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胶北新太古代两类片麻岩的岩石地球化学特征和成因指示

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摘要:

在胶北三口探矿深钻中识别出两类新太古代片麻岩,一种是TTG片麻岩,数量较多;另一类是石榴黑云斜长片麻岩,数量相对较少,以夹层状发育于TTG片麻岩中。已有年代学资料显示,两种片麻岩原岩均形成于~2.5Ga。TTG片麻岩SiO₂含量为53.95%~75.56%,Na₂O为1.51%~5.94%,Na₂O/K₂O>1;贫Fe₂O₃^T(2.22%~9.54%)和MgO(0.53%~4.87%),Al₂O₃多大于15%(10.45%~17.64%),A/CNK=1.18~1.75,说明其属于高铝TTG岩系。富集大离子亲石元素(如Rb、Ba、Sr),亏损高场强元素(如Nb、Ta、Zr、Hf),Sr含量高(204×10⁻⁶~2906×10⁻⁶),Sr/Y比值高(7.30~355)。ΣREE含量(40.4×10⁻⁶~512×10⁻⁶)相对较高,轻重稀土强烈分异((La/Yb)_N=11.5~121),Eu无异常或弱正异常(δEu=0.79~1.89)。以上地球化学性质表明,胶北TTG片麻岩是含水玄武质岩石高压下部部分熔融形成的,残留相主要是石榴石、角闪石和含Ti矿物,没有斜长石。全岩Nd和锆石Hf同位素数据显示其模式年龄与形成年龄相近,表明岩石源区可能是来源于亏损地幔的2.57~2.64Ga的初生玄武质地壳。另外,胶北TTG片麻岩高的Mg[#]值(40~67)和Cr(147×10⁻⁶~371×10⁻⁶)、Ni(6.68×10⁻⁶~156×10⁻⁶)含量,表示与地幔楔发生了反应,结合Nb、Ta负异常以及源区为初生的玄武质地壳等特征,说明研究区TTG形成于与俯冲有关的岛弧环境,而非加厚的下地壳。DF值和K-A关系图显示,石榴黑云斜长片麻岩原岩是泥质-粉砂质沉积岩。Cr/Zr比值(0.90~1.99,平均为1.62)和Th/Sc比值(平均为0.30)与太古宙沉积岩相应值相近(分别为1.44和0.4),稀土配分型式与太古宙沉积岩类似,表明源区物质以长英质为主。绝大多数样品显示轻稀土富集、重稀土平坦的特征,总稀土含量平均为176×10⁻⁶(La/Yb)_N比值平均为14.7,LREE/HREE平均为3.3,Eu无异常或微弱的负异常(δEu=0.69~0.92,平均为0.84),这些特征值表明原岩形成的大地构造背景为岛弧或主动大陆边缘。Grt-Bt地质温度计得到的变质温度为549~663℃,其中黑云母化学成分与角闪岩相中黑云母特征相同,共同指示变质程度为角闪岩相,可能代表了~2.5Ga麻粒岩相-高角闪岩相变质作用的退变质阶段。石榴黑云斜长片麻岩原岩与TTG属同一时代(~2.5Ga)的产物,形成的构造背景类似(岛弧或主动大陆边缘),说明当时该区有俯冲过程发生;TTG岩浆事件和~2.5Ga的变质事件大体同时,但变质事件较岩浆事件稍晚,可以用俯冲后的碰撞来解释。因此,研究区在~2.5Ga可能发生过一次重要的俯冲-碰撞拼合事件:TTG和石榴黑云斜长片麻岩原岩形成于俯冲阶段,后期发生碰撞引发麻粒岩相-高角闪岩相的区域变质作用。

英文摘要:

Two types of Neoproterozoic gneisses are identified in the three deep exploration drills in the Jiaobei terrane, including the dominating TTG gneisses and the minor garnet biotite plagiogneiss being sandwiched between the former. As recorded, their protoliths both formed at ~2.5Ga. The TTG gneisses are rich in SiO₂ (53.95%~75.56%), Al₂O₃ (most>15%, 10.45%~17.64%) and Na₂O (1.51%~5.94%) with high Na₂O/K₂O ratios (>1) and low Fe₂O₃^T (2.22%~9.54%) and MgO (0.53%~4.87%) contents. Their A/CNK ratios (1.18~1.75) indicate that they belong to high-Al TTG series. The TTG gneisses are rich in LILE (Rb, Ba and Sr) but deplete HFSE (Nb, Ta, Zr and Hf), characterized by high Sr contents (204×10⁻⁶~2906×10⁻⁶) and Sr/Y ratios (7.30~355), relatively high ΣREE contents (40.4×10⁻⁶~512×10⁻⁶), strongly fractionated REE patterns ((La/Yb)_N=11.5~121) and positive or no Eu anomalies (δEu=0.79~1.89). These geochemical features request melting of plagioclase component and relicts of garnet, amphibole and some Ti-bearing minerals in the source, indicating that the TTG were formed by partial melting of hydrous basaltic crust at high pressure. The whole rock Nd and zircon Hf isotopic studies, in which the t_{DM} is close to the formation age, indicate that the TTG may originate from a juvenile crust from a depleted mantle at 2.57~2.64Ga. In addition, their high Mg[#] numbers (40~67) and high Cr (147×10⁻⁶~371×10⁻⁶) and Ni contents (6.68×10⁻⁶~156×10⁻⁶) indicate reaction with mantle wedge. Combining features such as negative Nb, Ta anomalies and the juvenile source, the TTG in this study may have formed in island arc environment related to subduction instead of thickened lower crust. DF values and the K-A diagram show that the protolith of garnet biotite plagiogneiss is pelitic-silty sedimentary rocks. Their Cr/Zr ratios (0.90~1.99, 1.62 on the average), Th/Sc ratios (0.30 on the average) and REE patterns are similar to the corresponding characteristics (1.44 and 0.4, respectively) of Archean sedimentary rocks, thus indicating their source is mainly composed of quartz-feldspathic material. Most samples are rich in LREE with weak negative or no Eu anomalies (δEu=0.69~0.92, 0.84 on the average).

age) and have relatively flat HREE patterns. The characteristic values of REE (176×10^{-6} on average) contents, $(La/Yb)_N$ (14.7 on average) and LREE/HREE ratios (3.3 on average) indicate that the protolith may probably have formed in island arc environment or active continental margin. Amphibolite facies metamorphism, which is indicated by the peak metamorphic temperature obtained by Grt-Bi thermometer (549~663°C) and biotite composition, may represent the imprint of retrogressive metamorphic stages of granulite-high amphibolite facies metamorphism at ~2.5Ga. The protolith of garnet biotite plagiogneiss and TTG are the products of the same age and similar tectonic settings (island arc environment or active continental margin), suggesting a subduction process in the area at that time. And the metamorphism at ~2.5Ga, which is slightly later than the TTG magma event, may be related to the collision process after subduction. Hence, a significant subduction-collision event may have occurred in the study area at ~2.5Ga, during which TTG and the protolith of garnet biotite plagiogneiss formed at the subduction stage and granulite-high amphibolite facies metamorphism was caused by the following collision process.

关键词: [TTG片麻岩](#) [石榴黑云斜长片麻岩](#) [岩石成因](#) [胶北地体](#) [新太古代](#)

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