Journal of African Earth Sciences 86 (2013) 25–44

Contents lists available at SciVerse ScienceDirect

Journal of African Earth Sciences

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

Paragenetic sequences of carbonate and sulphide minerals of the Mamfe Basin (Cameroon): Indicators of palaeo-fluids, palaeo-oxygen levels and diagenetic zones

John Takem Eyong [a,*], Paul Wignall [b], Wilson Yetoh Fantong [a], Jim Best [c,1], Joseph Victor Hell [a]

[a] Institute for Geological and Mining Research, B.P. 4110 Yaounde, Cameroon
[b] School of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK
[c] University of Illinois, Dept. of Geology, 201 Natural History Building, 1031 W. Green Street, Urbana-Champaign, Urbana, IL 61801, USA

ARTICLE INFO

Article history:
Received 6 October 2012
Received in revised form 3 May 2013
Accepted 16 May 2013
Available online 5 June 2013

Keywords:
Calcite
Dolomite
Pyrite
Siderite
Palaeo-fluids
Mamfe Basin

ABSTRACT

The occurrence of evaporite minerals in the Mamfe Basin (Albian–Cenomanian) is considered to be an indicator of aridity and palaeo-saline waters. A detailed lithostratigraphic analysis of the Mamfe sedimentary basin-fill indicates the occurrence of carbonate and sulphide minerals in close association with halite and gypsum within the Manyu, Mamfe and Bagba Members of the Nfaitok Formation. The composition and textures of these carbonate and sulphide minerals were studied using the Scanning Electron Microscope (SEM), attached to Energy Dispersive Atomic X-ray analyser (EDAX) that generates Backscattered and Secondary Electron Imaging (BSEI). Two paragenetic suites were encountered in this study; calcite/dolomite/ankerite/siderite and pyrite/sphalerite/galena respectively. The compositional and textural variability of different suite members appear to be conditioned by the competition for CO_3^{2-} and SO_4^{2-} anions by metal cations with respect to redox conditions and diagenetic stages. Early formed authigenic minerals exhibit euhedral textures, while late diagenetic minerals exhibit pseudomorphic textures, as cations with higher ionic radii integrate into earlier structures. Calcite is a precursor for dolomite, ankerite and siderite at late diagenetic stages. Pyrite, sphalerite and galena indicate deposition in anoxic and sulphate reducing environments. Micron-sized euhedral pyrite framboids are syn-depositional, while Pb–Zn mineralization in voids and cavities are formed at late diagenetic stages below the sulphate reduction zone (SRZ), where siderite forms encrustations around skeletal pyrite. The pristine source of saline water, SO_4^{2-} and Mg^{2+} could be related to sea water splay into a lagoon. The source of Fe^{2+} is detrital, while Zn^{2+} and Pb^{2+} indicate metalliferous fluids with high heat flux, probably of hydrothermal origin.

1. Introduction

Carbonate, sulphide and evaporite minerals have widely been reported in Cretaceous sedimentary facies of the Mamfe Basin in Cameroon (Wilson, 1928; Le Fur, 1965; Dumort, 1968). Evaporites minerals were studied from brines collected in salt ponds situated within the youngest formation towards the western half of the basin (Eseme et al., 2002). Some indices for Pb–Zn mineralization have been reported in the Mamfe Basin (Le Fur, 1965). The evolution of saturated to under-saturated pore waters with respect to calcite is said to be consistent with the mixing zone between fresh and brackish water (Sibley, 1982; Sibley and Gregg, 1987). Zonation in dolomite has been reported to be partly caused by the replacement of Mg^{2+}, Fe^{2+}, and Mn^{2+} ions and in addition to strontium and sodium which incorporate into the growing crystals (Gawthrope, 1987; Choquette and Steinen, 1980; Bathusrt, 1976; Friedman, 1980). The occurrence of diagenetic pyrite in sediments has been reported by a number of authors (Berner, 1980, 1982, 1984; Berner and Raiswell, 1983; Al-Biatty, 1990; Wignall and Newton, 1998; Wilkin and Arthur, 2001). Pyrite framboid size distribution range has also been used as a measure of oxygen deficiency in British Jurassic mudrocks (Wignall and Newton, 1998). Micron-sized framboids have been interpreted as evidence of syngenetic (water column) pyrite formation adjacent to the oxygen-hydrogen sulphide boundary (Wilkin and Arthur, 2001). In the Mamfe Basin, little information is documented on the lithofacies assemblages that host carbonate, sulphide and evaporite minerals, while their stratigraphic positions and depositional environments are not well defined. Diagenetic mineral alterations associated with evaporites are poorly constrained in sedimentary sequences of the Mamfe Basin. In this study, 42 outcrops were described or logged from the different stratigraphic positions within the Mamfe Basin. A total of 109 samples were collected for thin sections and

* Corresponding author.
E-mail addresses: johneyong@hotmail.com (J.T. Eyong), P.B.wignall@leeds.ac.uk (P. Wignall), jimbest@illinois.edu (J. Best).
[1] Tel.: + 217244183.

1464-343X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jafrearsci.2013.05.002

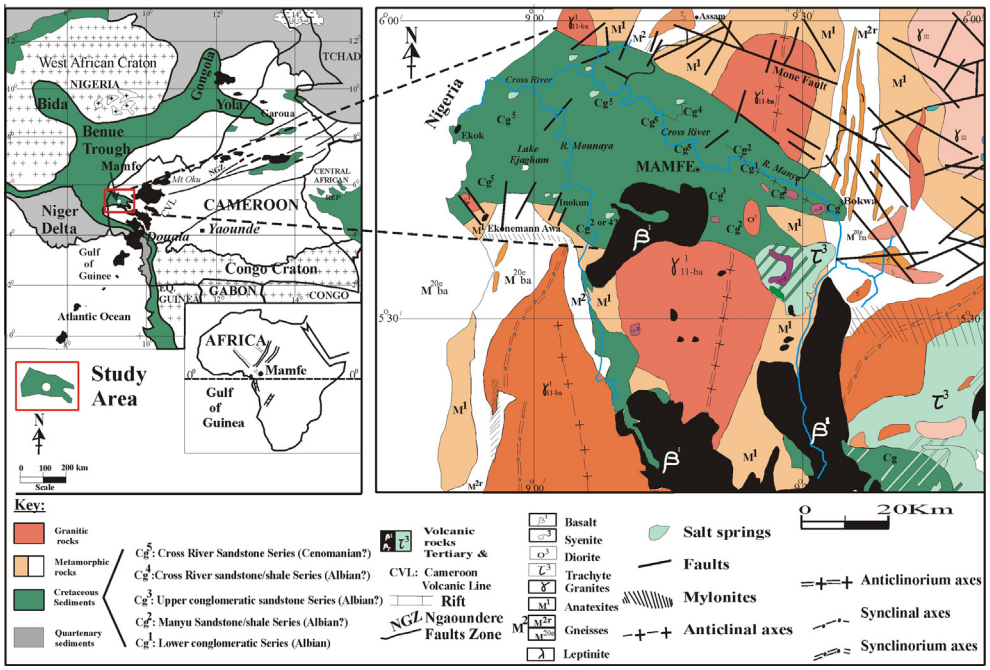

Fig. 1. Location of the Mamfe Basin in relation to the Benue Trough, Cameroon Volcanic Line (CVL) and the West and Central African Rift System (WCARS) (adapted from Benkelil, 1989 and the geologic map of Cameroon, 1979 edition).

21 polished blocks were used for optical and Scanning Electron Microscopes (SEM).

The purposes of this paper are: (1) to define the lithofacies and microfabrics that host evaporite, carbonate and sulphide minerals of the Mamfe Basin; (2) to define the lithostratigraphic positions of these facies in the stratigraphic column; (3) to diagnose the textures and chemical compositions of carbonate, sulphides and evaporite species and their paragenetic trends. This study will ultimately help to define lithofacies assemblages in their stratigraphic positions. The results of this study will help develop more comprehensive and precise conceptual models linked to palaeofluids, palaeo-oxygen levels and diagenetic environments that would have prevailed during depositional and post-depositional processes within the Mamfe Basin.

2. Geology of the Mamfe Basin

The Mamfe Basin is a south-eastern trending Cretaceous rift basin that bifurcates off the Benue Trough and is linked to the West and Central African Rift System (WCARS). Like the rest of the WCARS, the Mamfe Basin is linked with the opening of the South Atlantic Ocean (Petters, 1978; Fairhead and Green, 1989). The Mamfe Basin is thought to have formed during Albian to Cenomanian as a result of basement rifting associated with the reactivation of E–W trending mylonite zones (Dumort, 1968) within the Panafrican basement. The Mamfe Basin has been described as a rift splay, which is genetically linked with the Benue Trough (Petters et al., 1987; Genik, 1993). The basin is elliptically-shaped and trends WNW–ESE for 130 km into Cameroon and measures 80 km long by 20–40 km wide, with an estimated surface area of 2400 km^2 (Le Fur, 1965; Dumort, 1968; Eben, 1984). The basin narrows towards the east and widens towards the west across the Cameroon/Nigerian border into the Benue Trough where Albian marine deposits of the Abakaliki Formation outcrop. The basin is fringed by reactivated, fault-bounded granito- gneissic rocks of the Pan-African Mobile Belt (550 ± 100 Ma) and are both intruded by volcanic rocks. The basin is bounded to the south by the Oban Massif, which separates it from the Atlantic Ocean (Benkelil, 1989) and to the NE by the Bamenda Massif (Fig. 1). Foliated augen gneisses are found in association with N–S tectonized leptynite bands in Bokwa and Kendem Villages to the east. A mylonitic zone otcrops at Ekonemann-Awa to the SW region of the basin, with migmatites found at the fringes of syntectonic granite intrusions of Panafrican age (Wilson, 1928; Le Fur, 1965; Dumort, 1968). The basement and sedimentary rocks of the basin are intruded by Tertiary anorogenic and effusive basic intermediate rocks such as syenites, diorites, trachytes and basalts (Njonfang and Moreau, 1996). A basalt plateau belonging to the Cameroon Volcanic Line (CVL) covers the southern edge of the basin.

In terms of lithostratigraphy, the sedimentary deposits of the Mamfe Basin have formerly been classified as the Mamfe Formation (Wilson, 1928; Le Fur, 1965; Dumort, 1968; Uzuapunwa, 1980; Ajonina and Bassey, 1997) and subdivided into five sedimentary divisions termed 'Series', denoted from base to top: Cg^1, Cg^2, Cg^3, Cg^4 and Cg^5. The anticlinal unit (Series Cg^1–Cg^4) which outcrops to the eastern half of the basin is uncertainly dated as Albian, while the tabular unit (Cg^5) to the west is apparently Cenomanian. The five Series designated by Le Fur in 1965 became revised into four stratigraphic formations, which from the base to the top include Ngeme, Nfaitok, Baso and the Cross River formations (Eyong, 2003). The Cg^2 and Cg^4 Series of Le Fur (1965) were regrouped into Nfaitok Formation and sub-divided into three members namely Manyu, Mamfe and Bagba (Eyong, 2003) and proposed a summary lithostratigraphic column for the Mamfe Basin (Fig. 2a). Carbonate, sulphide and evaporite minerals are found to occur in lithofacies of the Nfaitok Formation, although salt springs from leached evaporites are concentrated within the younger Cross River Formation. Detailed lithological assemblages of the Nfaitok Formation have been given a keen attention in this study.

3. Methods

Field descriptions were compiled from 42 outcrops or stations (denoted S1,S2,...,S42) throughout the entire basin and especially along the Manyu and Cross River courses (Fig. 2b). At each outcrop, different lithofacies were described or logged and their distribution