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The Minimum Stable Pressure and Geological Significants of Supersilic Garnet in Continental Felsic Rocks: Constraints from HT-HP Experiments

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Abstract: A lot of previous experimental studies on ultramafic rocks (SiO_2 unsaturated system) (Ringwood and Major, 1971; Irifune et al., 1986; Gasparik, 1989; Ono and Yasuda, 1996) have demonstrated that characteristics of Si-rich and Al-deficient in garnet are resulted from coupled substitution of $Si^{VI}+M^{VI}=Al^{VI}+Al^{VI}$and $Si^{VI}+Na^{VIII}=Al^{VI}+M^{VIII}$(M=Mg, Fe, Ca) at ultrahigh pressures (UHP) (>5 GPa). The degree of substitution will be enhanced by increasing pressure which has a positive correlation with the content of Si^{VI}, but a negative correlation with the content of Al^{VI} in supersilic garnet. These experimental results established a theoretical foundation for further understanding the formation mechanism of the exsolution of pyroxene in garnet observed in deep mantle xenoliths and some ultrahigh pressure rocks, and also for estimating the pressure conditions of the formation of supersilic garnet before exsolution (Haggerty and Sautter, 1990; Sautter et al., 1991; van Roermund et al., 1998; Ye et al., 2000). Although some experimental studies on SiO_2 saturated system have been reported (Irifune et al., 1994; Ono., 1998; Dobrazhinetskya and Green.,2007; Wu et al., 2009), the stability conditions of supersilic garnet are still lack of unified understanding. Therefore, HP-HT experiments were carried out on felsic rocks under conditions of 6–12GPa and 1000℃–1400℃. Combined with previous experimental data, we try to figure out the minimum stable pressure and geological significants of supersilic garnet in SiO_2 saturated system.

Our experimental results from SiO_2 saturated system show the minimum stable pressure of supersilic garnet should be ≥10 GP of stishovite stability field. These results are similar as that from experiments using starting composition similar to average upper continental crust reported by Irifune et al (1994) who yielded that garnet gradually became supersilic and Al-deficient as pressures increased above 10 GPa, especially in a pressure interval between 13 and 18 GPa. Moreover, experiments with different starting materials (Ono, 1998; Dobrazhinetskya and Green, 2007; Wu et al. 2009) also indicate the stable pressure condition of supersilic garnet is mainly ≥9 –10 GPa in SiO_2 saturated system if data of small-size grains at low temperature are ignored due to measuring errors. Thus, it can be concluded that the minimum stable pressure of supersilic garnet in SiO_2 saturated system is distinctly different from that in SiO_2 unsaturated ultramafic rock system. The minimum pressure of the former is ≥9–10 GPa of stishovite stability field, while that of the latter is >5 GPa. Therefore, whether independent SiO_2 phase exist or rock system is SiO_2 saturated must be taken into considered when estimating the peak pressure of exsolutions in supersilic garnet in UHP rocks. Furthermore, pressure of >5 GPa directly estimated by supersilic garnet based on conclusion from SiO_2 unsaturation system rather than SiO_2 saturation in previous sdudies may have been underestimated and need to be re-estimated.

Supersilic garnets have been recognized by interior exsolutions of clinopyroxene in garnet pyroxene from Yinggelisayi South Altyn (Liu et al., 2005), and exsolutions of rodlike quartz+rutile in felsic gneiss from Songshugou North Qinling (Liu et al., 2003). According to the experimental results from SiO_2 unsaturated system, the peak metamorphic pressure of the both SiO_2 saturated rocks have been estimated to be >7Gpa and >5Gpa, respectively. However, combined with the new experimental results above, we re-estimated that the peak metamorphic pressure of these SiO_2 saturated rocks should be≥9 –10 GPa at least, implying an ultra-deep subduction to mantle depth of stishovite stability field.

This research, together with previous findings (Liu et al., 2007, 2018), shows that continental subduction to mantle depth (300km) of stishovite stability field and then exhumation to the surface is obviously more common than previously thought, and the rock types are also diverse. At the same time, it provides a new indicator and thought for recognizing the subduction to the mantle depth of stishovite stability field in UHP metamorphic belt.

Key words: supersilic garnet, the minimum stable pressure, SiO_2 saturated system, the mantle depth of stishovite stability field, ultrahigh pressure rocks

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