Porphyry deposits distribution along the western Tethyan suture: insights from a paleogeographic approach

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Abstract

In order to better understand the relationships between ore deposit distribution and their tectonic context, and help identifying geodynamic-related criteria of favorability, we propose a paleogeographic approach. We use this approach to study the distribution of porphyry copper deposits along the western Tethyan suture. Spatial and temporal distribution of the deposits is not random and show that they were emplaced in five distinct clusters. Two clusters, in the Aegean-Balkan-Carpathian area, that were emplaced in Upper Cretaceous and Oligo-Miocene, are associated with a specific polyphased kinematic context, within the framework of the Africa-Eurasia convergence. This context is characterized by 1) a fast subduction rate, shortly followed by 2) a drastic decrease of this rate. Although preliminary, these results highlight the control of the geodynamic context, and especially the subduction kinematics, on the genesis of porphyry deposits. This study also confirms that the paleogeographic approach is a promising tool that could help identifying geodynamic and tectonic criteria favoring the genesis of various ore deposit types.

Keywords: porphyry, deposits, geodynamics, kinematics, paleogeography, Tethyan suture

Introduction

The spatial approach of predictivity focuses on the geological context of mineral deposits and the parameters that control their distribution, from district to continental scales: geology, tectonic structures, geophysics and geochemistry, but also geodynamics and paleogeography. It is an upstream phase of prospection campaigns, which goal is to guide the exploration strategy by predicting the *a priori* most favorable areas.

Loiselet *et al.* (2010) have shown the strong impact of the geometry and dynamics of the eastern Mediterranean subduction zone on the distribution of porphyry and epithermal deposits. More generally, it is widely accepted that the genesis of many types of mineralization is closely linked to the geodynamic context (*e.g.* Lips, 2007). Therefore, a thorough knowledge of this context is a necessary condition to identify tectonic factors that control the genesis of ore deposits. A major problem, however, is to replace the mineralization within the geodynamic framework that prevailed at the time of its genesis. It is a necessary step to better understand the relationships between the mineralization and its environment (plate boundaries, tectonic structures, geology,…). This would, in turn, help identifying criteria that are favorable to their genesis. We believe that the paleogeographic approach, which has not been much used so far in the field of mineral resources predictivity, is appropriate to help solving this problem.

Porphyry copper deposits are associated to calc-alkaline magmatism in subduction zones. In the present study, we use the paleogeographic approach to better understand the geodynamic and kinematic context that controlled, at least in part, the genesis of porphyry copper deposits along the western Tethyan margin during Cretaceous and Cenozoic.

1. Spatial and temporal distribution of porphyry copper deposits

We have compiled a list of porphyry copper deposits along the western Tethyan suture. This compilation is based on data extracted from 1) the ProMine Mineral Deposits database (Cassard *et al.*, this volume), 2) the "Caucasus" Mineral Deposits database of the BRGM (unpublished) and 3) the "Porphyry copper deposits of the World" database of the USGS (Singer *et al.*, 2008). It contains 116 deposits of porphyry type, among which 114 explicitly contain copper. These deposits are distributed along the Tethyan suture from longitude 18°E to 66°E and range in age from 4.0 (Zanclean) to 143.5 Ma (Berriasian).

We have studied the spatial and temporal distribution of these porphyry copper deposits. This distribution is not random. On the contrary, it shows concentrations of deposits along specific segments of the western Tethyan suture and during distinct time periods. Plotting either the ages of deposits versus their longitude and their geographic distribution with age-based symbology, shows that their occurrences are organized into five distinct spatial and temporal "clusters" (Figure 1):

1. "Older" deposits of the Caucasus area (Armenia, Azerbaijan) – Lower Cretaceous (5 deposits);
2. Balkan-Carpathian area deposits (Bulgaria, Serbia, Romania) – Upper Cretaceous and Paleocene (29 deposits);
3. Eastern Turkey-Caucasus area deposits (Georgia, Armenia, Azerbaijan, Western Iran) – Eocene (11 deposits);
4. Aegean-Balkan-Carpathian area deposits (Aegean Sea, Greece, Macedonia, Serbia, Romania, Slovakia) – Oligocene and Miocene (47 deposits);
5. Middle-East area deposits (Iran, Afghanistan, Pakistan) - Miocene (19 deposits).

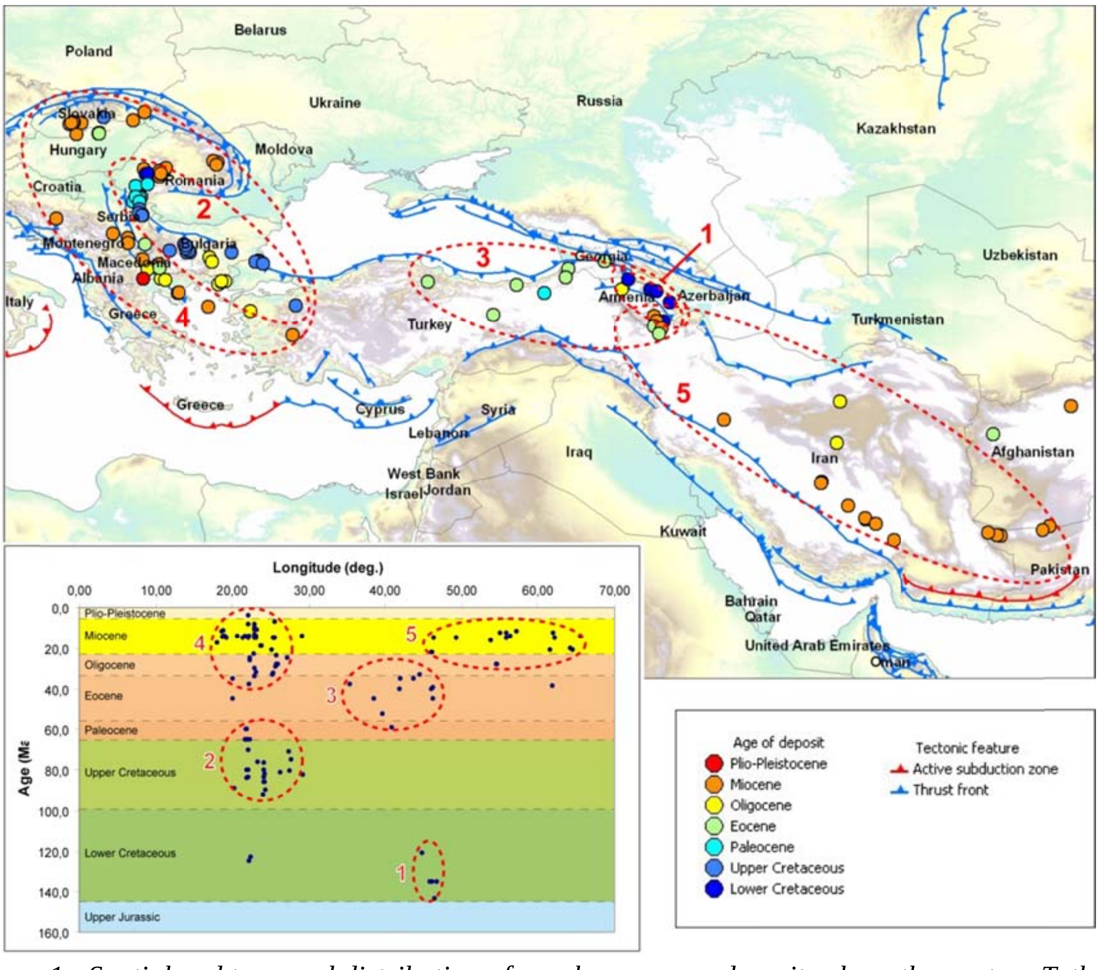

Figure 1 - Spatial and temporal distribution of porphyry copper deposits along the western Tethyan suture in five distinct "clusters".

Because clusters 1, 3 and 5 are too poorly sampled, and because the kinematics through time relative to Eurasia is better constrained for Africa than Arabia or Iran, we have focused our study on clusters 2 and 4. We have replaced these two clusters in the geodynamic and kinematic contexts that prevailed at the time of their geneses.

2. Paleogeographic and kinematic approach

In order to assess tectonic and kinematic factors that may have impacted the genesis of Upper Cretaceous and Oligo-Miocene porphyry copper deposits of the Aegean-Balkan-Carpathian area, we did regional paleogeographic reconstructions of the Africa-Eurasia convergence, from Upper Jurassic to Present Day, using the UTIG PLATES global kinematic model developed at the University of Texas at Austin (*e.g.* Ghidella *et al.*, 2007). Deposits and their chronology (*i.e.* age of appearance) were included in these reconstructions, as well as instantaneous velocity fields, in order to better image relative displacements of plates. These reconstructions show that the two clusters occurred during periods of relatively slow velocity of Africa relative to Eurasia.

We then have plotted the velocity of Africa relative to Eurasia (arbitrary point of coordinates 33°N and 19°E on the northern border of the plate). In addition to the UTIG PLATES model, we have also used the EarthByte global kinematic model, developed at the University of Sidney (*e.g.* Müller *et al.*, 1997, 2008). The diagram (Figure 2) shows that both clusters 2 and 4 were emplaced in specific and similar kinematic contexts. This context is characterized by 1) a relatively high rate of subduction, that may have resulted in higher melt production in the mantle wedge (Tatsumi & Eggins, 1995), followed by 2) a drastic decrease of the subduction rate, that may have favored slab retreat (*e.g.* Schellart, 2005), extensional regime in the upper plate and easier ascension of magmas. Regional tectonic studies confirm that emplacements of clusters 2 and 4 coincide, spatially and temporally, with extensional regimes that affect, respectively, the Moesian Platform in Upper Cretaceous, and the Aegean-Balkan area in Oligo-Miocene (*e.g.* Jolivet & Brun, 2010).

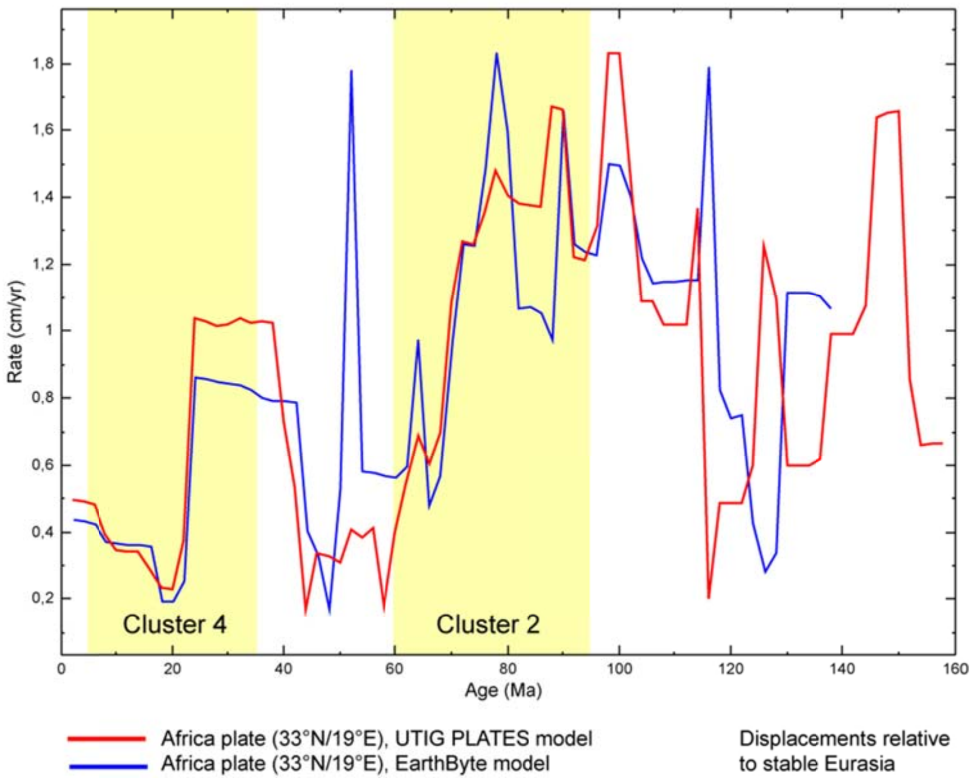

Figure 2 - Rates of convergence versus time of the African plate relative to fixed Eurasia, showing the kinematic context in which clusters 2 and 4 were emplaced.

Conclusion

The paleogeographic approach used in the present study allowed to evidence a specific kinematic context associated with the emplacement of two porphyry copper deposits clusters in the Aegean-Balkan-Carpathian area in Upper Cretaceous and Oligo-Miocene. This context is characterized by 1) first a relatively high velocity of subduction, shortly followed by 2) a drastic decrease of this velocity. Even though this result is preliminary, it confirms the control of the geodynamic context, and especially the subduction kinematics, on the genesis of porphyry deposits. It needs, however, to be confirmed by 1) studying other convergent margins, in order to check if other porphyry deposits clusters may also, or not, be associated with a similar kinematic context, 2) considering the magmatism associated with the porphyry deposits, in order to confirm the link between deep mantle processes and genesis of deposits in the upper crust, and 3) refining the kinematic models, that are global and lack the accuracy needed for such a regional studies. These points will be addressed in future developments of this work.

Nevertheless, the present study confirms that the paleogeographic approach is a promising tool that could help identifying geodynamic and tectonic criteria favoring the genesis of several mineral deposit types. As a corollary, concentrations of mineral deposits, according to their type, may also be interesting markers of past geodynamic contexts.

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