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Behaviour of Elements during Granite Formation and Its Relationship to Mineral-Zonation

CHEN Guoneng, CHEN Zhen and Grapes H. RODNEY

Department of Earth Sciences, Sun Yat-Sen University, Guangzhou, 510275, China

1 Introduction

In-situ Melting model for granite formation (Chen and Grapes 2003, 2007) suggests that granite is originated from in-situ melting of the upper-middle crustal rocks, reflecting the changes of material state from order (plotolith) to disorder (magma) to new order (granite) with variation of entropy of the system. Granite is layer-like in crustal scale and granite bodies are the protruding part of the irregular upper interface of crustal granitic magma layer (MI). Both rock- and ore-forming elements of granite are all from the original rocks involved in the in-situ melting process (Chen et al 1996, Chen and Grapes, 2003, 2007).

Crystallization of magma results in reorganization and redistribution of elements with lithophiles forming granite staying below the MI, and chalcophiles along with those unable to enter the lattice of silicate minerals being expelled from the melt system. During the upward movement of hydrothermal fluid, most of the ore-forming elements are again fixed in the lithosphere by precipitation from fluid resulting in mineralization. However, hydrofiles responsible for the transportation of ore-forming elements are ultimately released into the hydrosphere and atmofiles to the atmosphere (Fig.1).

2 GEF for Magma Crystallization

According to the behavior of different kinds of elements mentioned above, combining the position of elements in the Periodic Table, we find that behavior of elements in the in-situ crustal melting and crystallizing process shown in Fig.1 is evidently related to the texture of element themselves (Fig.2), a relationship explored by Goldschmidt, Zavaritsky, and many others. As textural variations of the elements are explained from the Periodic Table, the problem is to decipher the role of elements in geological processes. The in-situ melting model of granite genesis provides a framework for better understanding element behaviour during the crustal melting-crystallization process (Fig.1), and on this basis a concept referred to as Geochemical Fields of Elements (GEF) has been proposed by Chen et al. (1996) and Chen (1998), which divides the Periodic Table into four geochemical fields, e.g., magma field, hydrothermal field, media field and gas field. The magma field includes the lithophile, siderophile, rare and radioactive element groups of the Zavaritsky classification. Siderophile elements in the magma field used to be considered to be mainly concentrated in the Earth's interior, yet in the in-situ melting-crystallisation process, they enter silicates or form accessory phases such as Fe-Ti oxides. The gas field is equated with Zavaritsky's H and inert gas groups and the media field relates the magmatic-pneumatolytic and hydrothermal fields to the others. From Fig.2, the GEF mirror the layered structure of the crust and show the distribution of the various elements during crustal melting-crystallisation.

3 Zonation of Ore-Forming Elements

Numerous W, Mo, Cu, Pb, Zn, Au, Ag and Hg hydrothermal deposits associated with granite are distributed in SE China (Chen and Grapes 2007), in which vein-type W-Mo deposits are generally found in roof rocks close to or even in granite bodies indicating early, high temperature precipitation of W and Mo from the upward-moving hydrothermal fluid. Although W- and Mo-bearing phases such as wolframite and molybdenite are commonly intergrown in hydrothermal veins, maximum concentrations of Mo are usually below that of W as shown in Fig. 3.

In hydrothermal deposits, chalcopyrite, galena and sphalerite are commonly intergrown, yet the elements usually occur in the order of Cu–Zn–Pb with increasing distance from the granite(Fig. 4A). The precipitation of Cu takes place at a slightly higher level, later than W (Fig. 3).

The distribution of Au-Ag in Fig. 4A suggests that they

* Corresponding author. E-mail: chengn@mail.sysu.edu.cn

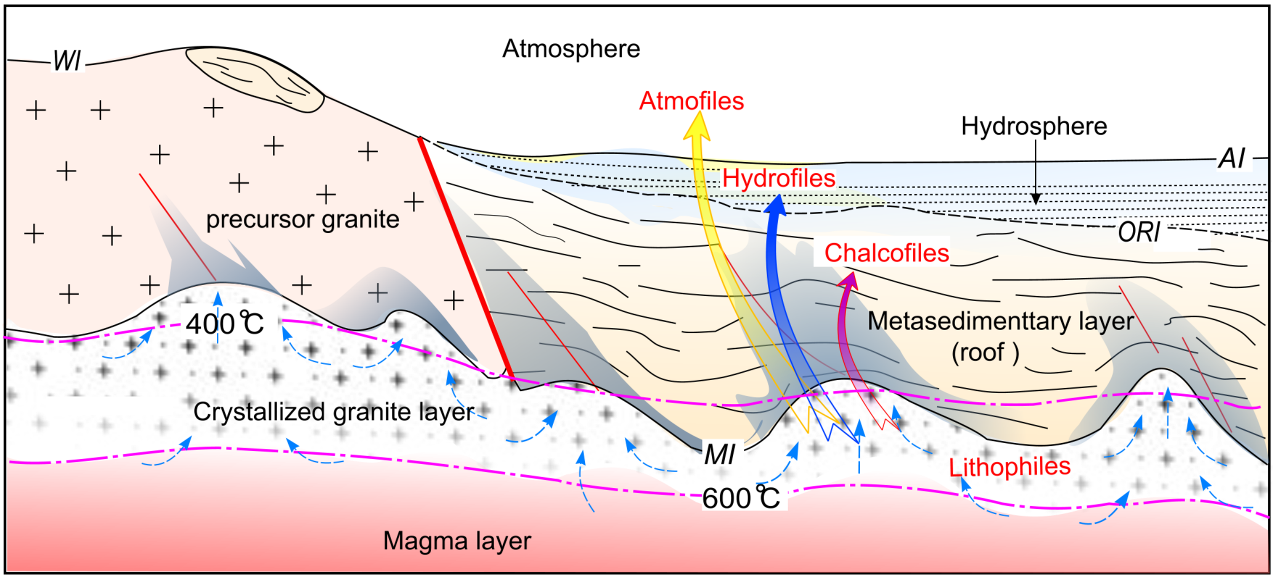

Fig.1. Diagram for the behaviour of elements during crystallization of crustal magma layer
MI = magma interface; WI = weathering interface between rock and atmosphere that develops in areas of erosion; layers pointed by arrow for the terminal places with the red = chalcofile, blue=hydrofiles and yellow=atmofiles, respectively; AI = accumulation interface; ORI=Oxidation-reduction interface

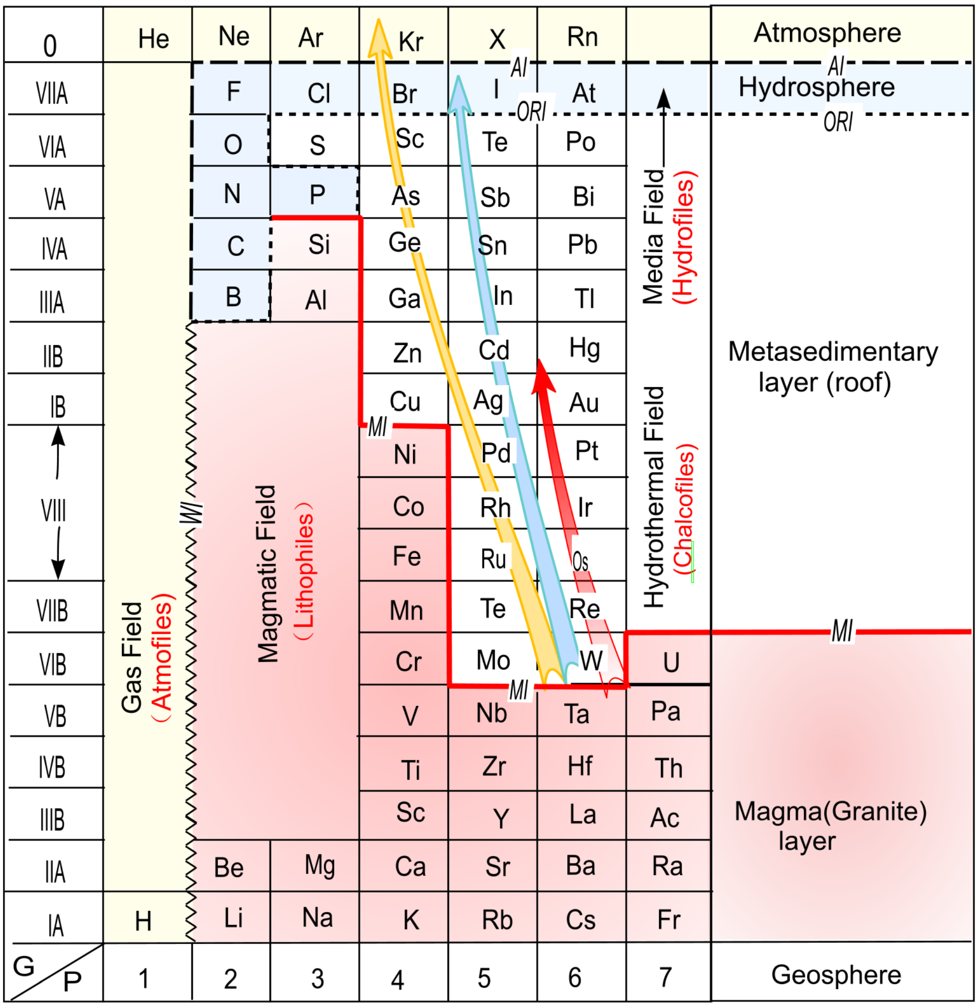

Fig.2. The Geochemical Fields of Elements for mineralization (compared with Fig.1). Different fields of the upper crust are characterized by different elements and represent the granite layer, roof rocks, hydrosphere, and the atmosphere.

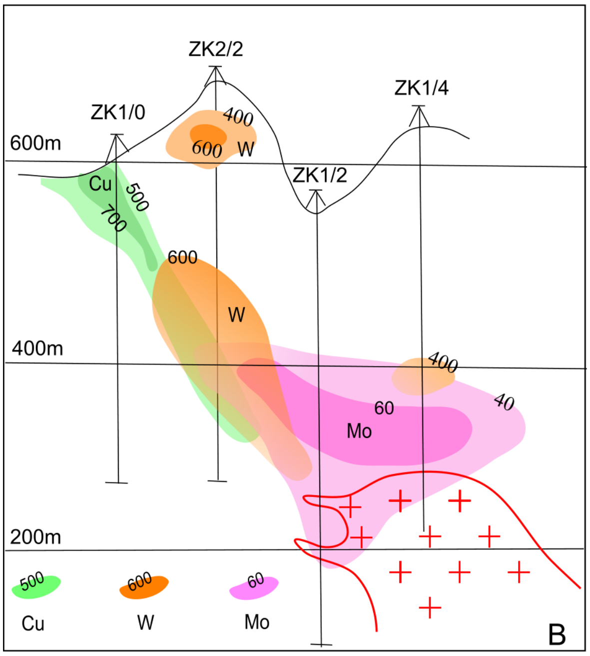

Fig.3. Contours of various ore-forming elements above the Longwangpai granite, Hunan Province, SE China

in investigation and exploration of the ore-deposits.

4 Conclusion

The main conclusions are as follows:

(1)Both rock- and ore-forming elements of granite are all from the melted original rocks involved into the in-situ crustal melting process.

(2)Crystallization of magma results in re- organization and redistribution of elements with lithophiles below the MI, chalcophiles to the roof cover, hydrofiles to hydrosphere and atmofiles to the atmosphere. The concept of GFE can perfectly reflect process and spatial framework.

(3)During upward-migration of hydrothermal fluid, various ore-forming elements are precipitated in the order of Mo – W – Cu – Zn – Pb – Ag – Au – Hg (Sb) with decreasing temperature.

Acknowledgement

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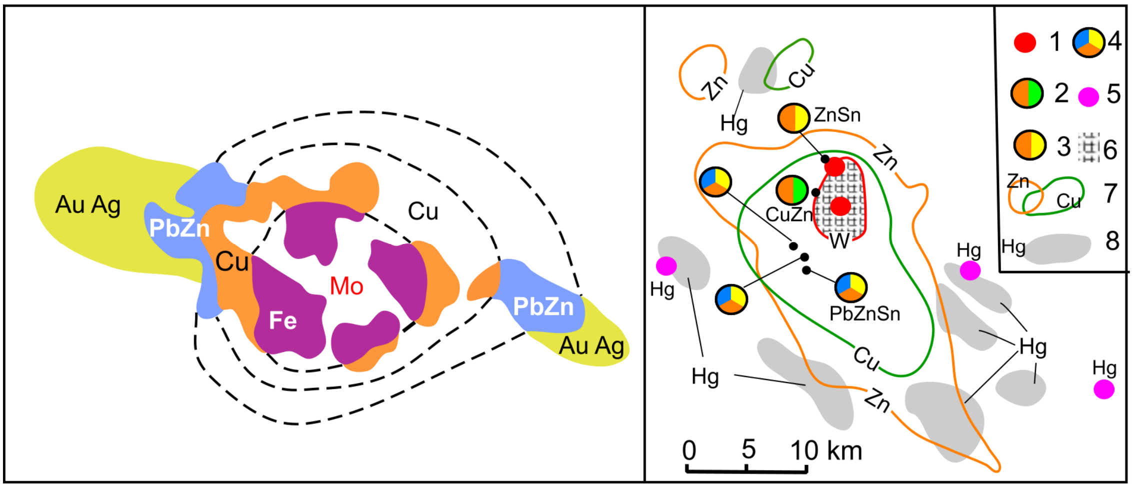

Fig.4. A. Sketch map showing metal-zoning in the Qibaoshan Mine, SE China. B. Ore deposits and geochemical anomalies of the concealed Xianggai granite, Guangxi Province, SE China (modified after Wang et al. 1988); 4. Pb-Zn-Sn deposit; 5. Areas of heavy mineral anomalies; 6–8. Areas of geochemical anomalies

precipitated later than Cu, Zn and Pb. In numerous Au-Ag deposits, the maximum concentration of Au is in the upper part of ore-body, and Ag in the lower part. An example is the Changkeng deposit, Guangdong Province, where the contents of Pb, Zn and Cu increase significantly downward from the upper Au to lower Ag ore body of the deposit (Zhuang et al. 2011).

In comparison with the distribution of the other elements described above, element Hg is typically present furthest from the granite (Fig.4B).

Summing up, during upward-migration of thermal fluid, ore-forming elements are precipitated is in the order of Mo – W – Cu – Zn – Pb – Ag –Au– Hg deposited in different crustal levels. Obviously, it is important to know this order

References

Chen GN, Cao JJ, Zhang K (1996) In-situ melting and the geochemical field of elements. Geol. Pub. House Beijing: 1–98 (in Chinese).

Chen GN (1998) Geochemical field of the elements and its geo-implications. Geochimica 27: 566–574 (in Chinese with English abstract).

Chen GN, Grapes R (2003) In-situ melting model for granite formation: evidence from SE China.Int Geol Rev 45: 611-622.

Chen GN, Grapes R (2007) Granite genesis: in-situ melting and crustal evolution Springer, Dordrecht, The Netherland

Zhuang WM et al (2011) Metallogenesis of subgroup elements and related ore files, Earth Science Frontiers, 18(1):102-109 (in Chines with English abstract)