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Sedimentology and stratigraphic architecture of syn-rift alluvial fan conglomerates in Nam-phrae, Chiang Mai basin

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Abstract

This study focuses on an exposed outcrop of an alluvial fan. It is comprised of footwall conglomerates in Nam Phrae syn-rift within the larger intracratonic Chiang Mai basin. Its lithofacies architecture and stratigraphy is a product of the interactions of deBris flow, over bank deposits, sheetflood flows and braided channel depositional mechanism in conjunction with allocyclic and autocyclic controls changing with time. By using a lithofacies correlation model, the complex stratigraphy is revealed to show its three dimensional geometry and its relation to the overall basin in terms of its hydrocarbon reservoir potential.

Keywords: Chiang Mai Basin, Alluvial, lithofacies, stratigraphy, lithofacies correlation

1.INTRODUCTION

The alluvial fan in Nam Phrae within Chiang Mai basin has deposits of footwall conglomerates, with subordinate mudstones and sandstones. Its facies and architecture is under the influence of different depositional systems as well as allocyclic and autocyclic factors. These factors are dynamic and sometimes cyclic.

The main objectives of the study are:

- To identify lithofacies and organize them into sedimentary facies that can reflect their depositional environments.
- Make lithofacies correlation to trace distribution of deposits.
- Reconstruct the stratigraphical architecture.
- Assess the connectivity of syn-rift Cenozoic deposits
- Understand alluvial fan-scale reservoir potential models and its role within the syn-rift sedimentary basin scale petroleum system in intracratonic settings.

Figure 1) Location of the study area, Nam Phrae, in Chiang Mai basin

2. METHODOLOGY

The method of study involves field work by observation as most of these deposits are large enough and don't require laboratory work and they lack sedimentary structures. It also involved alot of literature review and interpretation.

3. SEDIMENTOLOGY

The outcrop is characterized by a variety of lithofacies. The characteristics of the lithofacies are predominantly extraformational and epiclastic oligomict orthoconglomerates with surbodinate sand and mudstones. Six genetic lithofacies have been identified from this sub-basin outcrop. The lithofacies are characterized by bedding, grain-size and sedimentary structures.

The lithofacies present are;

1. Clast supported conglomerates-G2
2. Matrix supported conglomerates-G1
3. Horizontally stratified sandstone-S1
4. Cross bedded sandstone-S2
5. Massive mudstones-M1
6. Interbedded sand and mudstones-M2

3.1 Lithofacies

3.1.1 Clast supported conglomerates

The clast supported conglomerate is well sorted, clast supported pebble and cobble grain sized gravel. It has pronounced imbrication but lacks any internal structure. It has 70% components of quartz and chert clasts and a 30% matrix of sand sized particles that follows a parallel lamination towards its top.

Figure 2) Image of a clast supported conglomerate

Individual beds are 0.5m to 6m in thickness and 5m to 20m in lateral extent. They have a fining upward trend. Most have erosional bases (as shown by the red curved line in figure 2) with infilling by lag deposits.

3.1.2 Matrix supported conglomerate

The matrix supported gravel includes pebble and cobble conglomerates. This unit ranges from 0.5m to 3m thickness and can range from 2 to 14m in lateral extent. It is composed of 70% matrix of mud and 30% components of chert and quartz clasts. The clasts size ranges from 2-12cm.

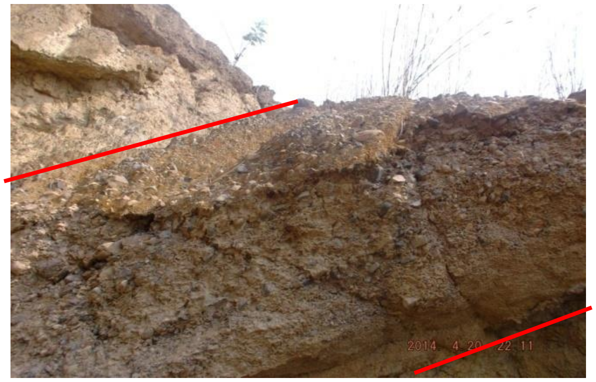


Figure 3) Matrix supported conglomerate

The clasts are subrounded to angular. They lack an erosive base and are poorly sorted.

3.1.3 Horizontally stratified sandstone

The stratified sandstones have medium sized grains that are sub rounded. Its thickness ranges from 0.5 to 1m with a lateral extent of 2 to 8m. It has a sharp basal contact with the underlying pebble conglomerate.

Figure 4) Horizontally stratified sandstone

3.1.4 Cross bedded sandstone

This facies consists of medium-coarse sub angular grains. They are about 1-1.5m in thickness and 10m in lateral extent. They have a cross bedded structure and have a sharp basal contact to the underlying mudbed.

Figure 5) Cross bedded sandstone

3.1.5 Massive mudstone

These deposits are found in various areas within the outcrop ranging in thicknesses from 30cm to 2m with a lateral extent of between 50cm to10m.

Figure 6) Massive mudstone

3.1.6 Interbedded mudstone

The mudstone is around 30cm thick and is around 8m in lateral extent. It is deposited between a fine granule matrix bed with sharp contacts.

Figure 7) Interbedded mudstone

4. DEPOSITIONAL PROCESSES

The lithofacies deposited here are a product of various depositional processes that happened over time. Each depositional process is responsible for yielding a distinct deposit.

4.1 Braided channel

The braided channel has the channel separated by braided bars.The concave up eroded base reflects an erosional process that infilled with channel lag deposits. The imbricate clasts reflect a palaeodirectional deposition by braided channels.

Figure 8) Caricature of a braided channel

The braided channel has good interconnection of its deposits and its braided bars.

Braided channels are responsible for the deposition of clast supported conglomerates.

4.2 Debris flow

The debris flow process has a strong cohesive internal strength that makes it capable of carrying boulders on top of its surface. This gives it its characteristic of having poorly sorted clasts.

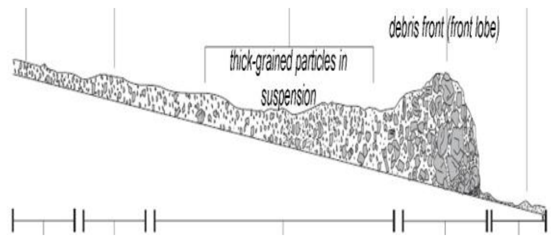


Figure 9) Schematic profile of a debris flow

The debris flow is responsible for deposition of matrix supported conglomerates.

4.3 Sheetflood deposition

Sheetflood deposition transports clay-sand size deposits. It lasts for a brief duration and it results from intense precipitation and spreads widely.

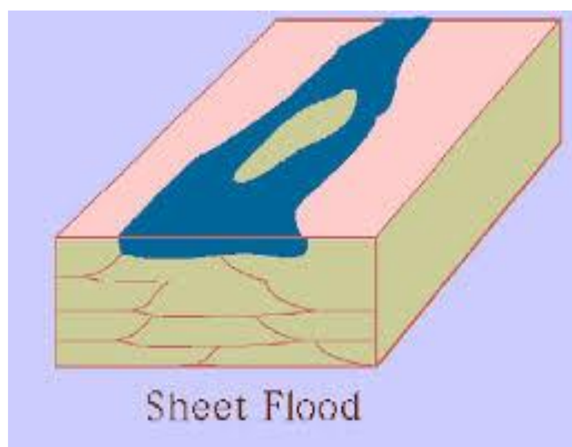


Figure 10) A sheetflood deposition cartoon

The sheetflood deposition is responsible for depositing cross bedded sandstone and horizontally stratified sandstone.

4.4 Overbank deposits

The overbank deposition results from mud carried in suspension outside from the main channel onto the floodplain.

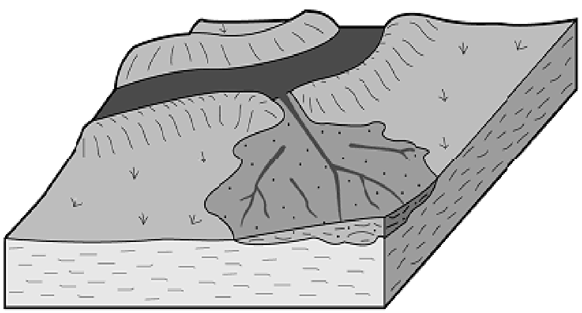


Figure 11) An overbank deposition cartoon

It results in deposition of massive mudstone and some interbedded fine grained sandstone and mudstone.

5. STRATIGRAPHY

The outcrop is divided into three blocks. The left block, the valley face and the right block.

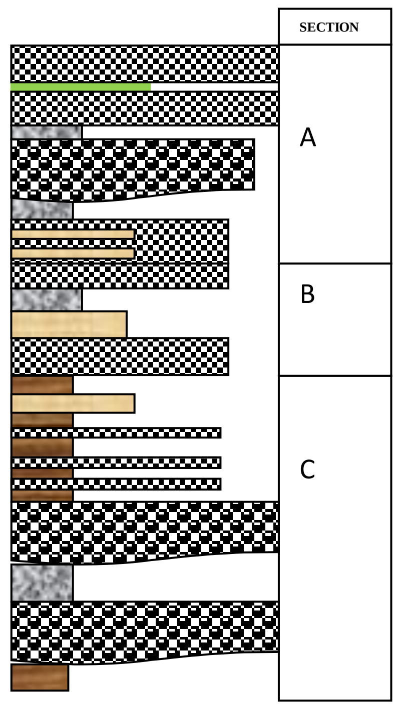
Figure 12: Profile of the outcrop

The lithofacies architecture is influenced by a) the interaction of debris flow, sheetflood, overbank and braided channel depositional mechanisms.
b) Autocyclic processes of surficial reworking, weathering and tectonics.
c) Allocyclic controls of climate and relief.

5.1 Interaction of debris flow, sheetflood, overbank and braided channel depositional mechanisms

5.1.1 Left Block unit

The divisions are based on its facies association and lithology structural orientations into three sections A, B and C.



LITHOFACIES	DEPOSITIONAL PROCESES
G1	Debris flow
G2	braided channels
S1	sheetflood deposits
S2	Sheetflood deposits
M1	overbank deposits
M2	waning flows

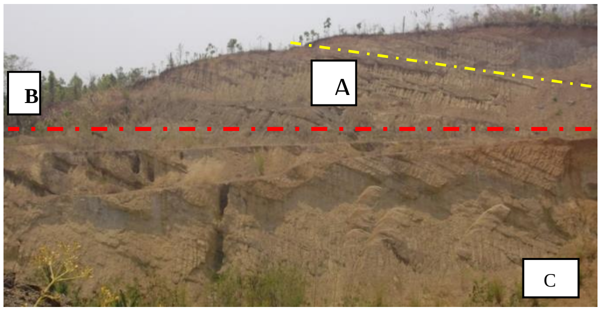


Figure 13) The left block stratigraphy

C- This unit of deposition fines upwards from a clast supported cobble conglomerate to interbedded sands and gravels in massive mudstone. This unit reflects a change from a braided channel to a sheetflood deposition. The structural unit orientation is inclined at N15W/235.

B- This unit is a fining upward sequence from a matrix supported pebble conglomerate to a blocky crossbedded sandstone that gives way to a mudstone. The unit structural orientation is N19W/240. Its depositional mechanism starts from a debris flow and is succeeded by a sheetflood deposit. Its top most matrix supported granule conglomerate bed is a product of debris flow.

A-This unit is a coarsening upward sequence from a clast supported pebble conglomerate to a red colored matrix supported cobble conglomerate. In between there is a 1m thick horizontal stratified sandstone. The unit structural orientation is N14W/255. Its depositional mechanism begins from a braided channel that is succeeded by a debris flow. There is a brief sheetflood deposit that gives way to the latest debris flow.

5.1.2 **<u>The valley face</u>**

Figure 14) The valley face section

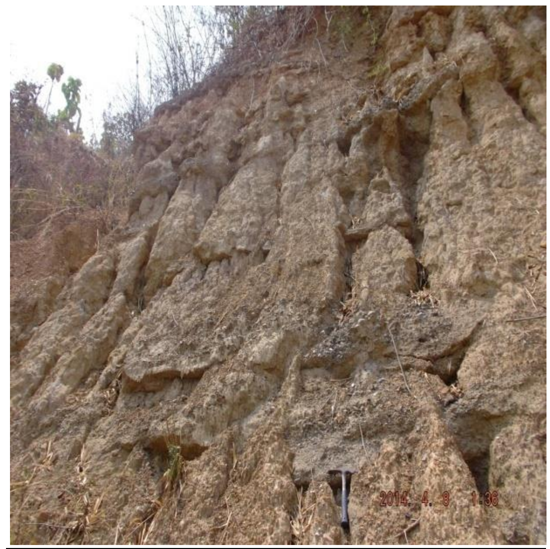
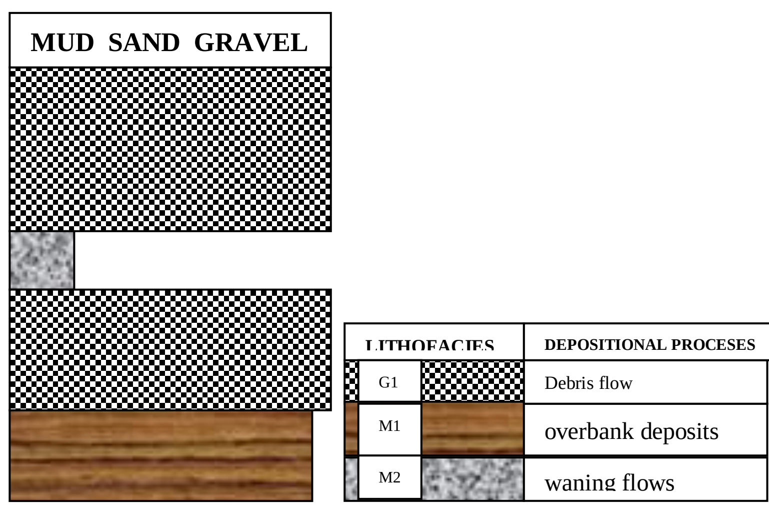


Figure 15) Lithofacies wihin the valley face



LITHOFACIES	DEPOSITIONAL PROCESES
G1	Debris flow
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S1	sheetflood deposits
S2	Sheetflood deposits
M1	overbank deposits
M2	waning flows

5.1.3 <u>Right block unit</u>

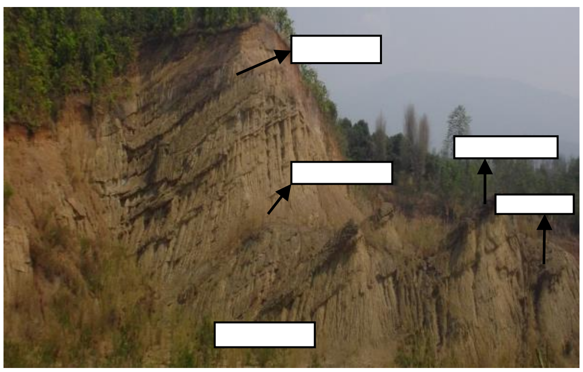
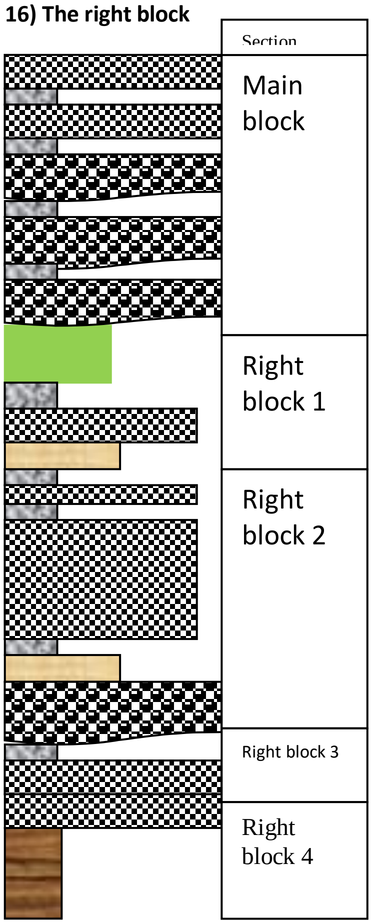


Figure 16) The right block



6.0 <u>LITHOFACIES ARCHITECTURE</u>

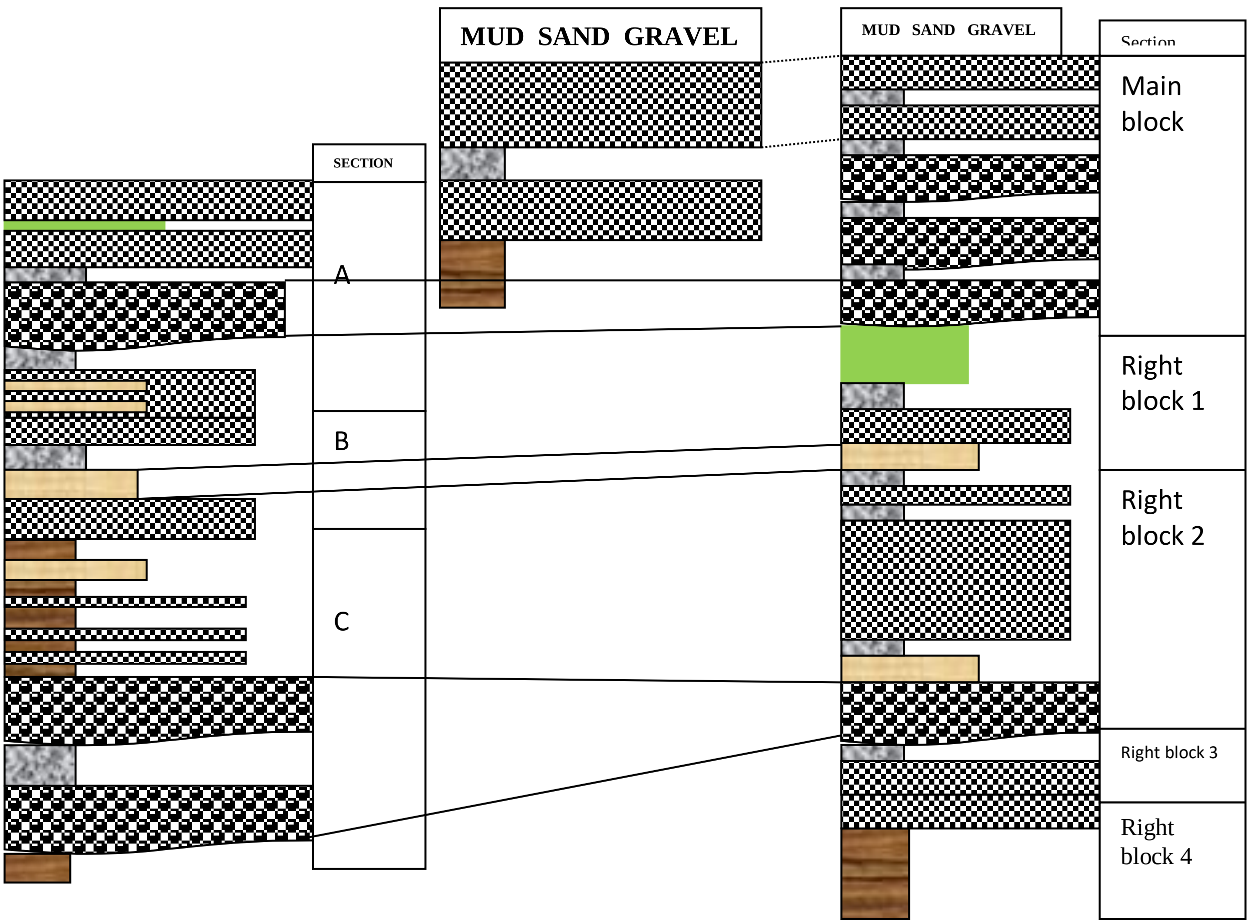
The topmost correlated beds are of the valley face and the right block unit with a lithology of a red colored matrix supported pebble conglomerate. It is 3m thick in the right block and thicker within the valley face with 7m. It is a product of debris flow.

The second correlation is between two clast supported conglomerates. The main block of the right unit is a cobble conglomerate with an orientation of S16W/320 and section A of the left unit is a pebble conglomerate with an orientation of N14W/255. They are both imbricated and 2m thick. These two correlations are indicative of a similar braided channel deposition mechanism.

The third correlation is found between two blocky cross bedded sandstones from Right block 2 within the right unit which has an orientation of S14/30 and the 1m thick blocky sandstone in section B within the left block with a structural orientation of N23W/213. They are both products of sheetflood deposition.

The fourth correlation is between a 3m thick, coarsening up, subangular, imbricated clast supported pebble conglomerate bed with an orientation of 15W/235 in section C within the Left unit that correlates with a 1.5m thick clast supported cobble conglomerate bed with similar characteristics of an orientation of S13W/25 in the Right block 3 within the Right unit. They are both indicative of braided channel deposit.

The colour coding links the depositional process to the lithofacies deposited.



LITHOFACIES		DEPOSITIONAL PROCESES
G1		Debris flow
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S2		Sheetflood deposits
M1		overbank deposits
M2		waning flows

6.1 Alluvial fan

This outcrop is an alluvial fan. It resembles a cone radiating down slope from a point where a channel emerges from uplands as described by (Bull 1977). Its gradient is steep at the apex, moderate at the middle and low gradient at the bottom. The coarsest grained sediments (boulders and cobbles) are deposited within the proximal areas, while the finer grained sediments (clay-pebbles) are located more distally according to size.

It is adjacent to an upland topography of Doi Suthep mountain that is 9km North from this outcrop. Trigger mechanisms like high water discharge and faulting that can transfer sediments from the drainage basins down slope to construct this fan.

These characteristics are sufficient to classify it as an alluvial fan.

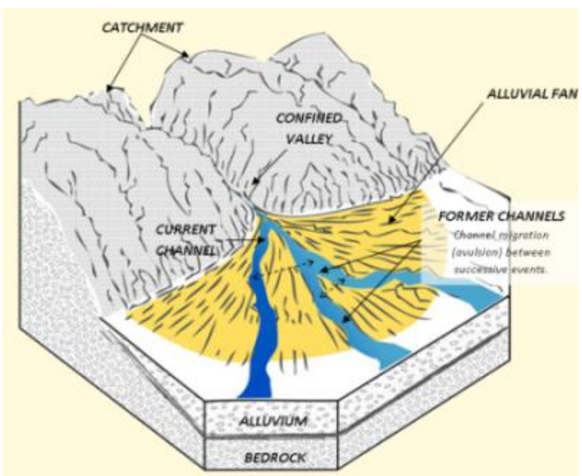

Figure 17) A cartoon depicting an alluvial fan

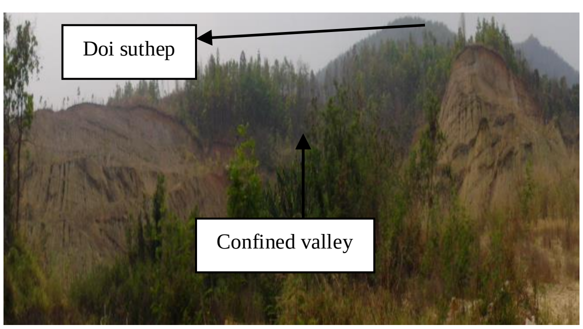

Figure 18) The alluvial fan in the outcrop

6.2 **Autocyclic processes**

The intrabasinal factors that shape the alluvial fan development here are surficial reworking and tectonics. Surficial reworking by direct precipitation of raindrops or overland flows from a large water discharge are capable of winnowing out fine sediments from primary deposits. Increased surficial reworking creates rills and gulies prevalent within this fan. Tectonics is exhibited here by faulting.

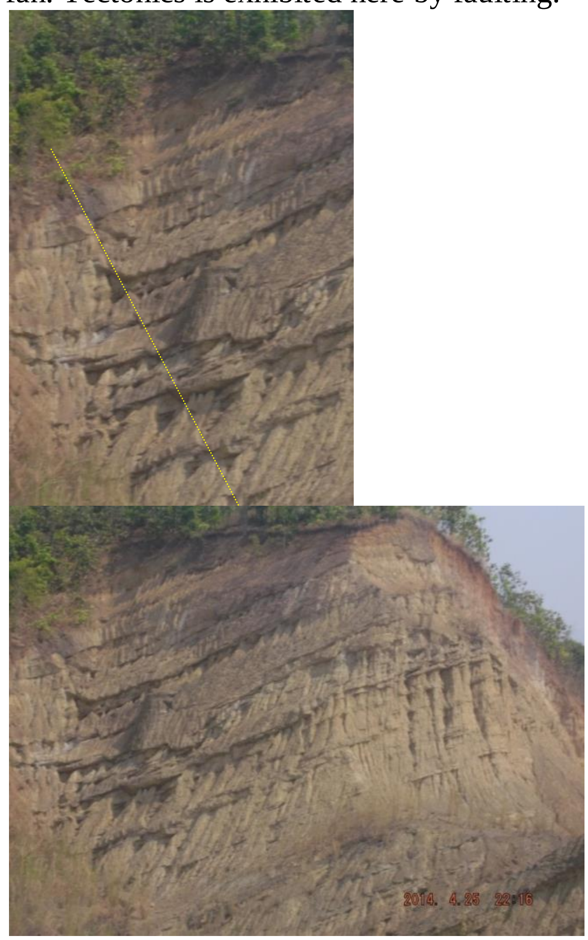

Figure 19) The yellow line depicts a normal fault cutting across the right block

The faulting caused vertical offset of fan sediments by nearly 1m displacement that uplifted the source area and caused the subsidence of the fan area. The fault scarp trends parallel to the mountain front and creates unstability by causing a steeper slope that triggers more sediments to fall into the alluvial fan.

6.3 **Allocyclic processes**

The extrabasinal factors that influence the development of this fan are climate and relief. The relief is as a result of the topography created by the Doi Suthep granite rich mountain. It is plausible that it supplies coarse grained sediments to this fan considering that it is only 9km away northwards. This is through mass wasting that is instigated by this high relief. Climate is also a crucial control because these are young Cenozoic deposits. With increased precipitation, the moisture lowers the internal shear strength facilitating gravity to overcome the cohesive shear strength of colluviums (Leeder 1999). Prolonged wet climates raise water tables that induce slope failures. Interglacial periods have increased rates of fan deposition due to higher meltwater run off that erodes the upland basin. Global glacial periods have higher deposition of sheetflood deposition (Blair and McPherson 1994). Judging from the deposits within the fan there are varying climate cycles that are reflected. There is intense flooding, some arid climate initiating erosion as well as prolonged wet climates.

7.0 **DISCUSSION**

With careful analysis from the lithostratigraphic correlations, we can reconstruct a picture of alluvial fans' spatial position in relation to the subsurface in linking the lithofacies and their role as hydrocarbon reservoirs.

7.1 **Reservoir implications**

Separation of correlatable beds is widespread showing a poor continuity. Cross bedded sandstones have a slightly good reservoir potential. With its lateral continuity stretching over 1km, it has a good connectivity. Judging from its medium grain size it appeared to have modest permeability and porosity as it is a product of sheetflood deposition. Its 2m thickness is the only disadvantage for it to serve as a hydrocarbon reservoir.

Matrix supported gravels from debris flow processes have the least reservoir potential because of their mud dominated matrix that reduces its porosity. Clast supported conglomerates, products of braided channels, have good porosity and permeability owing to their interconnected pebble and cobble clasts. They are laterally continous across the outcrop and have at least 10m in thickness. They have the best reservoir potentials according to these factors.

The heterogeneity of deposits from interbedded mudstones diminish the reservoir potential.

8.0 **CONCLUSIONS**

1) The depositional mechanisms here are debris flow, braided channel, overbank and sheetflood systems.
2) The lithostratigraphy architecture reflects an alluvial fan system.
3) The best reservoir potential is within braided channel deposits and the least favorable are debris flow deposits.
4) The reservoir potential is diminished by heterogeneity of deposits and poor continuity.
5) The linkage of lithofacies stratigraphy, distribution and its correlation is a useful model that can be used to interpret the complex stratigraphy of other complex alluvial fans.
6) Alluvial fan deposit correlation can help to evaluate the connectivity of deposits and

give an insight to the role they can play as hydrocarbon reservoirs.

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