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Pore-infillings Characteristics of Siliceous Rocks in Nadanhada Terrane

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Abstract: In order to reveal the mineral filling sequence and fluid action process in the dissolution pores of the bedded siliceous rocks in the Dongrong Formation of the Sanjiang Basin, the petrological characteristics, geochemical analysis and testing methods were comprehensively applied to research, and the databases of major amount and rare earth elements of siliceous rocks were established, and the sedimentary environment, origin and source of siliceous materials were systematically judged again. The results show that the siliceous rocks of the Nadanhada terrane exposed in the Sanjiang Basin are biogenic. On the basis of early metasomatic microbial dolomite, the layered siliceous rocks have experienced six stages (three fluid properties) of fluid filling, including magnesium rich hydrothermal fluid, siliceous hydrothermal fluid, asphalt and siliceous hydrothermal fluid. Siliceous rock cavity filling material is the product of fluid rock coupling under different temperatures, concentrations and reaction systems under the control of different tectonic movements and hydrocarbon maturation.

Keywords: Siliceous rocks, Geochemistry, pore-infillings, Nadanhada terrane.

1. Introduction

Siliceous rocks are special rocks rich in silicon dioxide (more than 70%) formed by chemical, biological and biochemical processes or volcanism, which are distributed in different times and environments around the world. The siliceous rocks of different origins, including biological, metasomatic, volcanic and hydrothermal origin, have obvious differences in source of diagenetic materials, diagenetic environment, and diagenetic physicochemical conditions [1]. Sanjiang Basin is located in the east of Heilongjiang Province, China, between Yitong Shulan Fault Zone and Dunmi Fault Zone. It is a Mesozoic Cenozoic superimposed residual basin, mainly developing the Middle Jurassic Suibin Formation, Upper Jurassic Dongrong Formation, Lower Cretaceous Chengzihe Formation, Muling Formation, Dongshan Formation, Upper Cretaceous Hailang Formation, Qixinghe Formation, Yanwo Formation, Paleogene Baoquanling Formation and Neogene Fujin Formation. Sanjiang Basin is divided into three primary structural units from west to east, namely Suibin Depression, Fujin Uplift and Qianjin Depression [2-4].

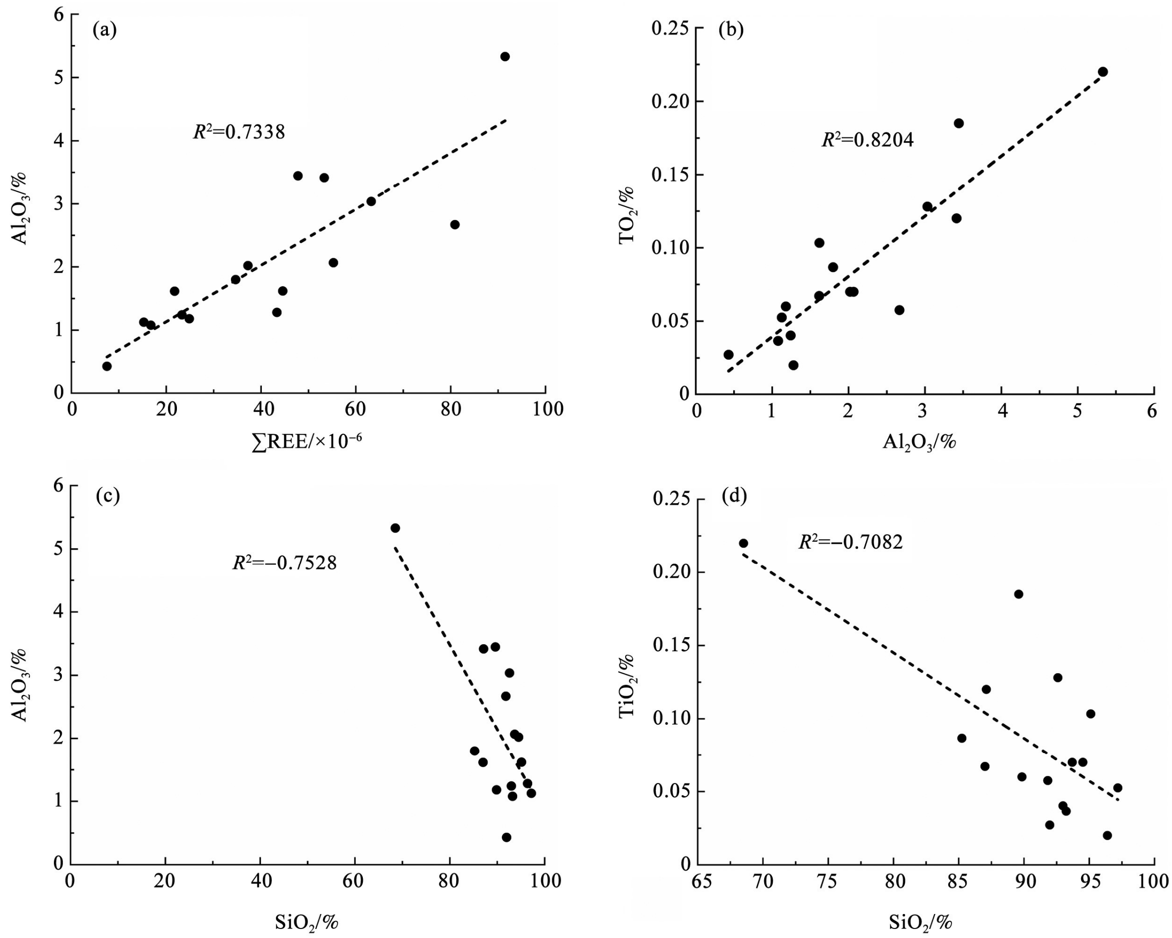
2. Genesis of Siliceous Rocks in Nadanhada Terrane

The siliceous rocks of Nadanhada terrane are biogenic in Sanjiang Basin and hydrothermal in the southern marginal basin. Sanjiang area is a biogenetic siliceous rock driven by the long-term evolution of ancient ocean and ancient climate [5]. The siliceous rock mudstone rhythmic layer is accumulated in the continental shelf basin widely distributed in the north and south margins of Sanjiang Basin, and laterally, it is simultaneously and heterogeneously deposited with the Maokou Formation dominated by carbonate rocks. The lithostratigraphy, radiolarian biostratigraphy and geochemical characteristics of the Dongrong Formation in the northern margin of the Sanjiang Basin suggest that these siliceous rocks are biogenic in general, the sedimentary environment is continental shelf, and the redox status in the Xiasanjiang area shows the change of aerobic secondary oxygen anoxic, while the southern part of the Sanjiang area shows the change of aerobic anoxic secondary oxygen.

The correlation diagram of Al_2O_3 and Σ REE contents shows that there is a significant positive correlation between them (Figure 1a), that is, terrigenous materials play an important role in controlling the formation of siliceous rocks; Al_2O_3 and TiO_2 contents are highly correlated (R_2=0.8204) (Figure 1b), and negatively correlated with SiO_2 contents (R_2=-0.7528, -0.7082) (Figure 1c, d), indicating that the siliceous content decreases with the increase of terrigenous materials, that is, there is no siliceous contribution of terrigenous materials to siliceous rocks [6-7].

3. Petrological Characteristics

The siliceous rocks in the area are mostly interbedded with microcrystalline dolomite and algal bound microbial dolomite. Among them, the siliceous rocks of the third member of Dongrong Formation are mainly distributed in centimeter scale thin layers, widely developed in the middle and upper dolomite and dolomitic siliceous rocks, partially in lenticular or nodular shape sandwiched in silty mudstone or shale, and occasionally mixed with sandy dolomite and microbial dolomite; The siliceous rocks in the fourth member of Dongrong Formation are mainly characterized by zonal metasomatism, with a small amount distributed along fractures and karst caves. The observation of hand specimens and rock cores shows that most of the layered siliceous rocks are gray to gray black, dense and hard, slightly greasy, with shell like fractures and weakly affected by weathering. It can be seen that the gray algal bound dolomite in the siliceous rock has developed dissolution holes, which are fully filled to half filled with siliceous material. The quartz crystal filled in the cave is coarse and well shaped. A large number of fine fractures with vertical laminae can be seen in laminated siliceous rocks.



(a) Plots show correlations betweenAl_2O_3 and ∑REE;
(b) Plots show correlations between TiO_2 and Al_2O_3;
(c), (d) Plots show correlations betweenAl_2O_3, TiO_2 and SiO_2 contents of bedded cherts
Figure 1. Diagrams to identify the origin of cherts

Microscopic observation shows that there are a large number of fractures and dissolution holes formed along the fractures in the siliceous rocks. The siliceous rocks contain a small amount of residual microbial dolomite matrix, and they are interlaced with microcrystalline quartz formed by metasomatic microbial dolomite. A large number of dolomite crystal mold holes (10-20μm) It is distributed in siliceous rocks in isolation; Karst caves are occasionally seen, and black asphalt is commonly seen on the wall. The pores are mainly filled with silica, occasionally filled with calcite/dolomite and fluorite minerals; From the edge of the hole to the inside, the crystalline degree of the silicon becomes better and the crystal becomes larger; The siliceous materials filled in the holes include microcrystalline quartz, fibrous chalcedony, fine to medium crystal quartz and coarse to giant crystal quartz; Some siliceous rock fractures are relatively developed, and the fractures are half filled with aphanitic siliceous.

Radiolarian assemblages in the T-J boundary strata of the Nadanhada terrane in northeastern China are shown in Figure 2.

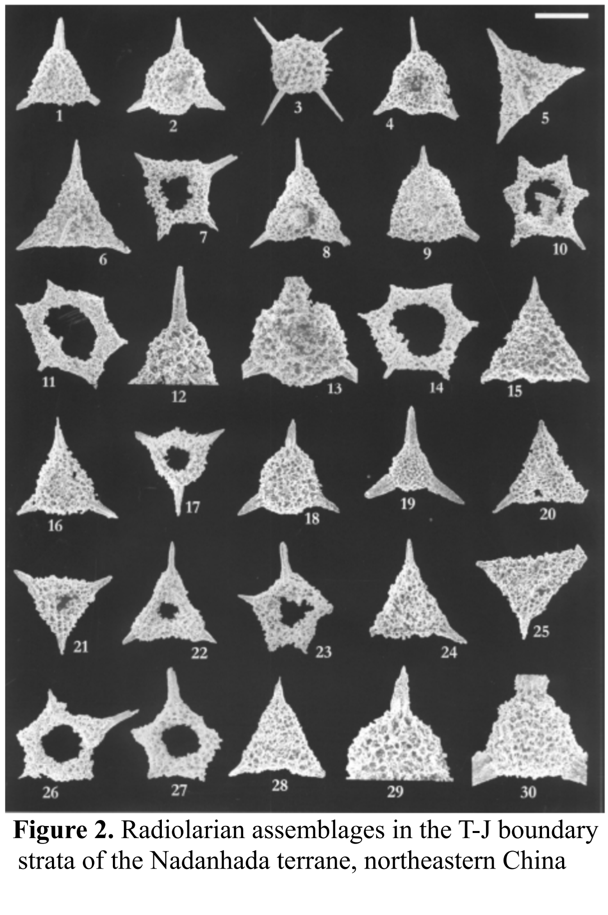


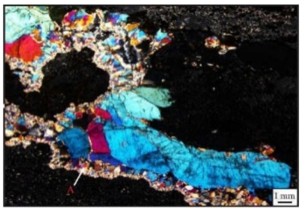
Figure 2. Radiolarian assemblages in the T-J boundary strata of the Nadanhada terrane, northeastern China

4. Mineral Filling Sequence

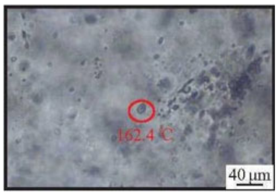
According to the multi-phase mineral growth morphology and generation sequence in the pores, the minerals filled in the pores of siliceous rocks in the area are divided into five generations: dolomite → calcite → microcrystalline quartz → fibrous chalcedony → fine medium crystal quartz → coarse giant crystal quartz. Among them, dolomite/calcite and siliceous filling assemblage are mainly used in karst caves, and multistage siliceous filling assemblage is mainly used in karst caves. There are 3~4 typical generations of fillings in siliceous rock pores in this area.

Dolomite crystals and microbial (bacterial) residues can be clearly seen under the thin sections of siliceous rocks, indicating that the siliceous rocks are caused by microbial dolomites at the early stage of metasomatism. The well preserved dolomitic rhombic crystal mold holes can be seen under the scanning electron microscope. Most mold holes are not filled with other minerals, and few are partially filled with clay minerals and quartz.

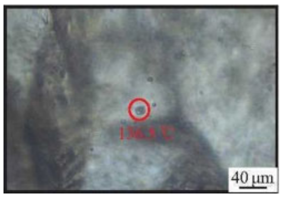
The inclusion temperature measurement can effectively determine the crystal formation temperature and salinity. Except for the inclusion in microcrystalline quartz and dolomite crystal which is too small to measure the homogenization temperature, it can be measured in other fillings (Figure 3). The homogenization temperature test of fluid inclusions shows that the fluid inclusions in the siliceous rocks in the area are saline solution inclusions, which are gas and liquid two-phase at normal temperature, and are mostly distributed in minerals in elliptical isolated shape, with a size of 2~10 μm. Gas liquid ratio is 10%~20%. Among them, the homogenization temperature of fluid inclusions in fibrous chalcedony is 160~170 ℃, with an average of 164.5 ℃ (Figure 3b); The homogenization temperature of the fluid inclusion of fine medium crystal quartz is 120~140 ℃, the average is 135.6 ℃, the freezing point temperature is -17.8~-10.8 ℃, and the corresponding salinity is 20.82%; Although the peak homogenization temperature of fluid inclusions in fine medium crystal quartz is not prominent, their morphology is similar and they should belong to the same phase of fluid products (Figure 3c, Figure 3d). The homogenization temperature of fluid inclusions in megacryst quartz is 120~160 ℃, the average is 139.4 ℃, the freezing point temperature is about - 15.6 ℃, and the calculated salinity is 19.13% (Figure 3e).



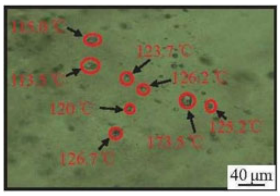
(a) Typical location of inclusion characteristics temperature measurement



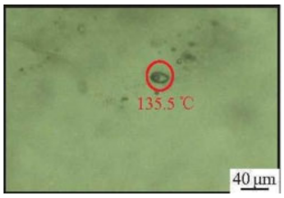
(b) Fibrous chalcedony inclusion characteristics



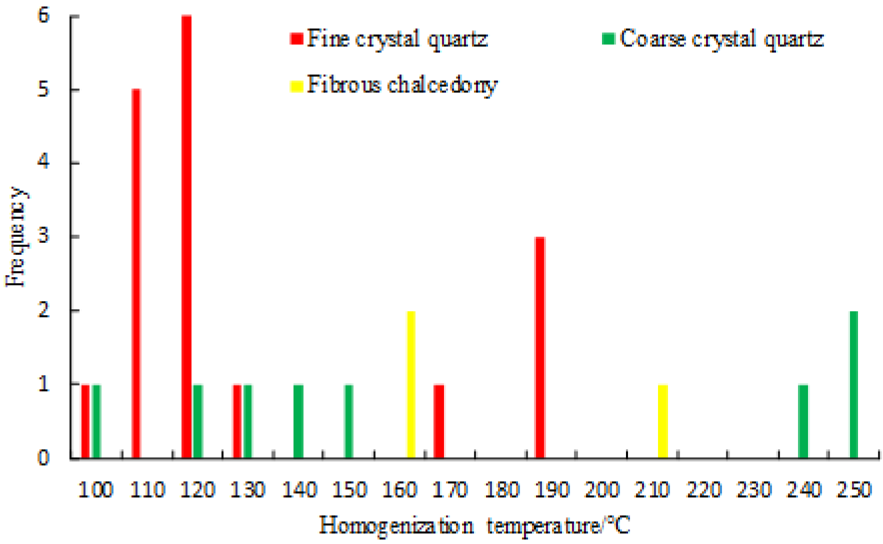
(c) Fine crystal quartz inclusion characteristics



(d) Medium crystal quartz inclusion characteristics



(e) Coarse crystal quartz inclusion characteristics



(f) Homogeneous temperature histogram of fluid inclusions

Figure 3. Inclusion characteristics and homo-temperature histogram of siliceous fillings in pores of Dengying Formation

5. Fluid Action and Filling Mechanism

The siliceous rocks are obviously controlled by fluid action in the process of formation, dissolution and sedimentation, and the fillings can effectively indicate the changes of fluid properties during the geological history. Combined with petrology, mineral filling sequence and inclusion temperature measurement, it is believed that the layered siliceous rocks of Dongrong Formation in Sanjiang Basin experienced six stages of fluid action after their formation.

Because the Precambrian tidal flat environment may be affected by evaporation, resulting in the enrichment of siliceous materials in seawater, which is conducive to the precipitation of layered siliceous rocks (except for subtidal and open sea environments), silicified residual common micron dolomite inclusions formed by the replacement of carbonate rocks in early diagenetic period. The siliceous rocks of Dongrong Formation in the area have the microstructure of carbonate rock metasomatism and direct precipitation of silicon dioxide (completely mineralized and cemented). The siliceous rocks metasomatized dolomite have a grain size of 6-8 μ M microcrystalline quartz is formed, and most of the siliceous rocks are characterized by microbial dolomite and microcrystalline rock interbedding or disorderly metasomatism. The degree of silicification is controlled by microbial dolomite micro fabric and microbial community.

In general, the layered siliceous rocks in Sanjiang Basin, on the basis of early metasomatic microbial dolomite, have experienced six stages (three fluid properties) of fluid filling, including magnesium rich hydrothermal fluid, siliceous hydrothermal fluid, asphalt and siliceous hydrothermal fluid. Siliceous rock cavity filling material is the product of fluid rock coupling under different temperatures, concentrations and reaction systems under the control of different tectonic movements and hydrocarbon maturation. Among them, the magnesium rich hydrothermal fluid is dominated by initial dissolution and later filling transformation; Early siliceous hydrothermal fluid metasomatized dolomite to form calcite metasomatism, and then dolomite mold holes were formed, which has a certain transformation significance for siliceous rock reservoirs. If it is effectively matched with faults in the late diagenetic stage, it is expected to make a breakthrough; The later siliceous fluid is mainly filled, which is the main factor leading to the final densification of the reservoir.

6. Conclusion

The siliceous rocks of the Nadanhada terrane exposed in the Sanjiang Basin are of biological origin. On the basis of the early metasomatic microbial dolomite, the layered siliceous rocks have experienced six stages (three fluid properties) of fluid filling, including magnesium rich hydrothermal fluid, siliceous hydrothermal fluid, asphalt and siliceous hydrothermal fluid. Siliceous rock cavity filling material is the product of fluid rock coupling under different temperatures, concentrations and reaction systems under the control of different tectonic movements and hydrocarbon maturation.

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