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Lithogeochemical, mineralogical analyses and oxygen–hydrogen isotopes of the Hercynian Koudiat Aïcha massive sulphide deposit, Morocco

F. Lotfi [a,*], A. Belkabir [a], S. Brunet [b], A.C. Brown [c], E. Marcoux [d]

[a] Université Cadi Ayyad, Laboratoire Géoressources, Faculté des Sciences et Techniques, Marrakech, BP. 549, Marrakech, Morocco
[b] Mine Draa Sfar, Marrakech, Morocco
[c] Dept. of Civil, Geological and Mining Eng., École Polytechnique de Montréal, Canada
[d] Institut des Sciences de la Terre d'Orléans, Université d'Orléans, Orléans, France

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ABSTRACT

Koudiat Aïcha is a Visean stratiform, volcanogenic massive sulphide (VMS) zinc–copper–lead deposit, situated northwest of Marrakech, within the Central Domain of the Jebilet massif of the Western Moroccan Meseta. The Central Domain is formed mainly of sedimentary (argillite, siltstone, sandstone, carbonate) and magmatic (gabbro and rhyodacite) rocks that host numerous massive sulphide deposits (e.g., Koudiat Aïcha, Kettara and Draa Sfar) in a thick grayish argillite sequence (rhythmic metapelite). The deposit is stratabound and consists of highly deformed, sheet-like lenses of massive sulphide located structurally on the eastern flank of a large anticline. Prior to metamorphism, the country rocks were subjected to hydrothermal alteration which is particularly pronounced in the immediate vicinity of the sulphide deposits where chloritization and sericitization are prevalent. Hydrothermal alteration extends into both the stratigraphic footwall and the stratigraphic hanging wall. The footwall lacks an obvious pipe zone (sulphide stringers or vent complex) beneath the sulphide mineralization, but is characterized by an increase in the modal proportion of Mg-chlorite and by the breakdown of feldspar and sericite. Chloritization, the most extensive and readily recognizable alteration useful in mineral exploration, is evident for more than 60 m above the subcropping sulphide deposits. The hanging wall rocks show a pervasive sericitization (over 30 m wide) and a weak chlorite alteration accompanied by disseminated nodules of pyrrhotite stretched parallel to the S_1 foliation. Because chlorite and sericite are metamorphic minerals that also occur in unaltered rocks surrounding the sulphide deposits, abundant Mg-rich chlorite and the absence of feldspar in the footwall are used to distinguish hydrothermal alteration facies from metamorphic facies. The chlorite geothermometer reveals temperatures between 250 and 330 °C. Higher temperatures (up to 300 °C) are associated with chlorite located in and adjacent to sulphide mineralization, whereas lower temperatures correlate with distal chlorite in both the footwall and hanging wall rocks.

Chemical trends in altered footwall rocks are shown by absolute mass gains for Fe_2O_{3total}, MnO and MgO, by absolute mass losses for CaO, K_2O and Na_2O, and by a moderate loss in SiO_2. Oxygen and hydrogen isotope compositions of Koudiat Aïcha lithofacies (6.2–12.4‰ for oxygen and −51‰ to −36‰ for hydrogen) have also been used to determine the temperature and origin of metalliferous fluids. The couple plagioclase–amphibole of gabbros provides equilibrium temperatures between 310 and 380 °C and suggests that the heat source for the ore-forming fluid system may have been igneous. On the other hand, oxygen and hydrogen isotope ratios cluster between normal values for sedimentary and magmatic rocks, suggesting a magmatic–metamorphic origin for the ore fluid.

1. Introduction

The volcanogenic Koudiat Aïcha massive sulphide deposit is situated in the Central Domain of the Hercynian Jebilet massif, 32 km northwest of Marrakech, Morocco (Fig. 1). It consists of closely-spaced, thin sulphide lenses within mainly siliciclastic sedimentary strata (argillite, sandstone, siltstone, ±carbonate) intercalated with gabbro sills and minor rhyodacite flows and tuffs.

As described by Lotfi et al. (2008), the sulphide mineralization consists principally of several lenses of massive to semi-massive pyrrhotite, 1–20 m in thickness, enclosed by a large halo of asymmetrically disseminated sulphides. The ore sulphides are pyrrhotite, along with lesser amounts of sphalerite, chalcopyrite, arsenopyrite, galena, pyrite and stannite. Well-preserved sedimen-

* Corresponding author. Address: ONHYM, Direction Générale, 5, Av. My-Hassan, BP. 99, Rabat, Morocco. Tel.: +212 66 93 58 95; fax: +212 24 43 31 70.
E-mail address: lotf_fouad@onhym.com (F. Lotfi).

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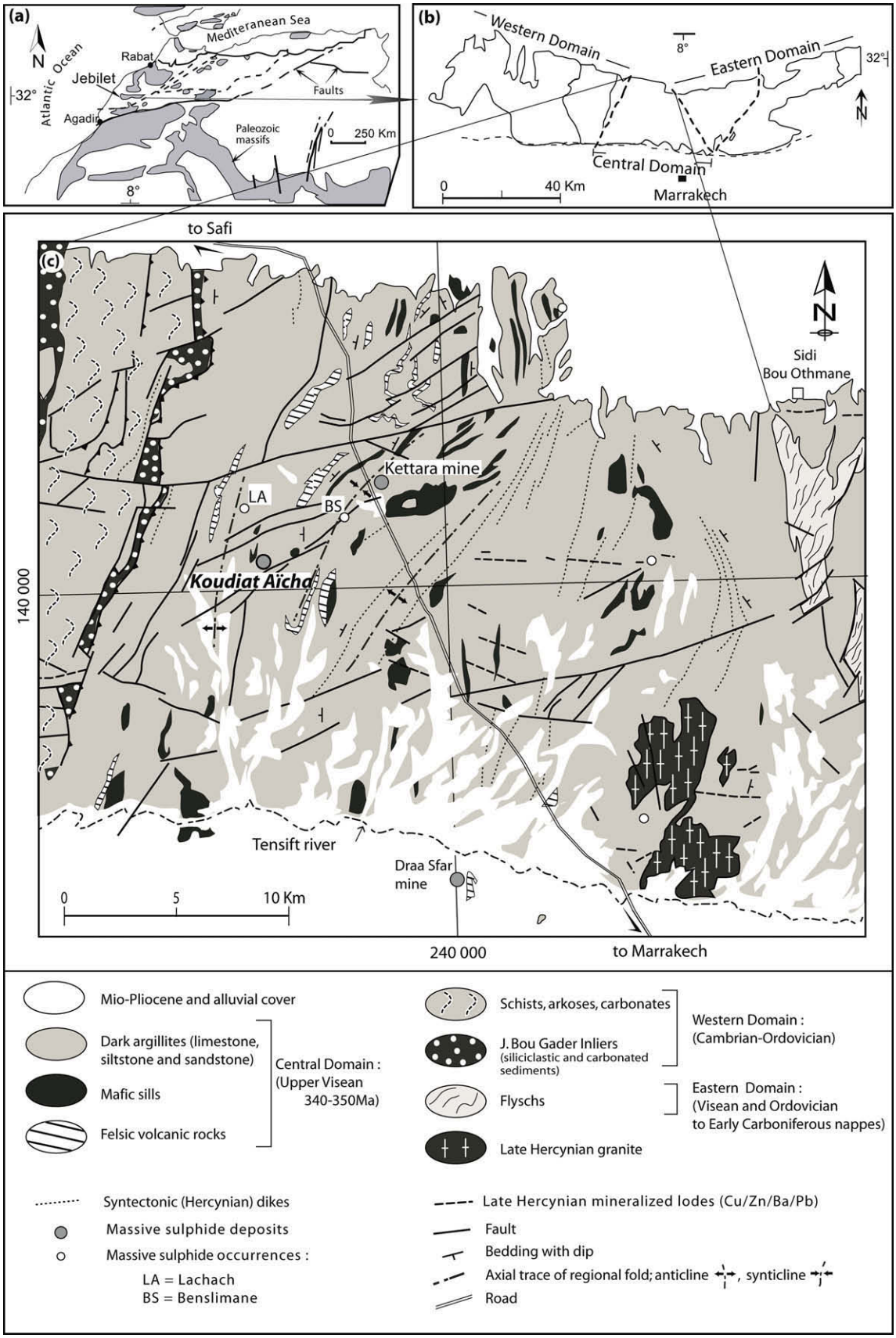

Fig. 1. (a) The Jebilet massif in the framework of the Paleozoic outcrops of North Africa (in grey). (b) Scheme of the Jebilet massifs showing its subdivision in three domains. (c) General geological map of the Central Jebilet massif showing the location of the principal massive sulphide deposits (modified from Huvellin, 1977).