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THE HELLE IGNEOUS ROCK AND ASSOCIATE PORPHYRY COPPER MINERALIZATION (EASTERN BELGIUM): A SUMMARY OF THE PRESENT-DAY KNOWLEDGE

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(4 figures, 1 table)

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ABSTRACT.
This paper summarizes the mineralogical, petrological, geochronological and metallogenical data acquired at the present-day (2002) on the Helle igneous rock and the associated cupriferous mineralization. This sill-shaped intrusion surrounded by a plurihectometric aureole of spotted schists was described as tonalite in the old literature. In fact, the petrographical composition of the intrusion is variable. Diorites, monzodiorites quartz diorites, granodiorites and quartz granodiorites have been identified. Most of the rocks however correspond to quartz diorite (trondhjemite and tonalite) and to a lesser extent, to granodiorite. A geochronology study (U-Pb isotopic ratios of zircon) indicates that the magma emplacement took place between the Silurian and the lower Devonian (minimum age of emplacement : around 381 ± 16 Ma). The mineralization associated to the intrusion shows many similarities with the porphyry copper deposits. However, the small size of the intrusion and the low Cu and Mo considerably reduce its mining interest, at least in the present-day economic and technologic conditions.

KEYWORDS : Acadian, Belgium, sill, quartz diorite, tonalite, trondhjemite, granodiorite, porphyry copper deposit.

1. Introduction

The Helle (Hill in German) and Lammersdorf magmatic intrusions are the only significant igneous occurrences from Eastern Belgium, in the Hautes Fagnes area (Hohes Venn in German). They are hosted in Cambrian siliciclastic rocks (Revin Group) of the Stavelot Massif (Fig. 1).

The Lammersdorf magmatic rock was discovered in 1884 during the works for the railway connection between Aachen and Sankt-Vith. An Eupener engineer, J. Winkold, discovered the Helle magmatic rock in 1896, near the Herzogenhügel locality. These rocks were first described as granites (Von Lasaulx, 1884) and, later on, as tonalites (Ronchesne, 1930). The main studies devoted to the intrusions, their host rocks and their associated metamorphisms and mineralizations are those of Ronchesne (1930), Van Wambeke (1953, 1955, 1956a,b), Schreyer & Abraham (1979), Weis *et al.* (1980), Kramm & Buhl (1985) and Dejonghe & Melchior (1996).

This paper aims at summarizing the mineralogical, petrological, geochronological and metallogenical data acquired at the present-day (2002) on the Helle igneous rock and the associated cupriferous mineralization.

2. Geological framework

The Helle intrusion has the shape of a sill dipping 30° towards the SE, stretching along about 500 m in a NE-SW trend and having a maximum thickness of about 100 m. Small secondary sills or dykes are also connected to the main sill. A subvertical fault intersects the centre part of the main sill (Fig. 2).

The petrographical composition of the magmatic rock is variable and overlaps several fields of the Streckeisen (1973) classification, namely: diorite, monzodiorite, quartz diorite, granodiorite and quartz granodiorite. Most of the rocks however correspond to quartz diorite (trondhjemite and tonalite) and to a lesser extent, to granodiorite (Fig. 3).

The major minerals are: plagioclase (from labradorite to albite), quartz and biotite (often altered in hydrobiotite or prochlorite). Among the accessory minerals, we may mention: orthoclase, sericite, kaolinite, zoïsite, zircon,

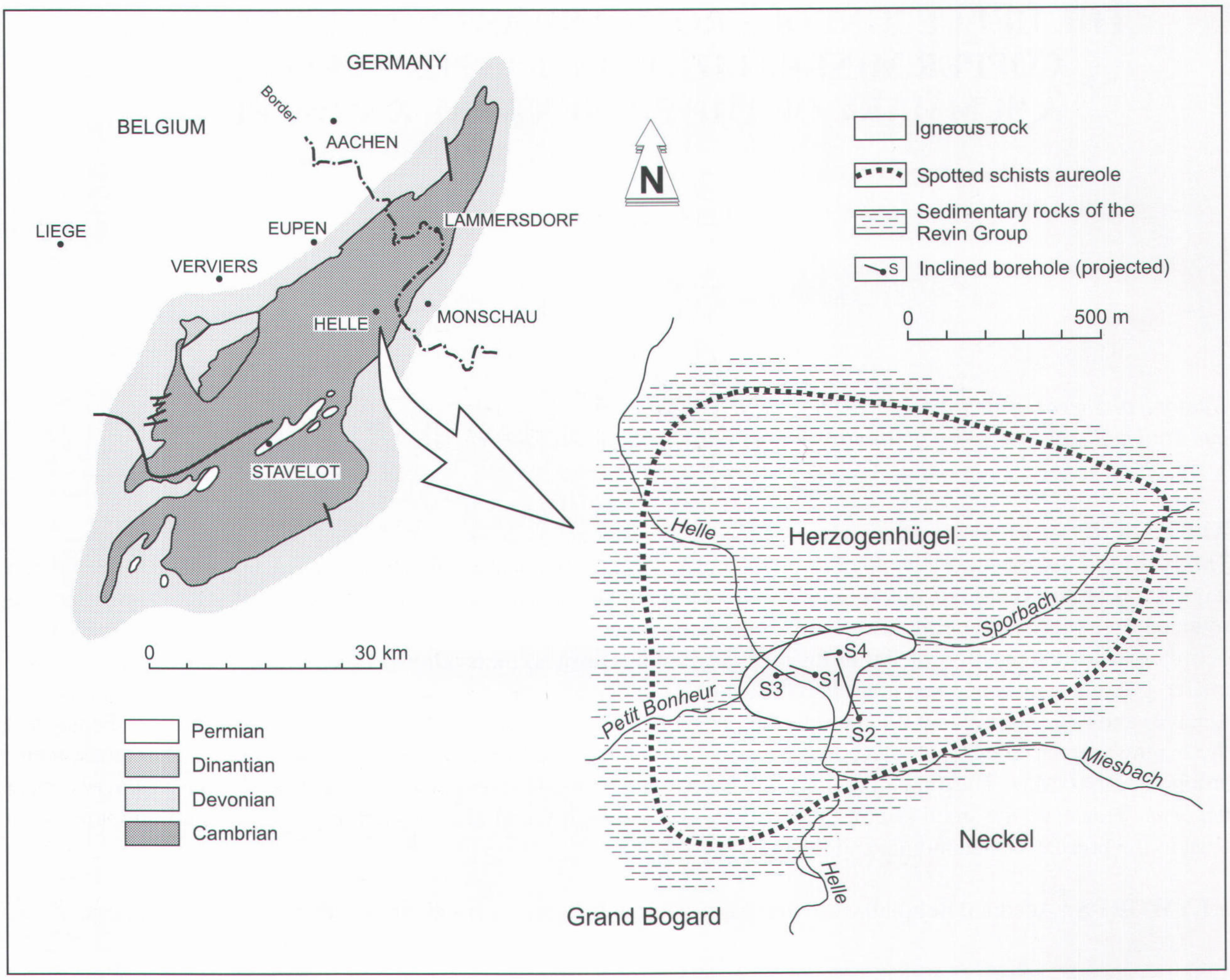

Figure 1. Location map of the Helle and Lammersdorf intrusions in the Stavelot Massif and outcrop area of the Helle intrusion and its aureole of spotted schists (lower right side).

apatite, calcite, magnesite, titanite, ilmenite, rutile; leucoxene, Mn oxydes and opaques minerals listed hereafter in 3. Most of the calcic minerals could be due to regional metamorphism (by transformation of pyroxene or amphibole, titanite and plagioclase in low P-T minerals such as epidote, leucoxene and carbonates). The NE and SW zones of the intrusion are approximatively two times richer in K feldspar than the central and southern zones.

The crystallization order has been detailed by Van Wambeke (1956a) and Dejonghe & Melchior (1996). They distinguish a magmatic phase {1a.biotite with zircon, ilmenite and apatite inclusions, 1b. zonal plagioclase (andesine-labradorite); 2. albite-andesine microlites with orthoclase rims; 3. quartz} from an hydrothermal phase (4. silicification and albitization; 5. saussuritization and sericitization of the plagioclases; chloritization of hydrobiotite). The structures of the magmatic assemblage vary from microgranular to porphyritic. Chemical analyses of the major elements are given in Table 1.

References	1	2	3	4
SiO_2	71.2	70.28	70.06	68.28
TiO_2	0.4	n.a.	n.a.	0.37
Al_2O_3	14.7	14.93	14.86	15.59
Fe_2O_3	0.8	1.42	1.64	0.2
FeO	1.2	n.a.	0.63	2.9
MnO	0.02	0.06	0.06	0.18
MgO	1.1	0.76	1.02	1.37
CaO	2.3	3.29	3.45	2.52
Na_2O	3.6	4.57	4.83	3.98
K_2O	2.6	2.62	2.06	3.03
P_2O_5	0.04	n.a.	n.a.	n.a.
H_2O/CO_2	1.4	1.44	1.24	0.77
S	0.8	1.34	1.28	0.44
Total	100.16	100.71	101.13	99.63

Table 1. Chemical analyses of four samples from the Helle intrusion, after : (1) Schreyer & Abraham (1979); (2) Dannenberg & Holzapfel (1898); (3) Ronchesne (1930); (4) Van Wambeke(1955). n.a. = not analyzed.

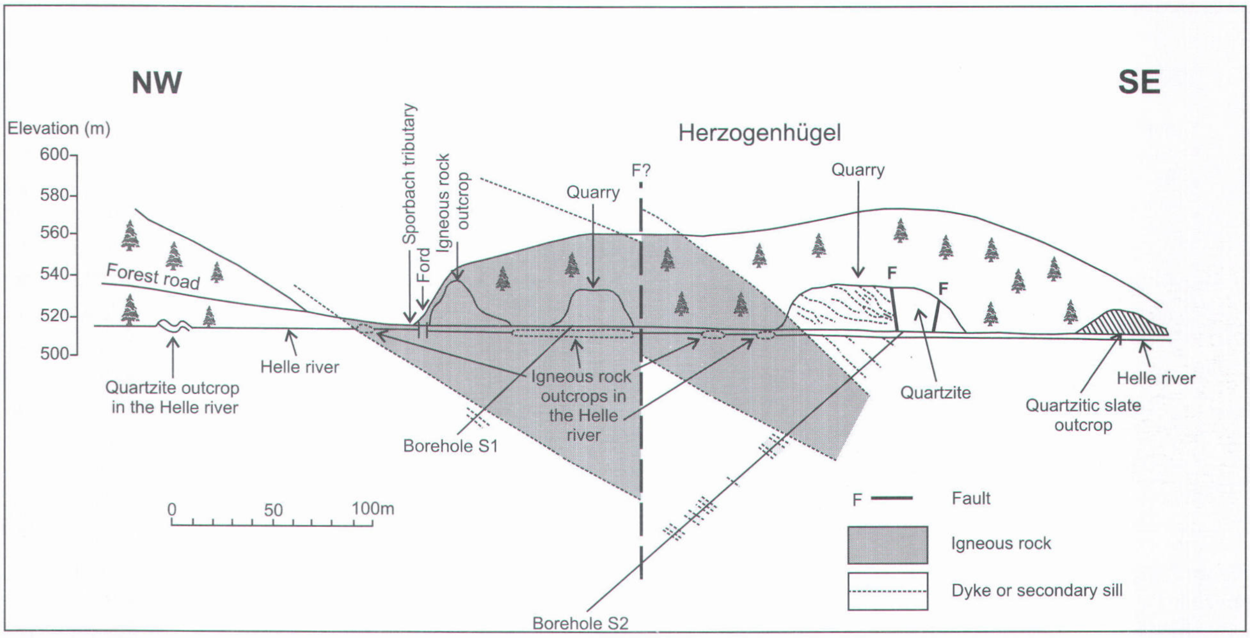

Figure 2. NW-SE cross-section parallel to the Helle valley (S1 and S2 are boreholes projected on the cross-section plane).

The intrusion is surrounded by an aureole of thermal metamorphism marked by a very thin (< 1m) zone of hornfels and a plurihectometric halo of spotted schists (Fig. 1). The Variscan orogeny has also induced a low grade regional metamorphism (chlorite-prehnite-epidote) in the Helle magmatic rock and its host-rocks (Schreyer & Abraham, 1979).

A geochronology study (U-Pb isotopic ratios of zircon) by Kramm & Buhl (1985) indicates that the magma emplacement took place between the Silurian and the Lower Devonian (minimum age of emplacement : around 381 ± 16 Ma). The Helle intrusion emplacement is coeval with Acadian intrusive activity in the Appalchian mobile belts, ranging from 373 - 410 Ma after Rodgers (1970). Acadian events including magmatic intrusions as well as metamorphic processes are described from several localities of the Variscan fold belt of central Europe. Kramm & Buhl (1985) suggest that the Helle intrusion is in connection with a stockwork structure of the Central German crust at Acadian times. The Stavelot Massif is indeed a major thrust nappe coming from a much more SE original position as revealed by the deep seismic profiles (e.g. Dekorp, 1991).

3. Mineralization

The Cu-Mo mineralization associated with the outcropping parts of the intrusion was first studied by Van Wambeke (1953, 1956b) who pointed out similarities with a porphyry copper deposit. Indeed, porphyry deposits are characterised by low grade and large tonnage sulfide deposits normally intimately associated with intermediate to acid plutonic intrusives. They are also all characterised by an extensive hydrothermal alteration of the host rocks. Lowell & Guilbert (1970) drew up a model defining an alteration zoning pattern consisting of four coaxial zones, namely, from inside to outside: potassic, phyllic, argillic and propylitic zones. Like the alteration, the mineralization also tends to occur in concentric zones. Occurrence of sulfides changes upward and outward from dissemination at the low-grade core of the deposit through microveinlet to veinlet and finally vein occurrence indicating the progressively increasing effect of structural control.

In 1976-1977, Union Minière S.A. has drilled 4 inclined boreholes (S1 to S4 in Fig. 1) to assess the economical potential of this mineralization. The deepest drill hole (S2) was 228.80 m long with a 45° inclination (see Fig. 2). From a study of drill hole samples, Weis *et al.* (1980) mentioned in order of decreasing abundance:

- **As hypogene minerals**: pyrite, chalcopyrite, rutile, molybdenite, pyrrhotite, sphalerite, marcasite, titanite, galena, a Bi telluride of the tellurobismuthite-hedleyite series (Bi_2Te_3 to Bi_2Te_7), ilmenite, cobaltite and hessite;
- **As supergene minerals**: goethite, malachite, covellite, chalcocite, lepidocrocite, neodigenite, ferrimolybdite and native copper.

The mineralization is disseminated in the centre of the intrusion and becomes gradually concentrated in veins and veinlets at its periphery and in the enclosing rocks. Cu and Mo grades vary much from place to place, but a general trend is to higher grades near the periphery of the intrusion. Core analyses have given the following

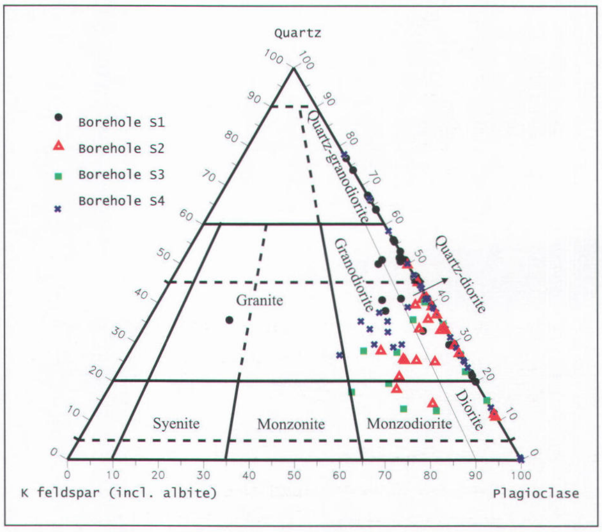

Figure 3. Petrographical variations of rocks from the four boreholes drilled in the Helle intrusion (Dejonghe & Melchior, 1996).

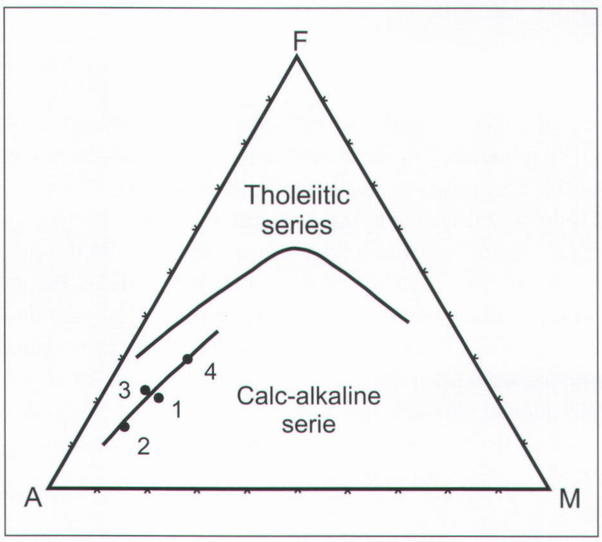

Figure 4. Plots in a AFM diagram of 4 rocks from the Helle intrusion (A = $Na_2O + K_2O$; F = $FeO + Fe_2O_3$; M = MgO).

grades: Cu average: 0.17 % - Cu extrema : 0.01 % - 0.45 %; Mo average: 0.02 %; Mo extrema : 0.001 % - 0.097 %). Reserves are estimated to ± 35 000 tonnes Cu and ± 4 000 tonnes Mo (Dejonghe, 1983). Cailteux (1974) published tests of ore concentration by flotation.

Although chemical analyses were specially performed to detect gold, this element was never identified in samples from the Helle igneous rocks. Dimanche & Sterpin (2001) however assume a possible origin for gold from the Helle intrusion. They have indeed observed, under the microscope, micrometric granules of chromite-rutile-gold-zircon-martite in ferriferous crusts found near the Helle-Soor junction, about ten kilometres downstream from Herzogenhügel.

4. Interpretation

4.1. Petrological interpretation

The petrographic study of the drill holes (Dejonghe & Melchior, 1996) indicates that the rocks of intermediate composition (between 25 and 40 % modal quartz) are the richest in calcic minerals. The CaO variation may be explained by a classic process of magmatic differentiation (for example, by fractionation of plagioclase and/or Ca-bearing pyroxene). The chemical variations of major elements, in particular the opposite trends of FeO-MgO and CaO-Na_2O-K_2O associations vs SiO_2, are indeed better explained by fractional crystallization. The AFM diagram of figure 4 indicates that the Helle rocks correspond to a calc-alkaline series, which is generally associated to a magmatism of subduction in global tectonism context. The variation from a weak K feldspar pole to a potassic pole in the 10-30 % quartz composition range is another major trend. This variation corresponds to the transition from a quartz diorite to a granodiorite or from a diorite to a monzodiorite.

The occurrence of abundant porphyritic rocks, near the contact between the intrusion and the country rocks, suggests quick cooling of the melt (quenching). Furthermore, cataclastic to brecciated structures in this zone indicate that the deformation varied from plastic at an early stage of emplacement to brittle at a postmagmatic stage. During the magma emplacement, the intrusion which was already partly solidified, has probably mechanically deformed its external envelope due to persistent push of the magma. Felsic and quartz veins are indeed abundant near the margins of the sill and are probably related to an early fracturation of the country rocks. These various factors facilitated the circulation of late to postmagmatic hydrothermal fluids at the periphery of the intrusion.

4.2. Metallogenical interpretation

The analogies and differences between the Helle mineralization and porphyry copper deposits were assessed by Dejonghe & Melchior (1996).

- **Analogies are** : 1. differentiated igneous host rocks ranging from diorites to quartz diorites, monzonites and granodiorites. 2. occurrence of porphyritic rocks, but only near the periphery of the intrusion. 3. potassic assemblage (K feldspar, hydrobitotite) in the upper part of the intrusion. However, coexistence with phyllic and propylitic assemblages suggesting telescoping of the hydrothermal alteration zones due to the small size of the intrusion. 4. strong alteration (saussuritisation) of the feldspar. 5. disseminated type mineralization (mainly made up of chalcopyrite and pyrrhotite, with pyrite, sphalerite, cobaltite, rutile, titanite and ilmenite as accessory minerals) associated with vein type mineralization prominent near the periphery of the intrusion.

- **Differences are** : 1. absence of breccia pipe. 2. Cu/Mo = 8.5 (Cu/Mo ≅ 40 for typical porphyry copper and ≅ 0.08 for typical porphyry molybdenite).

5. Conclusion

Most of the rocks of the Helle intrusion, which is emplaced between the Silurian and the Lower Devonian, correspond to a calc-alkaline series, namely to quartz diorite (trondhjemite and tonalite) and to a lesser extent, to granodiorite. A mineralization of porphyry copper type is associated with this sill-shaped intrusion. The alteration and mineralization zoning of Lowell & Guilbert (1970) is however not clearly identified due to the telescoping of the alteration zones. The small size of the intrusion and the low Cu and Mo grades considerably reduce its mining interest, at least in the present-day economic and technologic conditions.

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