

Syn-exhumation magmatism during continental collision: Evidence from alkaline intrusives of Triassic age in the Sulu orogen

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While oceanic subduction zones are characterized by syn-subduction arc magmatism, continental subduction zones are characterized by syn-exhumation alkaline magmatism. The latter is illustrated by alkaline intrusive rocks (including gabbro, syenite and granite) in the Sulu orogen, eastern China. In order to decipher the crust-mantle interaction in the continental subduction zone and subsequent decompression melting of ultrahigh-pressure (UHP) metamorphic rocks, we carried out a combined study of zircon U-Pb ages and Lu-Hf isotopes, mineral O isotopes, whole-rock major-trace elements and Sr-Nd isotopes. SIMS and LA-ICPMS zircon U-Pb dating yields Late Triassic ages of 201 ± 2 to 212 ± 1 Ma for their crystallization. These ages are younger than Middle Triassic ages for UHP metamorphism of country rocks, corresponding to the syn-exhumation magmatism during continental collision. The alkaline rocks are characterized by the arc-like patterns of trace element distribution, with relative enrichment of LILE and LREE but relative depletion of HFSE. They have high initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.7064 to 0.7114 and highly negative $\epsilon_{\text{Nd}}(t)$ values of -16.4 to -13.8 with two-stage Nd model ages of 2.11 to 2.33 Ga for whole-rock. Zircon Lu-Hf isotope analyses also show highly negative $\epsilon_{\text{Hf}}(t)$ values of -20.9 ± 0.5 to -14.1 ± 0.9 , with two-stage Hf model ages of 2.10 ± 0.06 to 2.56 ± 0.03 Ga. The zircon exhibits relatively consistent $\delta^{18}\text{O}$ values of 5.6 to 6.2‰, slightly higher than normal mantle values. The enrichment of radiogenic Sr-Nd-Hf isotopes in the gabbro indicates its origination from an isotopically enriched mantle source, whereas the arc-like pattern of trace element distribution for it suggests a fertile mantle source with enrichment of LILE and LREE. Thus, it is part of the orogenic lithospheric mantle that would be generated by underplate reaction of the subcontinental lithospheric mantle-wedge peridotite with hydrous felsic melts derived from the subducted continental crust during the Triassic continental collision. On the other hand, there are general similarities in trace element and radiogenic isotope characteristics between the syenite-granite and UHP metaigneous rocks in the Dabie-Sulu orogenic belt, suggesting its genetic link to the subducted continental crust itself. Therefore, the alkaline intrusives are derived from partial melting of the orogenic lithospheric mantle and the subducted continental crust in the stage of exhumation. They provide a petrological record of recycling the subducted continental crust into mantle depths with the crust-mantle interaction in the continental subduction channel.

Hydrocarbon generation kinetics of oil cracking in different reaction system

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Pyrolysis experiment of crude oil with 3 reaction systems ($\text{MgSO}_4 + \text{H}_2\text{O} + \text{crude oil}$, $\text{CaSO}_4 + \text{H}_2\text{O} + \text{crude oil}$, crude oil) are carried out to simulate the gas generation characteristic when H_2O and ions such as SO_4^{2-} , Mg^{2+} , Ca^{2+} participate in the oil cracking, and discuss the generating mechanism of natural gas containing H_2S , and quantitatively calculate the deplete of hydrocarbons and their carbon isotope by TSR.

The experiment results show that the TSR reaction did not occur under the system of " $\text{CaSO}_4 + \text{H}_2\text{O} + \text{crude oil}$ ", oppositely, TSR obviously occurred under the system of " $\text{MgSO}_4 + \text{H}_2\text{O} + \text{crude oil}$ " and the yield rate of H_2S reach up to 60~80ml/g. Hydrocarbon yield rates under the reaction system with TSR occurred are significantly lower than that in the reaction system without TSR occurred (Fig 1), indicating the deplete of gaseous hydrocarbons by TSR [1]. In addition, TSR also had a significant effect on the carbon isotope fractionation of hydrocarbons, so that methane, ethane, propane carbon isotope weight gain with a range of 3~6‰ (Table 1). The activation energy distribution show that, the activation energy of gas generation under the system of " $\text{MgSO}_4 + \text{H}_2\text{O} + \text{crude oil}$ " lower than that in the system of " $\text{CaSO}_4 + \text{H}_2\text{O} + \text{crude oil}$ ", the former is 48~60KJ/mol, while the latter is 62~74KJ/mol. It could indicate that participation of Mg^{2+} make a low activation energy of hydrocarbon generation and oil cracking reaction easier.

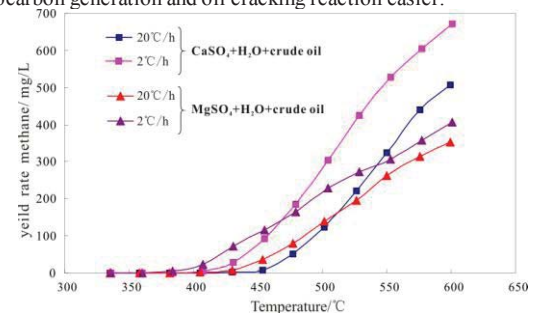


Figure 1: Yield rate of the methane generated in different system

Recent research show that adding buffer such as NaCl into the system of " $\text{CaSO}_4 + \text{H}_2\text{O} + \text{crude oil}$ " could help to TSR, indicating that only SO_4^{2-} -hydrocarbon molecules is not enough in TSR, and the catalyst of metal ions (e.g. Mg^{2+} , Na^+) is very important.

Temperature /°C	$\text{MgSO}_4 + \text{H}_2\text{O} + \text{crude oil}$		$\text{CaSO}_4 + \text{H}_2\text{O} + \text{crude oil}$	
	Methane	Ethane	Methane	Ethane
453.7	-45.19	-41.73	-54.08	-43.09
501.8	-45.79	-36.74	-49.35	-37.55
550.0	-39.90	-24.66	-43.89	-31.04

Table 1: Carbon isotope of hydrocarbons generated in different system (‰)

[1] Cai C F, *et al.* (2003) *Chemical Geology* **202**, 39-57.