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The Discovery and Significance of The Special Mix Crystal Xenoliths in Shoshonitic Volcanic Breccia at Maguan, Southeastern Yunnan

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The Cenozoic post-collisional high potassium magmatic rocks and their deep xenoliths which occurred in western Yunnan, provide a natural "window" to the deep geological processes and magmatic activity in eastern Tibet Plateau. The pre-researchers (Yu Xuehui et.al. 2006, Xia Ping et al. 2006, Wei Qirong et al. 2006, 2009, Mo Xuanxue et al.2009, Li Chunhui et al. 2011,) had a system study for these rocks and their mantle rock xenoliths, and obtained a series results. The authors discovered a kind of special xenoliths in the shoshonitic volcanic breccias that outcrop in Maguan area, Wenshan, southeastern Prefecture, Yunnan Province. The special xenolith has two types in color. One is red and the other one is black. They look like single mineral rather than rocks in hand specimen with size of 2~10cm, no streak, no cleavage, no mineral crystal face, luster of glass-oily-asphalt, specific gravity of medium-heavier, greater hardness than a knife, and conchoidal fracture, and exist in the shoshonitic volcanic breccias as mineral agglomerate. They are micro-transparent with plane-polarized light and weak optical properties with perpendicular polarized light under the microscope, and no any inclusion in the inclusion piece observation under the high-powered microscope. The X-ray powder diffraction analysis by Cu Ka Ni filter using DMAX-3C diffractometer, in Chengdu University of Technology shows that the two xenoliths are a mixture of micro-crystalline and amorphous, and the red one is mainly composed of spessartine-based, while the black one is omphacite-based. In addition, it is particularly noteworthy that the diffracted baseline intensity (density) is up to 450~500 counts in the X-ray powder diffraction pattern of the two xenliths. That shows they contain a lot of ultracrystalline and amorphous materials that can not make the X-ray diffraction. However, X-ray diffraction cannot display the optical properties observed under the microscope. This shows that these minerals as micro crystalline are in a mixed state with amorphous. And they may be similar to the Fe-rich glass or Fe-rich melt inclusion existing in alkali-rich porphyry and its deep source xenoliths(Liu Xianfan et al. 2010), or similar to the melt pocket with properties(Ionov et.al.1994, Eniko″Bali et al.2002, Paola et al.2009, Su Benxun et al. 2010), may represent the garnet-phase mantle source, or eclogite-phase lower crust component. On the basis of above, this paper gives the xenoliths a preliminary definition with cryptocrystalline mineral mix crystal xenolith, and the specific components need determination and analysis with scanning electron microscopy, electron-probe and transmission electron microscopy.

Compared the major elements of two mix crystal xenoliths with each other, that shows the Al_2O_3 content of red spessartine mix crystal xenolith(MGBZ-4-1) is higher than the black one(MGBZ-4-2), while the SiO_2 and CaO content is lower. Considered that the TiO_2 and alkali (Na_2O+K_2O) content is obviously higher than primitive mantle xenolith, while the other components are similar, and these imply that although original melts composition of two mix crystal xenoliths are different, they may hold a similar geological condition to the mantle xenoliths. And the different melt composition may reflect the differences of metasomatism and evolution in the migration process. In addition, compared the chemical composition of two mix crystal xenoliths to that of typical spessartine and omphacite respectively, the components, especially MgO, of the former are higher in different degrees except the lower MnO. That suggests spessartine is not dominant in the mix crystal xenolith. And the latter has higher TiO_2, MgO and Na_2O relatively, while the other components are basically equal. That shows the two mix crystal xenoliths are not all garnets and omphacites or equivalent single microcrystalline mineral in composition, otherwise it may represent a later stage melt system after partial melting

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from eclogite-phase source region.

Compared with the mantle xenolith with melt pocket which have been reported in the world (Ionov et.al.1994, Eniko″Bali et al.2002, Paola et al.2009, Su Benxun et al. 2010), the bulk rock analysis data of the cryptocrystalline mineral mix crystal xenolith shows the significantly lower MgO content, higher Al_2O_3, TiO_2, CaO, FeO(individual sample is equal), and the basically equal total alkali content. Their major elements compositions are similar to Eniko″Bali et al. (2002) founded the mantle rock xenoliths which contain melt pocket at the Bakony-Balaton highland volcanic field in western Hungary. That suggests the two mineral mix crystal xenoliths have the similar formation background to mantle rock xenoliths with melt pocket, and relatively stronger metasomatism, and with a certain degree of crust-mantle contamination.

The total rare earth elements content(∑REE) of two mineral mix crystal xenoliths is not high, with 39.59×10^{-6} and 36.32×10^{-6} respectively, and LREE and HREE have taken fractionation effect obviously (LREE/HREE=0.29 and 4.01, $(La/Yb)_N$=0.05 and 1.75 respectively), and the LREE has also a certain fractionation internal[$(La/Sm)_N$=0.39 and 0.49 respectively], and with a weak negative Eu and negative Ce anomaly(δEu=0.92 and 0.93,δCe=0.88 and 0.92 respectively). In the primitive mantle standardization pattern of REE (Fig.1), the curve of red spessartine mix crytal xenolith shows a different trend from the other samples, that is HREE-rich obviously and the LREE and HREE fractionation heavily. This suggests the red mix crystal xenolith may represent a residual solid-phase after highly partial melting of garnet-bearing mantle. While the curve of black omphacite mix crytal xenolith in the pattern shows a reciprocal coupling relation with the red one, that is a type of weak enrichment in LREE relatively, higher enrichment in medium REE relatively, and depleted in HREE relatively.

The two mix crystal xenoliths are enrichment of partial LILE, such as Rb, Ba, and delpletion of HFSE, such as Nb, Ta, Zr, Hf, and which is a result of slab fluid metasomatism with mantle according the pre-research(Li Chunhui et al.). The Nb/Ta ratio is 4.54 and 5.76, and $(Rb/Yb)_N$ ratio is 0.33 and 3.03 respectively. The ratio value is much smaller than that of host rock and other types of xenoliths. The Zr/Hf ratio is 52.68 and 20.3 respectively and shows a negative correlation with Nb/Ta ratio, which suggests the two mix crystal xenoliths have fractional crystallization from a same source. In the spider diagram of trace element (Fig.2), the two xenoliths patterns of LILE are quite similar, while the patterns of the other elements display a reciprocal relationship. This suggests they came from the same melt system, and effected with a different degree of deep geological process in subsequent differentiation and evolution. The Th positive anomaly of two mix crystal xenoliths may caused by addition of crust water-rich fluid (Li Chunhui et al. 2011). In addition, the mix crystal xenoliths appear the same Nb-Ta negative anomaly, which suggests a certain degree of crust-mantle contamination. And the omphacite mix crystal xenolith has a higher La/Nb and Nd/U ratio than the spessartine mix crystal xenolith, which suggests the crust-mantle contamination degree of former is stronger than the latter (Xia Ping et al. 2004). And it also suggests the melt of omphacite mix ctystal xeonlith is still liquid phase when the melt of spessartine tends solid-phase in another hand.

The red spessartine mix crystal xenolith with $(Rb/Yb)_N$ ratio<1, indicating it derived from depleted mantle, and residual melt with the higher degree of partial melting and the lowest degree of fractional crystallization. While the black omphacite mix crystal xenolith with $(Rb/Yb)_N$ ratio>1, indicates it on the basis of deriving from depleted mantle, had the mantle-derived fluid metasomatism, and with the residual melt characteristics of lower partial melting degree while the higher fractional crystallization degree relatively(Li Changnian, 1992). In fact, if they exist in the same melt system after eclogite-phase partial melting, the fractionation of LREE and HREE represents

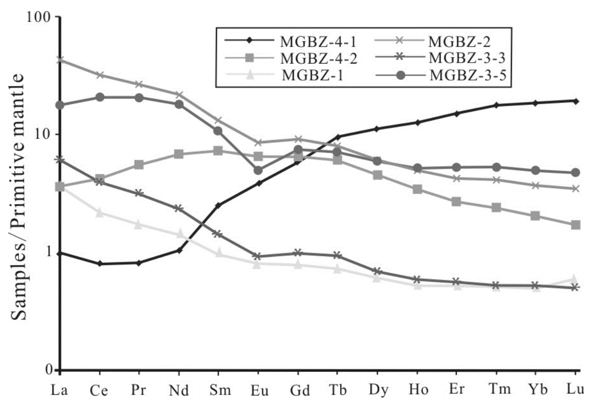

Fig.1. REE pattern of mix crystal and mantle xenoliths at Maguan

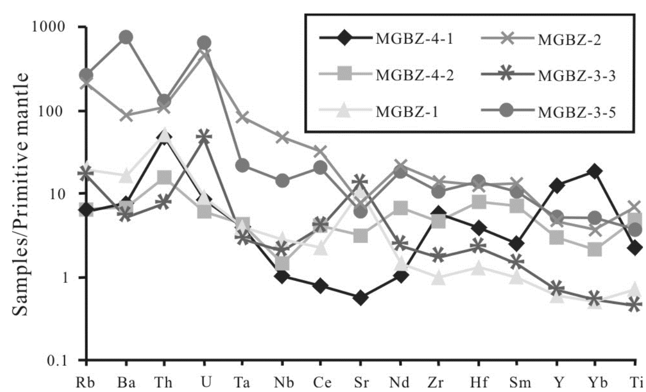

Fig.2. Trace elements Spider Diagrams of mix crystal and mantle xenoliths at Maguan

their crystallization degree in some extent.

The $\delta^{30}Si$ value of two mix crystal xenoliths is tested using the method of SiF4, NBS-28 international standard, in the Isotope Laboratory of the Institute of Mineral Resources Chinese Academy of Geological Sciences. The $\delta^{30}Si$ of red spessartine mix crystal xenolith is -0.4‰, similar to that of primitive earth (-0.5‰). (Ding Tiping et al. 1994); and $\delta^{30}Si$ of black omphacite mix crystal xenolith is -0.7‰. These suggest the original melt and metasomatic fluid of xenoliths derived from the same magmatic system in mantle, and the magmatic system may be eclogite zone in the upper mantle or crust-mantle transitional zone. And the differences in silicon isotopic composition of them may have a relationship with silicon isotope dynamic fractionation caused by crust-mantle overprint and metasomtism in their evolution.

The silicon isotope composition of two mix crystal xenoliths explains their mantle-derived characteristic, and rules out the possibility that they are catched randomly by alkaline basaltic magma as xenocrysts during raising to crust, or they are aphanocrystalline-amorphous that had no time to crystallization in instantaneous high temperature and pressure when the basaltic magma erupted. They may represent the melt of garnet-phase (eclogite phase) mantle with partial melting, which are carried and migrated synchronously as an immiscible system with host alkaline basaltic magma. Li Ruilu (2009) calculated the temperature and pressure of the formation of omphacite mix crystal xenolith as clinopyroxene megacryst is 1152℃ ~1356℃, 19×10^{8}Pa~27×10^{8}Pa, and the origin depth of 63~86km. They represent the composition of the upper mantle. By contrast with this, the other types of mantle xenoliths are significantly lower with temperature and pressure range, and shallower with depth.

According to the various characteristics of two mix crystal xenoliths, they represent the composition of mantle-derived garnet-phase or eclogite-phase lithosphere. However, the pre-research (A E Ringwood et al. 1981) thought that alkaline basalt magma rising migration through the upper mantle is mainly in the spinel lherzolite area. And It could occur only in depth of 90~100km that spinel-phase transition to garnet-phase lherzolite. Therefore, the two mix crystal xenoliths especially the spessartine, may suggest the spinel-phase mantle source region with phase transition under the high pressure. This also indicates there were garnet phase mantle source besides spinel-phase peridotite in Maguan area. And the coexistence of the mix crystal xenoliths and other types of mantle xenoliths in the host rocks shows the vertical phase transition zone of the Cenozoic upper mantle in western Yunnan. The alkaline basalt magma origin has reached the depth of garnet-phase mantle region. The characteristic with phase transition belt is related to lithosphere mantle delamination caused by asthenosphere upwelling. The feature of upper mantle on the vertical section in Maguan area is similar to that in eastern China in Cenozoic (E Molan et al, 1987; Chi Jishang et al, 1988). This suggests theupper mantle of **two** regions had similar evolution mechanism in the same period. The two mix crystal xenoliths originated in the metasomatic depleted mantle, and the host rock -shoshonitic magma- originated in the enriched mantle. So in this article study, we think that the lithosphere mantle happened twice transformation by metasomatism: the first is the lower primitive mantle transformed to depleted mantle by lithosphere mantle delamination, and through partial melting, provided the original melt of the mix crystal xenoliths; the second is the depleted mantle transformed to enriched mantly by mantle metasomatism, then formed rich alkaline magma and mutual immiscible mantle fluid which is enrichment ore-forming elements. In this process, a part of crust source substances that are contributed with the plate subducted into the mantle may mix with the mantle fluid or melt released by asthenosphere upwelling, and composed commonly the alkaline basalt magma with carrying immiscible melt and rised quickly. This process would lead to rapid changes in temperature and pressure, and made the immiscible melt formed aphanocrystalline-amorphous xenoliths by percondensation effect.

Key words: Maguan,Yunnan; mix crystal xenoliths; crust-mantle contamination; garnet-phase mantle; lithospheric delamination

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