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High resolution tephra and U/Pb chronology of the 3.33–3.26 Ga Mendon Formation, Barberton Greenstone Belt, South Africa

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ABSTRACT

The Mendon Formation in the Barberton Greenstone Belt of South Africa marks the boundary between the Onverwacht and Fig Tree Groups. These groups are characterized by mafic to ultramafic volcanism and felsic volcanism with related epiclastic sedimentation, respectively. This transition marks the end of komatiitic volcanism in the Barberton Greenstone Belt and is accompanied by numerous impact-related spherule layers. This study characterizes the upper Mendon Formation texturally and geochemically over a wide areal extent and across structure and facies changes in an attempt to better understand the evolution of tectonic processes at this boundary. A suite of whole rock and handheld X-ray fluorescence analyses are presented in conjunction with textural information, stratigraphic relationships, and U/Pb ages to create a temporal and chemostratigraphic framework for the Mendon Formation. Local and regional stratigraphic variations, including absence of distinctive layers and variation in layer thickness, seen across the Mendon preclude ascription of a single stratigraphy that accurately describes the >1.2 km of section present in this formation. These variations indicate diachronous deposition of the Mendon Formation over a wide areal extent and into multiple basins or sub-basins by more than one magmatic source. ^{204}Pb-corrected $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ concordia model ages of 3279 ± 9.1 Ma and 3287.3 ± 2.9 Ma for two samples from upper portions of the Mendon Formation provide temporal context for deposition. Two samples from the basal 10 m of the Fig Tree Group, above the S2 spherule bed that marks the boundary between the Onverwacht and Fig Tree Groups, give model ages of 3267.8 ± 6.9 Ma and 3261 ± 18 Ma. These ages provide added constraints for the Onverwacht-Fig Tree boundary and confirm that the Weltevreden Formation is roughly age-correlative with the uppermost Mendon Formation. While the Mendon and Weltevreden Formations are in part age-correlative and have similar lithologies, they do not appear to be genetically related. The dominance of ultramafic volcanic rocks and the paucity of felsic volcanic and terrigenous sedimentary rocks within the Mendon and Weltevreden Formations indicate that the primary mode of crustal formation was likely plume-related magmatic accretion and not subduction. The relatively sharp transition within the Barberton Greenstone Belt from ultramafic volcanic sequences to more felsic volcanic and epiclastic sedimentary sequences is everywhere marked by impact-related spherule layers, which suggest that major impacts may have played a role in the evolution of early tectonics to more modern, subduction-related styles.

1. Introduction

Greenstone belts are crustal sequences typically composed of a variety of volcanic and sedimentary rocks that represent a large portion of preserved Archean crust. Considerable debate remains over the tectonic processes and surface environments that gave rise to these terranes (de Wit et al., 2011; Furnes et al., 2013; Grove and Parman, 2004; Lowe and Byerly, 2007; Shirey and Richardson, 2011; Van Kranendonk, 2011a), which partly reflects the discussion over how plate tectonics operated in the early to middle Archean or whether some form of non-uniformitarian tectonics existed (e.g. Moresi, 2013). One of the best preserved of these crustal sequences is the Barberton Greenstone Belt (BGB) of South Africa. This relatively well-studied supracrustal sequence has been divided into three major lithostratigraphic units (Fig. 1): the Onverwacht, Fig

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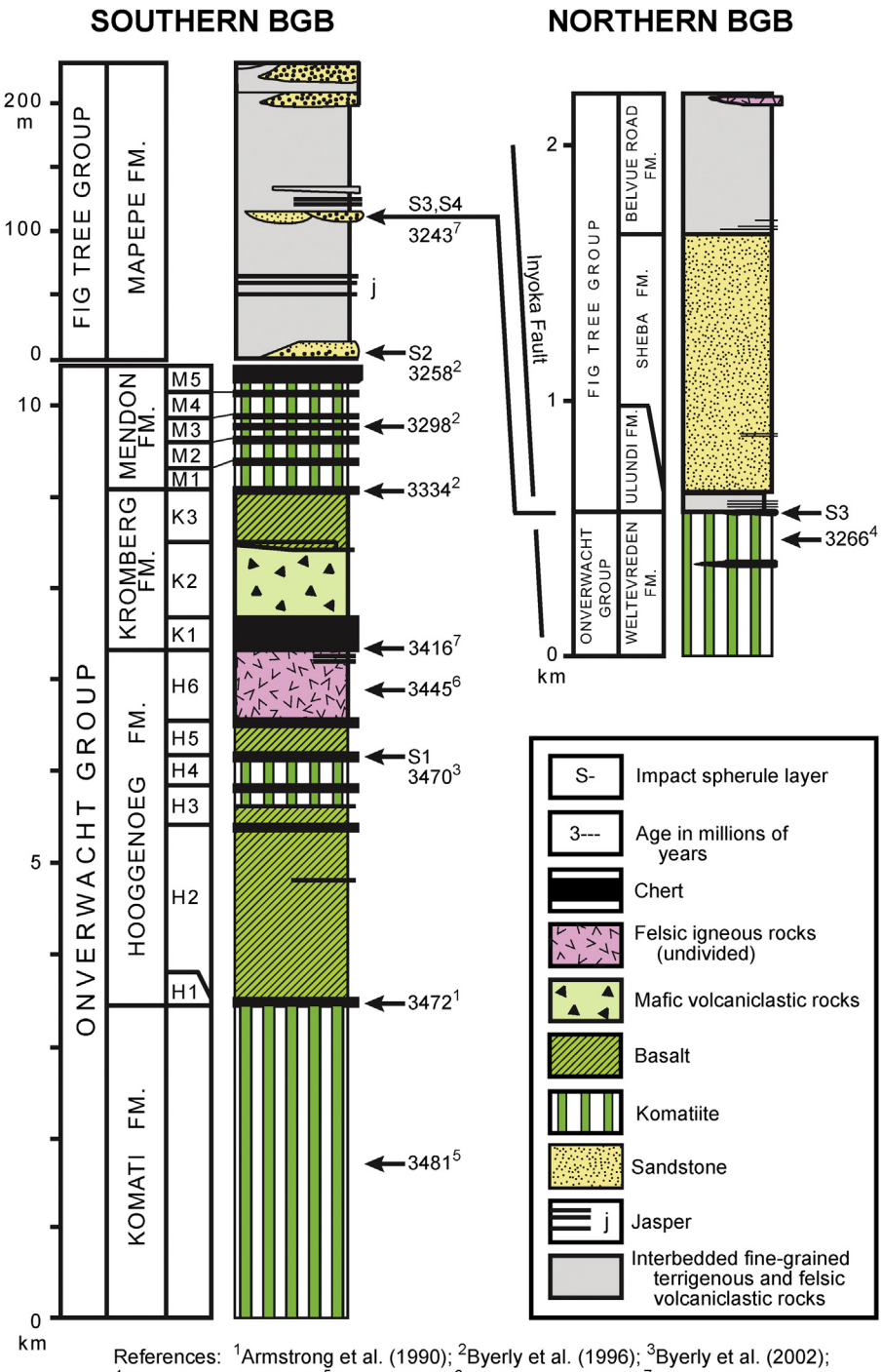

Fig. 1. Generalized stratigraphic column of the Onverwact and Fig Tree Groups.
Modified from Lowe et al. (2003).

Tree, and Moodies Groups (Lowe and Byerly, 1999, 2007). The Onverwacht Group consists primarily of mafic and ultramafic volcanic rocks with interbedded volcaniclastic units and cherts. The Fig Tree Group is a dominantly sedimentary and felsic volcanic sequence. The overlying Moodies Group is composed primarily of quartz- and feldspar-rich sandstones. Each of these distinct stratigraphic sequences likely represents a profoundly different tectonic setting, ranging from plume volcanism in the Onverwacht Group (Chavagnac, 2004) to arc volcanism, uplift, and fold-and-thrust belts in the Fig Tree Group (de Ronde and de Wit, 1994; Lowe and Nocita, 1999) to plate collision, uplift, and deep erosion of plutonic and high grade metamorphic rocks in the Moodies Group (Heubeck and Lowe, 1999).

Within the Onverwacht Group, the Mendon Formation is a dominantly ultramafic volcanic succession that represents the last major episodes of komatiitic volcanism in the BGB (Fig. 1). Komatiites are high-magnesian, ultramafic extrusive rocks that were, with one known exception (Arndt et al., 1997; Echeverria, 1980), erupted only in the Precambrian. They contain >18 wt.% MgO (Le Bas, 2000) and commonly exhibit olivine or pyroxene spinifex textures, a distinctive textural feature typical of the upper chilled margins of komatiitic flows (Nesbitt et al., 1982). Since they make up a