theoretical models, a 100m by 100m transmitter loop was laid out near the so-called TOM 6 borehole, which contained the best example of the presence of tar at the time of doing the experiment. A 25m grid was laid out over the area extending up to 50m away from the transmitter loop. Measurements were taken at each station and the IP effect is clearly noticeable in the results.

As an example of what has been measured Figure 33 (a) shows the $S\tau$ curves of measured field data for the first four stations at the so-called TOM 6 borehole.

The measurement position was off-set by 25m from the central position. The plot of Sτ curves demonstrates the distortion of all curves by an IP effect. The same distortions are apparent in Figure 33(b) for the same transmitter loop position, but measured at positions closer to the center of the transmitter loop. Station 1 is in the center and 11 and 13 are further away.

Figure 34(a) depicts a cross section identifying the interpreted electrical layering at the TOM 6 borehole and surrounding area. It should be taken note that the cross section is not linear and its position can be followed by making use of the sounding location plan also present on Figure 34(a). The calculated electrical model from the TDEM soundings, results in a 4 layer earth with the upper layer being ~25m thick with a resistivity of about ~22Ωm, followed by a layer of ~20m thickness with a resistivity of ~26Ωm, a thin ~10m layer with a resistivity of 50Ωm followed by basement with a high resistivity. Figure 34(b) depicts the same model but identifies the layers by their contribution to the IP effect. Layer 3 is identified as having the highest IP values.

More than 150 transmitter loop positions were occupied and Figure 35 shows the sounding positions. The soundings were collected to the west of the ISCOR perimeter, inside and outside the area where DNAPL pools are is expected. To determine the IP effect a best fitting theoretical curve with IP effect included was fitted to the data. This approach has a fallacy in that no distinction can be made at the moment between the membrane and osmosis effects. The theory for this has still to be completed. The measured transient sounding curves, as well as the best fitting models, are given in Appendix C of Volume II of the report.

If the IP effect can be equated with the occurrence of DNAPL pools, then contouring the percentage IP effect may highlight previously unknown pools. Figures 35 and 36 map the expected IP effect west and northwest of the steel mill.

Virtually no IP effects were encountered at the upper waste site and pond. The highest values were encountered west of the lower waste site. Figure 36 also indicates the sites where DNAPL pools were encountered with subsequent drilling and it is clear that the detection of hydrocarbons with the TDEM technique is only about 65 percent accurate. Due to the high incidence of man made noise in the area certain distortions on the TDEM field could have been erroneously identified as IP effects and the presence of clay could have added to the problem.