International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 13 No. 4 Dec. 2015, pp. 775-780

http://www.ijias.issr-journals.org/

Open pits geochemistry form the abandoned mine area of the High Moulouya District (NE-Morocco)

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ABSTRACT: The abandoned mine area of the High Moulouya District still represents an important resource. Main activities closely related to the abandoned mine are artisanal extraction, fossil and mineral trade, tourism, agriculture, and scientific research. The aim of this work is to investigate the geochemistry of open pits and waters flowing out of abandoned mine galleries. These waters are used by the inhabitants for agricultural purposes. The quality of those waters is moderately bad, the waters show contamination by trace and heavy metal.

KEYWORDS: abandoned mine, mine water, Water quality, water geochemistry, openpits.

1 INTRODUCTION

The High Moulouya is an abandoned metallogenic district with high levels of leads and zinc mineralization. The deposit is hosted in a tabular wide depression located in between the Middle Atlas Mountains to the North and the High Atlas to the South and South-East. The area corresponds to the internal sector of Moroccan hercynids [1]. The study aims to study the geochemistry of the open pits in the abandoned mine areas, especially in the localities of Zaida and Mibladen [2] and to assess their water quality. Water samples have been taken from open pits, shallow aquifers, and inside the abandoned mine galleries.

2 GEOLOGICAL FRAME

Geological investigations on the High Moulouya district have been carried out since the past century. The substratum of the Zaïda is made by granite with coarse-grained, it is outcrops along the O. Moulouya and it is also visible in the open pits[3].

The sedimentary cover has been subjected to various tectonic deformations, and levelled by energetic pre-Triassic erosion.

Peneplanation was remarkably intense, and the products of bedrock alteration are deposited on site or have undergone a small transport. In particular,arkose sediments cover large areas. Upon these arkoses were deposited shales and mudstones, then red sandstone with thin psammitic interlayers and frequent levels of evaporite minerals (anhydrite, gypsum and halite) showing lagoon sedimentation. These levels are covered by Triassic formations.

The Post Palaeozoic is sub tabular, and is made by Triassic to Cretaceous facies[4]. The Jurassic is made by 300 to 600 m thick of Lower Lias limestone and dolomite, the Dogger is made by marls and limestone up to 800 m thick. Cretaceous began with the Cenomanian marls (150m) and a 40 m Turonian limestone (Fig. 1). The Cenozoic formations consist of 5 to 30 m of conglomerates and lacustrine limestone from the Eocene and Oligocene. The Miocene starts with a 30 to 250m of

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conglomerates surmounted by the marls which occupy the largest surface of the basin. The Plio-Villafranchien is made up of conglomerates and sandstone, which make the junction with the Quaternary made up of conglomerates, rollers, sands, sandy clays[1].

In the study area, the Palaeozoic formations are the most outcropping on the surface. The open pit geology can be resumed by the stratigraphic log reported in Fig. 2.

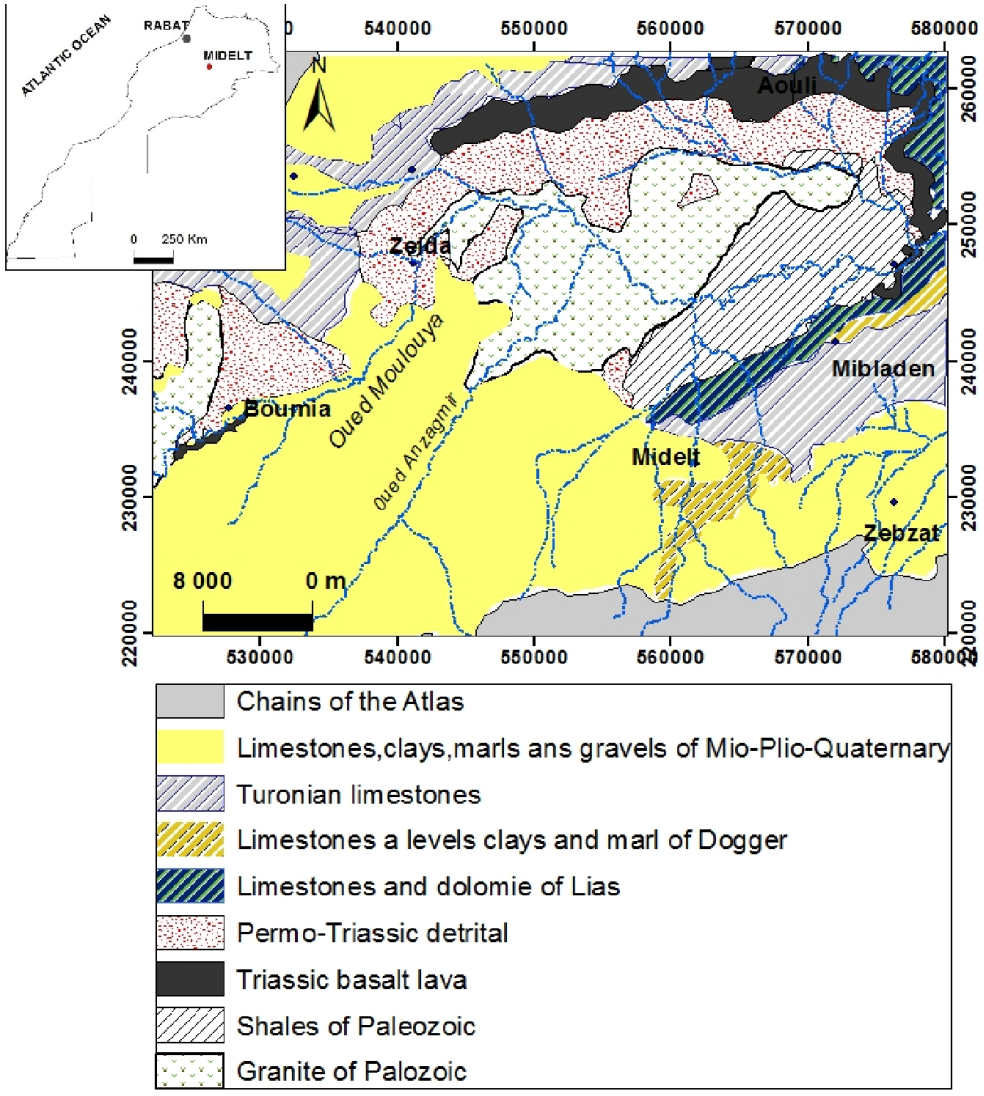

Fig. 1. Simplified Geological Map of the High Moulouya

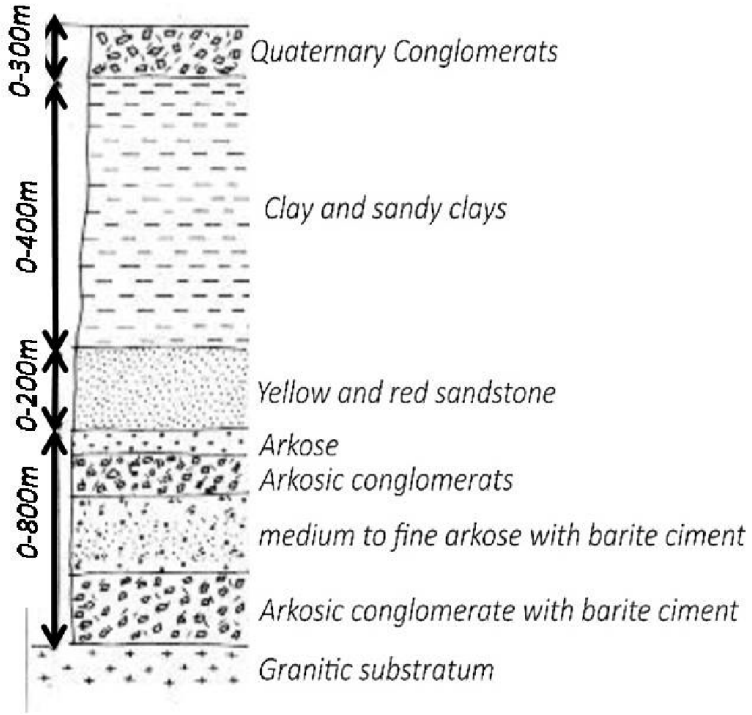

Fig. 2. Stratigraphic log of typical open pit

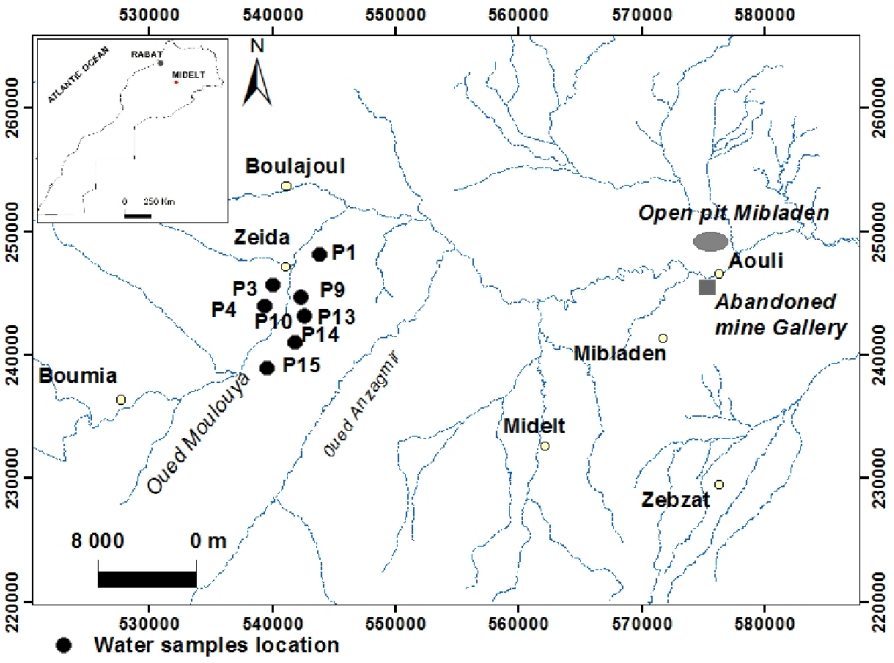

Fig. 3. Location Map of sampling point

3 WATER RESOURCES

The Moulouya river length is approximately 600km. It takes birth in the Middle Atlas Mountains and the high lands. The superficial water resources are estimated to 1150 Mm^3 per year[5].

The groundwater resources are distributed in more than 20 hydrogeological units. The shallow aquifer and the deep aquifer are in most case multilayer. To resume the hydrogeology of the area three aquiferous units have been taken into consideration:

- Waterhosted in Jurassic limestone and dolomites constitutes the deep aquifer,
- The Turonian limestoneaquifer is the most important groundwater resources in the area; several sources have been inventoried, their total flow is about 600 l/s;
- Waterhosted in the conglomerates, limestone and quaternary alluvia constitutes the shallow aquifer; although discontinuous it is the most exploited in the area to supply water for local population.

Several small water bodies are also hosted in granites, arkoses, mudstones and basalts of Permo-Trias in Aouli and Bou Mia. The open pits are alimented by superficial waters, from the Turonian aquifer and from localy from the shallow aquifer; they emerge in the open pits like sources or they are directly alimented from the O. Moulouya and its affluents.

3.1 SAMPLING AND ANALYTICAL METHODS

Physical parameters (Temperature, Electrical conductivity and Redox potential), dissolved oxygen, and alkalinity were measured on site. Some geochemical data derived from unpublished works are also used to consolidate the geochemical analysis. Case of the open pits P1 to P3 [3] [4] and the waters from abandoned mine gallery.

3.2 WATER CHEMISTRY

Despite the geographic proximity, the open pit waters are distinguished in two families (Fig.4) : chloride-sodium water, and a bicarbonate-calcium-magnesium. The origin of this differentiation could be found in the stratigraphic log and depth of each open pit. In fact, some pits reached the granitic-arkosic substrate, others were stopped at upper levels specially in the clayey level (Triassic) more rich in evaporite minerals, those levels are more charged on sulphates than the others. Waters from three open pits were collected on two different seasons; the last one was on June 2012 after a drought year, and the water seems to be more saline.

Water samples collected from Mibladen district inside open pit and inside the abandoned mine gallery show an SO_4-Ca-Mg-Na facies. Both of the open pit and the abandoned mine gallery show an enrichment on sodium salts in a period of six years [6].

The studied waters are in equilibrium with respect to calcite, dolomite and aragonite, with regard to gypsum those waters show a tendency to equilibrium but the saturation index is less than -1.5 for all the waters.

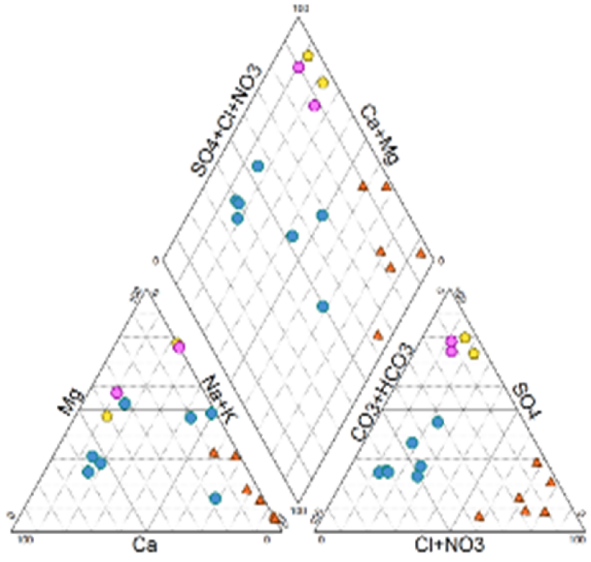

Figure 4: Piper diagram showing the different water families. Legend: Triangle and circle: Open pits from Zaida, yellow: water from the gallery, pink: water from Mibladen open pits

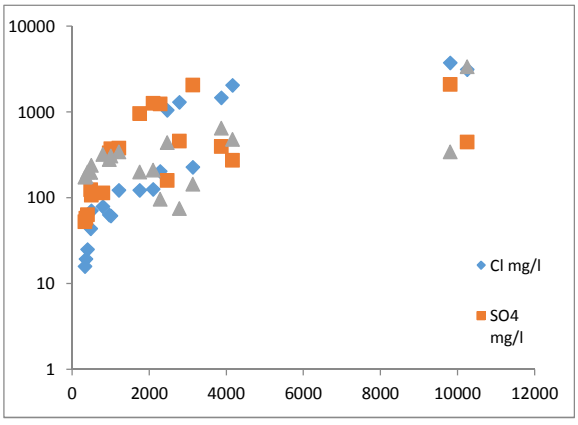

Fig. 5 a: Plot of TDS versus Major components

Thus, some open pits have a very good inorganic water quality and are used as easy access small water dumps; the population uses this water for irrigation and farming. On the other hand, some other open pits have more saline waters. In both this two kinds of open pits, and inside the mine gallery, the sulphate ions are predominant in those waters (Fig.5a & b). The high level of sulphates is closely related to the mineralization type. The area was exploited since the antiquity, from 1926 to 1983 were extracted about 500 000 tonnes of lead in Aouli, and about 400 000 tonnes of lead at Mibladen and Zaida.[2]

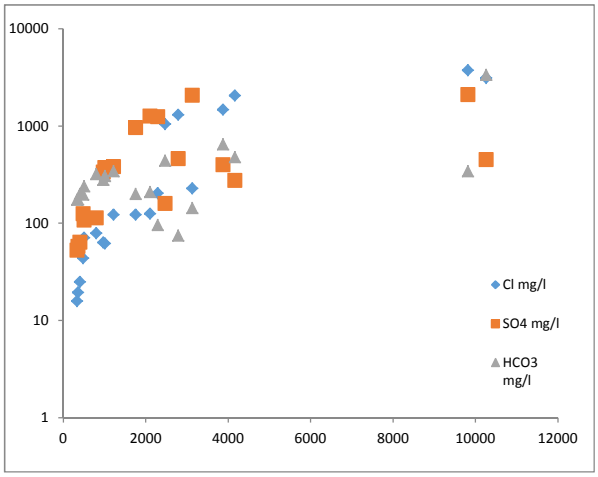

Fig. 5 b: Plot of TDS versus Major components

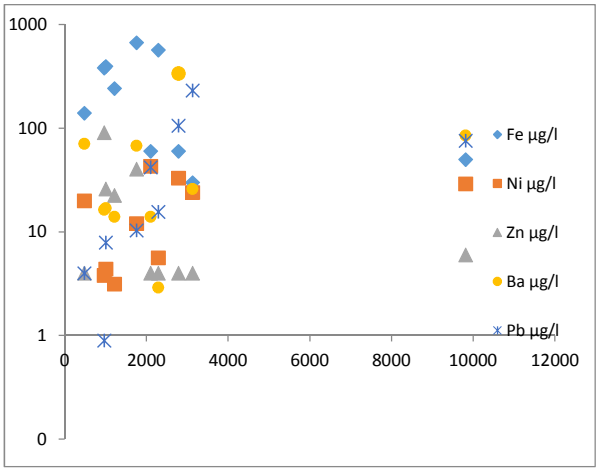

Fig. 6: Plot of TDS versus some trace elements and Heavy metals

4 CONCLUSION

The studied waters show some high levels of some trace elements and heavy metals, their origin is slightly related to the mineralization of the area [7] , Barium, lead and zinc are the most present in waters (Fig. 6), their levels exceed the world health organization recommended values for drinking waters. However those punctual anomalies from the open pits and inside the gallery do not have a lot of impacts for human health in this area, in fact, these water resources are used for irrigation purposes and for livestock watering. Regarding the human consumption, most of the localities are related by national water supply canalisations, except for some localities where the drinking waters come from wells.

ACKNOWLEDGEMENTS

The water analyses were performed at the UATRS platforms which are a set of technological unit that offers to the Moroccan universities and industry expertise, and different type of analysis. The University of Mohammed V Agdal has gently covered the fees for the analyses.

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