BMM WHS NOMINATION DOSSIER
APPENDIX K:
GEOLOGICAL COMPARISON INVENTORY

BARBERTON – MAKHONJWA MOUNTAINS WORLD HERITAGE SITE PROJECT

Geological Comparison Inventory: Some Additional Comments

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Summary

The following Appendix simply elaborates on the comments given in the Nomination Dossier regarding the comparison of the geology of the Barberton Mountainlands. In particular it gives a more detailed account of the merit of the BGB as a WHS which can be measured in two WHS categories: “Earth’s History” or “Record of Life” after the definition of Wells (1996). The following short account is an elaboration deemed unnecessary for the main text of the Nomination Dossier, but still relevant with regards to this topic.

Merit of the Barberton Greenstone Belt

The merit of the BGB as a WHS can be measured in two WHS categories: “Earth’s History” or “Record of Life” (Wells, 1996).

Category I: Earth’s history- This subset of geological features includes phenomena that record important events in the past development of the planet such as the record of crustal dynamics, the genesis and development of mountains, plate movements, continental movement and rift valley development, meteorite impacts, and changing climate in the geological past. Properties that may be considered for inscription on the WHS list under this category would primarily involve places where major discoveries have been made in relation to our overall understanding of earth processes and forms as revealed by rock sequences or associations rather than fossil assemblages.

Since the late 1960s, many eminent palaeontological researchers from the USA, UK and Germany have conducted collecting expeditions in the Barberton Mountain Land. NASA funded some of these investigations to learn more about the likely environments and appearances of the earliest life on Earth, to assist in developing guidelines for its missions to Mars and other searches for extra terrestrial life. Many internationally based scientists return to the BML annually to pursue long-term projects in various geo-scientific fields of cutting-edge research (C. Anhaeusser in lit.).

For more detail of the literature of the BGB and the record of contributions the reader is referred to Appendix X (the detailed Geological report).

Category II: The re cord of life: This subset includes paleontological (fossil) sites. For evaluating such nominations IUCN has developed a checklist and a three-step procedure.

STEP 1
The checklist of 10 questions developed by IUCN for evaluating the paleontological significance of fossil sites along with the nine recommended criteria
of Wells (1996) was used to establish the World Heritage standing for the BGB and its fossil sites.

1. As compared to other greenstone belts the BGB is special because its strata encompass a uniquely long time window of 330 Ma within the Archean, beginning in the Sandspruit Fm of the Onverwacht Group(ca. 3550 Ma) and ending in the Baviaanskop Fm. of the Moodies Group (ca. 3220 Ma). Their respective ages have been established by U-Pb radiometric dating. Obviously, in the 13

km-thick stratigraphic column, accumulation rates differ widely. Stratigraphic gaps measuring tens of Ma contrast with very-high-resolution units.
Fossils are, of course, all microbial but are widespread and can be reasonably argued to have employed different metabolic strategies. Black, organic-matter-rich cherts which contain traces of fossil life occur in the Hooggenoeg Formation (ca. 3470-3450 Ma); abundant microbial mats also occur in the Moodies Group (ca. 3223-3218 Ma).

2. The morphological diversity, even among the microbial community, is considerably better than elsewhere. It includes coccoid, spindle, and filamentous forms. The microbial mats in the Moodies Group, representing high-energy tidal settings, are all filamentous.
The variable D/G-peaks of kerogen in Raman spectra from the same microbial mat even within the same mm-sized thin section suggests variable recalcitrance.
BGB strata preserve and document in a uniquely accessible way that various metabolic strategies had been active early in Earth history: (1) Banded-Iron-Formation give evidence of photoferrotrophs (obligate anerobic photosynthesizers); (2) detrital pyrite grains with overgrowths depleted in $_{34}$S near former sulfate concretions suggest the activity of sulfate-reducing bacteria in moist sands of floodplains and shorelines. (3) Tough and thick microbial mats associated with mudcracks and paleosols in supratidal settings of the Moodies Group likely required light and were thus photosynthesizers. (4) The sulfate of barite crystals in the Fig Tree Group shows signs of microbial disproportionation. (5) There has been a considerable body of literature documenting microbial coating and possible microborings of pillow basalts in volcanic-platform settings of the Onverwacht Group.

3. The traces of microbial fossils found in the BGB are unique to that area. These would therefore be the 'type locality '. Although several microbial metabolisms have also been documented from the Pilbara many others have not, but these would be independently considered as' type localities' for those particular organisms. Aside from BGB and Pilbara, there are no other eminent sites worldwide.

4. There is no other comparable site to the BGB, thus a serial nomination would be irrelevant. The 330 Ma of Earth history represented within the BGB sedimentary and volcanic strata span a significant part of evolutionary time. There are no places where one can go back further in time and extract as confidently, readily and accessibly a variety of microbial prokaryotic fossils from rocks. o Older rocks (such as in Greenland) have only yielded chemofossils, not body fossils, and have done so in a vastly reduced stratigraphic context.

5. The BGB has been the main location where scientific advances have been made and has contributed to humanity's understanding of the Archaean environment. These advances contained in the scientific published literature is referenced and shown in Appendix...

6. The prospects for ongoing discoveries are excellent given that large parts of the BGB remain poorly mapped geologically or studied, and continued analytical and instrumental improvements hold the promise of deeper insights.

7. The international level of interest by geologists and academics is considerable as shown by the fact that the great majority of scientific publications on the BGB are from non-South Africans. The

BGB is a hive of activity during the southern winter field season, and geological field excursions, both national and international, stream through the region all year long.

Interpretation and displays have been provided easy access to people as a series of roadside panels along a 27 km stretch that illustrates the geologic significance of the mountains forming the greenstone belt. In addition a booklet is available that provides information to the general public on the regions ancient geology. This has significantly increased the popularity of the BGB to visitors and educational groups of both young and old..

8. The site is largely in its original natural state and has a unique and rich biodiversity comprising many endemic plant species in particular. Of special interest to botanists has been the flora associated with the soapstone areas. Part of the site has been transformed where plantation forestry has been developed or where communities live in rural settlements. There are no active mines operating or prospecting areas located within the site area. However some decommissioned mines are included.

9. Widespread early silicification has preserved abundant microbial morphologies and matter and prevented compaction and degradation. The BGB is fundamental to establish that a high diversity of microbial ecological habitats existed already early in Earth's history. It shows, for example, that continental margins, shallow-water environments, high-energy shorelines, the vadose zone of primitive soils, and perhaps even terrestrial floodplains (i.e., remote from oceans) were colonized as soon as these habitats had become available through processes of continental growth.

The Barberton Mountain land

> *"The Barberton Mountain Land offers the geologist a unique opportunity to study the early stages in the evolution of the Earth. There, remnants of the oldest upper mantle, oceanic crust, and an overlying island-arc-like rock complex are fossilised in a sea of granite and granitic gneiss …Studies of these rocks offer deep insight into many aspects of terrestrial differentiation, especially the early evolution of oceanic and continental crusts, the seas and the atmosphere."*
>
> Prof Al. Engel, 1970, as cited in McCarthy & Rubidge (2005)

The most noteworthy feature of these exposures is that they reveal the oldest microfossils ever described (see Fig 1), at ca.3500 million years old (Walsh and Lowe, 1985). And, as fossilized shallow water biomats, some of these can be seen with the naked eye.

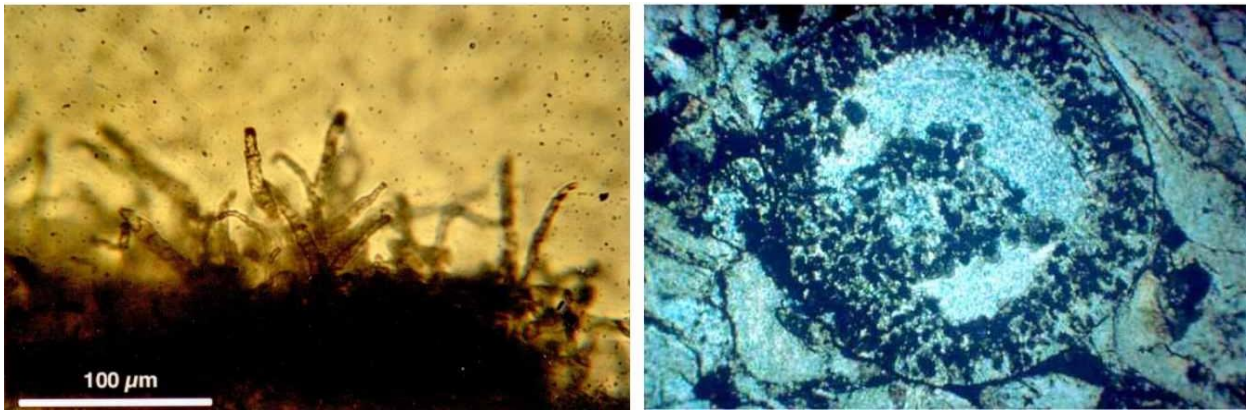

Fig 1. *Left: BML's oldest volcanic rocks contain minute traces of the world's earliest life forms, seen here as hair-like tubes created by bacteria found in the glassy rims of pillow lavas, photographed through an electron microscope and dated at about 3 480 million years in age. (Ref: M de Wit, in Delius, Mpumalanga History and Heritage, 2007)*

Right: Spherule beds resulting from meteorite impact events that occurred on earth over 3.4 billion years ago arerevealed in the Dycedale Syncline as spherules of less than 1mm in diameter, seen here under a microscope.

Additional value lies in the ancient granitic rocks that intrude into and envelop the Barberton Greenstone Belt. These range in age from over 3 000 million years and present an extended evolutionary history that is also outstanding in terms of exposure and preservation. The oldest granitic and gneissic rocks consist of sodium-rich tonalites, trondhjemites and granodiotites, evolving into more potassium-rich 'normal' granites. These granitic rocks played an important role in the structural and metamorphic history of the region and their relationships with the volcano-sedimentary Barberton Greenstone successions can rarely be matched elsewhere in the world (Robb et al., 2006).

- The BGB contains by far the oldest geology ever proposed for WHS inscription, but that is not its main outstanding value. **The reason for its high value lies in the remarkable state of preservation and diversity of the rocks that allow scientists, with increasingly sophisticated technology, to interpret the earliest history of the earth.**
- **Pilbara,** in northern West Australia, is the most comparable. It is more extensive than the BML site "This site is poorly exposed, deeply weathered and includes a much lower diversity and a smaller age range than that available in the BGB" (D.R Lowe, in lit).
- The Barberton Greenstone Belt presents an intact 350 million-year-long sequence of Archaean rocks that is unmatched anywhere. As the 'Barberton Supergroup' they have unsurpassed Outstanding Universal Value for this reason.

It is also necessary to look at the range of WHS inscriptions within South Africa to consider the balance provided by other candidate sites, and those that have already been inscripted. Only two of the SA sites have any geological features of value. These are the Vredefort Impact Structure and the Cradle of Humankind. The first is truly ancient (~2023 mya), but is otherwise one-dimensional as the stand-alone oldest and largest known meteorite impact site. The second is very recent, comprising karst breccia deposits around 3 million years old, one of the richest hominid/pre-hominid sites known. No meaningful comparison can otherwise be made with the extremely old, multidimensional, well-preserved and accessible Archaean features of the Barberton Mountain Land.