

RESEARCH OUTPUTS / RÉSULTATS DE RECHERCHE

From Precambrian to Cenozoic

Dekoninck, Augustin; Ruffet, Gilles; Barbarand, Jocelyn; Missenard, Yves; Lafforgue, Ludovic; Verhaert, Michele; Mattielli, Nadine; Gautheron, Cécile; Magoua, Mohamed; Mouttaqi, Abdellah; Bouabdellah, Mohammed; Poot, Julien; Yans, Johan

Published in:

7th Geologica Belgica Meeting

Publication date:

2021

[Link to publication](#)

Citation for published version (HARVARD):

Dekoninck, A, Ruffet, G, Barbarand, J, Missenard, Y, Lafforgue, L, Verhaert, M, Mattielli, N, Gautheron, C, Magoua, M, Mouttaqi, A, Bouabdellah, M, Poot, J & Yans, J 2021, From Precambrian to Cenozoic: the manganese odyssey of Morocco. in *7th Geologica Belgica Meeting: Abstract book.*, 01-12, 7TH INTERNATIONAL GEOLOGICA BELGICA MEETING 2021, Tervuren, Belgium, 15/09/21.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

From Precambrian to Cenozoic: the manganese odyssey of Morocco

Augustin DEKONINCK*¹, Gilles RUFFET², Jocelyn BARBARAND³, Yves MISSENARD³, Ludovic LAFFORGUE³, Michèle VERHAERT¹, Nadine MATTIELLI⁴, Cécile GAUTHERON³, Mohamed MAGOUA⁵, Abdellah MOUTTAQI⁵, Mohammed BOUABDELLAH⁶, Julien POOT¹, Johan YANS¹

1. Université de Namur, ILEE, Département de géologie, Belgium

(augustin.dekoninck@unamur.be) (johan.yans@unamur.be) (michele.verhaert@hotmail.com)

(julien.poot@unamur.be)

2. CNRS (CNRS/INSU) et Université de Rennes 1, Géosciences (UMR6118), France

(gruffet@univ-rennes1.fr)

3. Université Paris-Sud, GEOPS, France (jocelyn.barbarand@universite-paris-saclay.fr)

(yves.missenard@universite-paris-saclay.fr) (ludovic.lafforgue.c@gmail.com)

(cecile.gautheron@universite-paris-saclay.fr)

4. Université Libre de Bruxelles, Department of Earth and Environmental Sciences, Belgium

(nmattiel@ulb.ac.be)

5. Office National des Mines et des Hydrocarbures – Morocco (MAGOUA@onhym.com)

(mouttaqi@onhym.com)

6. Université Mohammed I^{er} Oujda, Morocco (mbouabdellah2002@yahoo.fr)

Morocco is a relevant place to study Mn deposits considering its multistage geodynamic story. In the last decades, several new studies significantly improved our understanding of various genetic types. Three main districts have been mined since the beginning of the 20th century: (i) Ouarzazate (Anti-Atlas), (ii) Bou Arfa (eastern High Atlas) and (iii) Imini-Tasdrent (High Atlas). The first and third are currently mined, accounting for the production of 80,000 tons Mn in 2018 (data from the Ministry of Energy, Mines and Sustainable Development of Morocco). The deposition of Mn spans over four main periods: Neoproterozoic, Jurassic, Upper Cretaceous and Cenozoic.

(i) The Ouarzazate deposits are vein-type and stratiform Mn-Fe orebodies (42-48% Mn) closely associated to Neoproterozoic felsic volcanic and terrigenous series (Choubert and Faure-Muret, 1973). It is the largest Mn field in Morocco (>90x60 km). Stratiform orebodies clearly improve the mining potential. The Mn-bearing assemblage includes braunite, cryptomelane, hollandite, hausmannite and pyrolusite in a hematite, goethite, barite, quartz, dolomite and calcite gangue. The formation model implies a polycyclic epithermal and epigenetic Mn accumulation during and at the final stage of the Neoproterozoic volcanic activity at ~580 Ma. Extensional tectonics of the Neoproterozoic Ouarzazate basin would be of primary order in delimiting the number and regional extension of lodes.

(ii) The Bou Arfa Mn deposit is hosted in Sinemurian dolostones, as stratabound, run-type and lenses of Mn orebodies crisscrossed by late veins hosting the high-grade pyrolusite ore (33-82% Mn). Ore formation follows a sedimentary-diagenetic model driven by three dolomitization episodes after the Sinemurian sedimentation, and an epigenetic stage similar to other MVT of the Atlas range (Lafforgue et al., 2021). The concentration of Mn in a narrow area of about 10 km² is due to the geometry of the Bou Arfa basin and its position above basement paleohighs acting as a threshold for marine inputs during transgression/regression intervals. The primary manganite-hausmannite ore was transformed into pyrolusite during burial of the Mn-rich sediments.

(iii) The Imini-Tasdremt district is the most economically important of Morocco providing the highest Mn grade (74-92% Mn) due to two stratabound pyrolusite-bearing orebodies hosted in the ~10-20 m thick Cenomanian-Turonian dolostone. A metallurgical third ore (40-48% Mn) occurs in relics of a paleosurface in the uppermost dolostone and is composed by coronadite group minerals (Dekoninck et al, 2016). Although the pyrolusite ore is restricted to the 25-30 km Imini Mn belt, the metallurgical ore has a larger extension of ~100 km and may extend across the Atlas belt (Dekoninck et al., 2020). New dating of K-Mn oxides (^{40}Ar - ^{39}Ar) and goethite (U-Th)/He dating suggest that this geometric distribution is materialized by different formation age: the upper coronadite level is late Cretaceous, whereas the pyrolusite ores are Cenozoic, indicating the importance of local processes. Goethite ages cover a period of ~40 Ma since the Turonian, involving long mineralization processes. The Atlas geodynamics played a significant role in the metallogenesis of these karst-hosted accumulations since late Cretaceous times.

References:

- Choubert, G. & Faure-Muret, A. The Precambrian iron and manganese deposits of the Anti-Atlas. in *Genesis of Precambrian iron and manganese deposits* vol. 9 115–124 (1973).
- Lafforgue, L. *et al.* Geological and geochemical constrains on the genesis of the sedimentary-hosted Bou Arfa Mn(-Fe) deposit (Eastern High Atlas, Morocco). *Ore Geology Reviews* 104094 (2021)
- Dekoninck, A. *et al.* The high-grade Imini manganese district—karst-hosted deposits of Mn oxides and oxyhydroxides. in *Mineral Deposits of North Africa* 575–594 (Springer International Publishing, 2016).
- Dekoninck, A. *et al.* Multistage genesis of the late Cretaceous manganese karst-hosted Tasdremt deposit (High Atlas, Morocco). *Mineralium Deposita* (2020)