Field Trip

Channel-Levee Facies and Sea Floor Fan Lobes in The Turbidites of Lower Kutei Basin, East Kalimantan

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Abstract

Recently open outcrops in the lower Kutei basin have been interpreted as slope turbidites. The new outcrops show channel-levee complexes. The sandstone bodies are mostly constituted by mass flows and debris flows which pinch out in short distance to thin bedded turbidites and silt shale alternations. This is interpreted as the transition from channel margin to levees. Channels are filled in general by thick mass flow deposits.

A detailed geometry of sandstone reservoirs in slope turbidite channel – levee complexes is described. Precise measurements of different architectural elements of the complexes are carried out in field outcrops. Two outcrops will be the object of this paper. One of them shows sea floor lobe and the other shows channel levee complexes in a slope.

Keyword: Lower Kutei basin, Samarinda, Lower to Middle Miocene, slope turbidites, channel – levee complexes, reservoir geometry, reservoir model.

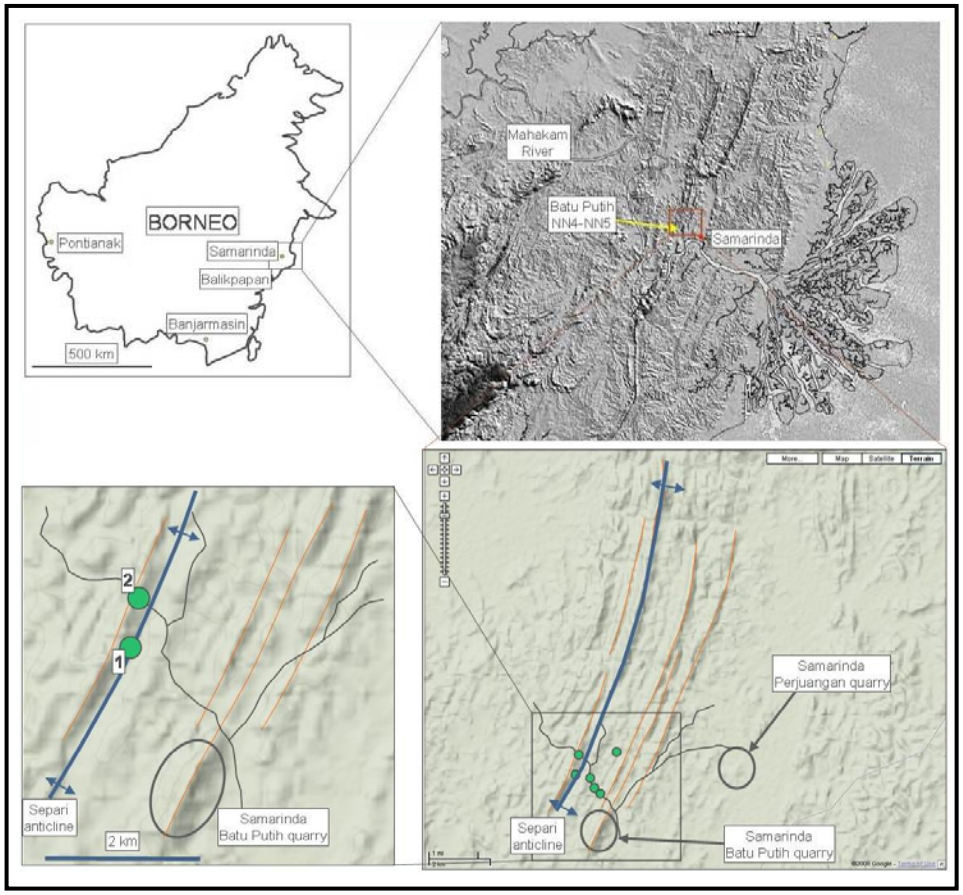


Figure 1. Outcrop location maps.

Introduction And Geological Setting

Deltaic sedimentation has been continuous in the Kutei basin from late Oligocene to the present-day, represented by the modern Mahakan delta. A fluvial plain is associated to the delta upstream in the continent and carbonate buildups are observed in the shelf offshore to the delta. Turbidites are described beyond the shelf break further down slope (Sherwood et al., 2001, Saller et al., 2004, Saller et al., 2008) as well as in Miocene oil and gas fields (Saller et al. 2006). These four environments shift continuously seaward and landward during the geological time constituting a complex geological history of the basin.

We are focusing in this paper on a section in North West of Samarinda city (Figure 1). The outcrops are currently easily accessible and are situated close to the main road from Samarinda to Tengarong. Three hill rows dominate the relief of this area. The first hill row is constituted by Batu Putih carbonate buildups (Figure 1), dated as Late of Early Miocene to Early of Middle Miocene age (NN4 to NN5 nanoplancton zones, (Wilson, 2005). Shelf sand lobes and shelf break geometry can be observed above Batu Putih carbonate buildup (previously object of sedimentological and stratigraphic studies (Cibaj and Wiweko, 2007). The second hill row is occupied by Samarinda city rubbish damp. Hand phone web antennas are erected on the top of the third hill row. The section is Early to Middle Miocene in age. Our biostratigraphic studies show more precisely Late of Early Miocene to Early of Middle Miocene age (NN4 to NN5 nanoplancton zones).

Samarinda anticlinorium is constituted by a series of very wide synclines and very narrow anticlines. The studied outcrops are situated in Separi anticline, which constitutes the central part of Samarinda anticlinorium in almost its higher part (Allen & Chambers, 1998), representing, therefore, the oldest outcropping rocks. The vegetation cover makes it difficult to understand the exact detailed structure of the Separi anticline core. Nevertheless the selected outcrops show in their majority a strong structural dip (40 to 70 degrees) towards east (eastern flank of the anticline) with the exception of the outcrop No 2 dipping to the west (west flank of the anticline). We assume going stratigraphically upwards from the core of the anticline to the east (Batu Putih carbonate buildup).

The series is dominated by shale, interrupted from time to time (every 100 to 150 m) by sand pulses which form 5 to 30 m thick successions. These sand successions will form high relief hills in the landscape. A series of sand outcrops have been studied in the section. Dense vegetation covers the shale separating the sand intervals. The outcrops are numbered 1 to 7 from the stratigraphic bottom to the top (for more details see Cibaj, 2011). This is the only area in the Samarinda anticlinorium showing fairly well linked outcrops interpreted as slope turbidites. In this paper we are focusing in detail only in the outcrops 1 and 2. This succession is capped at the very top by Batu Putih carbonate which is interpreted as deposited in a shelf break environment.

The series cropping out at the core of Separi anticline has been previously described and interpreted as slope turbidites (Allen & Chambers, 1998, Cibaj & Wiweko, 2008). This study focuses on a detailed description of old and new outcrops of sand formations. Their interpretation shows the presence of channel-levee systems in the slope as well as the basin floor fan lobes.

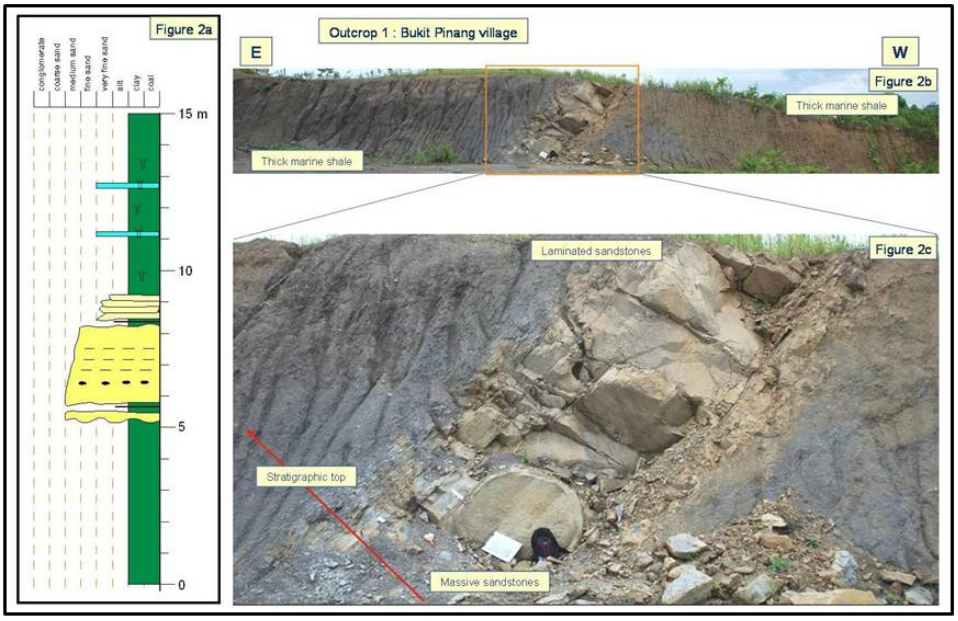


Figure 2. Log description and photos of the outcrop No 1.



Figure 3. Detailed photographs of the outcrop No 1.

Outcrop Detailed Description And Interpretation

Outcrop No. 1

Situation:
The outcrop is situated on a hill flank where new housing complex has been developed last few years (Bukit Pinang village) (Figure 1, 2).

Description:
The outcrop shows a structural dip towards the east (Figure 2). It is constituted by very thick shale (more than 100 m) with a 4 m thick sand bed in the middle of the shale. This thickness is very constant laterally over a 300 m distance. The bottom surface of sands is very irregular and erosive (Figure 2c). The sand shows a massive texture at the bottom (Figure 3a) laminated at the top (Figure 3c). Clay clasts, 1-2 cm in diameter, are observed in 2 or 3 levels in the middle of the sand. They are oriented parallel with the stratification. Vegetal organic mater is dispersed all over the sand interval; print leafs can be observed in many cases (Figure 3b). Parallel laminations are observed towards the middle part of the sand. The top is constituted by

thin sand layers, 1-2 cm thick, with sharp base, massive at the bottom to parallel laminated structure at the top. Sometimes current ripples are observed. Thin shale separates sand layers (Figure 3c).

Shales are very dark and rich in vegetal organic matter. Dense vertical burrows are observed in the shale (fig 3d) visible only in oblique sun light. Their diameter can rich up to 0.5 cm and their length can be up to 2-5 cm. They have a slightly conical shape.

Interpretation:
Thin sand layers are interpreted as Bouma thin-bedded turbidites, Ta, Tb and Tc divisions. The massive sand is interpreted as gravity flow deposits. This sand is fairly extensive laterally and is interpreted as deposited in a basin floor, or in the transition between slope and the basin floor. Thick shales are interpreted as deposited in open marine conditions.

Outcrop No. 2

Situation:
The outcrop is situated in the road from Samarinda to Tengarong on the top of the third hill row near the portable telephone network antennas.

Description:
The outcrop is constituted by two main parts a lower part and an upper part. The formations show a structural dip towards the west (west flank of Separi anticline, Figure 4).

The **outcrop No 2 lower** is around 100m X 100m in dimensions (Figure 4). Two sand intervals are observed overall in this outcrop. The inferior sand interval is constituted by coarse-grained sand beds with floating clay clasts showing frequent lateral pinch out (Figure 5a, b, d, and e) to medium and fine-grained sands. The superior sand interval is around 15 m thick (Figure 4, 5a, and c). The bottom surface of this sand interval is very irregular and erosive showing some flute casts oriented overall to the east – north east. Sand beds are very massive, rich in clay pebbles and clasts.



Figure 4. Log description and photo of the outcrop No 2 lower.

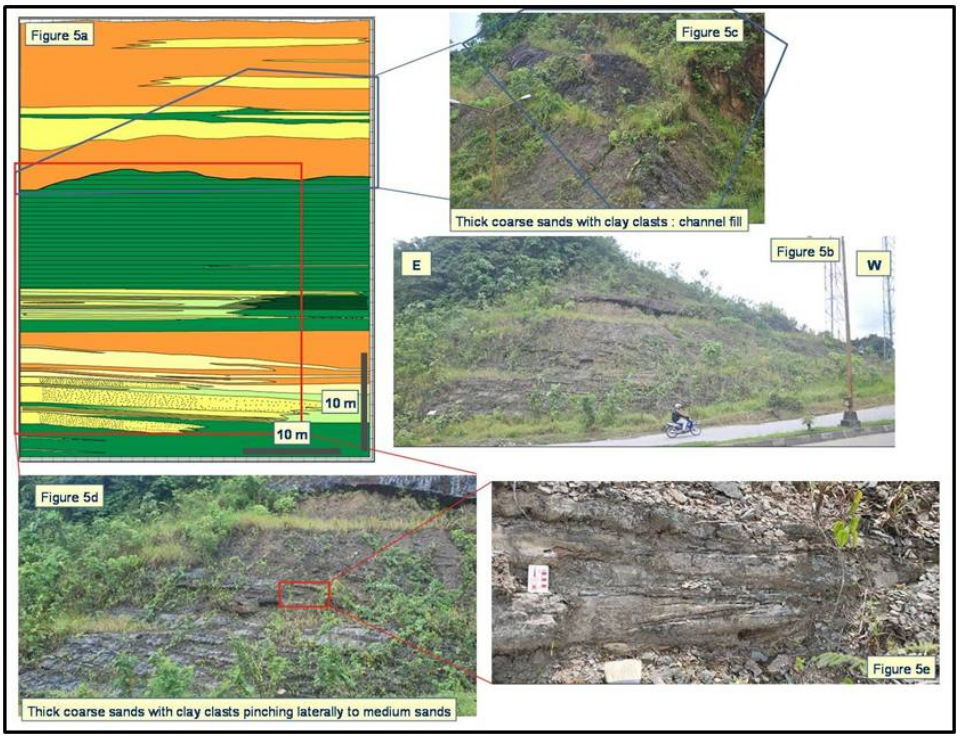


Figure 5. Detailed structure and photographs of the outcrop No 2 lower.

The **outcrop No 2 upper** is around 50m X 200m in dimensions and is constituted by three sand complexes (Figure 6). The inferior complex is around 7 m thick, the intermediate complex is around 11 m thick and the superior complex is around 15 m thick. They show important lateral variations.

- *Inferior sand complex* is constituted by medium-grained sands forming 0.1 - 2 m thick beds. Well cemented clay clasts float in the sand matrix. Their concentration decreases upwards in the complex. Rapid changes of the sand bed thickness are observed in the eastward direction. These changes are associated with the decrease of clay clasts in the formation as well.

- *Intermediate sand complex* exhibits a very rich internal structure. It is constituted by three sand beds 2 – 5 m thick (Figure 6). A detailed observation of the **section near the road** shows mostly mass flows constituted by well cemented clay clasts and pebbles floating in sand matrix (Figure 7b). Clay pebbles are around 2-5 cm and can reach until 10-20 cm in diameter. They show a high frequency presence in beds. Sand matrix is medium grained size, mostly constituted by Qz and coal clasts. Beds show a massive structure while clasts seem to be oriented slightly parallel with the bedding (imbrications). The top of sand beds shows very fine grained sands with parallel lamination. The top surface is not exactly parallel but shows mostly mounds or dunes with wavelength around L = 5-10 m. The clay pebbles show lower frequency in the upper part of sand beds. Consequently the sand beds show an overall fining upward trend of the grain size. The observation of the **section up cliff** shows lateral pinching out of many of the sand beds (Figure 7a). They are constituted by very fine grained sands with parallel lamination at their bottom, interpreted as traction carpets (Figure 7c). Clay pebbles floating in sand matrix are still observed but in much lower quantity. The pebbles are around 1-2 cm in diameter and show low frequency presence in thinner beds (around 10-20 cm thick). Concentrated vegetal organic matter is very frequent in the stratification planes.

- *Superior sand complex* is constituted by thinly laminated, fine to medium-grained sand beds 1 cm to 1 m thick separated by extremely rich in vegetal organic matter interbeds (Figure 8a & b). High content of vegetal organic matter is dispersed all over the sand beds. Parallel lamination is dominant in the sands at small scale but in big scale the whole series is constituted by mound or dunes with wavelength around L = 5-10 m constituting HCS like structures and sometimes cross bedding structures.

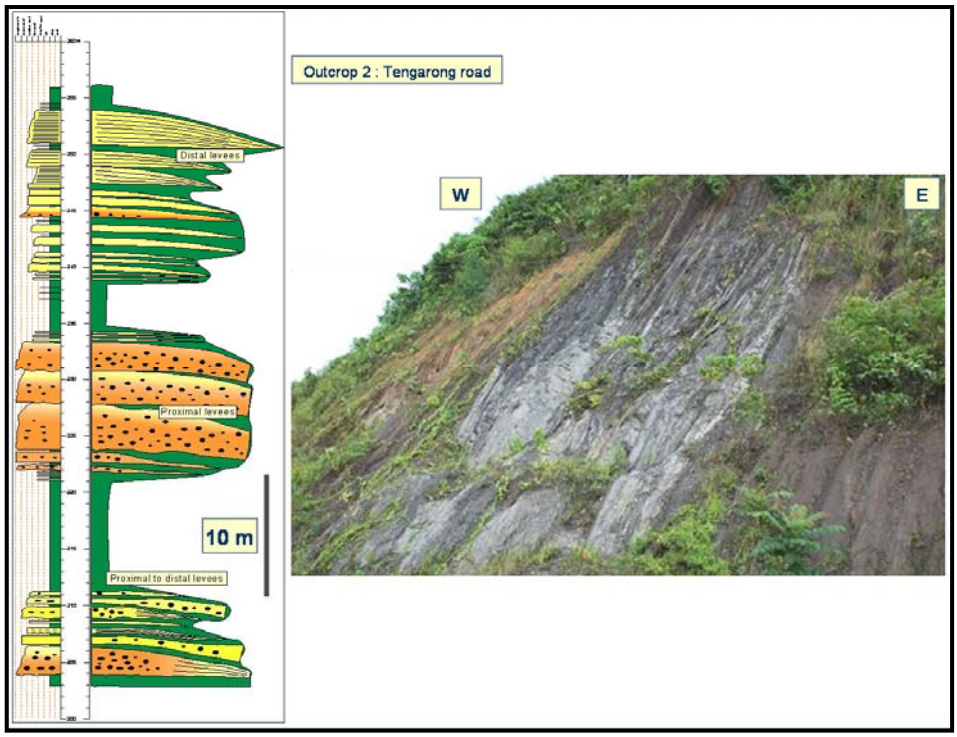


Figure 6. Log description and photo of the outcrop No 2 upper.

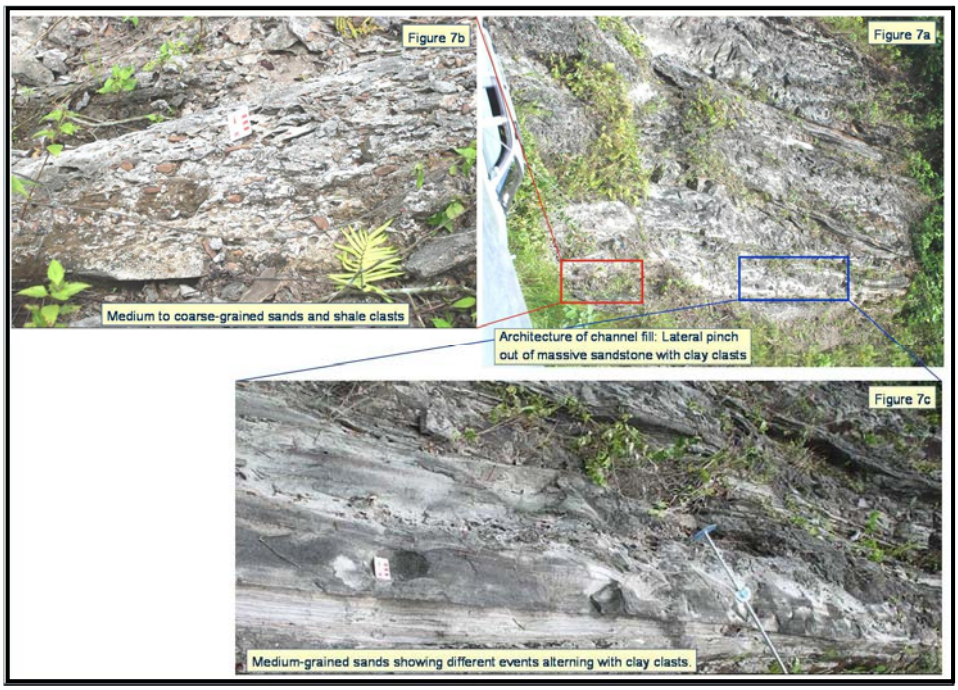


Figure 7. Detailed photographs of coarse-grained facies of the outcrop No 2 upper.

Interpretation:
The whole outcrop No 2 upper is interpreted as mass flow and debris flow. The wing shape of sand beds indicates deposition in levees. The inferior complex, around 7 m thick, is interpreted as a proximal to distal (related to the channel proximity) levee complex. The intermediate complex, around 11 m thick, is interpreted as proximal levee complex and the superior complex, around 15 m thick, is interpreted as distal levee complex. The 15 m thick sand interval observed in the top of the outcrop No 2 lower is interpreted as turbidity channel in a slope.

Although the dimensions of outcrops are small and do not give enough view of the sand development laterally we try to understand the geometry of channels and levees. A small sand layer at the bottom of the outcrop No 2 lower has been taken as miniature fractal model (Figure 9).Scouring at the

bottom of the sand are very often observed as well as the filling of scours with sand in the same way as the filling of the channels (Figure 10). Two different shapes can be distinguished. One is very thick and not very wide showing a massive structure (Figure 10). This can be interpreted as sand dominated channels described in McHargue et al, (2010). The other is wider and is interpreted as filled with sand and fine-grained sediments (Figure 11, Mchargue et al. 2010). Thin sands develop laterally to the scouring interpreted a overbank and levees (Figure 10, 11).

The whole section of the outcrop No 2 is interpreted as channel-levee complexes (Figure 12). Different parts of the section can be interpreted as being deposited in different parts of the channel or in overbank levees. This interpretation is based on the lithology and sedimentary structures present in different parts of the section.

Fowler at al., (2001) and Saller et al., (2004) have shown that sand can be deposited in sinuous turbidity channels in the Pleistocene and modern slope offshore Kutei basin. These channels are associated with levees as well. Slope channels filled with sands are formed in canyons related with delta front distributary channels. The whole outcrop No 2 is interpreted as channel – levee complex in a slope environment. The quantity of sand and the extreme variety of structures can be interpreted as an indication of the proximity of the basin floor. The lower slope environment is preferred as a best choice. Channel – levee complexes can be formed in intra slope small basins. The extreme rich vegetal organic matter deposited with the mineral material indicates that both mineral and organic matter have been transported and deposited together. Their source is related with fluvial input in the basin and probably the presence of a protoMahakam delta since these early times of Miocene in the Kutei basin.

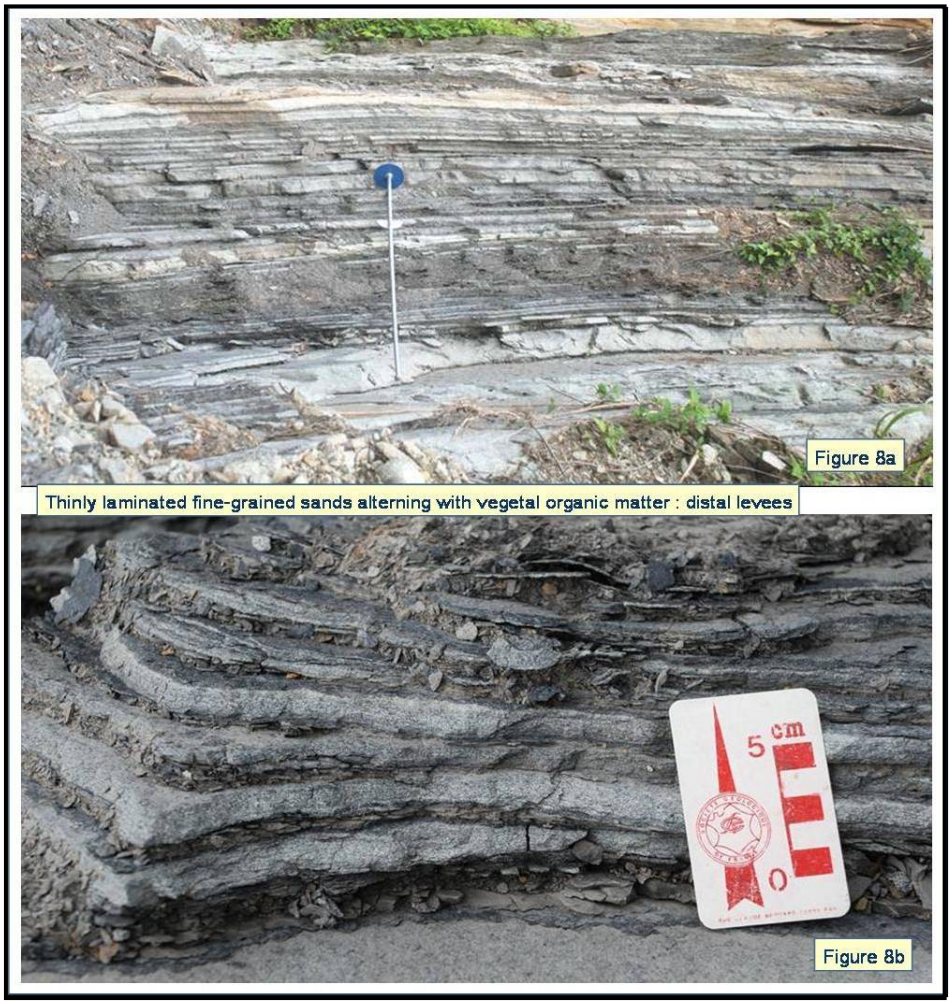


Figure 8. Outcrop No 2 upper, fine-grained facies photographs.

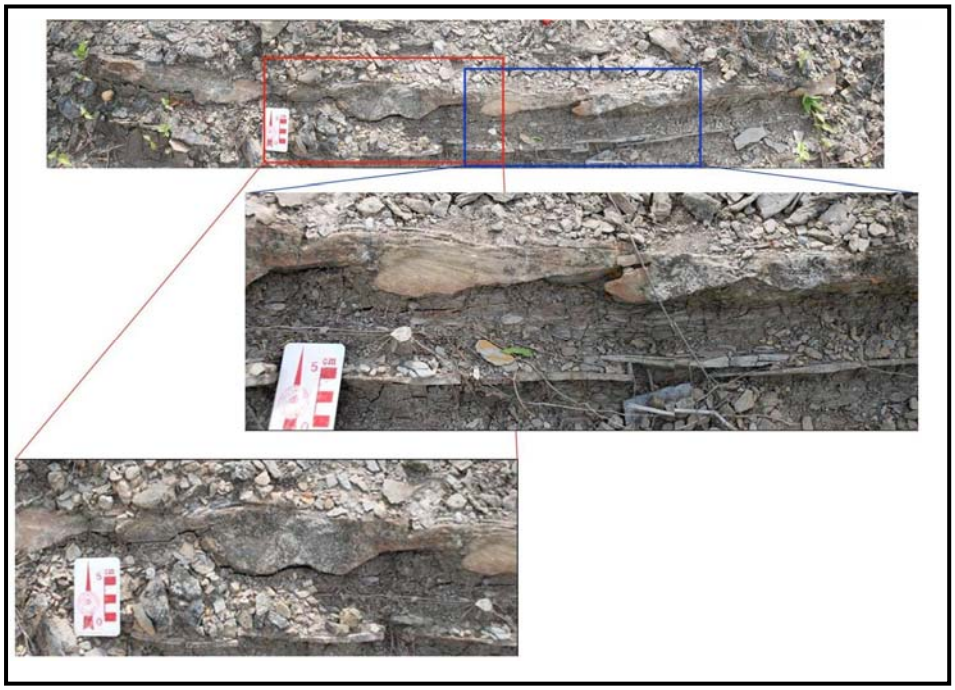


Figure 9. Miniature fractal model for channel – levee systems of the outcrop No 2, as observed at the bottom of the outcrop.

Discussion - Interpretation

Described outcrops show a wide variety of sedimentary features. There is a big difference between outcrop No 1 constituted by massive and parallel laminated sands (interpreted as lobe deposited at the end of the slope beginning of the basin floor) and the outcrop N2 constituted by mass and debris flows interpreted as turbdite channel-levee complex.

Channel-Levee Complexes are observed in the recent deposits of the deep water basin (Fowler et al., 2001). Individual levees are described as wedge shaped, thinning away from the channel, and show mudstone dominated lithology in wells. Large depocentres occur at points of gradient decrease, in slope mini-basins or on the basin floor. Deposition by the high-density part of turbidity currents is most likely, inferring a sand prone nature.

From outcrop No 2 to outcrops No 3 and 5 there is a variety of facies transition from mass and debris flow to thin–bedded turbidites, to highly bioturbated thin bedded turbidites. A detailed description of these outcrops is provided in Cibaj (2011). At the top of this trend is observed the Batu Putih carbonate which shows shallow marine conditions and interpreted as shelf break separating shelf from slope deposits (Cibaj & Wiweko, 2008).

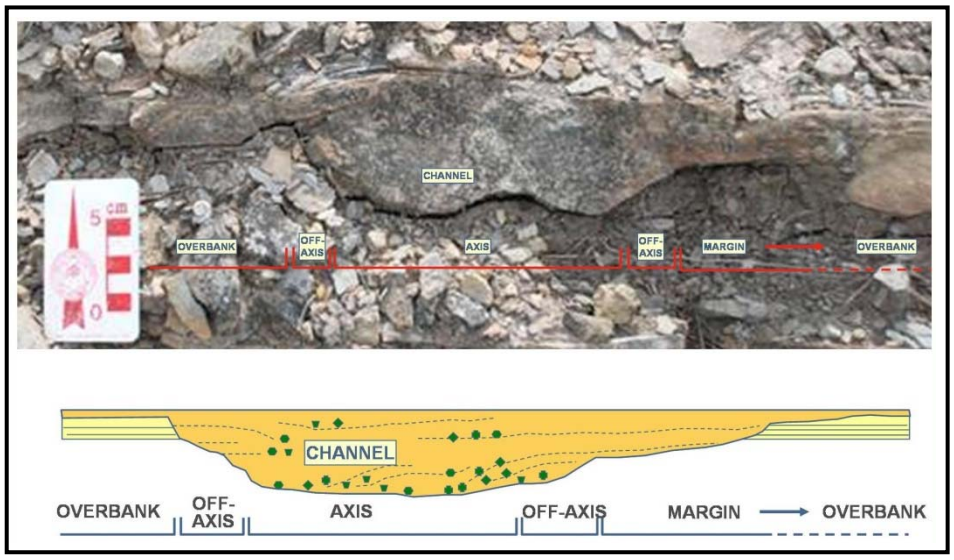


Figure 10. Miniature fractal model and detailed sedimentological model of a sand filled channel.

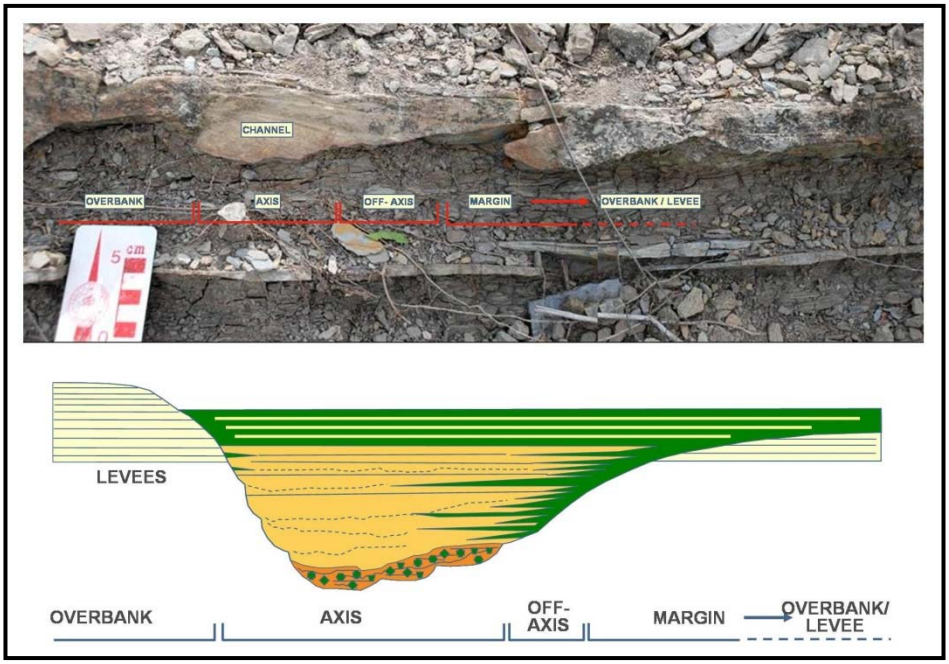


Figure 11. Miniature fractal model and detailed sedimentological model of a sand and shale filled channel.

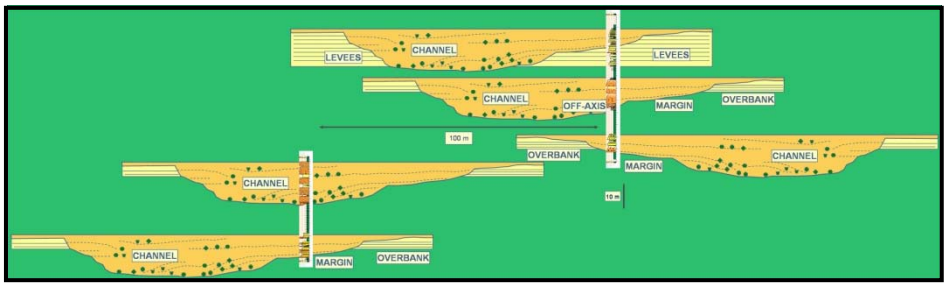


Figure 12. Sedimentological interpretation of the outcrop No 2.

Acknowledgments

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