Diagenetic and thermal history of a fore-arc basin sequence – the Himalia Ridge Formation, Alexander Island, Antarctica

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Introduction

The processes of diagenesis/low temperature metamorphism are a function of tectonic setting; each environment is characterised by several intensive parameters such as lithology, diagenetic/metamorphic gradient and fluid composition. The determination of the diagenetic pathways of sedimentary sequences from arc-related basins allows more clearly defined constraints on the models of basin burial history and geothermal gradients. This is a study of the diagenesis of a single sedimentary sequence from a little-deformed fore-arc basin of Mesozoic age in Antarctica.

Geological Setting

The Himalia Ridge Formation (HRF) is exposed on Alexander Island as a 2.2km-thick sequence of Tithonian to Berriasian conglomerates, sandstones and mudstones deposited in a fore-arc basin (see Macdonald and Butterworth, 1990, for review).

Sampling and methods of investigation The sampling strategy was designed to test the effects of grainsize, depositional facies and stratigraphic height on the mineral paragenesis. Groups of sandstones were selected from a particular stratigraphic height and contained the range of grain sizes found at that height, plus representatives from each of the major facies associations. The authigenic mineral assemblages were examined by light microscopy, scanning electron microscopy with EDAX and X-ray diffraction techniques (both bulk rock and $<2\mu m$ fraction). In addition, a suite of mudstone samples was collected for vitrinite analysis.

Results

The diagenetic effects include compaction, pore-space reduction and cementation by clay minerals (smectite, illite/smectite, corrensite and kaolinite),

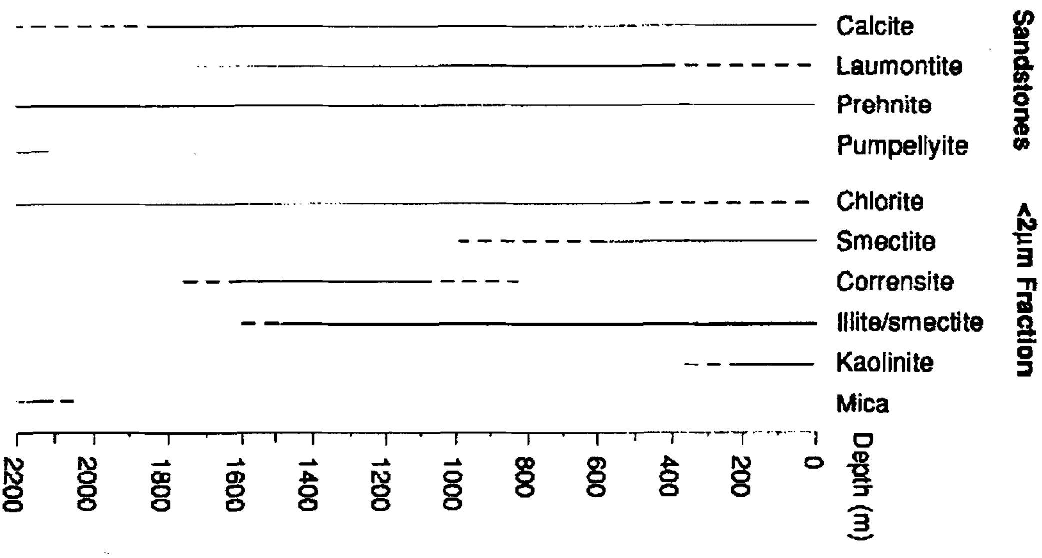

FIG. 1. Distribution of the authigenic minerals with depth in the sandstones and mudstones of the Himalia Ridge Formation, Alexander Island, Antarctica.

calcite, chlorite, laumontite and prehnite with less common quartz, haematite, pyrite and epidote. There is also dissolution and replacement of volcanic fragments by calcite, chlorite, laumontite, prehnite, pumpellyite, albite and mica. Depth variation of diagenetic features differ from moderate to strong changes down section in the HRF. The distribution of authigenic minerals with depth is shown in Fig. 1. The chlorite 'crystallinities' increase with increasing depth.

Detrital organic matter in the argillaceous layers have values ranging from R_o = 2.3–3.7%, indicative of semi-anthracite to anthracite coal rank (Teichmuller, 1987).

The mineral assemblages presented here define two metamorphic grades; the uppermost 2000m belong to the zeolite facies, while the bottom 200m of the HRF are prehnite-pumpellyite grade.

The interpretation from the authigenic mineralogies is that the probable diagenetic/metamorphic temperature range is between 150°C and 250°C. The reactions involved in the thermal maturation of organic matter are both temperature and time dependant (e.g. Lopatin and Bostick, 1974). The data and field observations imply maximum burial times of between 80 and 97 Ma for base and top of the HRF respectively. By using the chart of Bostick *et al.* (1978), in the HRF we find that the temperature for R_o of 2.3% (equivalent to semi-anthracite coal rank) and a time factor of 41My is 160°C. Similarly, that the temperature for R_o of 3.7% (equivalent to anthracite coal rank) and a time factor of 56My, is 225°C.

The temperature range calculated for the HRF yields a geothermal gradient for the sequence of approximately 45°Ckm^{-1}; a somewhat higher gradient for the HRF compared to an 'average' burial metamorphic gradient (25°Ckm^{-1}; Frey, 1987). High heat flow is common in active basins with a larger sediment thickness (Watanabe *et al.*, 1977). The higher metamorphic gradient may also be a result of increased heat flow in the basin due to arc relocation from the Peninsula area to western Alexander Island during early Tertiary times (Hole *et al.*, 1991). The observations on the thermal history of the HRF would therefore indicate that the top of the section was buried by between 3000 and 3500m of younger sediment, rather less than the maximum possible overlying sediment thickness of close to 5000m. Examination of the burial history of the HRF thus provides evidence that sedimentation varied considerably across the basin.

References

Bostick, N.H., Cashman, S.M., McCulloch, T.H. & Waddell, C.T. (1978). In: Oltz, D.F. (ed.), *Low temperature metamorphism of kerogen and clay minerals*. Pacific Section, Soc. Econ. Paleontol. Mineral., Los Angeles, CA. 65–9.

Coombs, D.S. (1954). *Roy. Soc. New Zealand Trans.*, **82**, 65–109.

Frey, M. (1987). In: M. Frey (ed.) *Low Temperature Metamorphism*, Blackie & Son, Glasgow, 9–58.

Hole, M. J., Pankhurst, R. J. & Saunders, A.D. (1991). In M. R. A. Thomson *et al.* (eds), *Geological Evolution of Antarctica*, Cambridge University Press, Cambridge, 369–74.

Lopatin, N.V. & Bostick, N.H. (1974). *Ill. State Geol. Survey*, Repr. Ser. 1974Q, 1–16.

MacDonald, D. I. M. & Butterworth, P. J. (1990). In: B. St. John (ed.), *Antarctica as an exploration frontier*, American Assoc. Petrol. Geologists, Studies in Geology No. 31, 101–25.

Teichmuller, M. (1987). In: M. Frey (ed.), *Low Temperature Metamorphism*, Blackie & Son, Glasgow, 114–61.

Watanabe, T., Langseth, M. G. & Anderson, R. N. (1977). In: M. Talwani & W. S. Pittman (eds.), *Island arcs, deep-sea trenches and back-arc basins*, Am. Geophys. Union, Maurice Ewing Ser. 1, 137–61.