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The geochemistry of sedimentary rocks from the Fig Tree Group, Barberton greenstone belt: Implications for tectonic, hydrothermal and surface processes during mid-Archaean times

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Abstract

The ca. 3.25 Ga old Fig Tree Group in the southern part of the Barberton greenstone belt consists of deep- to shallow-water shale, greywacke, jaspilitic banded iron formation (BIF), and carbonaceous chert. The sequence is more than 1200 m thick and crops out as tectonically duplicated, but stratigraphically distinct tectono-stratigraphic units. Chemical weathering of the source terrain of Fig Tree strata was minor. Instead, hydrothermal-metasomatic events affected the sedimentary rocks in the study area, resulting in the depletion of alkaline earth elements and K metasomatism. Provenance modelling using REEs and trace element ratios indicate varying contributions from ultramafic to mafic greenstones, TTGs and HREE-undepleted granites. A clear stratigraphic control on the composition, in the form of increasing trace metal contents and decreasing La_N/Yb_N ratios, reflects progressive increase of ultramafic and mafic volcanic rocks in the source. Banded iron formation shows REE-Y patterns consistent with its precipitation in a marine environment from Eu-enriched seawater. Carbonaceous cherts at the base of the Fig Tree Group do not represent chemical precipitates out of a hot Archaean ocean, but represent carbonaceous sediments that were silicified during low-temperature hydrothermal fluid emanations on the seafloor.

Keywords: Archaean; Barberton greenstone belt; Chert; Provenance; Sediment geochemistry; Hydrothermal alteration

1. Introduction

The geochemistry of clastic and chemical sedimentary rocks is a powerful tool in the study of the provenance, tectonic setting and palaeoclimatic conditions of Archaean sedimentary sequences (e.g. Wronkiewicz and Condie, 1987) and has provided constraints on the composition and evolution of the atmosphere, hydrosphere, and continental crust through time (e.g. Holland, 1984; Taylor and McLennan, 1985; Klein and Beukes, 1989; Condie, 1993). Sediment geochemistry has been used extensively in the last few years to also shed light on the environment for early organic evolution, especially in the ancient supracrustal rocks from Greenland and the younger, but better preserved rocks from Archaean greenstone belts in Western Australia and South Africa (e.g. Van Kranendonk et al., 2003; Bolhar et al., 2005a). The Barberton greenstone belt of South Africa has been the focus of considerable geological interest for several decades, not only because possible remains of ancient life forms were described from carbonaceous cherts (references in Schopf and Walter, 1983; Walsh, 1992), but also because it contains a well preserved and well

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exposed volcano-sedimentary sequence that has yielded important information on Archaean igneous, tectonic and surface processes (Viljoen and Viljoen, 1969; Lowe and Byerly, 1999).

A number of geochemical studies were conducted in the last 35 years on turbiditic shales and greywackes of the 3.25 Ga Fig Tree Group in the northern part of the greenstone belt. These studies focused mainly on aspects of provenance of the sedimentary rocks. This paper reports new analytical data from more shallow-water Fig Tree rocks in the central part of the belt and attempts to refine the existing models for provenance, palaeoweathering and depositional setting. Carbonaceous cherts at the base of the sedimentary sequence have also been included in this study in order to evaluate the origin of these poorly understood rocks.

2. Geological setting

2.1. Stratigraphy

The Barberton greenstone belt (Fig. 1) consists of a NE–SW striking succession of supracrustal rocks, termed the Swaziland Supergroup, which ranges in age from ca. 3550 to 3220 Ma and which is surrounded by granitoid domes and intrusive sheets, ranging in age from ca. 3500 to 3100 Ma (see Hofmann et al., 2004, for a recent summary). The Swaziland Supergroup is made up of three stratigraphic units, the Onverwacht, Fig Tree and Moodies Groups. These rock units are tightly folded into a number of synclines that are separated by narrow anticlines or shear zones. A major fault zone, the Inyoka Fault, is present in the central part of the greenstone belt. Differences in the stratigraphy, age and depositional environment of rocks north and south of the Inyoka Fault suggest that it may represent a tectono-stratigraphic boundary.

2.1.1. Onverwacht Group

The Onverwacht Group formed between 3550 and 3300 Ma and consists of komatiites, komatiitic basalts, basalts, and minor felsic volcanic and sedimentary rocks that formed in a deep to shallow marine environment. South of the Inyoka Fault, the Onverwacht Group has been subdivided into six formations (Fig. 2), the Sandspruit, Theespruit, Komati, Hooggenoeg, Kromberg and Mendon Formations (Viljoen and Viljoen, 1969; Lowe and Byerly, 1999). Metamorphic grade is mainly greenschist facies, but locally reaches amphibolite facies close to the contact with the surrounding granitoid domes. Onverwacht Group rocks north of the Inyoka Fault have been grouped together as the Weltevreden Formation (Lowe and Byerly, 1999). The Sandspruit and Theespruit Formations are separated from the overlying units by a major fault, but the younger units are stratigraphically mostly conformable. Thrust faults that were active during Fig Tree and Moodies times are common in the uppermost sedimentary package.

2.1.2. Fig Tree Group

The Fig Tree Group, 3260–3226 Ma in age, consists of siliciclastic and felsic volcanic rocks. North of the Inyoka Fault, five formations have been distinguished, the Ulundi, Sheba, Belvue Road, Bien Venue and Schoongezicht Formations (e.g. Condie et al., 1970; Reimer, 1983; Lowe and Byerly, 1999; Kohler and Anhaeusser, 2002). The Ulundi Formation (Fig. 2) consists of carbonaceous and pyritic shale and banded chert that overlie altered Onverwacht Group komatiites. The Sheba Formation is made up of a homogeneous sequence of turbiditic sandstone and shale interbeds. The Belvue Road Formation consists of carbonaceous shale with minor turbiditic sandstone intercalations. Deposition took place in a deep-marine environment (Eriksson, 1980). Kohler and Anhaeusser (2002) introduced a new stratigraphic unit, the Bien Venue Formation, which overlies the Belvue Road Formation in the northeastern part of the greenstone belt and consists predominantly of quartz-muscovite schist derived from dacitic to rhyodacitic volcaniclastic protoliths dated at ca. 3256 Ma. The Schoongezicht Formation, which is ca. 30 Ma younger than the Bien Venue Formation, overlies the Belvue Road Formation in the central and northwestern part of the greenstone belt. It consists of plagioclase-rich turbidites intercalated with shale at the base and cross-bedded volcaniclastic sandstones and dacite clast conglomerates at the top (Lowe and Byerly, 1999). Intercalated felsic volcanic rocks have been dated at 3226 ± 1 Ma (Kamo and Davis, 1994).

South of the Inyoka Fault, the Fig Tree Group has been subdivided into the Mapepe and Auber Villiers Formations by Lowe and Byerly (1999), whereas Heinrichs (1980) distinguished a number of formations and members. Heinrichs (1980) regarded the Msauli Chert as the base of the southern Fig Tree Group. This chert overlies altered komatiites, consists of graded beds of accretionary lapilli, and is overlain by carbonaceous banded chert (Heinrichs, 1984; Lowe, 1999a). Lowe and Byerly (1999) regarded this unit as the uppermost part of the Mendon Formation of the Onverwacht Group. The Msauli and associated cherts are overlain by carbonaceous shales of the lower Fig Tree Group, for which no formation name was defined. These shales include a sandstone-dominated, more weathering-