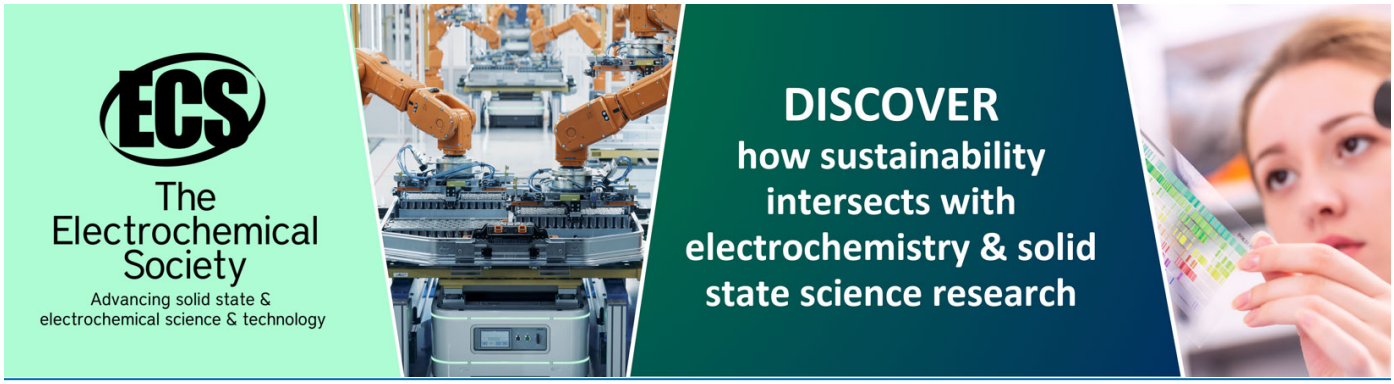
Sedimentary Environment and Geochemical Characteristics of Source Rocks from Later Carboniferous and Middle Permian in Santanghu Basin, NW China



Sedimentary Environment and Geochemical Characteristics of Source Rocks from Later Carboniferous and Middle Permian in Santanghu Basin, NW China

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Abstract. There is a long-term controversy on sedimentary environment of Late Carboniferous-Permian in Santanghu Basin. In this paper, we study on the geochemical characteristics of source rocks from Harjiawu Formation of Upper Carboniferous and Lucaogou Formation of Middle Permian in Santanghu Basin. The results show that the abundance and maturity of organic matter of source rocks in Harjiawu Formation are both high, which shows excellent source rocks. In contrast, the abundance of organic matter from source rocks in Lucaogou Formation is relatively low and the maturity of organic matter is between immature and mature, which suggests good-excellent source rocks. The organic geochemical characteristics indicate the freshwater lacustrine environment of Late Carboniferous, while Lucaogou Formation is the high salinity lacustrine environment. In addition, magmatic-hydrothermal activity may result in the water salinization of Permian.

1. Introduction

Santanghu Basin is located at the conjunction of Siberia, Junggar and Tarim plates, NW China, which is an intracontinental superimposed reformation basin from Late Palaeozoic to Meso-Cenozoic [1,2,3,4]. The Late Paleozoic is the important period of ocean-land transformation and source rocks formation in Santanghu Basin. It is far-reaching significance for oil and gas exploration and development to study on the sedimentary environment of Late Paleozoic.

There is an enormous controversy on sedimentary environment of Later Carboniferous-Permian in Santanghu Basin [5,6,7,8]. Some scholars believe that it's a residual sea [9], while others think it's a typical paralic epicontinental lake [10,11]. This paper focus on the characteristics of geochemistry, carbon and oxygen isotope of source rocks from Harjiawu Formation in Upper Carboniferous and Lucaogou Formation in Middle Permian to discuss the sedimentary environment of Late Paleozoic in Santanghu Basin.

2. Geological setting and lithological association

Santanghu Basin is located in the East Junggar, and extends in NW-SE direction (Fig.1). Santanghu Basin is composed of two thrust belts and one center depression zone. The center depression zone can be divided into five secondary depressions, such as Malang depression, Tiaohu depression, Hanshuiquan depression, and Naomaohu depression, and four secondary uplifts, like Shitoumei uplift, and Fangfangliang uplift.

Magmatic-hydrothermal activity is intensive in Santanghu Basin from Carboniferous to Permian, and form a special rock assemblage in this geological background. The statigraphy of Later Carboniferous-Middle Permian are Harjiawu Formation, Kalagang Formation, Lucaogou Formation and Tiaohu Formation from bottom to top. Harjiawu Formation of Upper Carboniferous contain basic-intermediate volcanic rocks and pyroclastic rocks [3,12,13], while Kalagang Formation in Lower Permian is fresh intermediate and acidic rocks [14]. Lucaogou Formation in Middle Permian develop laminar sedimentary rocks, with hydrothermal exhalite [15,16,17]. Tiaohu Formation in Middle Permian is mainly massive basalts, clipping a small amount of picrite rocks and andesite [1,4] . We selected 4 wells of Lucaogou Formation and 3 wells of Harjiawu Formation from full coring wells in the Malang and Tiaohu depression, which are located in the middle of Santanghu Basin.

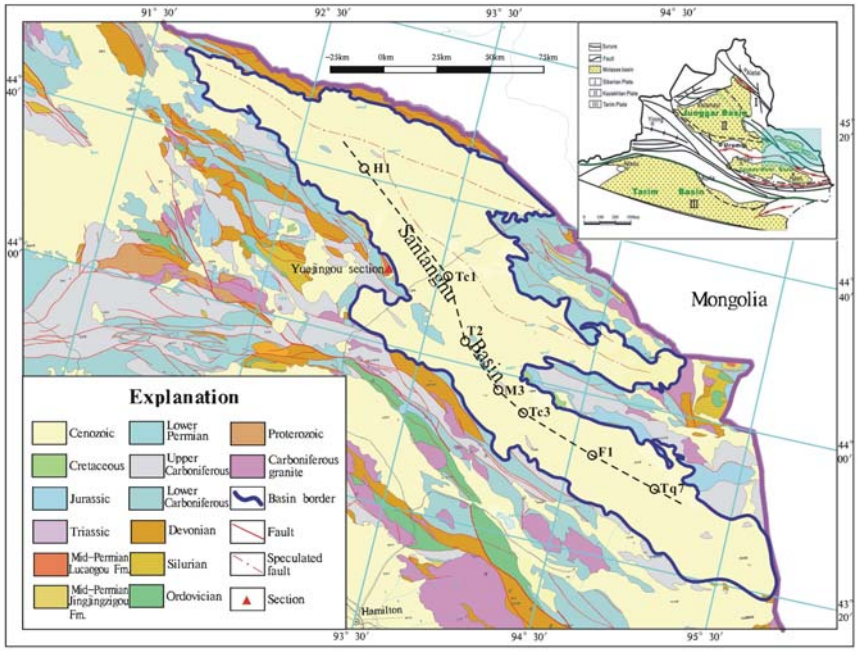

Figure 1. The simplified tectonic map of Santanghu Basin (modified after [15])

3. Distribution and mineral composition of source rocks

Harjiawu Formation in Upper Carboniferous is widely distributed in the study area with a large thickness. The source rocks in Harjiawu Formation has small thickness, as thin interbed of volcanic rocks. The source rocks consist of tuff mudstone and a little limestone. The tuff mudstone is composed of quartz, plagioclase, and minor amounts of clay minerals, such as smectite and chlorite (Fig. 2a,b,c,d).

The Lucaogou Formation in Upper Permian mainly distributes in the Malang and Tiaohu depression. The thickness ranges from 800m to 17m, mainly at 50-200 m, 300-400 m, and 500-600m. The source rocks are dolomitic mudstone, lamellar dolomite, argillaceous dolomite, and little tuffaceous mudstone. The mineral composition of dolomitic mudstone is quartz, k-feldspar and carbonate minerals (dolomite, iron dolomite, calcite) (Fig. 2e,f,g,h), while lamellar dolomite is maily composed of dolomite with little quartz, k-feldspar and smectite (Fig. 2i,j,k,l).

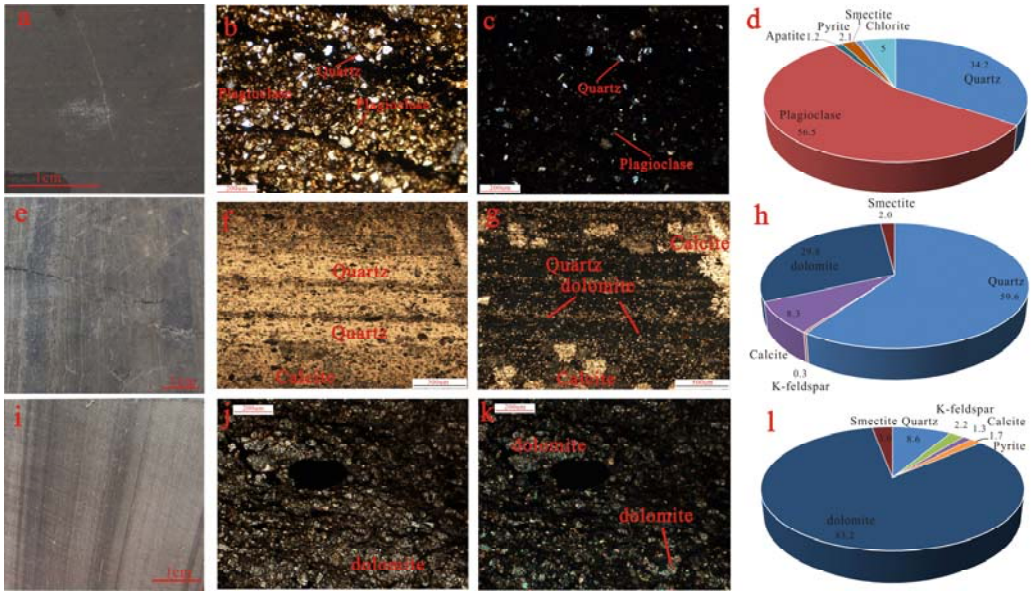

Figure 2. Photos from hand specimen and thin section, and the pie charts of mineral composition for source rocks in Santanghu Basin

a,b,c,d is the samples of tuff mudstone in Harjiawu Formation. e,f,g,h is the dolomitic mudstone from Lucaogou Formation. I,j,k,l is from lamellar dolomite of Lucaogou Formation.

4. Geochemical Characteristics of source rocks

4.1. Organic geochemistry

The average values of TOC are 7.63% in Harjiawu Formation, and 3.57% in Lucaogou Formaiton. On the S_2-TOC source rock assessment diagram, the samples of source rocks from Harjiawu Formation mainly plot in the excellent source rocks field, while Lucaogou Formation are in the area of good–excellent source rocks with little fair source rocks (Fig. 3). The mature of source rocks in Harjiawu Formation is higher than that of Lucaogou Formation. The kerogen type of Harjiawu Formation belong to type Ⅱ-Ⅲ, which is different with type Ⅰ - Ⅱ kerogen of Lucaogou Formation on HI-T_{max} diagram (Fig. 4).

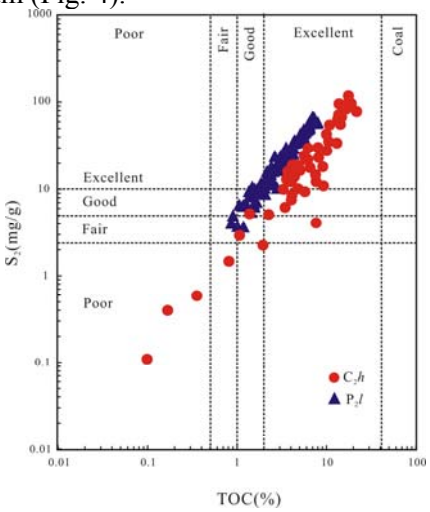

Figure 3. Diagram of TOC Vs. S_2 for source rocks (base map from [18])

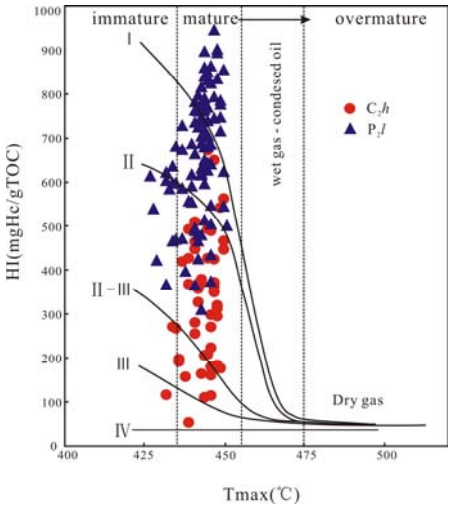

Figure 4. Diagram of Tmax Vs. HI of source rocks（base map from [19]）

Organic geochemistry features of source rocks in Harjiawu Formation shows high Pr/Ph value(between 1.10 and 3.01), low gammacerane abundance and very low β-carotane abundance, which reflects a freshwater and weak reduction-weak oxidizing environment in Late Carboniferous (Fig.5, Fig.6a). Characteristics of biomarkers in saturated hydrocarbon of source rocks in Lucaogou Formation show low Pr/Ph value(between 0.7-1.5), extremely high β-carrots alkanes, gammacerane and long chain tricyclic terpane abundance(Fig.6b), which indicate a salinized and reductive environment in Middle Permian(Fig.5).

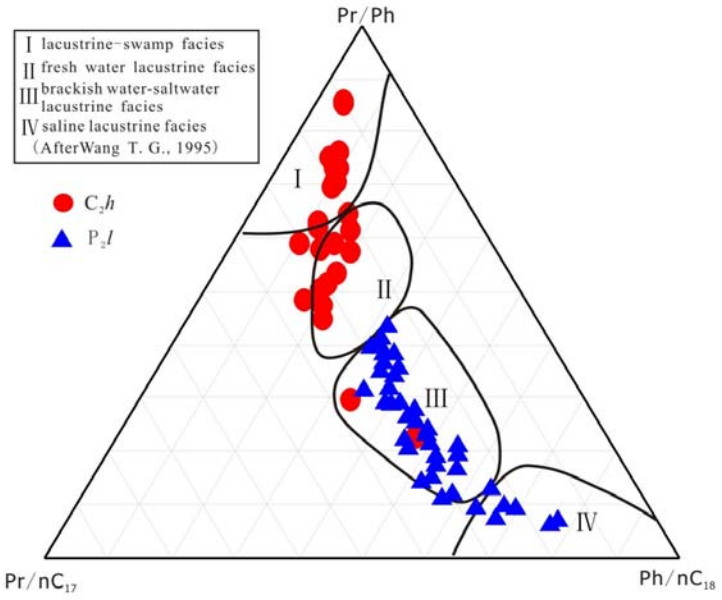

Figure 5. Ternary plot of Pr/Ph-Pr/nC_{17}-Ph/nC_{18} in Harjiawu Formation and Lucaogou Formation

4.2. Element geochemistry and stable carbon and oxygen isotope

Sr/Ba ratio of source rocks in Harjiawu Formation is less than 1.5, and B content is less than 300×10^{-6}. Z values calculated from carbon and oxygen isotope of limestone are between 94.67 and 116.12, with an average of 102.18. All these data suggest low salinity and freshwater environment of Late Carboniferous.

Sr/Ba ratio of source rocks in Lucaogou Formation is from 10 to 13.86, and B content is 463×10^{-6}. Z values of dolomite in Yuejingou outcrop range from 129.03 to 141.43, with an average of 134.6. All data above suggest the saltwater environment with high salinity in Middle Permian, which is consistent with the results of organic geochemistry analysis.

5. Discussion

5.1. Sedimentary environment

Based on the study of lithological association, organic geochemistry, element geochemistry, and stable carbon and oxygen isotope, and integrated with analysis of geotectonic evolution, we think Late Carboniferous is freshwater lacustrine environment, while the environment of Middle Permian exsit different views, including residual sea and paralic epicontinental lake. The lithofacies-paleogeography research show that sea has retreated to the Yanchi bay. In addition, the fauna of Lucaogou formation is dominated by the combination of brackish palaeoniscoid and ostracoda of *Tomiella-Kelameilia-Panxiania* [11], which show the saltwater lacustrine environment of Middle Permian.

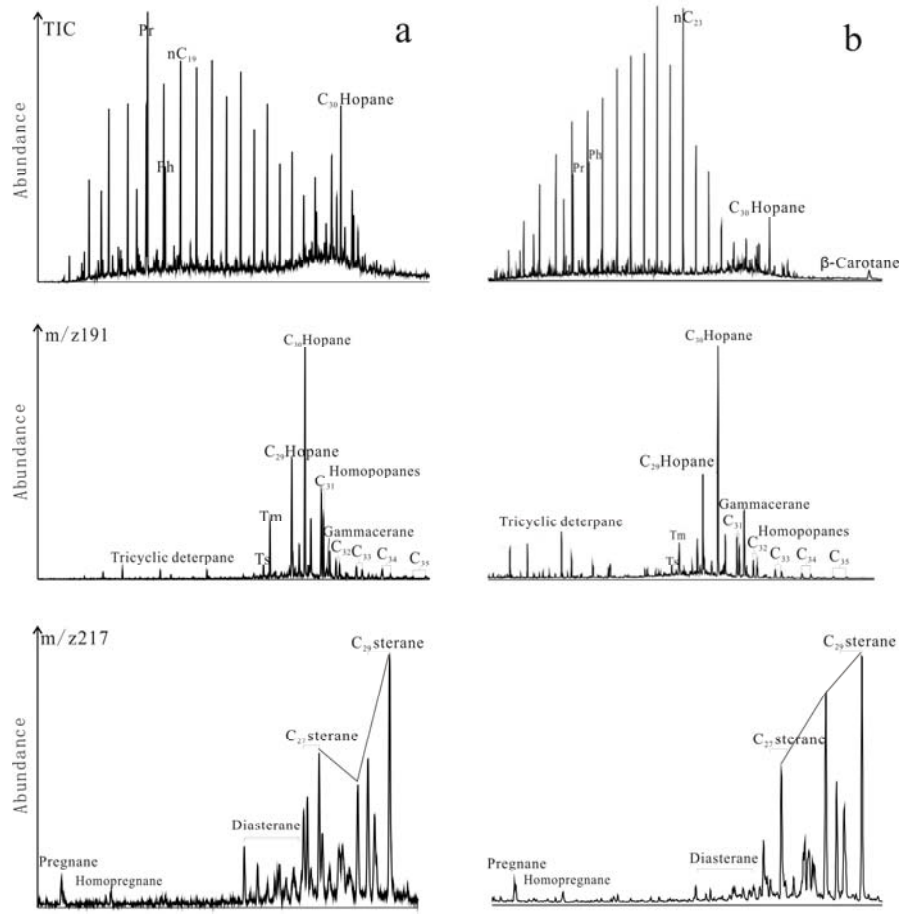

Figure 6. (a)TIC, m/z 191, m/z217 chromatograms of saturated hydrocarbon of the source rocks in Harjiawu Formation.(b) TIC, m/z 191, m/z217 chromatograms of saturated hydrocarbon of the source rocks in Lucaogou Formation.

5.2. The reason for water salinization of Middle Permian

The water salinization is mainly controlled by dry climate, intrusion of sea water and magmatic-hydrothermal activity [20]. The plant fossil and sporopollen assemblage of Lucaogou Formation reflect the features of Angara flora and represent the warm-humid climate [11]. In addition, seawater has retreated from study area, which show that seawater intrusion is impossible. Lucaogou Formation in Middle Permian are between two sets of volcanic rocks, which develop hydrothermal eruptive sedimentary rocks with abundant magmatic and hydrothermal minerals, such as augite, analcite, dolomite and calcite [15, 16, and 17]. These magmatic-hydrothermal minerals added into the water and released Fe, Mg and Ca ions, which may lead to the water concentration and salinization increase. We think the water salinization of Middle Permian may be affected by magmatic- hydrothermal activity.

Acknowledgments

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