

ORIGIN OF THE OUED AMIZOUR ZN-DEPOSIT, NE ALGERIA: A STABLE ISOTOPE STUDY (S, O, C).
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Abstract

The igneous rocks of Oued Amizour area outcrop in favor of large faults trending dominantly NW-SE and are intruded in cretaceous formations that are covered by Oligocene flysch formations. Petrographic study shows the presence of two igneous formations: volcanic and plutonic. The volcanic lithologies are composed of layers ranging from intermediate to felsic composition and are hydrothermally altered. From the top to the bottom, the following volcanics are distinguished: chloritised porphyritic pyroclastites, microbreccia cross-cut by andesites, bedded tuff, vesicular andesites, silicified microgranite, siliceous tuff and kaolinized andesite. The plutonic rocks are composed mainly of coarse-grained granodiorite locally cross-cut by anhydrite and gypsum veins indicating submarine environment.

Metallographic investigations show that the main orebody is massive Zn - Pb - Fe sulphides mineralization. Replacement texture, pseudomorphism and open-space filling texture indicate hydrothermal process during two main stages: (1) early stage characterised by rare chalcopryite – pyrite – magnetite – hematite hosted by granodiorite pile contemporaneous to anhydrite and gypsum percolation; and (2) late riche stage represented by massive sulphides such as pyrite – marcasite – galena – melnikovite – marmatite – schallblend. The latter are associated with calcite gangue and hosted within kaolinized, locally brecciated, andesites.

Stable isotope analyses were carried out on sulphides, sulphates and gangue minerals. $\delta^{34}\text{S}$ of sulphides (pyrite, sphalerite and chalcopryite) varies between -7.2‰ and +4.5‰ (n=22 ; mean = -1.3‰). Theses values reflect the major influence of magmatic fluid for the origin of sulphide mineralization. Magmatic fluid is also reflected when observing $\delta^{18}\text{O}_{\text{V-SMOW}}$ and $\delta^{13}\text{C}_{\text{V-PDB}}$ data of gangue calcite (+11.2‰ to +20.2‰ and -3.7‰ to -11.0‰ respectively). $\delta^{34}\text{S}$ of sulphates (anhydrite) show heavier values ranging from +13.2‰ to +20.6‰ (n = 10; mean = +16.3‰) which reflect marine sulphates, more likely Miocene seawater sulphates. The isotopic data indicate that the Oued Amizour Zn-deposit was deposited from mineralized magmatic fluids within seawater environment.

Keywords: Massive sulphides, Miocene igneous rocks, Stable isotopes, Oued Amizour.

Introduction

The Miocene igneous formations of the Algerian coast are characterized by the presence of diverse mineralization both in composition and volume. In the Béjaia region the main mineralized sectors are those of Ait Bouzid, Bouzenane, Iheddadène and Ait Dali and are located between the Oued Amizour village and Béjaia town. They are distributed in a general direction trending NW-SE. Some of these sectors were studied for their geology and metallogeny by Benali (2007) and earlier by Semroud (1976) and Semroud et al. (1994) who presented detailed geology, petrology and geochemistry of the igneous rocks of Oued Amizour.

1. Petrography of igneous rocks

The igneous rocks of Oued Amizour massif were emplaced within Cretaceous formations that are locally covered by Tertiary sediments. The Ait Bouzid Sector, subject of this study, is located at the central part of the volcano-plutonic massif and hosts the main Zn-Pb mineralization. Petrological study was carried out on a bore-hole of about 800m that cross-cut the whole volcano-plutonic pile. From the top to the bottom, the following formations are distinguished: about 150 m pyroclastites, 130 m andesites and dacites, 100 m porphyric pyroclastites, volcanic tuff and lava flows, metasomatized granitoids and, finally, massive granites.

The pyroclastites are generally porphyritic and are composed of millimetric sub-idiomorphic and corroded quartz, laths of twinned plagioclase and rare K-feldspar crystals. These phenocrysts are embedded within a microlithic mesostasis that often show fluidal textures. The accessory minerals are mainly idiomorphic zircon grains and sub-idiomorphic opaques (pyrite). The alteration phenomena are represented by severe calcitization and the development of sericite.

The andesites are composed mainly of twinned and zoned plagioclase phenocrysts, chloritized biotite and rare quartz and K-feldspar phenocrysts. The mesostasis shows microliths of plagioclase in a fluidal texture. The accessory minerals are monazite, zircon and ubiquitous, disseminated, idiomorphic pyrite, sometimes filling the microcracks of the rocks.

The porphyritic pyroclastites consist of idiomorphic phenocrystals of K-feldspar often perthitic and altered to sericite, recrystallized xenomorphic quartz and chloritized biotite. Calcite is the secondary mineral (alteration product) and allunite, apatite and pyrite are the main accessory minerals. The mesostasis is often microlithic.

The volcanic tuff is about 150 m thick, it is grey, dark grey, to strongly dark coloured lava and formed by consolidated volcanic ash, it is locally bedded and characterized by glassy texture, however recrystallized fine-grained (<0,2m) quartz can be distinguished. Sedimentary xenoliths are also present, they show centimetric various shapes and are represented by marl and Oligocene sandstone fragments. The volcanic tuff is cross-cut by andesite and calcite veins. Calcite veins are millimetric to centimetric and are locally plugged by disseminated pyrite and acicular crystal of actinote.

The microgranites are strongly altered and consist of idiomorphic, often perthitic, K-feldspar phenocrysts, recrystallized quartz and chloritised biotite. Prismatic apatite is the main accessory mineral. The mesostasis is composed of microliths and microcrystals that suffered severe alteration. This alteration is represented by calcite

which develops on the K-feldspar phenocrysts and sericite. Pyrite is ubiquitous and is disseminated in the rocks as idiomorphic millimetric grains.

The aplites rocks are metric veins in size, they cross cut brecciated kaolinized andesite and are white colour. Fine grained quartz aggregates and K-feldspar are the main components, they show a fine grained granular texture. Aplites are silicified and xenomorphic recrystallized quartz fill almost interstices. Aplites are fractured, idiomorphic crystals of pyrite plug microcracks.

The metasomatized granitoids are composed quartz aggregates, K-feldspar and secondary millimetric calcite crystals. The granular texture of the granitoid is wholly obliterated and the rock is transformed into a real metasomatite. In this facies, pyrite shows idiomorphic grains that could reach 0.5 mm and is disseminated within the rock. Massive anhydrite appears as a layer of more than 10 m thick and is composed of centimetric crystals associated with pyrite grains.

The granodiorite forms the basement of this igneous series. It consists of quartz aggregates, K-feldspar phenocrysts, subidiomorphic plagioclase of oligoclase-andesine composition, biotite forming nests, and apatite as accessory mineral. The rock is often fissured and the microcracks are filled with anhydrite crystals and pyrite. Pyrite is also disseminated within the rock as idiomorphic grains of 1 to 5 mm in size.

2. Geochemistry

Igneous rocks of Oued Amizour are intermediate to felsic in their composition, their silica content oscillate from 52,90 to 75,20 w.%. For the whole igneous suite, the Na and K content show a wide range of variation (from 0.11 to 8.51 w.%, mean = 3.54 w.% and from 0.18 to 8.20 w.%, mean = 3.57 w.% for Na₂O et K₂O respectively n= 22), however, almost of them fall in the field of calc-alkaline rocks.

3. Orebody & mineralization

Oued Amizour Zn-deposit is located in the central part of the volcano-plutonic massif, it is hosted in brecciated andesite affected by high hydrothermal alteration (mainly kaolinization). Drilling investigations made first by ORGM and recently by WMZ (Western Mediterranean Zinc) showed that the stratabound orebody is ovoid and its thickness varies from 30 to 400 meters. The main base metal mineralization consists of sphalerite, pyrite, galena, magnetite, hematite and rare chalcopyrite. The latter show diverse texture, massive, vein, collomorphic. The sphalerite ore body is about 20 to 30 m thick and is located between the anhydrite layer and the volcanic series. Sphalerite is often soft and show yellowish colour. Pyrite is ubiquitous and is disseminated within the whole plutonic and volcanic pile. In places, it show millimetric veins and space filling within the rocks. Chalcopyrite is rare and often shows xenomorphic crystals usually interstitial within the grains of the rocks. Replacement texture, pseudomorphism and open-space filling texture indicate hydrothermal process during two main stages: (1) early stage characterised by rare chalcopyrite – pyrite – magnetite – hematite hosted by granodiorite pile contemporaneous to anhydrite and gypsum percolation; and (2) late rich stage represented by massive sulphides such as pyrite – marcasite – galena – melnikovite – marmatite – schallblend. The latter are associated with calcite gangue and hosted within kaolinized, locally brecciated, andesites.

4. Stable isotopes

Stable sulphur isotope analyses were carried out on sulphides, sulphates and gangue minerals. $\delta^{34}\text{S}$ of sulphides (pyrite, sphalerite and chalcopyrite) varies between -7.2‰ and +4.5‰ (n=22 ; mean = -1.3‰). These values reflect the major influence of magmatic fluid for the origin the sulphide mineralization. $\delta^{34}\text{S}$ of sulphates (anhydrite) show heavier values ranging from +13.2‰ to +20.6‰ (n = 10; mean = +16.3‰) which reflect marine sulphates, more likely Miocene seawater sulphates. Ohmoto (1996) indicated that simple heating of seawater by hot fluids may precipitate anhydrite instead of barite which precipitates with decreasing temperatures (Holland and Malinin, 1979). He also pointed out that the S-isotopic composition of anhydrite could be essentially identical to that of SO_4^{2-} in local seawater.

Stable oxygen and carbon isotope analyses carried out on twenty (20) secondary calcite samples (alteration product) distributed along the whole igneous column gave the following results: $\delta^{18}\text{O}_{\text{SMOW}}$ varies between 11.2 and 20.2‰ (mean = 16.7‰) and $\delta^{13}\text{C}_{\text{PDB}}$ varies between -3.7 and -11.0‰ (mean value = -7.8‰). These results confirm the large contribution of seawater to the precipitation of secondary carbonates of the Oued Amizour Zb-Pb deposit since the Miocene seawater has $\delta^{18}\text{O}_{\text{SMOW}}$ composition around +10‰ and $\delta^{13}\text{C}_{\text{PDB}}$ OF normal seawater carbonates around 0. However, low $\delta^{13}\text{C}_{\text{PDB}}$ could be attributed to the contribution of unconsolidated mudstones, since the CO_2 content of the fluids increased locally through thermal decomposition by hydrothermal fluids of organic matter in the mudstones (Ohmoto, 1996).

Conclusion

The Oued Amizour massif is composed of igneous rocks with diverse compositions and emplacement style. They vary from plutonic (granites) through subvolcanic (microgranites) to volcanic rocks (andesites, lava flows, etc.). These rocks exhibit almost all concentrations of base metal sulphides (sphalerite, pyrite, galena and chalcopyrite). Stable S, O, and C isotopic composition of the sulphides, sulphates and calcite (alteration product) indicate (1) the major contribution of magmatic fluid to the generation of primary sulphide deposit, (2) the Miocene seawater mixing for the generation of anhydrite, and (3) the contribution of unconsolidated mudstone to the input of organic carbon into the fluids during the calcitization phenomena.

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