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THE TUNGSTEN MINERALISATION AT NYAKABINGO AND GIFURWE (RWANDA): PRELIMINARY RESULTS

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(6 figures, 1 table and 1 plate)

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ABSTRACT. The Kibara belt in Central Africa hosts numerous important deposits of Sn, Nb, Ta and W. These mineral deposits mainly occur in pegmatites and hydrothermal quartz veins. A petrographical and stable isotope study has been carried out on two main tungsten deposits of Rwanda, namely at Nyakabingo and Gifurwe. These tungsten deposits are present in the central part of Rwanda and occur as mineralised quartz veins that are hosted by graphite-rich black shales. Wolframite minerals formed after the precipitation of the main quartz vein. The mineralising fluids have a H_2O–CO_2–CH_4–N_2–NaCl composition, a moderate salinity (7.4-9.9 eq. wt.% NaCl) and a minimum temperature of 300°C. The isotopic composition of the fluids indicates that the mineralised quartz veins most likely formed from a fluid largely influenced by metamorphic processes. The wolframite minerals precipitated due to interaction of the fluid with graphite-rich black shales. The origin of the tungsten is still a matter of discussion. Whether the mineralising fluid was originally a metamorphic or a magmatic fluid is still unknown.

KEYWORDS. Kibara belt, Central Africa, Microthermometry, Fluid inclusions, Stable isotope

1. Introduction

Rwanda is situated in the western part of the northeastern Kibara belt (NKB). The Kibara belt extends from Katanga (D.R.Congo) in the south to Uganda in the north. It is composed of rocks of Palaeo- to Mesoproterozoic age. In the western part of the NKB, sedimentation in shallow-water (sub)basins started around 1420 Ma (Tack et al., 2006). The rocks comprise turbiditic and deltaic sediments, shallow marine deposits and volcanogenic sediments. Carbonates were rarely deposited (Baudet et al., 1989; Pohl, 1994). Around ~1400 Ma the rocks were deformed during the Kibara orogen (Tack et al., 2006). The Palaeo- and Mesoproterozoic rocks have been intruded by several granites. Historically, based on petrographical observations and Rb-Sr dates, the granites which intruded the Kibara belt were subdivided in several types (G1 to G4) (e.g. Cahen & Ledent, 1979; Cahen et al., 1984; Klerckx et al., 1984, 1987). Based on recent U-Pb SHRIMP dating, it is demonstrated that the G1 to G3 granites were formed at 1380 ± 10 Ma, while the G4 granites (or the so called 'Sn-granites') formed at 986 ± 10 Ma (Tack et al., 2006).

The Kibara belt is best known for its richness of Sn, Nb-Ta, W and Au mineralisations (Pohl, 1994). The Sn-Nb-Ta-W mineralisations mainly occur in pegmatites and quartz veins (Varlamoff, 1972; Pohl & Günther, 1991; Dewaele et al., 2007, accepted). The mineralised pegmatites and quartz veins are interpreted to be related to the 'Sn- or G4-granites'. These granites show enrichment and depletion trends which are typical for granites associated with mineral deposits (Dewaele et al., accepted). Lehmann & Lavreau (1987) have determined the tungsten content of seven G4-granites. It varies between 3 and 11 ppm W, with an average of 6.5 ppm W. The pegmatites are dated at 968 ± 8 Ma and the Nb-Ta-mineralisation in the pegmatites at 962 ± 2 Ma (Romer & Lehmann, 1995) and 965 ± 5 Ma (Brinckmann et al., 2001). The pegmatites are sometimes crosscut by mineralised quartz veins (Varlamoff, 1972; Pohl, 1994). The Sn-mineralised quartz veins formed at 951 ± 18 Ma (Brinckmann et al., 2001). The temporal relationship between the Sn- and W-mineralised quartz veins is not clear since both vein types mostly occur at different locations. In addition, the age of the tungsten mineralisations has not yet been determined. Tungsten mineralisations are, next to quartz veins, also found in skarns associated with mafic intrusions. These skarns have been described for several locations in Rwanda (unpublished data from Programme des Nations Unies pour le Développement). In the southwest of Rwanda, these skarns contain scheelite. The present study focuses on the tungsten mineralisation that occurs in the central part of Rwanda, more specifically at the mines of Nyakabingo and Gifurwe (Fig. 1). Based on a petrographical and geochemical study, a preliminary metallogenetic model is proposed.

2. Geological Setting

The NW- to SE-orientated Bugarama-Gifurwe-Nyakabingo zone with abundant tungsten mineralisation

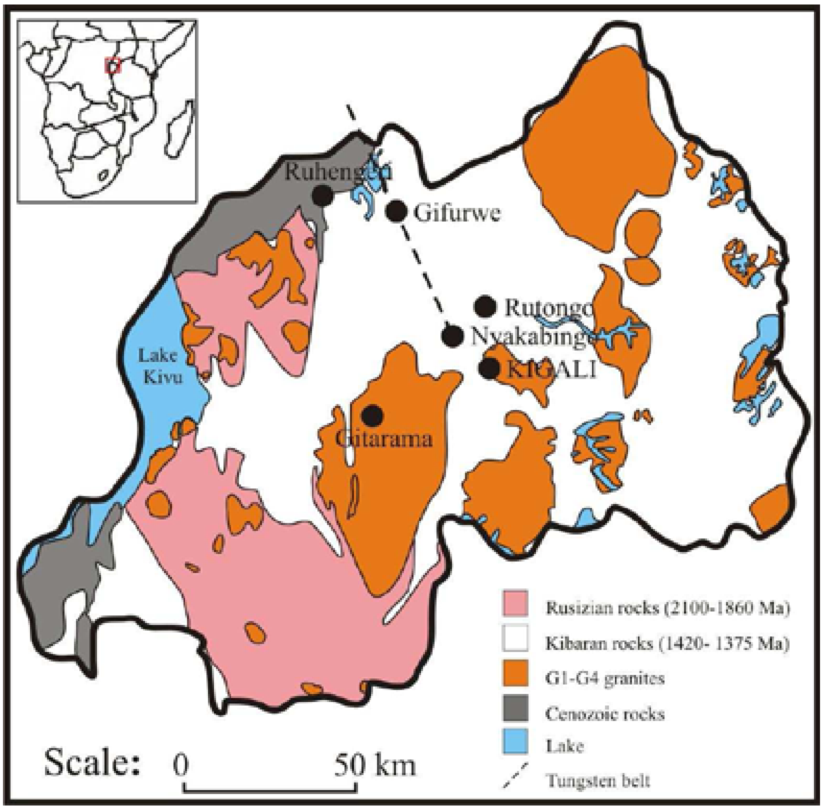

Figure 1. Simplified geological map of Rwanda (modified after Fernandez-Alonso et al., 2007).

is situated in the central part of Rwanda (Fig.1). This zone is called the 'Tungsten belt' (De Magnée & Aderca, 1960; Pohl, 1994), analogous to the 'Copperbelt' in Katanga (D.R. Congo). The rocks in the 'Tungsten belt' are dominantly siliciclastic. Their composition ranges from black shales to quartzophyllades and quartzites (Baudet et al., 1989). According to Frisch (1975) and Croese (1984) these rocks only underwent a low-grade greenschist metamorphism. The tungsten mineralisation is dominantly present in quartz veins, which are orientated along two main directions (De Magnée & Aderca, 1960; Frisch, 1975). The first group lies parallel to the bedding, whereas the second group of quartz veins crosscut the bedding. Concordant veins are mostly crosscut by discordant veins, but the reverse relationship can also be observed (De Magnée & Aderca, 1960; Frisch, 1975; Pohl, 1994). The mineralised quartz veins are typically hosted by graphite-rich black shales (De Magnée & Aderca, 1960; Frisch, 1975). At Gifurwe, an important enrichment of disseminated tungsten is found in the host rocks (Frisch, 1975). According to Jeffery (1959) and De Magnée & Aderca (1960), the tungsten concentration of metasedimentary rocks in the 'Tungsten belt' is relatively high (4 to 6 ppm W). Especially the carbonaceous metasedimentary rocks are relatively enriched in tungsten, due to the absorption of tungsten by organic matter (Jeffery, 1959; Beus, 1986). However, a more regional exploration campaign in 1974 only reports a regional background value of ~0.5 ppm W, with an increase of the tungsten content near the known mineralisations (unpublished data from Projet de Recherches Minières RWA 74/001).

Two models are proposed in literature for the formation of the tungsten mineralisation. The first model supposes remobilisation of tungsten from the host rock to the quartz veins by metamorphism and/or the intrusion of a granite body (Jeffery, 1959; De Magnée & Aderca, 1960). However, different observations are reported in literature that are in disfavour with this model: e.g. the host rocks of the mineralised quartz veins do not show any sign of quartz mobilisation, quartz veins only occur in areas were the host rocks have an elevated W-content, the host rocks underwent only very low grade metamorphism and an elevated tungsten content of the host rocks is only present near the mineralisation (Frisch, 1975; Pohl, 1994). A second model suggests a supply of tungsten by a magmatic fluid, which originated from the G4-granites. From this fluid, W-mineralised quartz veins formed and tungsten was distributed through the host rock (Frisch, 1975; Pohl & Günther, 1991; Pohl, 1994).

3. Petrography

A petrographical study was carried out on the mineralised quartz veins from Nyakabingo (Fig. 2) and Gifurwe (Fig. 3), using transmitted and reflected light microscopy and Scanning Electon Microscope-Energy Dispersive X-ray analysis (SEM-EDX). The samples were taken from both concordant and discordant mineralised quartz veins. The tungsten mineralisation at the studied deposits shows an identical paragenetic sequence (Fig. 4), which can be divided into three phases. Muscovite was the first mineral to precipitate, followed by massive quartz (Pl. 1A) with cubic pyrite crystals (phase 1) (Pl. 1B). Massive quartz

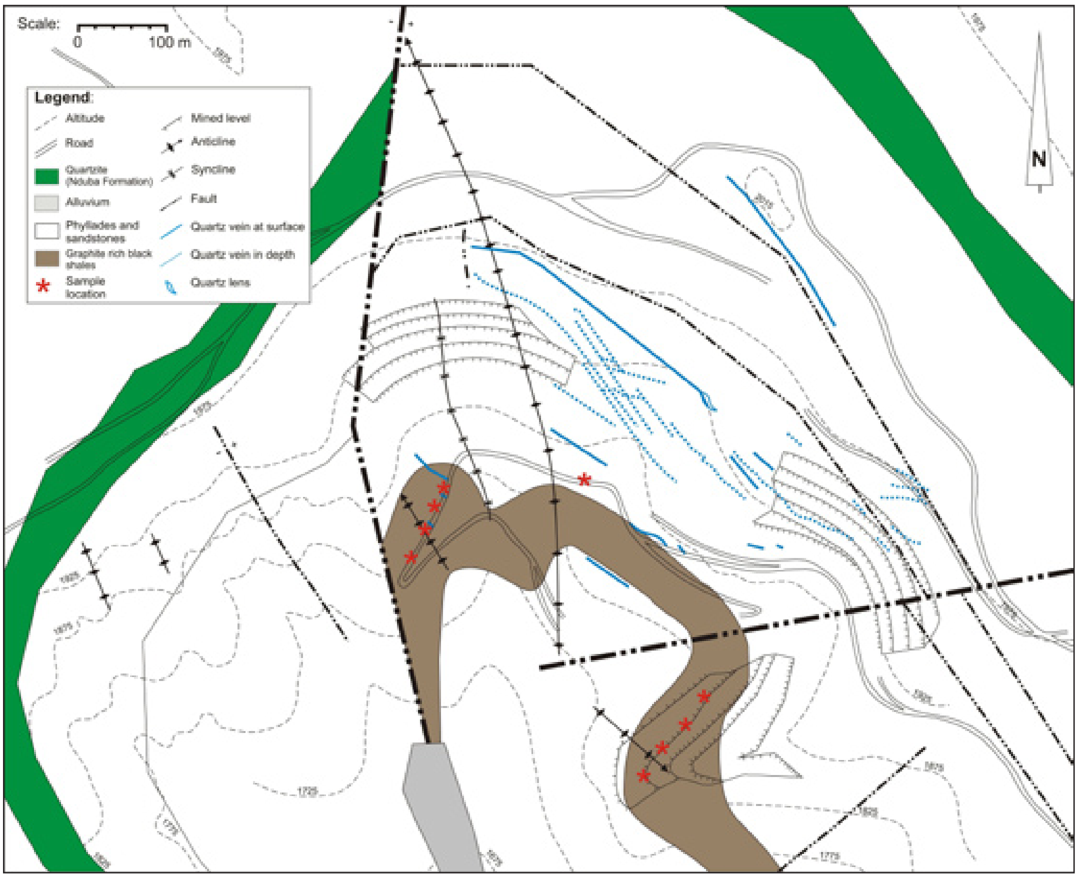

Figure 2. Simplified geological map of the Nyakabingo mine (after unpublished data from SOMIRWA, 1977, 1985).

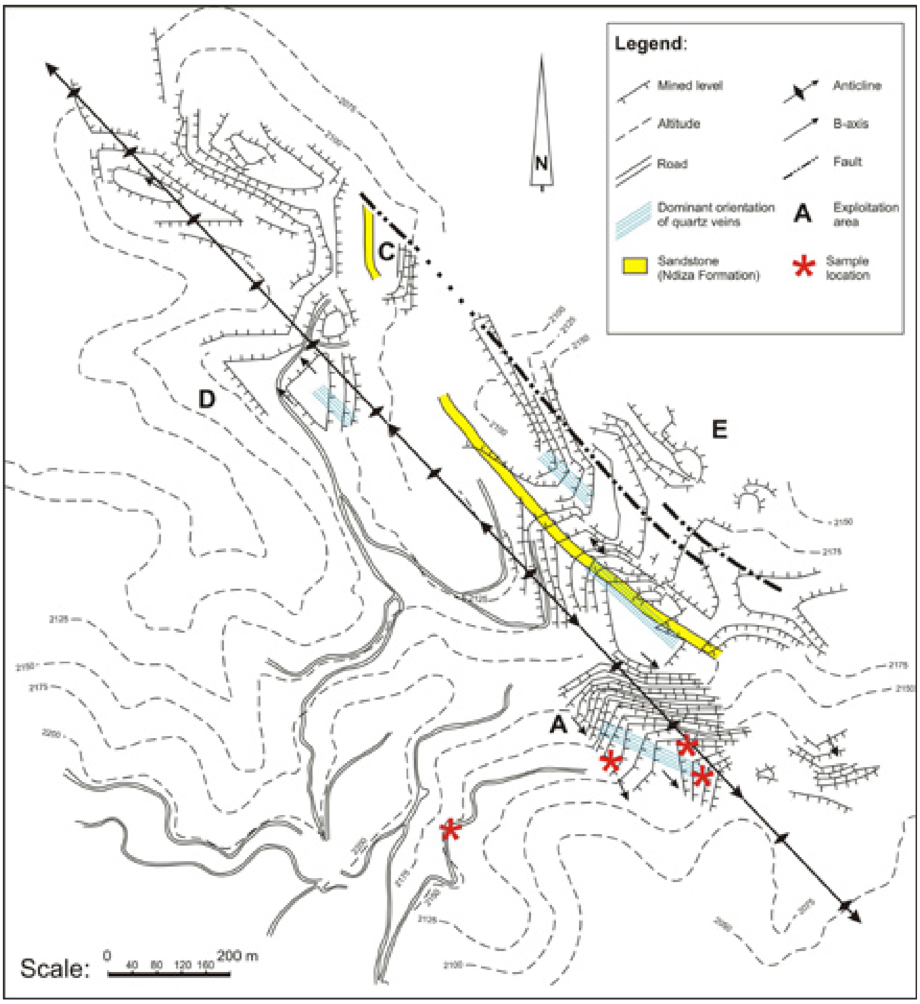

Figure 3. Simplified geological map of the Gifurwe mine (after unpublished data from SOMIRWA, 1980; Frisch, 1975).

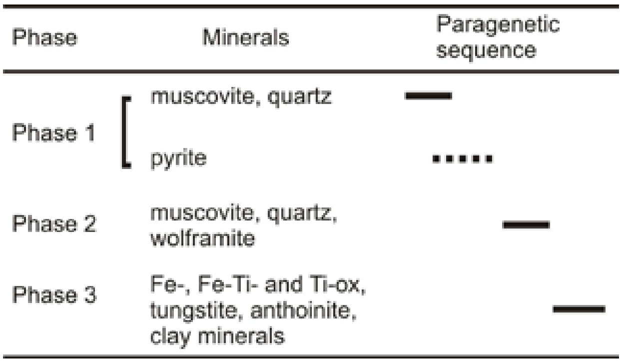

Figure 4. General paragenetic sequence of the tungsten mineralisations at Nyakabingo and Gifurwe.

veins are crosscut by tiny quartz and muscovite veins that contain the tungsten mineralisation (phase 2) (Pl. 1A). During this phase, pyrite crystals in quartz veins could have partly been replaced by wolframite (Pl. 1C, D). In literature, the main tungsten minerals are described as reinite (spongy ferberite after scheelite) and/or ferberite (De Magnée & Aderca, 1960; Frisch, 1975; Pohl & Günther, 1991; Pohl, 1994). However, during this study we were not able to make the distinction. Therefore, we use the general term ‘wolframite’ to describe the tungsten minerals. In the last phase (phase 3), wolframite and pyrite were altered and clay minerals, tungstite, anthoinite and Fe- and Ti-oxides precipitated (Pl. 1B, D, E).

Pohl & Günther (1991) and Pohl (1994) have also described the occurrence of minor amounts of cassiterite, tourmaline, scheelite and arsenopyrite. These minerals have not been observed in our samples. UV-light has been used to scan for the occurrence of fluorescent minerals like scheelite, but without results.

4. Stable isotope geochemistry

The stable isotopic composition of five quartz samples from the mineralised veins from Nyakabingo and Gifurwe was analysed to determine the source of the mineralising fluids. The oxygen isotopic composition of quartz crystals and the hydrogen isotopic composition of fluid inclusions inside the quartz crystals were measured. Quartz samples were hand picked and stable isotope analyses were carried out at SUERC. All samples were analysed using a laser fluorination procedure, involving total sample reaction with excess ClF_3 using a CO_2 laser as a heat source. Reproducibility is better than 0.3% (= 1 σ). Results are reported as ‰ deviation from the Vienna Standard Mean Ocean Water (V-SMOW) standard. The results of the analysis are summarized in Table 1. The samples analysed have almost identical δ^{18}O values, but the δD values vary significantly, i.e. between -33‰ to -51‰ V-SMOW. The δ^{18}O composition of the ambient fluid from which the quartz crystals precipitated has been calculated using the equation of Matsuhisa et al. (1979). Pohl & Günther (1991) and Pohl (1994) estimated a formation temperature between 300 and 500°C for the quartz crystals based on microthermometry. The δ^{18}O composition of the ambient fluid in equilibrium with quartz has been calculated for the temperatures 300 and 500°C (Table 1). In a δ^{18}O-δD

Sample	δD fluid (V-SMOW)	δ^{18}O quartz (V-SMOW)	δ^{18}O fluid (300°C) (V-SMOW)	δ^{18}O fluid (500°C) (V-SMOW)
GI06SD02	-47	16.0	9.1	13.7
GI06SD08	-37	15.9	9.0	13.6
NY06SD01	-51	15.2	8.3	12.9
NY06SD06	-44	14.9	8.0	12.6
NY06SD07	-33	14.4	7.6	12.2

Table 1. Stable isotope data of mineralised quartz veins at Nyakabingo and Gifurwe.

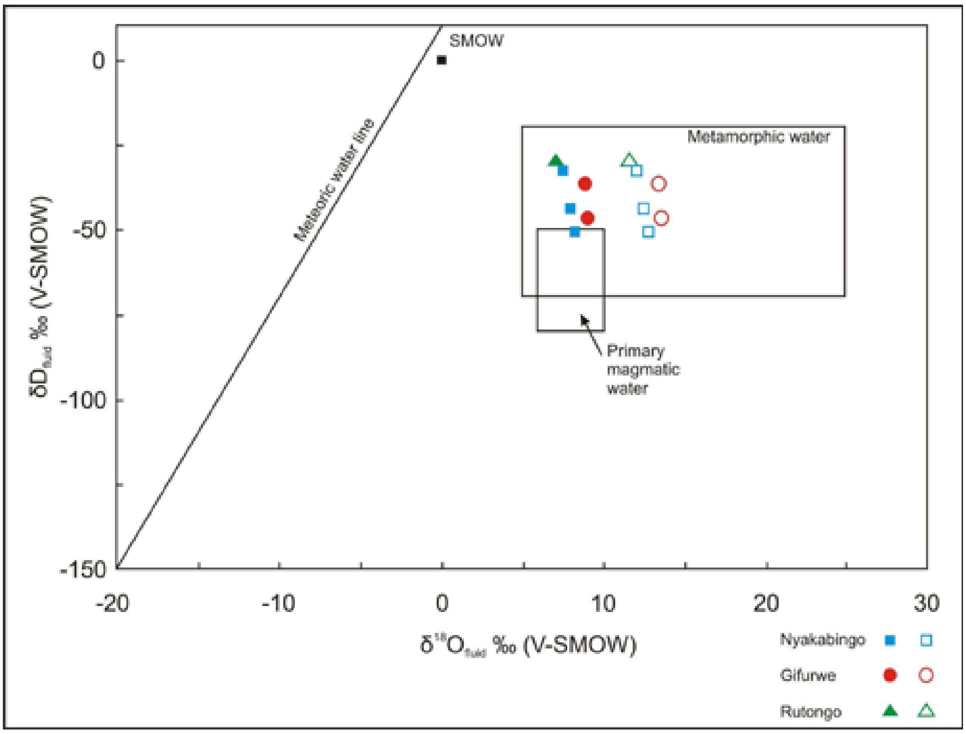

Figure 5. δ18O-δD isotopic plot for the calculated fluid composition of the mineralised quartz veins of Nyakabingo, Gifurwe and Rutongo (data for Rutongo from Dewaele et al., 2007). Full symbols represent the calculated fluid composition at 300°C, empty symbols represent the calculated fluid composition at 500°C. The meteoric water line, the composition of seawater and the range of isotopic composition for metamorphic and magmatic water are drawn after data from Hoefs (2004).

isotopic diagram, these values plot in the area typical for metamorphic water. At 300°C, there is a slight overlap with the area typical for the composition of primary magmatic water (Fig. 5).

Pohl & Günther (1991) postulated that the tungsten- and tin-mineralised quartz veins (at Nyakabingo and Rutongo respectively) formed from fluids that had the same primary magmatic origin and a similar evolution, based on a comparable geological setting and a similar paragenesis and fluid inclusion composition. Dewaele et al. (2007, accepted) determined the oxygen and hydrogen isotopic composition of tin-mineralised quartz veins from Rutongo (Rwanda). The $\delta^{18}O$-δD values of the tin-mineralising fluids also fall in the field typical for metamorphic water (Fig. 5) (Dewaele et al., 2007).

5. Discussion and conclusion

According to Pohl & Günther (1991) and Pohl (1994) the tungsten mineralisation at Nyakabingo formed from an H_2O–CO_2–CH_4–N_2–NaCl fluid with a moderate salinity (7.4-9.9 eq. wt.% NaCl). According to these authors, the mineralising fluid was a primary magmatic (G4-granite) fluid. However, the stable isotope analysis of quartz crystals from Nyakabingo and Gifurwe points to metamorphic conditions. It must, however, be noted that Pohl & Günther (1991) describe the presence of three generations of fluid inclusions in the quartz crystals, including late meteoric water. It can not be excluded that the deuterium isotopic analysis include later generations of fluids due to the bulk sampling method. However, petrographic observations of the selected samples did not show the presence of visible/measurable inclusions of meteoric water. A review of literature data (e.g. Roedder, 1984; Shepherd et al., 1991; Kilias & Konnerup-Madsen, 1997; O'Reilly et al., 1997; Rios et al., 2003; Huff & Nabelek, 2007) shows that the gas composition (CH_4 and N_2) and the temperature of the tungsten mineralising fluid rather point to metamorphic conditions. Carbon and nitrogen are generated and released to mineralising fluids as a result of fluid-rock interactions (Shepherd et al., 1991). CO_2, CH_4 and N_2 are generated during these processes, most likely due to maturation of organic matter and the breakdown of phyllosilicates (Higgins, 1980; Kreulen & Schuiling, 1982; Dubessy et al., 1989; Shepherd et al., 1991; Huff & Nabelek, 2007). Pohl & Günther (1991) also state that the Kibaran metapelites are the source of the different gases, which are found in the fluid inclusions. According to Huff & Nabelek (2007), high nitrogen concentrations are an important indicator of a metamorphic origin of fluids in comparison with magmatic fluids. Moreover, Cauet & Pohl (1988) have shown that the lead isotope ratios of pyrite in mineralised veins at Nyakabingo and in pyrite in black shales far from the mineralisation are similar. As a consequence, the pyrite crystals in the quartz veins could have precipitated from a fluid that interacted with the pelitic host rocks. It can be concluded that the mineralised quartz veins most likely formed from a fluid largely influenced by metamorphic processes. Wolframite precipitated due to interaction of the mineralising fluid with graphite-rich black shales.

The origin of the tungsten is still a matter of discussion. If all data and interpretations mentioned above are taken into consideration, two models for the formation of the tungsten deposits at Nyakabingo and Gifurwe can be proposed (Fig. 6). According to the first model the mineralising fluid was originally a metamorphic fluid, i.e. a fluid which was in equilibrium with metasedimentary and magmatic rocks at temperatures below 500°C. In this model, the emplacement of G4-granites triggered

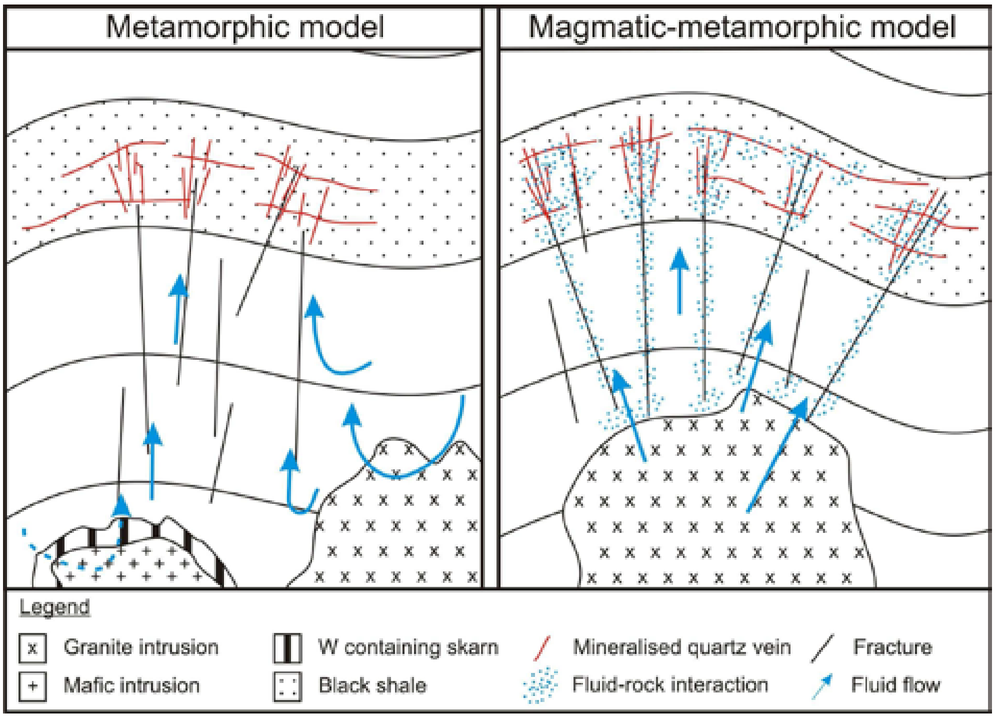

Figure 6. Two possible metallogenetic models for the formation of the tungsten deposits at Nyakabingo and Gifurwe, Rwanda.

hydrothermal circulation around the contact zone between the intrusion and the country rocks. The circulating fluids could have remobilised tungsten from G4-granites and maybe to a minor extent from skarns and metasedimentary rocks (cfr. Dewaele et al., 2007, accepted). The second model supposes an original magmatic origin (G4-granite) for the mineralising fluid. This magmatic fluid could have interacted with the metasedimentary rocks, explaining its oxygen and deuterium isotopic composition. The current available data do not allow to make a distinction between these two models.

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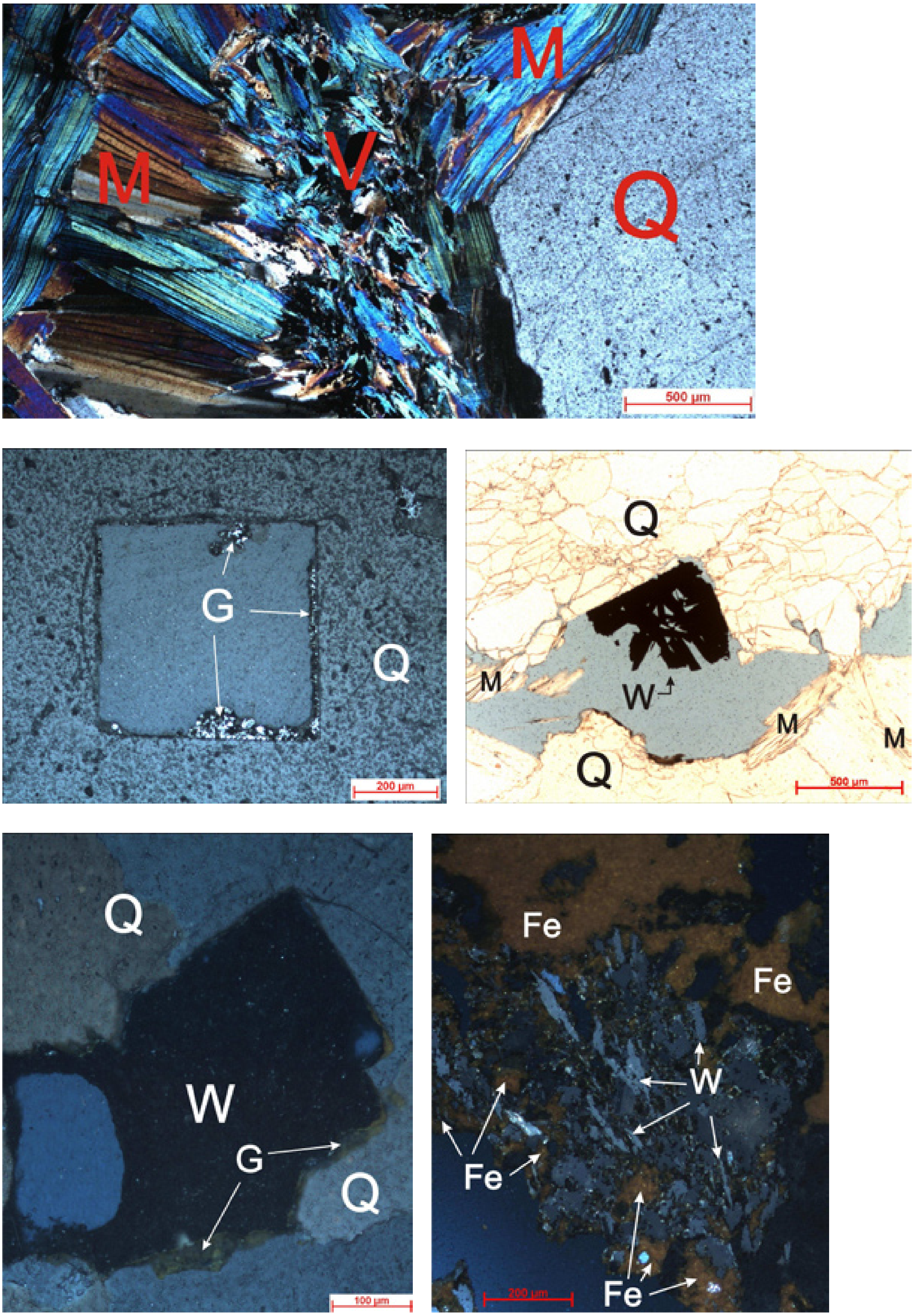

Plate 1.

(A) Large muscovite crystals (M), followed by the precipitation of large quartz crystals (Q). The muscovites are crosscut by a vein (V) which contains wolframite, small quartz crystals and muscovite (transmitted light).

(B) Square cavity in quartz vein (Q) which contains goethite (G) at the edge (transmitted light).

(C) Wolframite (W) and muscovite (M) crystals in quartz vein (Q) (transmitted light).

(D) Quartz vein (Q) with altered wolframite (W) in the centre and goethite (G) at the edges (reflected light).

(E) Wolframite (recognisable by the typical internal twins) (W) is altered to an iron oxide (Fe) (reflected light).