HU Baoqun, LÜ Guxian, WANG Fangzhang, SUN Zhanxue and GUO Tao, 2014. Theory on Water Phase Transitions Controlling Hydrothermal Mineralization. *Acta Geologica Sinica* (English Edition), 88(supp. 2): 1616-1617.

Theory on Water Phase Transitions Controlling Hydrothermal Mineralization

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1 Introduction

Water is the most primary factor controlling the hydrothermal mineralization. The physico-chemical properties sudden changes related with the phase transition of water will provide a new aid to understand the hydrothermal mineralization (Hu et al., 2008; 2009).

2 Methods and Results

Taking the isobaric heat capacity (C_p) as the example, the study has calculated the physico-chemical properties changes of water on the phase transition curve, the critical point and the geothermal curves (Wagner et al., 2000). The method is from NIST WEBBOOK.

(1) There are some sudden changes of water's physico-chemical properties on the phase transition curve (between 100℃ and 374℃), critical point and pseudo phase transition curve (between 374℃ and 450℃). On the curve of gas-liquid phase transition (including the critical point) and pseudo phase transition in supercritical area, water physico-chemical properties will suddenly change, which are distinct from gradual change with small amplitude in no phase transition area. These physico-chemical properties changes between phase transition and no phase transition, make it to be possible bring mineralization matter in or out the water-bearing system. As shown in Fig.1.

(2) It is necessary descending pressure caused by fracture in hydrothermal mineralization. There are no sudden changes (or mutations) of physico-chemical properties under the closed water-bearing system with the normal geothermal gradient. Fig.2 shows that according to the normal geothermal gradients, from shallow to deep in the lithosphere, the isobaric heat capacities are gradient change with the small amplitude by less than 10%, and no sudden changes appear. On the lines of geothermal curves 5 ℃ / km, 10 ℃ / km, 20 ℃ / km and 50 ℃ / km, the curves of isobaric heat capacities are similar.

In the lithosphere, the condition with the mutation of water physico-chemical properties is that the temperature and pressure of water-bearing system are simultaneously on the phase transition curve and the critical point. Only some special geological environment can satisfy these conditions. The typical condition with pressure descending is fracture broken zone, and the typical condition with temperature increasing is magmatic activity. If the fracture and magmatic activity simultaneously occur in some areas

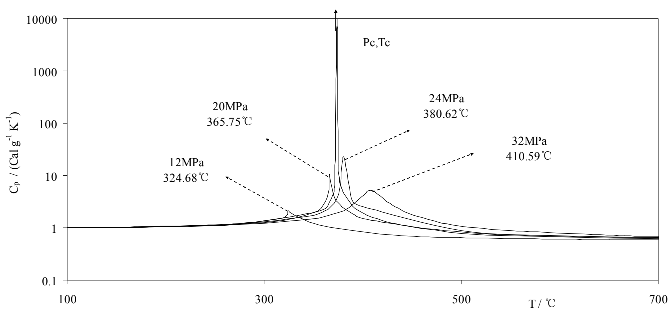

Fig.1. shows the critical singularity and the variation of the isobaric heat capacity (Cp) of water at various pressures

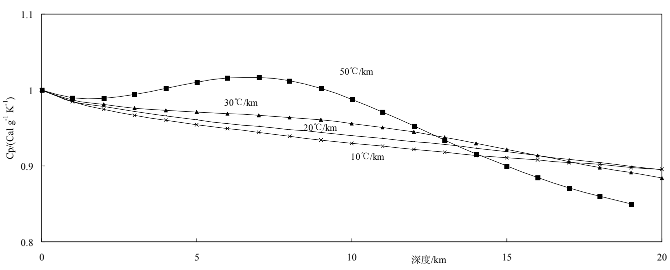

Fig.2. shows the changes of isobaric heat capacity Cp according to various geothermal curves

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of the lithosphere, the temperature and pressure of these areas will be easy to be on the phase transition curve and critical point.

In short, the pressure descending is a necessary condition to contribute to water phase transition and cause the significant changes in physico-chemical properties. Magmatic activity is a favorable conditions, rather than necessary conditions.

3 Discussion

The water phase transition curve (including the critical point) controls the activation, migration and sedimentation of ore-forming matter. The differences of physico-chemical properties between the phase transition and non-phase transition give the possibility of mineralization, and geo-pressure descending is a necessary condition for sudden changes of the physico-chemical properties. So for a water-bearing system, the longer the states near the phase transition but without phase change keeps, and the more conducive to the formation of large ore bonanza. The sedimentations of ore-forming matter and gangue mineral will occur in temperature and pressure area with the solubility significantly reducing.

In the deep lithosphere the supercritical fluid with high temperature and high pressure does not possess strong solvency, and only the supercritical water with the temperature and pressure near the critical point of has a very strong leaching ability. This may be a reason why in the lithosphere there are often the super critical water, but there are not always the hydrothermal deposits (especially big and rich hydrothermal deposit), and the hydrothermal deposits only occur in some special regions (such as the pressure descending environment).

4 Conclusions

Based on the researches of water physicochemical properties above, and combined with the studies of the hydrothermal deposits and mineral solubility experiments (Foustoukos et al., 2007; Loucks et al., 1999; Manning, 2006; Newton et al., 2008), the sketch of this theory was given as follow: the water phase transition may cause some mutations of physico-chemical properties, such as the heat capacity, mineral solubility in water and expansion coefficient. Especially the second-order phase transition at the critical point induces the critical singularity which some parameters tend to be the infinity. The significant changes are obviously different from small amplitude and gradual change at the district without phase transition. The differences will significantly influence the dissolution, migration and depositing of ore-forming materials. The water phase transition and its type depend on the structure, magmatic activity and the geothermal gradient. According to normal geothermal curves in the lithosphere, the pressure reducing from fracture or fold or ductile shear is essential to induce the water phase transition. In short, the curve of water phase transition (including critical point) and pseudo phase transition between 100℃ and 450℃ controls the hydrothermal mineralization.

There are 3 key steps in this theory. Firstly, the significant differences of water physico-chemical properties between phase and non-phase transition area, can give the probability to carry the ore-forming materials into or out of the water-bearing system. Second, the geological environment with the temperature and pressure near to water phase transition is essential. Lastly it is also necessary reducing pressure in some parts of the lithosphere.

Acknowledgements

This study was supported by the National Natural Science Foundation of China (41172078 and 40862005), 863 Program (2012AA061504), 973 Program (2012CB723101) and International Cooperation Projects Funded by Ministry of Science and Technology (2011DFR60830).

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