LETTER OF INTENT: SCIENTIFIC DRILLING IN THE BARBERTON BELT, SOUTH AFRICA

Coordinators
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Abstract
The Barberton Greenstone Belt in South Africa, one of the best-preserved successions of mid-Archean (3.5-3.2 Ga) supracrustal rocks in the world, is a remarkable natural laboratory where conditions and processes at the surface of the Archean Earth can be studied in detail. Investigation of shallow (100 to 1000m) diamond drill cores in carefully selected volcanic and sedimentary successions will be used to reconstruct the environments at or near the Earth's surface where life first emerged and subsequently evolved. We aim to understand, in greater detail than ever before, the complex processes of Archean sedimentation and volcanism, and how these interacted at the interface between lithosphere-hydrosphere-atmosphere-biosphere.

Despite generally good outcrop, nowhere in the Barberton belt are complete field sections preserved, and crucial features such as the contacts of lava flows and continuous successions of critical sedimentary rock sequences are not exposed. Only through diamond drilling will we be able to obtain the continuous sections and relatively unaltered samples through the volcano-sedimentary successions. Two main targets have been identified. (1) **Sedimentary sequences**, which will provide information about erosion and sedimentation on the early Earth, the composition and temperature of Archean seawater, and one possible site where life may have emerged and evolved. Study of tidal sequences will provide information about the dynamics of the Earth-Moon system, and the investigation of spherule layers (including impact debris) provide information about the nature and magnitude of meteorite impacts on the early Earth. (2) **Successions of ultramafic to felsic volcanic rocks** will provide new insights into volcanic processes, dynamics of the crust and mantle, interaction between oceanic volcanic crust and the hydrosphere and biosphere. The sources of hydrothermal fluids on the ocean floor, driven by circulation of seawater through the volcanic pile, constitute a second habitat of early life.

The project is supported by scientists from 13 countries in five continents and by the mineral exploration industry. Planning meetings have already been held in Johannesburg (Oct 2006), San Francisco (Dec 2006) and Berlin (March 2007). Proposals for funding have or will be submitted to agencies in Europe, America and Asia. Site investigation is currently underway and drilling is planned for mid to late 2008. Here we request ICDP support for a field workshop in the Barberton belt in October 2007, with the aim of preparing a full drilling proposal to ICDP for January 2008.

Scientific Objectives

Our aim is to understand how the early Earth functioned and the conditions in which life emerged and evolved. Through the investigation of cores drilled in the sedimentary and volcanic sequences of the Barberton belt, we will address issues such as

- the temperature and geodynamic activity in the Archean mantle,
- the geodynamic setting and thermal structure of the Archean crust,
- the nature of the earliest volcanism,
- hydrothermal circulation through the Archean oceanic crust
- microbial habitats and metabolic activity of microorganisms in volcanic and sedimentary settings,
- the temperature and composition of the Archean oceans.
- sedimentation under conditions different from those of the Phanerozoic e.g. no vegetation, and a hotter, more acidic atmosphere
- dynamics of the Earth-Moon system.
- meteoritic projectile flux during the mid Archean.

The Barberton Greenstone Belt, South Africa

The ca. 3.55-3.23 Ga Barberton Belt, a small, cusp-shaped succession of volcanic and sedimentary rocks invaded on all sides by granitoid plutons (Fig. 2.1) is located about 350 km east of Johannesburg. It is world famous for its komatiites, a type of ultramafic lava named after the Komati River which runs through the southern part of the belt and for its thick sequences of sedimentary rocks, which have yielded some of the earliest records of early life. The greenstone sequence, assigned to the Swaziland Supergroup, has been subdivided into three stratigraphic units. From base to top, these are: (1) the Onverwacht Group, dominated by ultramafic and mafic volcanic rocks with minor but important sedimentary chert units; (2) the Fig Tree Group, a meta-turbiditic succession made up of greywackes, shales, and cherts; and (3) the Moodies Group, characterized by coarse-grained clastic sedimentary rocks, mainly including sandstones and conglomerates (Fig. 1). The protracted, 350 million year long evolution of the region, from initial volcanism and sedimentation through to deformation and granite intrusion, has been used as a model for the formation of the continental crust (de Wit et al., 1992).

Extensive field-based studies in the Barberton belt have already provided evidence for the existence as early as 3.5 Ga of a rich microbial ecosystem situated in shallow and deep hydrothermal habitats (Walsh, 1992; Walsh and Lowe, 1985; Furnes et al., 2004. Westall et al., 2006). Micropaleontological studies show that filamentous and spherical structures reminiscent of modern bacteria, as well as laminated stromatolites representing fossilized microbial mats are widespread (Westall et al., 2001) but controversial (Altermann, 2001). The stromatolites from the Barberton Belt and some other early Archean occurrences are equivocal (Lowe, 1994; Brasier et al., 2004) Stable isotopic data have revealed the likely emergence of diverse groups of prokaryotes including carbon fixing Bacteria and Archaea, methanogens, sulfate reducers and possibly photosynthesizers (Nealson & Rye, 2003). Archean sedimentary sequences provide information about conditions at Earth’s surface: the nature of erosion, the transport, deposition and

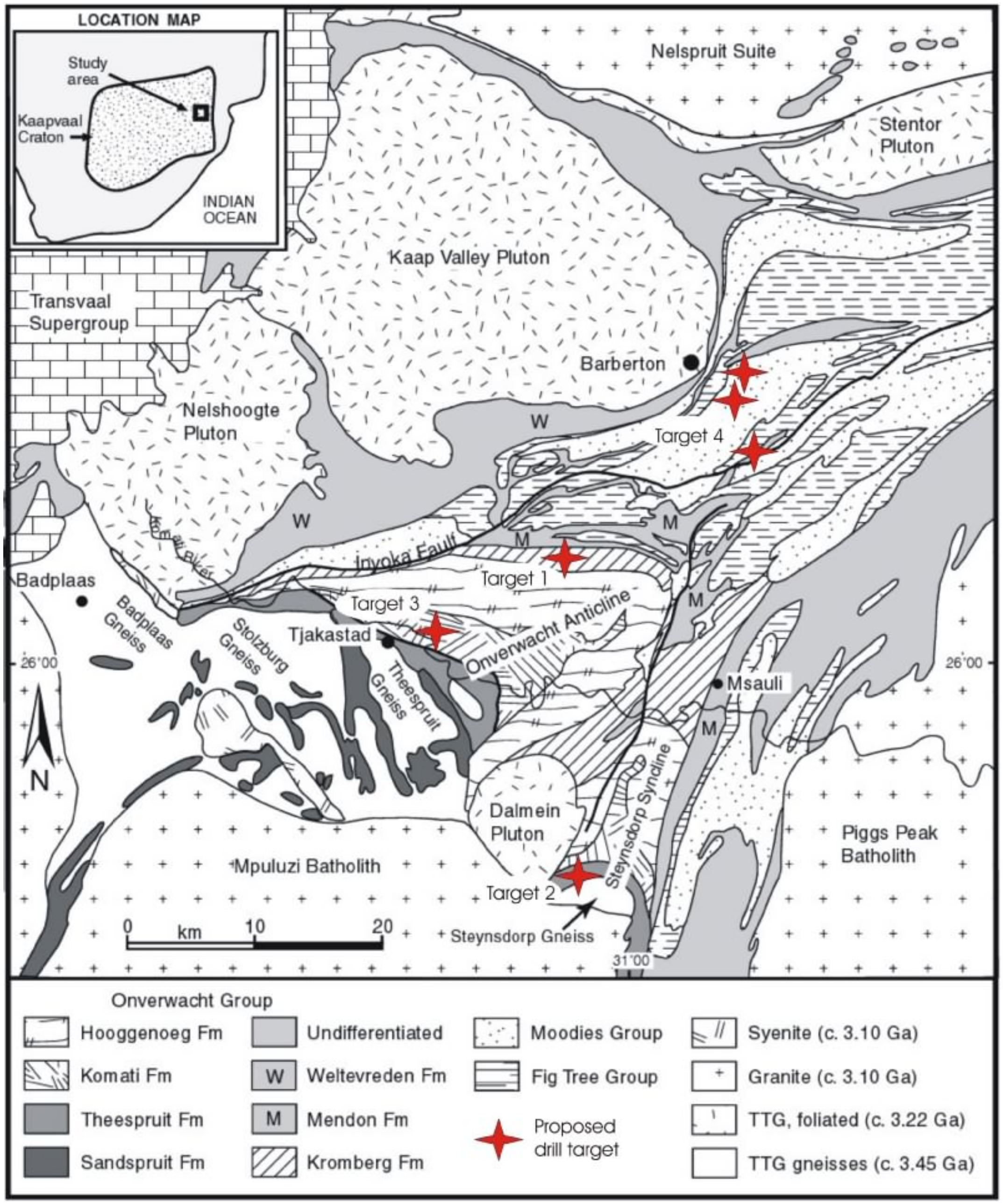

Figure 1. Geological map of the Barberton Greenstone Belt showing the proposed drill sites. Target 1 - Buck Reef Volcano-sedimentary complex ; Target 2- The Theespruit formation ; Target 3 - Komatiites and basalts of the Komati Formation ; Target 4 - Upper Onverwacht and Fig Tree Groups

diagenesis of sedimentary material, the thermal history and evolution of sedimentary basins, and thus the overall geodynamic setting on the early Earth.

The ultramafic lavas of the Barberton Belt have unusual compositions that have been used to define the so-called Al-depleted or Barberton-type komatiite (Nesbitt and Sun, 1976; Arndt, 1994). These rocks formed through melting under unusual conditions in the mantle. Controversy surrounds the exact setting: most geologists support a model in which the melts form in an unusually hot mantle plume (e.g. Arndt et al. 1998) but others advocate melting in cooler conditions in an Archean subduction zone (e.g. Grove and Parman, 2004). Resolution of the issue has important implications for our understanding of Archean geodynamics. Despite more than 30 years of research, very few complete chemical analyses of Barberton komatiites are available. The rims of basaltic pillows contain micrometer-scale mineralized tubes that provide evidence of submarine microbial activity during the early history of Earth (Furnes et al., 2004). Black and white smokers on the Archean ocean floor, the exits of hydrothermal fluids that circulated through the basaltic crust represent a possible setting for the emergence and evolution of life (Russell and Martin, 2005).

Drilling Targets

Four possible targets have been identified as described below. Some of these will intersect a dominantly volcanic succession, others will target mixed sedimentary sequences.

Target 1: Buck Ridge Volcanic-Sedimentary Complex

Coordinators:

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Jens Gutzmer	Mineral Deposits, Geochemistry, RAU Johannesburg
Paul Mason, Wout Nijman	Earth Sciences, Utrecht University.

(a) The scientific issues to be addressed by the drilling:

Sedimentary context and habitats of early life, origin of silicification, paleo- land surface processes, role of microorganisms (past and present), hydrothermal cycle (incl. structural control and shallow crustal level-intrusions), chemistry of the volcano-sedimentary system, properties & composition of Archean seawater and atmosphere.

There is an urgent requirement for new robust geological and geochemical data that will help to provide a better control on formation of the early continents and the timing and location of the emergence and evolution of life. The ca. 3.4 Ga Buck Ridge volcano-sedimentary complex is a key target area for solving these problems since it is one of the most well studied and extensive chert units in the early Archean. It consists of a wide range of rock types including alternating mafic and felsic volcanics, sedimentary cherts and a variety of intrusive rocks. The most prominent chert, the Buck Ridge Chert, has been investigated in detail with focus on analysis of sedimentary facies, paleoenvironment, (isotope) geochemistry and structural control (e.g. Lowe & Byerly 1999, Tice & Lowe, 2006, De Vries et al., 2006). Tice and Lowe (2006) relate abundant carbonaceous matter in the Buck Ridge Chert to microbial mats in a non-hydrothermal environment. On the other hand, De Vries et al. (2006) advocate hydrothermal venting to be a common growth-fault related phenomenon directly related to the depositional history of the Buck Ridge Chert (see also De Vries and Touret 2006). The potential for having hosted abundant microbial life renders the Buck Ridge Chert a priority target for the proposed drilling project. However, an important limitation to all of these studies is their focus only on surface outcrop.

(b) The need to drill:

Drilling will provide access to those parts of sedimentary and igneous rock successions that are typically unavailable across the eroded and vegetated outcrops. It will allow us to:

(1) analyse in a third dimension (in addition to surface outcrop) the detailed lithostratigraphic relationships between different rock types including intrusive contacts and erosive surfaces

(2) log continuous sequences of sedimentary or igneous rocks, reveal contacts between units and identify the eventual presence of soft rock types absent from surface outcrop.

(3) gain fresh material for chemical or isotopic analysis (e.g. biomarkers, PT conditions, fluids)

(4) reconstruct hydrothermal processes using unaltered material

(5) obtain fresh material for paleomagnetic study (avoiding surface lightning affected rocks).

(c) **Specific Drilling Targets and Drilling Procedure**

Three main target areas in the Buck Ridge complex are proposed for drilling. The drill site localities are derived from investigations in Utrecht University's "Earth's Earliest sedimentary Basins" project (De Vries, 2004) and are shown in Fig. 1.

Drill site I: **Buck Ridge-West.** Target: complete section through the complex

Coordinates: 30°51'65"E/25°55'11"S to 30°51'33"E/25°56'6.5"S; core length ca. 1000-1500m

The site is located in the crest of a roll-over anticline of the complex where strike rotations due to the growth-fault character of the complex are minimal. Average bedding orientation is subvertically overturned. Thickness of the sedimentary sequence at this locality, from the top of the Buck Ridge Chert to the sole detachment of the complex, is ca. 1500 m in agreement with the proposed core. Whether the entire length is drilled will depend on the funds available and the cost of drilling to this depth.

The rock sequence to be drilled includes (from bottom to top): basal shear zone, pillow basalts with minor chert and komatiite, felsic porphyries (syndepositionally intrusive), a felsic volcanic suite, thin sedimentary chert, basalt with silicified top, thin felsic volcanic rock, complete sequence of Buck Ridge Chert (4 superposed units; detailed sedimentary log A in De Vries 2004, Fig.4.3), and finally pillow basalts and serpentinites.

Drill site II: **Buck Ridge-central.** Target: complete section of Buck Ridge Chert

Coordinates: midpoint 30°53'43"E/25°55'23"S; core length ca. 500 m

This site covers the full thickness of the Buck Ridge Chert at the top of the complex with a pronounced lateral facies change from site I. It covers a very complete sedimentary rock succession including high energy large-scale cross-bedded cherts to low energy banded chert with complex diagenetic generations of silicification with erosion surfaces and Fe oxide rich areas. The site is located 850 m east of sedimentary log B in De Vries 2004, Fig. 4.3).

Drill site III: **Buck Ridge-East**. Target: complete section of unit 3 of Buck Ridge Chert
Coordinates: midpoint 30°56’45”E/25°55’53.5”S; core length ca. 300 m
The site will core the generally badly exposed Fe-rich 3rd unit of the Buck Ridge Chert where relatively good outcrop control is available in the observed superposition of coarsening-up cycles (log D of De Vries 2004). In places these cycles are abruptly overlain by wedges of coarse breccia, interpreted as related to hydrothermal vents in the immediate surroundings.

Drilling Procedure
Excellent control is provided at all three sites by low-level aerial photographs and extensive surface mapping. Subvertical overturned bedding will require careful orientation of the drill rig. The orientation of bedding at depth might change due to the synclinal structure of the targeted areas. Field experts will supervise the drilling progress, technique and contamination problems together additional key staff and students from South African universities. We will rely on the existing extensive experience of groups at the institutes involved in previous work.

(d) Preliminary Site Studies
The three drill sites will be further mapped although 1:5000 scale geological maps and sedimentary logs are available. Geophysical work is required to constrain structural changes at depth (e.g. bedding directions, lateral continuity of units) in order to optimize drill core targeting.

(e) Follow-up work on drill core
Analytical work will include thin-section petrography, cathode-luminescence analysis, cement stratigraphy, fluid inclusion studies, major and trace element geochemistry, radiogenic isotope analysis, stable isotope (S, C, Si, N, Fe, Mo, O) measurements, U-Pb zircon dating, paleomagnetism, *in-situ* mineral geochemical measurements (ASD, Raman, etc), modern microbial analysis, molecular biology & contamination control. Results from all of these techniques are complimentary and will be combined in order to address the wider research goals that we have identified in this area.

Target 2: the Theespruit Formation

Coordinators:

Annika Dziggel — Metamorphic Petrology and Tectonics, RWTH Aachen
Alex Kisters — Structural Geology and Tectonics, University of Stellenbosch

(a) The scientific issues to be addressed by the drilling:
Geodynamic setting of the habitat of early life, the thermal structure of the Archean crust; the age, Nd and Os isotopic composition, and metamorphic and structural evolution of the oldest rocks in the Barberton belt.

The existence and modalities of plate tectonic processes during the formation of the Early Earth is one of the central controversies in Archean geology. In the Barberton greenstone belt, there is increasing evidence that “modern-style” plate tectonics were operating by c.

3.23 Ga (e.g., Moyen et al., 2006), contemporaneously with the deposition of the Fig Tree and Moodies Groups. However, the earliest known traces of life in the belt formed during a much more elusive period of greenstone history prior to 3.4 Ga (e.g., Furnes et al., 2004). Elucidating the geodynamic setting in which life emerged throughout the tectonic history of the belt is fundamental for our understanding about the habitat of early life, the nature of early Archean crust, its thermal regimes, and the rates and mechanisms of plate-tectonic processes that formed the early continents

The Theespruit Formation of the lower Onverwacht Group is a highly tectonized mélange consisting of metabasites, felsic volcaniclastic rocks and rare, aluminous clastic sediments, whose original relationship with the other litho-tectonic units of the Barberton Belt is not known. Its felsic volcaniclastic units represent the oldest known (c. 3.55 Ga) period of felsic volcanism in the Barberton Belt (e.g., Kröner et al., 1996). In contrast to the low-grade supracrustal rocks of the tectonically overlying Komati Formation, the Theespruit Formation is characterized by penetrative fabrics and considerably higher metamorphic grades that correlate time wise with the main collisional episode in the centre of the belt (e.g., Dziggel et al., 2002).

(b) The need to drill:

Despite the significance of this unit for the overall tectonic evolution of the belt, its origin, stratigraphic position, age relationships, as well as the structural and metamorphic record are poorly constrained. Our current understanding is severely limited by: i) limited exposure of fresh and well-preserved rock types of the Theespruit Formation; and ii) the high degree of alteration and erosion of the exposed units. Thus, drilling is required in order to obtain a continuous cross-section through the Theespruit Formation that has not been exposed to recent weathering and oxidation. Such unaltered drill core samples are essential for studying the metamorphic petrology, zircon geochronology, Nd and Os isotopic systematics and contact relationships needed to constrain the precise age, origin, geothermal gradients and geodynamic setting of this early Archean crustal unit.

(c) Specific Drilling Targets and Drilling Procedure:

The Steynsdorp Anticline is particularly noteworthy, as it has been proposed to represent the oldest nucleus of the Barberton greenstone belt (e.g., Kisters et al., 1995; Kröner et al., 1996). The Steynsdorp Anticline is cored by tonalitic gneisses of the c. 3.5 Ga Steynsdorp pluton, which intruded into unexposed crust, possibly represented by foliated tonalite xenoliths in the pluton. The pluton is rimmed by highly deformed rocks of the Theespruit Formation, which reaches a thickness of up to 1.5 km. The drill site should be located close to the Theespruit/Steynsdorp pluton contact zone, targeting those rock types that include fabrics, mineral assemblages, and hydrothermal fracture zones that predate the intrusion of the pluton. Expected core length: c. 300 m.

(d) Preliminary Site Studies:

Detailed structural mapping and petrological investigations are currently being carried out in the Steynsdorp Anticline by a team from Stellenbosch University. The aim is to resolve the complex structural and metamorphic evolution of the area, with particular emphasis on the contact relationships between the high-grade gneisses and overlying supracrustal sequences. Fieldwork will be completed by the end of 2007.

(e) Follow-up work on drill core:
Microstructural analyses on oriented samples; detailed petrology and mineral chemistry; major and trace element geochemistry, detailed single zircon SHRIMP geochronology and Nd isotopic systematics on felsic volcaniclastic rocks for geodynamics; Re-Os systematics on ultramafic rocks. Search for xenocrystic zircons in felsic metavolcanics and granitoid gneisses (in collaboration with Prof. Alfred Kröner, Mainz University).

Target 3: Komatiites and basalts of the Komati Formation

Coordinators:

Iain Pitcairn Geology and Geochemistry, Stockholm University, Sweden
Alan Wilson University of the Witwatersrand, Johannesburg

(a) The scientific issues to be addressed by the drilling:
Volcanic settings, understanding the geochemistry and dynamics of the Archean mantle, hydrothermal alteration of the ocean crust, properties and composition of Archean seawater and hydrothermal fluids, chemosynthetic development of early life, habitat of micro organisms in the Archean ocean crust

Volcanic processes in the Archean were distinctly different to those of today, and are poorly understood. Barberton is the type area of komatiite but these rocks have not yet been characterized completely using modern geochemical methods. Very few complete analyses incorporating major and trace elements and isotopes are available. Controversy surrounds the origin of komatiite – whether they are flows or sills and whether they formed in a hot plume (Arndt et al. 1998) or in a cooler subduction zone (Grove and Parman, 2004). An adequate understanding of volcanic processes and mantle dynamics in the Archean requires new geological, mineralogical and geochemical data of the type that can only be obtained by analyzing complete suites of well-preserved samples.

Hydrothermal alteration of the oceanic crust by seawater has occurred throughout Earth history and the resulting chemical redistribution has strongly effected composition of the crust and oceans. Modern theories on the origin of life suggest that life emerged chemosynthetically due to the interaction between hydrothermal fluids seeping from the ocean crust and the Archean ocean (Russell et al., 1988, Russell and Arndt, 2005). Indeed, the glassy margins of pillows in Barberton basalts contain structures interpreted as the traces of microbial activity (Furnes et al., 2004). However, the chemical composition, temperature, pH, and redox conditions of the Archean ocean and hydrothermal fluids are poorly known. Investigation of the nature and extent of seafloor alteration of Archean crust will provide unique insight into the composition of the hydrothermal fluids vital for the synthesis of early life on Earth. Such a study could answer vital questions such as:

- What were the composition and physical conditions (temperature, pH, alkalinity and redox conditions) of the hydrothermal fluid?
- What were the scale, geometry and vigor of hydrothermal circulation?

- How did the fluids interact with seawater on the ocean floor

(b) The need to drill:
Drilling will provide access to well-preserved continuous sequences of volcanic rocks that are unavailable in the limited surface outcrops. Portions of mafic and ultramafic rocks such as the commonly brecciated or glassy margins of flows and pillows are soft and easily altered and are poorly exposed even in the best outcrops along riverbeds. These rocks are crucial in any investigation of the volcanology and conditions at the Earth's surface. The hydrothermally altered sections of flows and sills, which provide valuable information about the circulation of fluids through the crust are similarly affected. In addition, surface weathering has variably affected these rocks to a depth that is currently poorly known.

The drill core would yield (1) complete sections through a number of individual flows, providing complete sampling needed to interpret how the magmas erupted and solidified; (2) a large number of minimally altered samples which can be analyzed mineralogically and geochemically, to help solve questions of magma formation and mantle geodynamics; (3) complete sections through alteration zones, which provide information about the nature of hydrothermal circulation.

(c) Specific Drilling Targets and Drilling Procedure
Coordinates: 25°59; 30°51'; core length 500 m.
A possible drill site is situated in the Komati Formation of the lower Onverwacht Group. The site corresponds to outcrop 2-15, identified in Jesse Dann's (2000) map as a tumulus in a komatiite flow. A 500m long hole drilled at 020° at an inclination of 45° would intersect a ~300 m thick section made up of thick komatiite units, thinner komatiite flows and pillowed or massive basalts. The site is easily accessible (a dirt road comes to about 500 m of its position) and it does not lie in the National Park.

(d) Preliminary Site Studies
The 1:5000-scale mapping of Dann (2000) provides a record of the distribution of important outcrops and fairly detailed picture of the geology. What is needed is more detailed mapping of the surface outcrop of the section to be sampled by drilling, accompanied by detailed structural interpretation. Geophysical work is unlikely to be useful in this region of rocks with uniform physical characteristics although magnetic studies might provide information about the shallow structure and distribution of faults.

(e) Follow-up work on drill core
Recovered core will be subjected to a complete battery of petrographic and geochemical techniques:

- Petrographic study of magmatic and secondary minerals; electron microscopy; in-situ analysis using electron and ion microprobe
- Separation of magmatic and secondary minerals; analysis of trace element and isotopic compositions (O, H, C, Si, N, transition elements; Rb, Nd, Pb, Hf, Os)
- Analysis of whole-rocks using similar techniques

- Vitreous margins of flows and pillows will be analysed for traces of microbial activity; fluid inclusions in magmatic and secondary minerals.
- Microthermometry and laser ablation ICP-MS analysis of fluid inclusions from alteration-related veins within the volcanic sequence
- Paleomagnetic studies such as …..
- Investigation of microbial and molecular biology

Target 4. Upper Onverwacht and Fig Tree Groups

Coordinators:
Axel Hofmann, University of KwaZulu-Natal, Durban
Paul Mason, Utrecht University, Netherlands
Uwe Reimold, Humboldt-University, Berlin
Harald Strauss, University of Münster, Germany
Allan Wilson, University of the Witwatersrand, Johannesburg

(a) The scientific issues to be addressed by the drilling
Hydrothermal sea-floor alteration and Archean seawater composition, Archean mantle processes, Traces of early life in carbonaceous cherts, shales and sulfates. Origin of banded iron formations and barites and the evolution of the Archean atmosphere. Evidence for meteorite impacts.

The uppermost part of the Onverwacht Group consists of ca. 3.30 Ga komatiites of the Mendon Formation that are overlain by a predominantly sedimentary sequence of the 3.26-3.23 Ga Fig Tree Group (Fig. 1). This part of the Swaziland Supergroup hosts a number of lithological units that are crucial for the understanding of a number of geological processes in the Archean.

- Several spherule layers as the oldest evidence for meteorite impacts on the early Earth (Lowe et al., 2003; Hofmann et al., 2006).
- Komatiites of the Mendon Formation are compositionally distinct from those in the classic Komati Formation (Byerly, 1999) and appear to contain olivine of exceptionally high Mg-content. These komatiite appear towards the top of the sequence and being slightly later may be correlated with komatiites of similar composition that occur in Commondale area of northern KwaZulu-Natal. The latter komatiites are recognized as being unique in the global Archean record and should a lithogeochemical and age correlation be established for the Mendon Formation, then important deductions can be drawn regarding this volcanic episode in Southern Africa.
- Highly silicified komatiites at the top of the Mendon Formation record low-temperature hydrothermal sea-floor alteration and provide important clues to ancient seawater chemistry (Duchac and Hanor, 1987; Hofmann, 2005; Hofmann and Wilson, 2007).
- Silicified volcaniclastic and sedimentary rocks (now banded cherts) at the Onverwacht - Fig Tree contact contain well preserved carbonaceous matter of likely biogenic origin (Hofmann and Bolhar, 2007).

- Carbonaceous shale of the lower Fig Tree Group contains carbonaceous matter not affected by silicification and may preserve organic biomarkers.
- Bedded barite and banded iron formation that provide information on the composition of the Archean atmosphere and hydrosphere.

(b) The need to drill

The Mendon Formation is extremely poorly exposed throughout the entire Barberton greenstone belt with the exception of the uppermost 30+ metres that have been affected by hydrothermal seafloor alteration and silicification. The poor exposure of this unit makes it a prime target for drilling. The overlying sedimentary rocks of the lower part of the Fig Tree Group are reasonably well exposed in places, but continuous exposure is rare and recent weathering has affected the rocks near the surface and removed easily weatherable minerals such as sulphides.

(c) Specific Drilling Targets and Drilling Procedure

The possibility: to drill two holes through the Onverwacht – Fig Tree contact, each 300 - 400 m long, one in the Mendon Farm area (focus on Mendon Fm) and one in the Barite Valley Syncline (focus on Fig Tree strata); a third (short) hole within the FigTree Group could be optional

site A: **Mendon/Auber Villiers Farm.** Target: Mendon Formation and Fig Tree Shales/ Cherts

Fig Tree strata in this area are overlain by a several hundred metres thick sequence of poorly exposed pillow basalts and komatiites of the Mendon Formation, which contains a horizon of accretionary lapillistone (Msauli Chert) halfway up in the stratigraphy. The lower contact is represented by a shear zone (Granville Grove Fault of Lowe and Byerly, 1999) along which gossaneous horizons may indicate the presence of sulphides at depth. Komatiites at the top of the Mendon Formation are strongly silicified (Skokhola sequence of Duchac and Hanor, 1987; Hanor and Duchac, 1990). The silica alteration zone is overlain by ca. 20 m of banded carbonaceous chert and hosts spherule horizon S2. Chert is overlain by a ca. 500 m thick homogeneous sequence of rather poorly exposed parallel-laminated fine-grained sand- and siltstones which may be correlated with the Mapepe Formation. A few metres thick sequence of hematitic shales and jaspilitic BIF occurs immediately at the base of this sequence. A 350 m long borehole will sample approximately 250m of stratigraphic section. The sequence to be drilled will include: 50m, Fig Tree shale with jaspilitic BIF,15m, banded chert, S2 spherule bed, 25m, silicified komatiites, Mendon Fm, >150m, komatiites, Mendon Fm

site B: **East limb of Barite Valley Syncline.** Target: Fig Tree/ Onverwacht contact

The contact between the Onverwacht and Fig Tree Group is well exposed in the Barite Valley Syncline (BVS; Fig. 17), where a variety of important lithologies can be found in close proximity. These include sedimentary barite deposits, several impact spherule layers, and bedded carbonaceous cherts. A 570 m long core would be sited to intersect a 400m stratigraphic section and would encounter:250m Fig Tree shale together with barite and spherule beds, 50m, banded chert, 30+m of silicified/carbonated Mendon komatiites.

site C: **Mendon/Auber Villiers Farm. Target:** contact Ngwenya/Mapepe Formations
The Ngwenya Formation consists of ferruginous shale and two units of jaspilitic BIF that are separated by fine-grained sand- to siltstone. The iron formation consists of intercalated bright red jasper and ferruginous shale and fine-grained sandstone layers. The Mapepe Formation is characterized by a homogeneous sequence of parallel-laminated and rarely cross-bedded fine-grained sandstone. Thickly bedded pebbly grits and conglomerates are present along the base. The beds are tabular, show normal grading and contain a high proportion of chert detritus. Spherule layers S3 and S4 are associated with the pebbly grits. A 200 m long borehole will reveal a 140m stratigraphic section including 100m ofshale, chert, conglomerate and spherule layers S3/S4 with a further 40m of jaspilitic BIF

(d) Preliminary Site Studies
Detailed mapping has been done in the area by numerous people (e.g. T. Heinrichs, D. Lowe and G. Byerly, C. de Ronde, M. de Wit) during the last 30 years, much of which has been field checked by A. Hofmann in 2004 and 2005. The possible drill sites are all located close to the boundary between the Songimvelo Game Reserve and private forest plantations and the exact locations would partly depend on any access problems regarding drilling in a nature reserve.

(e) Follow-up work on drill core

- Trace element and radiogenic isotope work on Mendon Formation komatiites for studies on Archean mantle processes
- Trace element, fluid inclusion and stable isotope (O, Si) work on silicified Mendon Formation komatiites for hydrothermal alteration processes and sea water chemistry
- Detailed sedimentological-stratigraphic logging of spherule layers and environmental analysis; petrographic work to obtain more information on spherule formation/ emplacement/ secondary overprint; geochemical (PGE, Cr isotope, Ge isotope; Koeberl et al., 2007) studies related to identification of the meteoritic signature and its carrier phase
- Geochemical analysis including trace element (Hofmann, 2005), stable isotope (C, S, N, Fe, Se, noble gases) and radiogenic isotope (Sr, Nd, Pb, Hf) analysis of chemical and clastic sedimentary rocks of the Fig Tree Group in order to establish the interplay between physical, chemical, and biological processes on the early Earth surface
- Paleomagnetic studies of a number of volcanic and sedimentary rocks in order to obtain a time-series of geomagnetic field (intensity and direction) variation for studies of Archean core-mantle processes, Archean tectonics and paleolatitude constraints

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National and international context:

The evolution of the early Earth and the origin of life are priority themes at many European and American Universities and research in these domains are strongly supported by funding agencies. Examples include the “Terre Primitive” and “Origines des Planètes et de la Vie” of the French funding agencies.

The theme is also prominent at an international level. The European Science Foundation supports a research networking program called “Archean Environment: the Habitat of Early Life” http://www.see.leeds.ac.uk/research/igs/arcenv/index.htm which supports exchanges of scientists and students between European laboratories and specialized workshops (e.g. Archean Oceans: the first habitat of life on Earth April 12-14, Rio Tinto, Spain). The Barberton Drilling Project is a priority initiative of this program.

Participation in the drilling project and in follow-up studies of recovered drill core will include a broad spectrum of earth scientists from five continents. South Africans from at least five universities will be in charge of local direction of the project, assisted by a steering committee containing European and American representatives. Other participants will be drawn from at least seven European countries, as well as from the USA, Australia, China and Japan. Funding of the project is being negotiated with national funding agencies in each of these countries, and well as with private foundations and industry.

Participation and training of students, and in particular those from previously disadvantaged backgrounds, will be an important aspect of the project. The project will be coordinated with the activities of !Kure, a training and research network linking IPGParis, DFZ Potsdam and the University of Cape Town, and with Africa Array, a broad-based program directed from Johannesburg (http://www.africaarray.psu.edu/).

Komatiites and other rocks in the Archean crust are important depositories of economic minerals such as gold, Ni and platinoids that are highly sought after in the present economic environment. We are confident that South African mining companies will support the project by aiding with logistics, by integrating our drilling into their broader scale activities (and thus considerably reducing the drilling costs) and perhaps by directing funding one or more drill cores.

Current situation :

Initial plans are to drill a series of short diamond drill holes each 200-1000 m in length. One or more holes are planned for the volcanic site and for 2-5 are planned in sedimentary sequences.

A code of conduct will be agreed and documented to assure that all core material recovered will be curated properly, prepared correctly and distributed fairly to participating scientists. The core will be stored in the National Core Archive of the Council for Geoscience in Pretoria. At least half of the split core will be archived for future studies. Drilling and core handling under sterile practices will be used to limit biological contamination. The core will be investigated by state-of-the-art analytical techniques involving petrographic, geochemical and isotopic analysis, micropaleontology, structural and molecular techniques. The integrated nature of the studies will result in a data base that is unprecedented in geological terrains of this type and age.

Funds will be raised through 2007 and early 2008 from national funding organizations in Europe, South Africa and the USA, in parallel with preliminary site investigation and documentation. It is anticipated that drilling could begin in mid 2008 and that samples could be ready for distribution to interested groups by late 2008. The cost of drilling the Barberton region, with the assistance of local mineral exploration companies is estimated at less than 400 k euros (see budget below) and that of follow-up investigations about 400 k euros. The costs will be shared between 5-8 funding organizations in Europe, North America and South Africa.

A field workshop in the Barberton Belt is planned for the autumn of 2007. This workshop will be funded by the ESF ArchEnviron program, with a possible contribution from ICDP, as described in the budget below. At the workshop we will evaluate each of the proposed drill site in the light of field studies that will be carried out during the (northern) summer 2007. We will also evaluate at this time the logistic aspects of the project and other important issues such as the acquisition of the permission to drill at the various sites, the availability and cost of a drill rigs, supervision of the drilling procedure and the procedure used to store, prepare and distribute the drill core samples.

Preliminary Budgets

(1) Drilling project

Expenses

Drilling operation	Euros
4000 m of core @ € 90/m (estimate from local drilling companies)	360 000
Cost of moving the rig from site to site	50 000
Small equipment (core boxes, etc)	50 000
Contamination control and down-hole operations	50 000
Travel and accommodation during drilling operations	50 000
Total	560 000

Follow-up studies on core will be financed separately

Sources of funding

European Research Agencies (Germany, France, Switzerland, Netherlands, UK, Sweden, Denmark, Spain)	150 000 to 300 000
National Science Foundation (USA)	50 000 to 100 000
Other sources (Agouran Foundation, industry)	100 000
ICDP	200 000 to 400 000

The South African contribution will be mainly in the form of support for site surveying, logistic support during drilling and core storage, archiving and distribution

Total	€ 500 000 to 900 000

(2) Field workshop in the Barberton Belt

Costs estimated on the basis of 20 overseas participants and 10 South African participants

Airfare € 950 x 20	19 000
Accommodation first day in Johannesburg € 50 x 20	1 000
Road travel to Barberton and return € 40 x 30	1 200
Accommodation in Barberton or Badplaas for 3 nights €135 x 30	4 050
Administration, supplies, communication	500
Total	€ 25 750

Contribution from ESF ArchEnviron	€ 12 750
Requested contribution from ICDP	€ 13 000

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