



辽西阜新夏家沟地区新元古界殷屯组发现的意义

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摘 要: 在对辽西夏家沟地区出露的中元古界长城系、蓟县系岩石地层单位进行考察时, 在中元古界长城系串岭沟组之上, 发现了新元古界北方南华系下统殷屯组冰碛杂砾岩地体, 该地体与中元古界长城系串岭沟组呈角度不整合接触. 该项发现填补了辽西地区新元古代时期陆相岩石地层单位沉积的一项空白, 对于讨论辽西地区新元古代地壳的演化历史增添了新的内容, 具有重要的地质意义.

关键词: 北方南华系; 殷屯组; 新元古界; 冰碛杂砾岩; 辽西

DISCOVERY OF THE NEOPROTEROZOIC YINTUN FORMATION IN XIAJIAGOU AREA OF FUXIN, WESTERN LIAONING: Geological Implication

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Abstract: During the investigation of Mesoproterozoic Changchengian and Jixianian lithostratigraphic units occurred in Xiajiagou area of western Liaoning Province, the moraine conglomerate terrane of Yintun Formation of Lower North Nanhuan System, Neoproterozoic, is found above the Chuanlinggou Formation of Mesoproterozoic Changchengian System. The two show an angular unconformity contact relation. The discovery fills a gap in the Neoproterozoic continental lithostratigraphic unit deposition and adds new content to the discussion of Neoproterozoic crustal evolution history in western Liaoning, which has great geological implication.

Key words: North Nanhuan System; Yintun Formation; Neoproterozoic; moraine conglomerate; western Liaoning

0 引言

笔者于 2020 年 4 月在对辽西夏家沟地区中元古界长城系常州沟组、串岭沟组、团山子组、大红峪组进

行野外考察过程中, 在阜新夏家沟地区发现新元古界北方南华系殷屯组. 前人研究未发现该层位的存在. 该地层以角度不整合覆在长城系串岭沟组之上, 出露

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面积约 90 m²,呈北西向展布,出露宽度 3.5 m,长度大于 25 m,由一套混杂堆积的紫红色冰碛杂砾岩构成.

1 地质背景

研究区出露的地层主要有中元古界长城系常州沟组、串岭沟组、团山子组、大红峪组,蓟县系高于庄组、杨庄组、雾迷山组;新元古界北方南华系下统殷屯组;中生界上三叠统一下侏罗统羊草沟组,侏罗系髫髻山组、土城子组,白垩系义县组、阜新组、沙海组等组成.岩浆岩主要有新太古代小牵马岭英云闪长质片麻岩,中生代基性火山岩、花岗斑岩及安山玢岩.构造以脆性北东向构造为主,其次为北西向和弧形断裂,褶皱构造不发育(图 1).

2 主要地层分区

本区出露的中、新元古界分属于中朝地层大区(I)华北地层区(I₁)燕辽地层分区的辽西小区(I₁¹⁻²).以下主要描述与新发现的新元古界北方南华系殷屯组有关的岩石地层单位.

2.1 中元古界长城系常州沟组(Pt₂¹c)

分布于九官台至头道营子一带,下部主要为浅紫色厚层中粗粒含砾石英砂岩、灰白色石英砂岩;上部为浅粉色中厚层中粒、中细粒石英杂砂岩、石英砂岩.底部以砾岩与新太古代片麻岩呈角度不整合接触.本组在辽西地区变化较大,凌源一带较厚,可达 1 600 m,向北、向东逐渐变薄.建平地区厚 600 m,朝阳地区厚 290 m,义县地区厚 790 m,葫芦岛地区厚 130 m.

2.2 中元古界长城系串岭沟组(Pt₂¹cl)

分布地点同常州沟组.岩性下部为灰紫色薄层、中厚层铁质石英砂岩,中细粒长石石英砂岩夹黄绿色、灰褐色、灰紫色泥质粉砂岩及页岩;上部为灰绿色-灰黑色微薄层-薄层粉砂质页岩,粉砂岩夹薄层粉晶白云岩;底部出现灰紫色砂质页岩与大红峪组分界,与下伏常州沟组呈整合接触.该组厚 300 m.

2.3 新元古界北方南华系下统殷屯组(Pt₃¹y)

分布于阜新市夏家沟村南东 750 m 处,地理坐标: 41°46'39"N, 121°19'43"E,是本次考察发现的新元古界岩石地层单位.该套地层出露面积约 90 m²,呈 300°走向,宽约 3.5 m,长约 25 m,与中元古界长城系

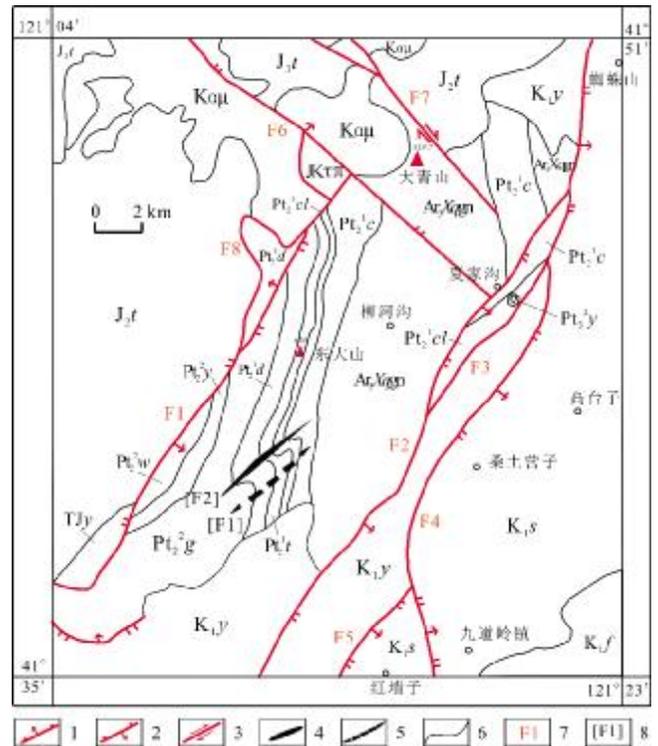


图 1 辽西夏家沟地区地质略图

Fig. 1 Geological sketch map of Xiajiagou area in western Liaoning

1—正断层 (normal fault); 2—逆断层 (reverse fault); 3—平移断层 (strike-slip fault); 4—背斜 (anticline); 5—向斜 (syncline); 6—地质界线 (geological boundary); 7—断层编号 (fault number); 8—褶皱构造编号 (fold number); K_f—白垩系阜新组 (Cretaceous Fuxin fm.); K_s—下白垩统沙海组 (L. Cretaceous Shahai fm.); K_y—下白垩统义县组 (L. Cretaceous Yixian fm.); J₂t—上侏罗统土城子组 (U. Jurassic Tuchengzi fm.); J₂t—中侏罗统髫髻山组 (M. Jurassic Tiaojishan fm.); TJ₃—三叠-侏罗系羊草沟组 (Triassic-Jurassic Yangcaogou fm.); Pt₃¹y—北方南华系下统殷屯组 (放大表示) (Yintun fm. of Lower North Nanhuan sys.); Pt₂²w—蓟县系雾迷山组 (Jixianian Wumishan fm.); Pt₂²y—蓟县系杨庄组 (Jixianian Yangzhuang fm.); Pt₂²g—蓟县系高于庄组 (Gaoyuzhuang fm. of Jixianian sys.); Pt₂¹d—长城系大红峪组 (Changchengian Dahongyu fm.); Pt₂¹t—长城系团山子组 (Changchengian Tuanshanzi fm.); Pt₂¹cl—长城系串岭沟组 (Changchengian Chuanlinggou fm.); Pt₂¹c—长城系常州沟组 (Changzhougou fm. of Changchengian sys.); K_αμ—白垩纪安山玢岩 (Cretaceous andesite porphyry); JKγπ—侏罗-白垩纪花岗斑岩 (Jurassic-Cretaceous granite porphyry); Ar₃Xqgn—新太古代小牵马岭片麻岩 (Neoproterozoic Xiaoqianmaling gneiss)

串岭沟组呈角度不整合接触(图 2、3). 岩性由紫红色中厚层粗砾状冰碛杂砾岩组成^[3],厚约 3 m.

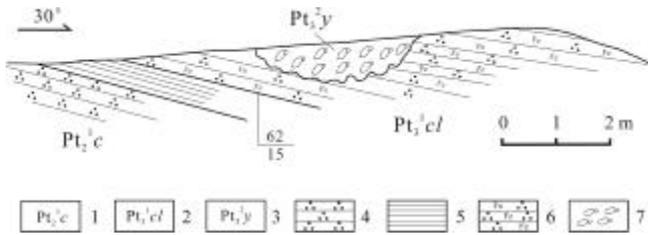


图2 辽西夏家沟地区新元古界北方南华系下统殷屯组剖面图
 Fig. 2 Profile for Yintun Formation of Neoproterozoic Lower North Nanhuan System in Xiajiagou area, western Liaoning
 1—长城系常州沟组 (Changchengian Changzhougou fm.); 2—长城系串岭沟组 (Changchengian Chuanlinggou fm.); 3—北方南华系殷屯组 (Yintun fm. of Lower North Nanhuan sys.); 4—中厚层石英砂岩 (medium-thick quartz sandstone); 5—紫红色砂质页岩 (mauve sandy shale); 6—中薄层铁质石英砂岩 (thin-medium ferruginous quartz sandstone); 7—殷屯组冰碛杂砾岩 (moraine conglomerate of Yintun fm.)



图4 铁岭殷家屯地区殷屯组冰碛砾岩混杂堆积图
 Fig. 4 Moraine conglomerate melange of Yintun Formation in Yinjiatun area of Tieling City

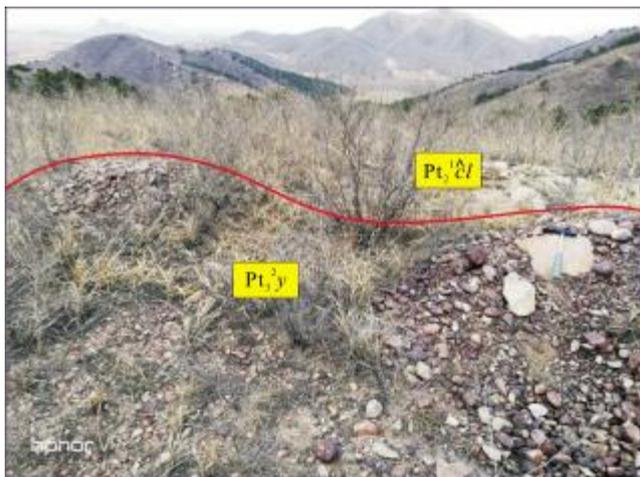


图3 辽西新元古界北方南华系殷屯组冰碛砾岩混杂堆积
 Fig. 3 Moraine conglomerate melange of Yintun Formation of Neoproterozoic Lower North Nanhuan System in western Liaoning
 Pt2^3y—新元古界北方南华系下统殷屯组 (Yintun fm. of Lower North Nanhuan sys., Neoproterozoic); Pt2^3cl—长城系串岭沟组 (Chuanlinggou fm. of Changcheng sys.)



图5 辽南大孤山地区殷屯组冰碛砾岩混杂堆积
 Fig. 5 Moraine conglomerate melange of Yintun Formation in Dagushan area, southern Liaoning

3 辽西夏家沟地区殷屯组与辽北辽南地区殷屯组对比

1) 辽西夏家沟地区新发现的北方南华系下统殷屯组与辽北殷屯(图4)、辽南大孤山(图5)等地区发现的殷屯组从岩性组合、产出特征等均具有广泛的一致性, 呈混杂堆积, 可见砾石压扁、压坑(图6a), 小砾石镶嵌在大砾石中(图6b、c)及砾石上的冰川擦痕(图6d)等冰碛作用现象。

2) 辽西夏家沟地区出露的北方南华系殷屯组岩性

已固结成岩, 不同于第四纪冰川形成的产物(松散堆积)。

3) 辽西殷屯组与下伏长城系串岭沟组呈角度不整合接触(图2), 而辽北、辽南出露的殷屯组则是平行不整合在新元古界永宁组之上。

4 新发现的北方南华系下统殷屯组意义

笔者于2000年4月考察了辽西夏家沟地区中元古界长城系、蓟县系岩石地层单位剖面。以往众多学者认为辽西地区缺失陆相新元古界岩石地层单位沉积, 只见有少量的海相新元古界岩石地层单位沉积(长龙山组、景儿峪组)。笔者在中元古界长城系串岭沟组上部首次发现殷屯组, 虽然该套岩石地层单位出露范围不大, 但具有重要的地质意义。前人认为辽西地区

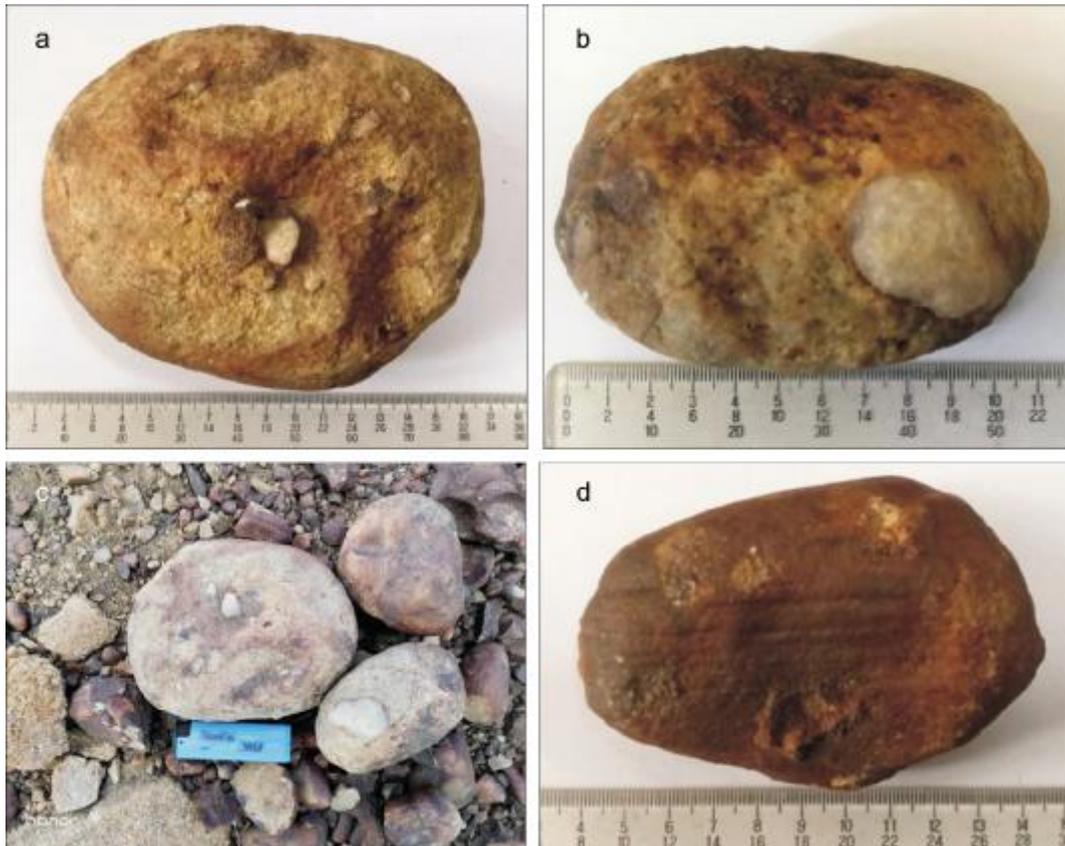


图6 辽西新元古界北方南华系殷屯组冰碛杂砾岩特征

Fig. 6 Characteristics of moraine conglomerates from Yintun Formation of Neoproterozoic North Nanhuan System in western Liaoning
 a—砾石压扁、压坑及小砾石镶嵌在大砾石中 (gravel flaser and pits, with smaller gravel embedded in large one); b—小砾石镶嵌在大砾石中 (smaller gravel embedded in large one); c—砾石压坑及小砾石镶嵌在大砾石中 (gravel pit and smaller gravel embedded in large one); d—冰碛杂砾岩中的擦痕 (striation on moraine conglomerate)

在新元古代时期整体处于抬升期^[4],缺少陆相岩石地层单位沉积. 本次在辽西夏家沟地区新发现殷屯组的存在,从其岩性特征表现出冰碛活动特征,证实了新元古代早期阶段在辽西地区局部存在冰川活动. 该发现的地质意义如下.

1)新发现的辽西地区殷屯组出露长大于 25 m,宽约 3.5 m, 由一套紫红色混杂堆积的冰碛杂砾岩构成(图 3). 岩石已固结成岩,砾石可见压坑、砾石压扁、小砾石镶嵌在大砾石中(图 6),砾石中可见冰川擦痕(图 6d)等冰碛作用现象. 砾石大小在 10 cm × 5 cm,呈混杂堆积(图 3),胶结物由小砾石及粗砂构成. 砾石成分比较单一,主要为石英岩或石英砂岩,成岩物质与中元古界长城系常州沟组石英岩及石英砂岩特征一致. 因此,推断物质来源为中元古界长城系常州沟组.

2)辽西地区殷屯组岩性与铁岭殷屯和大连复州城

地区出露的新元古界北方南华系下统殷屯组岩性进行对比^[5-7],具有完全一致的特征. 即岩性均呈紫红色色调,混杂堆积,可见砾石压扁、小砾石镶嵌在大砾石中,砾石具有压坑、冰川擦痕等冰碛作用特征.

3)辽西夏家沟地区出露的殷屯组形成的大地构造环境不是裂谷中产生的(伸展作用),而是该期冰碛作用的产物.

4)据报道^[8-11],有关学者在辽南地区桥头组和兴民村组中采集了侵入在该地层中的辉绿岩样品. 采用锆石 U-Pb 和 Pb-Pb 法测定同位素年龄,获得了(900±34)~(886±5) Ma 等 4 个年龄数据. 虽然个别年龄数据曲线和谐不十分理想,但提供了一个重要信息,即辽宁地区成冰纪形成的时代大约在 950~850 Ma,推测成冰纪在中国北方地区时限约为 100 Ma. 这导致下步亟待解决的 2 个问题:一是在北方地区是否存在拉伸系的

问题,如果北方地区存在伸系,形成至演化有多长时间?二是北方的成冰期时代可能要比国外和南方形成得早^[12-21],需要采集可靠样品介质,做同位素测年样品加以厘定.上述2个问题有待今后详细研究予以确定.

4 结论

1)在辽西夏家沟地区首次发现陆相新元古界北方南华系殷屯组冰碛砾岩.冰碛砾岩具有紫红色混杂堆积特点,砾石可见压坑,压扁,小砾石镶嵌在大砾石中及冰川擦痕等冰碛作用现象.该发现为讨论辽西地区新元古代地壳演化提供了新的资料.

2)辽西夏家沟地区新发现的北方南华系殷屯组,通过与辽北、辽南出露的北方南华系殷屯组对比,具有较高的一致性,均属于冰碛作用成因,为辽宁地区新元古代第一次冰碛作用的产物.此项新发现对讨论北方地区是否存在拉伸系具有一定的地质意义.

参考文献(References):

- [1]辽宁省地质矿产调查院,辽宁省地质勘查院.中国区域地质志:辽宁篇[M].北京:地质出版社,2017:45-115.
Liaoning Institute of Geological and Mineral Survey, Liaoning Institute of Geological Exploration. Regional geology of China: Liaoning[M]. Beijing: Geological Publishing House, 2017: 45-115. (in Chinese)
- [2]辽宁省地质矿产勘查局.辽宁省岩石地层[M].武汉:中国地质大学出版社,1991:6-57.
Liaoning Bureau of Geology and Mineral Exploration. Lithology and stratigraphy of Liaoning Province[M]. Wuhan: China University of Geosciences Press, 1991: 6-57. (in Chinese)
- [3]地质矿产部地质辞典办公室.普通地质-构造地质分册:上册[M].北京:地质出版社,1983:128-160.
Geological Dictionary Office of Ministry of Geology and Mineral Resources. General geology-structural geology: Volume one[M]. Beijing: Geological Publishing House, 1983: 128-160. (in Chinese)
- [4]赵辰,巩恩普,刘锦,等.华北克拉通北缘东段“开原岩群”的解体及重新认识[J].地质与资源,2018,27(3):209-217,256.
Zhao C, Gong E P, Liu J, et al. Disintegration and reunderstanding of the “Kaiyuan Rock Group” in the east section of the northern margin of North China Craton[J]. Geology and Resources, 2018, 27(3): 209-217, 256.
- [5]卢崇海,田德欣,曹煜昊,等.辽宁新元古界南华系[M].武汉:中国地质大学出版社,2019:1-405.
Lu C H, Tian D X, Cao Y H, et al. Neoproterozoic Nanhua System in

- Liaoning Province[M]. Wuhan: China University of Geosciences Press, 2019: 1-405. (in Chinese)
- [6]卢崇海,邢德和,张耀华,等.辽宁南华系殷屯组及永宁组冰碛岩沉积特征[J].地质与资源,2015,24(6):511-520.
Lu C H, Xing D H, Zhang Y H, et al. Sedimentary characteristics of the tillite in Yintun and Yongning formations, Nanhua System, in Liaoning Province[J]. Geology and Resources, 2015, 24(6): 511-520.
- [7]卢崇海,田德欣,李彪,等.辽北地区新元古代原殷屯组岩石地层单位的重新划分及其地质意义[J].世界地质,2018,37(4):1085-1091.
Lu C H, Tian D X, Li B, et al. Re-division of lithostratigraphic units of previous Neoproterozoic Yintun Formation and its geological significance in northern Liaoning[J]. Global Geology, 2018, 37(4): 1085-1091.
- [8]Tang Q, Pang K, Yuan X L, et al. A one-billion-year-old multicellular chlorophyte[J]. Nature Ecology & Evolution, 2020, 4(4): 543-549.
- [9]Zhang S H, Zhao Y, Ye H, et al. Early Neoproterozoic emplacement of the diabase sill swarms in the Liaodong Peninsula and pre-magmatic uplift of the southeastern North China Craton[J]. Precambrian Research, 2016, 272: 203-225.
- [10]Zhao H Q, Zhang S H, Ding J K, et al. New geochronologic and paleomagnetic results from early Neoproterozoic mafic sills and late Mesoproterozoic to early Neoproterozoic successions in the eastern North China Craton, and implications for the reconstruction of Rodinia[J]. GSA Bulletin, 2020, 132(3/4): 739-765.
- [11]Wan B, Tang Q, Pang K, et al. Repositioning the great unconformity at the southeastern margin of the North China Craton[J]. Precambrian Research, 2019, 324: 1-17.
- [12]耿志洪,曲若达,王然,等.辽西地区常州沟期一团山子期岩相古地理概况[J].地质与资源,2014,23(3):246-250.
Geng Z H, Qu R D, Wang R, et al. A general review of the lithofacies and paleogeography in western Liaoning during Changzhougou Age to Tuanshanzi Age[J]. Geology and Resources, 2014, 23(3): 246-250.
- [13]李晓波,王旖旎,王晗.辽宁兴城中元古界常州沟组砂岩中微生物成因沉积构造[J].沉积学报,2020,38(1):32-45.
Li X B, Wang Y N, Wang H. Microbially induced sedimentary structures (MISS) in Meso proterozoic Changzhougou Formation sandstone, Xingcheng area, Liaoning Province, China [J]. Acta Sedimentologica Sinica, 2020, 38(1): 32-45.
- [14]侯静,马维,王岐,等.简述辽宁中元古界长城系一新元古界青白口系形成与演化[J].地质与资源,2014,23(S1):12-15.
Hou J, Ma W, Wang Q, et al. Analysis on the formation and evolution of Mesoproterozoic Changcheng System to Neoproterozoic Qingbaikou System in Liaoning[J]. Geology and Resources, 2014, 23(S1): 12-15.

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- considerations[J]. *Geochimica et Cosmochimica Acta*, 1984, 48(7): 1523-1534.
- [16] Roser B P, Korsch R J. Determination of tectonic setting of sandstone-mudstone suites using SiO₂ content and K₂O/Na₂O ratio[J]. *The Journal of Geology*, 1986, 94(5): 635-650.
- [17] Maynard J B, Valloni R, Yu H S. Composition of modern deep-sea sands from arc-related basins[C]//Leggett J K. *Trench and Fore-arc Sedimentation*. Geological Society, London, Special Publications, 1982, 10(1): 551-561.
- [18] Floyd P A, Leveridge B E. Tectonic environment of the Devonian Gramscatho Basin, South Cornwall: Framework mode and geochemical evidence from turbiditic sandstones[J]. *Journal of the Geological Society*, 1987, 144(4): 531-542.
- [19] Floyd P A, Winchester J A, Park R G. Geochemistry and tectonic setting of Lewisian clastic metasediments from the Early Proterozoic Loch Maree Group of Gairloch, NW Scotland[J]. *Precambrian Research*, 1989, 45(1/3): 203-214.
- [20] Bhatia M R. Rare earth element geochemistry of Australian Paleozoic graywackes and mudrocks: Provenance and tectonic control[J]. *Sedimentary Geology*, 1985, 45(1/2): 97-113.
- [21] Gu X X, Liu J M, Zheng M H, et al. Provenance and tectonic setting of the Proterozoic turbidites in Hunan, South China: Geochemical evidence[J]. *Journal of Sedimentary Research*, 2002, 72(3): 393-407.
- [22] 郭莹莹. 松辽盆地南部姚家组沉积体系分析[D]. 长春: 吉林大学, 2008: 36-46.
- Guo Y Y. The analysis of the sedimentary system of Yaojia group in the south of Songliao Basin[D]. Changchun: Jilin University, 2008: 36-46.
- [23] 王黎明, 刘长明, 席海银, 等. 松辽盆地南部协尔苏凹陷构造沉积演化与铀成矿关系[J]. *地质与资源*, 2009, 18(4): 274-278.
- Wang L M, Liu C M, Xi H Y, et al. The relationship between structural-sedimentary evolution and uranium mineralization in Xiersu Depression, southern Songliao Basin[J]. *Geology and Resources*, 2009, 18(4): 274-278.
- [24] 白静, 徐兴友, 陈珊, 等. 松辽盆地长岭凹陷乾安地区青山口组一段沉积相特征与古环境恢复——以吉页油 1 井为例[J]. *中国地质*, 2020, 47(1): 220-235.
- Bai J, Xu X Y, Chen S, et al. Sedimentary characteristics and paleo-environment restoration of the first member of Qingshankou Formation in Qian'an area, Changling Sag, Songliao Basin: A case study of Jiyeou 1 Well[J]. *Geology in China*, 2020, 47(1): 220-235.
- [25] 王天琪, 韩江涛, 侯贺晟, 等. 综合物探剖面揭示松辽盆地基底地质与地球物理特征——以过松科二井剖面为例[J]. *中国地质*, 2019, 46(5): 1126-1136.
- Wang T Q, Han J T, Hou H S, et al. The utilization of integrated geophysical profiles to reveal the basement geology and geophysical characteristics of the Songliao Basin: A case study of the profile of Well SK-2[J]. *Geology in China*, 2019, 46(5): 1126-1136.

(上接第 525 页/Continued from Page 525)

- [15] 杨明春, 郑常青, 张梅生, 等. 辽宁兴城地区中元古界长城系大红峪组石英砂岩质砾岩古沉积环境研究[J]. *矿物岩石*, 2012, 32(3): 103-109.
- Yang M C, Zheng C Q, Zhang M S, et al. Study on paleo-sedimentary environment of Dahongyu Formation sandstone conglomerate of Changcheng System of Mesoproterozoic in Xingcheng area, Liaoning Province[J]. *Journal of Mineralogy and Petrology*, 2012, 32(3): 103-109.
- [16] 曲洪祥, 刘杰, 郝明, 等. 辽北震旦系殷屯组层位归属及其区域对比问题探讨[J]. *地质与资源*, 2013, 22(4): 296-298.
- Qu H X, Liu J, Hao M, et al. Stratigraphic assignment and regional correlation of the Sinian Yintun Formation in northern Liaoning[J]. *Geology and Resources*, 2013, 22(4): 296-298.
- [17] 王长青, 范玉柏, 王厚兴. 辽北上前寒武系殷屯组冰碛砾岩地质特征[J]. *辽宁地质*, 1986(2): 136-145.
- Wang C Q, Fan Y B, Wang H X. The geological characteristics of the till conglomerate of the Yintun Formation in the upper Precambrian of the Northern Liaoning[J]. *Liaoning Geology*, 1986(2): 136-145.
- [18] 牛绍武, 辛后田, 王树庆. 中-朝地台南华系的内涵、厘定及其地质意义[J]. *地质调查与研究*, 2017, 40(4): 241-252, 262.
- Niu S W, Xin H T, Wang S Q. Collation on the Nanhua System in China-Korea platform and geological significance[J]. *Geological Survey and Research*, 2017, 40(4): 241-252, 262.
- [19] 杨忠杰. 辽北凡河群时代探讨兼论殷屯组的时代[J]. *辽宁地质*, 1991(4): 356-362.
- Yang Z J. A discussion on the time of Fanhe Group and Yintun Formation of north Liaoning[J]. *Liaoning Geology*, 1991(4): 356-362.
- [20] 杨森, 王东方. 辽北殷屯组的时代归属及其大地构造意义[J]. *吉林地质*, 1990(1): 31-41.
- Yang S, Wang D F. Timing of the Yintun Formation in northern Liaoning province and its significance in tectonics[J]. *Jilin Geology*, 1990(1): 31-41.
- [21] 孙敬书, 王敏成, 任福顺. 辽宁建昌八家子地区中元古界[J]. *中国区域地质*, 1990(3): 206-214.
- Sun J S, Wang M C, Ren F S. The Middle Proterozoic in the Bajiazia area, Jianchang, Liaoning Province[J]. *Regional Geology of China*, 1990(3): 206-214.