Applied Geochemistry 24 (2009) 1724–1738

Contents lists available at ScienceDirect

Applied Geochemistry

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

Petrology and isotopic geochemistry of dawsonite-bearing sandstones in Hailaer basin, northeastern China

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ARTICLE INFO

Article history:
Received 17 April 2008
Accepted 4 May 2009
Available online 13 May 2009

Editorial handling by R. Fuge

ABSTRACT

The CO_2 gas reservoir sandstones in the Hailaer Basin contain abundant dawsonite and provide an ideal laboratory to study whether any genetic relationship exists between dawsonite and the modern gas phase of CO_2. The origins of dawsonite and CO_2 in these sandstones were studied by petrographic and isotopic analysis. According to the paragenetic sequence of the sandstones, dawsonite grew later than CO_2 charging at 110–85 Ma. The dawsonite $\delta^{18}O$ value is 7.4‰ (SMOW), and the calculated $\delta^{18}O$ values of the water present during dawsonite growth are from −11.4‰ to −9.2‰ (SMOW). This, combined with the $NaHCO_3$-dominated water linked to dawsonite growth, suggests meteoric water being responsible for dawsonite growth. The $\delta^{13}C$ values of gas phase CO_2 and the ratios of $^3He/^4He$ of the associated He suggest a mantle magmatic origin of CO_2-rich natural gas in Hailaer basin. Dawsonite $\delta^{13}C$ values are −5.3‰ to −1.5‰ (average −3.4‰), and the calculated $\delta^{13}C$ values of CO_2 gas in isotopic equilibrium with dawsonite are −11.4‰ to −7.3‰. These C isotopic values are ambiguous for the dawsonite C source. From the geological context, the timing of events, together with formation water conditions for dawsonite growth, dawsonite possibly grew in meteoric-derived water, atmospherically-derived CO_2 maybe, or at least the dominant, C source for dawsonite. It seems that there are few relationships between dawsonite and the modern gas phase of CO_2 in the Hailaer basin.

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1. Introduction

Dawsonite, a sodium aluminium hydroxy carbonate $NaAlCO_3(OH)_2$, was first collected as "a probably new mineral species" by Principal William Dawson of McGill University and named in his honor by Harrington, who described the new mineral as "covering the joint planes of a trachytic dike in McGill campus" (Harrington, 1874). Dawsonite is now known to be present in many localities worldwide as a hydrothermal mineral within or near igneous rocks (Stevenson and Stevenson, 1965, 1977, 1978; Birina, 1973; Baksa et al., 1975; Heritsch, 1975; Stankevich and Batalin, 1977; Ferrini et al., 2003), as a diagenetic or authigenic mineral in volcaniclastic rocks (Brobst and Tucker, 1974), clastic rocks (Du, 1982; Xu et al., 1994; Baker et al., 1995; Huang, 1996; Worden, 2006), oil shales (Smith and Milton, 1966), marine carbonate (Baker et al., 1995; Gregor et al., 2004) and coals (Loughnan and Goldbery, 1972; Golab et al., 2006, 2007), as a weathering product in soils (Hay, 1963), and as a daughter mineral in fluid inclusions in Au-quartz veins (Coveney and Kelly, 1971) and quartz (Sirbescu and Nabelek, 2003). Recently, dawsonite has also been proposed as a possible mineral product resulting from the injection of CO_2 into many types of sandstone reservoirs to reduce greenhouse gas emissions (Klusman, 2003; Moore et al., 2005; Xu et al., 2004, 2005; Kharaka et al., 2006). Numerous numerical simulations and laboratory experiments on synthetic dawsonite show that dawsonite forms at elevated CO_2 pressures or when abundant CO_3^{2-} or HCO_3^- is coupled with aluminosilicate dissolution (Zhang et al., 2004; Hellevang et al., 2005; Alvarez-Ayuso and Nugteren, 2005). In field observations, occurrences of dawsonite are typically considered to reflect past accumulations (Du, 1982; Moore et al., 2005; Golab et al., 2006) or seepage (Baker et al., 1995) of CO_2 associated with magmatic or volcanic activity.

In Hailaer basin, northeastern China, dawsonite is widespread in Lower Cretaceous CO_2 gas reservoir sandstones as a cement and replacement mineral. Xu et al. (1994) and Liu et al. (2006a) described the distribution of dawsonite and its relationship with oil and CO_2 gas in Hailaer basin, and suggested that the formation of dawsonite was related to inorganic CO_2 associated with Yanshan magmatic activity. Carbon and O stable isotopic data of two dawsonite samples were cited by Sui et al. (1996), who pointed out that the C for dawsonite originated from inorganic CO_2 gas. These previous studies provide important first steps towards documenting the origin of dawsonite. In this paper the authors aim to determine the origin of dawsonite and coexisting CO_2 gas in Hailaer basin, and, specifically, to clarify whether any genetic relationships exist between dawsonite and CO_2 gas using detailed petrographic and geochemical data. Specifically, an attempt is made to (i) investigate

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0883-2927/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apgeochem.2009.05.002

the possible alteration or influence on sandstone diagenesis by CO_2 injection recorded by dawsonite-bearing sandstone and (ii) determine whether dawsonite can act as a tracer mineral for inorganic CO_2 gas migration, accumulation and leakage in Hailaer basin.

2. Geological setting

The study area is found in the Wuerxun depression, located within the central portion of the down-faulted Hailaer basin, northeastern China. The Hailaer basin has an area in excess of 40,550 km^2, contains up to 6 km of late Mesozoic–Cenozoic continental sediments and forms a NE-trending basin together with the adjacent Tamuchager basin in Mongolia to the south (Zhang and Long, 1995) (Fig. 1). To date, 68 wells have been drilled in the Wuerxun depression, whereupon commercial crude oil was obtained from 27 wells (Mu et al., 2004) and commercial inorganic CO_2 gas with He was obtained from 11 wells (Wang et al., 2002; Luo and Pang, 2003). The igneous rocks including Hercynian and Yanshan granites, rhyolite, basalt and andesite are widely distributed in the Wuerxun depression where granite intrusions, occurring as stocks and dikes (Liu, 2007), are the most widespread igneous rocks, while acidic rhyolite, intermediate-basic andesite and basalt have a limited distribution. Most CO_2 wells occur within the igneous rock area or near the deep Huangdezhagenhure Fracture (Fig. 1). Dawsonite is widespread in both the igneous rock area and non-igneous rock area. It has not previously been established if the dawsonite and CO_2 gas have a genetic relationship with one or more of the igneous rocks.

The stratigraphy of the Hailaer basin has been summarized by Ye and Zhang (1989), Wang et al. (1990), Liu et al. (2006b) and Wan (2006). The stratigraphic succession adopted in this paper is shown in Fig. 2, from bottom to top it comprises Lower Cretaceous Xing'anling and Zhalainuoer Groups, Upper Cretaceous Beierhu Group and Tertiary units. Details on the sampled dawsonite- and CO_2-bearing units are given in Fig. 2 and the accompanying caption.

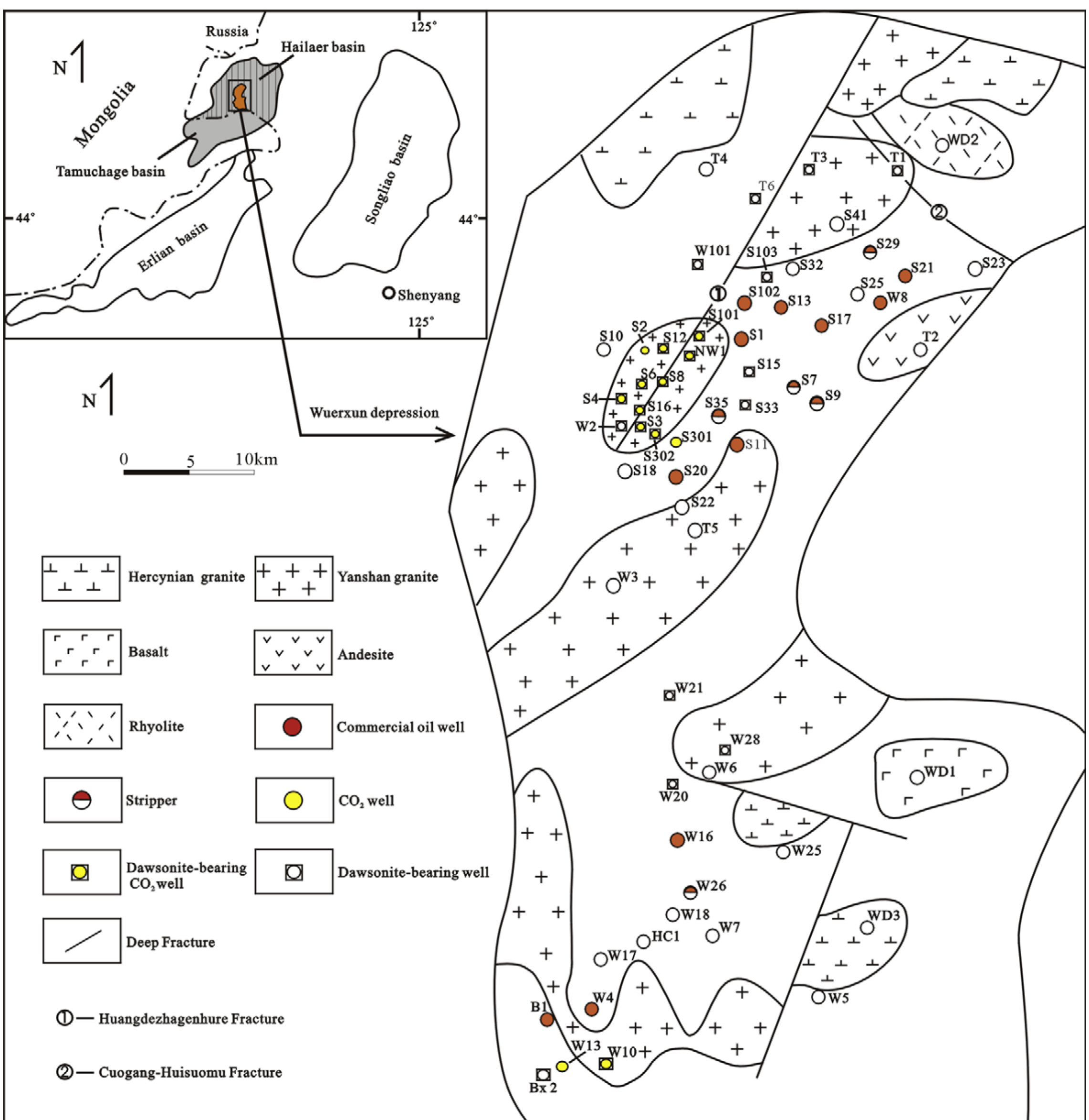

Fig. 1. Location of the Hailaer basin, distribution of dawsonite, CO_2, igneous rocks and deep fractures, and wells from which dawsonite-bearing sandstones and CO_2 were petrologically and geochemically analyzed.

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