

## Lithologic and biostratigraphic properties of the Paleocene Lockhart Formation, Hazara and Potwar basins, northeast Pakistan: preliminary results

Ahmad Khan<sup>1</sup>, Osman Salad Hersi<sup>1</sup> and Sajjad Ahmed<sup>2</sup>

<sup>1</sup>Department of Geology, University of Regina, <sup>2</sup>Department of Geology University of Peshawar

### Summary

The carbonate-dominated Lockhart Limestone occurs in the Kohat, Potwar and Hazara basins in northern Pakistan. The current study reports the lithofacies and biostratigraphic attributes and depositional setting of the Lockhart Limestone in the Potwar and Hazara Basins. In the study areas, the thickness of the Formation varies from 50m to 115m in Potwar and Hazara, respectively. The Formation has confirmable lower contact with the early Paleocene Hangu Formation and confirmable upper contact with the latest Paleocene to early Eocene Patala Formation. The Lockhart Limestone comprises of diverse lithofacies with grey and dark grey in color, medium- to thickly-bedded, nodular, highly fossiliferous carbonate lithofacies with marl and shale intercalations. At this stage of the study, four stratigraphic sections, including Kahi, Askari, Darkot and Dhudial were examined. Field data combined with petrographic examination permit recognition of seven lithofacies (Lf1-Lf7) from the studied sections. These lithofacies encompass planktonic-benthic foraminiferal wackstone (Lf1), planktonic-benthic foraminiferal packstone (Lf2), benthic foraminiferal wackstone (Lf3), coral-foraminiferal wackstone (Lf4), benthic foraminifera packstone (Lf5), benthic foraminifera mudstone (Lf6), and algal-foraminifera wackstone (Lf7). The depositional setting of the formation is envisaged to be a quiet to moderately-agitated ramp setting where lithofacies Lf1 represents outer ramp, Lf2 represents transition zone of mid-outer ramp, Lf3 and Lf6 represent mid ramp, and lithofacies Lf4, Lf5 and Lf7 represent inner. Index fossils in the formation include *Miscellanea miscella*, *Lockhartia haimei* and *Lockhartia Tipperi*. They suggest late Paleocene Thanetian SBZ3 zone (56 Ma 58 Ma) for the formation.

### Introduction

The Lockhart limestone is deposited throughout the upper Indus basin which is located in Northern Pakistan. This basin is divided into three sub basins; Hazara, Potwar and Kohat. The study is focused on the Hazara and Potwar basins. The Hazara Mountains form the northern border divide of the Hazara and Potwar basins.

Four sections, two in the Hazara and two in the Potwar, were studied (Fig. 1). The two sections in the Hazara Basin are Dhudial section (Lat. 34°10' 07, Long. 73°16' 33°52'15' ) and Darkot section (73°09'15', 33°52'15'). The two sections from the Potwar Basin are Kahi section (33°48' 42, 72°40'92 ) and Askari cement factory section (33°48'10', 72°56'05). The Lockhart Limestone is composed of bioclastic limestone with marl and shale intercalations. The formation lies over the Hangu Formation and is overlain by the Patala Formation. Both upper and lower contacts are conformable. The formation is well-exposed and well-developed throughout Kohat-Potwar regions (Latif, 1970; Shah, 1977). The fossils of the formation are dominated by foraminifera, mollusks, algae and echinoids (Raza, 1967; Cheema, 1968; Latif, 1970). The larger benthic foraminifera dominate the framework content of the formation. Cheema (1968) and Latif (1970) have recorded various species of *Miscellanea miscella*, *Alveolina* sp., *Lockhartia*

sp., *Discocyclus* sp., *Rotalia* sp. and *Ranikothalia* sp. from the formation. The occurrence of the larger benthic foraminifera in the Lockhart Limestone indicates a shallow marine depositional environment in a carbonate ramp platform (Akhter and Butt, 1999). The study area is a tectonized mountainous region with difficult access to study. This has hindered previous research to perform a more detailed work on this formation, as well as other associated formations. Recent road-cuts expose new sections (e.g., Fig. 2) offer an easy access to study these rocks. Therefore, the present study aims a more detailed sedimentologic and biostratigraphic investigation of the Lockhart Formation and to infer its deposition setting, correlation with coeval regional (in Pakistan) and inter-regional (circum-Tethyan Ocean) zones. The senior author is working on this project as a MSc thesis project and the preliminary results based on the four sections so far logged and studied are presented here.

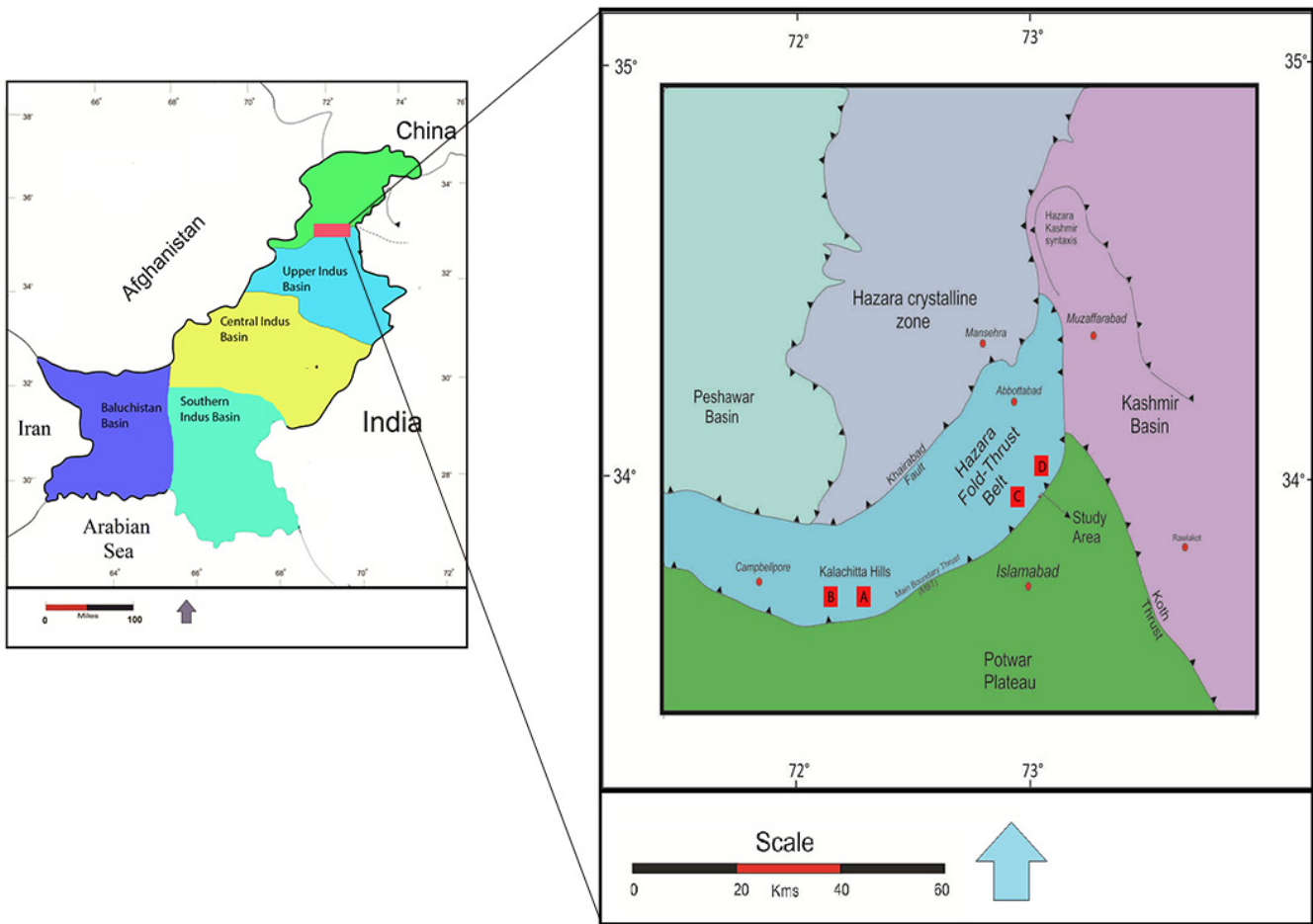


Figure: 1 Map of Pakistan show the study area in the upper Indus basin north. The red boxes show the four studied sections in Hazara and Potwar basins. The C represents “Darkot section”, D represent “Dhudial section” in Hazara and in Potwar A represents “Askari cement factory” & B represents “Kahi section”. The arrow shows the geographic north of Pakistan (Latif, 1970).

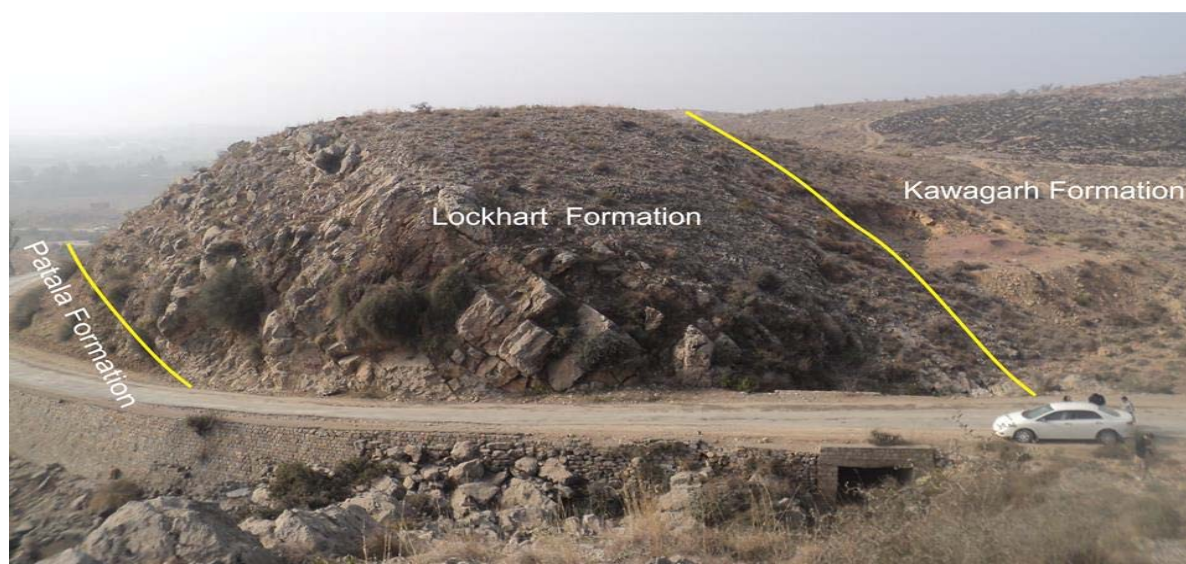
### Lithofacies properties

The field and petrographic analysis of the Lockhart limestone from the four studied sections revealed that formation consists of 7 lithofacies. These lithofacies units include: planctonic-benthic foraminifera wackstone (Lf1), planctonic-benthic foraminifera packstone (Lf2), benthic foraminifera wackstone (Lf3), coral-foraminifera wackstone (Lf4), benthic foraminifera packstone (Lf5), benthic foraminifera mudstone

(Lf6), and algal foraminifera wackstone (Lf7). Brief descriptions of the various lithofacies and interpretation of their depositional environments are summarized in Table 1.

#	Lithofacies	Description	Depositional Energy and Environment
Lf1	Planktonic-Benthic Foraminifera Wackstone	Nodular, Orangish yellow, medium to thick bed, wackstone.	Deep marine and low depositional energy.
Lf2	Planktonic-Benthic Foraminifera Packstone	Nodular, yellowish grey, medium to thick bed, Packstone.	Deep marine, low-moderate depositional energy,
Lf3	Benthic Foraminifera Wackstone	Nodular intercalation of marl, grey, thick bed, Wackstone.	Open- deep marine and moderate depositional energy.
Lf4	Coral-Foraminiferal Wackstone	Thick bedded, Light grey, Wackstone	Open marine and low depositional energy.
Lf5	Benthic Foraminifera Packstone	Nodular, thick bedded, Packstone.	Open Marine high depositional energy.
Lf6	Benthic Foraminifera Mudstone	Thick bedded, light grey, Mudstone	Open-Deep marine and low depositional energy.
Lf7	Algal-Foraminifera Wackstone	Less Nodule, Dark grey, thick bedded, Wackstone	Open-restricted marine and low to high depositional energy.

**Table: 1** Brief description of the seven lithofacies units that constitute the Lockhart Limestone in the study area. Interpretation of the depositional environments and level of marine water energy are shown.



**Figure: 2** The photograph show Lockhart limestone overlain and underlain by Kawagarh Formations and Patala Formation respectively in Kahi section.

## Biostratigraphy

The formation contains a certain number of foraminiferal index fossils (mainly larger benthic foraminifera) that are useful for biostratigraphic age dating. The recognized fossils include *miscellanea miscella* and *Lockhartia haimei*. The age range of these species is SBZ 3 to SBZ 4. Further biostratigraphic analysis from more sections will be conducted and further refinement of the age of the formation and its local and regional correlations will be considered.

## Conclusions

The study area encompasses two Paleogene basins, namely Hazara and Potwar in the northern part of Pakistan. Due to the Himalayan collision, the study area is deformed, and most of the strata are tectonically folded. However, recent road-cuts offer fresh surfaces that are accessible for study. The Paleocene strata in the Hazara and Potwar basins consist of Hangu Formation, Lockhart Limestone and Patala Formations. The Lockhart Limestone contains different limestone lithofacies with marl and shale intercalations. The formation lies conformably over the earliest Paleocene Hangu Formation and overlies, also conformably, by latest Paleocene to early Eocene Patala Formation.

The outcrop examination combined with the petrographic study permits identification of seven lithofacies units (Lf1-Lf7) for the formation. These lithofacies units are: planktonic-benthic foraminifera wackstone (Lf1), planktonic-benthic foraminifera packstone (Lf2), benthic foraminifera wackstone (Lf3), coral-foraminiferal wackstone (Lf4), benthic foraminifera packstone (Lf5), benthic foraminiferal mudstone (Lf6), and algal-foraminiferal wackstone (Lf7). The fossil associations of these lithofacies suggest deposition in a low to moderate energy carbonate ramp setting. The Lf1 represents outer ramp, Lf2 represents transition zone of mid-outer ramp, Lf3 and Lf6 represent mid ramp, lithofacies Lf4, Lf5 and Lf7 represent inner.

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