ARCHITECTURAL ELEMENTS OF A LONGITUDINAL TURBIDITE SYSTEM: THE UPPER MIOCENE HALANG FORMATION SUBMARINE-FAN SYSTEM IN THE BOGOR TROUGH, WEST JAWA

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ABSTRACT

The lower part of the Upper Miocene Halang Formation in the south of Kuningan, West Java is re-interpreted to have developed as a longitudinal turbidite system downsloping in the east along the axis of Bogor Trough. The Halang Formation turbidite system is represented by high-sinuosity channels in association with crevasse- and frontal-splays, and is interpreted to have developed as a mud-dominated submarine-fan system. Detailed field mapping of the deposits and observation of centimeter-scale lithofacies features were identified on the basis of five major lithofacies associations: (1) channel deposits; (2) overbank deposits; (3) sheet sandstones; (4) basin-plain deposits (5) sediment-wave deposits. Hemipelagite-dominated intervals were used as datums for clarifying spatial and temporal variations in the five major lithofacies associations. In general, channel deposits documents high-sinuosity channel patterns and locally contain lateral accretion surfaces. Sinuosity of submarine-fan channels decreases upsection along with the increase of sandstone to mudstone ratio, and this temporal variation in geometry of channels appears to have responded to the increase in the supply of coarse-grained particles into the basin. Sheet sandstones are interpreted to represent both frontal-splay and crevasse-splay deposits in relation to channel mouth and proximal overbank deposits in upslope areas, respectively. Sediment-wave deposits identified in overbank deposits. The generally eastward-directed paleocurrents are dominant, and interpreted to reflect the existence of paleohigh in the western margin of Bogor Trough that appears to have been one of the major hinterlands for the lower Halang Formation. Furthermore, the increase in the sandstone-to-mudstone ratio upsection may have responded to the activation of this hinterland. The present sedimentological study can provide a framework for new avenue of petroleum geology in the border of West-Central Java.

INTRODUCTION

Study on deep-water turbidite systems has considerably improved in recent years with the use of high-resolution seismic data (e.g. Posamentier and Walker, 2006), but detailed internal architecture of these turbidite system below seismic resolution still remains uncertain (Saller, et al., 2008). Outcrop analogues may provide high resolution investigation and models of heterogeneity distribution which can be used to optimize field development in such geological settings (Eschards, et al., 2003). The characterization of outcrops of ancient deposits into their component elements at a variety of scales may help unravel complex depositional histories and help in understanding the development of the growth stages within turbidite systems (Clark and Pickering, 1996).

This present study focuses on the outcrop of Halang Formation in the south of Kuningan, West Java (Figure 1). This formation was interpreted as a volcanogenic deep marine turbidites deposited in the Late Miocene back arc basin. The objectives this study is to describe the characteristic of the architectural elements of Halang Formation turbidite system. This detailed study on the anatomy and stratigraphic architecture elements could give an outcrop analogue in understanding the internal character of such deep-marine sandstones below seismic resolution.

GEOLOGIC SETTING

The south of Kuningan area, West Java, is located in the Bogor – North Serayu – Kendeng anticlinorium zone as described in the physiographic map of van Bemmelen (1949). At

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least since the Oligocene, this zone was initiated as a fault-bounded graben in a back-arc basin (e.g., Bolliger and de Ruiter, 1975; Sujanto and Sumantri, 1977; Wilson, et al., 2002). The nature of basement within the Bogor – North Serayu - Kendeng Zone is uncertain since it covered by thick sedimentary sequence and modern volcanic products. The strong negative Bouguer anomaly indicates that the basement is deep, and it is suggested to contain more than 8 km to around 11 km of sedimentary deposits (e.g. Smyth, 2005). During Late Miocene, the research area belongs to the western part of North Serayu Basin (Satyana and Armandita, 2004) or in the easternmost of Bogor Trough (Sribudiyani, et al., 2003). This basin was bounded to the north by the adjacent Tanjung – Pemalang – Kendal Sub-Basins, and to the south by a region of structural highs: Karangbolong – Lok Ulo-Serayu – Kulonprogo Highs.

The Halang Formation was interpreted being transversely received sediments from the uplifted southern mountain, remnant of the Oligocene-Miocene volcanic arc products. These eroded materials transported to the north via a fault-generated slope, and deposited by sediment gravity flows into the deeper marine (Martodjojo, 1983; Martodjojo, 1994; Djuhaeni and Martodjojo, 1989). This model was largely accepted for nearly two decades, modified by Clements and Hall (2007) who suggested that the Late Miocene arc to the east of present research location was located not in the same position as the modern volcanoes nor was it located to the north.

DATA SET AND APPROACH

This study focus on the lowermost, 400 m thick mud/sand-rich depositional system of the lower part of Halang Formation or the Gununghurip Member of the Halang Formation (Kastowo and Suwarna, 1996). Data were observed along tributaries of Cipedak river, aligned parallel to the Ciniru anticlinal axis, 20 kilometers to the south of Kuningan, West Java. Outcrop exposure allows measurement of vertical sections, and this permits lithofacies distributions, geometries and depositional environments to be interpreted at scales from the individual architectural element to the complete fan. The vertical sections combined with bedding trace derived from the interpretation of landsat satellite imagery, confirmed by the ground truth checking, constrained the correlation constructing the architecture and depositional style interpretation. On the basis for the sequence stratigraphic analysis, the most reliable correlation markers in the deep-water setting system at all scales are condensed sections (e.g. Wunut Field: Kusumastuti et al., 2000). Depositional sequence boundaries are difficult to trace into the deep marine section where pelagic drapes reflecting relative highstand are widely used for sequence correlation (Galloway, 1989). Depositional age of Halang Formation is taken from previous published data (e.g. ter Haar, 1935; Hatzel, 1935; and Lunt, et al., 2008).

Individual sedimentation units and their internal characters represent fundamental depositional processes which are differentiated into lithofacies. Lithofacies are grouped into major lithofacies associations based on primarily grain size, sedimentary structures, sedimentation unit thickness. Grain size is one of the parameters that more directly affect the depositional system and can be measured and observed with reasonable ease (Reading and Richards, 1994). These facies associations combined with their bounding surfaces, geometrical aspect of beds, paleotransport attributes, and distributional pattern, temporal and spatially, constructed the architectural element (e.g. facies association in Sixsmith, 2001). The characterization of outcrops of ancient deposits into their component elements at a variety of scales may help unravel complex depositional histories and help in understanding the development of the growth stages within turbidite systems (Clark and Pickering, 1996).

FACIES ASSOCIATIONS OF THE LOWER HALANG FORMATION

a. Facies association 1: Channel-fill deposits

Description

Channel-fills dominantly characterized by medium- to very thick-bedded, graded and massive sandstones show concave-up and distinct scour base with recognizable abrupt vertical facies changes mainly fining and thinning upward, sharp flat tops, and associated amalgamation surfaces, and capped by mud dominated bed deposited as the distal turbidite interbeds with the hemipelagic deposits (Figure 2). Bed thickness range from 0.7 – 4 m in the channel axis, comprised of thick- to very thick-bedded pebbly sandstone graded into medium- to coarse-grained sandstones graded and massive sandstones. Sandstone and siltstone interbeds in the upper part of channel-fill shows fining and thinning upward succession. These sandstones range from medium- to fine-bedded show sedimentary structures mainly parallel and wavy lamination, rare ripple laminations. The composite of channel-fill can reach to 9 m in thickness. Dewatering structures are common, mud clasts and mud chips occurred but not frequent. Lateral accretion surfaces are locally found as intra-channel deposits. Mudclasts are abundant and beds are commonly capped by siltstone. Generally the sandstones are medium- to very thick-bedded, grey – bluish grey, medium- to coarse-grained, subangular-subrounded, moderate sorted to well sorted, sometimes poorly sorted, and locally in the lower part of the sections abundant bioclastic fragments. Pebble- to granule-sized rock fragments comprised of sandstone-clasts, and volcanic fragments. Net to gross ratio for the channel-fill deposits is 70-90%.

Interpretation

Deposits of channel fill-deposits shows the waning of gravity flows as they passed through a particular location within the axial channel belt of Bogor Trough. The pebbly units locally shown in the log of the channel-fill were deposited from suspension, or by traction processes beneath immense turbiditic gravity flows (cf. Lowe, 1982), progressed to the deposition of thick- to thin-bedded turbidities on the upper part. A rapid decrease in flow velocity results in abrupt fall-out of sediment, which suppresses development of tractional structures or sorting of grains at the base. The presence of floating rip-up clasts and clast-rich tops to beds suggest possibly aggrading flows of a high-density nature that form in a depletive steady flow (Kneller, 1995).

The succession of lower Halang shows downslope direction to the east, with net to gross ratio range from 70% to 25%, from west to the east sections respectively. The channel fill deposits do not laterally continuous in stratigraphic sections. Paleocurrent directions of channel-fill deposits are diverging from the general paleocurrents downslope to the east. The lateral accretion deposits can be observed in outcrop close to the channel-fill deposits. The channel-overbank deposits also developed in significant thickness, suggest that long-lived feeder channel existed in the area.

Figure 2 show the outcrop features of channel-fill deposits, lateral accretion, channel-overbank and micro-scale sediment-wave deposits in Cipedak. By assuming this outcrop is showing the half of the channel width, from thalweg to the channel margin, the sinuosity of the channel axial belt of the Halang Formation can be deduce by the empirical equation derived from the cross-plot of channel depth vs. maximum sinuosity (Hickson and Lowe, 2002). The calculated maximum sinuosity developed in the lower Halang Formation is equal to ~2.3 which mean showing high sinuosity channel. The mender wavelength and the meander radius curvature can be calculated by using the equation derived from Wonham et al., (2000). By using the dimension of the channel measured in the location 6, the calculated channel meander wavelength is equal to ~3800 m and the meander radius of curvature is equal to ~1300 m. The channel dimension of Halang Formation is largely in the same pattern with the samples from the modern submarine channels.

b. Facies association 2: Channel-overbank deposits

Description

The levee deposit is virtually impossible to be recognized as positive relief morphology in ancient channel complexes (Clark and Pickering, 1996), therefore we grouped the ancient levee deposits into the more general facies-association term "overbank" deposits, as described by Mutti and Normark (1987). The Halang Formation channel-overbank deposits can be recognized in the field by their thin to medium-bedded fine- to medium-grained sandstones packages, distinctive sedimentary structures associations: climbing-ripple, convolute laminations, mudstone clasts and chips (Figure 3), and the diverge paleocurrents directions from the one of the channel deposits (30-80 degree). Locally, thin-bedded sandstones are intercalated with thin-bedded siltstones and mudstones. Base of sandstones beds show no obvious scour, even locally centimeter scale scour existed. Heterolithic slumped beds and soft sediment deformation structures frequently observed within this facies association. Figure 3.A. shows the slumped structures interpreted develop on the slope of the channel-overbank deposits. The channel-overbank sandstone thickness is reach to 30 m, showing thinning and thickening upward succession as well. Sand percentage within this deposit is reach up to 25 %.

Interpretation

Channel-overbank deposits that generally show mud-rich contents, interpreted to having formed as spilling of the sediment transported trough the channels. Patterns of fining and thinning upward successions suggest waning flow of turbidity currents. Extensive climbing current ripples suggest rapid deposition from high rates of suspension fall-out from sustained flows. The presence of floating rip-up clasts suggest possibly aggrading flows of a high-density nature that form in a depletive steady flow (Kneller, 1995). Channel-overbank deposits exhibit specific type pattern and lithofacies association similar to slope fan or ones deposited in the lower end of a submarine canyon (e.g. Flood et al, 1995). These features suggest high-sinuosity channel patterns develop in the Halang turbidite system along the axis of the Bogor Trough. It has long been recognized that many deep-water leveed-channels on recent fans are of high to moderate sinuosity (Posamentier and Kolla, 2003).

c. Facies association 3: Sheet sandstones

There are two types of sheet sandstones, crevasse-splay and frontal-splay deposits. These can be recognized by their close relations to the channel-overbank and basinal plain deposits respectively.

<u>Sheet sandstones: crevasse splay</u>

Description

The crevasse-splay sandstones can be recognized in the outcrops or in the log as anomaly within the fine-grained intervals of channel-overbank deposits and show paleocurrent parallel to the channel-overbank deposits. Typically these sandstones show coarsening and thickening upward succession, but some just appeared as alternation of medium- and thick bedded sandstones (Figure 4). These sandstones can reach up to 7.5 m for composite bed, in association with some graded sandstones, muddy sandstones, and mud-clast debrites, exhibit sheet-like geometry. Grain size are fine- to medium-grained, and fine- to coarse-grained composite beds. In the outcrops these sheet-sandstones appear structureless, or show sedimentary structures such as wavy-ripple and climbing ripple laminations. Some beds locally contain reworked bioclasts and calcareous cemented. Bed contact are mainly erosional flat base or show shallow local scours. Mud clasts are common in the base of beds or floating within beds.

Interpretation

Sheet-like sand-rich deposits that thin away from the associated levee crevasse can be interpreted as crevasse splays. These sandstones which often give appearance of coarsening upwards interpreted accomplished via passing through breaches in channel levees. The crevasse-splay is similar to frontal splays, but smaller in size (Posamentier and Kolla, 2003). Sedimentary structures such as climbing current ripples, which commonly are associated with rapid sedimentation out of suspension are more common in crevasse splays than frontal splays. Thick bedded sandstone with indicative high sedimentation rates deposited in interchannel area has been considered to characterize the crevasse-splays (Kirschner and Bouma, 2000). In the other case the overbank lobes formed in close association with the switching of channel migration direction in the proximal area (e.g. Hubbard, 2008). Here the 2D cross-section can not provide such information to support similar interpretation for the cause of the crevasse splay deposits.

<u>Sheet sandstones: frontal splay</u>

Description

The frontal-splay sandstones relatively show no obvious vertical succession trend, common blocky pattern, associated with the basinal-plain deposits, characterized by medium- to thick-bedded massive sandstones, in association with some graded sandstones and muddy sandstones (Figure 4). In the Halang outcrop, these sandstones range from 0.3 – 4.5 m individual bed thickness, and composite bed can be maximum to 8.5 m thick, fine- to medium-grained, graded to massive, parallel-wavy lamination but locally found ripples and lenticular bedding, bed contacts show mainly sharp to shallow erosional base, associated with debrites.

Interpretation

Sheet-package sandstones are interpreted to represent both frontal-splay and crevasse-splay deposits in relation to channel-sheet package and overbank deposits in the upslope areas, respectively. The frontal-splay deposits are commonly intercalated with muddy sandstones, very thin-bedded sandstones and hemipelagic deposits. These sandstones which show pattern of blocky motif in log (Posamentier and Kolla, 2003) spread basinward to the southeast.

d. Facies association 4: Distal overbank – basin-plain deposits

Description

The distal turbidites mainly comprised of turbidite mudstones are grouped with the hemipelagic deposits and together they built the condensed sections separated the sandstone-rich units. The turbidite mudstone mainly intercalated by very thin-bedded to laminations of very fine-grained sandstone and siltstones. Locally these mudstone are massive or associated with massive siltstones. Hemipelagic deposits characterized by fine-grained intervals are dominated by laminated mudstones and massive mudstones, in local association with very fine-grained sandstone laminae and some concretionary horizons.

Interpretation

The mudstone dominated intervals represent hemipelagic background deposition from suspension. The concretionary horizons that locally associated with mudstones are interpreted to represent condensation associated with minimum rates of clastic deposition in the basin, allowing early diagenetic growth at or close to the sediment water interface. The presence of isolated starved ripple lamination the siltstone also indicates deposition from weak tractional currents. These facies are the products of dilute turbidity currents represent the distal turbidites deposited on the distal basin floor.

e. Facies association 5: Sediment wave deposits

Description

These deposits were recognized overlain deposited over the channel-overbank deposits. These sediment waves were built by mudstone dominated interval interbeds with thin- to very thin-bedded sandstones and siltstones. Massive mudstones show color of grey to dark grey, dense to friable, locally bioturbated. The laminated mudstones were alternated with laminated siltstones, giving the appearance alternating of lighter and darker colors. This laminated mudstone thickness range from 20-15 cm, deposited over the fine sandstone or siltstone fine-beds. The laminated mudstones locally show bioturbation. sandstones range 0.8 to 4.8 cm thick, and occupied less than 5 % of the whole succession of these fine-grained sediments.

The mudstone shows no obvious structures. The sandstones intervals mainly show sharp erosional based. Normal grading and oblique lamination can also be observed. The bed thickness in the stoss side is thicker than the one in the lee side. Groove cast on the overlain mudstones shows this sediment waves directed parallel to the paleotransport of the overbank sediments. The upper successions were overlaid by the hemipelagic deposits. Some of this lithofacies geometry exhibit wave-like geometry with upstream migration (Figure 5). The upstream migration can be observed by the movement of the crest of the waves toward the proximal part. The bed thickness in the proximal is thicker than the one in the distal. These intervals was found deposited in close relation to the channel axis, directed in oblique to the channel axis. In the upper successions, sediment waves were overlain by the hemipelagic deposits. Sediment-wave deposits were observed developed over the channel-overbank deposits The aspect ratio of the present example of the sediment-wave deposits is largely similar to that of the modern sediment waves: Amplitude, length, and vertical height-form progressively decreased away from the channel axis. Furthermore, fine-grained sandstones and siltstones are thicker on the stoss side than the lee side, and indicate migration in the upstream direction.

Interpretation

Sediment-wave deposits exhibit climbing forms migrated in the upslope directions to the channels. Although the size of sediment-wave deposits is smaller than the modern examples, aspect ratio of the present example is largely similar to that of modern sediment waves. The geometry of wave height, wave length and ratio of wave length-to-height were plotted against the relative to the channel. These plots generally show all of the parameter in wave geometry were decrease from proximal to the distal part. The graph of length to height ratio for the upper section of the sediment wave show difference pattern, where in the distal part the ratio were increase compared to the more proximal. The appearance of the decreasing wave geometry of the sediment-waves also shown by modern samples of sediment waves (e.g., Nakajima and Satoh, 2001). The difference pattern in the upper section of the sediment waves for the upper section compared to the lower section might be related to the increasing pattern in the sandstone percentage for the whole fan development. All these lithofacies and geometrical features support that the sediment-waves deposits in the Halang Formation were likely formed by turbidity current in response to spilling over from the channels. Sediment waves are formed by overbanking tops of turbidity currents, which behave in a relatively uniform manner independent of initiation process (Normark, et al., 2002).

DISCUSIONS

In general, the lower part of the Halang Formation turbidite system is characterized by deposition of mainly channel and overbank deposits in the western part and the sheet-sandstone deposits in the more eastern part, which can be interpreted as proximal and distal, respectively. The overbank deposits interpreted to developed with low sandstone percentage and identified to construct the channel-levee system. The significant thickness of the overbank deposits indicate this mud-rich turbidite system (Bouma 2000) developed in high sinuosity channel as has been modeled in Peakall et al., (2000). The locally observed lateral accretion surfaces, and the diverge paleocurrent directions also confirm this sinuous channel interpretation (e.g. Dykstra and Kneller, 2008). These characters associated with the channel deposits largely indicate high-sinuosity channel patterns developed in the lower part of the Halang Formation submarine fan system (Figure 6). One of the controlling factors on the sinuosity as in the style of deposition at the channel bend was dictated by the degree of bypass within the system, which was found to be related to channel aspect ratio (Kane et a al, 2008).

The sandstones in the lower stage shows diminished channelization toward the eastern part, and change into the development of thin sheet-sandstones interbedded with basin-plain deposits. This suggests the relatively lower gradient morphology in the eastern part during sand deposition (cf. Mutti and Normark, 1987). The middle of lower stages in the eastern sections shows abundance of mudstone-rich chaotic unit/mass transport deposits and interbedded meter-scale sandstone intervals that interpreted as the deposition of lobate bodies in a poorly channelized to unconfined setting. The accumulation of numerous debris flow events interpreted this site was the base of slope deposition setting. These changes on the paleomorphology of the trough show to the eastward direction, degree of slope interpreted to decrease along with the increase deposition of basinal-plain deposits and the interbedded sheet-sandstones.

The volcanogenic sediments in the Halang formation was interpreted to be transported from the Late Miocene arc (e.g Clements and Hall, 2007), and here in we believed, not in the same position as the modern volcanoes nor was it located to the north. In the east of Majalengka-Banyumas area, there are two possibilities regards the position of the Late Miocene volcanic arc. The first probability is the arc volcanoes were to the south of the present day arc and Halang Formation rocks. These arcs are no longer observed on land since they have been removed by erosion; or second, a gap existed in the arc in central Java and no Late Miocene volcanoes were present (Clements and Hall 2007). In east Java, the present-day volcanic arc has been active since Late Miocene, and located some 50 km to the north of the southern Mountain arc (Smyth, 2005, Soeria-atmadja et al., 2005). The work of Sribudiyani, et al., (2003) depict the existence of Miocene volcanics to the north of Bogor Trough and within the Oligocene-Miocene volcanic arc in the Southern Mountain. The relatively abundance calcareous and bioclastic fragments and well calcareous cemented in some location in the Halang Formation demanding source from relatively shallower area that allowed the development of carbonates. Therefore the evidence of west derived paleocurrent for the Halang Formation suggest that provenance could not be simply addressed to the Southern Mountain.

The generally eastward-directed paleocurrents are dominant, and interpreted to reflect the existence of paleohigh in the western margin of Bogor Trough (Figure 6) that appears to have been one of the major hinterlands for the lower Halang Formation. Even though the Halang Formation submarine-fan system was developed in a longitudinal system directed in west-east direction, it is not necessary to have the hinterland directly located to the west of the trough. Multi direction of provenance of turbidite system can be developed in a topographically complex slope (Fugelli and Olsen, 2007), as here in the present location the control of regional fault parallel to the Sumateran trend (cf, Satyana 2007) considered to control the deposition for the Late Miocene turbidites deposited in the area between Majalengka and Banyumas region (Noeradi, et al., 2006).

Many previous publications on the driving mechanism of the sequence sedimentary deposition addressed to the combination between eustatic and tectonic. A more objective approach is to compare the timing and duration of stratigraphic features with known rates of potential driving mechanisms. This is only possible within the available time framework, which is limited in the case of the eastern part of the Bogor Trough. The Halang Formation were deposited during 11 – 7 Ma and ended with the unconformity that recognized along the Java Island (Lunt at al., 2008). A simple division would give crude depositional rate of 600 m/ma, very high number that would interpreted as there were rapid subsidence in this basin (cf. Lunt and Sugiatno, in press). The deposition of Pre-Rajamandala clastic in the West Java also show crude deposition rates of 350-850 m/Ma during Oligocene. This high deposition rate is likely to developed in this such active margin tectonic setting (cf. Lunt, et al., 2008), and is likely to be addressed to the subsidence as a compensation to the uplift of the Southern Mountain (Satyana and Armandita, 2004). The decrease of sinuosity of submarine-fan channels up section along with the increase of sandstone to mudstone ratio, appears to have responded to the increase in the supply of coarse-grained particles into the basin. The increase in the sandstone-to-mudstone ratio upsection in the lower Halang Formation may have responded to the activation of the hinterland for the basin-fills. Detailed sedimentological study and other related major as well in other part of this basin, will improved our knowledge in understanding the development of deep marine turbidite in this such setting.

CONCLUSIONS

The lower part of the Upper Miocene Halang Formation in the south of Kuningan, West Java is re-interpreted to have developed as a longitudinal turbidite system downsloping in the east along the axis of Bogor Trough. The Halang Formation turbidite system is represented by high-sinuosity channels in association with crevasse- and frontal-splays, and is interpreted to have developed as a mud-dominated submarine-fan system. Five major lithofacies associations were identified: (1) channel deposits; (2) overbank deposits; (3) sheet sandstones; (4) basin-plain deposits (5) sediment-wave deposits. Hemipelagite-dominated intervals were used as datums for clarifying spatial and temporal variations in the five major lithofacies associations. In general, channel deposits documents high-sinuosity channel patterns and locally contain lateral accretion surfaces. Sinuosity of submarine-fan channels decreases upsection along with the increase of sandstone to mudstone ratio, and this temporal variation in geometry of channels appears to have responded to the increase in the supply of coarse-grained particles into the basin. Sheet sandstones are interpreted to represent both frontal-splay and crevasse-splay deposits in relation to channel mouth and proximal overbank deposits in upslope areas, respectively. Sediment-wave deposits identified in overbank deposits. The generally eastward-directed paleocurrents are dominant, and interpreted to reflect the existence of paleohigh in the western margin of Bogor Trough that appears to have been one of the major hinterlands for the lower Halang Formation. Furthermore, the increase in the sandstone-to-mudstone ratio upsection may have responded to the activation of this hinterland. The present sedimentological study can provide a framework for new avenue of petroleum geology in the border of West-Central Java.

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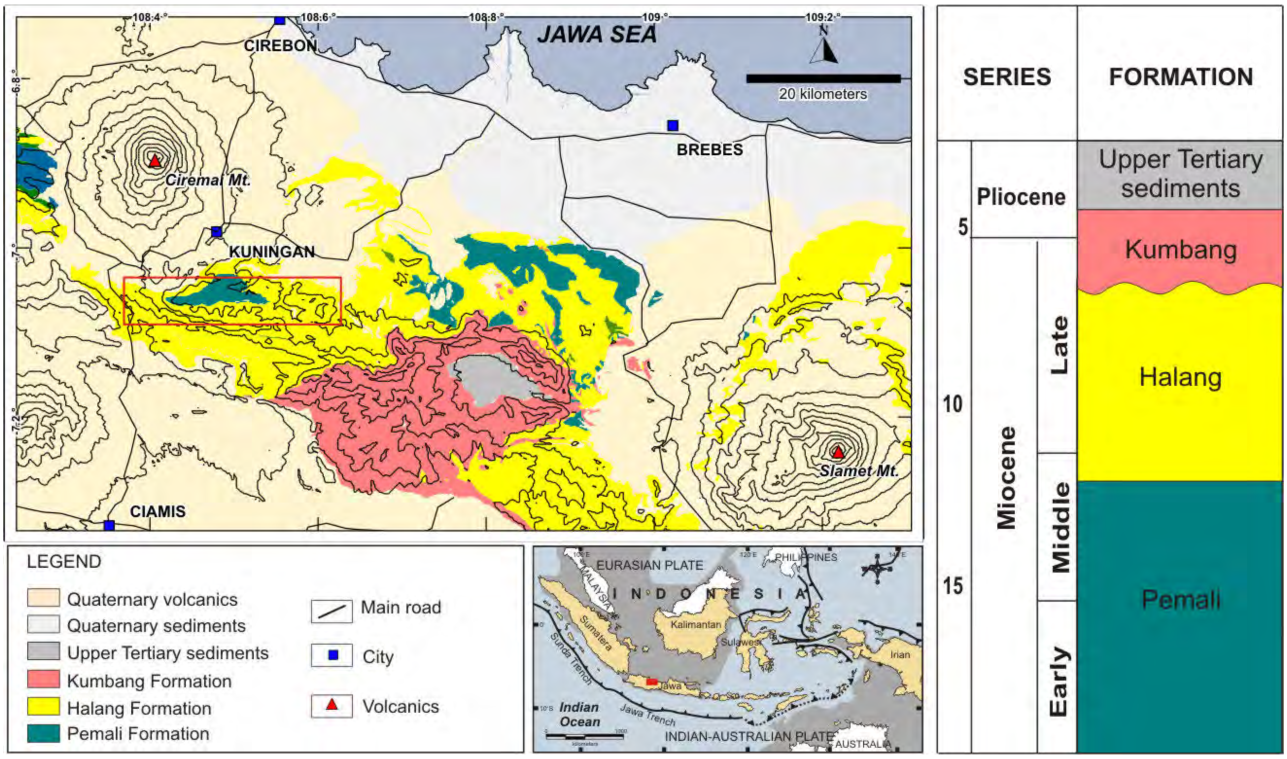

Figure 1 - Geologic map of area between Ciremai and Slamet shows the relation between the Halang Formation and the other younger and older deposits. The map and stratigraphic column of the research were modified from Kastowo and Suwarna, (1996). The Index map is a present-day tectonic framework of Indonesia. The light shaded areas are the continental shelves of Eurasia and Australia (modified after Hall, 2002).

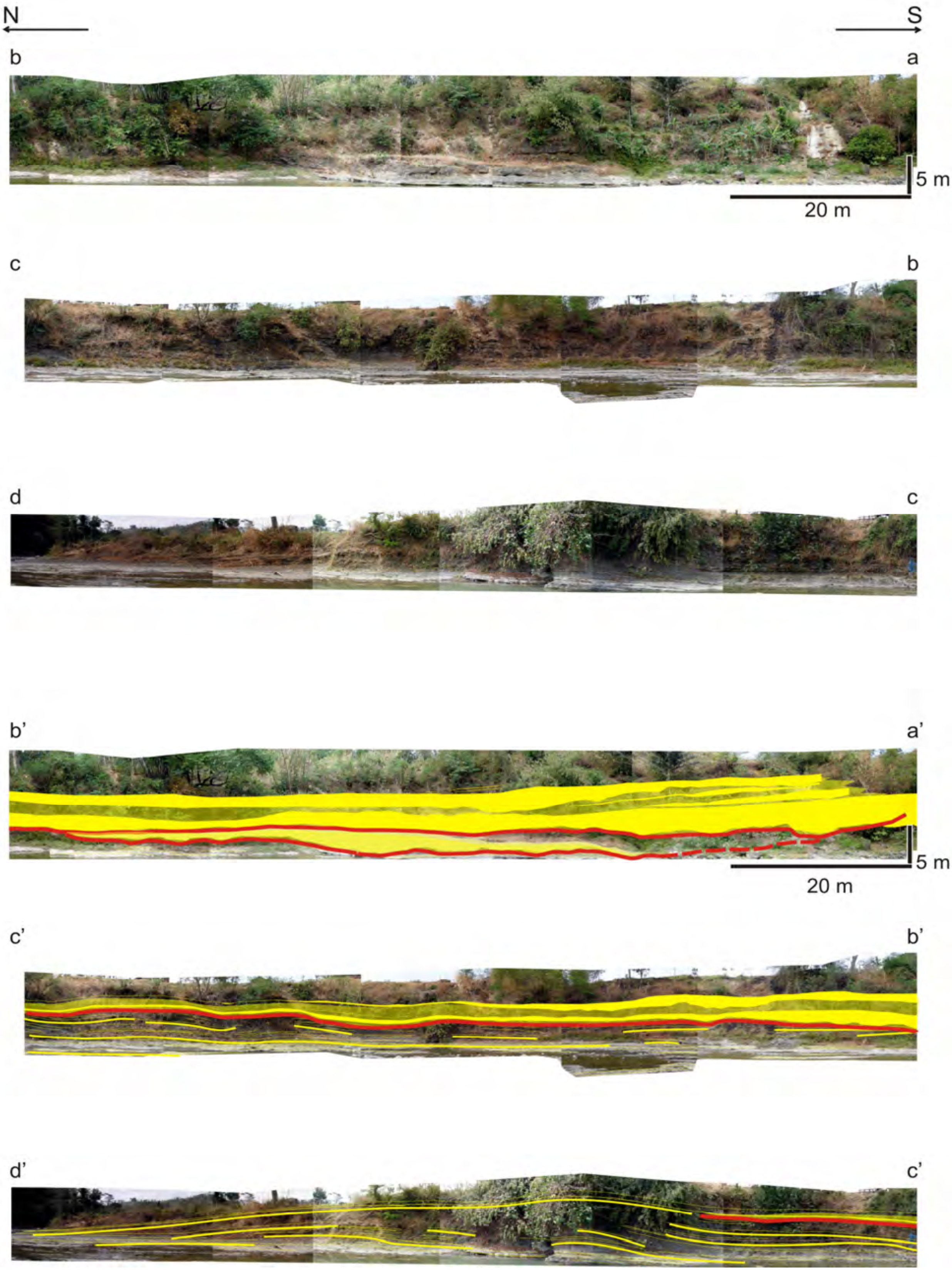

Figure 2 - The 3 top pictures show outcrop features of channel and overbank deposits oriented in a north – south direction in the Cipedak river, south of Kuningan. Lateral accretion surface was identified in the channel-fills, micro-scale sediment waves deposited in the overbanks. Traces of bedding features were shown in the lower 3 pictures, yellow is for the channel-fills, red for the channel base; the lower and upper beds are the overbanks.

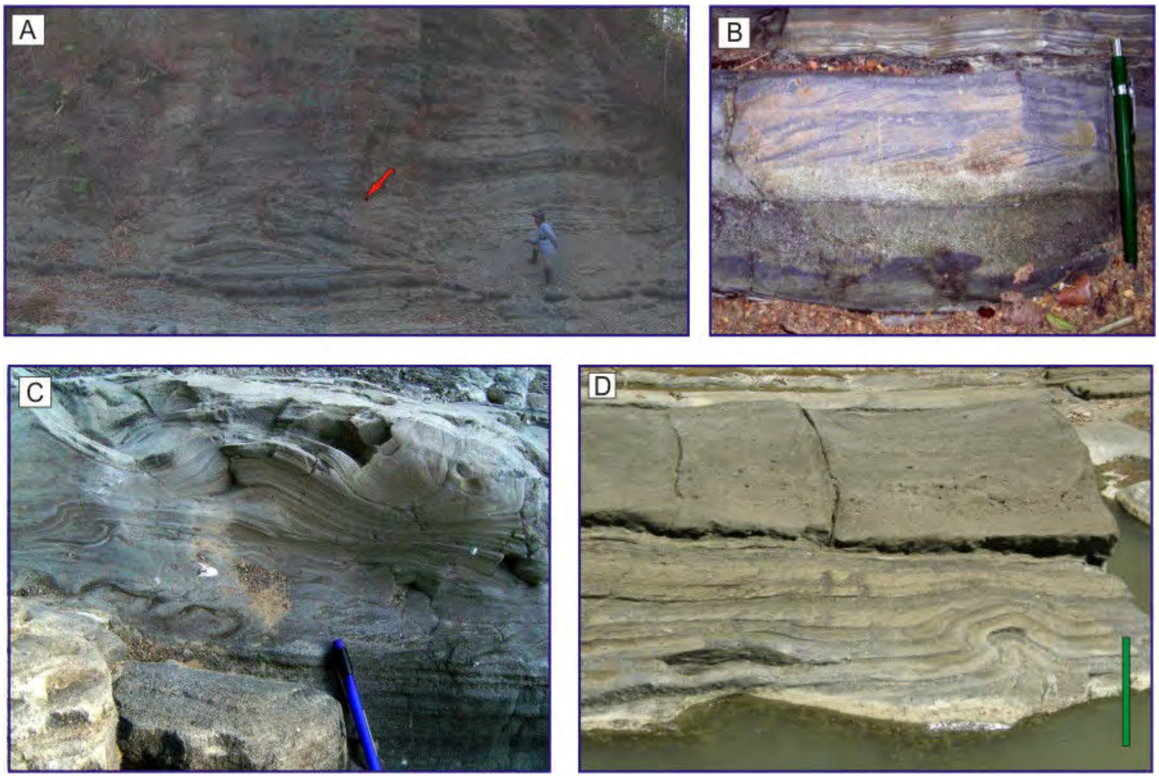

Figure 3 - Outcrop features of overbank deposits, (A) slumped heterolithic beds, (B) climbing ripple in thin-bedded sandstones, (C) convolute on the upper part of medium-bedded sandstones, (D) medium-bedded sandstone with floating mudclast overlain slumped beds. Pencil is 14 cm, and the scale bar in D is 20 cm.

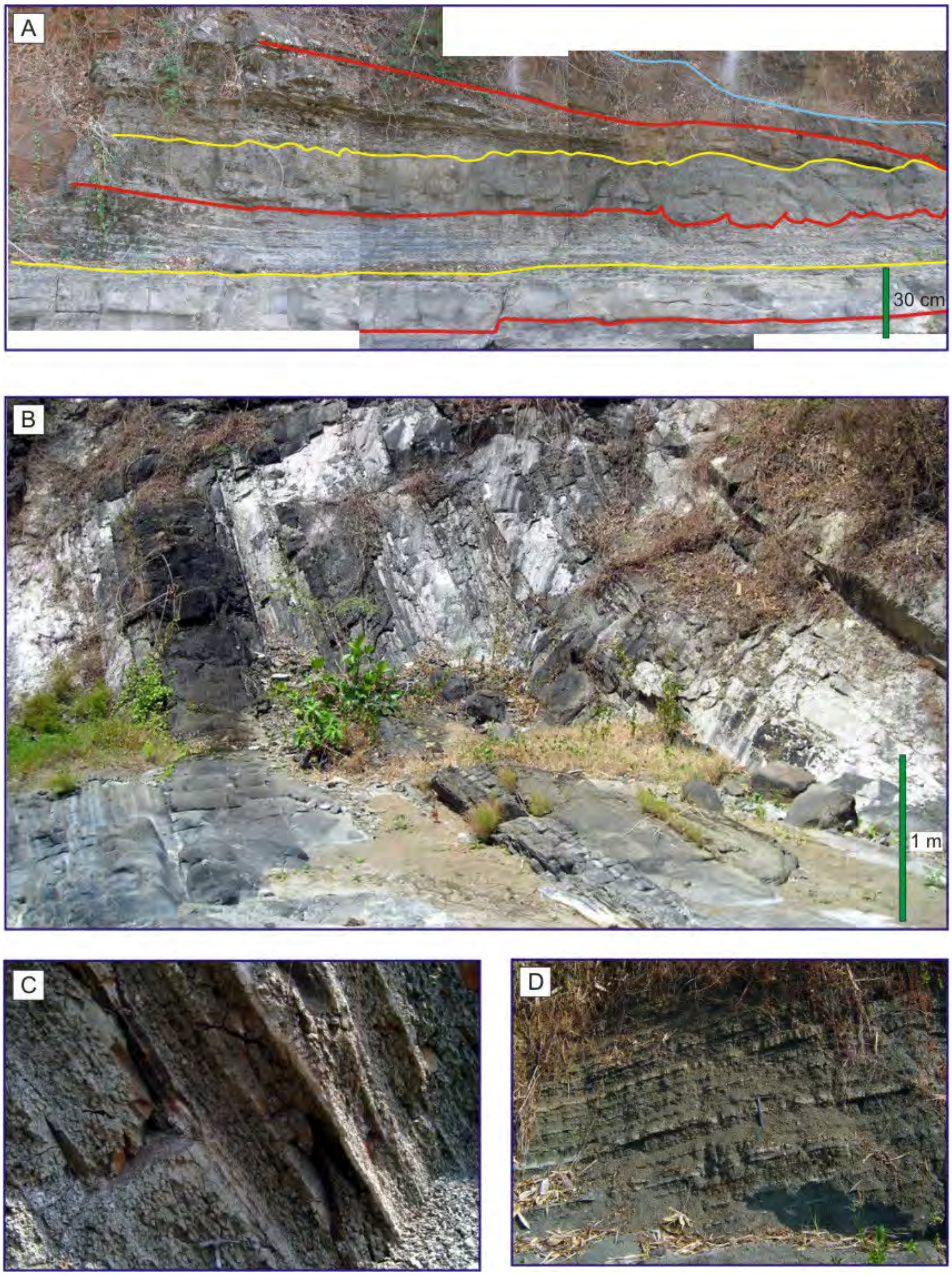

Figure 4 - Outcrop features of (A) Sheet-sandstones characterized by medium-bedded muddy sandstones with shallow scour based with flat tops, thickening and coarsening upward of medium bedded sandstones and alternating mudstones-fine-bedded sandstones. The second and the top bed were eroded, overlain by mud-dominated overbank deposits. (B) alternating thick-bedded sandstone and mudstones with intercalation of thin bedded sandstone, interpreted as frontal splay, deposited in the end of channel-levee deposits. (C) Hemipelagic mud, typically associated in with frontal splay in the basinal plain setting (D) fine grained deposits dominated by mudstones.

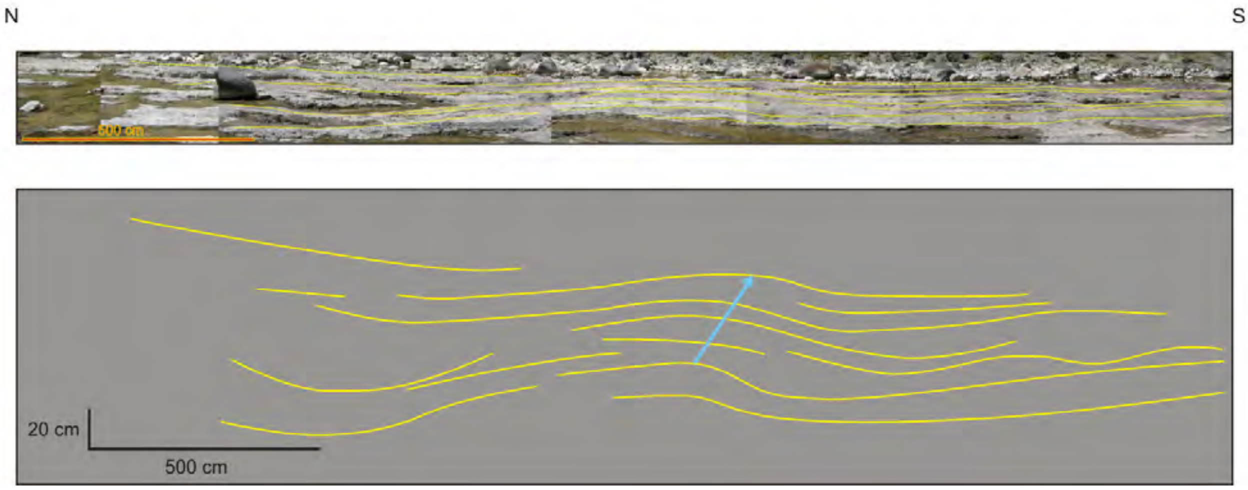

Figure 5 - Pictures of sediment waves outcrop (top) and bedding traces (bottom). Paleocurrent is from right to left, yellow is trace of fine-grained sandstones intercalating in mod-dominated sediment waves. Migration of the trough of the waves marked by blue arrow, directed to the right.

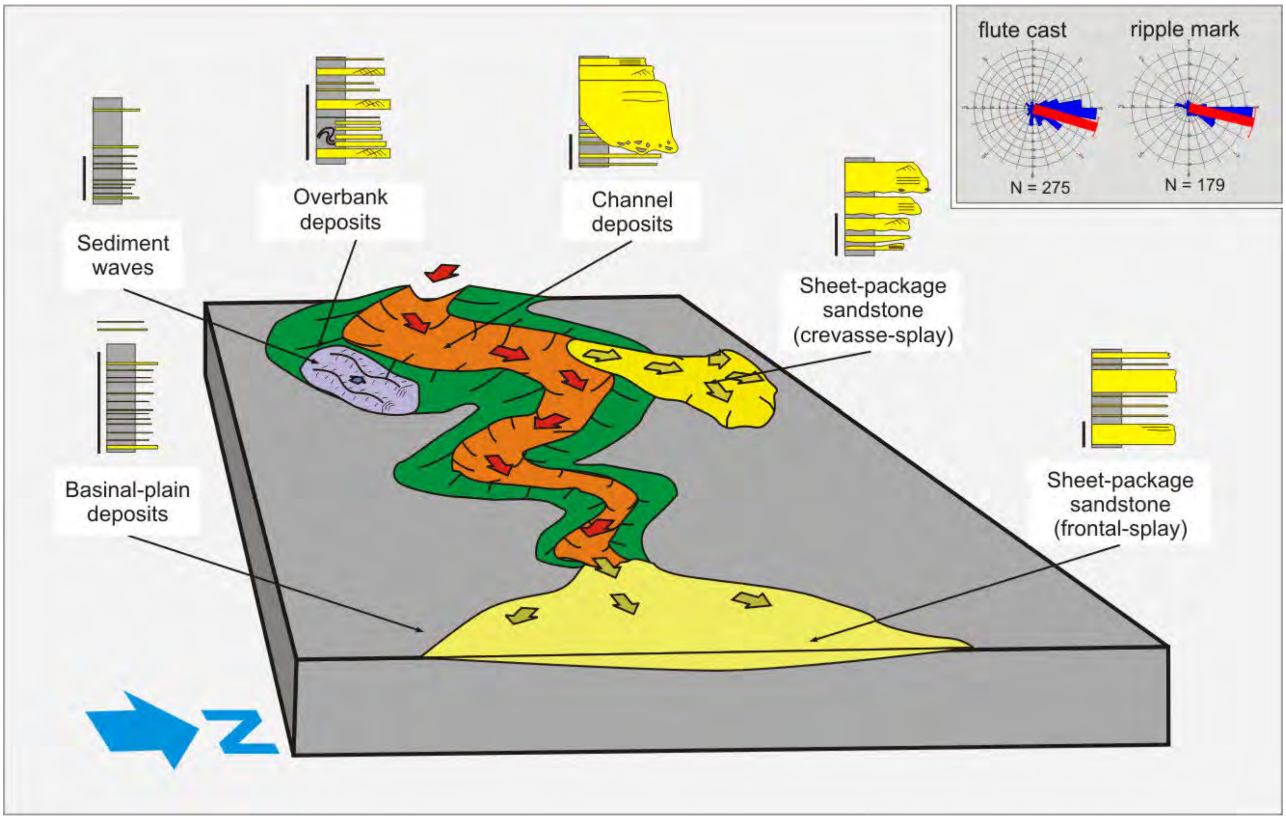

Figure 6 - The general depositional elements of the Halang Formation turbidite system in the south of Kuningan area. The turbidite system shows longitudinal system downsloping to the east. The channel and overbank deposits show high sinuosity, in association with the sheet-sandstones. The general trend of paleocurrent (top right) show the dominant in eastward direction.