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Keywords	Western Belt, flysch, turbidite, sandstone, trace fossils
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Geology of the rocks exposed near Rih Lake and its environ, Tidim Township, Chin State

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Abstract

The study area is situated at north latitude 23° 20' and east longitude 93° 23', occupying the parts of half-inch topographic maps 84 E/SW. The exposed rock, the most extensive unit in the Western Belt of the Chin Hills area, occupies most of the upper and middle slopes of the valleys and forms some of the ridge tops. It overlies the Falam Mudstone-Micrite Formation. The flysch sequence exposed near Rih Lake can be classified into four main rock types; laminated siltstone-fine sandstone, thin-bedded sandstone, thick-bedded sandstone and pebble to conglomerates. The age of this unit may be Eocene on the basis of the stratigraphic position and trace fossils. The thick-bedded, non-graded or poorly graded sandstones are interpreted as proximal turbidites on the study of ancient and modern flysch-type sequences. The composition of the sandstones is matrix-supported greywacke sandstones. Moreover, these sandstones are quartz wacke and lithic wacke due to the abundance of quartz and lithic fragments. 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, and the composite sandstone units are interpreted as being mainly channel deposits in a submarine fan complex.

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Introduction

Rih Lake is situated in Falam Township, Chin State. It is a well known lake for its heart-shaped outline and scenic views. 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' (Fig. 1). It is bounded in the east by Tiddim Township, in the north by Tonzang, in the west by India, and in the south by Falam/Haka 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.

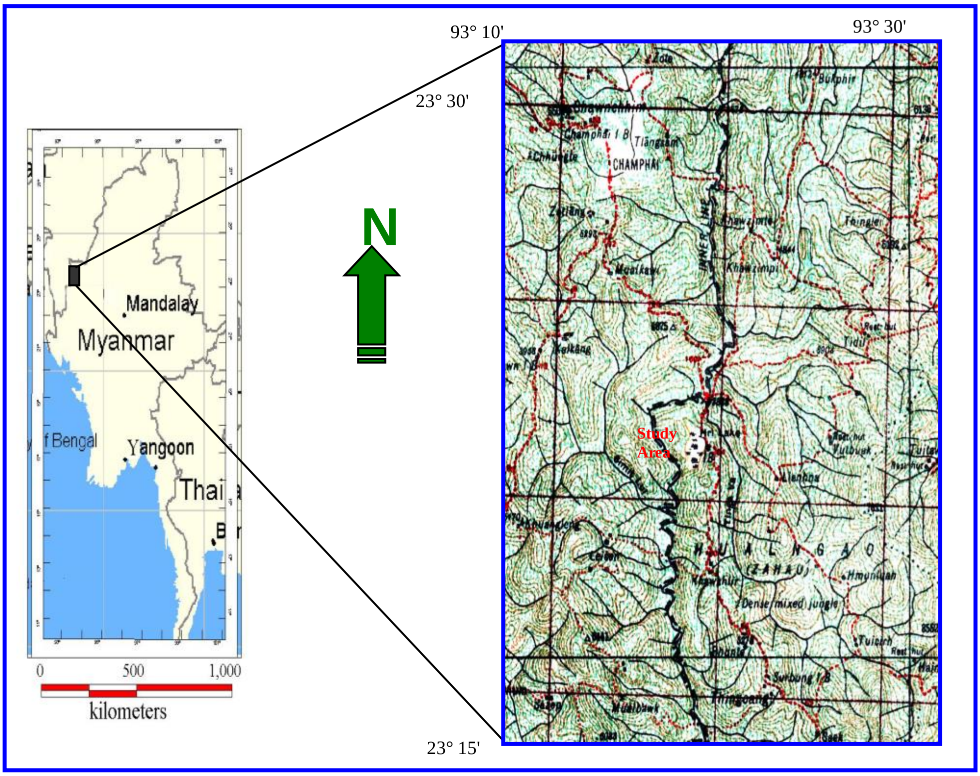

Fig. (1) Location map of the Rih Lake and its environs

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. According to terrain, all weather roads are scanty. In some places it is difficult to maintain roads in this area due to heavy rain, which lead to landslides damaging and blocking roads. Especially this condition is found in Falam-Rih road.

Size and Shape of Rih Lake

The whole region is mountainous region. The general elevation is between 4000 feet and 5000 feet. The greater parts of this region lie above 3000 feet. The landsat image of the Rih Lake and its environs is shown in Fig. (2).

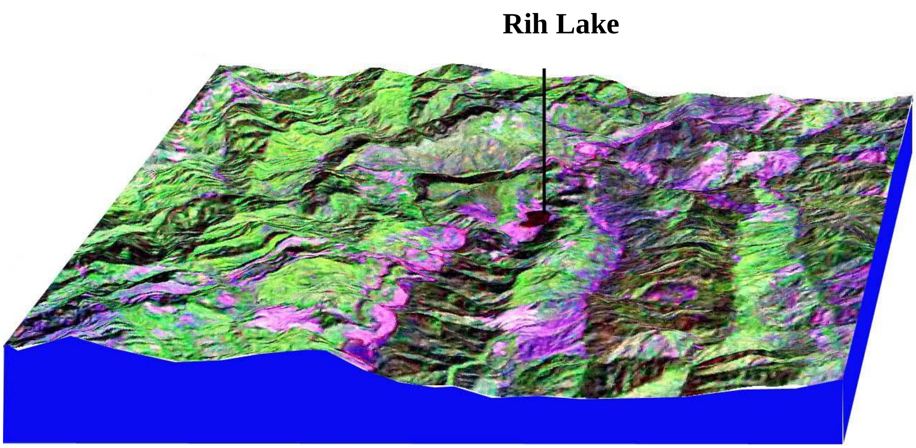

Fig. (2) Landsat image and three-dimensional view of the Rih Lake and its environs

The maximum depth of the lake is 43 feet. Its average depth is 29 feet. The subsurface contour map is shown in Fig. (3) (Bo San *et al*., 2001). The slope of the lake declines steeply at its margin and becomes gentle towards the center. The length of the lake from north to south is 2,800 feet. Since it is a heart-shaped lake, its width varies from 1,800 feet on the southern half to 1,600 feet on the northern half. It wides only 1,000 feet at constricted margin. The water surface area is about 96.7 acres.

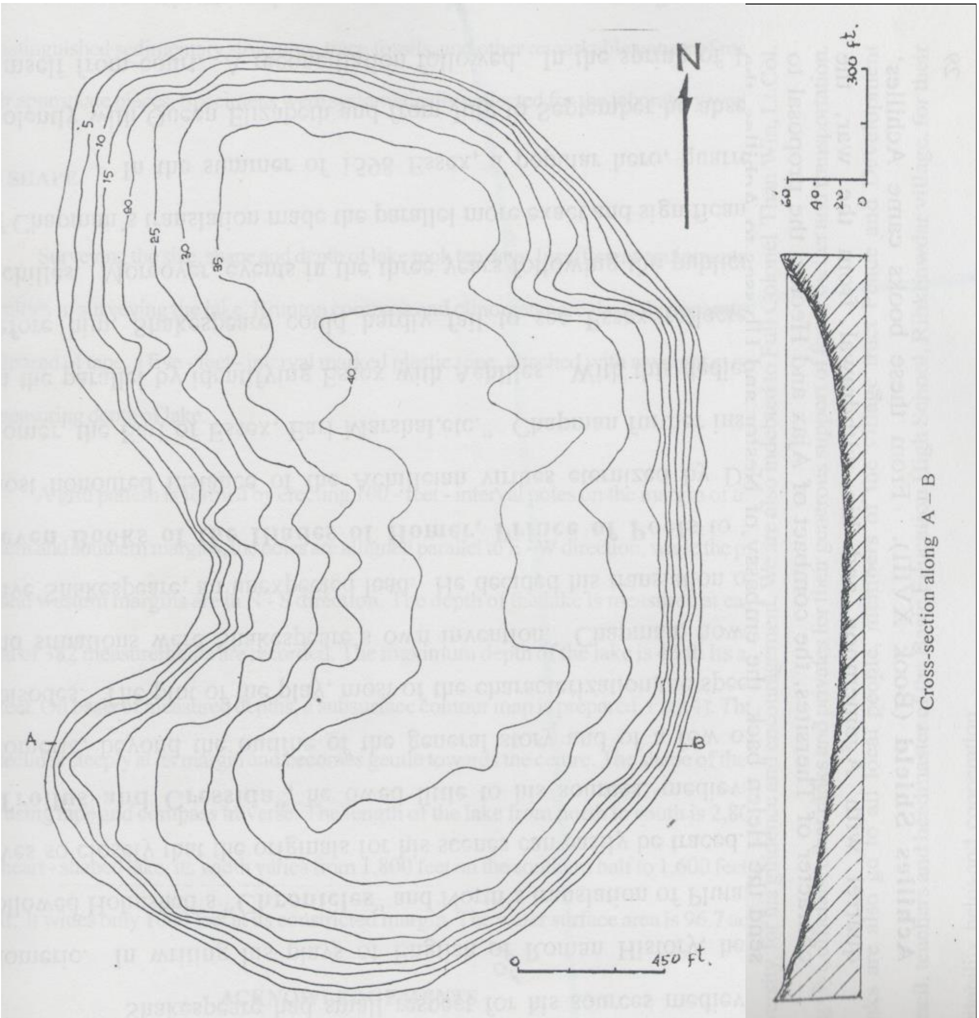

Fig. (3) Subsurface contour map showing depth of the Rih Lake (after Bo San, Myo Min and Aung Khin Soe, 2001)

Previous Work

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 minerals. The first account of geological work including the research area in Indoburma ranges were described by Theobald (1871) who prepared the Geology of Burma (Myanmar).

Chibber (1934) reported that the flysch of the Western Ranges in rocks that range in age from Middle Triassic to Late Eocene although the continuity of deposition cannot be demonstrated due to complexity of structure.

Triassic olistoliths can also be expected to occur in the Tertiary flysch series. Brunnschweiler (1966) published cross-sections of parts of the Arakan and Falam-Kalemyo area and described eastward-dipping thrusts within the succession, but did not recognize the presence of pre-Cretaceous sedimentary rock; his ideas on the stratigraphy and structure of the Ranges were based partly on his interpretation of all upper Cretaceous limestones as exotics.

Fauna in the upper Triassic sediments of the Chin ranges were described for the first time by Myint Lwin Thein (1966) and Gramann (1974).

Detailed description of sedimentary structures, especially sole markings, of flysch deposits at the eastern foothills of Western Ranges were made by Myint Thein (1972). In the same year, Win Swe (1980) described the deformation style of Western Ranges in his "Tectonic evolution of the Western Ranges of Burma".

Mitchell and Mckerrow (1975 in Bannert *et al*., 2011) reported the occurrence of Upper Cretaceous flysch in the Haka/Falam area of the northern Chin Hills. Cretaceous sediments are generally restricted to the eastern part of the Indoburma Ranges, where they form the basis of the Western outcrops of the Innerburman Tertiary basin.

United Nations (1979) studied this area and they provisionally named the sequence of the rocks in the Pane Chaung northeast of Kan in Falam-Kalemyo area as Pane Chaung Group. Again in 1978, the team made a several traverses in northern and southern Chin hills and Rakhaing Yoma and presented on up-to-date report on geology and exploration geochemistry at part of the northern and southern Chin Hills and Arakan Yoma, Western Burma. U.N. report (1979) pointed out that the eastern part of the Falam-Kalaymyo and Mindat-Saw area and the south-eastern part of the Arakan area lies within the Western Trough, which together with the Volcanic Arc. The Western Trough is underlain by Late Cretaceous to Quaternary sediments mostly in the forms synclines.

Win Swe *et al*. (1972) described the western Trough succession in the Falam-Kalemyo Area, and a Cretaceous fauna from near the base of the succession has also been identified.

Bender (1983) compiled the reports written by Bannert et al. and Geological Map of the Socialist Republic of the Union of Myanmar (1:1,000,000, 1977). Bender (1983) studied that flysch sediments, i.e, alternating beds of greywacke, sandstones, siltstones, claystones and shale constitute the major part of the Indo-Burma Ranges. Sole-marks, ripple mark, graded bedding, large-scale cross-bedding are evidence of a rapidly sedimented through filling.

Bo San, Myo Min and Aung Khin Soe (2001) made a preliminary report on the geological investigation of Rih Lake and its environs and surveyed the size, shape and depth of lake.

Regional Geologic Setting

Geotectonically, the study area lies in the western ranges, which are composed of the mountainous tract of the western parts of Burma (Chibber, 1934). The Arakan-Chin fold Ranges lies between the Assam to the west and central Cenozoic belt (Central low lands) to the east. This belt includes the Arakan, Chin and Naga Hills. It has a total length of nearly 1300 km and north-south structural trends. The Arakan-Chin folded Belt is divided into Eastern and western ranges. The regional geologic setting of the study area and its environs is shown in Fig. (4).

Flysch sequences, exposed near Rih area are parts of the central Chill Hills. The most conspicuous member of east-dipping sequences on the eastern flank of the Kennedy Peak ridges is the exotic flysch which contains large blocks of Upper Cretaceous *Globotruncana*-limestone as well as Lower Eocene, bituminous, limestone with *Assilina* (eg. Lung Pi, near Falam and road section from Falam to Rih Lake) (Brunnschweiler, 1966).

The Western Ranges are underlain dominantly by a thick sequence of turbidite, greywacke and shales of open ocean type (i.e. flysch) which are locally associated with chert and submarine basic lavas, tuff and *globotrancana* bearing pelagic limestone (Clegg, 1941; Brunnshweiler, 1966; Kyaw Win, 1969).

West of the Kennedy Peak ridge the Flysch is first overfolded to the west then thrust folded into eastward dipping nappes right through to the Indian border. The colossal sequences of Flysch down to the Var Bridge over the Manipur River without sighing anything that could be called "Axials" in the sence of Theobald (1871). Neither is there any sign of "Axials" farther west past Falam to the Indian border on the Rih Lake road. Only Flysch was seen; there simply is no other formation present.

UNDP (Report 6) subdivided the flysch series into Falam mudstone micrite formation (Campanian-Maastrichian), which is followed by the early Tertiary (Paleocene and Early Eocene), Chunsung mudstone-Turbidite formation and Middle Eocene Kennedy Sandstone.

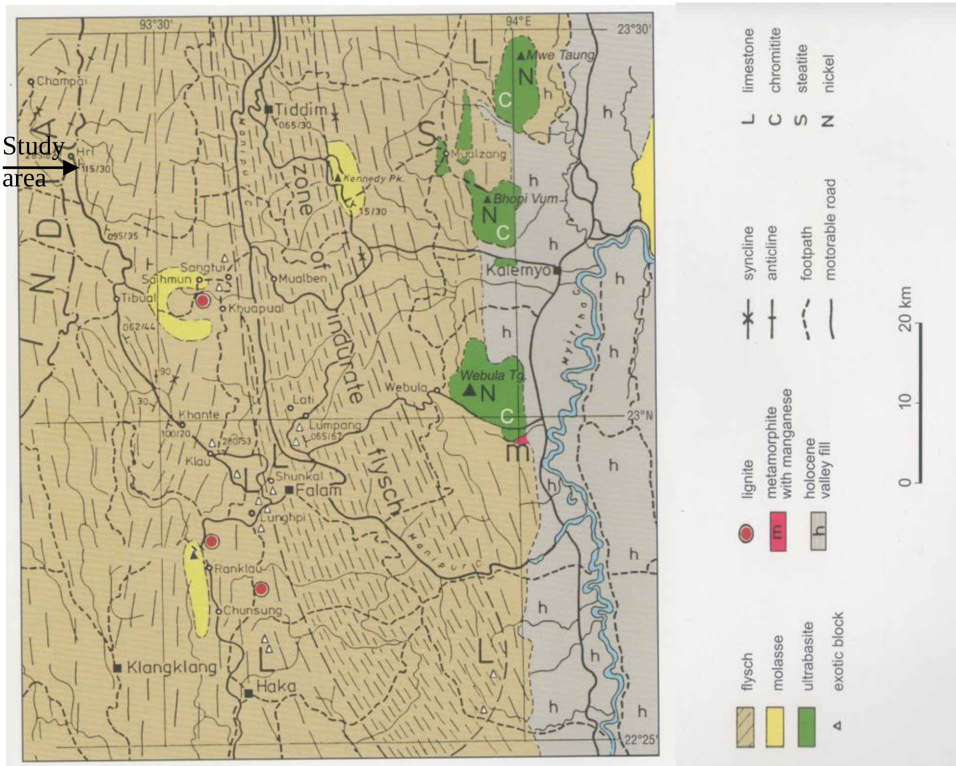

Fig. (4) Regional geologic setting of the study area and its environs (after Bannert, D., Sang Lyen, A., and Than Htay, 2011)

Lithology, Fauna and Age

This is the most extensive unit in the Western Belt of the Chin Hills Areas, occupying most of the upper and middle slopes of the valleys and forming some of the ridge tops. On air photographs it is not easily distinguished from the Falam Mudstone-Micrite Formation, and although in places faint bedding traces are visible near the top of the Formation, the structure is generally apparent only from stream traverses. Dips are mostly steep or vertical, although in the upper parts of the Formation the dip decreases.

It consists very largely of mudstones, siltstones and minor sandstones, similar in the lower part to much of the Falam Mudstone-Micrite Formation, but lacking micrite limestones and with thin fine-grained sandstones interbedded throughout. There are also numerous units consisting of thicker sandstones interbedded with thin mudstones, which locally form topographic features visible on air photographs. Grits and fine-grained conglomerates with clasts of mudstone, quartz and chert occur at a few horizons in the lower and middle part of the unit.

The flysch sequences exposed near Rih Lake can be classified into four main rock types. They are (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.

The thin bedded sandstones mostly show sharp bases and tops a lack both sole marks and distinct internal sedimentary structures (Fig. 5).

Interbedded mudstones and siltstones are mostly grey, but a faint purple to green color is present in some weathered exposures (Fig. 6).

The thicker sandstones, some of which are up to 2 m thick, are mostly medium to coarse-grained with abundant mudstone pebbles (Fig. 7). Some show erosive bases with grading and sole marks. Most occur in units comprising 2 to 30 or more sandstone, interbedded with thin mudstones. Broken beds, comparable to those in the underlying Formation, are common in the lower part of the unit. 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. Sole marks are characteristically the products of environments with episodic sedimentation.

It was previously thought that sole marks were diagnostic of turbidites; but storm surges in shallow seas, sheet floods in semi-arid environments, and crevasse surges into floodplains all have the necessary properties and may produce sole marks. One of the most common events generating such beds is the turbidity current.

Slump structures are found at the thicker sandstone beds in some places (Fig. 8). Slump structures are generally associated with rapid sedimentation. Such regions may be unstable because of greater slopes, type of sediment deposited, or other reasons. Slump of a sediment mass may result in the breaking and transportation of sedimentary layers, generally producing a chaotic mixture of different types of sediments, such as a broken mud layer embedded in a sandy mass. Some of the slump structures and slump deposits, especially those associated with flych deposits, may be thick and widespread.

Many beds have the complete or partly sequence of the Bouma's T_{a-e}, with a basal structureless division followed by a division of flat lamination followed by ripple cross-lamination. The upper division of flat 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.

Although the majority of the beds consist of more or less uniform medium to fine sand 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, but such beds are not common. An abrupt decrease in grain-size, accompanied by an improvement in sorting, commonly occurs at the beginning of the flat-lamination division. The improvement in sorting is partly due to the much of the micaceous material, and consequently the laminated division tends to be lighter-colored than underlying sand.

Graded beds commonly occur in thick sequences of flysch type of sediments for which it seems to be the characteristic bedding type. Commonly, the graded beds are separated by parallel bedded clayey layers, which represent the product of normal sedimentation interrupted by turbidity currents depositing graded sandy beds.

The tops of many beds have a thin division of ripple mark (Figs. 9 and 10) and cross-lamination (Fig. 11), generally only a few centimeters thick. The ripples tend to be irregular in form, with oval or sub-circular troughs separated by rounded crest. Linear ripple have also been observed on these beds.

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. Cross-lamination is the pattern of internal lamination which develops within sand as a result of the migration of ripples. It can be seen both on bedding planes and on vertical surfaces.

Dish structures (Fig. 12) are distinct sedimentary structures developed in sandy beds parallel to bedding, where they appear as subhorizontal to concave-upward, and dark clay-rich laminae varying in width from a few centimeters to 50 cm. Each dish becomes sandier upwards. They are commonly separated by vertical streaks of massive sand, named pillar. Wentworth (1967) reported them from turbidite deposits where they commonly occur in the lower graded horizons of turbidites. Lowe (1975) demonstrated that dish structures are water-escape structures, and represent a penecontemporaneous deformation structure formed during the consolidation and de-watering of quickly deposited sediments which undergo liquefaction and fluidization.

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. In situ death assemblages comprising macrofossils are rarely reported from Chin flysch sequences. Microfossils collections are preserved best in finer grained lithofacies of a turbidite. Trace fossils are locally well developed in sandstones of study area (Fig. 13). Trace fossils of *Scolicia plana, Scolicia prisca, Granularia, Spriophycus, Cosmorhaphe,* and *Chondrites* are well developed (Myo Min et al., 2002). The Formation overlies the Falam Mudstone-Micrite Formation with its Campanian fauna and the palaeontological results indicate a Palaeocene to middle Eocene age (U.N., 1979). The lower part of the Formation is of similar age to but differs in lithology from the upper part of the Paunggyi Conglomerate; the upper part of the formation shows some lithological similarities to the Laungshe Shales of the Western Trough, although it lacks the thin bands of concretionary limestones present in the Shales.

Fig. (5) Thinly laminated fine-grained sandstone interbedded with dark grey siltstone (N 23º 20' 21.2", E 93º 23' 23.8")

Fig. (6) Interbedded sequence of thinly laminated siltstone and shale (N 23º 20' 48", E 93º 23' 09.8")

Fig. (7) Thick bedded to massive sandstone with mud clasts (N 23º 20' 25.6'', E 93º 23' 15.8'')

Fig. (8) Slump structures exposed at the cliff of the Rih Lake (N 23º 20' 25.6'', E 93º 23' 15.8'')

Fig. (9) Asymmetrical ripples with continuous crestlines and with ridges and troughs on their stoss side in sandstone beds (N 23º 21' 20.2'', E 93º 23' 16.3'')

Fig. (10) Asymmetrical ripples in sandstone beds (N 23º 21' 20.2'', E 93º 23' 16.3'')

Fig. (11) small-scale cross-laminated fine-grained sandstone (N 23º 20' 19.8", E 93º 23' 25.8")

Fig. (12) Dish structures of the thinly laminated sandstone beds (N 23º 20' 51.7", E 93º 23' 00.8")

Fig. (13) Burrowing trace fossils exposed around the Rih Lake (N 23º 20' 19.8", E 93º 23' 25.8")

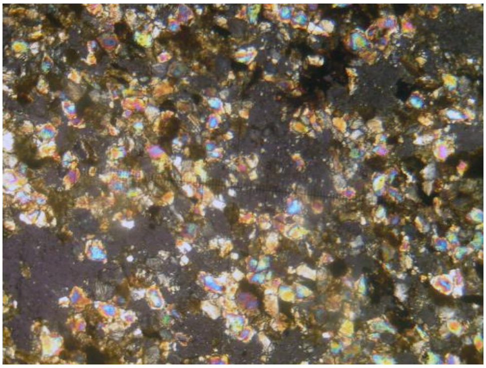

Fig. (14) Moderately sorted, medium-grained greywacke with abundant quartz clasts

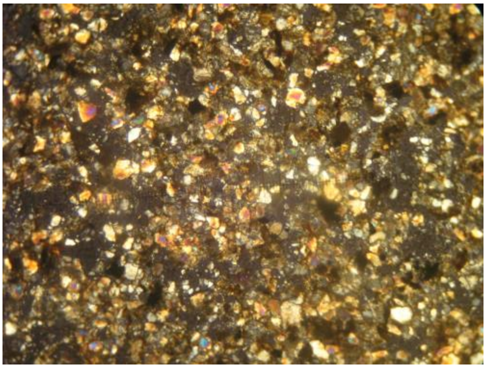

Fig. (15) Moderately sorted, fine-grained greywacke with abundant quartz clasts and lithic fragments

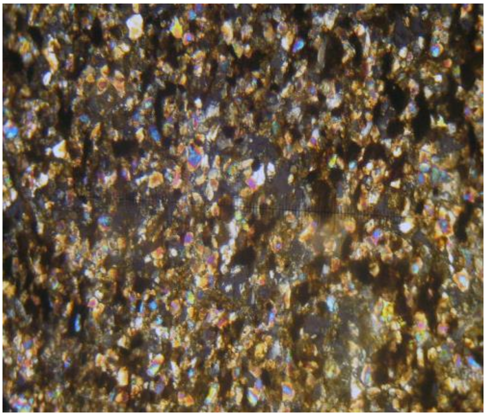

Fig. (16) Moderately sorted, fine-grained greywacke with abundant quartz clasts and lithic fragments

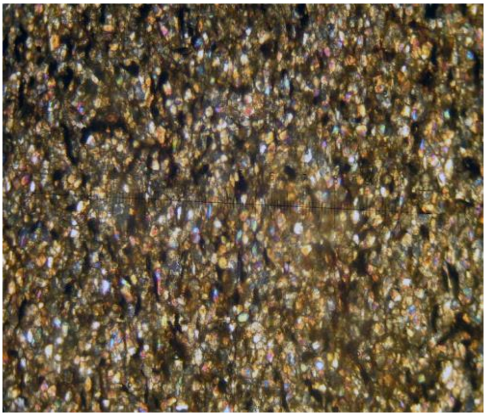

Fig. (17) Siltstone with abundant fine-grained quartz clasts

Petrography

The sandstones exposed at Rih Lake mainly composed of quartz, feldspar and lithic fragments. The clasts are medium- to fine-grained and is moderately sorted (Figs. 14, 15, 16 and 17). The graded bedding and parallel lamination are commonly found. This sandstone consists of 50-70% framework and 30-40% matrix.

The compositions of the sandstones are slightly variable. Some are enrich in quartz and some are lithic. Feldspars contain a small amount approximately less than 5%.

Quartz grains are generally found as single euhedral grains and unclouded in appearance. Quartz show wavy extinction. The rock fragments are composed mainly of volcanic and sedimentary clasts. In some slides, the lithic fragments are slightly less than that of quartz grains.

According to Pettijohn's classification (1975), the component of the matrix is approximately 30%. Therefore, this sandstone may be of the greywacke. Moreover, the average sandstone of the Pane Chaung Group may be quartz wacke and lithic wacke.

Moreover, the thin sections of the siltstone have numerous silt-size quartz particles.

Discussion

Flysch sequences, which are well exposed on the Chin Hills, contain numerous examples of thick-bedded sandstones and conglomerates interbedded with graded sandstones and laminated siltstones.

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". They are probably turbidity current deposits rather than the products of some mass-flow mechanism.

A complete gradational series exists between normal graded beds which are usually less than 30 cm thick and have about equal proportions of basal structurless division (division 'a' of Bouma, 1962) and upper laminated part (division 'b and c'), through thicker beds in which the basal structureless division predominates, to beds in which the laminated part is thin and discontinuous 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.

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.

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