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Impact of Fabric Modifications Induced by Faunal Content on Thermal Conductivity, Offshore Sarawak, Malaysia

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Abstract: Thermal conductivity refers to heat flow within a rock and is controlled by fabric. Primary rock fabric can be changed or modified by external factors. Faunal content modifies fabric. However, its impact on thermal conductivity remains unclear. The causes for these variations remain unclear as well. Sandstones from a sequence of stacked shallow marine sands and shale of late Miocene age (Upper Cycle V) were selected from offshore Sarawak. Fabric characterization was done using stereomicroscopy, petrography and mineralogy. The distribution of calcareous fauna was studied using Computer Tomography (CT) scan. Fossil fragments were detected at three different depths at different degrees of abundance. The fauna were randomly distributed with sizes upto 1 cm. Pores were randomly distributed and individual grains were moderately sorted. This contributes to the meso-scale variation in fabric. Change in porosity due to the presence of foraminifera is attributed to enhanced porosity within the foraminifera (dissolution, porous framework). The fabric is also modified by sand grains that imbricate around fossil fragments. CT scan confirms this variability in 3-D.

Key words: Computer tomography, fossil fragments, shallow marine sands, thermal conductivity

INTRODUCTION

The term rock fabric is defined by Hobbs *et al.* (1976) and Twiss and Moores (2007) as to describe the spatial arrangement and orientation of the fabric elements.

These elements are defined according to Prikryl (2006) as texture (crystallographic preferred orientation), microstructure (shape preferred orientation) and micro-cracks; whereas, according to Pettijohn *et al.* (1987) they may be a single grain, crystal, or fossil.

Original or primary fabric is the fabric formed during the deposition of rocks. Many processes can lead to change this primary fabric to form a secondary fabric. Some factors that lead to change in fabric are accounted for depth, lithology, sediment deformation and changes in physical properties (Sunderland and Morgan, 2003) and the degree of bioturbation. Sokolov and O'Brien (1990) and Pedley (1992) who gave the name bio-texturing for such bioturbation-based change; which destroy the original fabric and form new inorganic structures.

Because thermal conductivity of calcareous material is different from siliciclastic material (Clauser and Huenges, 1995), the occurrence of calcareous fauna in siliciclastic rocks is expected to have some impact on thermal conductivity. This assumption is applicable also to rock fabric because fossils are considered to be one of the textural changers at different scales of observation.

This study aims to evaluate the impact of calcareous fauna occurrence on fabric modification in some siliciclastic rocks and to evaluate the impact of such fabric modifications on thermal conductivity values and trends.

MATERIALS AND METHODS

Materials used for this study comprised of sandstone hetereolithic samples selected from the Well A, located in the Field B from the west Baram Delta of the North West Borneo. The field represents a staked sequence of shallow marine sands and shale of the late Miocene age Upper Cycle V of Tan *et al.* (2005).

Detailed sedimentological and reservoir characteristics were studied by Johnson *et al.* (1989), who categorized the field as storm/wave dominated which deposited in inner neritic to near shore/coastal depositional environments within the Baram Delta complex. According to his study, four sedimentary facies were identified, with corresponding sub-facies. The main facies include sandstone, sand-dominated hetereolithic, mud-dominated hetereolithic and mudstone facies.

The study started with the macro and mesoscale description of the cores, with focus on the samples showing fossil fragments. Characterization of the facies included visualization and photography via stereomicroscopy using Olympus SZX16.

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Images were captured at different magnifications using microscope attached digital camera. Samples for thin sections were collected parallel and perpendicular to bedding planes. The internal distribution of calcareous fauna was conducted via Computer Tomography (CT) scan using an Inspexio/Shimadzu SMX-225 CT microfocus X-Ray CT system, with Inspexio version 5, 5, 0, 12, with the maximum voltage of 250 kV and 150 mA. CT scan tomography was taken in horizontal planes (slices) at a half centimeter vertical interval for sample C12B244 which showed the highest faunal content. Interpretation of CT scan was done by mapping a surface tomograph against the top of the sample. Thermal Conductivity (TC) was measured for different core cuttings for the same facies included those with no faunal content, with very minor content and with high content. Multiple TC measurements were taken using needle probe method, with a constant of 40 W and data was processed according to Forier's Law (Clauser and Huenges, 1995).

Statistical analysis: Data was analyzed using one way analysis of variance.

RESULTS AND DISCUSSION

The meso-scale description showed that the well A column is dominated by sandstone, with mudstone and shale interbedded at different depths. The faunal content is detected at three zones of different depths. Figure 1 shows the sedimentary column of well A with a zone of high faunal content.

The hand specimen investigation also showed the occurrence of fossil fragments at different depths and different abundance. Samples used represent hetereolithic sand-dominated, with subordinate mud, fine to medium grained, intercalated and disseminated mostly in a non uniform structure and rarely in a form of mud clasts, but siderite clasts and nodules were identified. All samples are of yellow greyish color with the color code 10YR6/2 (Munsell Color, 2009) and moderate hardness. Regarding the size and the absence of sedimentary structures and bioturbation, the meso-scale interpretation suggests moderate energy and a rapid sedimentation from unidirectional source in an inner neritic zone environment.

The facies consists of very fine sandstone, with some parts of high silt and clay intercalation as matrix, repeated at different depth intervals, with shells of bivalves ranging in size from a few millimeters to 1 cm. The content of fossil fragments varies considerably with abundance in C13 B244 below the centre of the sedimentary section.

The shell fragments act as mold and cast as seen from top and bottom surfaces and are subjected to dissolution. Photographs from binocular microscope showed that casts of fossil fragments were filled by different material which acted as burrows (Fig. 2).

The CT scan interpretation is done by mapping CT scan against the hand specimen description (Fig. 3) showed materials of different densities occur in the sample range from calcareous fauna (most dense) to air pebbles (least dense) with extremely dark color equivalent to the surrounding of the sample.

The most useful data on fabric modification by faunal content revealed from CT scan (Fig. 4) is the size, distribution and percentage of faunal coverage. The CT scan showed that calcareous fauna varies in size from 1-10 mm with size varying horizontally and vertically. The distribution pattern is random and percentage of faunal coverage range from 0-40%. Some parts show casts and molds with faunal fragment totally decomposed.

Thin section photo micrograph showed that quartz grains are poorly sorted with varying grain sizes from very fine to fine, angular in shape and mostly elongated. The abundance of clayey matrix is remarkable, with clay in filling the shell fragment. The most remarkable feature in fabric around fossil fragments is the linear and elliptical imbrications of quartz grains immediately beneath the fragment (Fig. 5). The section shows cross cut (from top to bottom), with small rounded fragment (top right), possibly a cross section of foraminifera.

Comparison of photomicrograph of scanning electron microscopy at low magnification showed that differences between the two samples mostly lie in grain size. The first sample has a size ranging from 150-500 μm, with a dominant grain size of 300 μm which is a medium sandstone. The other sample showed grain size ranging from 100-250 μm, with a dominant grain size of 200 μm which is a fine sandstone. This data agree with data obtained from microscopy. The grain size reflects moderate sorting. The grain shape in both samples show low sphericity with angular to sub angular grains. Grain shape, angular to sub angular margins and rough surfaces reflect moderate energy and less reworking of sandstones. Packing of grains is close and is almost octahedral where sand grain deposited in troughs and contact of pre-deposited grains; which gives the shape of linear porosity.

Plotting of TC (Fig. 6) for samples without, with very minor and with intense fossil content showed that both samples with no and minor fossil content have relatively lower TC values and narrower range; with the lower range

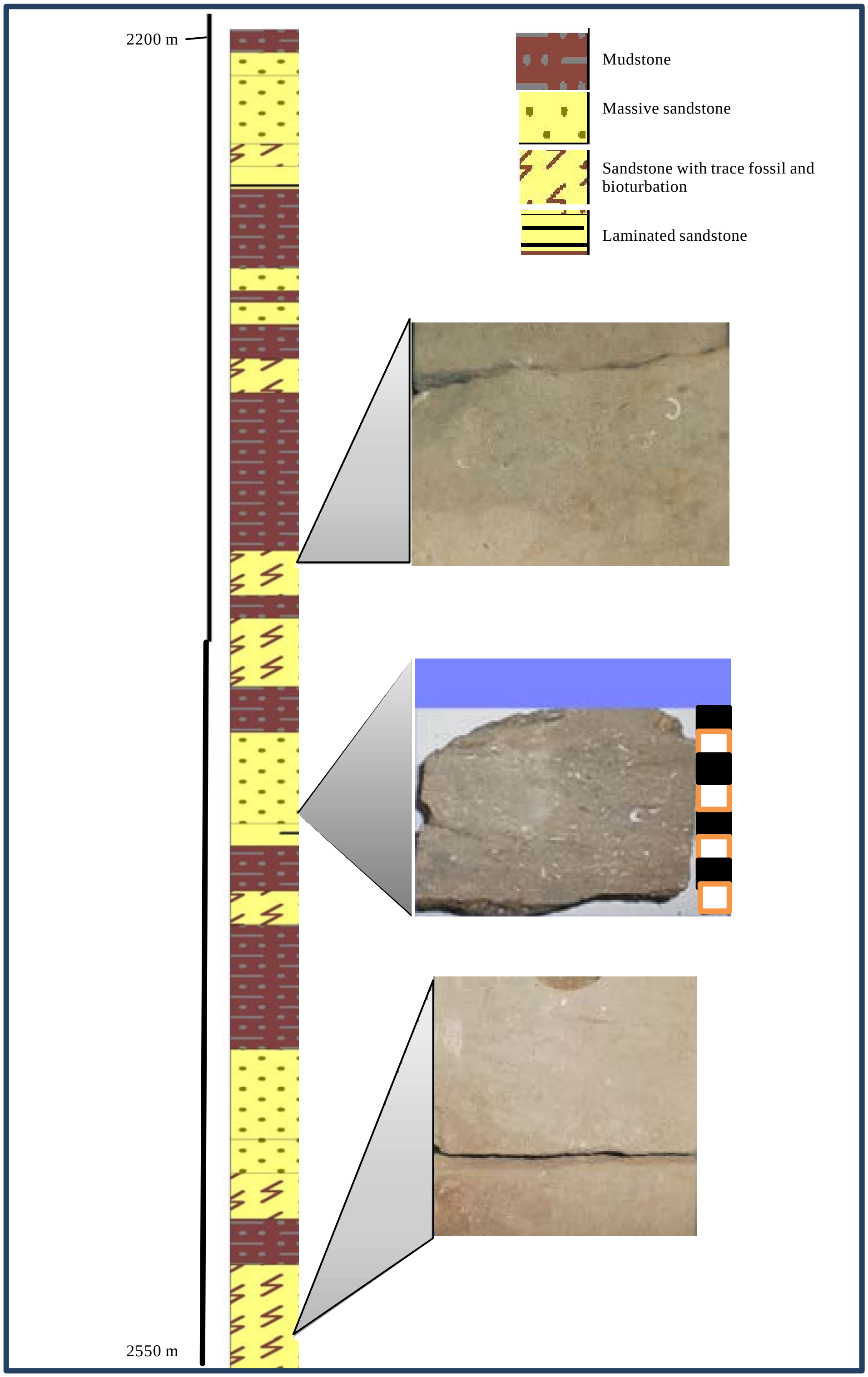

Fig. 1: Zone with high faunal content in the sedimentary section in well 1

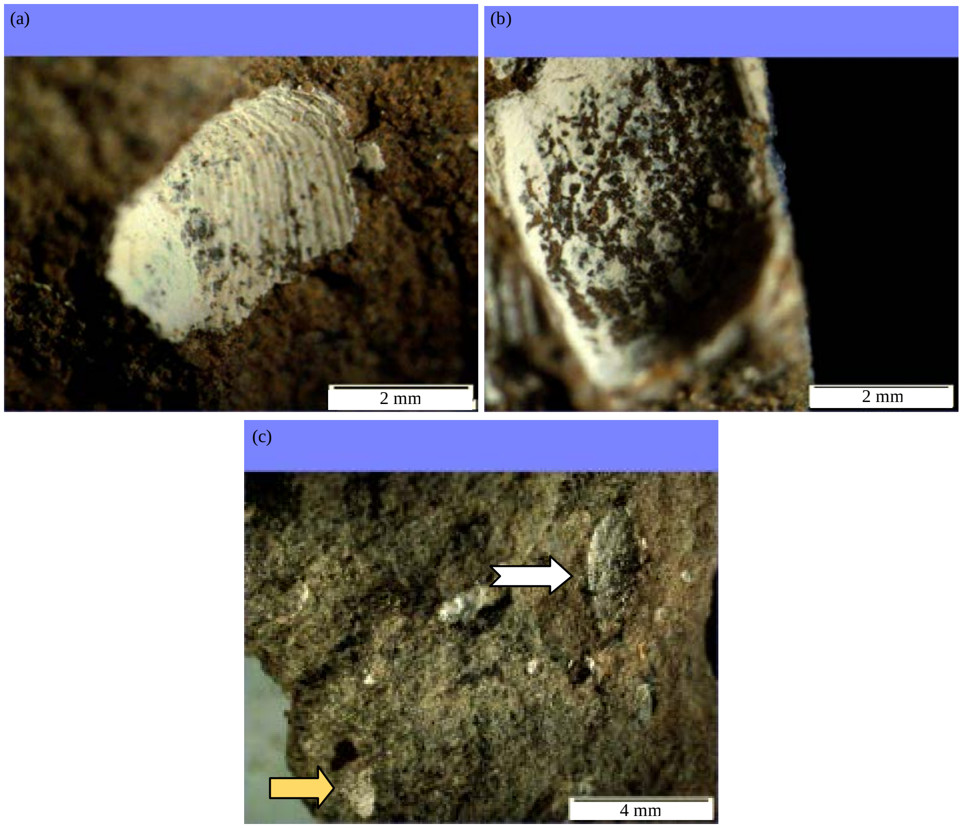

Fig. 2(a-c): (a-b) Shell fragments showing different degrees of dissolution and (c) Cast (white arrow) and mold (yellow arrow) as bio-erosive structures

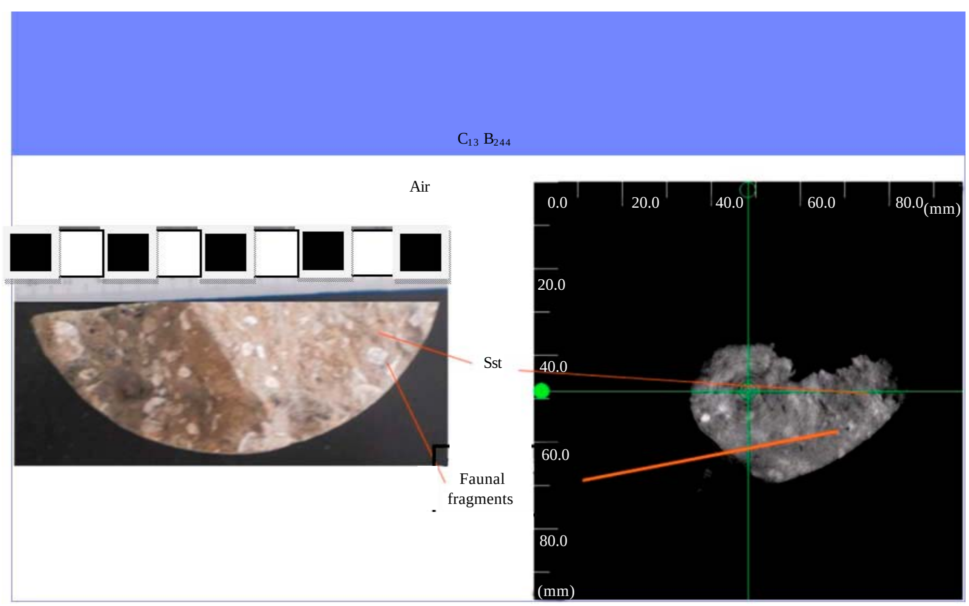

Fig. 3: Mapping of CT against hand specimen for interpretation of tomographs.

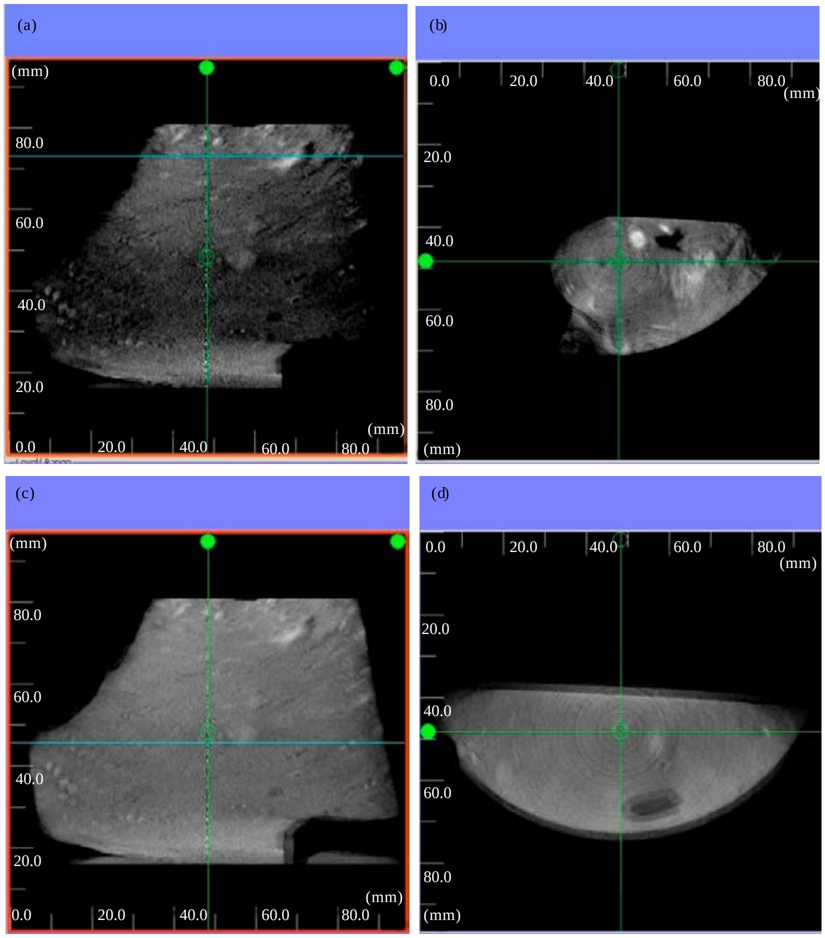

Fig. 4(a-d): CT scan tomography of sample C2B244, each graph at the right side is a slice view or cross section taken from a horizontal planes from top to bottom. Background grey color is the lithic part, (a, c) Lighter color is the calcareous fauna and (b, d) Darkest color is the air pebbles

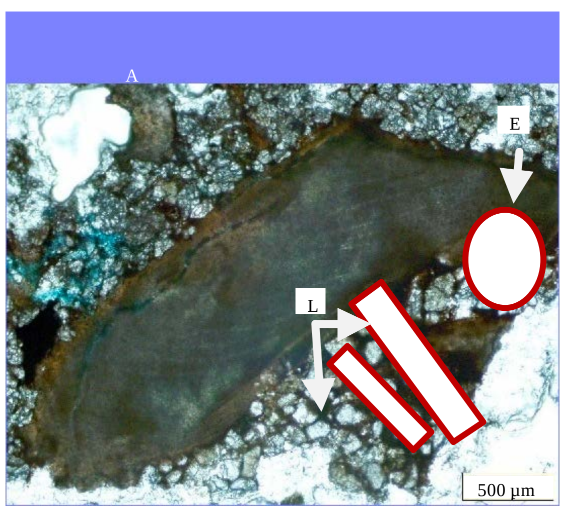

Fig. 5: Thin section photomicrographs, Grain imbrication linear (L) and elliptical (E) imbrication of quartz grains immediately beneath the fragment

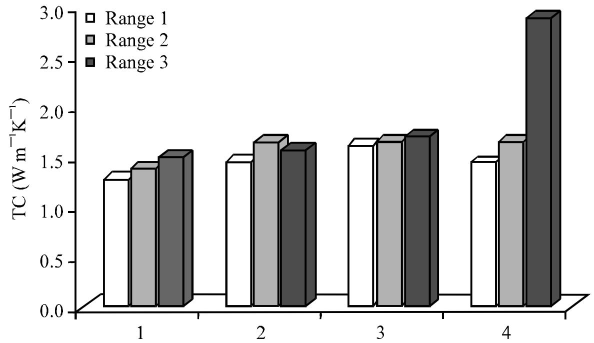

Fig. 6: Trends and values of TC in different samples from the same facies: 1Facies barren of fossil, 2 and 3 very minor fossil content and 4 facies with intense fossil content

almost the same in all cases. The higher range in sample with high fossil content is justified due to the higher TC value of calcareous material. Low thermal conductivity values could interpreted as a result of impact of zones with air pebbles as seen from CT scan.

CONCLUSION

The well showed a facies of litho-biogenic origin composed of calcareous fauna (bivalves and foraminifera). Presence of calcareous fauna is supported by thin sections and binocular microscopy. The rock fabric is modified from the original one due the occurrence of fossil fragments, microfossil and biogenic erosive structures observed; moreover, remarkable imbrications of quartz grains around shell fragments are observed. Thermal conductivity trends and values for zones of low or no fossil content showed similar trend in that a narrower range of TC was observed; whereas, for zones with high fossil content, a much wider range of TC was reported.

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