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阴山及邻区三叠纪富碱侵入岩的成因意义

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摘要：

富碱侵入岩主要包括碱性岩和碱性花岗岩以及碱长花岗岩，其全碱含量（K_2O+Na_2O）一般>8%。碱性岩主要包括正长岩、霞石正长岩、辉石正长岩、霓霞正长岩、闪石正长岩等，在岩石化学上相对贫硅富铝高碱。碱性花岗岩是指含碱性角闪石、碱性辉石的花岗岩，相对富硅贫铝高碱。在各类侵入岩中，富碱侵入岩所占比例很小，其出露面积约占各类侵入岩出露总面积的2%。但是，富碱侵入岩却有重要的矿产和地质意义。富碱侵入岩的研究不仅对于揭示岩石圈地幔的组成特征、壳幔相互作用及其地球动力学背景具有重要的意义，而且，能为有关岩石圈演化、找矿勘查和资源评价工作提供科学依据。根据对现有资料的总结，燕辽-阴山地区目前已发现很多三叠纪的富碱侵入岩体，它们西起内蒙古包头市，东到吉林省的中部，向东一直延伸到朝鲜的北部，大体分布于北纬40°~42°之间（宽度约100km），构成一条近EW向、长达1500km的碱性岩带。阴山及邻区的三叠纪富碱侵入岩分布在包头、凉城、四子王旗、察哈尔右后旗和察哈尔右中旗地区，东边与之相邻的碱性侵入岩主要分布在天镇、阳原和矾山，它们形成于268~190Ma，其中凉城和包头富碱侵入岩的形成年龄较小（197~190Ma）。这些杂岩体的岩石学和地球化学组成变化较大，其SiO_2含量变化可从35%到70%。相比之下，四子王旗和察哈尔地区的正长岩具有较高的SiO_2和Al_2O_3含量，较低的TiO_2、Fe_2O_3和MgO，这可能反映了它们是地幔源区物质较高程度部分熔融的产物，而且经历了相对较大程度的辉石、橄榄岩和角闪石的分离结晶作用。绝大多数正长岩具有很低的MgO含量，落在了板片熔融实验（1~4GPa）所产生的熔体范围之内，部分样品具有相对较高的MgO含量和$Mg^{\#}$，落在了来源于大洋板片熔融所产生的埃达克岩范围内，说明这些岩石的形成可能与再循环的俯冲板片熔融有关。这些侵入岩普遍富集轻稀土元素和大离子亲石元素（如Ba，K和Sr）富集、亏损高场强元素（Nb、Ta、Ti）、Th、U和P，其$\varepsilon_{Nd}(t)$和（$^{87}Sr/^{86}Sr$）$_i$值的变化范围分别为-17~-3和0.7054~0.7092。多数数据点落在了大洋沉积物的范围内，显示出II型富集地幔参与的特征，即这些正长岩的原始岩浆主要来源于富集的岩石圈地幔。四子王旗正长岩具有最低的$\varepsilon_{Nd}(t)$值（-17），表明下地壳物质的贡献较大，这与其钾长石的Pb同位素组成特征相一致。现有的Pb同位素数据也表明在研究区富碱侵入岩的岩浆形成过程中有大洋物质的参与。从$\varepsilon_{Nd}(t)$值与侵入岩形成年龄的相关性变化可以看出，随着形成年龄的减小，下地壳物质的贡献在增加。总之，上述特征表明它们主要来源于富集的岩石圈地幔，并有不同程度的下地壳物质的参与。该富集地幔的形成与古亚洲洋的俯冲作用有关。由于富碱侵入岩通常形成于拉张的构造背景下，因此研究区富碱侵入岩的形成标志着古亚洲洋的闭合以及华北-蒙古陆块碰撞的结束。这些俯冲和碰撞事件造成了华北北缘岩石圈地幔组成和性质的明显改变。该区富碱侵入岩的岩浆活动时空分布规律及其动力学背景尚需精确的年代学和详细的地球化学研究来进一步制约。

英文摘要：

Alkali-rich intrusive rocks mainly include alkaline rocks and alkaline granites as well as alkali-feldspar granites. The total alkali contents of these rocks are generally more than 8%. Alkaline rocks mainly include syenite, nepheline syenite, pyroxene syenite, aegirine-augite syenite and amphibole syenite. The most striking feature of their chemical composition is relatively poor in silica, but rich in aluminum and total alkali. Alkaline granites refer to the alkaline amphibole and alkaline pyroxene-bearing granites. They are relatively rich in silica and total alkali but poor in aluminum. Alkali-rich intrusive only account for a very small proportion of total intrusive rocks. Their outcrop area approximately occupies 2% of the total area of all kinds of intrusive rocks. However, alkali-rich intrusive rocks have very important mineral and geological significance. As a result, the investigations of alkali-rich intrusive rocks not only are of important significance to reveal the characteristics of lithospheric mantle, the processes of crust-mantle interaction and their associated geodynamic background, but also can provide scientific basis for the research of lithospheric evolution, mineral exploration and resource evaluation. Based on the comprehensive summary of available information, there are lots of Triassic alkali-rich intrusions occurred in the Yanshan-Liaoning-Yinshan regions in the northern margin of the North China Craton. These alkali-rich intrusions start at the Baotou City in the Inner Mongolia in the west and end at the central part of Jilin Province and even the north part of North Korea in the east. They are generally located between north latitude 40° and north latitude 42° with width of about 100km and constitute a nearly east-west-direction and 1500-kilometer-long alkaline rock belt. The Triassic alkali-rich intrusive rocks in the Yinshan and its neighboring areas are mainly located in the territories of Baotou, Liangcheng, Siziwangqi, Chahar Right Back Banner and Chahar Right Middle Banner cities in the Inner Mongolia. The adjacent alkaline intrusive rocks to the east mainly occurred in the regions of the Tianzhen City in the Shanxi Province, Yangyuan and Fanshan cities in the Hebei Province. Base on early published data of whole-rock and mineral Rb-Sr isochron ages, these alkali-rich intrusions formed during 268~190Ma (these data have large errors of about 5~11Ma). Compared to those in the Siziwangqi and Chahar regions, the Liangcheng and Baotou alkali-rich intrusions are relatively younger (about 197~190Ma). The geochemical compositions of these alkali-rich intrusive rocks are highly variable, with SiO_2 contents ranging from 35% to 70%. In contrast, the syenites in the Siziwangqi and Chahar areas have higher contents of SiO_2 and Al_2O_3, but lower contents of TiO_2, Fe_2O_3 and MgO than those in other areas, which possibly reflect that these intrusive rocks are the products of higher-degree partial melting of mantle source and greater degree of fractional crystallization of pyroxene, olivine and amphibole. It should be noted that most of the syenites are very lo

w in MgO contents, which are plotted in the field for the melt derived from plate in the experiments of 1~4GPa. Some of them ha ve relatively high MgO contents and $Mg^{\#}$ values and drop in the field for the adakites generated by the melting of oceanic slab. These signatures suggest that the formation of those alkali-rich intrusive rocks could be related to the melting of recycled subdu cted slab. In the meanwhile, these alkali-rich intrusive rocks are characterized by enrichment in light rare earth elements (LREE), la rge-ion lithophile elements (LILE, such as Ba, K and Sr) and depletion in high field strength elements (HFSE, such as Nb, Ta and T i), Th, U and P. Their $\varepsilon_{Nd}(t)$ and initial $^{87}Sr/^{86}Sr$ values vary from -17 to -3 and from 0.7054 to 0.7092, respectively. Most of the s amples drop in the filed of marine sediments and show the contributions of type-2 enriched mantle (EM2) material to the mantle source of these rocks, indicating that the primary magmas of these syenites were mainly derived from enriched lithospheric mant le. The Siziwangqi syenite has the extremely low value of $\varepsilon_{Nd}(t)$ (-17), suggesting a greater contribution of lower crustal material. This reference is well consistent with the result of Pb isotopic compositions of potassium feldspar. The currently available Pb isot opic data also suggest the involvement of oceanic material during the magma generation of the alkali-rich intrusive rocks in the s tudy area. The correlation between the $\varepsilon_{Nd}(t)$ values and formation ages of the alkali-rich intrusive rocks indicates that the involv ement of lower crustal material increased with the decrease of formation ages of these rocks. To sum up, the above observations imply that the Triassic alkali-rich intrusive rocks in the Yinshan and its neighboring areas were mainly derived from partial melting of enriched lithospheric mantle with different-degree contributions of lower crustal material. The enriched mantle could be prod uced by mantle metasomatism of melts/fluids derived from the subducted oceanic plate, which was closely related with the closu re of Paleo-Asian Ocean and the collision between the North China Craton and Mongolia block. The formation of these alkali-rich intrusive rocks could mark the complete closure of the Paleo-Asian Ocean and the end of North China Craton-Mongolia collision because alkali-rich intrusive rocks generally formed in an extensional tectonic setting. These events of subduction of Paleo-Asian Oceanic plate and collision between the North China Craton and Mongolia block have caused the considerable change in chemic al compositions and geophysical property of the lithospheric mantle beneath the northern margin of the North China Craton as e videnced in many previous studies. The spatial and temporal distribution of magmatic activities and associated geodynamic back ground of these alkali-rich intrusive rocks will be further constrained by precise dating and detailed geochemical investigation in the near future.

关键词： 富碱侵入岩 岩石成因 阴山 三叠纪 古亚洲洋 华北克拉通

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