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ABSTRACT

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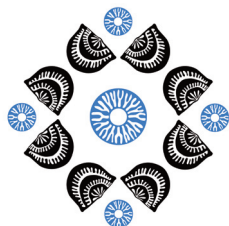
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Distribution pattern of the Ordovician black shale constrained by graptolite zonation in the western margin of the Ordos Block, North-West China

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The graptolitic shale from the late Middle to early Late Ordovician along the western margin of the Ordos Block is a good target bed for shale gas exploration. The horizontal well Zhongping-1 drilled by the Changqing Oilfield Company in 2019 produces a daily gas output of 6.42×10^4 m³ and has proved the tremendous potential for shale gas exploration on the west margin of the Ordos Block. However, strong heterogeneity of total organic carbon (TOC), thickness, porosity and other parameters of the black shale have been revealed at different levels and localities. Therefore, a study of graptolite zonation, aiming to illustrate and predict the temporal and spatial distribution of the black shale in high resolution, is essential for shale gas exploration.

A total of four wells were investigated carefully during the summer of 2022 and 102 samples were collected for the identification of graptolites. The well Qitan-9, the northernmost of the studied wells, is located in the Ordos Etok Banner, Inner Mongolia Autonomous Region. The graptolite faunas can be assigned into two biozones, the *Pterograptus elegans* Biozone and the *Jiangxigraptus vagus* Biozone. The latter is correlated with the *Didymograptus murchisoni* Biozone. The base of the *J. vagus* Biozone is defined at the first appearance datum (FAD) of *J. vagus* at the depth of 4741.42 m.

The well Ren-16 is located in the Etok Front Banner, Inner Mongolia Autonomous Region. The *Nemagraptus gracilis* was found at the depth of 2880.06 m. Additionally, graptolites *Pseudazygograptus incurvus*, *Cryptograptus tricornis* and *Reteograptus geinitzianus* were collected from the level of 2881.93 m, showing also the characteristics of the *N. gracilis* Biozone. The boundary between the *N. gracilis* Biozone and *J. vagus* Biozone is tentatively placed at the depth of 2881.93 m.

The well Li-105 is located in the Yanchi County, Wuzhong City, Ningxia Hui Autonomous Region. Graptolites are well preserved in this drill core. Some of them are preserved in 3D or half relief. *N. gracilis* was found at the depth of 4262.60 m while *Climacograptus bicornis* appears first 5.19 m above this depth. Accordingly, the base of *C. bicornis* Biozone is placed at the FAD of *C. bicornis* at the depth of 4257.41 m.

The well Yintan-2, the southernmost of the studied wells, is located in the Huanxian County, Gansu Province. According to the graptolite fauna, two biozones can be distinguished, the *Climacograptus bicornis* Biozone and the *Nemagraptus gracilis* Biozone. The boundary between these biozones is placed at the FAD of *C. bicornis*, i.e. at the depth of 3866.82 m.

The spatial and temporal distribution of the black shale, as constrained from the graptolite zonation, shows that the black shale is strongly diachronous, getting younger southwards along the western margin of the Ordos Block. The base of black shale is diachronous from the *P. elegans* Biozone in well Qitan-9 to the *J. vagus* Biozone in well Ren-16 and the *N. gracilis* Biozone in wells Li-105 and Yintan-2. The top of the black shale is also diachronous from the *J. vagus* Biozone in the well Qitan-9 to the *N. gracilis* Biozone in the well Ren-16 and *C. bicornis* Biozone in the wells Li-105 and Yintan-2.

The temporal and spatial distribution pattern of the black shale in the Ordos Region of North China shows that the sedimentary facies change from north to south and the depocenter has migrated southwards. This pattern differs significantly from the results of some former studies showing facies belts were being distributed westwards from the platform to shallow shelf, and further on to deep shelf and slope-basin. The distribution pattern of the black shale supports the hypothesis that the Alxa oldland thrust southwards is the driving force for southward migration of the depocenter during the foreland basin evolution process. Neither the peripheral foreland basin associated with the Ordovician arc-land collision event in the North Qinling orogenic belt nor the rift basin hypothesis is consistent with this pattern. The black shale distribution pattern as constrained from the graptolite zonation calls for a reconsideration of the tectonographic and palaeogeographic properties of the western margin of the Ordos Block.