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LATE PALEOZOIC-EARLY MESOZOIC TECTONIC EVOLUTION IN THE EAST MARGIN OF THE JIAMUSI MASSIF, EASTERN NORTHEASTERN CHINA

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The Jiamusi massif is a major tectonic unit in the eastern part of NE China and composed chiefly of the Early Paleozoic (about 500 Ma) metamorphosed crystalline basement containing Precambrian, even Archean crust and three suites of unmetamorphosed continental marginal sedimentary formations of the Devonian-Lower Carboniferous, the Late Carboniferous- Permian and the Late Triassic, which are similar to those in the Bureya and Khanka massifs in Russia. In the Devonian-Lower Carboniferous, the microcontinent consisting of the Jiamusi and Songnen massifs in China and the Bureya and Khanka massifs in Russia evolved independently, the eastern part of which was a passive continental margin, where a suite of the marine sedimentary-volcanic formation is overlain unconformably on the crystalline basement. The regional stratigraphic break in the middle Carboniferous in the whole northeastern China was related to the collision of the microcontinent with the Argun-Hinggan microcontinent in the west, indicating the formation of a new amalgamated continent (Heilongjiang plate). Therefore, the Late Carboniferous-Permian volcanic-sedimentary formation is the first unitary cover on the Heilongjiang plate. The Late Carboniferous-Permian and the Late Triassic sedimentary formations in the eastern part of the Jiamusi-Bureya-Khanka microcontinent represent the evolutional features of the eastern continental margin of the Heilongjiang plate. Summarily, the eastern margin of the Heilongjiang plate mainly suffered the following evolution stages from the Late Carboniferous to the Late Triassic: (1) the transform or passive continental margin in the Late Carboniferous, characterized by terrestrial facies clastic rocks with interbeded recoverable coal layers; (2) the active continental margin in the Permian marked by the magmatic arc composed mainly of intermediate-acid volcanics and granites; (3) the transform margin in the Early-Middle Triassic indicated by the simultaneous stratigraphic break, and (4) the passive continental margin in the Late Triassic characterized by the marine-terrigenous facies sedimentary formation.

Keywords: **Jiamusi massif, Heilongjiang plate, continental margin, Northeastern China.**

INTRODUCTION

The Jiamusi massif is an important tectonic unit in the Northeastern China characterized by widely exposed amphibolite-granulite facies metamorphosed supercrust rocks (khondalite). The massif is close to the Wandashan (Nadanhada) terrane in the east which is a part of the giant Sikhote-Alin Mesozoic accretional complex belt, so that the junction area is of great significance to understand the tectonic transformation of the PaleoAsian to the Pacific tectonic regimes. The early studies generally believed that the Jiamusi massif was a Precambrian massif involved into the eastern Asian Variscan geosyncline fold system [9], or to the Paleozoic accretional orogenic belt neighboring the craton [16] ,[28]. According to the metamorphic formations, the Jiamusi massif is often compared with the Bureya and Khanka massifs in Russia, used to be named as the Bureya-Jiamusi (-Khanka) massif [9]. Although the term is used by many researchers, its meaning has been changed greatly. At present, the Jiamusi and Songnen massifs in the northeastern China, as well as the Bureya and Khanka massifs in Russia, are considered an integrated microcontinent in the Early Paleozoic [14–16],[43–45],[49]. The more popular forms of address include the Bureya-Jiamusi paleoplate [15] and the Bureya-Jiamusi-Khanka microcontinent or superterrane [14]. Khanchuk [14] emphasized these massifs evolved as a continent or a part of the continent, rather than the epioceanic orogeny since the Middle Paleozoic. These researches favor the view that the paleoplate or microcontinent was amalgamated together with the Argun-Hinggan massif in the west along the Heihe-Nenjiang fault (China) and Nora-Soukhotin fault (Russia) in the middle Paleo-

zoic, forming a new Paleozoic continental plate. Zhang [49] named it the Heilongjiang Plate. Xie [43] also proposed that the northeastern China and adjoining areas in Russia are composed mainly of microplates with the Precambrian basement, on which the unmetamorphosed Paleozoic sedimentary covers were developed after the Salair orogeny. Milanovski [24] stated his belief that the Bureya area in Russia and the northeastern China were a paraplatform composed of several rigid massifs metamorphosed in the Early-Paleozoic. In recent years, Chinese scholars further suggest that the Jiamusi-Songnen massif and the Argun-Hinggan massif in the west once were two independent microcontinents, which were amalgamated together in the middle Carboniferous, on which a giant Late Carboniferous-Permian sedimentary cover was developed. It is noteworthy that the sedimentary cover is not subjected to the regional metamorphism [21–22, 46–48, 52].Thus it can be seen that the Jiamusi massif as the eastern margin of the amalgamated continental plate plays a major significance to understand its tectonic evolution in the Late Paleozoic.

THE GENERAL FEATURES OF THE JIAMUSI MASSIF

The crystalline basement

The Jiamusi massif is located in the eastern part of the Heilongjiang Province northeastern China. It is bounded by the Heilongjiang mélange in the west neighboring the Songnen massif [44–45] and by the Tongjiang-Mishan thrust fault in the east with the Wandashan (Nadanhada) Mesozoic terrane. The massif is composed mostly of the amphibolite-granulite facies metamorphic rocks (khondalite) and granites of different ages. In the earlier studies, the granulites and granites were suggested to have been formed in the Early Proterozoic or Archean [1, 6, 12, 19] . Wilde [37–39] had obtained the zircon ages of prevailing 490–520 Ma and minor ages older than 700 Ma from sillimanite-garnet gneiss and garnet granite, advancing for the first time that the Early Paleozoic granulite facies metamorphism in the Jiamusi massif was related to the pan-African orogeny. The standpoint is accepted by some researchers [53–55]. Xie [41–42] got the zircon age of 486 Ma from the S-type granite in the massif, further supporting the high-grade metamorphism took place in the Early Paleozoic. In recent years, a large amount of zircon dating results show that the ages prevailing 500 Ma and in the Precambrian and evening the Archean are widely recorded not only in the Jiamusi massif but also in the Songnen and Argun-Hinggan massifs in the west [2–4, 10, 11, 18, 21, 23, 26–27, 34–36, 40–42, 46, 48, 53–55]. According to the available zircon dating data (Table 1), three age classes can be divided roughly in the individual massifs: 490–522 Ma, 700–1900 Ma, and 2512–2871 Ma in the Jiamusi massif, 499–508 Ma, 581–2465 Ma and 2543–2953 Ma in the Songnen massif, and 485–518 Ma, 601–1800 Ma, and 2500–2791 Ma in the Argun-Hinggan massif, correspondingly. Although the statistics is incomplete, it is enough to indicate that the all massifs in the northeastern China have the Precambrian, even Archean crust and were subjected to the high-grade metamorphism in the Early Paleiozoic. The tectonic significance of the metamorphism remains a question. However, it holds that this is an important orogenic event probably related to the pan-African or Salair orogeny, because they are generally simultaneous. What is more possible, it was deduced that the Argun-Hinggan massif in the west was related to the Salair orogeny, and the Songnen-Jiamusi massif in the east to the pan-African orogeny, because the Silurian marine strata containing Tuvaella fauna in the Argun-Hinggan massif are widely distributed in the southeastern and southwestern edges of the Siberian plate [31], but not discovered in the Songnen-Jiamusi massif up to now.

Sedimentary Covers of the Jiamusi Massif

The crystalline basement of the Jiamusi massif is for the most part covered by the Cretaceous sedimentary basin, but the Late Paleozoic and Late Triassic strata are widely exposed in the Baoqing-Mishan areas in the eastern margin (Fig. 1 c). The Late Paleozoic and Late Triassic strata stretching in a N-S direction can be divided into three sedimentary tectonic units of the Devonian-Lower Carboniferous, Upper Carboniferous-Permian and Upper Triassic, according to the sedimentary formations and stratigraphic contacts (Table 2).

The Devonian-Lower Carboniferous

The strata are widely exposed in the eastern margin of the Jiamusi massif and composed mainly of the marine sedimentary-volcanic formation. The Lower–Middle Devonian strata consist of dominantly quartz sandstone and carbonate rocks, overlying unconformably on the Early Paleozoic granite [6]. The abundant fossils represented by branchiopods, conodonts, and corals in the limestone indicate the geological ages from the Emsian of the Early Devonian to the Eifelian of the Middle Devonian [32]. The basal conglomerate in the bottom of the strata consists mainly of the gravels of metamorphic rocks and granite of the basement. The clastic zircon dating of the sandstone shows a prevailing minimum age population of 480–520 Ma and a few age populations older than 750 Ma (Fig. 2), indicating the Devonian sediments originated mostly from the crystalline basement of the Jiamusi massif. A suite of the marine facies volcanic rocks in the area was previously referred to the Late Devonia, but the new zircon datings prove that the ages of the volcanic rocks are concen-

Table 1. Statistics of zircon ages in the basement of major massifs, northeastern China.

Basements	Lithology	Zircon U-Pb ages(Ma)	Data source
Jiamusi Massif	syenogranite biotite granite	1134 2871	Song Biao et al. (1994）[29]
	garnet granulite sillimanite gneiss garnet granite	500，502, 1100，1 900 496，507, 700， 900，1050， 1300，502, 1600	Wilde S.A. et al. (2000, 2001, 2003) [37–39]
	amphibolite banded migmatite	777 843,1004	Xie HangQiang et al.（2008）[41–42]
	granite	496	Gao FuHong et al.（2010）[2]
	granitic gneiss dioritic gneiss	515, 522 493	Wen QuanBo et al.（2008）[36]
Khanka Massif	Enderbite in Russia	485	Karsakov L.P. (2008) [13]
	sillimanite gneiss garnet granite in China	490 522，515，510，500	Zhou JianBo et al. (2010, 2011) [53–55]
Songnen Massif	granite	1873	Pei FuPing et al. （2006，2008）[26–27]
	biotite-quartz schist mica-quartz schist quartz schist	772，696, 1384，1559，1649，1778，2450， 2579，2793，2953 1749，1886，2002，2208 1000， 1400， 1500，1700， 1800	
	metadiorite	1839，1996，2152	Wang Ying et al.（2006）[35]
	quartz sandstone	551, 749, 802，898，903，1833，2500，2503	Meng En et al.（2010）[21]
	metasandstone	503，808，951，1857，2442	Zhou JianBo et al.（2011）[54–55]
	granite	508，499	Liu JianFeng et al.（2008）[18]
Argun-Hinggan Massif	metaclastic rocks two-mica schist	1000，1200，1600，1800， 2500，2600	Miao LaiCheng et al.（2007）[23]
	granite amphibolite granodiorite	493, 494, 518 490 485	Ge WenChun et al. (2005，2007) [3–4]
	sillimanite gneiss plagioclase gneiss biotite gneiss	493，496，500，949，1373, 1496，2791, 496，497, 608，1015, 1637	Zhou JianBo et al.（2010）[53]

trated between 386–392 Ma [22], corresponding to the Eifelian-Givetian of the Middle Devonian. The bimodal volcanic association and geochemical characteristics indicate they originated in an extended passive continental margin. The Upper Devonian consists mainly of terrestrial facies tuffaceous sandstone and siltstone with intercalated tuff and tufflava, in which the plant remains indicate the Frasnian-Famennian ages. The Lower Carboniferous is composed of marine volcaniclastic rocks with intercalated greywacke, in which the brachiopods show the Tournaisian of the Early Carboniferous [25]. The biostratigraphic and isotopic evidences described above indicate that the Devonian-Lower Carboniferous sedimentary sequence is generally continuous in age. It is the first sedimentary cover on the crystalline basement of the Jiamusi massif.

The Upper Carboniferous – Permian

Starting from the Late Carboniferous, the sedimentary setting in the whole northeastern China changed greatly and a suite of the terrestrial facies sedimentary-volcanic formation marked by abundant Angara flora was formed. In the eastern margin of the Jiamusi massif, the Upper Carboniferous is composed mainly of conglomerate, sandstone, siltstone and carbonaceous mudstone with recoverable coal layers, in which the Angara flora represented by *Angaridium* sp. in the lower part shows the geological age of the Kasimovian-Gzhelian, indicating a sedimentary interval

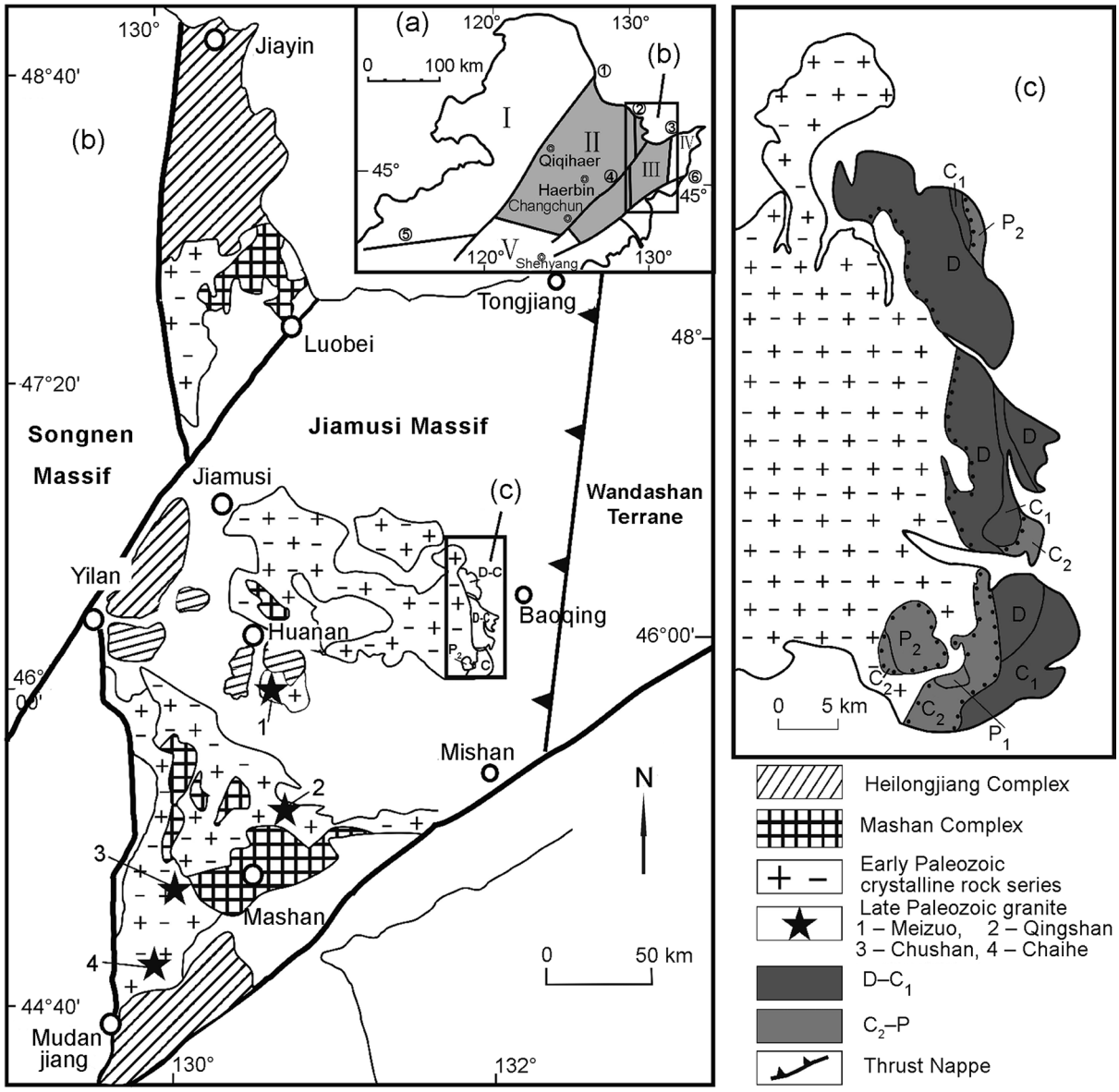


Fig. 1. Simplified geological map of the Jiamusi Massif and adjoining regions.

a – Major tectonic units: I – Argun-Hinggan massif, II – Songnen massif, III – Jiamusi massif, IV – Wandashan (Nadanhada) terrane, V – North China plate. Major faults: 1 – Heihe-Nenjiang-Kailu, 2 – Jiayin-Mudanjiang, 3 – Tongjiang-Mishan, 4 – Jiamusi-Yilan, 5 – Dunhua-Mishan, 6 – Xilamulunhe-Changchun-Hunchun. b – Geological constituents of the Jiamusi massif; c – The Late Paleozoic distribution in the eastern margin of the Jiamusi massif.

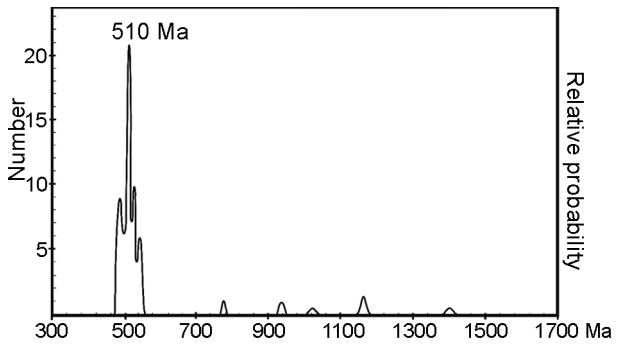
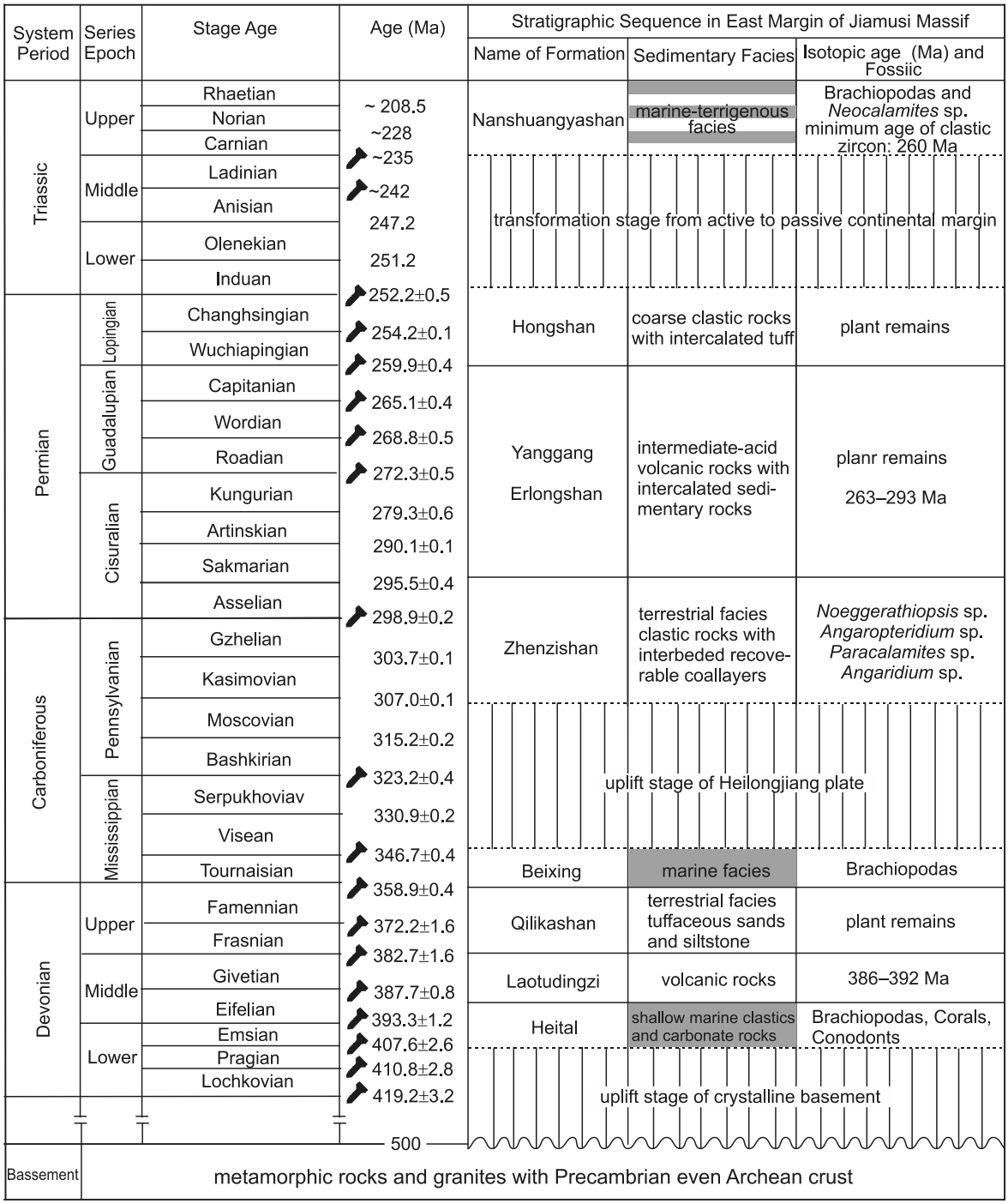


Fig. 2. The distribution of clastic zircon ages in the Early Devonian sandstone.

about 40 Ma between the Lower and Upper Carboniferous, but the most of the Angara flora in the upper part shows the Gzhelian age, and partly up to the Asselian of the beginning of the Early Permian [7] indicating the sedimentary sequence from the Late Carboniferous to Early Permian is continuous. The Lower-Middle Permian is composed dominantly of the terrestrial volcanic rocks with interbedded sedimentary rocks, in which the zircon ages of the volcanic rocks are 263–293 Ma [21] that is consistent with the geological age of the plant remains in the interbedded sedimentary layers. The Upper Permian consists mainly of the coarse clastic sedimentary rocks

Table 2. Stratigraphic sequence in the eastern margin of the Jiamusi massif.



with the intercalated conglomerate and tuff containing abundant plant remains.

The Upper Triassic

The Triassic strata are generally absent from broad areas of the northeastern China, only the Upper Triassic strata are exposed in the Mishan area in the southeastern margin of the massif, where the Upper Triassic strata are composed mainly of the transitional facies quartz sandstone, siltstone, silty mudstone, and mudstone containing abundant brachiopods, locally lying unconformably on the Permian volcanic rocks. In recent years, a suite of possible Upper Triassic strata is discovered in the Fujin area in the northeast of the Jiamusi massif. The strata consist mainly of quartz sandstone, siltstone and mudstone, which was previously referred

as the Late Carboniferous [6]. The new investigations have revealed that the gravel-bearing coarse sandstone in the bottom of the strata overlies unconformably the granitic gneiss with a zircon age of 500 Ma, in which the gravels are predominantly metamorphic rocks and granite, evidencing that the sediments came mainly from the crystalline basement. The clastic zircon dating of the coarse sandstone gives two prevailing population ages of 255–280 Ma and 480–530 Ma, and a few ages older than 750 Ma (Fig. 3), suggesting that the sandstones were deposited after the Late Permian. Especially, the plant remains of *Cladophlebis* sp., *Podojamites* sp. and *Neocalamites* sp. have been identified in the mudstone in the upper part of the strata, further proving the strata formed in the Early Mesozoic. Considering the absence of the Lower-Middle Triassic sediments in the whole northeastern China, they can be determined as the Early Mesozoic in age which originated mainly from the basement and the Permian igneous rocks of the Jiamusi massif. It is noteworthy that the Early Mesozoic coarse sandstone described above contains a large number of siliceous rock debris (chert), indicating that the siliceous rocks in the Jiamusi massif existed before the accretion of the Wandashan (Nadanhada) terrane of the Sikhote-Alin complex. Therefore the viewpoints on the classification of all the siliceous rocks in the region into the Wandashan terrane maybe uncorrect.

Discussion on the tectonic evolution and its geotectonic significance

The Jiamusi massif once included two continental margins, one is the Songnen-Jiamusi microcontinent and another is an amalgamated continent composed of the Songnen-Jiamusi and the Argun-Hinggan microcontinents. In the Devonian-Early Carboniferous, the Jiamusi massif as the eastern margin of the Songnen-Jiamusi microcontinent was situated in an extensional passive continental margin, where the marine sedimentary-volcanic formation as the first sedimentary cover was developed on the basement. In the middle Carboniferous, the Songnen-Jiamusi microcontinent collided with the Argun-Hinggan microcontinent in the west along the Heihe-Nenjiang fault, forming a new amalgamated continent. Consequently, the whole northeastern China was uplifted, resulting in a regional sedimentary break about 40 Ma from the Visean to Moscovian. After this, the Jiamusi massif as the eastern margin of the new continent started a new tectonic-sedimentary evolution. The Late Carboniferous-Early Permian deposits as the first unitary sedimentary cover were formed on the new continent, but their sedimentary and tectonic settings were different in the east and west. In the broad areas to the west of the Jiamusi massif, the prevailing volcanic rocks (284–307 Ma) were widely developed under the extensional setting, while in the eastern margin, the simutaneous terrestrial clastic sedimentary rocks and coal-bearing formation was developed. The evidences indicate that the whole northeastern China continent bore a postcollisional extensional setting, while the eastern part was probably in a passive or transform continental margin. In the Early-Late Permian, the eastern part of the Jiamusi massif was transformed to the active continental margin and formed a magmatic arc composed of the volcanics and granites. These granites were previously dated as the Precambrian [6], but the isotopic datings and geochemical studies indicate that the part of them was formed in the Middle-Late Permian and related to the subduction, such as the granite bodies of the Caihe (254 Ma), Chushan (256 Ma), Qingshan (270 Ma) and Meizuo (259 Ma) and so on [10, 40–42] . In the Upper Triassic, a suite of the transitional facies strata were developed and overlain unconformably the Permian volcanics or the crystalline basement in the eastern margin of the Jiamusi massif, indicating that the continental margin was changed from the active in the Permian to the passive in the Late Triassic. Because the Triassic strata are generally absent from the northeastern China, it is inferred that the eastern margin of the Jiamusi massif was located in a transform continental margin in the Early-Middle Triassic.

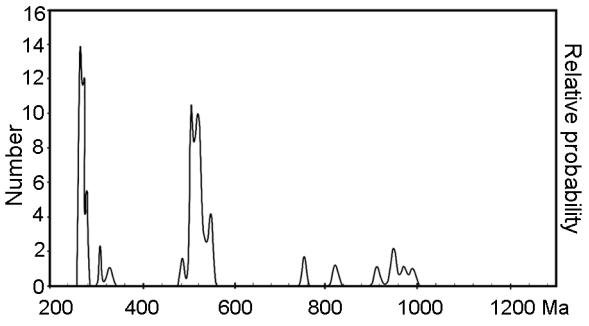


Fig. 3. Distribution of the clastic zircon ages of the sandstone in the Fujian area, northeastern part of the Jiamusi massif.

According to the data of the Russian scholars [13, 14], the Bureya and Khanka massifs exhibit the similar features with those of the Jiamusi massif. A zircon age of 485 Ma of the enderbite from the Iman group and some ages older than 700 Ma in associated metamorphic rocks in the Khanka massif had been obtained [13], indicating that high-grade metamorphism occurred in the Early Paleozoic and Precambrian crust in the Khanka massif is similar to that in the Jiamusi massif. Especially, the Late Paleozoic and Late Triassic sedimentary covers also existed in the eastern margins of the Bureya and Khanka massifs. In the eastern margin of the Khanka massif, the Devonian-Lower Carboniferous marine

sedimentary-volcanic rocks, the Permian volcanic rocks and associated Late Permian granites, as well as the Late Triassic transitional facies sedimentary rocks are developed, in which the Devonian-Lower Carboniferous sedimentary-volcanic rocks belong to a part of the Late Paleozoic continental marginal volcanic belt [13] and related to the rifting [14]. In the eastern margin of the Bureya massif, the unmetamorphosed Devonian-Lower Carboniferous marine and the Permian terrestrial strata are developed, which are overlain unconformably by the Upper Triassic sedimentary rocks containing the Norian bivalve fauna [13]. The evidences further prove that the Jiamusi (including Songnen), Bureya and Khanka massifs were a single microcontinent since the Early Paleozoic [14–16, 49]. The microcontinent evolved independently until it collided with the Argun-Hinggan microcontinent in the west and formed a new amalgamated continent in the middle Carboniferous. Zhang [49] termed the continent as the Heilongjiang plate. In view of the fact that the Heilongjiang (Amur) River is the boundary river between China and Russia which passes the massifs from west to east, the authors use the term the Heilongjiang plate to express the new Late Paleozoic continent. The tectonic and sedimentary features of the Jiamusi, Bureya and Khanka massifs generally represent the tectonic evolution features in the eastern margin of the Heilongjiang plate from the Late Carboniferous to the Late Triassic.

The Late Carboniferous-Permian volcanic-sedimentary formations are widespread in the Heilongjiang plate, but they differ in the formations. In the broad areas to the west of the Jiamusi massif, the Upper Carboniferous-Lower Permian sediments are composed predominantly of the extension-related volcanic rocks and characterized by the terrestrial background in northern part and marine one in southern part adjoining the North China plate, but at the same time the terrestrial clastic sedimentary rocks containing coal-bearing formations were formed in the eastern margin of the Jiamusi massif, indicating that the eastern margin of the Heilongjiang plate represented by the Jiamusi, Bureya and Khanka massifs was placed in a passive or transform continental margin setting in the Late Carboniferous-early of the Early Permian. In the Early-Late Permian, a magmatic arc composed of volcanic rocks and granites was formed in the Jiamusi massif, in which the ages of the volcanic rocks (263–293 Ma) are slightly older than those of the granites (254–271Ma), indicating that the eastern margin of the Heilongjiang plate was transformed into an active continental margin, probably related to the westward subduction. The Triassic strata are generally absent throughout the Heilongjiang plate, only the Upper Triassic transitional facies strata are developed and overlay unconformably the Permian volcanics or crystalline basement in the Jiamusi massif, suggesting that the eastern margin of the Heilongjiang plate experienced the changes from a transform boundary in the Early-Middle Triassic to a passive continental margin in the Late Triassic. After this, the eastern part of the Heilongjiang plate was involved in the West Pacific tectonic regime and experienced the continental marginal accretion in the Late Mesozoic.

CONCLUSION

The Jiamusi massif is composed chiefly of the Early Paleozoic metamorphosed basement containing Precambrian, even Archean crust and three suites of continental marginal sedimentary formations of the Devonian-Lower Carboniferous, the Late Carboniferous-Permian and the Late Triassic, which are similar to those in the Bureya and Khanka massifs in Russia. The Devonian-Lower Carboniferous sedimentary formation represents the passive continental marginal evolution features of the independent microcontinent composed of the Jiamusi, Songnen, Bureya and Khanka massifs. The regional stratigraphic break in the middle Carboniferous was caused by the collisional uplift of the microcontinent with the Argun-Hinggan microcontinent in the west, indicating the formation of a new amalgamated continent (Heilongjiang plate). Therefore, the Late Carboniferous-Permian volcanic-sedimentary formation is the first unitary cover on the Heilongjiang plate. The Late Carboniferous-Permian and the Late Triassic sedimentary formations in the eastern part of the Jiamusi-Bureya-Khanka microcontinent generally represent the evolutional features in the eastern continental margin of the Heilongjiang plate. Summarily, the eastern margin of the Heilongjiang plate mainly suffered the following evolution stages from the Late Carboniferous to the Late Triassic: (1) the transform or passive continental margin in the Late Carboniferous, characterized by terrestrial facies clastic rocks with interbeded recoverable coal layers; (2) the active continental margin in the Permian marked by the magmatic arc composed mainly of intermediate-acid volcanics and granites; (3) the transform margin in the Early-Middle Triassic characterized by the simultaneous stratigraphic break, and (40 the passive continental margin in the Late Triassic distinguished by the marine-terrigeous facies sedimentary formation.

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REFERENCES

1. Cao Xi, Dang ZengXin, Zhang XingZhou, Jiang JiSheng, Wang HongDe.The Composite Jiamusi Terrane. Jilin Publishing House of Science and Technology, Changchun,China, 1992: 1–137 (in Chinese with English and Russian abstracts).
2. Gao FuHong, Wang Feng, Cao HuaHua, Zheng YuHang, Liu Jun.Zircon U-Pb Ages of the Basement Granite from Suibin Depression in Sanjiang Basin and Its Tectonic Implications. Journal of Jilin University:Earth Science Edition, 2010, 40 (4): 955–960(in Chinese with English abstract).
3. Ge WenChun, Wu FuYuan, Zhou ChangYong.Emplacement age of the Tahe Granite and Its Constraints on the Tectonic Nature of the Ergun Block in the North Part of the Da Hinggan Range. Chinese Science Bulletin, 2005, 50 (12): 1239–1247.
4. Ge WenChun，Wu FuYuan，Zhou ChangYong.The Mineralization Ages of Porphyritic Cu-Mo Deposit in the Eastern Segment of Mongol-hinggan Orogenic Belt and Its Geodynamic Significance. Science Bulletin, 2007, 52 (20): 2407–2418.
5. Guo ShengZhe.The Permian palaeogeography in the geosynclinal region of the Inner Mongolia-Northeastern China. Bulletin of the Shenyang Institue of Geology and Mineral Resources, Chinese Academy of Geological Sciences, 1995, 4. 19–32.
6. Heilongjiang Bureau of Geology and Mineral Resources (HBGMR).Regional Geology of Heilongjiang Province. Beijing: Geological Publishing House, 1993: 1–734 (in Chinese with English abstract).
7. Huang BenHong.The Carboniferous-Permian terrestrial strata in the north part of the northeastern China. Geological Review, 1982, 28 (5): 395–401 (in Chinese).
8. Huang BenHong.The Carboniferous and Permian flora in the Da-Hinggan mountains. Geological Publishing House Beijing. 1993: 1–141.
9. Huang JiQing, Ren JiShun, Jiang ChunFa, Zhang ZhiMeng, Xu ZhiQin.An Outline of the Tectonic Characteristics of China. Acta Geologica Sinica,1977, 51(2): 117–135.
10. Huang YingCong, Ren DongHui, Zhang XingZhou, Xiong XiaoSong, Zhang ChunYan, Wang Yue, Zhao LiangLiang. Zircon U-Pb dating of Meizuo granite and geological significance in the Huanan Uplift, East Heilongjiang Province. Journal of Jilin University:Earth Science Edition, 2008, 38(04): 631–638 (in Chinese with English abstract).
11. Huang YingCong, Zhang XingZhou, Zhang HongBin, Xiong XiaoSong, Liu ChangLin, Zhao LiangLiang. Geochemical Characteristics and Sedimentation Age of the Majiajie Group in Eastern Heilongjiang Province,China. Acta Geologica sinica, 2009, 83(02): 295–303 (in Chinese with English abstract).
12. Jiang JiSheng.Regional Metamorphism and Evolution of Mashan Khondalite Series. Acta petrologica et mineralogica, 1992, 11(02): 97–109 (in Chinese with English abstract).
13. Karsakov LP, Zhao ChunJing, Malyshev YuF, Goroshko.Tectonics,Deep structure, Metallogeny of the central Asian-Pacific belts junction area.Geological Publishing House, Beijing, China, 2008: 41–50.
14. Khanchuk AI.Pre-Neogene Tectonics of the Sea-of-Japan Region: Aview from the Russian Side. Earth Science (Chikyu Kagaku), 2001, 55: 275–291.
15. Li JinYi.Framework of Burean-Jiamusi Paleoplate and Its Tectonic Evolution. Geoscience Research, 1995, 28: 96–98(in Chinese).
16. Li JinYi.Some New Ideas on Tectonics of NE China and Its Neighboring Areas. Geological Review, 1998, 44: 339–347(in Chinese).
17. Li JinYi.Permian geodynamic setting of Northeast China and adjacent regions:closure of the Paleo-Asian Ocean and subduction of the Paleo-Pacific Plate. J. Asian Earth Sci. 2006, 26: 207–224.
18. Liu JianFeng，Chi XiaoGuo，Dong ChunYan ,Zhao Zhi,Li GuangRong, Zhao YuanDong. Discovery of Early Paleozoic Granites in the Eastern Xiao Hinggan Mountains，Northeastern China and Their Tectonic Significance. Geological Bulletin of China，2008，27(4): 534– 544.
19. Lu LiangZhao, Xu XueChun.Early Precambrian khondalitic series in northern China. Changchun Publishing House, Changchun, 1996:126–194.
20. Meng En, Xu WenLiang, Yang DeBin, Pei FuPing, Ji WeiQiang, Yu Yang, Zhang XingZhou. Permian Volcanisms in Eastern and Southeastern Margins of the Jiamusi Massif, Northeastern China:Zircon U-Pb Chronology, Geochemistry and Its Tectonic Implications. Chinese science Bulletin, 2008, 53(8): 956–965 (in Chinese with English abstract).
21. Meng En, Xu WenLiang, Pei FuPing.Detrital-Zircon Geochronology of Late Paleozoic Sedimentary Rocks in Eastern Heilongjiang Province, NE China: Implications for the tectonic Evolution of the Eastern Segment of the Central Asian Orogenic Belt. Tectonophysics，2010, 485(1–4): 42–51.
22. Meng En,Xu Wenliang,Pei Fuping,Wang Feng. Middle-Devonian Volcanism and tectonic significance in the eastpartof Heilongjiang Province,ACTA Petrological ET Mineralogical, 2011, 30(5): 883–900.
23. Miao LaiCheng, Liu DunYi, Zhang FuQing, Fan WeiMing, Shi YuRuo, Xie HangQiang. Zircon SHRIMP U-Pb Ages of the «Xinghuadukou Group» in Hanjiayuanzi and Xinlin Areas and the «Zhalantun Group» in Inner Mongolia, Da Hinggan Mountains. Chinese Science Bulletin, 2007, 52(5): 591–601.
24 Milanovski E.E. Geology in Russia and Its Neighboring Areas (1987). Chen Zhen (translate in Chinese). Geological Publishing House, Beijing, 2010: 245–248, 395–398.
25. Nan RunShan, Guo ShengZhe.The Paleozoic biostratigraphy and palaeogeography in the geosynclinals region of the Inner Mongolia-Northeastern China, Geological Publishing House. Beijing,1992: 71–146.
26. Pei FuPing, Xu WenLiang, Yang DeBin, Zhao QuanGuo, Liu XiaoMing, Hu ZhaoChu.Zircon U-Pb Geochronology for Metamorphic Rochs from Basement of the Songliao Basin and Its Geological Implication. Chinese Science Bulletin, 2006, 51(24): 2881–2887.
27. Pei FuPing, Xu WenLiang, Yang DeBin ,Ji WeiQiang,Yu Yang, Zhang XingZhou.Mesozoic Volcanic Rocks in the Southern Songliao Basin: Zircon U - Pb Ages and Their Constraints on the Nature of Basin Basement. Earth Science：Journal of China University of Geosciences, 2008, 33(5): 603–617.
28. Sengör MC, Natalin B.A. Paleotectonics of Asia: Fragments of a Synthesis.Yin A, Harrison M. The Tectonic Evolution of Asia. New York：Cambridge University Press, 1996:486–640.
29. Song Biao, Niu BaoGui, Li JinYi, Xu WenXi.Isotope Geochro-

nology of Granitoids in Mudanjiang-Jixi Area. Acta Petrologica et Mineralogica, 1994, 13(3): 204–213.

30. Song Biao, Li JinYi, Niu BaoGui, Xu WenXi.Single-grain zircon ages and its implications in biotite-plagioclase gneiss in Mashan Group in the eastern Heilongjiang. Acta Geoscientia Sinica,1997, 18(3): 306–312.
31. Su YangZheng.On the Geological and Geographical Distribution of Tuvaella with Reference to its Habitat, Journal of Palaeontology,1981, 20(6): 567–576.
32. Wang ChengYuan, Shi CongGuang, Qu GuanSheng. Conodonts and Ostracoda in the "Heitai Formation" of the Devonian in the Mishan Area, Heilongjiang Province. Journal of Micropaleontology, 1986, 3(2). 205–216.
33. Wang HongZhen, Yang SenNan, Liu BenPei.The Tectonic and Bio-Palaeogeography in China and adjoining areas.Publishing House of China University of Geosciences, Wuhan. 1990: 35–86.
34. Wang LiWu, Wang Ying, Yang Jing, Wu GuoQing, Li GuoYan, Sheng Li.PreMesozoic Basement Provenance Tracing of the Songliao Basin Bymeans of Detrital Zircon SHRIMP Chronology. Earth Science Frontiers, 2007, 14 (4): 151–158.
35. Wang Ying, Zhang FuQin, Zhang DaWei, Miao LaiCheng, Li TieSheng, Xie HangQiang, Meng QingRen, Liu DunYi.Zircon SHRIMP U-Pb Age of the Metamorphic Diorite in the South of Songliao Basin and Its Geological Implication. Chinese Science Bulletin, 2006，51 (15):1811–1816.
36. Wen QuanBo, Liu YongJiang, Li WeiMin, Han GuoQing, Ding Ling. Monazite Age and Its Geological Significance of Granitoid Gneiss in the Jiamusi Massif. Journal of Jilin University:Earth Science Edition, 2008, 38 (2): 187–193 (in Chinese with English abstract).
37. Wilde Simon A, Zhang XingZhou，Wu FuYuan. Extension of a Newly-Identified 500 Ma Metamorphic Terrain in Northeast China: Further U-Pb SHRIMP dating of the Mashan Complex, Heilongjiang Province，China. Tectonophysics，2000，328 (1–2)：115–130.
38. Wilde Simon A , Wu FuYuan, Zhang XingZhou.The Mashan Complex: SHRIMP U–Pb zircon evidence for a Late Pan-African metamorphic event in NE China and its implication for global continental reconstructions. Geochemica 2001, 30: 35–50 (in Chinese with English abstract).
39. Wilde Simon A, Wu FuYuan, Zhang XingZhou. Late Pan-African magmatism in Northeastern China: SHRIMP U-Pb zircon evidence for igneous ages from the Mashan Complex. Precambrian Research, 2003, 122: 311–327.
40. Wu FuYuan, Wilde Simon A , Sun DeYou.Zircon SHRIMP U-Pb ages of gneissic granites in Jiamusi massif, northeastern China. Acta Petrologica Sinica, 2001, 17(3): 443–452 (in Chinese with English abstract).
41. Xie HangQiang，Zhang FuQin，Miao LaiCheng，Chen FuKun, Liu DunYi.Zircon SHRIMP U-Pb Dating of the Amphibolite from "Heilongjiang Group" and the Granite in Mudanjiang Area，NE China，and Its Geological Significance. Acta Petrologica Sinica，2008, 24 (6) : 1237–1250 (in Chinese with English abstract).
42. Xie HangQiang，Miao LaiCheng，Chen FuKun，Zhang FuQin，Liu DunYi.Characteristics of the "Mashan Group" and Zircon SHRIMP U-Pb Dating of granite in Muling Area, Souteastern Heilongjiang Province, China: Geological Bulletin of China，2008b. 27 (12) : 2127–2137 (in Chinese with English abstract).
43. Xie MingQian.Amalgamating plate tectonic and its droved mechanism-tectonic evolution of northeast China and adjacent area. Beijing：Science Press,2000:1–260.
44. Zhang XingZhou, Zhang YuanHou.Coexistence of blueschists and greenschists: A new evidence for the tectonic evolution of the Heilongjiang rock series. Journal of Changchun University of Earth Science, 1991, 21(3): 277–282 (in Chinese with English abstract).
45. Zhang XingZhou.Heilongjiang melange: The Evidence of Caledonian Suture Zone of the Jiamusi Massif (in Chinese with English abstract). Journal of Changchun University of Earth Science, 1992, 22: 94–101 (in Chinese with English abstract).
46. Zhang XingZhou, Zhou JianBo, Chi XiaoGuo, Wang ChengWen, Hu DaQian.Late Paleozoic tectonic-sedimentation and petroleum resources in Northeastern China. Journal of Jilin University (Earth Science Edition), 2008, 38 (5) :719 –725 (in Chinese with English abstract).
47. Zhang XingZhou, Qiao DeWu, Chi XiaoGuo,Zhou JianBo, Sun YueWu, Zhang FengXu, Zhang ShuQin, Zhao QingYing. Late-Paleozoic Tectonic Evolution and Oil-Gas Potentiality in Northeastern China. Geological Bulletin of China, 2011, 30 (2/3): 205–213.
48. Zhang XingZhou, Ma YuXia, Chi XiaoGuo, Zhang FengXu, Sun YueWu, GuoYe, Zeng Zhen. Discussion on Phanerozoic Tectonic Evolution in Northeastern China. Journal of Jilin University(Earth Science Edition), 2012, 42 (5) : 1269–1285.
49. Zhang YiXia，Sun YunSheng，Zhang XingZhou，Yang BaoJun.Instruction Book of Geoscience Transect of the Manzhouli-Suifenhe(1:1000000),Geological Publishing House，Beijing, 1998: 1–53.
50. Zhao Zhi，Chi XiaoGuo，Pan ShiYu, Liu JianFeng, Sun Wei, Hu ZhaoChu.Zircon U–Pb LA -ICP-MS Dating of Carboniferous Volcanics and Its Geological Significance in the Northwestern Lesser Xing'an Range. Acta Petrologica Sinica，2010, 26(8): 2452–2464.
51. Zhao Zhi，Chi Xiaoguo，Liu Jianfeng, Wang TieFu, Hu ZhaoChu. Late Paleozoic Arc-Related Magmatism in Yakeshi Region，Inner Mongolia: Chronological and Geochemical Evidence. Acta Petrologica Sinica，2010，26(11): 3245–3258.
52. Zhou JianBo，Zhang XingZhou, Ma ZhiHong, Liu Li, Jin Wei, Zhang MeiSheng, Wang ChengWen, Chi XiaoGuo.The tectonics and basin evolution in northeastern China. Oil and Gas Geology, 2009，30 (5)：530–538.
53. Zhou JianBo, Wilde Simon A, Zhao GuoChun, Zhang XingZhou, Zheng ChangQing, Wang Hu, Zeng WeiShun.Pan-African Metamorphic and Magmatic Rocks of the Khanka Massif, NE China: further Evidence Regarding Their Affinity. Geological Magazine, 2010, 147 (5):737–749.
54. Zhou JianBo, Wilde Simon A, Zhang XingZhou, Zhao GuoChun, Liu FuLai, Qiao DeWu, Ren ShouMai, Liu JianHui.A >1300 km Late Pan-African Metamorphic Belt in NE China: New Evidence from the Xing'an Block And Its Tectonic Implications. Tectonophysics，2011, 509 (3–4): 280–292.
55. Zhou JianBo, Zhang XingZhou, Wilde Simon A , Zheng ChangQing.Confirming of the Heilongjiang ~500 Ma Pan-African Khondalite Belt and Its Tectonic Implications. Acta Petrologica Sinica, 2011, 27 (4):1235–1245.

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Позднепалеозойско-раннемезозойская тектоническая эволюция восточной окраины массива Цзямусы, СВ Китая

Массив Цзямусы является главной тектонической структурой восточной части СВ Китая, состоящий в основном из раннепалеозойского (ок. 500 млн лет) метаморфического кристаллического фундамента, включающего докембрийскую, архейскую кору и трех свит неметаморфизованных осадочных формаций континентальной окраины девон-раннекаменноугольного, позднекаменноугольно-пермского и позднетриасового возраста, сходных с формациями Буреинского и Ханка массивов в России. В девон-нижнекаменноугольный период микроконтинент, включающий массивы Цзямусы и Суннэнь в Китае и Буреинский и Ханка массивы в России, развивались независимо. Восточная часть представляла пассивную континентальную окраину, на которой морская осадочно-вулканическая формация несогласно перекрывает кристаллический фундамент. Региональный стратиграфический перерыв в середине каменноугольного периода на всей территории СВ Китая был связан с коллизией микроконтинента с Аргунь-Хинганским микроконтинентом на западе, что привело к образованию нового объединенного континента (Хэйлунцзянская плита). Следовательно, позднекаменноугольно-пермская вулканогенно-осадочная формация представляет первый общий покров на Хэйлунцзянской плите. Позднекаменноугольно-пермские и позднетриасовые осадочные формации в восточной части Цзямусы-Бурея-Ханка микроконтинента характеризуют эволюцию восточной континентальной окраины Хэйлунцзянской плиты. В целом, восточная окраина Хэйлунцзянской плиты претерпела следующие четыре стадии эволюции от позднего карбона до позднего триаса: трансформная или пассивная континентальная окраина в позднем карбоне, представленная обломочными породами континентальной фации, содержащей угольные слои; активная континентальная окраина в перми с магматической дугой, сложенной в основном среднеми и кислыми вулканитами и гранитами; трансформная окраина в раннем-среднем триасе, представленная одновременным стратиграфическим перерывом, и пассивная континентальная окраина в позднем триасе, представленная осадочной формацией морской терригенной фации.

Ключевые слова: **массив Цзямусы, Хэйлунцзянская плита, континентальная окраина, СВ Китая.**