# Outcrop Sequence Stratigraphy

## 5 Days Course at OIST (15-19 June, 2015)

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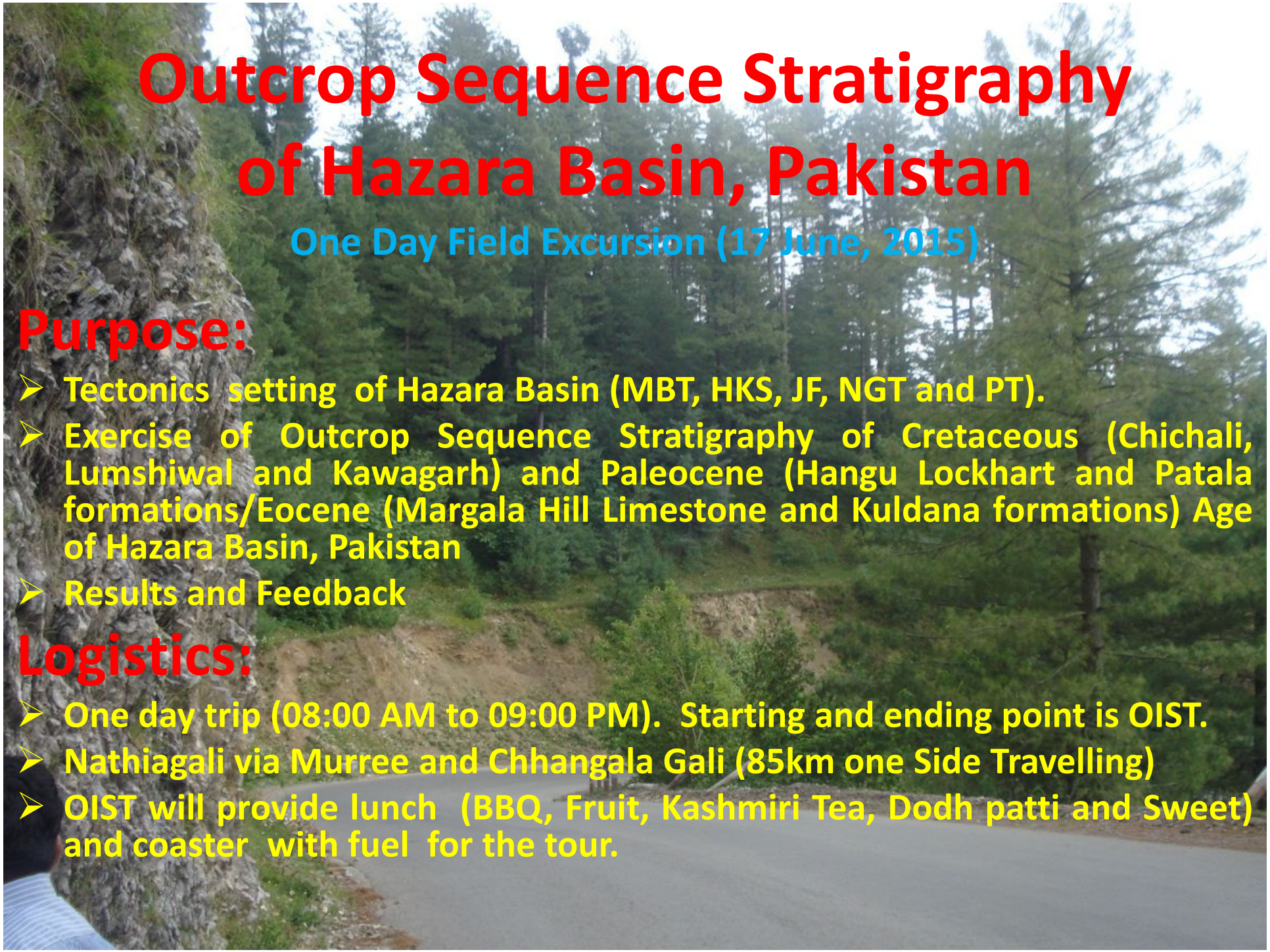
## Schedule:

| Day | | Date | Event Topic | Venue |
|---|---|---|---|---|
| 1. | Monday | 15th June | Concepts of Sequence Stratigraphy | OIST |
| 2. | Tuesday | 16th June | Outcrop Sequence Stratigraphy | OIST |
| 3. | Wednesday | 17th June | Field Excursion Examples from Hazara Basin | Nathiagali |
| 4. | Thursday | 18th June | Outcrop Sequence Stratigraphy of Salt Range | OIST |
| 5. | Friday | 19th June | Indus Basin Pakistan Sequence Stratigraphy | OIST |

| Expenditures | |
|---|---|
| fruit | 930 |
| dodh dahi | 360 |
| chicken | 2340 |
| biskit | 300 |
| morning tea | 720 |
| juice | 670 |
| roti | 200 |
| coal | 240 |
| plate galss | 260 |
| coald drink | 200 |
| water | 500 |
| **Total** | **6720** |



# Outcrop Sequence Stratigraphy of Hazara Basin, Pakistan

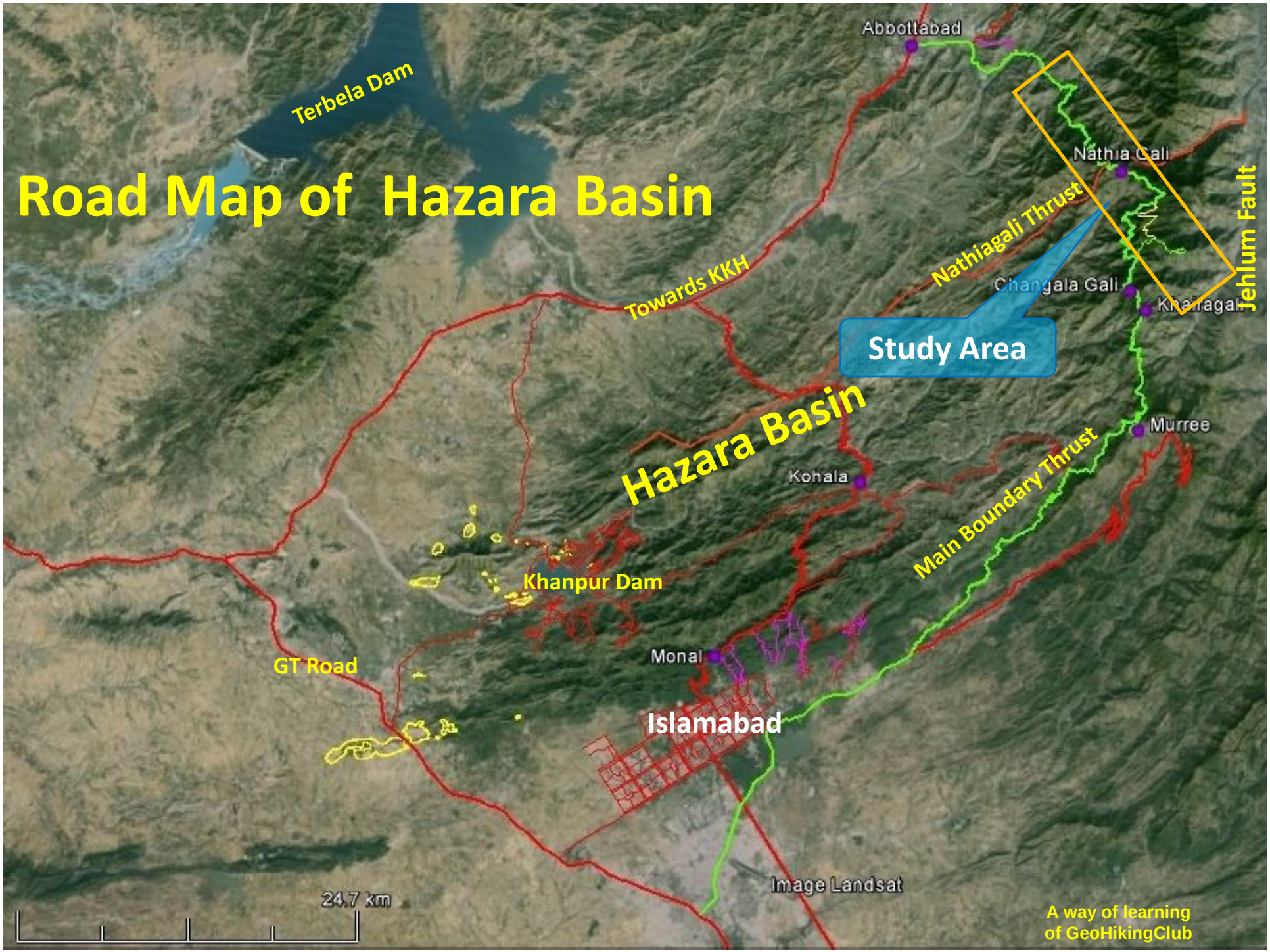
## One Day Field Excursion (17 June, 2015)

## Purpose:

- Tectonics setting of Hazara Basin (MBT, HKS, JF, NGT and PT).
- Exercise of Outcrop Sequence Stratigraphy of Cretaceous (Chichali, Lumshiwal and Kawagarh) and Paleocene (Hangu Lockhart and Patala formations/Eocene (Margala Hill Limestone and Kuldana formations) Age of Hazara Basin, Pakistan
- Results and Feedback

## Logistics:

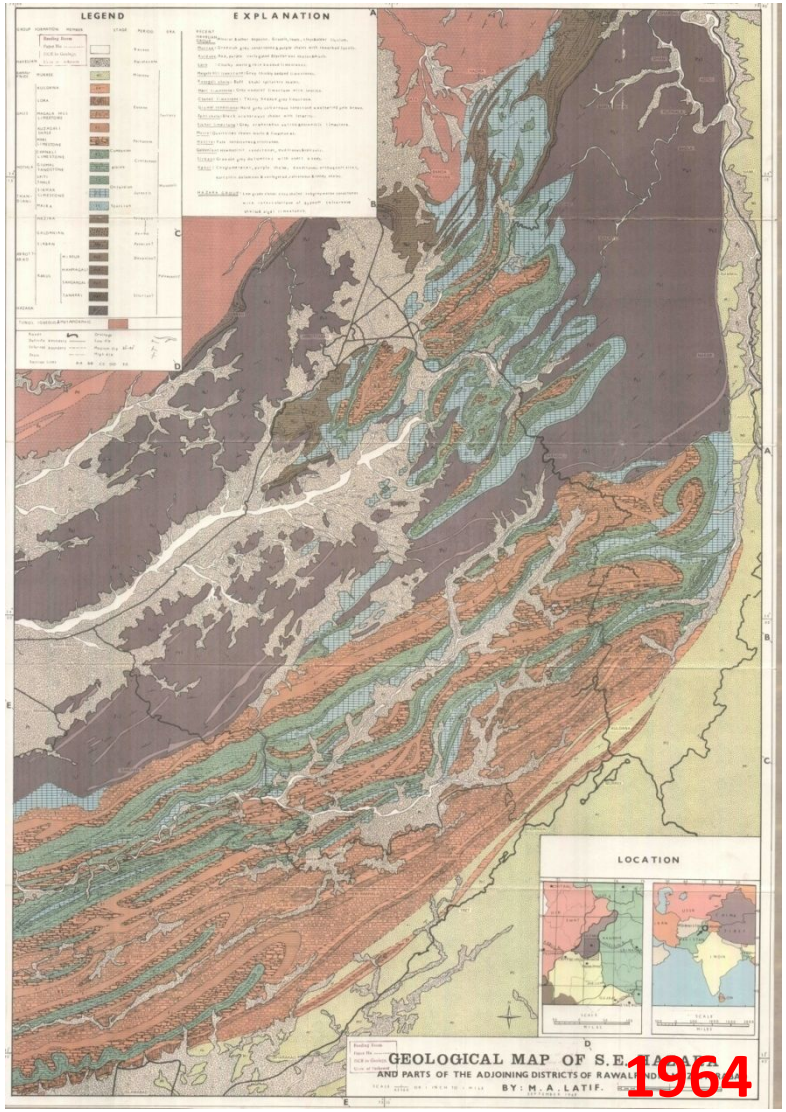
- One day trip (08:00 AM to 09:00 PM). Starting and ending point is OIST.
- Nathiagali via Murree and Chhangala Gali (85km one Side Travelling)
- OIST will provide lunch (BBQ, Fruit, Kashmiri Tea, Dodh patti and Sweet) and coaster with fuel for the tour.

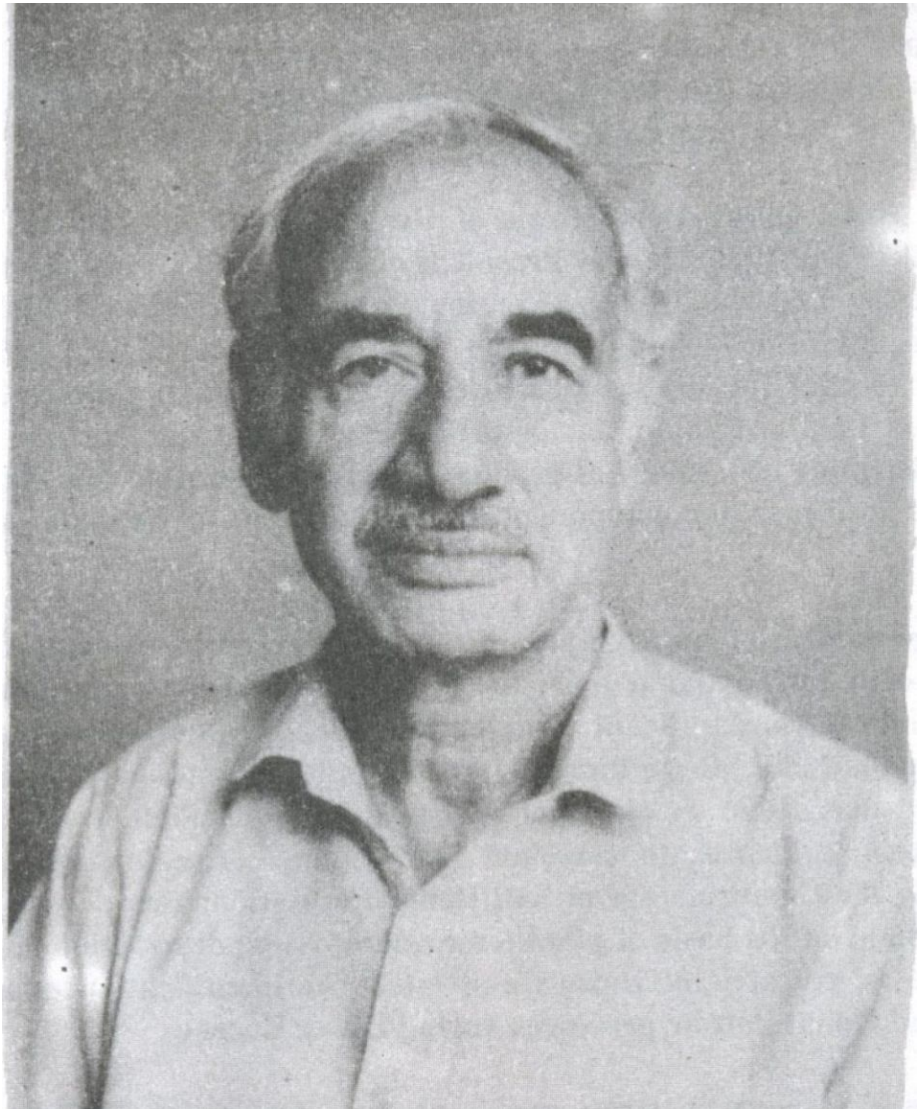

Road Map of Hazara Basin
Terbela Dam
Abbottabad
Nathia Gali
Jehlum Fault
Nathiagali Thrust
Towards KKH
Changala Gali
Khairagal
Study Area
Hazara Basin
Murree
Kohala
Main Boundary Thrust
Khanpur Dam
GT Road
Monal
Islamabad
Image Landsat
24.7 km
A way of learning
of GeoHikingClub

# Professor Dr. M.A. Latif (Retirement 1988)

## Major contribution for Geology of Hazara Basin

Institute of Geology University of the Punjab

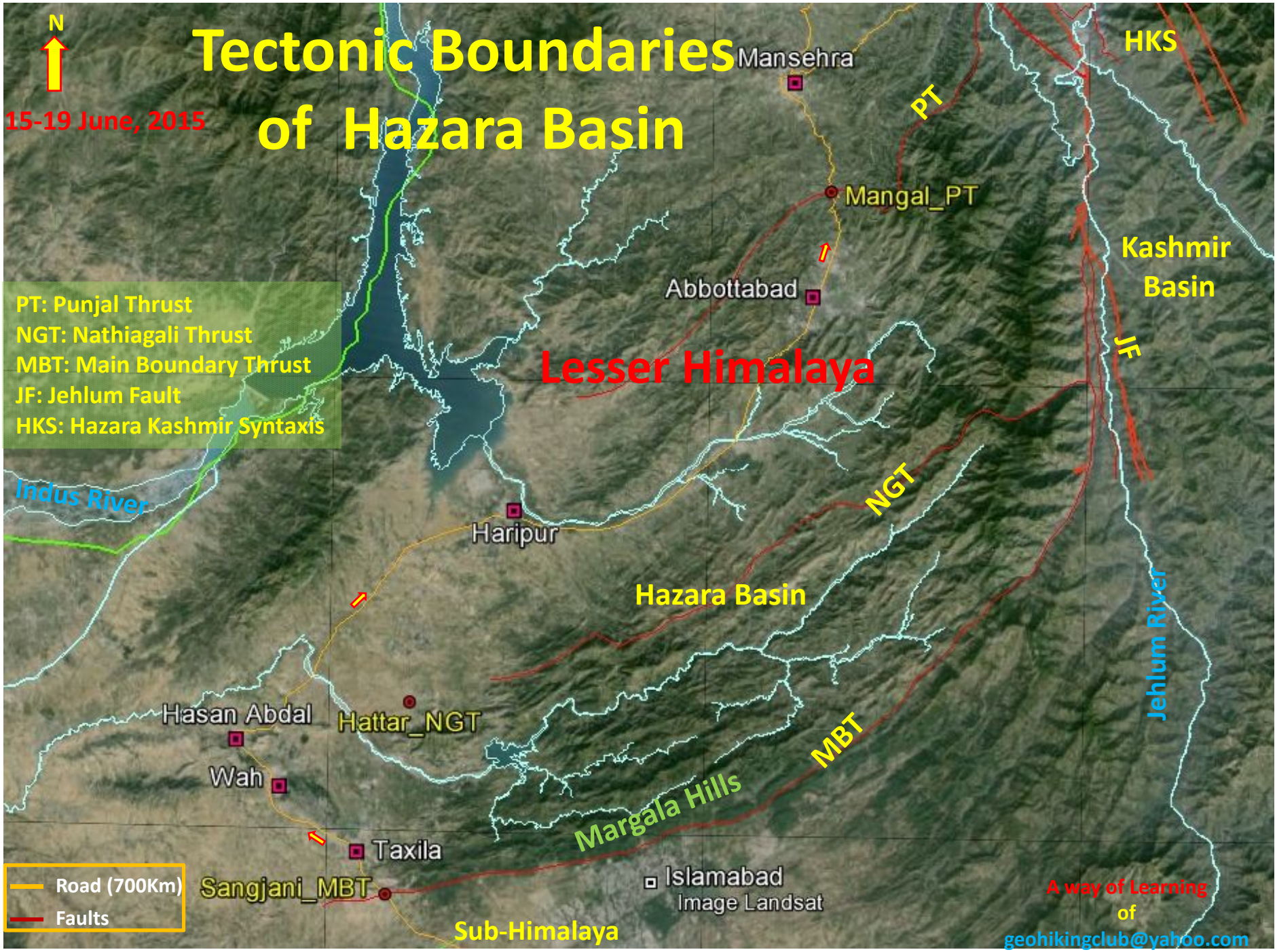



Dr. Naveed Ahsan
Major contribution for Geology of Hazara Basin
Institute of Geology University of the Punjab
He has mapped South Western part of the Hazara Basin and also done PhD on Kawagarh Formation Hazara area

# Tectonic Boundaries of Hazara Basin

1. Hazara Basin exits on the western limb of the Hazara Kashmir Syntaxes.
2. Hazara Basin Bounded in the South by MBT (Main Boundary Thrust).
3. In the North and North-West by PT (Punjal Thrust).
4. In the east by Jahlum Fault (MBT , NGT and JF).
5. Whereas, near Balakot, MBT, NGT, PT and JF merge together to form western limb of the Hazara Kashmir Syntaxes.


N
Tectonic Boundaries of Hazara Basin
15-19 June, 2015
Mansehra
HKS
PT
Mangal_PT
Kashmir Basin
Abbottabad
JF
PT: Punjal Thrust
NGT: Nathiagali Thrust
MBT: Main Boundary Thrust
JF: Jehlum Fault
HKS: Hazara Kashmir Syntaxis
Lesser Himalaya
Indus River
NGT
Haripur
Hazara Basin
Jehlum River
Hasan Abdal
Hattar_NGT
MBT
Wah
Margala Hills
Taxila
Road (700Km)
Faults
Sangjani_MBT
Islamabad
Image Landsat
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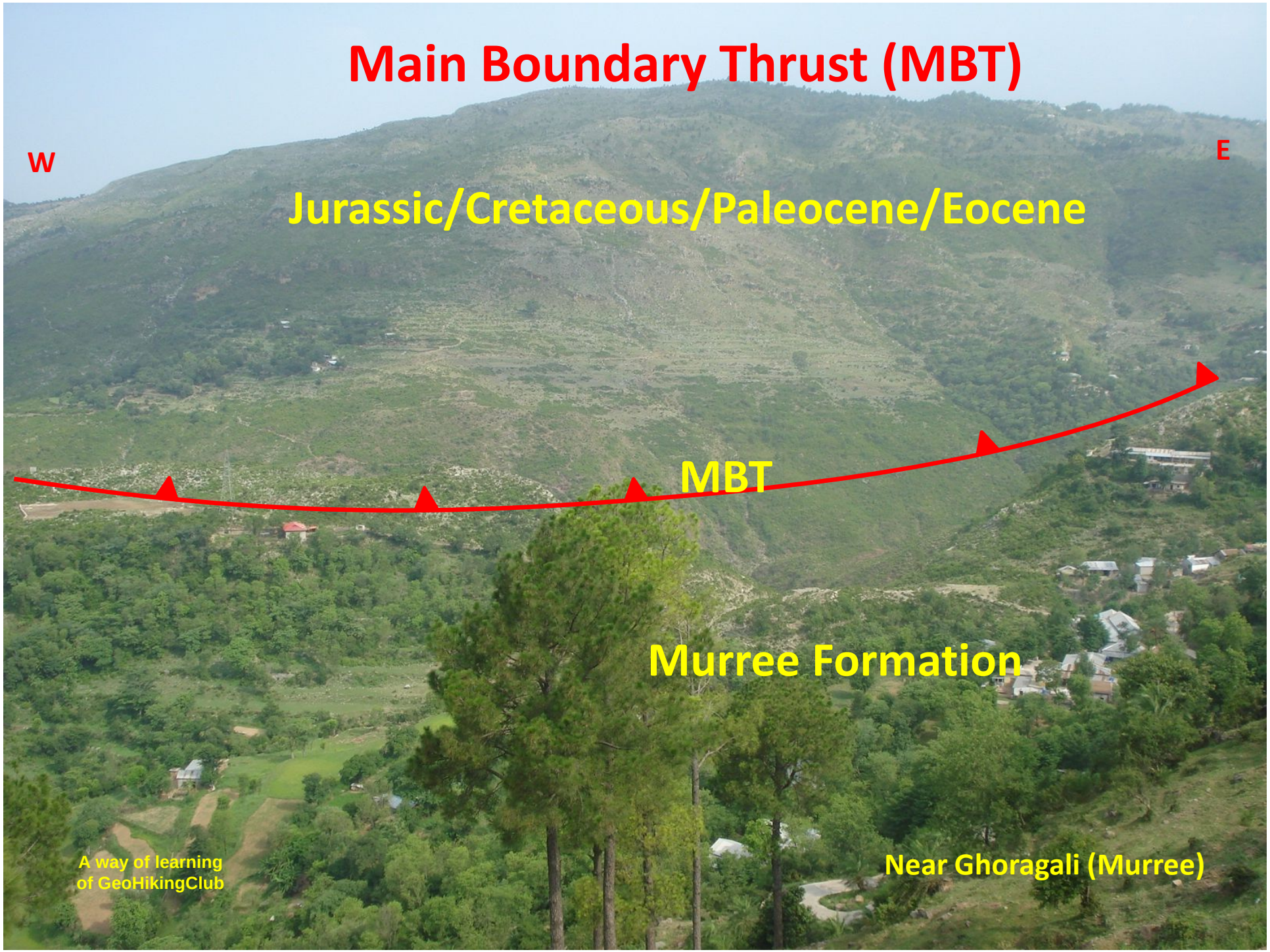
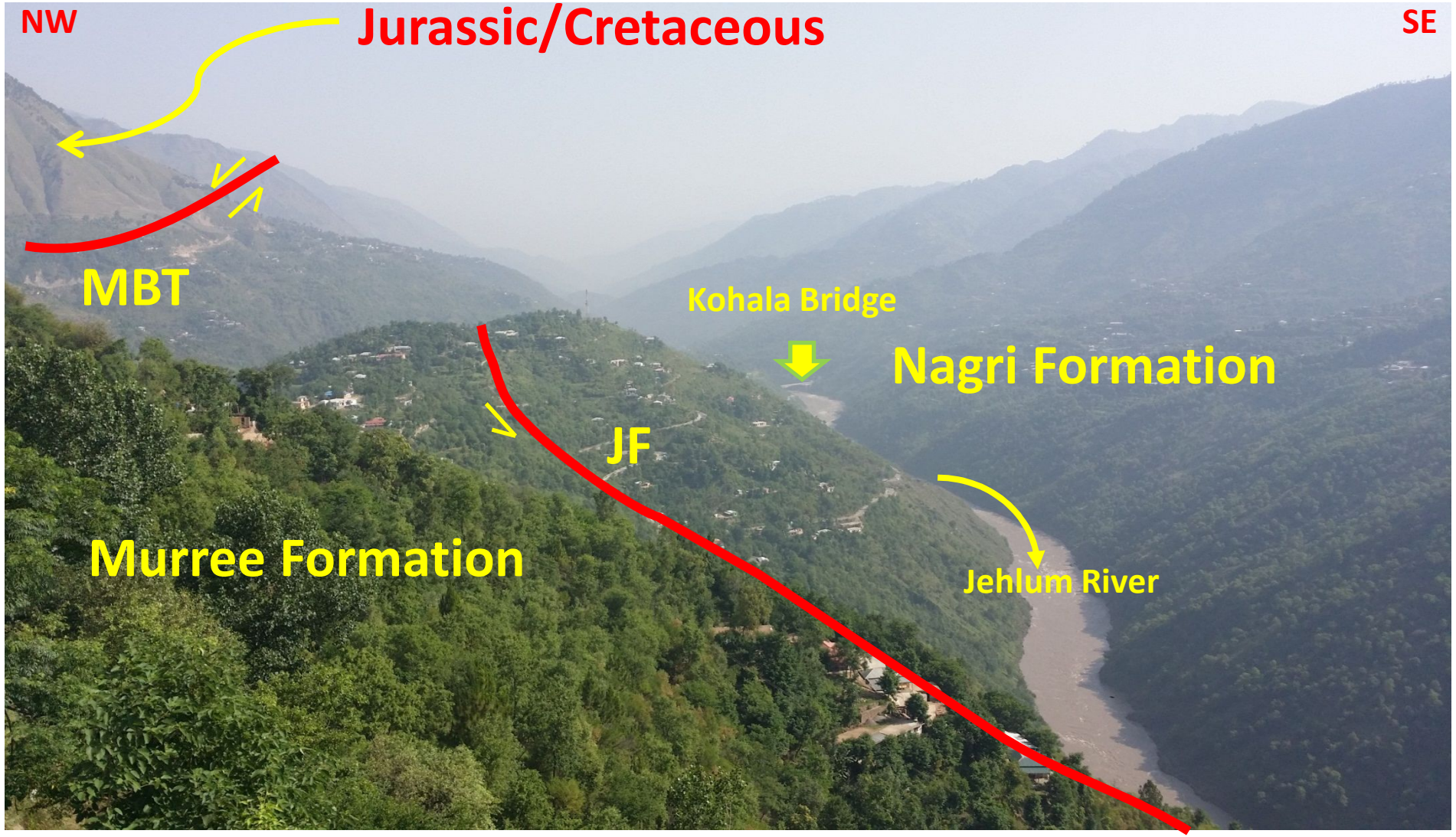
of
geohikingclub@yahoo.com
Sub-Himalaya


Main Boundary Thrust (MBT)
W
E
Jurassic/Cretaceous/Paleocene/Eocene
MBT
Murree Formation
A way of learning
of GeoHikingClub
Near Ghoragali (Murree)

# Main Boundary Thrust (MBT)

# Main Boundary Thrust (MBT) and Jehum Fault (JF)




At Nathia Gali Thrust (NGT)
Welcome to Ayubia National Park
Eocene
Hazara Formation
NGT

# SEQUENCE STRATIGRAPHY OF HAZARA BASIN

In Hazara Basin, Hazara Formation (Slates, slightly metamorphosed) are the result of turbiditic currents at the Precambrian age. In Muzafarabad (Yadgar Section) Abbotabad Formation unconformabily overlies the Hazara Formation, whereas, near Baragali Hazara Formation has composite unconformity with Datta Sandstone of Lower Jurassic age. Oolitic carbonate platform deposits of Samana Suk Formation were terminated at the time of Middle Jurassic in shoaling/shallowing upward conditions. Lowstand/Transgressive deposits of Chichali Formation gained its maximum accommodation space at the time of middle Cretaceous and Glauconitic tight sands of Lumshiwal Formation were deposited below the Kawagarh Formation. Inner to Outer ramp deposits of Kawagarh Formation were deposited forming finning and coarsening upward cycles.

Hangu Formation marks the sequence boundary and coarsening & finning cycles were deposited in Lockhart Formation. Maximum flooding surface is marked in between Patala Formation whereas three coarsening upwards cycles closed the deposition of new Tethys Sea.

# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

- The Mesozoic to Eocene Hazara Basin dominated by shelf carbonates is characterised by a distinct package of sediments punctuated by a number of
  - diastems,
  - hiatus and
  - unconformities.
- The environment of deposition vary from supratidal to shelf edge (250m) and from open shelf to restricted circulation anoxic conditions as a consequence of plate movement.
- The average lithified rates of sedimentation vary from 0.96mm to 83.30mm per 1000 years.

During upper Hettangian the Hazara landmass changed into a marine basin with the development of a transgressive shore line with the deposition of Datta Formation which overlies either Upper Proterozoic Hazara Formation or Cambrian Hazira Formation.

| Age | Abbottabad Area | Galiat | Lithology |
|---|---|---|---|
| E. Miocene | | Murree Formation | Grey to reddish sst. and shales. |
| M. Eocene | | Kuldana Formation | Maroon to varicolor shales, marls and Lst. |
| E. to Middle Eocene | | Chorgali Formation | Thinly bedded Lst and marls. |
| E. Eocene | Margala Hill Lst. | Margala Hill Lst. | Nodular foraminiferal Lst. |
| Late Paleocene | Patala Formation | Patala Formation | Khaki greenish grey. Shales with Lst. |
| Middle Paleocene | Lockhart Formation | Lockhart Formation | Nodular Foraminiferal Lst |
| Early Paleocene | Hangu Formation | Hangu Formation | S.St/laterite. |
| **Unconformity** | | | |
| Late Cretaceous | Kawagarh Formation | Kawagarh Formation | Limestone/marl. |
| E.Cretaceous | Lumshiwal Formation | Lumshiwal Formation | Coarse to fine grained Sst. |
| L. Jur to E. Cre | Chichali Formation | Chichali Formation | Dark grey shales with Sst. beds |
| **Unconformity** | | | |
| Middle Jurassic | Samanasuk Formation | Samanasuk | Limestone/Dolomitic Lst. |
| E. Jurassic | Datta Formation | Formation<br>Datta Formation | Sst, shale and limestone. |
| **Unconformity** | | | |
| Cambrian | Hazira Formation<br>Galdanian Formation | | Shale, Siltstone<br>Shale, Siltstone |
| **Unconformity** | | | |
| Lower Cambrian | Abbottabad Formation<br>i) Tanaki Member<br>ii) Sangargali Member<br>iii) Mohamda Gali Member<br>iv) Mirpur Member<br>v) Sirban Member | | <br>Conglomerate<br>X-bedded red Sst. and shale.<br>Pink Dolomite<br>X-bedded red Sst. and shale.<br>Offwhite dolomite and chert |
| **Unconformity** | | | |
| Eo-Cambrian | Tonol Formation | | Quartzite |
| Eo-Cambrian | Hazara Slate | Hazara Slate | Turbidites sequence with algal limestone |
| **Base Not Exposed** | | | |

| SALT RANGE | AGE | HAZARA |
|---|---|---|
| Murree Formation | Early Miocene | Murree Formation |
| Kuldana Formation | Middle Eocene | Kuldana Formation |
| Chorgali Formation | Early (?)Eocene | Chorgali Formation |
| Sakeser Limestone | Early (?) Eocene | |
| Nammal Formation | Early Eocene | Margala Hill Limestone |
| Patala Formation | Upper Paleocene | Patala Formation |
| Lockhart Limestone | Middle Palaeocene | Lockhart Limestone |
| Hangu Formation | Early Paleocene | Hangu Formation |
| **UNCONFORMITY** | | |
| | Upper Cretaceous | Kawagarh Formation |
| | Middle Cretaceous | Lumshiwal Formation |
| Lumshiwal Formation | Early Cretaceous | |
| Chichali Formation | Early Cretaceous to late Jurassic | Chichali Formation |
| **UNCONFORMITY** | | |
| Samanasuk Formation | Middle Jurassic | |
| Shinawari Formation | Early Jurassic | Samanasuk Formation |
| Datta Formation | Early Jurassic | Datta Formation |
| **UNCONFORMITY** | | |
| Kingriali Formation | Late Triassic | |
| Tredian Formation | Middle Triassic | |
| Mianwali Formation | Early Triassic | |
| **PARACONFORMITY** | | |
| Chhidru Formation | | |
| Wargal Formation | Late Permian | |
| Amb Formation | | |
| Sardhai Formation | | |
| Warcha Formation | | |
| Dandot Formation | | |
| Tobra Formation | | |
| **MAJOR UNCONFORMITY** | | |
| Baghanwala Formation | Cambrian | Galdanian/Hazira |
| Jutana Formation | | Abbottabad Formation |
| Kussak Formation | | i) Tanaki Member |
| Khewra Sandstone | | ii) Sangargali Member |
| | | iii) Mohamda Gali Member |
| | | iv) Mirpur Member |
| | | v) Sirban Member |
| Salt Range Formation | Eo-Cambrian | i) Langrial Lst. |
| | | ii) Miranjani Lst. |
| | | Hazara Formation |

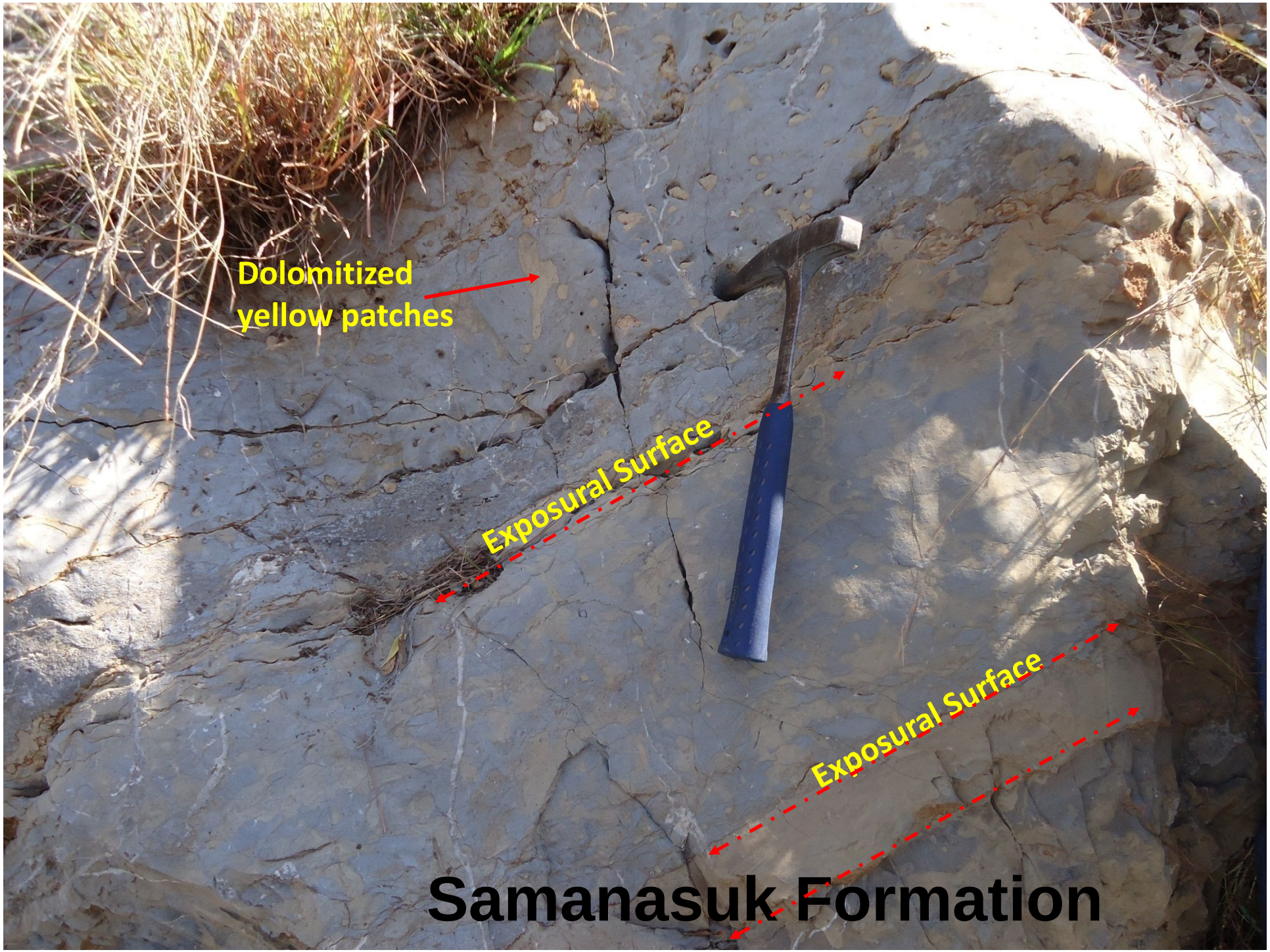
| Formation | Detailed Lithology | Environment of Deposition |
|---|---|---|
| Murree | Maroon to red Molasse deposits | Continental/fluvial |
| Kuldana | Shale-Siltstone beds with intercalations of fossiliferous marine mudstone to packstone | continental to marine |
| Chorgali | Shales, foraminiferal mudstone, wackestone and packstone | Carbonate ramp. |
| Margala | Foraminiferal mudstones, wackestone and packstone | Carbonate ramp upper subtidal to lower subtidal |
| Patala | Olive grey splintary shale with occasional foraminiferal mudstone to packstone | Open shelf with in put of siliciclastic material. |
| Lockhart | Foraminiferal nodular mudstones, wackestones and packstones. | Open shelf |
| Hangu | Fire clay, pisolitic bauxite and laterite. Occassional coaly layers | Subareal. |
| **UNCONFORMITY** | | |
| Kawagarh | Pelagic mudstones, wackestones and packstones and occasional marls. | Subtidal |
| Lumshiwal | Quartz, clay, iron oxide or glauconite cemented quartz arenites with submarine hardgrounds | Gradually deepening basin in open marine conditions |
| Chichali | Condenced pyrite rich and belemnite bearing black shale-siltstone sequence | Restricted anoxic |
| Samanasuk | Oolitic pelletoidal wackestone to packstones, bioclastic limestones and dolomitic horizons Burrowed and cross beddes with rare calcirudite and hardgrounds | Epicontinental intertidal and upper shelf. |
| Datta | Lenses, sheets and layers of poorly sorted medium to coarse grained quartz arenites with rare grit and interlayers of carbonaceous shales, marls and oolitic/pelletoidal limestone. | Open marine, lower to upper shoreface, lagonal to subaereal regims. |
| **UNCONFORMITY** | | |

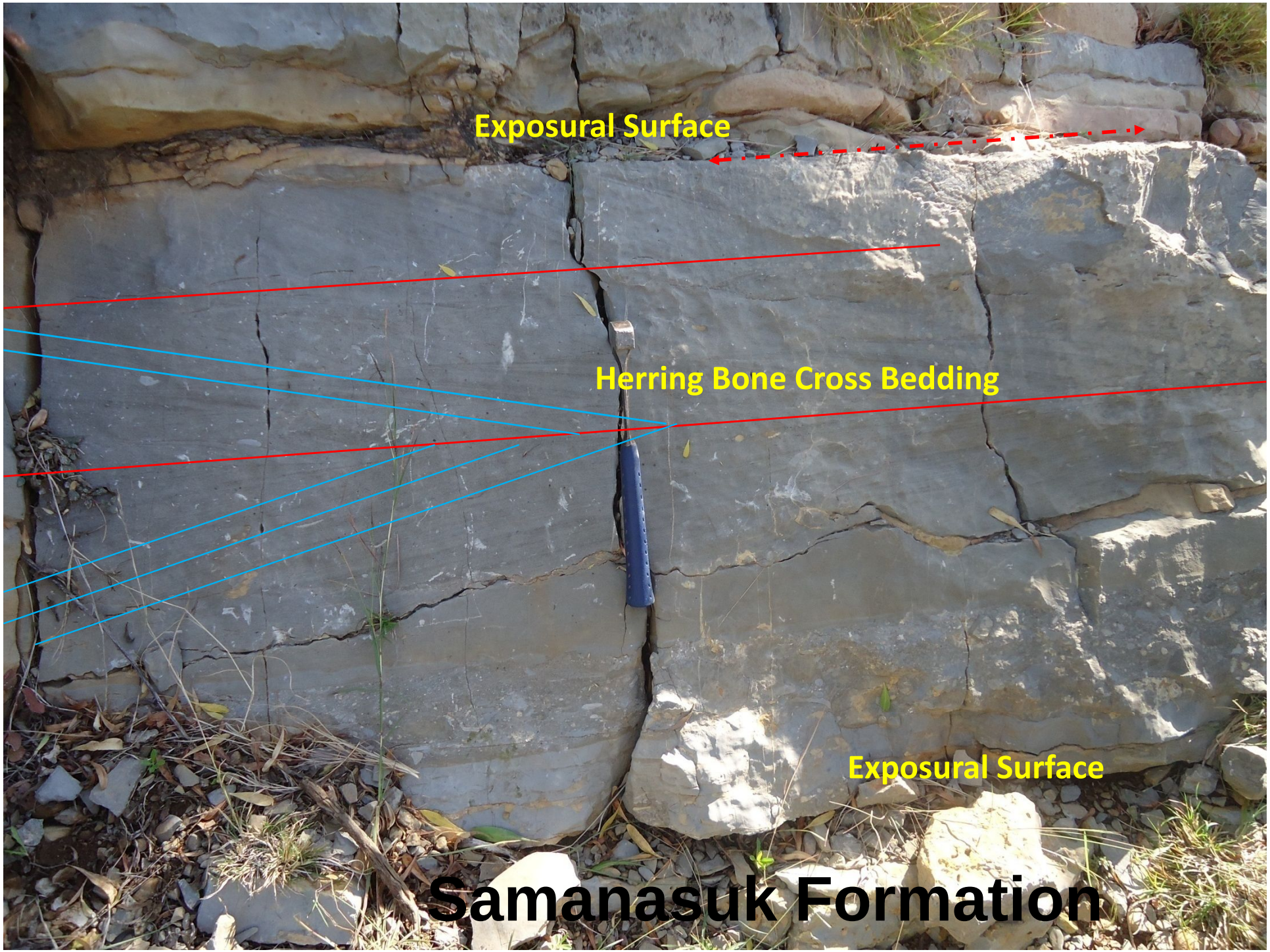
# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

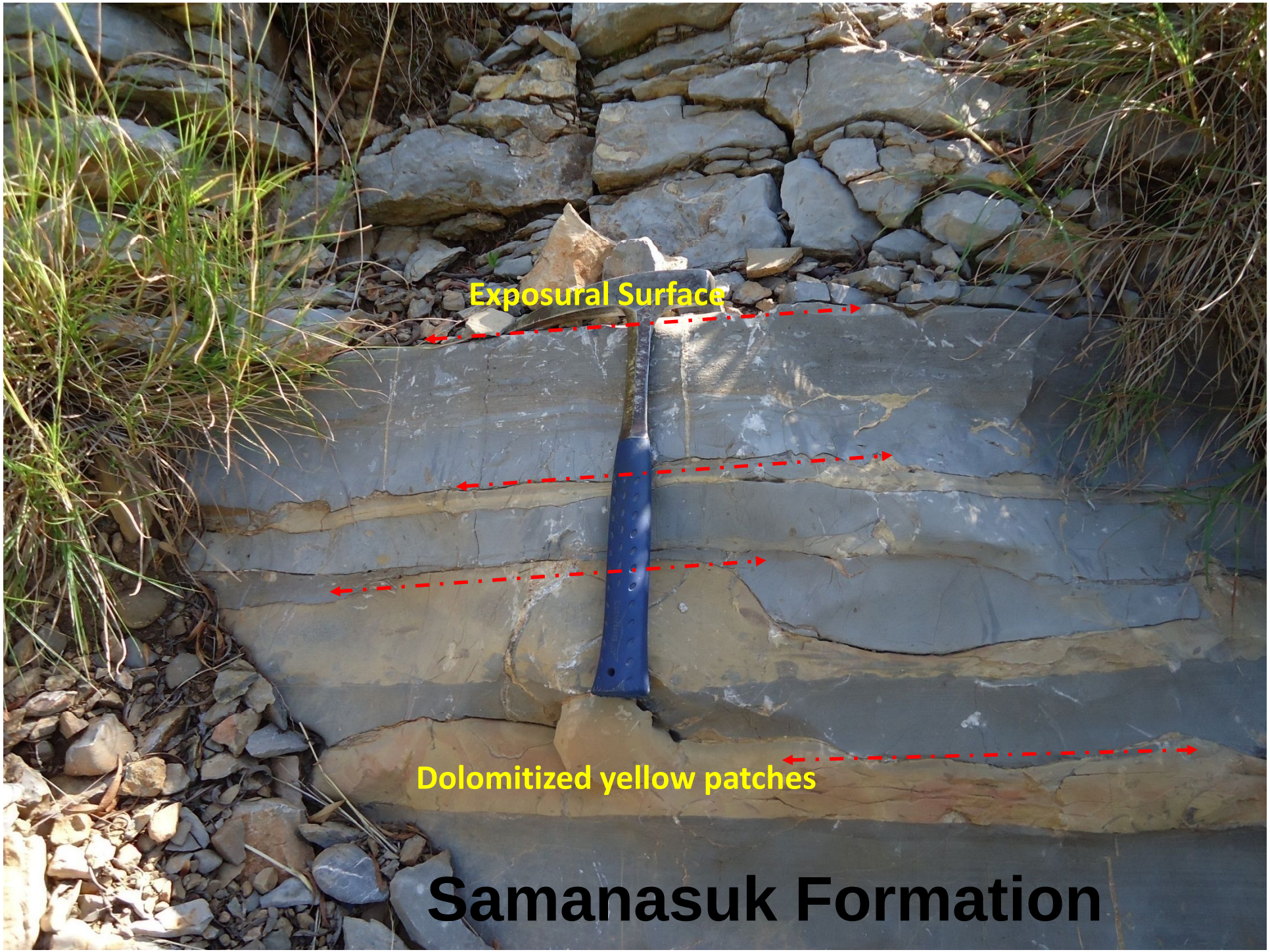
- It was deposited during open marine, lower to upper shoreface, lagoonal to subareal regimes (Chaudhry et al. 1997; Chaudhry et al. 1996; Chaudhry et al. 1995).
- It is composed of lenses, sheets and layers of poorly sorted medium to coarse grained quartz arenites with rare grit and interlayers of carbonaceous shales, silty shales, marls and oolitic to pelletoidal limestones.
- The average lithified rates of sedimentation were approximately 2mm/1000 years.
- Provenence studies show derivation from an igneous metamorphic sialic Indian plate source lying to the south.

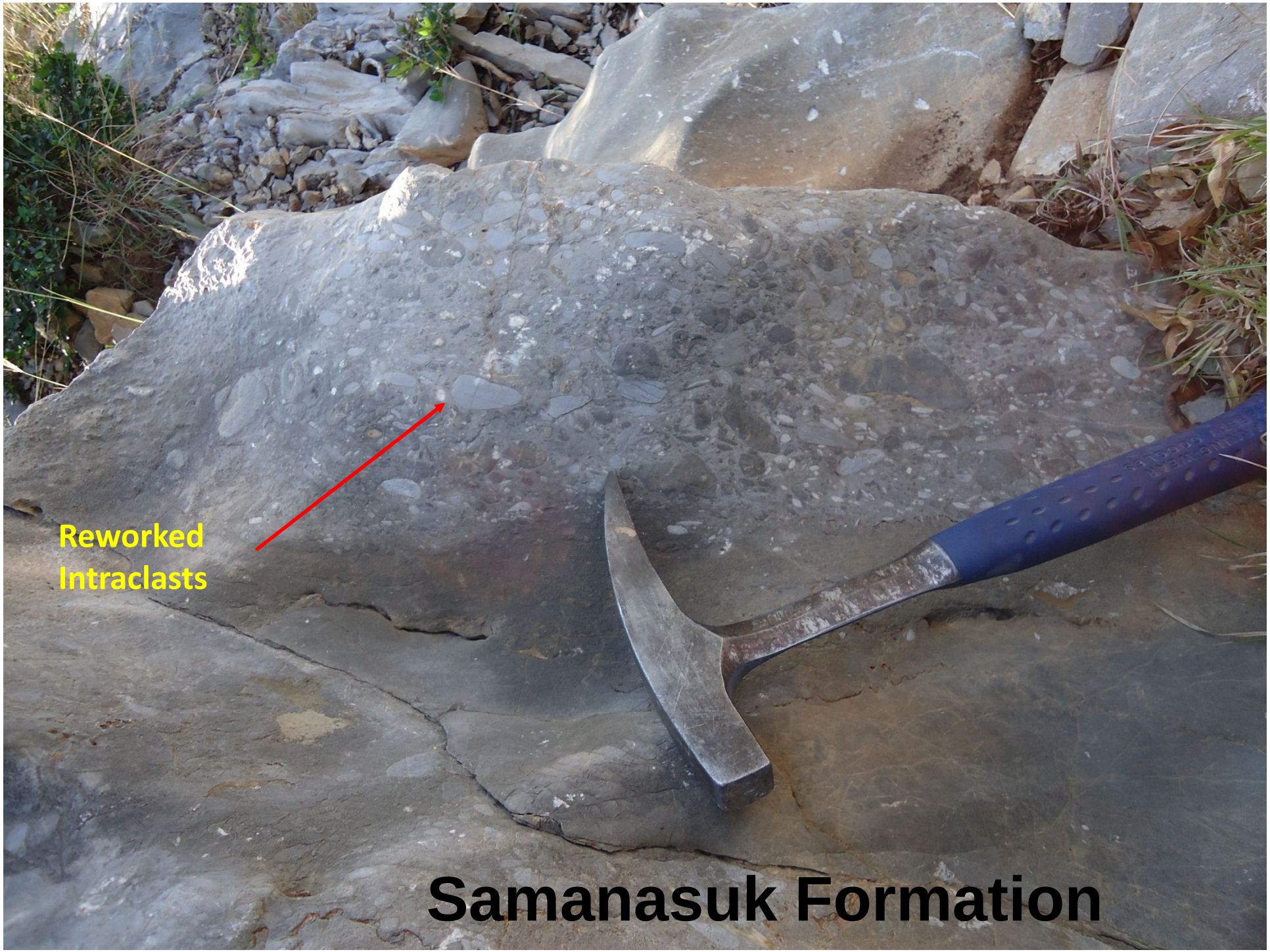
# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

The Samanasuk Formation represents an epicontinental intertidal environment with upper shelf oolitic-pelletoidal shoals deposited from Toarcian to Callovian.
Cross bedding and burrows are frequent.
The sediments are composed of oolitic-pelletoidal wackestones to grainstones, bioclastic limestones and dolomitic horizons.
Rare calcirudites also occur.
The oyster topped beds and hard grounds represent slow rates of deposition and subareal exposures.
The average lithified rates of deposition were about 6mm/1000 years.


Dolomitized
yellow patches
Exposural Surface
Exposural Surface
Samanasuk Formation


Exposural Surface
Herring Bone Cross Bedding
Exposural Surface
Samanasuk Formation

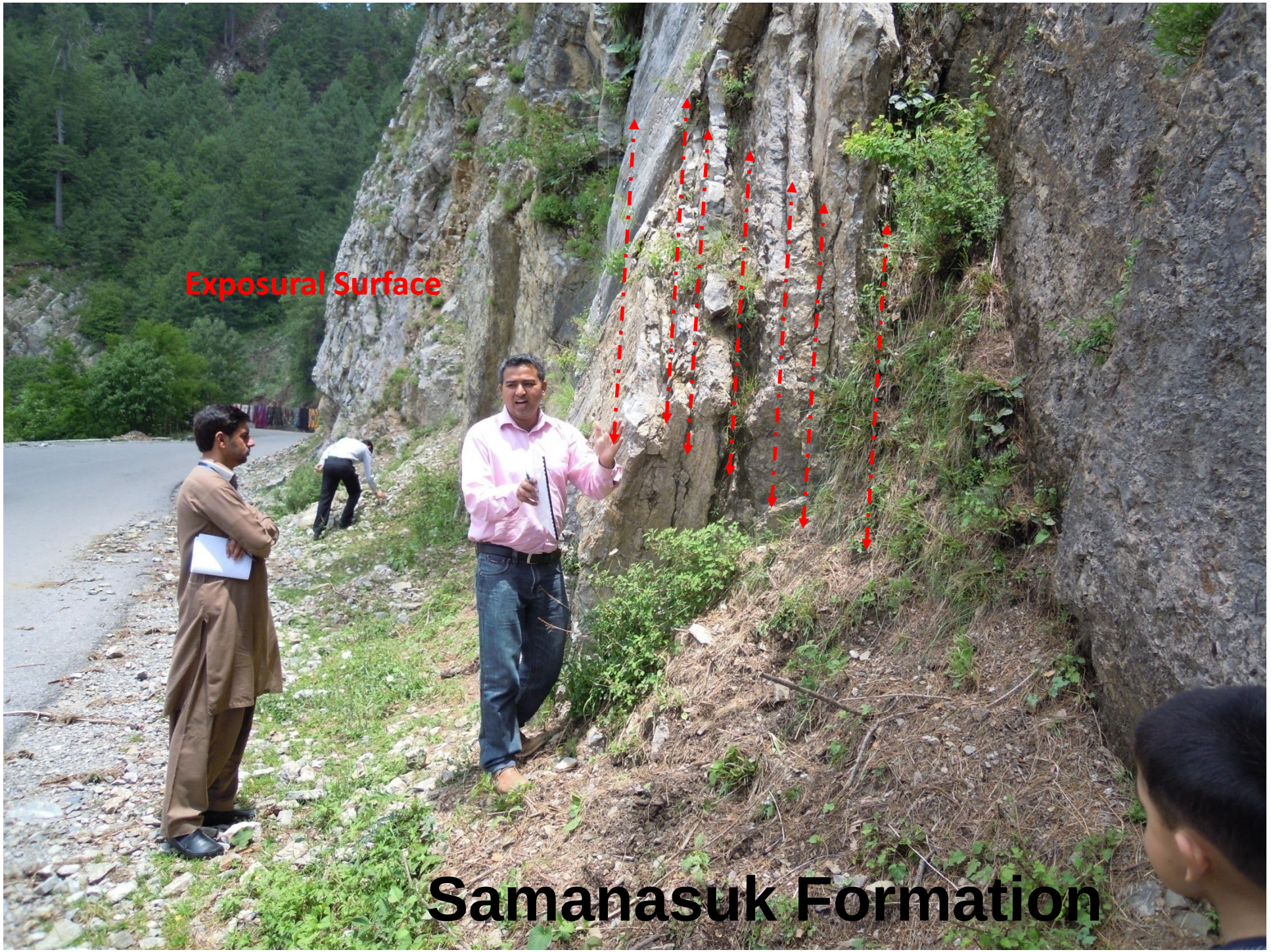

Exposural Surface
Dolomitized yellow patches
Samanasuk Formation


Reworked
Intraclasts
Samanasuk Formation


Changlagali
چھانگلہ گلی
Height 8600 ft


17 June 2015


January 2015


Exposural Surface
Samanasuk Formation


Exposural Surface
Samanasuk Formation

# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

At the close of Callovian restricted anoxic environment prevailed and condensed pyrite rich and belemnite bearning black shale - siltstone sequence represented by Chichali Formation of Oxfordian to Kimmerdgian age was deposited.

The lithified sedimentation rates were about 2.3mm/1000 years.

Strongly reducing conditions changed to mildly reducing conditions with better circulation in Tithonian during which was deposited Lumshiwal Formation composed mainly of glauconitic quartz arenites (Chaudhry et al. 1997, Chaudhry et al. 1994) with submarine hard grounds.

These sediments are generally cemented with quartz, clay, iron oxides or glauconite.

The ubiquitous glauconite indicates slow rates of deposition in mildly reducing environments.

The suite of heavy minerals once again indicates sialic igneous metamorphic provenance. The average lithified rates of sedimentation were about 0.96mm/1000 years.


Samama Suk Formation (HST)
SB-1
Chichali Formation (LST)
Equivalent to Sembar Formation
Future shale gas prospect


Reworked Intraclasts in
Lumshiwal Formation
Samanasuk Formation


Lumshiwal Formation
Condensed Section

# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

In Cenomanian, the Hazara basin deepened (upto a maximum of 250m as shown by the presence of oligostigena, Ahsan et al 1993, Ahsan et al. 1994, Chaudhry et al. 1992) during a major global transgression with deposition of Kawagarh Formation composed of pelagic mudstones, wackestones and packstones.

The upper beds (Maastrichtian in age) of Kawagarh Formation were exposed during a widespread regression due to initial contact of the Indian Plate with the Kohistan Arc at 67±2 Ma prior to main India-Eurasia collision (Bard et al. 1979) at 50 - 55 ma.

The average lithified rates of sedimentation of Kawagarh Formation have been estimated as 9mm/1000 years (Chaudhry et al. 1994).

The subareal exposure under subtropical conditions reworked the Maastrichtian sediments of the Kawagarh Formation into fire clay, pisolitic bauxite and laterite. The rate of accumulation of these residual sediments of Hangu Formation are about 1.77mm/1000 years.

# Shortest Murder Story

Biwi:- Sunte Ho.

Husband:- Nahi.


# Facies

- The term **facies** refers to all of the **characteristics of a particular rock** unit. For example, you might refer to a “oolltic limestone fades”. The characteristics of the rock unit come from the **depositional environment.**
- Every depositional environment puts its own distinctive imprint on the sediment, making a particular fades. Thus, a facies is a distinct kind of rock for that area or environment.
- **Sandstone facies** (beach environment).
- **Shale facies**(offshore marine environment).
- **Limestone facies** (far from sources of terrigenous input).
- Each depositional environment grades laterally into other environments. We call this **facies change** when dealing with the rock record.


Facies Change

# Fades Sequence

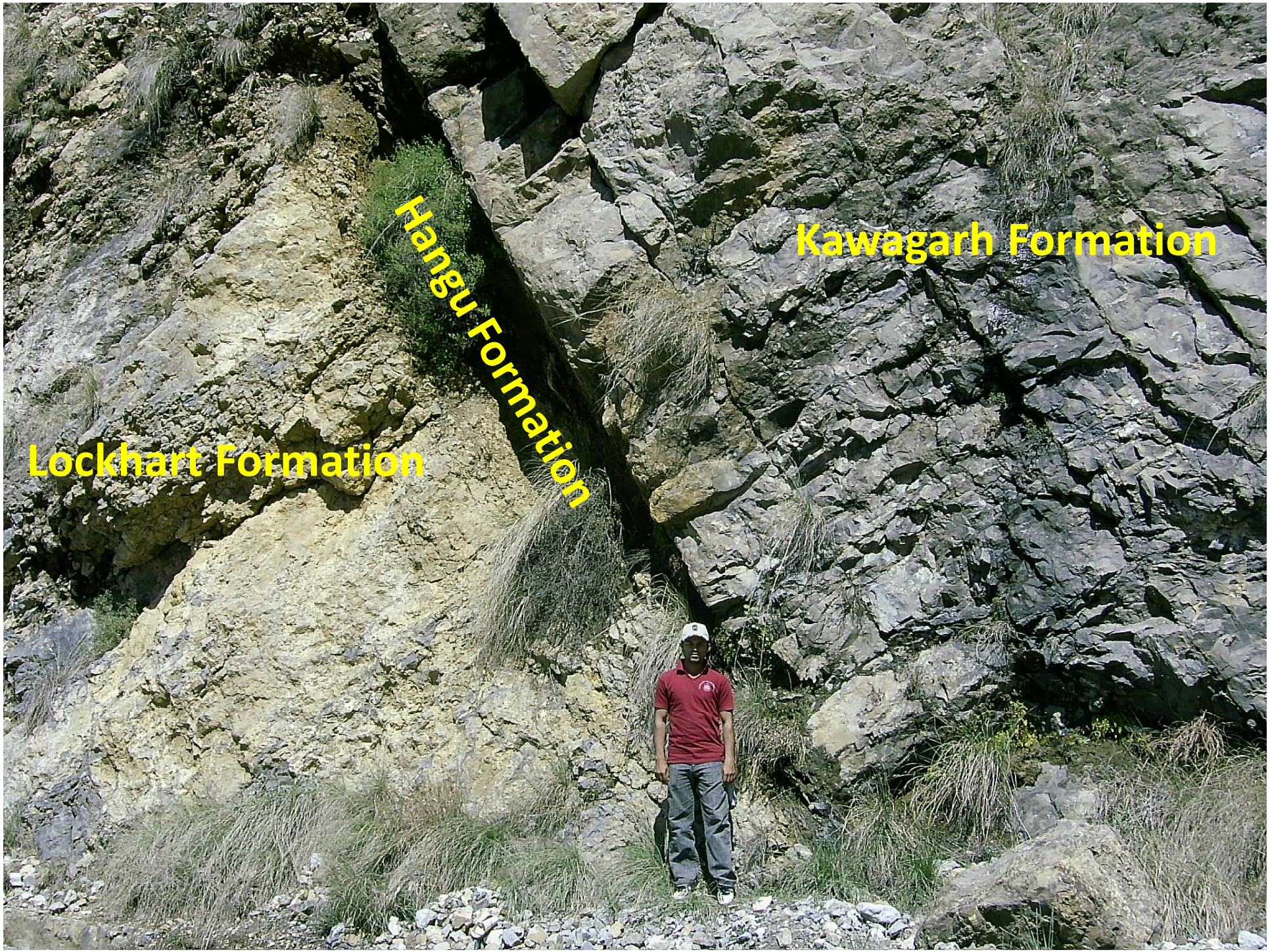
Change from one facies to another reflects a change in environment.

**Transgressive Facies Sequence**

- ❖ Sea level rise
- ❖ Sand is deposited on the beach
- ❖ Silt is deposited offshore
- ❖ Calcite is deposited further off shore
- ❖ Resulting facies sequence (top to bottom): Limestone, Shale, Sandstone

**Regressive Fades Sequence**

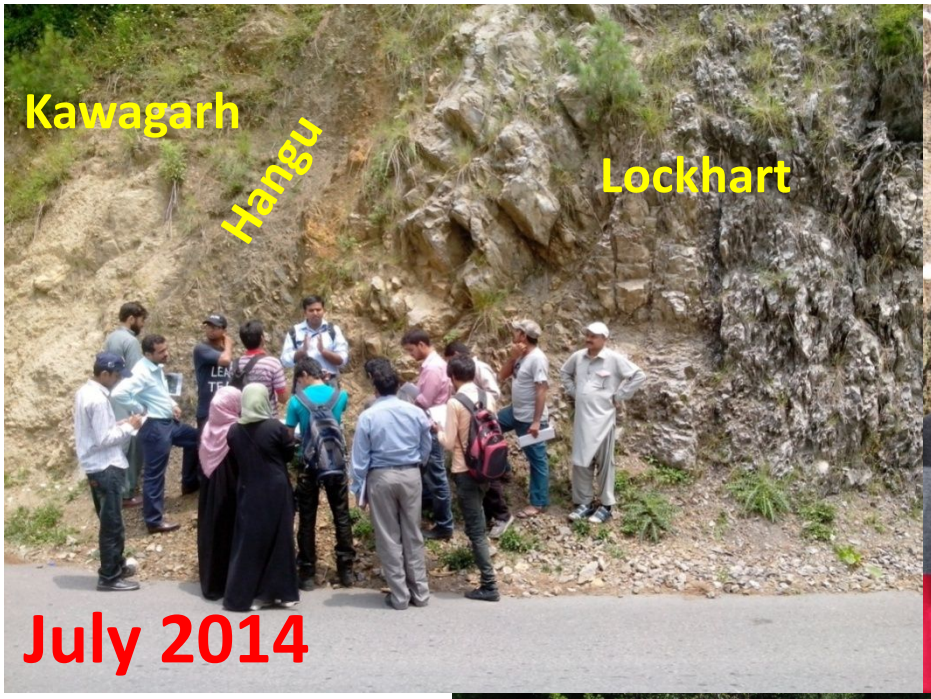
- Sea level fall
- Calcite is deposited further offshore
- Silt is deposited offshore
- Sand is deposited on the beach
- Resulting facies sequence (top to bottom): Sandstone, Shale, Limestone


Hangu Formation
Kawagarh Formation
Lockhart Formation

# SEDIMENTOLOGY OF HAZARA BASIN FROM JURASSIC TO EOCENE

The crustal bulge which developed due to initial Kohistan Arc Indian Plate contact at 67±2ma (Bard et al. 179, Chaudhry et al. 1994) subsided by Thanetian and Hazara Basin once again changed into an open shelf to deposit nodular Lockhart Limestone in shallow shelf (subtidal) environments.
The sediments of the Lockhart Limestone rich in benthic fora are composed of mudstones, wackestones and packstones.
The average lithified sedimentation rates are worked out at about 30mm/1000 years.
The carbonate shelf developed into a siliciclastic basin with increased turbidity which supressed deposition of carbonates and olive grey splintary shales of Patala Formation with occasional limestone bands were deposited.
The average lithified rates of deposition of Patala Formation are about 30mm/1000y.


Kawagarh
Laterite band/ K-T Boundary/unconformity/
Subaerial unconformity/ SB Type-1
Lockhart
Hangu





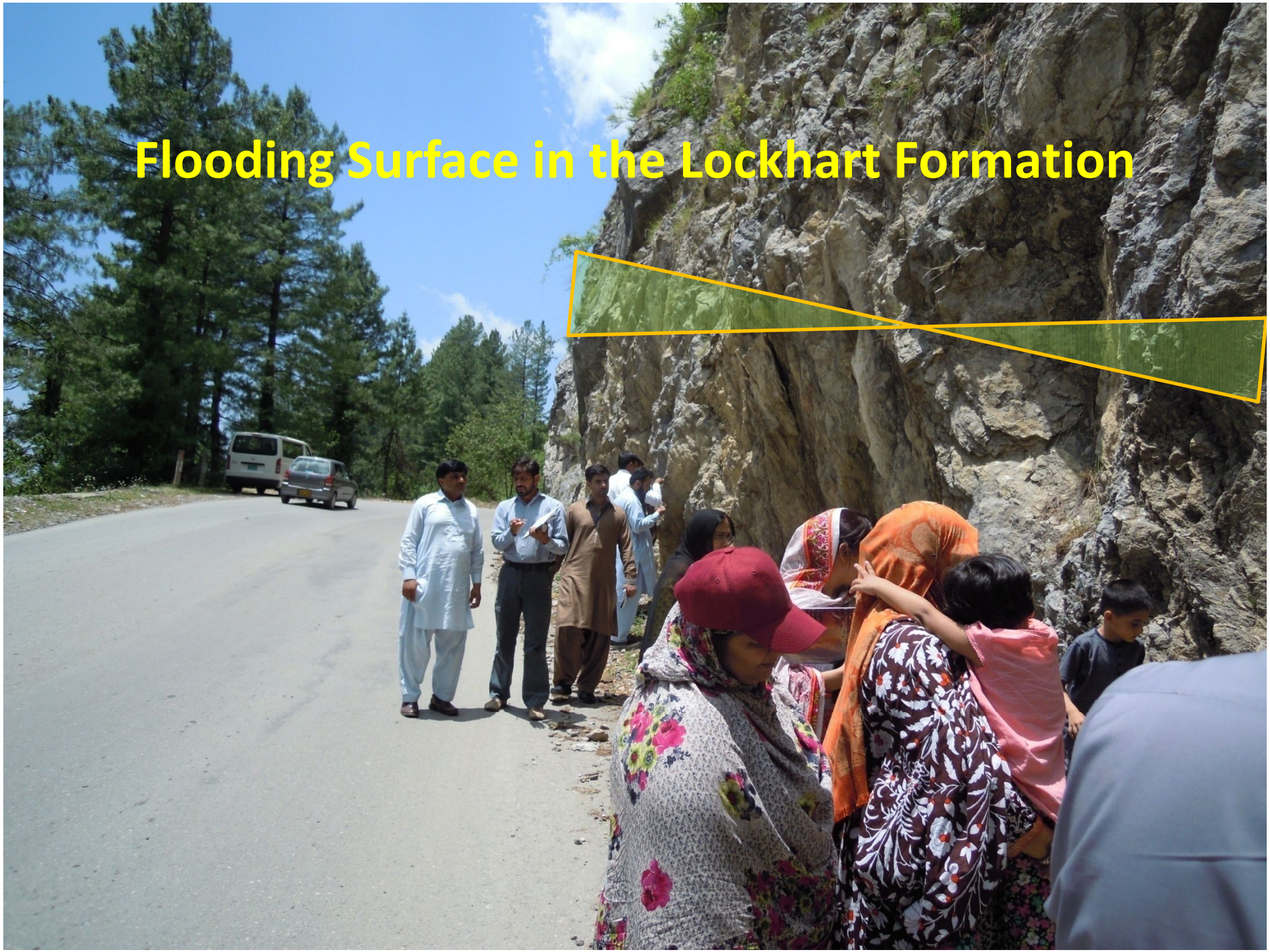

A way of learning
of GeoHikingClub


Lockhart
Coal bed/ K-T
Boundary/unconformity/ Subaerial
unconformity/ SB Type-1
Kawagarh
Hangu


Nodular Lockhart Formation
DOLLAR®
0.3mm


Flooding Surface in the Lockhart Formation


Flooding Surface in the Lockhart Formation


Flooding Surface in the Lockhart Formation


Paleocene Eocene Maximum Flooding Surface


Paleocene Eocene Maximum Flooding Surface

# Exercises of Sequence Stratigraphy

- **Exercise 1:**
  - Mark the Sequence boundaries in the Stratigraphy of Hazara Basin.
  - Facies change from south to north and mark the depocentere of Hazara Basin.
  - Depositional environments of formations.
- **Exercise2:**
  - Draw the sequence of Jurassic, Cretaceous, Paleocene and Eocene age bounded by Sequence boundaries.
  - Mark the $1^{st}$ / $2^{nd}$ order SB, TS and MFS and the systemtracts.
- **Exercise3:**
  - Mark detailed sequence stratigraphy of Lockhart and Kawagarh formations on the basis of microfacies / biostratigraphy.

# Where is the a gradational package?

# The Geologist

# کشمیری چائے


Welcome to Ayubia National Park