Latest Turbidite Paradigm: Dispute on Cinambo Outcrop as Turbidites?

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Introduction

Conoco Indonesia performed a one-day geological fieldtrip to Majalengka and Kadipaten, West Java in late November 2000. The trip was led by DR. Dardji Noeradi (ITB) and approximate location of the field trip is shown in Figure 1.

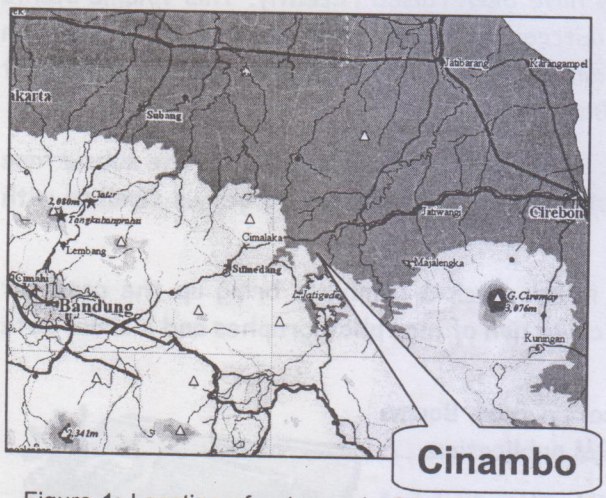


Figure 1: Location of outcrops in Cinambo, close to Sumedang, West Java

Discussion below is a short observation of the outcrops seen in Cinambo with no intention to describe or interpret the detail of the outcrops. It should be noted here that the short timing and condition during the fieldtrip was insufficient to further dig out geology of the area in more scientific manner. However, some critical points have been identified, two of them are, in fact, basic questions arose during and after the fieldtrip completed: (1) is there any turbidite sediments in Cinambo, and (2) how the sequences seen were deposited.

To respond to these crucial questions above one need further investigation and deep observation. It may take at least three to four months in the field just to prepare at least a couple dozen, correlatable detailed measured sections, observe and collect sedimentary structures, with no model-driven at all in mind ! Other months are to work in the laboratory to record lithology variations and changes through possibly of hundreds of thin sections of systematic rock samples. This is not a rocket science ! But why ? Here it is.

New Paradigm Of Turbidite

People tend to interpret any deep-water sediments as turbidites. The term "turbidite" is generally understood in the sense of Bouma (1962) and Walker (1965, 1967, 1970) as a bed, or better, a model for a bed, characterized by a fixed succession of sedimentary structures (the

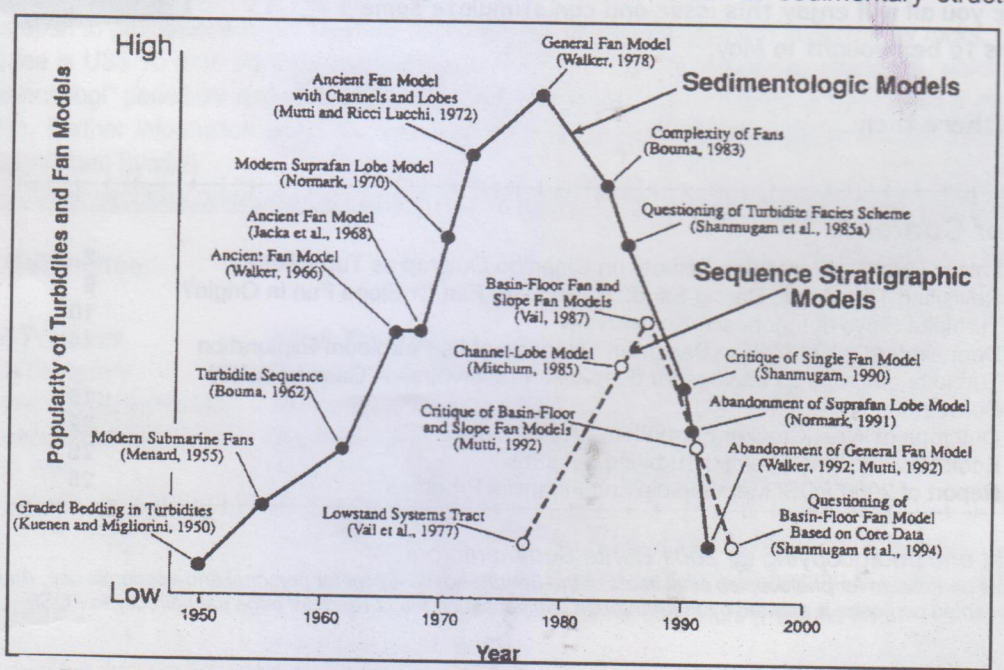


Figure 2: Rise and fall of popularity of submarine-fan models (Shanmugam, 2000)

Ta-e sequences) that reflects a precise depositional and hydrodinamic mechanism (Mutti and Ricci Lucchi, 1972). This definition led to well-known interpretative model of the Bouma Sequence and submarine-fan models of Mutti-Ricci Lucchi and Walker (1978). These fan models have served the geological community for about decade, but is now abandoned as shown in Figure 2. At present, there are no standard vertical facies models can be applied universally (Shanmugam, 2000).

On the other hand, Bouma (2000a and 2000b) suggested coarse-grained (sand-rich) and fine-grained (mud-rich) turbidite systems as end member models as shown in Figures 3 and 4. Hence the term 'turbidity system' and 'submarine fan' is synonymous. These models are based on transport mechanisms. Local tectonics, climate, sediment, and sea-level fluctuations, are the main parameters to select the models.

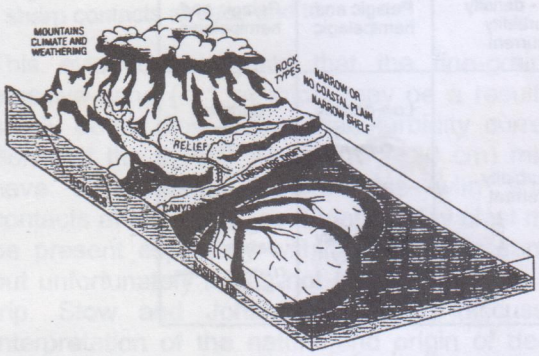


Figure 3: Coarse-grained, sand-rich turbidite system/ submarine fan (Bouma, 2000a).

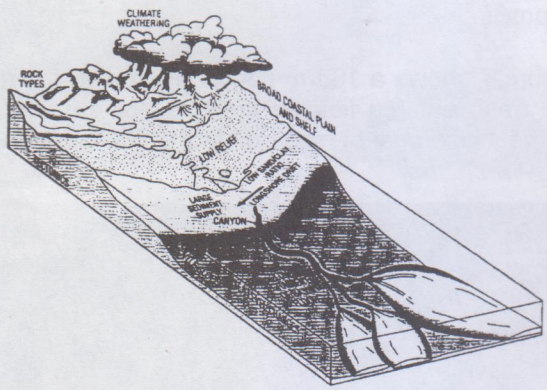


Figure 4: Fine-grained, mud-rich turbidite system/ submarine fan (Bouma, 2000a).

Shanmugam (2000) suggested classification of sediment-gravity flows into Newtonian flows (e.g. turbidity current) and plastic flows (e.g. debris flows) based on fluid rheology and fluid state. Based on fluid rheology and flow state, the natural turbidite sediment is deposit of turbidity current which sediment is suspended by fluid turbulence (Middleton, 1993). The turbidity currents transport sediment via suspended load, not via traction bed forms (laminar flow conditions) as shown in Figure 5.

Deposits of turbidity currents are characterized by normal size grading (ie. upward decline in grain size) and gradational upper contact (Shanmugam, 1997). In Bouma sequence, there is only Ta division represents turbidite. The remaining divisions (Tb to Td) are products of traction depositions or debris flows. However, if Ta division is ungraded, it may represent debris flows (Figure 6) especially if there are clay clasts floating in it. Therefore, the Bouma sequence as an interpretative model is composed of multi depositional events (Shanmugam, 1997) rather than a single event.

Stow and Mayall (2000) also believed that other processes and process combinations are important and in some cases dominant.

Debris Flows and Bottom Current Reworking In Cinambo

This seems to be consistent to the quick observation results of some of the outcrops in Cinambo. One of the outcrops observed (Figure 7) is composed of various depositional events. Perhaps most of the events occurred are debris flow and bottom-current reworking. Further investigation is required to see if there is any normal grading and record its relationships to the overlying and underlying sequences.

According to Djuhaeni and Martodjojo (1989), the Cinambo Formation is part of deep-sea fan turbidites series. It was deposited during N14 – N15 (late Middle to early Late Miocene). The Cinambo Formation is bracketed by deep-marine (bathyal) clay of the Cisaar (N9 – N14). Based on benthos foraminiferal paleobathymetric indicators found by Djuhaeni and Martodjojo (1989) in the Cinambo Formation, the findings of Gyroidina soldanii suggests it was upper bathyal (600' – 1500') but Uvigerina peregrina indicates outer neritic (300' – 600'). The Cisaar clay consists of Eponides umbonatus, Gyroidina soldanii, Cyclamina cancellata (upper bathyal), and Karrariella bradyi (upper bathyal).

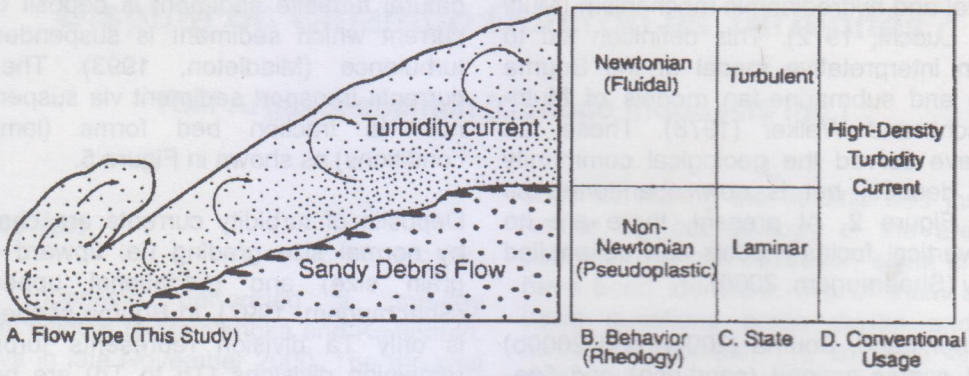


Figure 5: Flow type and state of turbidite (Shanmugam, 2000).

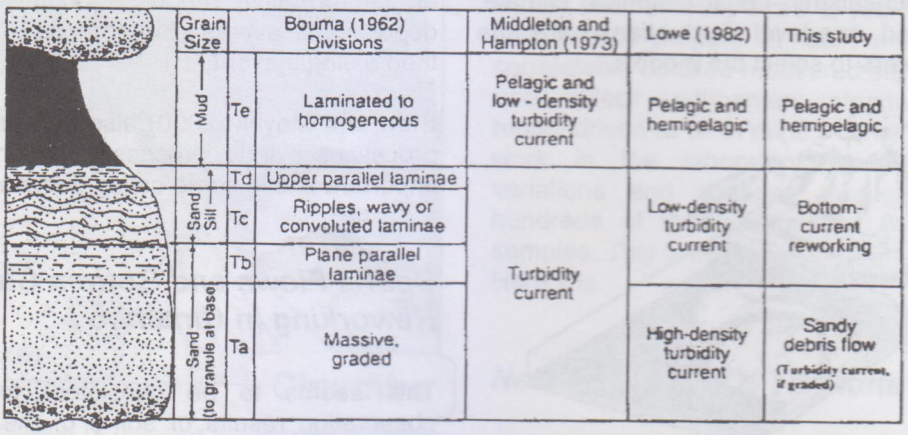


Figure 6. Ideal Bouma sequence (Shanmugam, 2000)

The deep-marine deposition continued untill N18 (late Late Miocene to Early Pliocene) when the Baturujeg Formation was deposited. Lithostratigraphy of the Majalengka area is part of regional stratigraphy of the Bogor-Kendeng Basin which are dominated by deep-marine deposits.

Figure 7 shows a 100-m continuous outcrop, but the fresh outcrop lies on the base of the river. Some close-ups of sedimentary structures are



Figure 7. One of the outcrops observed in Cinambo

shown in Figures 8 and 9. Figure 8 shows a thin fine-grained sand bed that has sharp contacts at base and top of the bed with structureless aspect. Thin clay separates the sand bed from other sands abruptly. These very thin clay layers, 5 – 10 cm in thickness, among thin sands, may indicate episodic depositional events.



Figure 8: One example of a structureless sand with sharp contacts at base and top

This evidence suggests that the fine-grained massive sand (< 1 m thick) may be a result of sandy debris flow rather than turbidity current. Some of the thinner sands (10 – 30 cm) might have structureless feature also with sharp contacts at base and top. Floating clay clast may be present especially within the thicker sands, but unfortunately it was not observed during the trip. Stow and Johansson (2000) discussed interpretation of the nature and origin of deep-water massive sands in detail. It needs further observation to see whether the massive sands in this area are a product of travel over short or long distances.



Figure 9. Flute or scour cast sedimentary structure

Some flute or scour surfaces were also observed as shown in Figure 9. The fine sands filled the erosional surface could partially be a product of reworking sands deposited by another depositional process. This is indicated by the presence of sand wedges over some of the scours. Although this small-scale scour surface is present which indicates turbulent state of the flow, this scour could be a product of bottom-current reworking. Therefore, this sedimentary structure should not be used to determine the presence of turbidity current since other processes may also produce scour casts.

Another sedimentary structure seen during the trip is ripple mark. Ripple-laminated interval of very thin sand (20 cm) has sharp contacts at base and top. This is interesting to note because the sand interval that has minor parallel-lamination at the base may originally be transported as bed-load of a bottom current. It is difficult to interpret whether or not the bottom current followed regional bathymetry contours of the area. Further investigation is needed particularly to measure paleocurrent directions and magnitudes of various sedimentary structures. The information is crucial to at least recognize the possibility of directions of both debris flow and bottom current.

Bioturbation was reported to also occur in the area, but it was not properly observed. If it did happen, it is necessary to investigate the intensity of bioturbation vertically to interpret direction of possible shallowing paleobathymetry of the sequences.

Conclusion And Suggestion

Some sedimentary structures recorded during this field trip are closely related to the debris flows and bottom current reworking. Unfortunately, there was no opportunity to observe normal grading and therefore it is difficult to interpret whether or not turbidity current took place in the area during deposition of the Cinambo Formation. Figure 7 shows rhythmic inverse grading of parasequences. This feature is common in both debris flows and bottom currents.

Some suggestions to develop further actions are as follows :

(a) it needs detail observation over larger area to cover sufficient data distribution of sedimentary structures, and vertical and lateral facies changes. These should be fully recorded to develop appropriate technical analyses.

(b) it is necessary to shift paradigm in building local depositional models based on fluid rheology and and fluid state approach rather than transport mechanisms.

(c) it is required to publish the results to add literature search on deep-water depositions in the country and sharpen local geological community on new findings and interpretations.

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