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## **Proximal features of thick-bedded sandstones in Eocene flysch sequence, Rih area, Chin State, Myanmar**

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### **Abstract**

The Eocene flysch sequence, Rih area, Chin State, includes a number of thick-bedded, generally non-graded or poorly graded sandstones as well as normal graded sandstones (turbidites), laminated siltstones, conglomerates, and shales. Most of the thick beds occur in composite units up to 60 m or so thick, within which there is interfingering and inter-grading with thinner sandstones, and frequent amalgamation of beds. The composite units are separated by siltstone sequences, and in some cases at least appear to be large lenses. They are interpreted as being mainly channel deposits in submarine fan complex.

Many of the thick beds are either structureless throughout or have only a thin division of flat lamination (with parting lineation) near the top, followed in some cases by ripple mark. Some beds, however, show unusual wavy lamination or “dish structure” beneath the flat lamination, and this in turn may be underlain by bioturbated sand/siltstone. Trace fossils of *Scolicia plana*, *Scolicia prisca*, *Granularia*, *Spriophycus*, *Cosmorhaphie*, and *Chondrites* are well developed. Narrow vein-like de-watering channels (elutriation columns) occur in the wavy-laminated division of some beds.

The thick beds from a gradational series with the normal graded beds, and apparently represent the over-thickened basal parts of such beds, i.e., they are lateral variants of the normal turbidites. Similar beds called “sandy high-density turbidity current deposits” by Lowe (1982) also appear to be proximal turbidites. The origin of the wavy lamination and dish and pillar structures are deposited by the direct sedimentation of a coarse-grained high-density suspension.

### **Introduction**

Rih Lake is situated in Falam township, Chin State. It is a well-known lake for its heart-shaped outline and scenic views. This forms a part of research work and much more detailed work remains to be done on this very well exposed but rather inaccessible sequence.

### **Location and Transportation**

In half-inch topographic map 84 E/SW, Rih Lake (2966 feet above sea level) is located at east longitude 93° 23′ and north latitude 23° 20′. It is situated on the western part of the Chin State in Falam Township. *Tio va*, a north to south running stream, which is immediate to the lake, is a border stream dividing Mezoram State of India and Chin State of Myanmar.

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Since the lake is situated in hilly region, it is very hard to reach there easily. The nearest towns to Rih Lake are Tiddim and Falam. The road between Tiddim or Falam and Rih Lake is neither embanked nor metalled. Communication between Rih Lake and its nearest town is very difficult, especially in rainy season. Rihkhawdar is situated on a hillock, very close to the lake. Khawmawi (a) *Tio va* village, situated on Myanmar-India border, is about two miles away from the lake.

### **Previous Works**

Chin State is hilly region. To communicate from one place to another is not easy. For years the terrain was left unsurveyed due to difficult accessibility and scarcity of economic minerals. In 1966, Brunschweiler made a comprehensive report of the region. Detailed description of sedimentary structures, especially sole markings, of flysch deposits at the eastern foothills of Western Ranges were made by Dr. Myint Thein in 1972. In the same year, Dr. Win Swe described the deformation style of Western Range in his "Tectonic Evolution of the Western Ranges of Burma". In 2001, Bo San, Myo Min and Aung Khin Soe made a preliminary report on the geological investigation of Rih Lake and its environs and surveyed the size, shape and depth of lake.

### **Geological Setting**

Flysch sequences, exposed near Rih area are parts of the central Chill Hills. Narrow motor roads climb steeply up from Kalemyo westward across the high ranges to Tiddim, Falam, Hakha and the Rih Lake, over the east flank of Kennedy Peak (2704 m), the road to Tiddim and the Manipur border climb to well over 2400 m. The most conspicuous member of east-dipping sequences on the eastern flank of the Kennedy Peak ridge is the exotic flysch which contains large blocks of Upper Cretaceous *Globo truncana*-limestone as well as Lower Eocene, bituminous, limestone with *Assilina* (eg. Lung Pi, near Falam and road section from Falam to Rih Lake) (Fig.1) (Brunschweiler, 1966; Bannert, D., Sang Lyen, A., and Than Htay, 2011).

The flysch sequences exposed near Rih Lake and its environs are made up of four main rock types, viz. (1) laminated siltstone-fine sandstone; (2) thin-bedded sandstones (less than 30 cm) which are usually graded; (3) thick-bedded sandstones (0.3-2.5 m) which are commonly non-graded or poorly graded and may show either dish and pillar structures or wavy lamination; and (4) pebble- to conglomerates, many of which are graded.

Lateral gradations from conglomerate to sandstone to siltstone occur within some beds and there are abundant intermediate types between the four groups, so that a common origin for all rock types from the one kind of current seems inescapable.

### **Features of the Thick-bedded Sandstones**

The study of ancient and modern flysch-type sequences has shown that a number of bedding types, as well as the normal graded beds or “turbidites”, may be represented, particularly in proximal sequences. One of the common types is represented by the thick-bedded, non-graded or poorly graded sandstones interpreted by as “proximal turbidites” by Walker (1967) and as “grain-flow deposits” by Lowe (1982). The thick-bedded sandstones are usually structureless but in some cases show an unusual discontinuous curved lamination which has been called “dish-structure”.

Flysch sequences, which are well exposed on the Chill Hills, contain numerous examples of thick-bedded sandstones and conglomerates interbedded with graded sandstones and laminated siltstones. The purpose of the present paper is to describe some of the thick sandstones, particularly those with wavy lamination or dish structure, and to show that they are probably turbidity current deposits rather than the products of some mass-flow mechanism. Other features of the sequences will be described elsewhere.

### **Mode of occurrences**

Most of the thick sandstones, and the conglomerates, occur in composite units up to 60 m or so thick within which siltstone is usually rare or absent. The composite units are separated by sequences of laminated siltstone-fine sandstone, so that any vertical section consists of alternating zones of siltstone and sandstone. The arrangement of coarse-grained lenses in a matrix of laminated siltstones and fine sandstones resembles the channel-interchannel arrangement described from ancient and modern deep-sea turbidite fans (Walker, 1965), and the composite sandstone units are interpreted as being mainly channel deposits in a submarine fan complex. Within the composite units the thick sandstone beds may intertongue with and grade laterally into thinner graded beds (Fig. 2), or be separated by sequence of thin, tabular or wedge-shaped beds (Fig. 3).

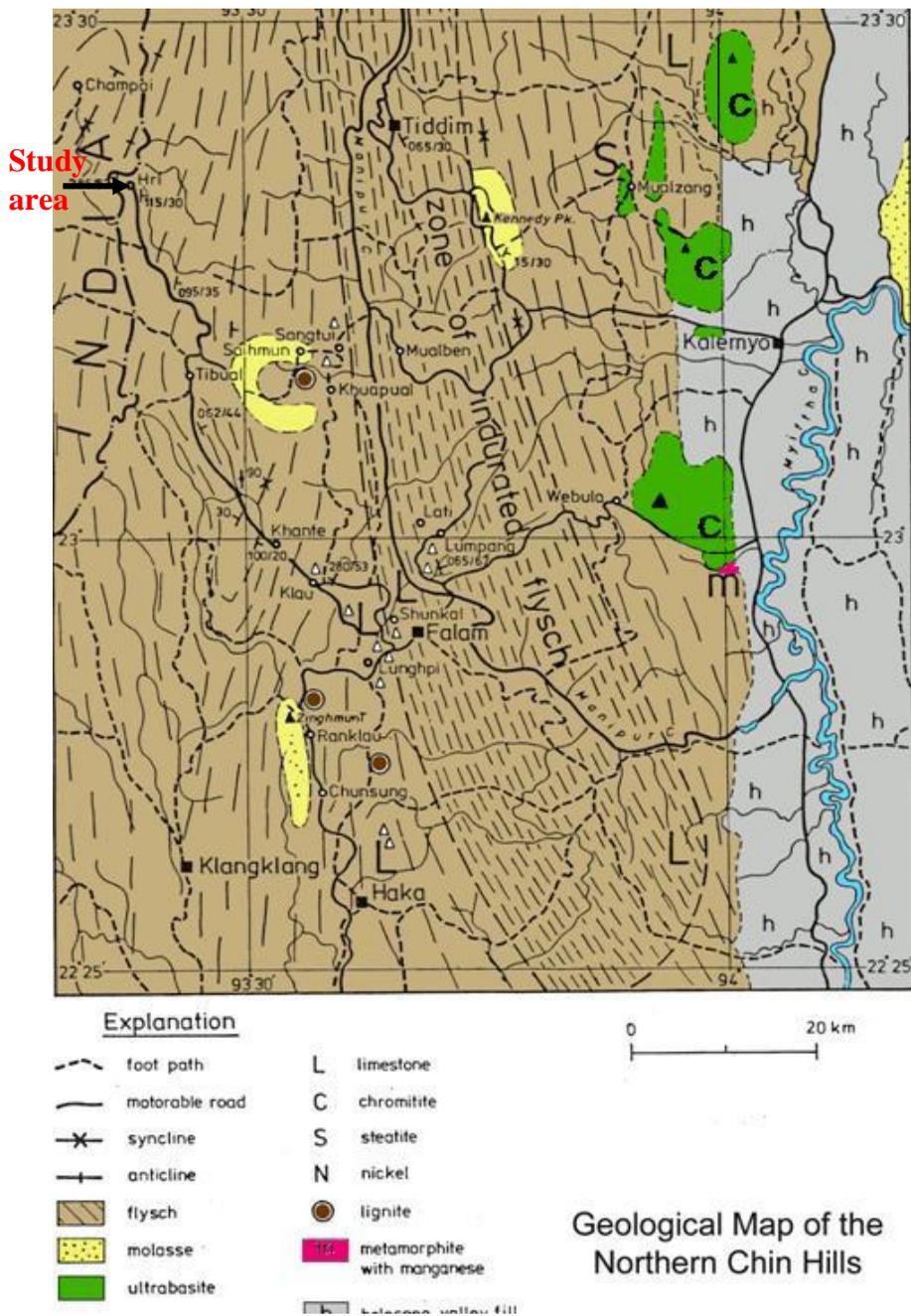


Fig. 1 Regional geologic setting of the study area and its environs (after Bannert, D., Sang Lyen, A., and Than Htay, 2011)



Fig.2 The composite units of the thick sandstone beds intertongue with and grade laterally into thinner graded beds.



Fig.3 Thick sandstone bed, with faint deformed lamination, separated by sequence of thin tabular or wedge-shaped beds.



Fig. 4 Undulating amalgamated beds.



Fig. 5 Undulating amalgamated beds.

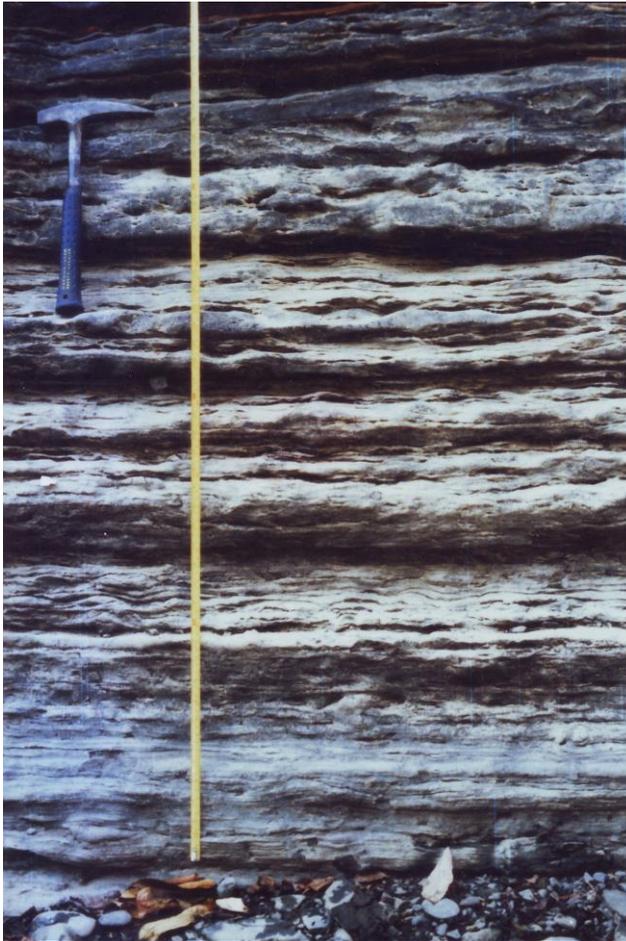


Fig. 6 Completed bed with wavy lamination and division of flat lamination forming top of the lower bed.



Fig. 7 Single thick sandstone bed showing contorted structure at base merging upwards into dish structure, followed erosively by lighter coloured and finer-grained division of flat lamination. Top of bed is ripple marks.



Fig.8 Trace fossils of *Scolicia plana*, *Scolicia prisca* and *Granularia*.



Fig. 9 Trace fossils of *Chondrites*.



Fig.10 Ripples of irregular in form, with oval or sub-circular troughs separated by rounded crests.

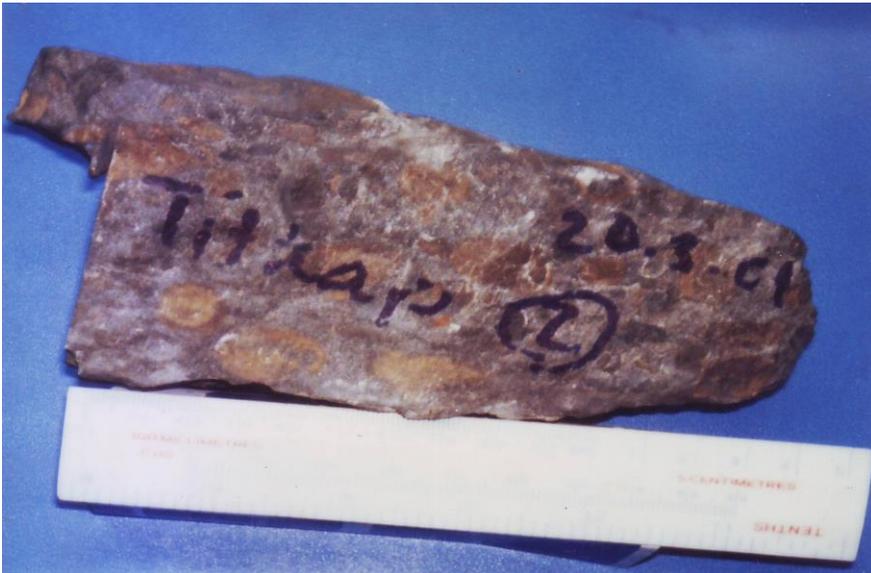


Fig.11 Pebbly sandstone of basal division with clasts up to 3 cm or more in diameter.

Undulating amalgamation surfaces are common in some exposures (Figs. 4 & 5), while others show mainly flat planar contacts (Fig. 6).

A complete gradational series exists between normal graded beds which are usually less than 30 cm thick and have about equal proportions of basal structureless division (division *a* of Bouma, 1962) and upper laminated part (divisions *b* and *c*), through thicker beds in which the basal structureless division predominates (Fig. 7), to beds in which the laminated part is thin and discontinuous (Figs. 4 & 5) or entirely absent. This strongly suggests that all types were deposited by same kind of current, the thick beds merely representing the over-thickened basal parts of the normal graded sandstones.

### Composition and texture

The sandstones of the Rih Lake and its environs are composed of detrital framework of about 70 %, matrix and chemical cement of 30 %. Detrital frameworks are made up of mostly detritus sediments and in them are mineral grains and rock fragments. Mineral grains are composed of quartz 83 %, feldspar 14 % and other constituents of biotite, muscovite, pyrite, magnetite, sphene 3 %. Shale fragments are abundant in some beds.

The majority of beds consists of medium to fine sand and is well sorted. A marked improvement in sorting commonly occurs at the base of the flat-laminated division, due to removal of many of coarser grains and much of the mica.

### **Sole marks**

Since most thick beds occur in composite sequences lacking siltstone, sole marks tend to be rare or poorly developed. Most beds have either flat concordant contacts on the sandstone below, or undulating erosional contacts with a relief of up to 17 cm. Beds of intermediate thickness may show flute and groove marks where they overlie siltstone, e.g., at the base of the composite unit.

### **Biogenic structures**

*In situ* death assemblages comprising macrofossils are rarely reported from Chin flysch sequences. Microfossils collections are preserved best in finer grained lithofacies, most particularly in the T<sub>ep</sub> interval of a turbidite. Trace fossils are locally well developed in sandstones of study area. Trace fossils of *Scolicia plana*, *Scolicia prisca*, *Granularia*, *Spriophycus*, *Cosmorhapha*, and *Chondrites* are well developed (Figs. 8 & 9).

### **Internal structures**

Although many beds are structureless throughout, the thick sandstones show a spectrum of internal structures including some not commonly recorded from flysch sequences. Many beds have the same sequence of internal structures as the normal graded sandstones, with a basal structureless division followed by a division of flat lamination followed by ripple cross-lamination. The upper division of laminated siltstone is seldom present, however. The basal structureless division is always predominant, and the laminated divisions may be only intermittently developed along the top of the bed.

A number of beds also show a faint to prominent wavy or scoop-like lamination in the basal division, and this is commonly underlain by a thinner unit of contorted and balled-up lamination. The complete sequence shown by such beds is as follows: (1) basal division of contorted lamination; (2) division of wavy lamination or dish structure; (3) division of

flat lamination with parting lineation; (4) division of cross-lamination and ripple mark.

*Contorted lamination.* A division of contorted or balled-up structures is developed at the base of many beds, and may grade upwards into wavy lamination, dish structure or structureless sandstone. Although the clustered ball-like features may resemble load marks in weathered outcrops, complete exposures generally show that the base of the bed beneath the structures is more or less flat, i.e., the structures are internal.

*Wavy lamination and dish structure.* A number of beds show a characteristic wavy or scoop-like lamination in the lower and middle parts. There appears to be a continuous series from the sub-horizontal wavy or dimpled lamination, through very broad flat scoops, to the smaller, more concave "dishes". The contact with the overlying division of flat lamination varies from transitional or slightly erosional. In some beds the structures becomes progressively more diffuse laterally and grades into structureless sandstone.

*Flat lamination.* Most of the beds showing wavy lamination or dish structure also have an upper division of flat lamination, as do many beds which consist mostly of structureless sandstone. This division almost invariably shows well-developed parting lineation. The thickness of the flat-laminated division may vary considerably along a single bed, and its lower surface in many cases is undulating rather than planar.

*Ripple mark.* The tops of many beds have a thin division of ripple mark and cross-lamination, generally only a few centimeters thick. The ripples tend to be irregular in form, with oval or sub-circular troughs separated by rounded crests (Fig. 10). Linear ripple have also been observed on these beds.

*Large-scale cross-bedding.* In some beds the division of flat lamination is overlain by and apparently grades laterally into, a division of large-scale cross-bedding. This in turn is overlain by ripple cross-lamination. The division is up to 50 cm thick, but is not continuous along the bed. Ripple cross-laminations are well-developed in all sections.

*Elutriation columns.* Some beds with dish structure or wavy lamination also show numerous small, irregular, sub-vertical "veins" of light-coloured,

mica-free sandstone. They are attributed to localized upward movement of water (de-watering channels) through the bed during deposition, causing washing out of the fines and some upward transport of coarse grains.

### **Graded bedding**

Although the majority of the beds consist of more or less uniform medium to fine sands throughout, there are many which show graded bedding, including some of those with wavy lamination and dish structure. The most spectacular examples have a basal conglomeratic division with pebbles up to 3 cm or more in diameter (Fig. 11), but such beds are not common. Most beds, which have an upper division of flat lamination, show graded bedding, since this division is nearly always finer-grained than the lower part. The uppermost division of ripple cross-lamination, where present, is usually finer still.

An abrupt decrease in grain-size, accompanied by an improvement in sorting, commonly occurs at the beginning of the flat-laminated division. The improvement in sorting is partly due to the loss of much of the micaceous material, and consequently the laminated division tends to be lighter-coloured than the underlying sand.

### **Origin of the Sandstones**

The gradational relationship with normal graded beds, and the occurrence of thick beds which are graded and show the typical turbidite sequence of internal structures as well as dish and pillar structures or wavy lamination, strongly suggests that the beds are lateral variations of the normal turbidites. Their characteristics agree closely with those of the "proximal turbidites" of Walker (1967).

Wentworth (1967) has described similar thick beds with dish structure as "coarse turbidites". His examples typically showed a coarse-grained structureless basal division passing upwards through flat lamination, dish structure and overlying flat lamination to a top of fine sandstone with convolute lamination. Some examples showed dish structure as a central division within an otherwise structureless bed.

An alternative origin has been proposed by Lowe (1982) for similar thick-bedded sandstones, some with dish and pillar structures, from upper Cambrian Thunderhead Sandstone, Great Smoky Mountains National Park, Tennessee. The beds include one or more dark, micaceous shear laminations near the base, a middle zone showing well-developed but

discontinuous inverse grading from medium-grained sandstone to granule conglomerate, and upper zone of massive, ungraded granule conglomerate. The origin of the wavy lamination and dish and pillar structures are deposited by the direct sedimentation of a coarse-grained high-density suspension (Lowe, 1982).

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