GEOSCIENCE FRONTIERS 3(5) (2012) 669–680

available at www.sciencedirect.com

China University of Geosciences (Beijing)

GEOSCIENCE FRONTIERS

journal homepage: www.elsevier.com/locate/gsf

RESEARCH PAPER

Petrologic characteristics and genesis of dolostone from the Campanian of the SK-I Well Core in the Songliao Basin, China

Xiang Gao [a,b,*], Pingkang Wang [c], Dairong Li [a], Qiang Peng [a], Chengshan Wang [a], Hongwen Ma [b]

[a] *Science Research Institute, China University of Geosciences, Beijing 100083, China*
[b] *National Laboratory of Mineral Materials, China University of Geosciences, Beijing 100083, China*
[c] *Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China*

Received 2 August 2011; accepted 9 January 2012
Available online 14 January 2012

KEYWORDS
Dolostone;
Genesis;
Cretaceous Nenjiang Formation;
SK-I well core;
The Songliao Basin;
China

Abstract The well SK-I in the Songliao Basin is the first scientific borehole targeting the continental Cretaceous strata in China. Oval concretions, thin laminae and beds of dolostone are found intercalated within mudstone and organic-rich black shale in the Nenjiang Formation of Campanian age. Low ordered ferruginous dolomite is composed of euhedral–subhedral rhombs with cloudy nucleus and light rims formed during the diagenesis, which are typical features of replacement. The heavy carbon isotopes ($\delta^{13}C_{PDB}$ − 1.16–16.0) are results of both the fermentation of organic matter by microbes and degassing of carbon dioxide during the period of diagenesis, and the presence of light oxygen isotopes ($\delta^{18}O_{PDB}$ − 18.53 ∼ −5.1) is a characteristic feature of fresh water influence which means the carbonate may have been altered by ground water or rainwater in the late diagenesis. Marine water incursions into the normally lacustrine basin have been proved by both the salinity of *Z* value and the occurrence of foraminifera in the same strata where dolomite occurs. Pyrite framboids observed by SEM are usually enclosed in the dolomite crystals or in the mudstones, supporting the sulfate reducing bacteria (SRB). The formation of both dolomite and pyrite are associated with marine water incursions, which not only supply magnesium

* Corresponding author.
E-mail address: xgao@cugb.edu.cn (X. Gao).

Peer-review under responsibility of China University of Geosciences (Beijing).
doi:10.1016/j.gsf.2011.12.014

ELSEVIER
Production and hosting by Elsevier

ion for dolomite, but also result in limited carbonate precipitation in the basin. The presence of pyrite framboids indicates the development of an anoxic environment associated with salinity stratification in the lake. The dolomite in the Nenjiang Formation is the results of marine water incursions, diagenetic replacement of calcareous carbonate and sulfate reducing bacteria (SRB).

1. Introduction

Dolomite has been extensively studied since it was described for the first time by French naturalist Deodalt de Dolemieu in 1791 (Hardie, 1987; Warren, 2000). It is the ubiquitous component of sedimentary strata from Precambrian to Cenozoic, but volumetrically less represented in younger strata (Given & Wilkinson, 1987; McKenzie, 1991). The major ambiguity of the dolomite formation mechanism is that recently formed dolomite has not yet been found, although "protodolomite" has been reported from Bahamas (Shinn et al., 1965) and Coorong lagoon of Australia (Von Der Borch and Jones, 1976). Stoichiometric dolomite has not yet been synthesized in the laboratory under normal temperature and pressure conditions, and also has not been found precipitated in modern lakes. Thus the question is still open, are all the dolomites formed by secondary replacement, or a part of them remains unchanged? The genetic models proposed for dolomite origin include at least 15 different hypotheses (Jiang, 2003). Therefore, the genesis of dolomite remains wide open and a subject of many sedimentary studies.

The Songliao Basin in northeast China is one of the largest Cretaceous continental rift basins in the world, and the largest oil-bearing basin in China. Dark mudstone in the Nenjiang Formation is one of the most important oil production layers, and it occurs interbedded with thin layer dolostone. However, the genesis of dolostone has been unclear since the basin was explored in 1950's (Yang et al., 1985). Studying the characteristics of dolostone formed in the Nenjiang Formation has a great significance in understanding the paleo-environment and the formation mechanism of petroleum.

2. Geological setting and sample description

The SK-I well with two drillings (south and north) is located in the Qijia-Gulong Sag which is one of the deposition centers of the Songliao Basin, northeast of China (Fig. 1). The basin is of rift origin, infilled with mainly lacustrine sedimentary strata of Cretaceous age, and deposited in moderate-deep to deep lake environments. The lacustrine dolostone are mainly found in the first and second members of the Nenjiang Formation in SK-I(s), Campanian in age (Jilin, 1993).

The well core of the dark mudstone encloses thin laminae and oval concretions of dolostone, limestone, small amount of siltstone, muddy siltstone and silty mudstone. Dolostone occurs as layers of few millimeters to several centimeters thick, which are interbedded with mudstone. The boundaries between dolostone layers and surrounding mudstone are sharp. Dolostone as oval shape concretions embedded within the mudstone are of small size (<5 mm). Both lithologies are found intercalated within dark mudstone and organic-rich black shale of the Nenjiang Formation. Because thin dolostone layers are always interbedded with mudstone, it is rather difficult to separate pure dolostone from mudstone. Therefore, only 15 samples were collected from the core of the first member of the Nenjiang Formation in SK-I(s), including 7 pure dolostone, 4 pure limestone and 4 mudstone samples (see Table 1). Distribution of the 11 carbonate samples is shown in Fig. 2. It shows that carbonate samples are mainly from layers, only two samples are from oval concretions.

3. Experimental methods and conditions

X-ray diffraction (XRD) was performed in the X-ray Laboratory of the China University of Geosciences, Beijing, on the D/Max-RC Powder Diffractometer (Rigaku). The experimental conditions are: Cukα1, graphite monochromator, scintillation counter, voltage at 40 kV, current at 80 mA, continuous scan, slit system DS = SS = 1°, and RS = 0.15 mm. Samples were ground into 300 mesh grains in agate bowl, packed in glass indentation, and pressed into plate type. The scan range is 3−70° 2θ, and scan speed is 8°/min.

The main chemical elements were analyzed in the Electron Probe Laboratory, Chinese Academy of Geological Sciences, Beijing, using a JXA-8800R Electron Probe. Experimental conditions are: voltage at 20 kV, current at 20 mA, spot diameter 5 μm. Samples were polished into smooth face, and sprayed with carbon for measurement.

The trace elements and rare earth elements were measured in the Laser Plasma Laboratory, China University of Geosciences, Beijing, using an Agilent 7500 plasma mass spectrometer (ICP-MS). The standard sample AGV2 from the United States Geological Survey was used, and the rock samples R1 and R2 from the National Research Center of Geological Analysis, China were used for quality control during the analysis. The experimental error is in the range of 10%−15% for Ni, Co, Cr, Sc and <10% for other elements.

Carbon and oxygen stable isotopes were analyzed in the Isotope Laboratory of China University of Geosciences, Beijing, using a MAT253 gaseous isotopic spectrometer. Phosphoric acid method was used, and the environmental conditions are temperature at 22 °C and humidity of 30%. Constant temperature reaction is at 90 °C for 2 h. The size of sample grains is about 74 μm, and analytical precision is ±0.2‰.

Scanning electron microscopic (SEM) analysis was performed in the Physics College of Peking University, and the Key Laboratory of Continental Dynamics, Chinese Academy of Geological Sciences. The apparatus are Amray 1910FE scanning electron microscope at Peking University and JSM-5610LV SEM of Japanese JEOL with INCA energy dispersive spectrometer (EDS) of British Oxford Company in Chinese Academy of Geological Sciences. The accelerating voltage is 20 kV, the focusing distance is 20 mm, and the beam diameter is 40 nm. Pure metal Co is used to optimize the EDS system. The EDS method was used to analyze chemical elements of the mineral. To improve the imaging performance, the fresh faces of cross sections were coated with carbon for testing.