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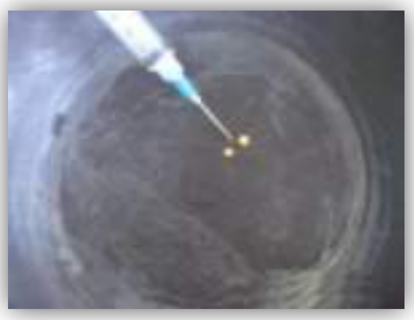
OF KHYBER PAKHTUNKHWA, PAKISTAN



REGIONAL GEOCHEMICAL EXPLORATION FOR PRECIOUS METALS IN THE SOUTHERN PARTS OF KHYBER

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December **2014**

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PREAMBLE

A project agreement was signed between National Centre of Excellence in Geology (NCEG), University of Peshawar and Directorate General of Mines and Minerals (DGMM), Mineral Department, Khyber Pakhtunkhwa province for conducting the Regional Geochemical Exploration for precious metals in the southern parts of Khyber Paktunkhwa. This project was funded by the Government of Khyber Pakhtunkhwa and is supposed to be completed in five phases (six months each) in thirty months. It covered the following areas of the province: 1) Peshawar and Mardan Divisions (Districts Peshawar, Charsadda, Nowshera, Swabi and Mardan), 2) Kohat and Bannu Divisions (Districts Kohat, Hangu, Karak, Bannu and Lakki Marwat) and 3) Dera Ismail (D.I.) Khan Division (District DI Khan & Tank). This project attained great importance because it was conducted with the aim to screen out those areas of the province which were not studied in detail for the mineral occurrences through geochemical survey in the past. The northern parts of the province have already been investigated through the same kind of geochemical survey in the past by various organizations. Therefore, after the completion of this project, a complete geochemical database will now be available for the whole province to encourage the investors for carrying out mineral exploration/mining activities in the province for its socio-economic development.

The NCEG is an international level teaching and research institute which has been pursuing its goals in a very efficient manner since its inception. Besides teaching and research the faculty and staff of this Centre is involved in carrying out national and international level projects, consultancies and entrepreneurships in the field of Earth and Environmental Sciences. This Centre has the best library shelved with thousands of books and hundreds of national and international journals. Its state of the art laboratories are equipped with sophisticated instruments required for research in the field of Earth, Environmental and Geospatial Sciences. Therefore, the NCEG has conducted this project by utilizing its all resources to fulfill the goals of this project in efficient manner.

The major component of this project assigned to NCEG were as follows:

1. Orientation Work

a) Literature search

b) Compilation of available geological maps on scale 1:250,000 using standard symbols for stratigraphy and structure along with cross sections.

c) Compilation of maps of known mineral occurrences as separate layer and as superimposed layer on geological map on scale 1: 250,000.

d) Interpretation of remote sensing data (satellite imageries) for anomalous geological features relating to metal deposits.

e) Preparation of preliminary report with description of the above data layers and interpreting the geological environments (geological modeling) for precious metal deposits.

f) Preparation of drainage cell maps on scale 1:50,000 as part of planning for stream sediments sampling / geo-chemical exploration.

2. Exploration field work

a.	Collection of Panned heavy minerals concentrate, Stream-sediments	200 samples
b.	Fine fraction stream-sediments samples	1,200 samples
c.	Coarse fraction/Tallus samples	200 samples
d.	Chip channel sampling of selected outcrops	200 samples
e.	Bulk sampling from selected outcrop if required	800 Kg

3. Laboratory Studies

a)	Chemical analysis	1,500 samples
b)	Petrography study	50 samples
c)	Pan-con mineralogical study	200 samples
d)	Processing study if required	800 Kg

4. Exploration data compilation

a) Preparation of geo-chemical exploration map / data layer

b) Geo-statistics of the stream sediments data / sample analysis

c) Exploration data compilation in integration with geology, known mineral occurrences and remote sensing data layers.
d) Interpretation of stream sediment data (including geo-statistics of laboratory data/analysis of samples) with delineation of anomalous targets for precious metals

5. Preparation of interim and final reports

a) Hard copy reports
b) Soft copy reports along with data layer in GIS format

The outcomes of this project were supposed to be submitted mid-yearly to the DGMM by NCEG in the form of following five phases:

1. Preparation of preliminary report regarding orientation work for compilation of available information on geology and known minerals occurrence as outlined in the Orientation Work above.
2. Reports regarding exploration field work of stream sediments sampling (including field work, laboratory studies and data compilation) for Peshawar and Mardan Divisions (Districts Swabi, Mardan, Nowshera, Charsadda & Peshawar)
3. Reports regarding exploration field work of stream sediments sampling (including field work, laboratory studies and data compilation) for Kohat and Bannu Divisions (Districts Kohat, Hangu, Karak, Bannu & Lakki Marwat)
4. Reports regarding exploration field work of stream sediments sampling (including field work, laboratory studies and data compilation) for Dera Ismail Khan Division (District DIKhan & Tank)
5. Preparation of final report of the feasibility by incorporating all the above information and the supported laboratory study in consolidated form as hard copy and in the form of GIS data layers using Survey of Pakistan standard datum and projection i.e.WGS1984, LCC, etc.

In this regard, the NCEG has completed the geochemical exploration work in all of the project area mentioned above. The previous reports have already been submitted to DGMM, while this is the comprehensive report of the project area.

a. Methodology adopted for performing the assignment

i. Orientation phase/strategy

1. Base map compilation (1:250,000)

Two approaches were supposed to be adopted during this project. In this project, firstthe Survey of Pakistan Topographic Maps (1:250,000) were digitized in terms of topography (contours), drainage, location of towns/villages, and political boundaries for districts, and then the, ASTER/Landsat TM images (15-30 m resolution) and SRTM satellite data was used to develop a Digital Elevation Model (DEM). These two tasks led to the development of a base maps at the scale of 1: 250,000 for project area i.e., the Central and Southern Pakhtunkhwa in the ARCGIS platform. These base maps were used to plan and design the mineral exploration survey as per requirement of the project.

2. Drainage-Basin Classification

Using the base map developed from Survey of Pakistan Topographic maps and DEM based on satellite data, the region mainly comprising the Indus River Basin was classified into drainage sub basins (e.g., Kabul River basin, Kurram River Sub basin, Tochi River Sub Basin, Gomal River Sub Basin etc). Since the sediment input into the Central and Southern Khyber Pakhtunkhwa is primarily governed by source rocks from the Western Himalayas in the north and Sufaid Koh (Khyber-Kurram-Waziristan Ranges) in the west, this sub-basin classification helped in differentiating the region based on source contribution, and thus greatly help in planning and designing the mineral exploration survey.

3. Geological Mapping Compilation

Existing Maps

NCEG has been pioneer in developing regional maps for Pakistan as exemplified by:

Searle and Khan (1996) Geological and Tectonic map of northern Pakistan and adjacent areas of northern Ladakh and Western Tibet (coloured, 1: 650,000). Sponsored Publication of British Petroleum, Shell & AMOCO.

Additionally, National Library of Erath Sciences, NCEG has a digital map collection of entire Pakistan especially Khyber-Paktunkhwa including USGS Map Series for Kohat, Kurram, Bannu, D.I.Khan. More than half of the NCEG Ph.D. and M.Phil.research work includes mapping exercises in different parts of the Khyber Pakhtunkhwa.

NCEG team used this wealth of existing maps to compile a comprehensive geological maps of Central and Southern Khyber-Pakhtunkhwa in its reports.

Geological Mapping through Satellite Image Processing

In recent years, NCEG has developed advanced skills in satellite image processing for applications in Geological Mapping. Using Landsat ETM, ASTER and SPOT 5 satellite imageries, NCEG had developed expertise in image-enhancement techniques like Principal Component Analysis (PCA), band rationing and Spectral Angle MapperClassification (SAM) to differentiate various lithological units as a powerful tool in geological mapping. Same techniques were used to pinpoint mineralized zones.

Using image enhancement techniques as described above, NCEG plans to improve the digitally compiled geological map in terms of quality and especially narrowing down the economically feasible mineralized zones. This technique especially helped in mapping those areas where geological mapping is absent or poor.

4. Mineralogical Database Compilation

Using base map, together with the newly compiled geological map, NCEG has planned to compile a mineral database, based on the existing published and unpublished data. This database is in GIS framework, where a mineral occurrence layer has been added to the system.

5. Geochemical Database Compilation

Although a systematic stream-sample geochemical database was non-existing for the Central and Southern Khyber Pakhtunkhwa, before the completion of this project, but the geochemistry of rocks from various parts are listed in a number of reports and research papers. A comprehensive database compilation of existing geochemical analysis, especially for rock samples has greatly assisted in planning/designing the survey but was also helpfull in cross correlation of already existing data with that of this project.

6. End Product

This exercise described above based on using a variety of Satellite Remote sensing Imaging Systems (Landsat ETM, ASTER, SPOT 5 etc.), compilation of published data on geological mapping, economic minerals, geochemistry, altogether in ArcGIS platform will yield a systematic databse comprising several thematic layers for planning and designing the mineral exploration required in the project. Figure 1.1 summarizes orientation stage studies which were planned before starting the project. This has greatly helped in materializing this project for achieving its goals.

Survey Planning/Designing Strategy

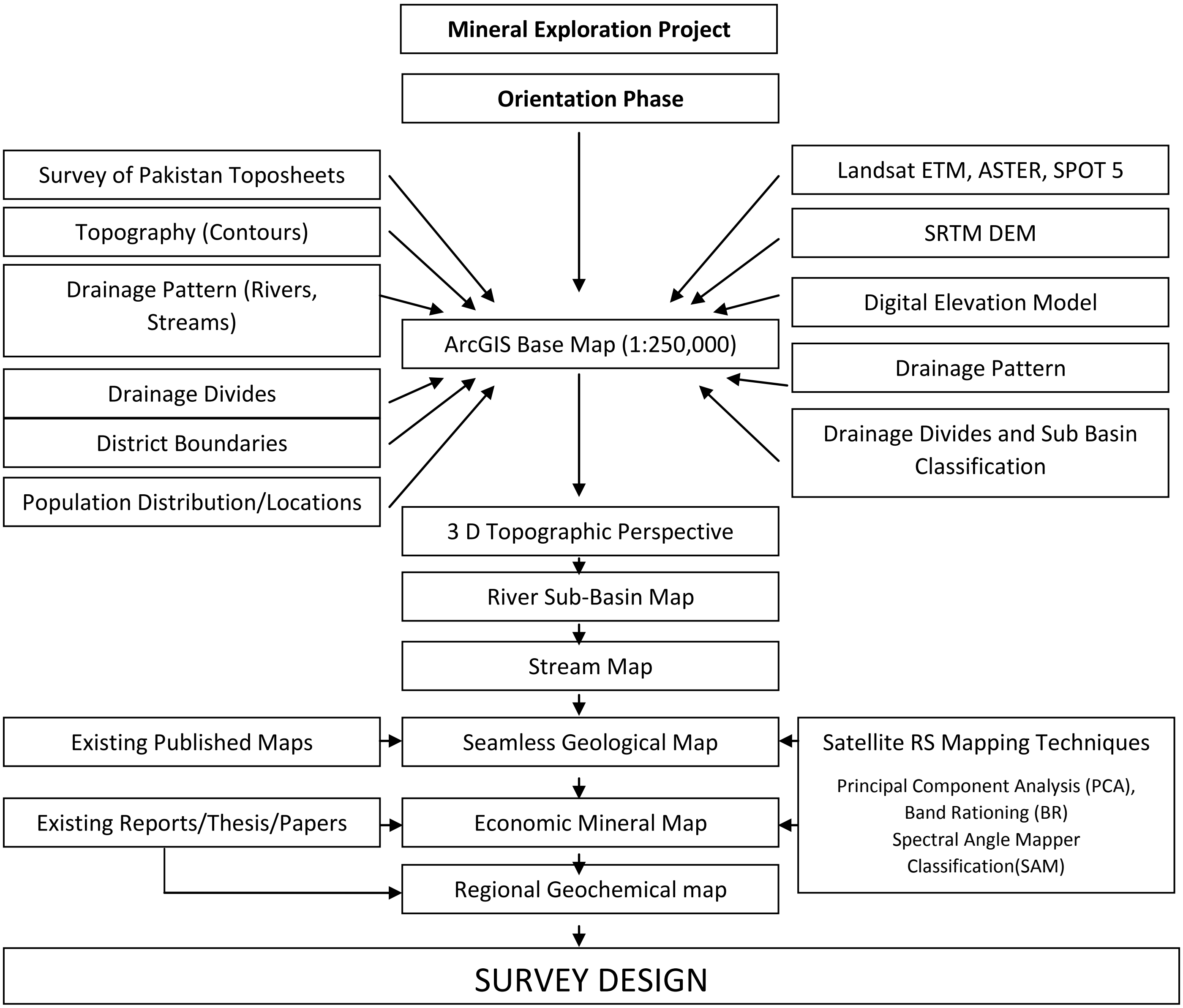


Fig. 1.1. Flow chart showing strategy for orientation (survey planning/designing phase.

i. Geochemical exploration phase/strategy

Peshawar and Mardan Divisions are the part of the Peshawar Basin which is the intermountain basin covering an area of about 5500 Km^2. It is comprised of Quaternary fanglomerates along the margins of the basin while the central part is generally covered with fluvial sand, gravels and lacustrine deposits. The Kohat and Bannu Divisions and Dera Ismail Khan Division are the part of the Kohat-Potwar plateau. This region is mainly comprised of the molasse sediments of the Siwalik Group. This group includes, in ascending order, Chinji, Nagri, Dhok Pathan and Soan formations. These formations are mainly composed sandstones with interbedded sandy clay and conglomerates. Besides, the whole region is widely covered with the Quaternary sediments, typically loessic silt interbedded with alluvial deposits.

Considering the geological environment of these regions, the work done during the geochemical exploration phase was based on the integrated drainage sampling. This technique is usually applied in the areas where the natural materials are deposited through natural physical and chemical weathering and downslope-downstream erosion processes in the catchment/drainage basins. This indicates that the mineralogical and geochemical studies carried out in these basins are representative of the upstream catchment areas and not the samples site itself. Keeping in view these criteria, the data generation, presentation and interpretation has been carried out in this study.

Before starting the geochemical exploration work, the drainage cells/basin maps (10-50 km2) on a scale of 1:50,000 were prepared for the Central and Southern Khyber- Pakhtunkhwa using the Survey of Pakistan toposheets and satellite imageries depending on the natural pattern of drainage basins. The appropriate sample locations were strategized at this stage for taking the pan-concentrates, stream sediment fine fractions (-80#) and grab and channel samples. All the drainage cells maps were prepared in the state of the art Geographic Information System (GIS) and Remote sensing (RS) laboratory of the NCEG using ARCGIS by the GIS/RS experts.

After preparing the drainage cells base maps of the Central and Southern Khyber- Pakhtunkhwa, the detailed field work was carried out in three phases. The first phase field work was conducted in the Peshawar and Mardan Divisions, second in the Kohat and Bannu Divisions and third in the Dera Ismail Khan Division. By looking at the geological environment of these regions, appropriate pan-concentrate and fine-fraction (-80#) of the stream sediments were collected from the closing point of each drainage cell and also from the other appropriate points. Where necessary, the coarse-fraction/Tallus samples were also collected in duplicate by applying standard sampling methods. Grab and channel rock sampling were done from each geological exposure for their petrographic studies. The float studies and other geological features of each drainage cell were conducted during field. The coordinates of all the collected samples were noted on spot by GPS. All the samples collected during field were transported to the NCEG for the following experimental work:

1. Petrographic studies
2. Mineralogical studies of pan-concentrates
3. Chemical analysis and processing
4. Data compilation and interpretation

1. Petrographic studies

For conducting petrographic studies, thin sections from the grab and channel samples of the rocks were prepared in the Thin Sections preparation laboratory of the NCEG. These thin sections were studied for the mineral composition and textural features of various rocks under the polarizing and reflected research microscope having automated computer image display and micro-photographic facility. These microscopes are available in the Petrographic/Gemological laboratory of the NCEG. These studies helped in identification and classification of rock types in the area. These studies have been conducted by the experienced mineralogists - petrographers.

2. Mineralogical studies

The mineralogical studies, especially of visible gold and heavy minerals in the pan-concentrates, collected during field, were carried out under the stereoscopic microscope by the experience mineralogists in the Petrographic/Gemological laboratory of the NCEG. The size and morphology (shape) and color of the gold particles were recorded as “color” (<0.3mm), “speck” (0.3-0.5mm) and “piece” (>0.5mm). These studies helped in the provenance studies of the placer gold and sediments.

3. Chemical analyses and processing

The chemical analyses and other extraction processes were carried out as follows:

a. Wet-chemical analysis

The wet-chemical analysis of all the samples, collected during field, were carried out for the precious and base and other metals such as gold (Au), sliver (Ag), copper (Cu), lead (Pb), zinc (Zn), nickel (Ni), chromium (Cr), cobalt (Co), cadmium (Cd), arsenic (As) and mercury (Hg) etc. All the samples collected were pulverized to -200 mesh size (-75 micron) in the tungsten carbide ball mill and properly split to appropriate quantity in the crushing and processing laboratory of the NCEG. The samples of appropriate quantity were digested in the microwave digestion oven by using acid mixture (aqua regia) following the well-established standardized procedures. However, the gold was extracted in the Methyle Isobutyle Ketone (MIBK) before its analysis. The concentrations of various metals in ppm (g/ton) were carried out using PerkinElmer 700 flame atomic absorption spectrometer while concentrations in ppb (µg/ton) were determined by electrothermal atomic absorption spectrometer equipped with HGA-600 graphite furnace in Wet-Geochemistry laboratory of the NCEG.

b. Treatment of Bulk samples

The geological environment of the Central and Southern Khyber-Pakhtunkhwa, as mentioned above, is such that where the placer gold deposits have been found world over. Therefore, there the chances of occurrences of placer gold deposits of economic importance in these areas are expected. For this purpose, the areas where from the anomalous gold values were found in the geochemical survey from there, the bulk samples weighing 800-1000kg were collected during the last (5^{th}) phase of the project. These bulk samples were transported to the mineral processing laboratory of the NCEG. Each bulk sample was processed through the shaking table for the collection of concentrates, middling and tail fractions. The concentrates were treated with magnetic separator for the removing of magnetic minerals so that interference with gold during analysis was minimized to a greater extant. The gold concentrations in the three fractions of the bulk sample were determined using the atomic absorption technique. This technique helped in calculating the extraction of gold in g/ton and hence the economic importance of the deposits was identified for future exploitation. This technique helped in knowing the recovery of gold through this process.

4. Data compilation and interpretation

a. Statistical analysis

The geochemical data of the stream sediments (both panned-con and -80#) obtained during this study was entered into the spreadsheet type computer data base. These data sets were synthesized through the statistical computer software programs such as SPSS and MINITAB for the determination of mean, variance, standard deviation, coefficient of variance and factor analysis of the geochemical data populations for data interpretation. Threshold values, above which the values are considered anomalous, for various metals were determined by plotting the data on the histograms and frequency distribution diagrams. In this way the anomalous and background populations were separated for further interpretation.

b. GIS analysis

Various layers were created through GIS by using the ARCGIS platform in the GIS/RS laboratory of the NCEG by the GIS/RS experts. The data were presented in different layers as follows:

Layer 1 contained all the geological maps/data/features/structures obtained through literature study as well as reported during the present field studies during orientation phase.

Layer 2 contained the information and locations of the known metallic and non-metallic mineral occurrences in these regions.

Layer 3 containe the petrographic and geochemical data of the rocks unites exposed in the area.

Layer 4 contained the mineralogical data of the pan-concentrates including the gold particles' size and morphological details.

Layer 5 contained the pan-concentrates' geochemical data maps compiled by plotting the geochemical data "standardized" to a normal 100 grams of pan-concentrate samples with all the attributes. The data were synthesized through GIS and anomalous zones / cells were delineated for detail follow-up studies.

Layer 6 contained the geochemical data of the entire stream sediments fine fractions (-80#) with all the attributes. The data were synthesized / analyzed through GIS and the anomalous zone / cells were delineated for follow-up studies.

c. Modeling

The petrographic, mineralogical and geochemical data obtained during this study were compiled and integrated with the geology and known mineral occurrences. In this way various features were correlated with Remote Sensing data and the modeling of mineral occurrences were established. These data were also be interpreted for understanding the following:

1. The provenance of the precious and base metals and heavy minerals
2. The distance covered by the gold particles, if any, and establishing the possible source material.
3. Geochemical modeling for strategizing the detailed exploration and exploitation program
4. Establishing the areas of economic importance for future studies.

The geochemical exploration stage studies designed before starting this project are summarized in Figure. 1.2.this strategy was followed during this project to achieve the goals in different manner.

Survey Planning/Designing Strategy

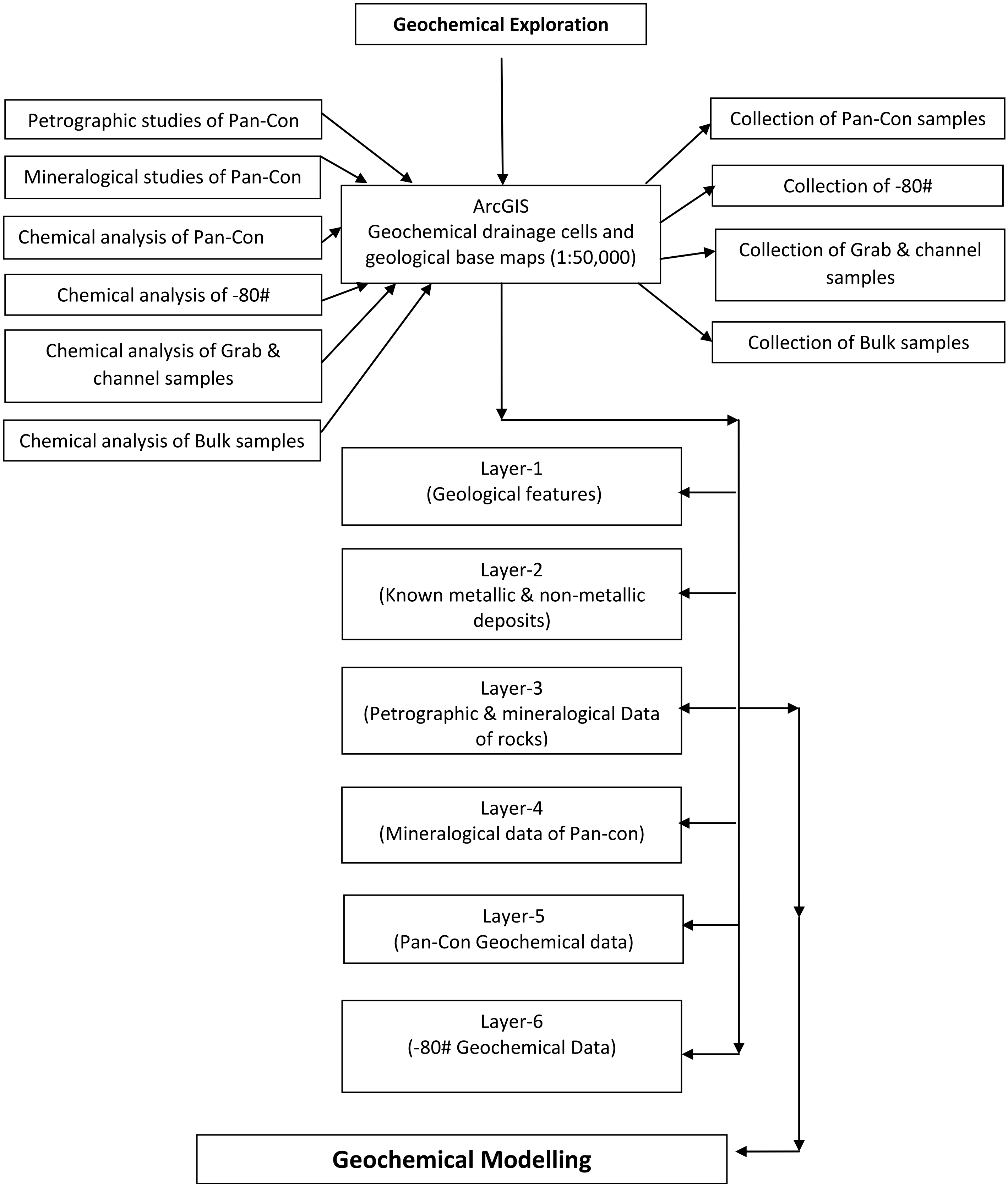


Fig. 1.2. Flow chart showing strategy for Geochemical Exploration (survey planning/designing phase)

DELIVERABLES

1. First quarterly report on the Orientation Work

The preliminary report covering the Orientation Work was submitted to the DGMM as first quarterly report on in March 2013. This report comprises of the following detail work carried out during the first quarter of the project:

1. Geological setting of the northern parts of Pakistan in the context of geology of the study area and its input of sediments into the sedimentary basins of the central and southern parts of the Khyber Pakhtunkhwa.
2. The existing mineral occurrences in the central and southern Khyber Pakhtunkhwa, their locations on the digitized geological maps and districts maps in different layers prepared in ArcGIS 10 software.
3. The construction of drainage pattern (watershed) map of the whole study area at the scale of 1.5cm = 30Km and the portion wise drainage pattern maps of the study area at the scale of 1:50000 by using ASTER DEM and ArcGIS 10 software.
4. Satellite image analysis were performed on Landsat Enhanced Thematic Mapper plus (ETM+) for extracting geological and mineral information by using band rationing technique and method of Principal Component Analysis (PCA).
5. The compilation of available Geological maps on a scale of 1:250000.
6. Photocopies of all the available literature including Geological Survey of Pakistan reports, MS/M.Phil./Ph.D thesis abstracts and other research papers and reports.

2. Mid yearly report regarding exploration field work in Peshawar and Mardan divisions

The geochemical exploration field work was conducted during the months of April to September, 2013 in the Peshawar and Mardan Divisions (Districts Swabi, Mardan, Nowshera, Charsadda and Peshawar). This Mid-yearly report was submitted in September 2013 to DGMM for further evaluation. The presentation was made in October 2013 before the Evaluation Committee and the work done was highly admired by the members of the committee. This report has reported the detailed work carried out as per PC-11 Scheme of the DGMM as follows:

1. **Exploration field work**
    a. Collection of Panned heavy minerals concentrate, Stream-sediments
    b. Fine fraction stream-sediments samples
    c. Coarse fraction/Tallus samples
    d. Chip channel sampling of selected outcrops
    e. Bulk sampling from selected outcrop if required

2. **Laboratory Studies**
    a. Chemical analysis
    b. Petrography study
    c. Pan-con mineralogical study
    d. Processing study if required

3. **Exploration data compilation**
    a. Preparation of geo-chemical exploration map / data layer
    b. Geo-statistics of the stream sediments data / sample analysis
    c. Exploration data compilation in integration with geology, known mineral occurrences and remote sensing data layers.
    d. Interpretation of stream sediment data (including geo-statistics of laboratory data/analysis of samples) with delineation of anomalous targets for precious metals

4. **Preparation of interim and final reports**
    a. Hard copy reports
    b. Soft copy reports along with data layer in GIS format

3.Mid yearly report regarding exploration field work in Bannu and Kohat divisions

The geochemical exploration field work was conducted during the months of October, 2013 to March, 2014 in the Bannu and Kohat Divisions (i.e., Districts of Kohat, Hangu, Karak, Bannu and Lakki Marwat). This Mid-yearly report was submitted in March, 2014 to DGMM for further evaluation. The presentation was made in April, 2014 before the Evaluation Committee and the work done was highly admired by the members of the committee. In this report, the detailed work carried out as per PC-11 Scheme of the DGMM was explained as the following steps:

1. **Exploration field work**
    a. Collection of Panned heavy minerals concentrate, Stream-sediments
    b. Fine fraction stream-sediments samples
    c. Coarse fraction/Tallus samples
    d. Chip channel sampling of selected outcrops
    e. Bulk sampling from selected outcrop if required

2. **Laboratory Studies**
    a. Chemical analysis
    b. Petrography study
    c. Pan-con mineralogical study
    d. Processing study if required

3. **Exploration data compilation**
    a. Preparation of geo-chemical exploration map / data layer
    b. Geo-statistics of the stream sediments data / sample analysis
    c. Exploration data compilation in integration with geology, known mineral occurrences and remote sensing data layers.
    d. Interpretation of stream sediment data (including geo-statistics of laboratory data/analysis of samples) with delineation of anomalous targets for precious metals

4. Preparation of interim and final reports

a. Hard copy reports
b. Soft copy reports along with data layer in GIS format

4. Mid yearly report regarding exploration field work in Dera Ismail Khan Division

The geochemical exploration field work was conducted during the months of April to September, 2014 in the D.I. Khan Division (i.e., D. I. Khna and Tank districts). This mid-year report was submitted to the DGMM on October 14, 2014 and the presentation was made before the evaluation committee. The committee appreciated the work done. In this Mid-yearly report the detailed work carried out in the D.I. Khan and Tank as per PC-11 Scheme of the DGMM was reported as follows:

1. Exploration field work

a. Collection of Panned heavy minerals concentrate, Stream-sediments
b. Fine fraction stream-sediments samples
c. Coarse fraction/Tallus samples
d. Chip channel sampling of selected outcrops
e. Bulk sampling from selected outcrop if required

2. Laboratory Studies

a. Chemical analysis
b. Petrography study
c. Pan-con mineralogical study
d. Processing study if required

3. Exploration data compilation

a. Preparation of geo-chemical exploration map / data layer
b. Geo-statistics of the stream sediments data / sample analysis

c. Exploration data compilation in integration with geology, known mineral occurrences and remote sensing data layers.
d. Interpretation of stream sediment data (including geo-statistics of laboratory data/analysis of samples) with delineation of anomalous targets for precious metals

4. Preparation of interim and final reports

a. Hard copy reports
b. Soft copy reports along with data layer in GIS format

5. Preparation of the final report

The preparation of final report is mainly based on the compilation of mineralogical and geochemical data obtained during the different phases in consolidated form. During this phase emphases are also given to the collection of Bulk samples from those areas wherefrom the anomalous values of gold were previously obtained during this project. The result obtained after treating the bulk samples have been copiled for their economic importance. During this phase the Remote sensing data of the project area was also evaluated to understand the extension of the lithological units and the correlation of the geochemical data was made. This final report is based on the work carried out in all central and southern districts of Khyber Pakhtunkhwa during the four phases (including the last phase) as per PC-II Scheme of the DGMM as follows:

1. Collection of bullk samples from selected points.
2. Preparation of Remote Sensing map and lithological correlation.
3. Preparation of final report and submission both in hard and soft form.

CHAPTER 1

INTRODUCTION

1.1. Background

The Directorate General of Mines and Minerals (DGMM), Mineral Department, Khyber Pakhtunkhwa province has awarded the consultancy work to the National Centre of Excellence in Geology (NCEG), University of Peshawar under the PC-II project for conducting Regional Geochemical survey for precious metals in the southern parts of Khyber Pakhtunkhwa. In this regard the NCEG has already submitted three quarterly reports to the DGMM in this regard. The first was the Preliminary Report regarding the orientation work for compilation of available information on geology and known minerals occurrences and the second was the Mid-Yearly report regarding exploration field work of stream sediment sampling of Peshawar and Mardan divisions as per TOR. The third report was the Mid-Yearly report regarding exploration field work of stream sediment sampling of Kohat and Bannu divisions (i.e., Districts of Kohat, Hangu, Karak, Bannu and Lakki Marwat). The fourth mid-year report was based on the studies carried out inD.I. Khandivision having districts of D.I. Khan and Tank. This report is the final report which has the compilation of previous data in consolidated form and some new geochemical, mineralogical and remote sensing data. All the analyses were carried out in the National Centre of Excellence in Geology, University of Peshawar involving sophisticated equipments of international standards.

It is worldwide accepted that the geochemical exploration is playing a vital role in locating mineral occurrences in any part of the world. Reconnaissance geochemical survey of an unknown area has significant utility for delineating areas of interest in a vast region within limited time. Therefore, the outcome of this final report will provide basic necessary information regarding the gold and other base metals concentrations and their source regions in the central and southern districts of Khyber Pakhtunkhwa. The purpose of this study was to locate target areas for mineral occurrences/placer Au in DI Khan and Tank divisions. It is hoped that the geochemical database, given in this report, and those already submitted, will provide the full geochemical and mineralogical details of the sediments (both Recent and

Quaternary) of the area of interest and will be helpful in strategizing the mineral exploration/mining activities in these areas accordingly.

1.2. Stream sediment composition as a major control

The chemical composition of stream sediments provides information on weathering and transport processes and also on the presence of mineral deposits as well as contaminants. Stream sediments represent the average composition of outcropping rocks upstream of a sampling point (Spadoni, 2006) and provide information on lithological composition of the drainage basin (Rantitsch, 2000). According to Spadoni (2006), the relationship of the stream sediment composition with bed rock depends largely on the physical and chemical processes operating in the catchment, and their nature is closely linked to a number of local processes, of natural and anthropogenic origin, that can significantly affect their composition. The input results from erosion/deposition processes according to local geomorphologic and hydrological features. The intensities of input sources are inhomogeneous due to variation in the catchments and can be localized in restricted areas (point sources). Geochemical data from a complex system involving stream sediments is affected by lithology, erosion, transport and accumulation. Different rock types have different rates of erosion and allow different levels of input of components into stream channels. An understanding of geochemical data from stream sediment samples, therefore, relies on knowledge of the types of rocks exposed to the stream. According to Day (1980), flow networks fluctuate along individual channel systems, particularly on neighboring catchments of contrasting lithology where similar rainfall, vegetation and slope occur. The author demonstrated this by comparing two drainage networks on different lithologies in S.E. Devon. The study showed that flow net variability could be explained in part by differences in rock type.

Another factor in determining the variation in stream sediment composition is local and regional variations in dispersion mechanisms (Butt and Nichol, 1979). The lithological composition of the catchment basin can be used as a factor which controls the dispersion of chemical constituents (Rantitsch, 2004). Variations in lithological compositions of the catchment area results in variability of geochemical signatures that can greatly alter the nature of significant stream sediment anomalies. As a consequence, uncertainties arise in establishing anomalous from background populations. General used criteria for distinguishing background and anomalous concentrations include histograms, probability graphs, Mean+2Standard Deviation and different percentile ranges. However, knowledge and experience of geochemist play an important role in order to establish difference between anomaly and background.

1.3. Heavy Mineral Placers

Placer deposits are formed by accumulation of heavy minerals with specific gravity more than 2.65 along the rivers and streams (Mudaliar et al., 2007). According to Gary et al. (1972) placer is defined as ‘‘a mineral deposit, formed by mechanical accretion of mineral particles from weathering fragments.’’ Exploration of placer deposits has got much attention because these deposits constitute 69% of world gold (Sutherland, 1985). Several of the world important mineral products have been obtained from placers, e.g. placer gold deposits in New Mexico (Johnson, 1972; North and Mclemore, 1988, McLemore, 1994), placer gold from Ghana, a major West African gold producing country (Komla and Sammy, 1995), placer gold from the Late Archean Witwatersrand sedimentary rocks in South Africa (Lalomov and Tabolitch, 1997), Klondike in Canada (McCracken et al., 2007) and the gold placers in Arizona (Wilson, 1961).

1.4. Project Narratives

1.4.1. Proposed Geochemical Work during the whole project

a. Collection of Panned heavy minerals concentrate, 200 samples

b. Fine fraction stream-sediments samples 1,200 samples

c. Coarse fraction/Tallus samples 200 samples

d. Chip channel sampling of selected outcrops 200 samples

1.4.2. Geochemical Exploration work for Mid-year Report, completed in Phase II

Mardan Division

a) Chemical analysis of stream sediments	272 samples
b) Chemical analysis of quaternary deposits	36 samples
c) Chemical analysis of pan con	92 samples
d) Chemical analysis of rock	16 samples
e) Petrographic study	16 samples
f) Pan-con mineralogical study	92 samples

Peshawar Division

a) Chemical analysis of stream sediments	393	samples
b) Chemical analysis of quaternary deposits	87	samples
c) Chemical analysis of pan con	98	samples
d) Chemical analysis of rock	66	samples
e) Petrographic study	18	samples
f) Pan-con mineralogical study	98	samples

1.4.3. Geochemical Exploration work for Mid-year Report, completed in Phase III

Kohat

Pan-concentrate samples:	30
Stream sediments (-80 mesh size):	99
Talus/Quaternary sediments:	10
Rock samples:	40
Total:	**179**

Karak

Pan-concentrate samples:	37
Stream sediments (-80 mesh size):	139
Tellus/Quaternary sediments:	10
Rock samples:	16
Total:	**202**

Bannu

Pan-concentrate samples:	12
Stream sediments (-80 mesh size):	38
Tellus/Quaternary sediments:	17
Rock samples:	0
Total:	**67**

Lakki Marwat

Pan-concentrate samples:	11
Stream sediments (-80 mesh size):	67
Tellus/Quaternary sediments:	36
Rock samples:	02
Total:	**116**

Hangu

Pan-concentrate samples:	08
Stream sediments (-80 mesh size):	50
Tellus/Quaternary sediments:	14
Rock samples:	08
Total:	**80**

1.4.4. Geochemical Exploration work for Mid-year Report, completed in Phase IV

D I Khan

Pan-concentrate samples:	28
Stream sediments (-80 mesh size):	208
Tellus/Quaternary sediments:	92
Rock samples:	07
Total:	**335**

Tank

Pan-concentrate samples:	23
Stream sediments (-80 mesh size):	57
Tellus/Quaternary sediments:	16
Rock samples:	00
Total:	**96**

1.4.5. Geochemical work completed in the last phase.

Collection of Bulk Sample (~130 kg) for Project

Total number of bulk samples collected 16

CHAPTER 2
METHODOLOGY

2.1 Field Methodology

The geological field work was conducted in the respective field areas (Peshawar Division, Kohat Division, D.I. Khan, of Khyber Pakhtunkhwa. The streams having catchment area up to 10 km were marked and samples were collected in the form of paned concentrates, stream sediments and quaternary/tallus samples. Two types of samples were collected from each site i.e., pan-concentrates (one original labeled A, and one duplicate C.) and stream sediments (one original labeled, B and one duplicate D). In the project areas in the Khyber Pakhtunkhwa, a total of 1578 samples were collected, which includes 245 pan-concentrate, 965 stream sediments, 249quaternary deposits, and 119 rock samples. Total number of bulk samples collected was sixteen (16). These samples were transported to the National Centre of Excellence in Geology, University of Peshawar for geochemical and mineralogical analyses.

2.1.1. Pan-concentrates

The Pan-concentrate samples from stream sediments were collected from potential sites.The locations of these collected samples were marked with hand held GPS. The locations of these collected samples were later marked on geological maps using Arc-GIS. A systematic technique was adopted to collect samples from the different streams of the respective divisions of Khyber Pakhtunkhwa. The samples were collected from the concave side of meander whereever available.Suitable points ranging from 3 to 6in number, were selected for collecting Pan-concentrate samples. A trap was selected away from scree/transported material of overburden/pollution. The ideal sample trap should represent all parts of the catchment basin equally so that mineralization anywhere in the basin would have an equal chance of being represented in the collected sample. The samples were collected from athree feet deep traps (Fig. 2.1.). Approximately 24 kg of material was passed through 7 mm sieve. The materials were paned upto 100-200 grams for sample A and the same process was repeated for a duplicate sample C.The final pan-con samples were studied in the field using a pocket microscope. Any gold grains,if found, were studied and recorded in a note book. The gold grains of size 0.3 mm were termed as color, while of size 0.3 mm to 0.5mm were classified as speck. Gold grains greater than 0.5mm are called a piece.

A bulk sample of ~ 130 Kg was collected in similar way as that of the pan-concentrate sample of up to 30 Kg during field. The bulk sample was transferred to the mineral processing laboratories of the NCE in Geology for further processing on the shaking table.

Fig. 2.1. Field Photographs A and B showing the samples collection for pan concentration.

2.1.2. Stream sediments

Stream sediments samples of 5kg were taken from the dry surface of each location. These collected samples were then dried in the open and were then passed through 80# size sieve. One fifty grams of the materials which passed through 80# size sieve were saved in the sample bags and the remaining part was discorded.

2.2 Laboratory Methodology

The collected samples including pan-concentrate, stream sediments, quaternary deposits and rock samples were processed in the petrographic lab, geochemistry lab, rock cutting and polishing lab, crushing lab and mineral processing lab of the NCEG (Fig.2.2.). Thin sections were prepared from the rock samples in the rock cutting and polishing and studied under polarized microscope in the petrographic lab. Detail methodology followed for pan-concentrates and stream sediments is mentioned below.

Fig. 2.2. Rock cutting and polishing lab of the NCEG.

2.2.1. Pan-concentrate

The pan-concentrate samples collected from the field were analyzed in the petrographic lab of the NCEG and the equipment's used for the detailed study of these heavy minerals are given below.

a) Magnetic separation

The heavy mineral concentrates obtained through panning during field were treated with the magnetic separator for separating the Fe-bearing phases from the silicates.

b) Heavy minerals separation

The concentrates obtained through panning were treated with heavy liquid (i.e., bromoform) to separate the heavy minerals for subsequent identification.

c) Heavy minerals identification

The heavy minerals e.g., zircon, garnet, tourmaline, apatite etc. were identified with the help of stereoscopic microscope.

d) Heavy minerals geochemical analysis

After taking detailed mineralogical study of the heavy mineral pan-concentrate samples they were further pan to approximately 20g and then this sample was used for the preparation of gold solution for finding the concentration of gold in these heavy pan-concentrate.

2.2.2. Scanning electron microscope (SEM)

The gold grains collected after panning from the heavy mineral pan-concentrates were studied under scanning electron microscope and morphological features of gold grains were identified.

Fig. 2.3. (A): Photograph showing stereoscopic microscope used for heavy minerals mineralogical study, (B): Photograph showing polarized microscope used for petrographic studies of the rock samples.

2.2.3. Stream sediments

The stream sediments collected in the field were passed through -80# sieve size for further analysis. From the -80# sieve size representative 20g sample for gold and one gram sample for trace elements were taken through quartering and conning technique. The same procedure was followed for taking sample from the quaternary deposits to be used for geochemical analysis.

2.2.4. Bulk samples

Bulk sample (~ 130 Kg) collected in the field was treated on the shacking table to collect the final panned sample of about 200 g containing heavy minerals and gold grains. The sample was further treated on magnetic separator for separation of magnetic minerals.

2.3 Rock samples

2.3.1. Crushing and powdering

Representative portion of rock sample after preparation of thin sections were crushed in the jaw crusher in the crushing and powdering lab of the National Centre of Exellence in Geology. Each rock sample was crushed to a smaller size. This portion was then pulverized to -200 mesh sizes by the tungsten carbide ball mill and 20g sample was taken for gold solution preparation while one gram was taken for base metals solution preparation to be run on atomic absorption.

2.3.2. Thin section preparation

The rock samples collected from the potential sites within the study area were taken to the rock cutting and polishing lab of NCEG. The petrographic analysis was carry out at petrographic lab.

Fig. 2.4. (A): Photograph showing tungsten carbide ball mill used for powdering of rock sample, (B): photograph showing automatic jaw crusher used for crushing of the rock samples at the crushing lab of NCEG.

2.4. Preparation of stock solution for geochemical analyses

a) Preparation of stock solution for gold

All the samples collected from the field were analyzed for finding the concentration of gold. For the preparation of gold stock solution, 20g of sample was taken in 100ml graduated pyrex beaker, 50ml aqua regia (HNO_3: 3HCl) was added to it and the beaker was cover with watch glass. After the addition of aqua regia it was heated on hot plate for 30 minutes at low heat and stirred after each ten minutes. After 30 minutes the beaker was removed from the hot plate and cooled for a while. Then distilled water was added into the beaker. After the addition of distilled water, the solution was then again heated until the required solution in the beaker reduced to 50ml and then it was filtered through Whatman 42 filter paper in the test tube. During filtration the pyrex beaker was washed with 6N HCl several times. The final solution was made to 50ml with distilled water. This solution was taken into separatory funnel and 50ml of distilled water was added to it and the separatory funnel was shaken for a while to mix the contents. Then 20ml Methyle Isobutyle Ketone (MIBK) was added to the funnel and then it was shaken for 10 minutes on automatic flask shaker. The lower layer was removed while the MIBK layer was retained in the funnel. 20ml of 2N HCl was added and again shaken for 10 minutes and again the lower layer was removed. The MIBK layer now contains the extracted gold. The MIBK was stored in the air tight brown color glass bottles until analyzed for gold. All the chemicals, acids and reagents used during the analytical process were of analytical grade.

b) Stock solution for base metals

For the preparation of stock solution for base metals one gram sample was taken in Teflon beaker and 20ml aqua regia was added in the beaker and heated until dried. 20ml of 2N HCl was then added and heated it for few minutes. After that the required solution was diluted to 50ml with distilled water and filtered through Whatmen No. 42 filter in a test tube All the samples along with the reference standards treated with the same method for the determination of Ag, Cu, Pb, Zn, Ni, Cr, Co, Cd and Mn.

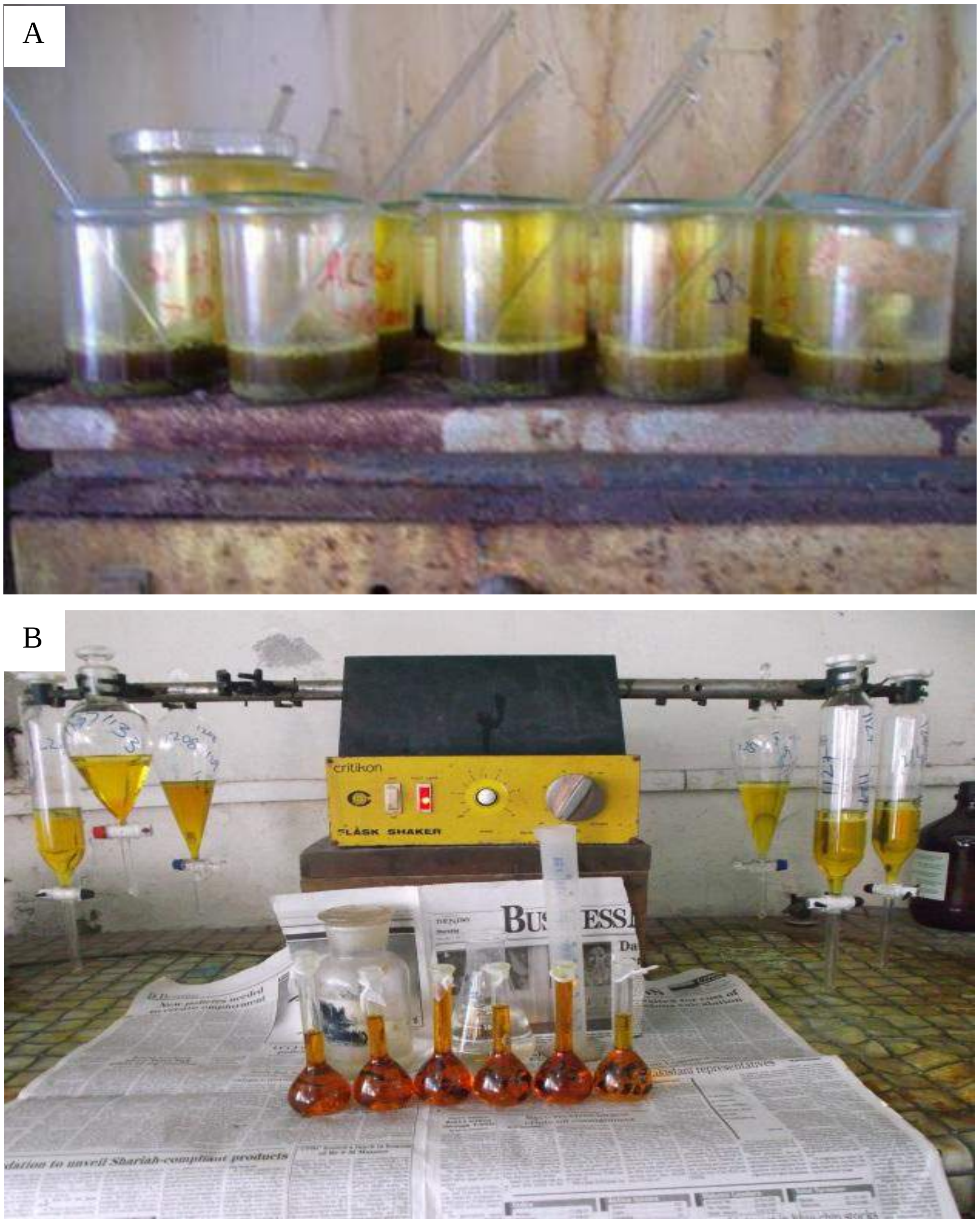


Fig. 2.5. Photographs showing preparation of stock solution for gold A: samples in pyrex beaker having aqua regia for gold digestion lying on hot plate, B: flask shaker used for the separation of gold through MIBK.

2.5 Instrumental analysis

All the stock solutions were analyzed for Au and Ag and base metals such as Cu, Pb, Zn, Ni, Cr, Co and Cd using Perking Elmer graphite furnace atomic absorption spectrometer (AAS) modal AAS-PEA 700 under the standard operating condition. The instrumental conditions and analytical analysis of each element are described below. The stock solutions prepared for gold and base metals were analyzed by using Perking Elmer graphite furnace atomic absorption spectrometer (AAS) modal AAS-PEA 700 under. The analytical analysis and instrumental conditions of each element are described below.

Fig. 2.6. Atomic absorption spectrometer (AAS) modal AAS-PEA 700.

i) Instrumental conditions

Determination of gold (Au)

Mode	Absorption
Wavelength	242.7nm
Energy	14
Current	10mA
Slit width	0.2nm

Reagent solution:

1000ppm of standard stock solution was prepared by dissolving 1g of gold in aqua regia and was transferred to 1L volumetric flask. The volume was made to the mark with distilled water. From this stock solution working standards of 2.5, 5 and 10ppm were prepared in the 20 ml volume of Methyle Isobutyle Ketone by the method as described earlier for the extraction of gold. The instrument was calibrated with these working standard solutions. The standards prepared were run on the atomic absorption as unknown. After the instrument calibration and attaining of above mentioned condition for finding Au concentration, the certified standards were run. Once the values of the certified standards were within the confidence level the samples were run through atomic absorption and the concentration of Au in each sample was recorded in ppm.

ii) Determination of silver (Ag)

Mode	Absorption
Wavelength	328.1nm
Lamp Energy	52
Lampe Current	10mA
Slit width	0.2nm
Air flow	17L/min

Reagent solution:

1000ppm of Standard stock solution was prepared by dissolving 0.787 g of $AgNO_3$ in 50ml of distilled water and diluted to one liter with 1% (V/V) HNO_3. Standard solution of 2.5, 5 and 10ppm were prepared from the standard stock solution. The atomic absorption was calibrated with the working standards under the above mentioned instrumental conditions. After making sure that the instrument is properly calibrated and the Ag values of the working standards matched the actual concentration, the sample solutions were then run through the AA and the concentration of Ag was noted in each sample.

iii) Determination of copper (Cu)

Mode	**Absorption**
Lamp Wavelength	324.8nm
Lamp Energy	56
Lamp Current	15mA
Slit width	0.2nm

Reagent solution:

1.0 g of copper metal in (1:1) HNO_3 was dissolved to prepare the stock solution of 1000 ppm and was diluted to 1litre with 1% (V/V) HNO_3 in a volumetric flask. The working standards of 2.5 ppm, 5 ppm and 10 ppm were made from standard stock solution of 1000 ppm.

The working standards were run for the verification of the standardization of the instrument. The diluted and certified rock standard solutions were then run to compare the results with certified values for accuracy of the method. According to the above mentioned conditions, instrument was set, calibrated with working standards and concentration of the Cu in each stock solution was determined in ppm.

iv) Determination of lead (Pb)

Mode	Absorption
Wavelength	283.3nm
Lamp Energy	35
Lamp Current	10mA
Slit width	0.2nm

Reagent solution:

For the preparation of standard stock solution for Pb, 1.598 g of lead nitrate in 1% (V/V) HNO_3 were used to prepare the solution of 1000 ppm and diluted to 1 % (V/V) HNO_3. The flame mode of atomic absorption spectrometer calibrated with the working standards of 2.5, 5 and 10ppm prepared from the standard solution of 1000ppm were used for finding the concentration of lead in the collected stream sediments, pan-concentrate and rock samples. The instrument was calibrated with the working standards and after attaining the above mentioned energy conditions the samples were run for finding the concentration of lead in the collected samples.

v) Determination of Zinc (Zn)

Mode	Absorption
Wavelength	213.9nm
Lamp Energy	22
Lamp Current	15mA
Slit width	0.2nm

Reagent solution:

A standard stock solution of 1000 ppm was prepared by dissolving 1.0g of zinc metal in 20 ml of HCl (1:1) and was diluted to 1 litre with distilled water. Working standards such as 2.5, 5 and 10ppm were prepared from the standard stock solution of 1000ppm. The working standards were run initially as unknown on atomic absorption to calibrate the instrument before running the actual samples for finding the concentration of zinc in the collected rock samples.

vi) Determination of Nickel (Ni)

Mode	**Absorption**
Wave length	232.0nm
Lamp Energy	31
Lamp Current	25mA
Slit width	0.2nm

Reagent solution:

For the preparation of standard stock solution for Ni, 1.0 g of nickel oxide in 10% (v/v) HCLwas dissolved to prepare 1000 ppm and was diluted to 1 liter with distilled waterin a volumetric flask. From this standard stock solution, working standards of 2.5, 5 and 10ppm were prepared to be run on atomic absorption to calibrate the instrument. After calibration of the instrument and attaining the above mentioned condition the collected rock samples were run on AAS to find out the concentration of nickel.

vii) Determination of Chromium (Cr)

Mode	**Absorption**
Wave length	357.9nm
Lamp Energy	76
Lampe Current	25mA
Slit width	0.7nm

Reagent solution:

For the preparation of standard stock solution of chromium, 3.735g of potassium chromate (K_2CrO_4) in distilled water was dissolved to prepare 1000 ppm solution and was diluted to 1 litre with distilled waterin a volumetric flask. From this standard stock solution working standards including 2.5, 5 and 10ppm were prepared and run on atomic absorption as unknown. After instrument calibration with the working standards and attaining the above mentioned energy conditions the stock solution prepared for trace elements was run to find out the concentration of Cr.

viii) Determination of Cobalt (Co)

Mode	**Absorption**
Wavelength	240.7nm
Lamp Energy	35
Lamp Current	30mA
Slit width	0.2nm

Reagent solution:

Standard stock solution of 1000ppm was prepared by dissolving 1g of cobalt metal in a minimum volume of (1+1) HCl and diluted to 1L with 1% (V/V) HCl. From this stock solution, working standard of 2.5, 5 and 10ppm were prepared and run on the atomic absorption as unknown. The instrument was calibrated with the working standards and after attaining the above mentioned conditions, the samples were aspired through AA one by one for the determination of cobalt concentration in ppm. Further calculations were done for the determination of total Co contents in the rock.

ix) Determination of Cadmium (Cd)

Mode	**Absorption**
Wavelength	228.8nm
Lamp Energy	36
Lamp Current	4mA
Slit width	0.7nm

Reagent solution:

Standard stock solution of 1000ppm for Cd was prepared by dissolving 1g of cadmium metal in minimum volume of HCl and diluted with 1% HCl was made to the volume with distilled water. Working standards of 2.5, 5 and 10ppm were prepared from standard stock solution and the instrument was calibrated with the above given conditions by using the working standards. After calibration this working standards were run through AA as unknown. Once the working standard values were found similar to the actual concentration of the standards for Cd, the sample solutions were then aspirated in the flame of AA and the concentration of Cd was recorded in each sample. Further calculations for the total Cd contents in the rock were done.

x) Determination of Manganese (Mn)

Mode	**Absorption**
Wavelength	279.5nm
Lamp Energy	34
Lamp Current	20 mA
Slit width	0.2nm

Reagent solution:

A standard stock solution of 1000 ppm was prepared by dissolving 4.054 g of $MnSO_4.4H_2O$ in distilled water in a volumetric flask and was diluted to one liter. From this standard stock solution working standards 2.5, 5 and 10ppm were prepared and run on atomic absorption as unknown. After calibration of the instrument with the working standards and attaining the above mentioned energy condition the samples were run on atomic absorption to find out the concentration of Mn.

CHAPTER 3

GEOLOGY AND REGIONAL SETTING

3.1 Geodynamic Setting

The Pakistani basins have acquired their primary structural and stratigraphic features from events associated with plate movements that occurred from Late Paleozoic to the Present. From Permian through Middle Jurrasic time, the Indo-Pakistani Plate was located in the Southern Hemisphere between the African, Antarctic and Australian Plates and comprised part of Southern Gondwana(Gansser, 1964).

Due to northward plate movement during Late Cretaceous, the Indian Plate has been drawn downwards and thrusted below the Eurasian Plate. This long process led the marine sediments being compressed, crumpled and then squeezed up into a mountain chain, now known as Himalayas. Even today, uplift of the Himalayas and subduction of the Indo-Pakistani Plate continues with associated crustal shortening as much as 55 km (Jaswal et al., 1997). The shrinkage and continental drift was facilitated by the consumption of Neo-Tethys. During the closure of Neo-Tethys Ocean, intraoceanic subduction generated a series of peculiar curved mountain ranges, namely Kohistan-Laddakh, Nuristan and Kandhar (Searle, 1991; Treloar and Izatt, 1993).

Following the final closure of back-arc basin, the Kohistan-Laddakh arc was accreted onto the Eurasian plate, forming an Andean type continental margin. The collisional boundary is referred to as the Main Karakorum Thrust (MKT) where the collisional event began at 50-55 Ma (Powell, 1979; Patriat and Achache, 1984). The fact that Indo-Pakistani subcontinent was rapidly drifting at 15 cm/yr northwards relative to Australia and Antarctica about 80 Ma ago also supports this collisional time. The subduction of Neo-Tethys beneath Kohistan-Laddakh Arc is still continued and resulted in the complete consumption of the leading edge of the Indian Plate that finally collided with the remains of Kohistan-Laddakh Arc (Powell, 1979).

Complete closure of Neo-Tethys in Eocene resulted in the collision between Indian Plate and Kohistan-Laddakh Arc, marked by Main Mantle Thrust (MMT) (Powell, 1979). The southward migration of Himalayan deformation from the site of MMT is represented by the Main Boundary Thrust (MBT). These collisional zones are marked by the extensive emplacement of ophiolites along Indus Tsangpo suture zone, Waziristan, Zhob Valley and Lasbela areas (Gansser, 1964; Le fort, 1975).

3.2. Major Tectonic Features of Pakistani Himalayas

There are five subdivisions of Pakistani Himalaya into tectonostratigraphic terrains, delineated by regional fault boundaries (Fig. 3.1). These subdivisions are as under.

3.2.1. Main Karakoram Thrust (MKT)

The Main Karakoram Thrust was formed due to the collision of Karakoram block and Kohistan Island Arc (KIA) (Tahirkheli, 1979, 1982, 1983). It is named as northern suture zone (Pudsey et al., 1986) and was formed during late Cretaceous (Coward et al. 1986). The Karakoram plate to the north of MKT is composed of high grade metamorphic rocks with granitic intrusions (Searle, 1991) whereas metamorphosed basic and ultra-basic rocks of KIA are exposed to the south of it, (Bard et al., 1980; Bard, 1983). This zone is in use by rocks of chalt ophiolitic melange composed of andesite, basalt, serpentinites, ophi-calcite and rare peridotite (Bender and Raza 1995). The ocean between KIA and Karakoram plate was shut down in the Late Cretaceous (between 102 and 75 million years) at the side of the MKT (Coward et al., 1986).

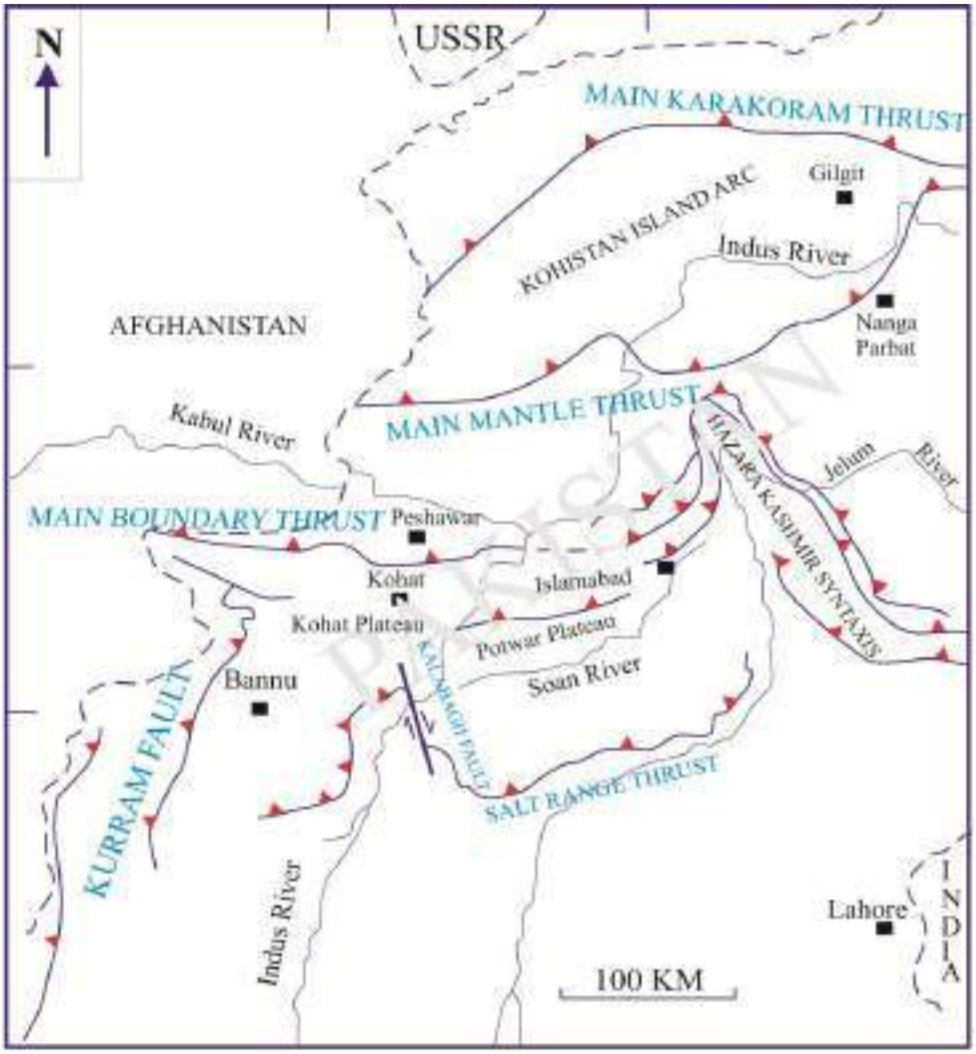


Fig. 3.1. Regional sketch map of north Pakistan showing major tectonomorphic terrains (after Kazmi and Rana, 1982).

3.2.2. Kohistan Island Arc (KIA)

The KIA was developed due to the subduction of northern Tethys under Asian plate during late jurrassic to Cretaceous (Searle et al., 1987). It also includes a complex of amphibolites, calc-alkaline intrusions, mafic, ultramafic, volcanics and volcano-sedimentary rocks about 40 km thick. It is supposed that this complex formed during the Mesozoic and was obducted onto the Indo-Pakistan plate during the late cretaceous (Bard et al., 1980). The Indus Tsongo suture zone is the major boundary separating Precambrian Indian plate from the younger Mesozoic-Cenozoic

Trans-Himalaya to the north. The suture, which is sharply dipping thrust zone, contains tethyan ophiolites, blue schists and granulites (Kearey and Vine, 1996).

3.2.3. Main Mantle Thrust (MMT)

Due to the underplating of Indian plate under KIA,the Main Mantle Thrust was formed. (Tahirkheli, 1979, 1982; Gansser, 1980). Main Mantle Thrust in Pakistan is composed of different rock units including blue schist, ophiolites, green schist, meta-sediments and meta volcanics (Tahirkheli and Jan, 1979, 1982; Kazmi et al., 1984).

3.2.4. Main Boundary Thrust (MBT)

The Main Boundary Thrust (MBT) is a regional fault which extends westward from the front of the Main Himalayas Ranges around the Hazara-Kashmir Syntaxial bend, and thrust the rock of the Lesser Himalayas towards south over the Neogene Siwalik molasses sub-Himalayan sequence along the MBT Zone. The Main Boundary Thrust (MBT) as an east west trending major linement extending from the Kohat in the West to Bengal in the east (McDougall and Hussain, 1991). The quantity of the uplift is inconsistent along its extension. The Main Boundary Thrust (MBT) is mapped to the south and southwest from Hazara as the Murree Fault and westward as the Main Boundary Thrust (MBT) along the southern edges the Kala Chitta Ranges (Burbank, 1983; Yeats and Hussain, 1984). Movement from the MCT been shifted to MBT before 10 million years (Le Fort, 1989). The MBT zone characterized by primary major thrusts both imbricate and duplex type and out of the Syncline faulting (Khan et al., 1990).

Focal mechanism solutions suggest that the fault plane dips northward at a shallow angle (Kearey and Vine, 1996). The lower Himalayas contribute the mountains of Azad Kashmir, east of Hazara-Kashmir Syntaxes (HKS), and those of Hazara, Peshawar, Malakand, Dir and Mohmand (Bender and Raza, 1995).

3.2.5. Salt Range Thrust (SRT) and Trans Indus Ranges Thrust (TIRT)

Salt Range Thrust (SRT) is located towards the south of MBT (Nakata, 1989; Gee, 1945, 1989; Yeats et al., 1984). There is a speedy thrusting of sub Himalaya at about 0.5 to 4 mm per year. They are therefore experiencing speedy erosion with the deposition of thick terrigenous sequence in the Sub-Himalaya (Kearey and Vine, 1996). This thrust is principally covered by alluvium and fanglomerates (Kazmi and Jan, 1997), however at places the thrust is exposed and shows the Paleozoic rocks overly the Neogene or Quaternary deposits of the Jhelum plain (Gee, 1945, 1989, Yeats et al., 1984).

The lithological map of the project area composed of the central districts (Peshawar, Charsadda, Mardan, Swabi and Nowshehra) and southern districts (Kohat, Karak, Hungu, Bannu, Lakki-Marwat, Tank and D.I.Khan) is given in figure 3.3.1. The detail tectonics and occurrences of these lithologies are discussed below.

3.3. Geology and Major Rivers

3.3.1. Peshawar Basin and regional tectonic

The Peshawar basin is located in the Lesser Himalayas within longitude 71°15́ and 72°45́ E and latitude 33°45́ and 34°30́ N. The major cities in Peshawar basin are Peshawar, Swabi, Nowshera, Charsada and Mardan. It is an Intermontain basin which mainly containsthe rocks of Quaternary age ranging from Pleistocene to Recent, located in the Himalayas. It is bordered by Swat in NE, Khyber Mountain Ranges to the West and the Northwest. To the south it is surrounded by Attock-Cherat Ranges and Indus River to the south eastern side (Moores and Fairbridge, 1997; Shah et al., 2007). There is metamorphic terrain to the north and sedimentary fold belt to the south of Peshawar basin. The Gandghar Range lies to the east of Peshawar basin (Hussain et al., 1991).

The sediments of Peshawar basin include lacustrine and fluvial sediments between the age range of 2.8-0.6 Ma (proved by the paleomagnetic and fission track data) (Burbank, 1982; Burbank and Tahirkheli, 1985). In addition it also contains catastrophic flood deposits, loess and alluvial fan deposits (Khan and Ahmed, 1987). Burbank (1982) recognized around 40 catastrophic inundates which flooded the basin in the prehistoric time. It includes the unlithified sediments like silts, fluvial sand and gravel (Hussain and Pogue, 1991). Peshawar basin came into existence in Plio-Pleistocene age, when more than 300m sediments were deposited by the uplifting of Attock-Cherat Ranges due to Attock thrust and the displacement of MBT

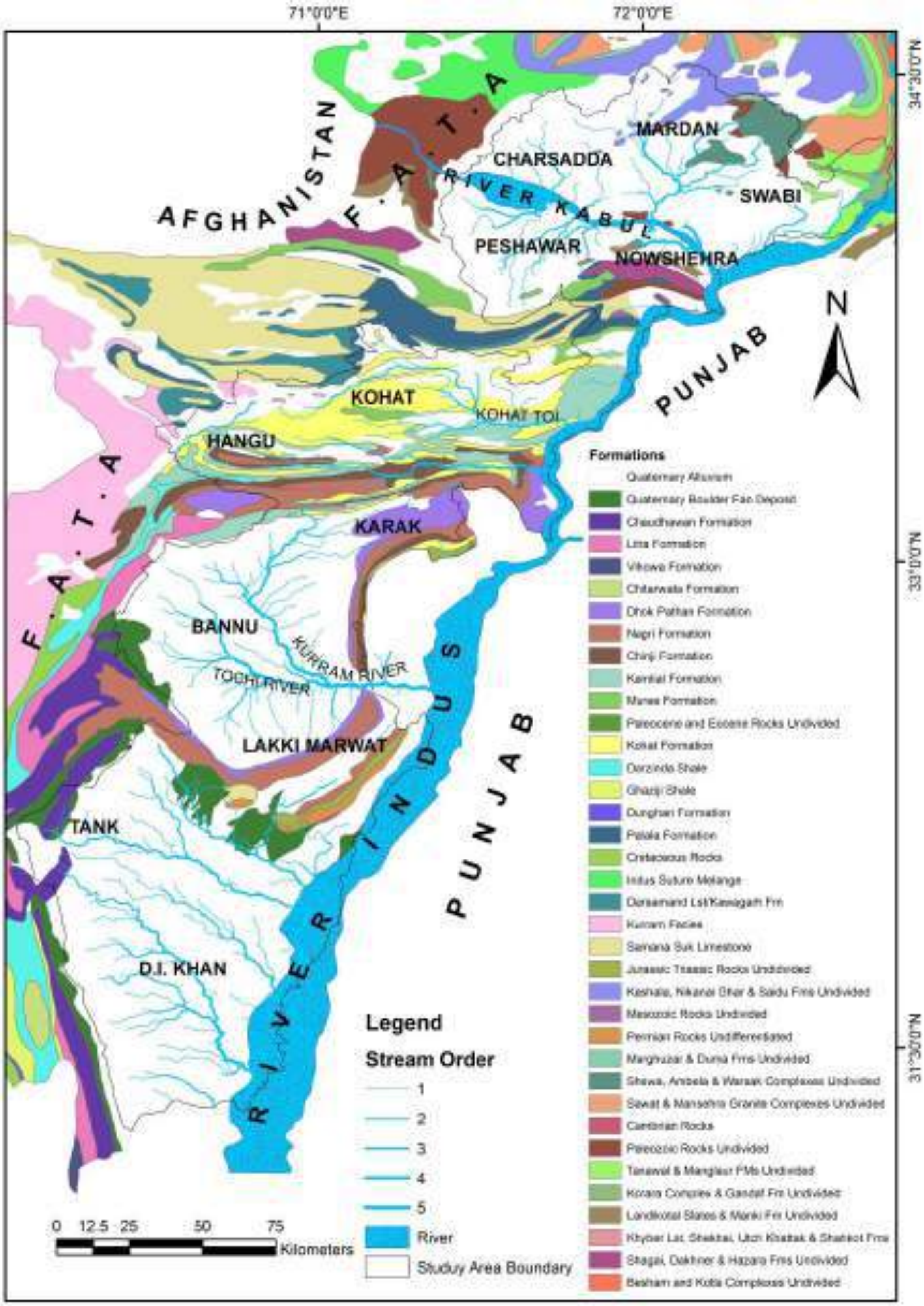


Figure 3.3.1. Lithological map of the project area (After Aslam et al., 2006).

(Burbank and Raynolds, 1984; Burbank and Tahirkheli, 1985). The rate of sedimentation at that time was about 15cm ka-1 (Burbank and Tahirkheli, 1985). According to Burbank (1982) the sedimentation was stopped about 600,000 years ago but the sedimentation is still continued in the main river channels and streams. Attock-Cherat Ranges is divided into Northern, Central and Southern blocks which are bounded by the thrust faults for the convenience of description of the stratigraphy. In the northern part, it includes Manki formation, Shahkot formation, Uch Khattak formation, and Shekhai formation where as the central part includes Dakhner formation. Darwaza formation, Hissartang formation and Inzari formation form the southern part (Hussain and Yeats, 1989).

The Cambrian to Jurrasic stratigraphic succession of rocks is exposed in Peshawar basin resting on the Precambrian basement rocks. Peshawar basin comprises of the following stratigraphic succession i.e. Nowshera Reef Complex and the Paleozoic sequence of Swabi area (Moores and Fairbridge, 1997). Paleozoic rocks are exposed in the small outcrops and limited areas and surrounds the Peshawar basin. The Cambrian and Precambrian rock sequence of Peshawar basin unconformably overlies the Ambar Formation. The Precambrian Attock slatelies to the south of Peshawar basin. (Coulson, 1936). Tiechert and Stauffer (1965) discovered for the first time the Silurian-Devonian reef rocks in Nowshera area. They also confirmed for the first time the presence of Paleozoic rocks in the southern part of Peshawar basin. These Paleozoic rocks were assigned as Late Silurian to Early Devonian age on the basis of conodont zonation (Barnett et al., 1966). Prior to the work of Pogue and Hussain (1986) the southern Peshawar basin rocks were assigned the age Late Silurian to Early Devonian (Barnett et al., 1966). Paleozoic sequence of Peshawar basin extends towards northwest in the Khyber Ranges, and towards northeast in Swat and Hazara Ranges. Martin and others (1962) subdivided the northeastern rocks into Swabi-Chamla Sedimentary Group and Lower Swat Buner Schistose Group.

Geochemical exploration program during this phase was carried out in the central districts (Swabi, Mardan, Charsada, Nowshera and Peshawar) covering major part of the Peshawar Basin. Indus River and Kabul River are the major rivers in the study area. These two reivers are the main source of deposition of the sediments in this basin. The east to west flowing Kabul river drains the basin and joins the Indus river eastward (Tariq, 2001). The Kabul river initiates from Chitral in Pakistan, move towards Afghanistan and enters into Pakistan again. It flows through Warsak and Nowshera (Pakistan) and join the Indus River at Kherabad. These river are the major agents of sediments transportation. The sediments are mainly sands, gravels, cobbles, sand and silt transported over a greater distance.

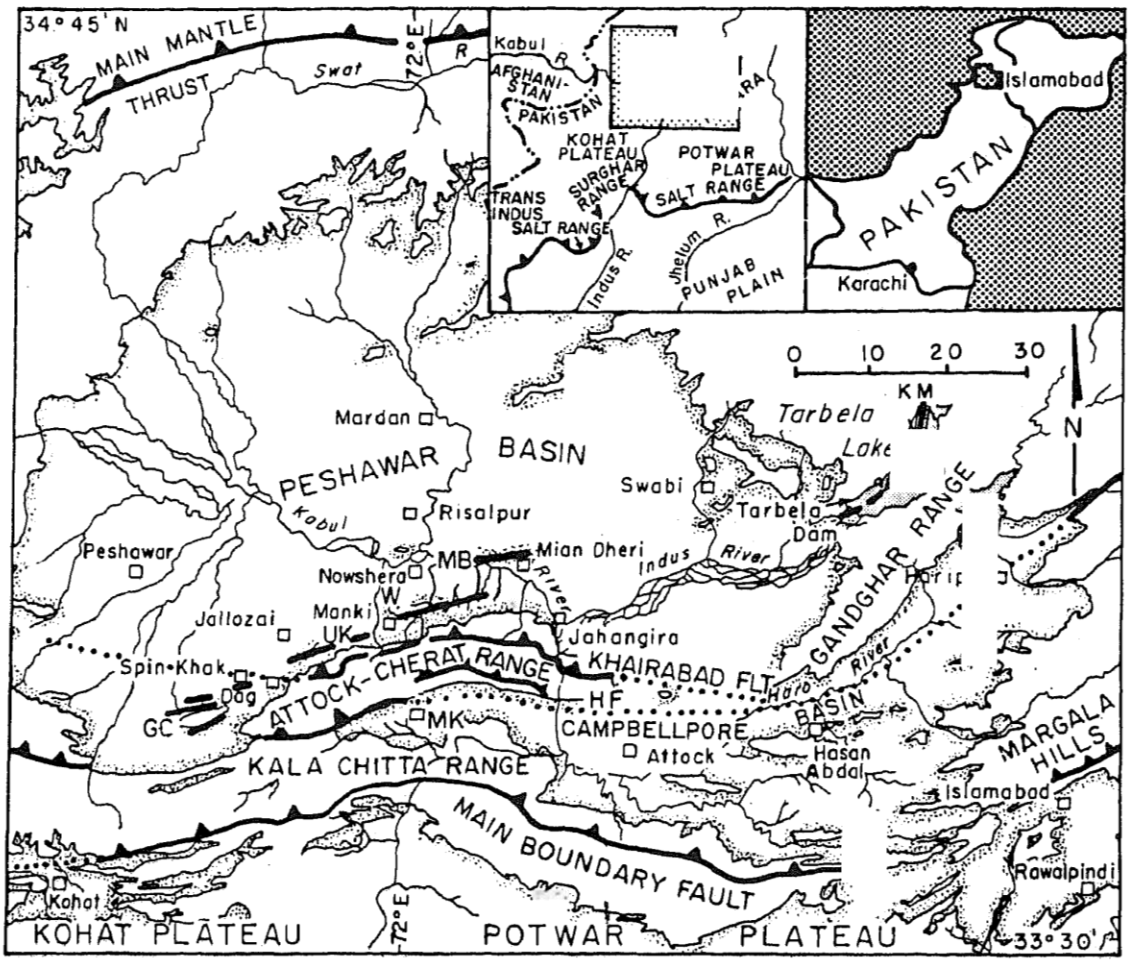


Fig. 3.3.2. General Geology of Peshawar basin and adjoining areas.

3.3.2. Geology and regional tectonics of the kohat plateau-bannu basin and surroundings

The Kohat Plateau-Bannu Basin (together termed here as the Kohat-Bannu Tectonic Block; KBTB) represent the Sub-Himalaya in the Khyber-Pakhtunkhwa (Fig. 3.3.2). This tectonic block is bounded by the Main Boundary Thrust (MBT) in the north, that defines a major mountain front against the Kala Chitta-Kotal-Samana Hill Ranges (Pivnik and Sercombe, 1993). To the east, the KTBT is geographically demarcated by the Indus River, though geologically it is considered continuous with the Potwar Plateau east of the Indus River (Kazmi and Jan, 1997). To the west, the KTBT is bounded by the NE-SW oriented Kurram-Wazirstan tectonic belt, the two are separated from each other by the NE-SW directed Kurram fault, which is also termed as the Melange Boundary Zone by Beck et al., 1995; 1996. The Surghar Range defines the southern boundary of the Kohat Plateau, though no identified fault defines this boundary. The Kohat district covers both the southern part of the Kohat Plateau as well as the Surghar Range. The southern political boundary of the Kohat district is defined by the highest ridgeline (drainage divide) of the Surghar Range. The Bannu Basin is SW continuation of the Kohat plateau in the hanging wall of the Bhittani-Marwat-Shinghar ranges. The Quaternary deposits in the Bannu Basin deposited by the Kurram River and its tributaries mostly cover the bedrock lithologies therefore the demarcation between the Bannu Basin and the Kohat Plateau is not possible. The exposed faults separating the Kohat Plateau and the Bannu Basin include Karak Thrust in the east and its splay termed Surdag-Latambar-Basiakhel Thrust in the west (Sajjad, 2003).

The KTBT is politically divided into five districts; Kohat, Hangu, Karak, Bannu and Lakki Marwat. The Kohat district occupies the north-eastern part of the Kohat plateau and is bounded in the north by the Orakzai Agency and Dara Adamkhel (FR Kohat) that occupy the Hill Ranges west of the Indus River including Kotal and Samana Ranges. A small portion of the Kohat District also occupies a part of the Hill Ranges exposed at the western bank of the Indus River in the Nizampur area, where the Kohat District is in direct contact with the Nowshera District. The Hangu District occupies the northwestern extremities of the Kohat Plateau and includes southern fringes of the Samana Hill Range. The Karak District consists of south-eastern parts of the Kohat Plateau as well as the northern flanks of the Shinghar and Surghar ranges. The Bannu and Lakki Marwat districts occupy the south-western part of the KTBT bounded by Shinghar-Surghar ranges to the east, Marwat Ranges to the southeast, and Bhittani ranges in the southwest. The Kurram Fault roughly coincides with the political boundary between the Bannu-Lakki Marwat districts and the Waziristan ranges.

Based on the geographic distribution of the five districts Kohat, Hangu, Karak, Bannu and Lakki Marwat, which were subject of the report in Phase, 2. The regional geology of the Kohat Plateau in four subdivisions: Hill Ranges, Kuram-Waziristan Ranges, Trans Indus Ranges and the Kohat Plateau. Although the Hill Ranges and the Kurram-Waziristan Ranges.

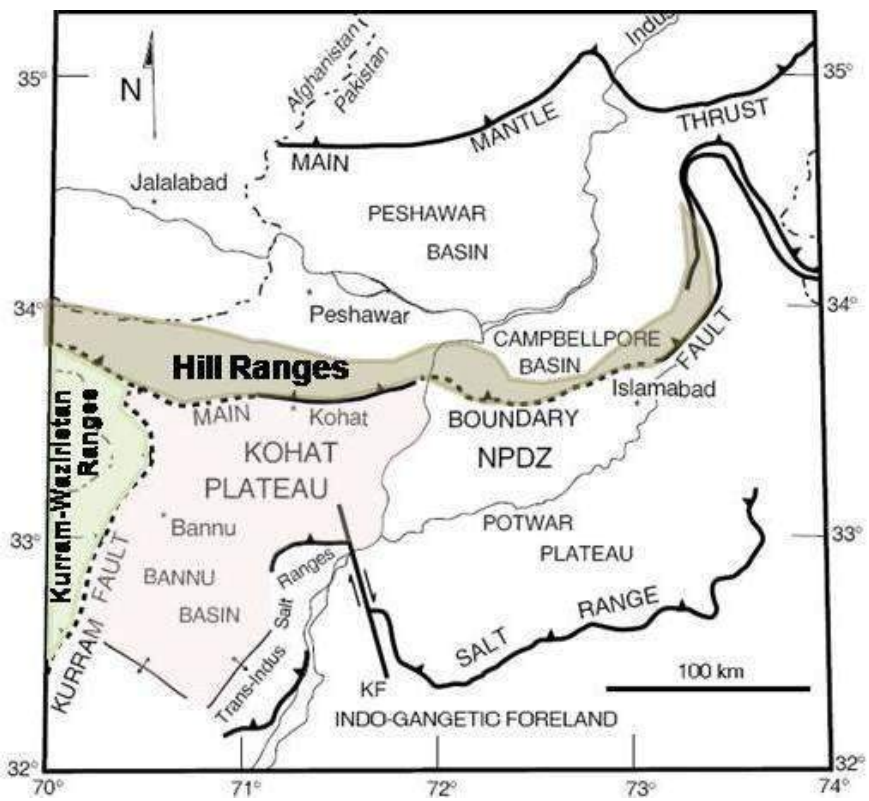


Fig. 3.3.3. Tectonic map of Northern Pakistan showing tectonic position of the Kohat Plateau-Bannu Basin Tectonic Block (KBTB) with respect to major tectonic features of the Northwest Himalaya

3.3.4. Geology and tectonics of the D. I. Khan region

The Bannu and Dera Ismail Khan quadrangles cover an area of more than 8,600 square miles in north-central Pakistan, between latitude 31" and 33"N and longitude 70" and 71E. This area contains two main physiographic units: the alluvial lowlands, which include the structurally undisturbed Indus and Bannu plains, and the folded belt, which includes the Khisor, Marwat, Bhittanni, and Sulaiman Ranges, as well as the highlands of Waziristan. These ranges and highlands form a nearly continuous mountain system between the Salt Range-Pothwar Plateau region to the northeast and Baluchistan to the southwest. Total stratigraphic thickness exceeds 14,000 feet in the Khisor and Marwat Ranges. Sedimentary rocks of the following age are present: Cambrian (?), Permian, Triassic, Jurassic, Cretaceous, middle and late Tertiary, and Quaternary. Lower Tertiary rocks are not present. The stratigraphic thickness in the Sulaiman Range-Waziristan area exceeds 38,000 feet. Sedimentary rocks of Jurassic, Cretaceous, Tertiary, and Quaternary age are present.

3.3.4.1.Khisor-Bhittanni-Marwat Range

The Khisor-Marwat Ranges surrounds the Bannu and takes a sharp turn at Shaikh Budin-Pezu, and extends NW as Bhittani Range, that joins the Suleiman Ranges north of Jandola. Like the Marwat Ranges, Bhittani Ranges are also dominantly comprised of Tertiary rocks.

The Marwat Range is an anticlinal feature largely covered by the Siwalik Group rocks. The Khisor Range, that lies south of the Marwat Range, exposes the non-outcropping Cambrian to Triassic rocks underneath the Bannu Basin. The Marwat-Khisor ranges are characterized by east west to east-northeast structural trends. The structural style of the range includes parallel to enechelon fold trends detached at the base of Jhelum Group rocks of Cambrian age (Alam et al., 2005). The Cambrian to Pliocene-Pleistocene rocks of the Khisor Range are thrusted southwards over the Punjab Foreland along the Khisor thrust that is probably the western extension of the Salt Range Thrust (Gee, 1980). Cambrian to Triassic age shallow marine lithologies predominantly underlies the Khisor Range that is unconformably overlain by the Pliocene-Pleistocene Siwalik Group rocks (Fig. 3.3.4). The exposed stratigraphic sequence of the Khisor Range is broadly correlative with that of the Western Salt Range with the exception that the Rawalpindi Group rocks (Miocene) are missing in the Khisor Range (Alam et al., 2005).

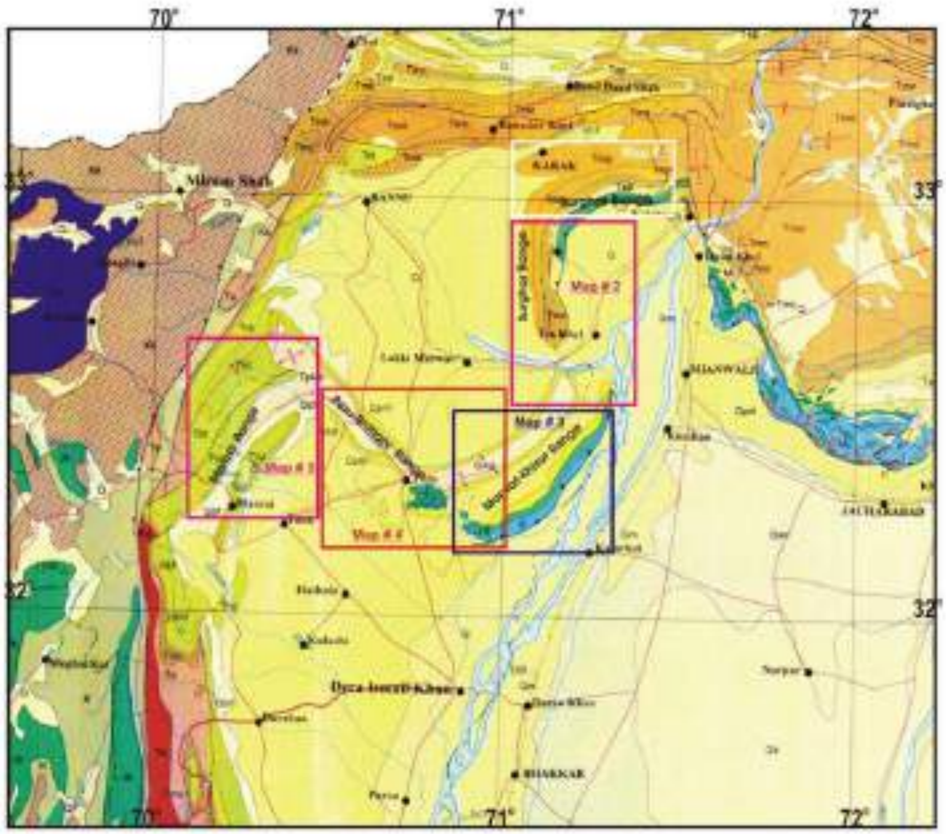


Fig. 3.3.4. Geologic map showing Surghar Range, Marwat Khisor Range, Bhittani Range and Marwat Range of the Trans Indus Pakistan (Ali 2010).

3.4. Indus River

The Indus River is one of the longest rivers in Asia. It flows through Pakistan, the Indian states of Jammu and Kashmir and Gujarat, and western Tibet (China) (Ferguson et al., 1984). Originating in the Tibetan Plateau in the vicinity of Lake Mansarovar, the river runs a course through the Ladakh region of Jammu and Kashmir, towards Gilgit-Baltistan and then flows in a southerly direction along the

entire length of Pakistan to merge into the Arabian Sea near the port city of Karachi in Sindh. Its principal right bank tributaries are the Shyok, the Gilgit, the Kabul, the Gomal and the Kurram. Beginning in a mountain spring and fed with glaciers and rivers in the Himalayas.It is Pakistan's longest river with total length of 3,180 km.
The river has a total drainage area exceeding (1,165,000 km). The Zanskar is its left bank tributary in Ladakh. In the plains, its left bank tributary is river Chenab which itself has four major tributaries, namely, the Jhelum, Ravi, Beas and Sutlej (Goudie et al., 1984). In conjunction with the rivers Chenab, Jhelum, Sutlej, Ravi, Beas and two tributaries from the Afghanistan and Khyber Pakhtunkhwa, the Indus creates the Sapta Sindhu (Seven Rivers) delta of Pakistan.

3.5. Kabul River

It is 700 km Long River originating from the base of Unai Pass in Paghman Mountains about 70 km west of Kabul city (Sabir, 1966; IUCN, 1994). It enters into Pakistan near Shalman in the Khyber Agency and later joins Indus River about 70 km downstream from Peshawar, at Kund. Kabul River has four main tributaries in Afghanistan namely Alingar, Panjsher, Kunar and Logar. The source of Kunar River lies in the Hindukush range in Chitral (Pakistan) is known as Chitral River. Chitral River is called Kunar River when enters in Afghanistan near Arandu and joins Kabul River near Jalalabad. About 30 km west of Peshawar, the Kabul River is dammed for irrigation and hydel power generation and is named as Warsak dam. Downstream of Warsak dam the Kabul River is divided into three distributaries namely Shah Alam, Naguman and Sardaryab. These three branches form a single river system at Charsadda and at the same time two more rivers, Bara and Swat joins this main river (locally called Khiali River). The Bara River comes down from the Khyber hills and enters into the Peshawar basin from the southwest near Jhansi post (Kruseman and Naqvi, 1988; Sabir, 1996). The Swat river is formed as a result of the union of Gabral and Ushu rivers at Kalam, flowing southward through Mingora. The Panjkora River is an important tributary of river Swat which drains in Dir district. These two rivers join at kalangal village near the border of Malakand and Bajaur Agencies.

3.6. Kurram River

The Kurram river flows in the Kurrum Valley, stretching west to east, across the Afghan-Pakistani border at 33°49′N, 69°58′E, about 150 km west-to-south-west of the Khyber Pass.

Kurram river is located in Paktia and Khost provinces of Afghanistan and Kurram Agency, North Waziristan Agency and Khyber Pakhtunkhwa, Pakistan. It drains the southern flanks of the Spin Ghar mountain range and is a right bank tributary of the Indus River.The Kurram River joins the Indus River near Isa Khel, after a course of more than 320 km. In the north it is surrounded by snow-covered or "white" mountains, the Safed Koh, which also forms the natural border with Afghanistan.

3.7. Chemical composition of stream sediment control

The chemical composition of stream sediments provides information on weathering and transport processes and also on the presence of mineral deposits and contaminants. Stream sediments represent the average composition of outcropping rocks upstream of a sampling point (Spadoni, 2006) and provide information on lithological composition of the drainage basin (Rantitsch, 2000). According to Spadoni (2006), the relationship of the stream sediment composition with bed rock depends largely on the physical and chemical processes operating in the catchment, and their nature is closely linked to a number of local processes, of natural and anthropogenic origin, that can significantly affect their composition. The input results from erosion/deposition processes according to local geomorphologic and hydrological features. The intensities of input sources are inhomogeneous due to variation in the catchments and can be can be localized in circumscribed areas (point sources). Geochemical data from a complex system involving stream sediments is affected by lithology, erosion, transport and accumulation. Different rock types have different rates of erosion and allow different levels of input of components into stream channels. An understanding of geochemical data from stream sediment samples therefore relies on knowledge of the types of rocks exposed to the stream. According to Day (1980), flow networks fluctuate along individual channel systems, particularly on neighboring catchments of contrasting lithology where similar rainfall, vegetation and slope occur. The author demonstrated this by comparing two drainage networks on different lithologies. The study showed that flow net variability could be explained in part by differences in rock type.

Another factor in determining the variation in stream sediment composition is local and regional variations in dispersion mechanisms (Butt and Nichol, 1979). The lithological composition of the catchment basin can be used as a factor which controls the dispersion of chemical constituents (Rantitsch, 2004). Variations in lithological composition of the catchment area results in variability of geochemical signatures that can greatly alter the nature of significant stream sediment anomalies. As a consequence, uncertainties arise in establishing anomalous from background populations. General used criteria for distinguishing background and anomalous concentrations include histograms, probability graphs, Mean+2 sdev and different percentile ranges. However, knowledge and experience of geochemist play an important role in order to establish difference between anomaly and background.

3.8. Heavy Mineral Placers

Placer deposits are formed by accumulation of heavy minerals with specific gravity more then 2.65 along the rivers and streams (Mudaliar et al., 2007). According to Gary et al. (1972) placer is defined as ‘‘a mineral deposit, formed by mechanical accretion of mineral particles from weathering fragments.’’ Exploration of placer deposits has got much attention because these deposits constitute 69% of world gold (Sutherland, 1985). Several of the world important mineral products have been obtained from placers, e.g. placer gold deposits in New Mexico (Johnson, 1972; North and McLemore, 1988, McLemore, 1994), placer gold from Ghana, a major West African gold producing country (Komla and Sammy, 1995), placer gold from the Late Archean Witwatersrand sedimentary rocks in South Africa (Lalomov and Tabolitch, 1997), Klondike in Canada (McCracken et al., 2007) and the gold placers in Arizona (Wilson, 1961).

CHAPTER 4

HEAVY MINERALS AND PETROGRAPHIC STUDIES

4.1. Heavy minerals study of Peshawar Basin

Peshawar Basin, covering Peshawar and Mardan Divisions, is the intermountain basin covering an area of about 5500 Km^2. It is comprised of Quaternary fanglomerates along the margins of the basin while the central part is generally covered with fluvial sand, gravels and lacustrine deposits.

The mineralogical studies of the pan-concentrate samples collected from various streams of the Peshawar Basin is presented in Table 4.1, while the stereoscopic features of various heavy minerals and gold particles in the pan-concentrates of these districts are presented in Plates 1-4. The visual estimates of various heavy minerals and gold particles are based on the stereoscopic studies of the magnetite free pan-concentrate samples as the magnetite grains have been separated by the hand magnet and magnetic separator (See Chapter 2 on Methodology). Therefore, the visual estimates of magnetite grains given in the data in the tables do not represent the actual amount of magnetite but represent those grains which could not be separated. For the gold grains the various sizes have been differentiated as: colors: <0.3 mm, Specks: 0.3-0.5 mm and pieces >0.5 mm (Giusti, 1986).

Among the heavy minerals in the pan-concentrate samples, fluorite (up to 13%), apatite (up to 15%), garnet (up to 20%), zircon (up to 17%), goethite (up to 15%) tourmaline (up to 18%), amphibole (10-26%), rutile (up to 14%), monazite (up to 10%), topaz (7-22%), pyroxene (up to 15%), magnetite (2-30%), epidote (up to 18%), hematite (up to 15%), and ilmenite (up to 14%) olivine (up to 15%), tremolite (up to 10%), ores (8-27%) and rock fragments (9-23%) have been identified (Table 4.1; Plates 1-4).This table shows that up to a maximum of 12 colors and 5 specks have been identified in the pan-concentrate samples.

Heavy minerals both of igneous and metamorphic origin have been frequently encountered in the pan-concentrates of the Peshawar Basin. The minerals include garnet, zircon, tourmaline, amphiboles, pyroxenes, epidote, ilmenite, and rutile etc. These heavy minerals are indicative of the derivation of the stream sediments within the basin from a wide variety of igneous rocks like, granites, gabbros, ultramafics, rhyolites, basalts and metamorphic rocks ranging in composition from low grade fine grained slates and phyllites to high grade amphibolites, garnet schists and granitic gneisses found ubiquitously in the northern part of the Himalayan Ranges. This is suggesting that the heavy minerals including gold in the stream sediments have the source rocks located within the north and north-western higher mountains of the Himalayan Ranges.

4.2. Heavy minerals study of Kohat and Bannu Divisions

The Kohat and Bannu divisions are part of the Kohat-Bannu Basin, also known as Kohat-Bannu Tectonic Block in the southern region of the Khyber Pakhtunkhwa province, Pakistan (Pivnik and Sercombe, 1993). This region is mainly comprised of the molasse sediments of the Siwalik Group. This group includes, in ascending order, Chinji, Nagri, Dhok Pathan and Soan formations. These formations are mainly composed of sandstones with interbedded sandy clay and conglomerates. Besides, the whole region is widely covered with the Quaternary sediments, typically loessic silt interbedded with alluvial deposits.

The mineralogical studies of the pan-concentrate samples collected from various streams of Kohat and Bannu divisions is presented in Table4.2, while the stereoscopic features of various heavy minerals and gold particles in the pan-concentrates of these districts are presented in Plates 5-7. The table shows that in the pan-concentrate samples the identified gold colors range in number from 1 to 8, whereas in only one sample it reaches up to 30. The gold specks range from 1 to 4 in number. The percentage of heavy minerals range as : fluorite (up to 10%), apatite (2-20%), garnet (10-30%), Zircon (10-20%), tourmaline (5-16%), amphibole (7-30%), rutile (2-14%), monazite (8-12%), topaz (3-20%), pyroxene (up to12%), magnetite

(2-25%), epidote (4-20%), hematite (4-15%), tremolite (2-10%), ilmenite (2-15%), hornblende (1-15%), chlorite (4-12%) and rock fragments (6-30%).Besides these, trace amounts of spinel and blue amphibole (glaucophane?) have been identified in Bannu Basin.

Heavy and resistant minerals of igneous, metamorphic and reworked sedimentary origin have been frequently encountered in the pan-concentrates of Kohat and Bannu divisions. The minerals include garnet, zircon, tourmaline, amphiboles, pyroxenes, epidote, ilmenite, and rutile, blue-green hornblende, blue amphibole (glaucophane?), and rarely spinel etc. Gold colors and specks have also been identified. The relatively higher amount of gold grains in Bannu District as compared to other districts is indicative of its derivation from the igneous (mafic-ultramafic), metamorphic and reworked sedimentary rocks from the localities of Waziristan, Khost, Parachinar and adjoining regions. The gold particles and other heavy minerals in Karak and Kohat districts seem to have a source in the paleo-placers of Siwalik rocks of the Kohat Plateau. The ultimate source of the paleo-placers of Siwalik Molasses is the Hinterland areas of Himalayas (Fatimi, 1973; Abid et al., 1983; Abbasi et al., 1990). The blue green hornblende in the stream sediments of Kurram River in Bannu and Lakki Marwat districts seems to have been derived from the Spin Ghar Crystalline Complex (Badshah et al., 2000) of Kurram Agency. Hangu District has negligible amount of gold, as compared to the other districts since the Hangu area has mostly carbonate sedimentary rocks and no input from other sources like igneous and metamorphic rocks further to the west.

4.3. Heavy minerals study of D.I. Khan Division

D.I. Khan Division, covering D.I. Khan and Tank districts, is consisting mainly of alluvial plains that slope from the mountain ranges in the northern and western parts toward the Indus River. Rocks in the bordering mountains are of Paleozoic to early or middle Pleistocene age. The unconsolidated rocks of the plain, mainly of Pleistocene to Holocene (Recent) age, consist of piedmont deposits derived from the hills to the north and west and of alluvial sediments deposited by the Indus River.

Results of mineralogical studies along with the distribution of visible gold conducted on the pan-concentrate samples from D.I. Khan Division have been presented in Table 4.3. Various heavy minerals and gold particles studies under stereomicroscope in the pan-concentrate samples of the D.I. Khan Division are presented in Plates 8-9. The table shows that only one pan-concentrate sample contains 4 colors of visible gold and no any speck was found in any sample. Estimate of heavy minerals such as apatite (5-22%), garnet (15-35%), zircon (10-35%), tourmaline (5-25%), amphibole (5-28%), rutile (2-12%), epidote (2-20%), hematite (5-25%), chlorite (up to 10%) and Ilmenite (5-12%) were determined visually.

Heavy and resistant minerals encountered in the pan-concentrates from D.I. Khan Division include garnet, zircon, tourmaline, amphiboles, epidote, ilmenite, rutile, and very rarely spinel etc. Few gold colors have also been identified in Tank District in all those streams having catchment in the Waziristan Agency. Heavy minerals in D.I. Khan and Tank districts have source areas in the western Sulaiman Range and in the paleo-placers of Siwalik Rocks of the Marwat, Bhittanni and Khisor ranges.

4.4. Heavy minerals study of Bulk samples (~130 kg/sample)

Bulk samples (~130 kg/sample) were collected from the entire project area from all those streams that had some visible gold in the form of specks. The mineralogical study of the pan-concentrates from bulk samples is presented in Table 4.4. The table shows that in the pan-concentrate samples the identified gold colors range in number from 8-40 while gold specks range from 1 to 15 in number. In two samples pieces of gold are also found Table 4.4. The percentage of heavy minerals range as: fluorite (up to 10%), apatite (up to 13%), garnet (14-22%), zircon (3-15%), hornblende (5-9%), tourmaline (7-13%), amphibole (12-22%), rutile (5-11%), monazite (5-8%), topaz (3-16%), pyroxene (up to 9%), magnetite (8-18%), epidote (11-16%), hematite (8-12%), ilmenite (4-10%), chlorite (up to 5%), goethite (up to 10%) and beryl (5-8%).

Table: 4.1. Float, visible gold and heavy minerals studies of pan-concentrate samples from Peshawar basin.

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Pyroxene	Apatite	Garnet	Zircon	Goethite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1101	34 04 33.7	72 36 07.3	Rhylite, quartz quartzite, granite, Meta-sediments, granodiorite,	-	-	-	-	7	17	15	-	11	12	4	-	-	9	16	6	3	-
1102	34 04 31.0	72 36 15.1	Quartzite, granodiorite, pegmatite, diorite, gabbro, granite, rhyolite	-	-	-	-	12	15	14	-	10	15	10	-	7	-	10	7	-	-
1103	34 09 14.2	72 41 50.8	Quartzite, gabbro, rhyolite Gneiss, meta-sediments	15	3	5	-	-	20	17	-	10	20	5	-	-	9	8	6	-	-
1105	34 11 50.0	72 40 50.8	Red quartz, quartzite, rhyolite, gneiss, carbonates	-	-	-	-	9	16	15	-	11	20	-	-	-	7	-	17	5	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1108	34 04 15.4	72 36 21.7	Granite, quartzite, rhyolite, gabbro, meta-sediments	-	-	-	-	18	9	-	9	18	12	4	15	7	8	-	-	-
1109	34 00 24.5	72 40 07.8	Phyllite, slate, schist, granite, meta-sediments, granodiorite, quartz.	1	-	-	10	20	-	-	12	21	8	-	13	-	4	12	-	-
1110	34 00 24.5	72 40 07.8	Granite, granodiorite, gabbro, diorite, volcanic	6	2	-	-	18	13	8	13	19	-	3	-	6	10	-	-	8
1111	34 08 08.3	72 27 54.0	Granite, gabbro, granodiorite, fossiliferous meta-sediments	1	-			15	15	6		10	12		16		6	10	-	10

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Pyroxene	Apatite	Garnet	Zircon	Olivine	Tourmaline	Amphibole	Rutile	Ores	Topaz	Magnetite	Epidote	Goethite	Ilmenite
1112	34 02 59.3	72 29 30.3	granodiorite, pegmatite, diorite, gabbro, granite, rhyolite volcanic	3	-		-	13	19	14	-	11	16	14	-	-	-	10	-	-
1113	33 59 29.1	72 22 07.4	Volcanic, rhyolite, granite Gabbro, pyroxenite	-	-		-	8	10	7	-	10	14	8	-	15	16	12	-	-
1114	34 12 59.2	72 16 25.8	quartz, gabbro, quartzite, meta-sediments, carbonates	-	-		13	8	-	15	-	9	18	-	-	-	13	17		7

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Pyroxene	Apatite	Garnet	Zircon	Olivine	Tourmaline	Amphibole	Rutile	Ores	Topaz	Magnetite	Epidote	Goethite	Ilmenite
1116	34 13 07.0	72 18 30.9	Granite, quartz, gabbro, meta-sediments	-	-		-	-	15	13	-	12	20	-	13	12	-	15	-	-
1117	34 14 54.6	72 20 34.6	Slate, granite, meta-sediments, gabbro, quartz.	8	1		-	11	18	10	-	14	10	10	-	-	20	-	-	7
1118	34 10 32.1	72 18 16.4	Granite, quartz, gabbro, meta-sediments	-	-		12	-	-	10	-	12	20	5	10	-	8	15	-	8
1119	34 13 10.1	72 20 32.4	Meta-sediments, slate, schist, quartz, quartzite	-	-		10	11	15	-	15	8	15	-	-	-	18	-	8	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Ores	Ilmenite
1120	34 23 13.5	72 17 37.8	Granite, gabbro quartzite, gneiss, schist, limestone, garnet schist	2	-	-	-	15	8	14	10	12	15	-	-	10	-	16	-	-	-
1121	34 21 16.3	72 17 06.2	Granite, gabbro, quartzite, slate, rhyolite, limestone	-	-	-	-	-	12	-	-	10	15	10	-	13	-	8	12	12	8
1122	34 20 37.9	72 17 35.1	Granite, quartz,quartzite, meta-sediments limestone	-	-	-	10	13	15	-	-	-	14	-		10	-	12	8	10	8
1123	34 20 53.0	72 16 28.8	Quartzite, meta-sediments, gneiss	-	-	10	-	20	15	10	-	-	20	-	-	-	-	-	14	11	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Ores	Ilmenite
1125	34 16 17.6	72 13 35.6	Gneiss, garnet schist, req quartz, slate, quartzite, meta-sediments	-	-	10	-	15	-	8	-	10	15	-	-	-	-	10	13	14	5
1126	34 15 55.8	72 11 46.9	Meta-sediments. Gabbro, quartzite, granite, quartz	-	-	-	12	15	10	-	8	10	10	10	-	-	5	10	10	-	-
1127	34 15 55.8	72 11 46.9	Meta-sediments, quartz, quartzite, gabbro, granite	-	-	-	-	15	-	11	-	12	12	12	-	-	10	15	13	-	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																	
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Ores	Ilmenite
1128	34 17 34.9	72 09 08.8	Meta-sediments, carbonate, quartzite, gneiss, goethite	-	-	-	-	15	-	15	-	10	18	-	-	22	-	5	-	10	8
1129	34 17 37.2	72 09 12.3	Carbonate, meta-sediments, quartz, quartzite	-	-	-	-	13	12	6	7	5	18	-	8	17	-	5	-	-	9
1130	34 27 09.7	72 03 10.2	Quartzite, meta-sediments, granite, goethite bearing phyllite	-	-	-	10	18	12	-	-	14	14	10	-	-	-	6	-	8	8
1131	34 27 05.5	72 03 39.3	Schist, phyllite, gneiss, phyllite, quartzite, carbonates	-	-	-	10	12	10	-	-	10	15	8	-	-	-	8	7	12	8

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Ores	Ilmenite
1133	34 27 18.4	72 06 10.9	Goethite, Fe ore bearing quartz, phyllite, braccia, carbonate	-	-	-	-	-	10	-	-	8	20	-	-	-	15	-	15	24	8
1134	34 14 52.7	72 00 06.0	Meta-sediments, garnet bearing schist, carbonate, phyllite, quartzite	2	-	4	7	15	10	-	-	6	14	-	9	17	5	5	-	-	8
1135	34 19 53.6	71 54 19.1	Meta-sediments, quartzite, schist Gneiss, garnet bearing schist,	-	-	-	-	15	6	-	10	10	15	11	-	-	10	8	15	-	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock fragments
1137	34 24 03.6	71 41 02.1	Granite, gneiss, braccia, garnet mica schist, quartzite	-	0	-	-	15	10	-	-	10	15	12	-	-	10	11	13	-	-	10
1138	34 23 56.6	71 43 02.5	Quartzite, meta-sediments, dunites, quartzite,	-	-	-	-	13	14	-	-	12	15	-	9	-	-	6	10	7	-	15
1140	34 23 27.1	71 49 05.3	Gabbro, dunite, serpentinite, granite, quartz limestone,	-	-	6	-	15	-	-	-	12	12	11	-	-	-	12	12	-	10	10
1141	34 23 07.3	71 47 20.5	Ultramafics, gabbro, dunites, quartzite, serpentinite,	-	-	-	12	15	14	-	-	13	18	-	9	-	-	8	-	-	11	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock fragments
1201	34 22 05.9	71 41 50.4	Garnet, gneiss, schist, gabbro, pyroxinite	10	2	-	-	15	-	8	-	-	12	9	-	13	-	23	10	-	10	-
1206	34 19 59.0	71 35 37.4	Granite, gabbro, quartzite, schist, dunite, meta-sediments	12	4	-	9	10	13	7	-	12	9	-	-	-	-	30	10	-	-	-
1207	34 20 05.4	71 38 32.5	Granite, quartz,gneiss, gabbro, dunite, carbonate, quartzite	-	-	6	-	14	12	-	-	10	14	-	6	-	7	21	10	-	-	-
1208	34 21 34.4	71 37 51.6	Dunite, granite, gneiss, schist, gabbro, ultramafic	3	-	8	7	14	12	-	-	-	10	10	-	-	-	22	9	8	-	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1210	34 20 50.2	71 37 41.3	Granite, dunite, quartzite, meta-sediments, gabbro, gneiss, volcanic, quartz	-	-	-	5	12	10	-	-	8	10	6	-	-	25	18	6	-	-
1212	34 10 35.0	71 34 40.9	Granite, quartzite, gneiss, garnet mica schist, ultramafic	-	-	7	-	18	12	-	-	10	8	8	-	-	16	12	-	9	-
1214	34 18 00.1	71 34 30.7	Granite, gabbro, gneiss, schist	2	-	-	-	17	-	-	5	5	24	-	15	3	12	12	-	7	-
1215	34 08 28.3	71 42 18.4	Granite, schist, gneiss, gabbro, dunite, volcanic	6	1	-	-	14	13	-	-	10	9	10	-	-	20	16	-	8	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1150	33 53 21.8	71 47 47.8	Meta-sediments, quartzite, slate, phyllite, gneiss, limestone, ultramafic	-	-	9	-	13	-	-	-	15	10	-	-	-	3	12	8	10	20
1152	33 51 54.5	71 45 38.2	Limestone, meta-sediments, quartzite, conglomerates, marble	-	-	6	-	15	12	-	12	15	12	-	-	12	6	-	-	-	10
1153	33 52 23.1	71 46 43.6	Meta-sediments, limestone, quartz, quartzite	-	-	-	10	-	15	-	-	15	-	12	-	-	8	18	7	-	15
1154	33 50 28.2	71 50 01.0	Meta-sediments, limestone, slates, quartzite	-	-	-	15	20	-	-	12	-	-	17	-	-	-	15	-	-	20

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1158	33 53 17.4	71 49 33.9	Limestone, meta-sediments, quartz, sandstone	-	-	-	8	15	-	-	10	17	5	10	-	-	-	15	-	10	10
1159	33 51 15.9	71 52 29.5	Meta-sediments, limestone, sandstone, quartzite	8	1	-	-	15	8	-	12	25	-	-	18	10	-	12	-	-	-
1162	33 57 35.8	72 02 04.8	Slate, sandstone, phyllite, quartzite, marble	-	-	-	-	15	-	-	6	15	-	13	17	-	-	16	-	9	9

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains			Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnett	Zircon	Chlorite	Rutile	Tourmaline	Amphibole	Goethite	Hematite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1164	33 55 39.9	71 57 00.3	Slate, meta-sediments, quartzite, limestone, quartz	-	-		10	20	8	13	-	13	16	-	8	-	-	2	-	-	-	10
1165	33 53 53.4	71 57 31.1	Meta-sediments, slate, marble, quartzite, quartz, limestone	-	-		12	15	-	10	-	15	15	-	-	18	-	-	-	-	-	15
1167	33 57 23.1	71 49 40.9	Meta-sediments, quartzite, phyllite, slate	-	-		-	14	-	12	-	15	10	-	-	14	-	-	15	8	-	12
1216	33 52 12.1	72 14 5.5	Limestone, slate	15	4		10	18	-	-	9	10	9	-	-	15	-	5	16	-	8	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnett	Zircon	Chlorite	Rutile	Tourmaline	Amphibole	Goethite	Hematite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1219	33 50 49.7	72 13 57.7	Slate, limestone	-	-		12	18	14	-	4	8	15	-	14	-	-	-	15	-	-	-
1220	33 50 27.1	72 13 52.2	Slate, limestone, dolostone,	-	-		-	15	12	-	-	11	20	10	-	-	9	-	-	-	8	15
1221	33 49 46.6	72 13 19.0	Granite, quartz, limestone, slate, mudstone	18	1		12	-	15	10	10	-	19	-	-	-	-	10	15	-	9	-
1222	33 48 51.1	72 11 09.9	Granite, quartz, limestone, slate	-	-		-	17	13	-	6	-	10	-	8	10	-	6	15	-	-	15

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Pyroxene	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Hematite	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1224	33 48 22.4	72 09 37.6	Granite, limestone, quartz, slate	-	-	-	-	14	-	-	8	10	13	10	8	15	-	10	12	-	-	-
1227	33 48 01.3	72 05 06.1	Quartzite, limestone	-	-	6	-	18	13	-	-	10	18	10	-	-	-	10	15	-	-	-
1229	33 48 48.7	72 03 26.5	Limestone, quartzite	-	-	-	-	17	-	8	-	-	18	-	-	-	12	13	-	-	10	22
1230	33 47 07.9	72 00 51.5	Quartzite, limestone	-	-	-	12	18	-	10	-	-	15	10	-	-	-	-	15	10	-	10

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Pyroxene	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Hematite	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments
1231	33 47 27.9	72 01 38.3	Limestone, quartzite, quartz	-	-	-	-	18	-	-	12	-	-	-	15	20	-	-	-	-	12	23
1233	33 53 36.1	72 13 46.5	Limestone, slate, granite, quartz, braccia	-	-	-	-	20	-	-	-	10	25	10	5	-	10	12	-	-	8	-
1234	33 59 38.7	72 06 35.0	Granite, gneiss, braccia, slate, quartz, schist	12	3	-	8	5	11	-	-	10	15	-	-	18	-	-	12	-	9	12

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnett	Zircon	Ilmenite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Calcite	Epidote	Rock Fragments	Tremolite
1235	33 59 39.7	72 05 09.2	Slate, limestone	-	-		10	7	15	-	10	15	9	-	-	-	11	-	-	15	8
1236	33 57 45.8	72 04 26.3	Slate, limestone, quartz	-	-		-	13	11	-	-	20	-	9	-	-	10	15	-	22	-
1237	33 57 45.7	72 03 54.0	Slate, limestone, quartz	1	-		10	15	12	5	8	25	-	-	-	7	-	-	-	10	8
1238	33 59 15.9	72 05 44.9	Slate, granite, limestone, quartzite	4	-		13	17	10	-	11	14	-	-	16	7	-	-	12	-	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnett	Zircon	Ilmenite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Calcite	Epidote	Rock Fragments	Tremolite
1240	33 57 49.3	72 09 27.6	Granite, garnet bearing schist, slate, limestone, sandstone, quartz	17	3		-	16	10	-	-	15	12	11	12	-	12	-	12	-	-
1241	33 58 40.2	72 10 31.6	Slate, quartz, granite, limestone, schist	-	-		-	20	-	7	12	15	9	-	18	-	7	-	12	-	-
1242	33 56 58.2	72 10 29.6	Quartzite, slate, limestone	-	-		-	16	-	14	-	19	-	-	15	10	11	-	-	15	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Monazite	Ilmenite	Rock Fragments	Hematite
1243	33 57 26.8	72 11 26.8	Granite, quartz, quartzite, slate, limestone	16	2	-	11	14	11	-	9	13	-	-	11	8	15	-	-	8	-	-
1244	33 55 19.0	72 10 26.0	Slate, quartzite, limestone	-	-	-	9	17	12	-	-	15	10	5	-	-	8	15	-	-	-	9
1245	33 59 29.6	72 08 19.2	Granite, quartzite, slate, limestone	-	-	-	-	25	13	7	-	15	-	-	20	-	-	14	-	-	-	6
1246	33 57 52.5	72 09 47.3	Granite, quartzite, slate, limestone, sandstone, schist	-	-	-	10	17	10	-	9	12	-	-	-	-	-	14	-	10	12	6

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	ores	Topaz	Monazite	Magnetite	Epidote	Hematite	Ilmenite	Goethite	Olivine
1247	33 59 11.4	72 08 36.2	Granite, limestone, slate, quartzite, braccia, schist	18	5	7	-	15	14	-	8	12	-	-	10	10	-	13	-	-	11	-
1168	34 05 34.1	71 29 05.2	Carbonates, volcanic, granite, quartz, quartzite, clay, meta-sediments.	-	-	8	10	13	12	8	9	15	6	10	-	-	9	-	-	-	-	-
1169	34 01 40.8	71 26 12.0	Quartz, quartzite, carbonates, granite, volcanics	-	-	5	10	-	15	10	10	20	-	10	-	-	5	10	5	-	-	-
1170	34 03 06.1	71 24 46.2	Carbonate, quartzite, granite, quartz.	-	-	8	13	-	14	-	9	15	-	12	-	-	8	11	-	10	-	-

Table 4.1 continued

S.No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	ores	Topaz	Monazite	Magnetite	Epidote	Hematite	Ilmenite	Goethite	Olivine
1172	34 05 23.1	71 24 34.6	Granite, quartz, quartzite, carbonates	-	-	-	-	15	10	-	9	12	12	8	8	-	4	-	-	10	12	-
1175	34 01 40.3	71 26 49.4	Carbonates, quartz, granite	-	-	-	-	15	20	-	5	15	10	15	-	-	-	10	-	-	5	5
1176	33 57 39.1	71 26 51.6	Granite, quartz, quartzite, carbonate	-	-	7	12	15	15	12	13	-	-	-	-	-	8	8	10	-	-	-
1177	33 57 26,0	71 25 11.4	carbonate, granite, quartzite, sandstone	-	-	-	-	20	15	-	11	17	-	-	-	-	10	-	15	12	-	-

Plate 1

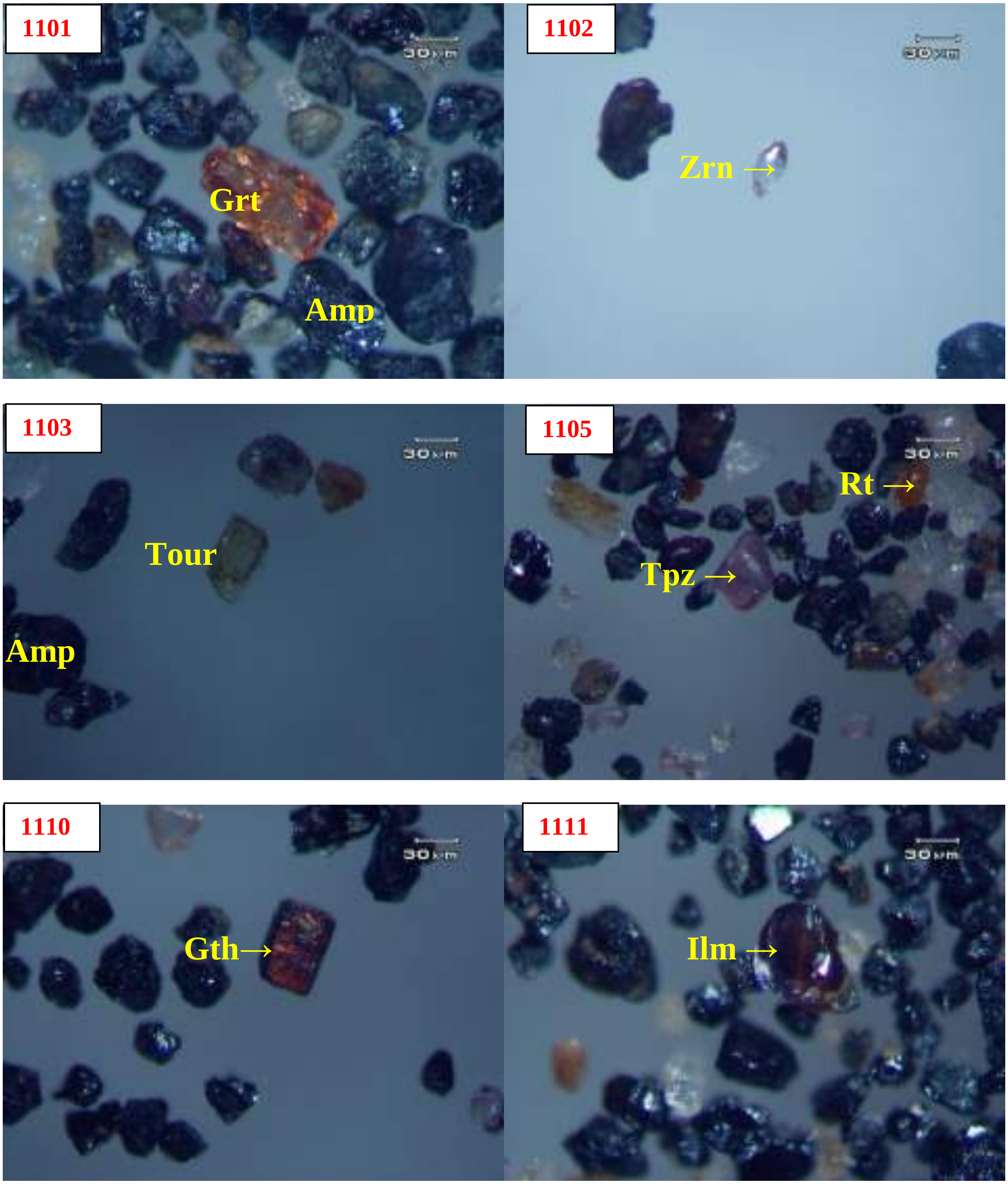


Plate1. View of the Heavy minerals in the pan-concentrate samples from Peshawar Basin under stereomicroscope. Grt (garnet), Zrn (zircon), Amp (amphibole), Tour (tourmaline), Gth (goethite), Ilm (ilmenite).

Plate 2

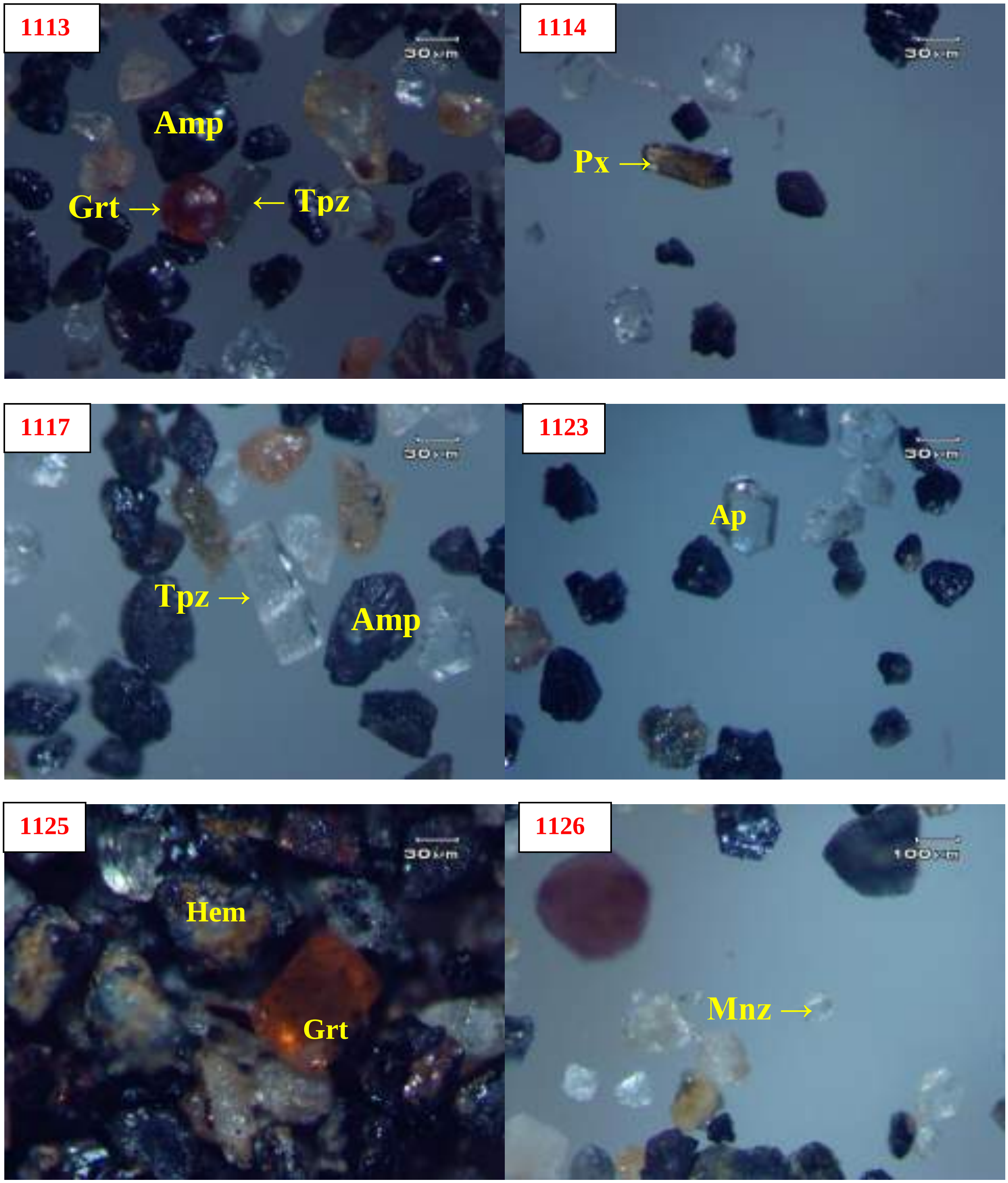


Plate2. View of the Heavy minerals in the pan-concentrate samples from Peshawar Basin under stereomicroscope. Grt (garnet), Amp (amphibole), Tpz (topaz), Px (pyroxene), Ap (apatite), Hem (hematite), Mnz (Monazite).

Plate 3

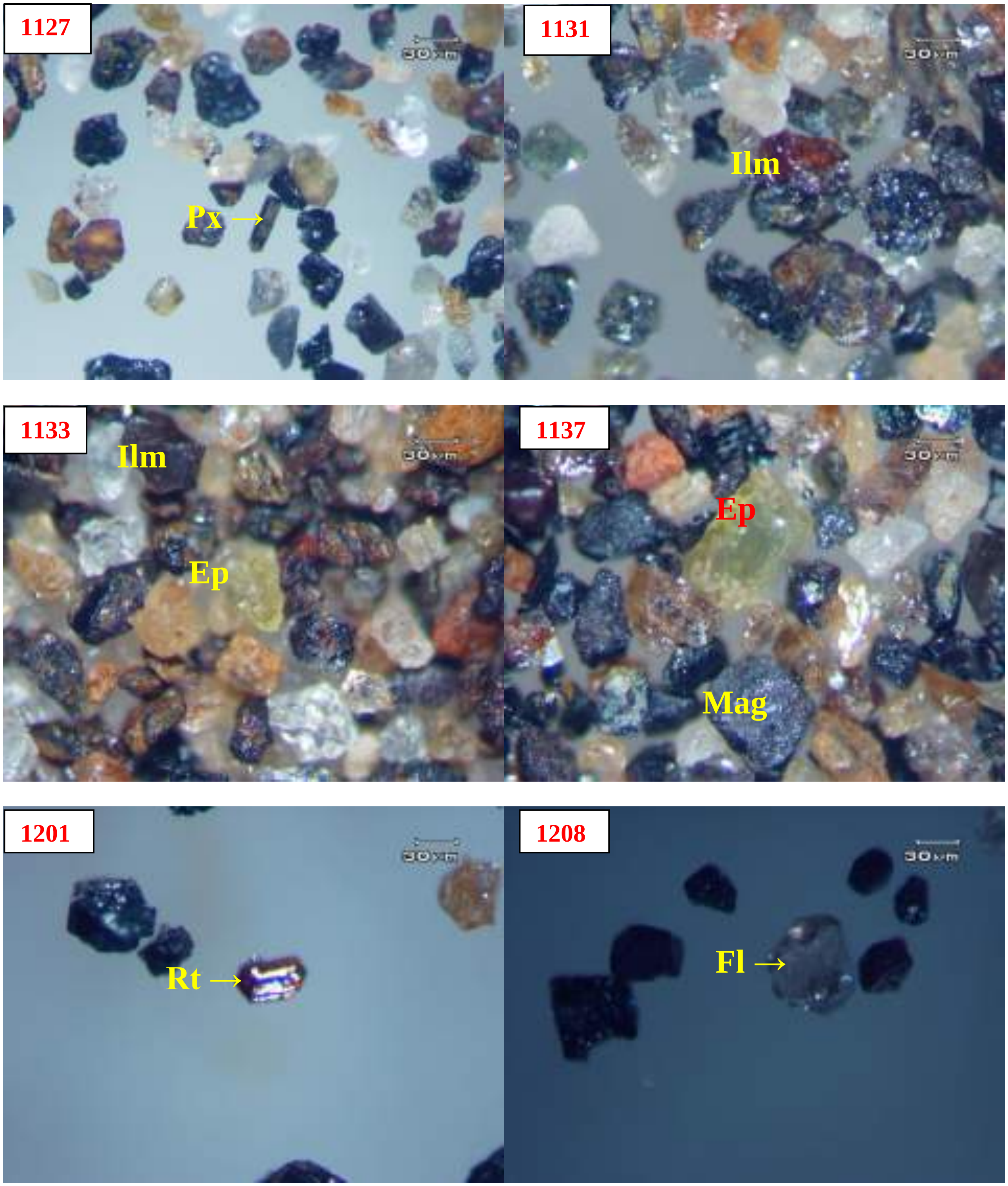


Plate3. View of the Heavy minerals in the pan-concentrate samples from Peshawar Basin under stereomicroscope. Px (pyroxene),Ilm (ilmenite), Ep (epidote), Mag (magnetite), Rt (rutile), Fl (flourite).

Plate 4

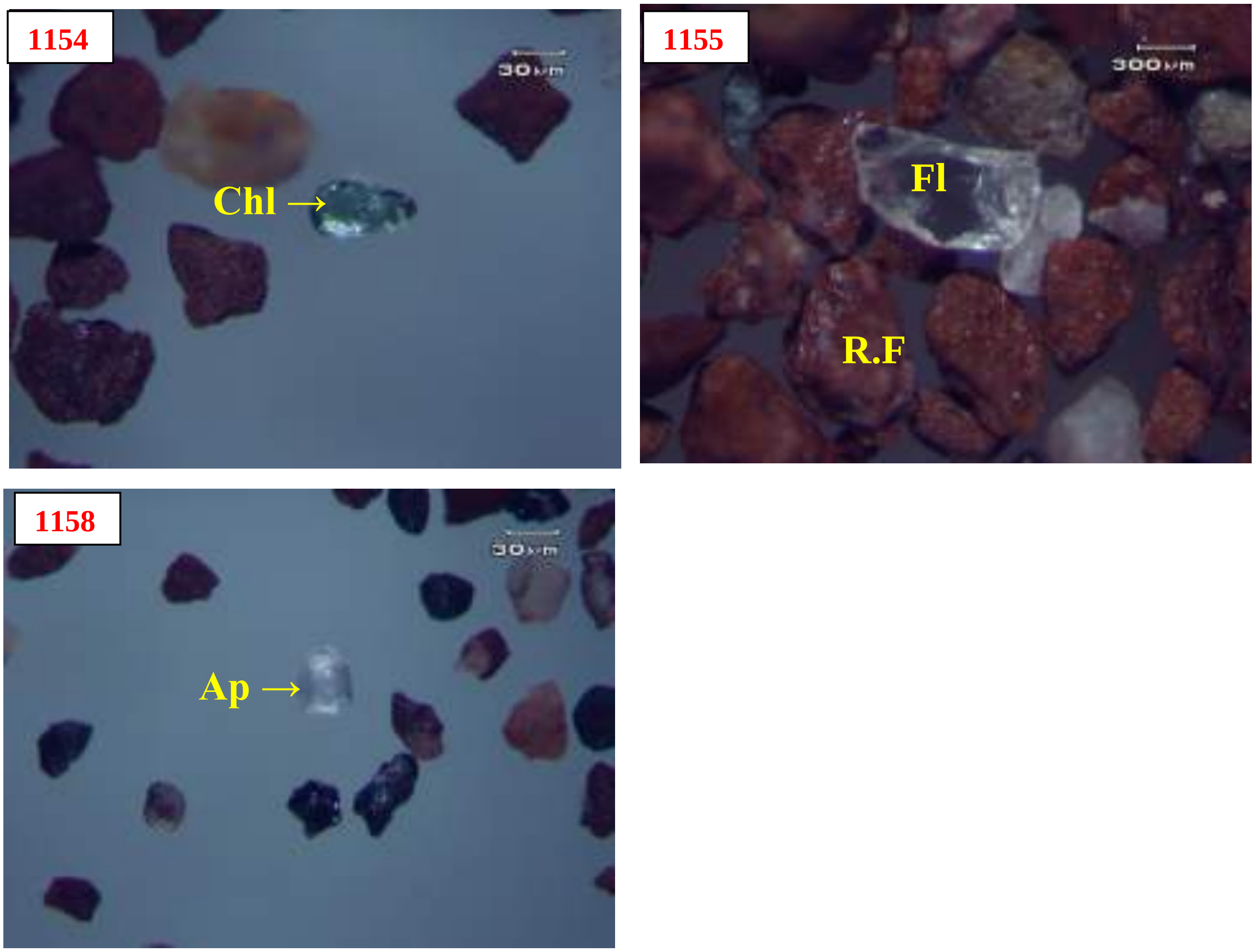


Plate4. Viewof the Heavy minerals in the pan-concentrate samples from Peshawar Basin under stereomicroscope. Chl (chlorite), Fl (fluorite), Ap (apatite), R.F (rock fragments).

Table:4.2. Float, visible gold and heavy minerals studies of pan-concentrate samples from Bannu and Kohat divisions.

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1502	33 36 01.0	71 30 50.1	Sandstone boulder, limestone, clay, siltstone,	1	-	-	12	20	15	-	10	12	-	8	-	-	-	12	-	11
1504	33 32 20.0	71 32 12.7	Conglomerate, limestone, sandstone, clay,	2	-	-	10	18	12	9	-	16	-	-	-	-	10	15	-	10
1506	33 30 51.2	71 36 51.0	Limestone, Sandstone, conglomeratic bed.	4	-	-	13	18	15	-	-	18	10	-	-	-	-	15	-	11
1509	33 26 14.8	71 35 22.2	Limestone, quartz, sandstone, gypsum	-	-	-	11	16	15	-	-	17	-	8	-	-	10	14	-	9

Table:4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1512	33 31 14.3	71 28 16.6	Thick conglomeratic bed, limestone, sandstone	-	-	-	12	15	-	-	-	16	-	-	10	-	12	10	15	10
1515	33 29 40.7	71 25 25.0	Limestone, quartz, sandstone, conglomerate	-	-	-	12	-	20	-	13	18	-	10	-	-	12	15	-	-
1518	33 28 23.6	71 28 41.0	Limestone, sandstone, quartz	-	-	8	13	-	13	-	12	18	11	-	-	7	6	-	-	12
1526	33 30 08.7	71 39 10.8	Limestone, sandstone, quartz	7	-	-	-	20	-	-	12	21	13	8	-	-	-	18	-	8
1531	33 30 36.7	71 45 31.9	Sandstone, shale, limestone	-	-	-	11	16	15	8	-	20	-	-	-	-	-	13	8	9

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)													
				Colors <0.3mm	Specks 0.3-0.5mm	Garnet	Apatite	Monazite	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
1536	33 28 51.0	71 54 27.9	Shale, sandstone, sand dunes, Carbonate	8	1	20	9	-	15	-	-	20	11	-	10	-	15	-	-
1541	33 32 51.8	71 53 07.8	Sandstone, conglomerates, shale	2	-	15	10	-	13	-	11	17	-	-	-	10	15	9	-
1542	33 33 49.2	71 54 22.3	Conglomerates, sandstone, shale	1	-	18	10	-	14	-	12	15	11	-	-	8	12	-	-
1545	33 35 44.9	71 58 39.3	Igneous rocks, meta-sediments, sandstone, shale	20	2	20	8	-	14	-	10	21	-	-	-	-	15	12	-
1551	33 38 39.4	71 56 21.8	Sandstone, limestone, red color clay	-	-	20	10	-	12	10	10	13	-	-	-	10	15	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)													
				Colors <0.3mm	Specks 0.3-0.5mm	Garnet	Apatite	Monazite	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
1556	33 26 53.0	71 18 52.6	Limestone, sandstone, quartz, shale	-	-	18	10	-	12	-	-	24	-	12	-	15	-	-	9
1559	33 22 35.4	71 19 56.4	Limestone, sandstone, quartz, shale	-	-	20	11	9	13	8	-	12	-	12	-	5	10	-	-
1567	33 24 44.0	71 26 25.7	Limestone, shale, sandstone	4	-	17	9	-	15	-	-	20	12	-	11	6	-	-	10
1572	33 36 13.9	71 17 49.4	Limestone, sandstone, quartz, shale	-	-	15	12	-	15	-	14	15	12	9	-	8	-	-	-
1573	33 36 26.2	71 14 45.4	Limestone, sandstone, quartz, red color limestone	-	-	-	12	4	16	-	13	10	13	-	-	9	-	13	11

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)													
				Colors <0.3mm	Specks 0.3-0.5mm	Garnet	Apatite	Pyroxene	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
1577	33 35 09.4	71 12 33.1	Limestone, Sandstone, quartz, shale	-	-	20	12	-	15	6	15	10	12	-	-	-	-	-	10
2003	33 12 07.2	71 30 49.9	Limestone, shale, sandstone	8	1	20	14	-	-	12	-	15	-	-	-	9	15	-	15
2007	33 12 20.6	71 34 42.9	Sandstone, granite, limestone, shale	6	2	12	-	-	-	-	15	24	-	-	14	8	15	-	12
2010	33 12 07.3	71 35 05.4	Sandstone, limestone, granite, quartz	10	-	22	12	-	16	-	-	16	14	15	-	5	-	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)													
				Colors <0.3mm	Specks 0.3-0.5mm	Garnet	Apatite	Pyroxene	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
2013	33 11 51.8	71 35 56.3	Granite, quartz, quartzite, sandstone, limestone	7	1	14	12	-	-	-	15	20	-	-	12	9	18	-	-
2027	33 17 54.3	71 26 55.6	Sandstone, limestone, shale, claystone	13	2	15	12	-	15	-	15	15	10	-	12	6	-	-	-
2035	33 17 36.5	71 28 48.4	Sandstone, limestone	6	2	20	14	12	15	-	-	15	12	-	-	2	-	10	-
2040	33 13 10.3	71 27 06.3	Limestone, siltstone, shale, sandstone	8	1	14	-	-	15	10	12	16	-	-	-	6	15	-	12

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Hornblende	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
3005	33 27 43.6	70 44 22.2	Limestone, siltstone, shale	-	-	-	-	20	-	-	30	-	10	-	-	-	-	12	-	28
3007	33 26 57.7	70 44 39.0	Limestone, siltstone, shale	-	-	15	10	20	-	-	20	2	-	-	-	-	-	-	12	21
3008	33 21 07.4	70 32 50.2	Limestone, siltstone, shale	-	-	-	10	20	-	12	20	-	-	-	-	6	12	-	-	20
3017	33 23 20.4	70 36 41.5	Limestone, siltstone, shale	-	-	12	10	18	-	-	15	-	10	-	-	-	-	5	-	30

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Hornblende	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
3042	33 22 27.7	70 59 32.4	Limestone, siltstone, shale	-	-	-	12	14	15	15	20	-	-	12	-	2	-	-	10	-
3050	33 35 12.5	70 12 30.4	Limestone, siltstone, shale	-	-	-	12	20	16	14	12	10	-	-	8	6	-	-	2	-
3069	33 29 55.5	70 47 49.4	Limestone, siltstone, shale	-	-	-	14	20	-	16	18	-	4	-	12	-	-	-	-	16

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Chlorite	Tremolite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
1602	33 08 24.8	71 08 45.2	Dolomite, gabbro, granite, quartz, limestone, quartzite	16	-	-	12	18	15	-	-	-	12	14	-	14	-	15	-	-
1604	33 08 39.9	71 09 02.9	Sandstone, gypsum, shale, clay	4	-	-	12	16	15	-	-	14	10	-	-	-	9	12	-	12
1606	33 10 00.3	71 09 56.8	Sandstone, gypsum, shale, clay, limestone	1	-	-	14	16	13	11	-	-	10	12	-	12	2	-	10	-
1612	33 10 33.6	71 07 53.9	Sandstone, shale, gypsum, clay	8	-	-	13	15	16	-	-	12	12	-	-	11	6	15	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Chlorite	Tremolite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Magnetite	Epidote	Hematite	Ilmenite
1628	33 08 06.6	70 58 19.6	Sandstone, shale, claystone	-	-	-	-	18	11	-	8	13	13	-	-	12	-	15	-	10
1630	33 09 36.8	70 57 39.9	Shale, sandstone, siltstone	-	-	-	20	15	15	-	-	5	-	10	-	-	5	10	10	-
1632	33 10 44.5	70 59 26.8	Sandstone, shale, claystone	2	-	-	10	25	15	-	-	5	10	-	-	10	5	20	-	-
1639	33 12 19.6	70 53 47.4	Sandstone, shale	-	-	5	-	16	14	-	10	-	15	8	12	10	10	-	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Fluorite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1650	33 13 07.2	71 09 55.7	Shale, sandstone, siltstone.	12	1	-	-	22	12	-	-	10	19	12	-	10	-	-	15	-	-
1655	33 14 19.5	71 11 00.6	Sandstone, siltstone, shale	-	-	12	-	20	16	-	-	-	12	-	-	10	-	15	5	-	10
1659	33 15 39.6	71 11 33.2	Sandstone, shale, salt	-	-	12	-	18	16	-	-	11	15	-	-	-	-	16	12	-	-
1663	33 17 36.1	71 08 10.7	Limestone, sandstone, shale, siltstone	-	-	-	-	20	15	10	3	5	10	4	-	-	8	-	15	10	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3m m	Specks 0.3-0.5mm	Apatite	Fluorite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1680	33 06 05.0	70 51 48.7	Sandstone, shale, limestone, siltstone	-	-	-	-	25	15	7	-	5	20	-	5	-	-	3	20	-	-
1682	33 05 52.8	70 51 12.1	Sandstone, claystone, limestone	-	-	-	10	18	12	-	-	-	10	12	-	13	-	14	-	-	11
1684	33 05 31.2	70 50 14.6	Shale, sandstone	5	-	13	-	15	16	-	-	12	18	-	-	-	-	3	13	-	10
1690	33 02 38.5	70 54 16.2	Claystone, shale, sandstone	10	-	-	-	20	20	-	-	-	15	-	-	-	5	15	20	-	5

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1695	33 04 35.0	71 09 39.8	Quartz, sandstone, limestone, shale	4	-	5	30	15	-	-	-	15	-	5	-	-	10	20	-	-
1697	33 05 55.3	70 57 30.4	Sandstone, siltstone, shale, quartz	15	1	10	18	20	-	-	5	15	2	-	-	-	-	20	7	3
1808	33 01 38.7	71 03 27.2	Sandstone, shale, conglomerate	4	-	12	18	13			12	20	12				2	11		
1810	33 00 52.5	71 05 14.6	Limestone, sandstone, shale, quartz, granite	16	2	10	20	15	-	-	-	15	-	-	10	-	-	15	5	10

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Olivine	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1822	33 01 37.9	70 59 11.5	Quartz, granite, sandstone, shale	5	-	-	20	20	5	2	5	20	5	-	3	-	-	10	5	5
1824	33 00 40.5	71 00 20.5	Quartz, granite, sandstone	7	-	5	18	15	-	-	10	15	-	2	10	-	5	10	-	10
1836	33 04 49.9	71 05 43.7	Sandstone, quartz, shale	-	-	-	21	17	-	-	12	12	13	-	-	-	-	14	-	11
1841	33 08 20.2	71 09 40.9	Shale, sandstone, conglomerate, granite	3	-	12	18	12	-	-	14	10	10	-	-	3	5	16	-	-
1845	33 09 06.7	71 12 32.4	Sandstone, shale	15	1	10	20	14	-	-	10	19	-	-	-	-	-	15	-	12

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Fluorite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1855	33 05 51.9	71 21 14.5	Sandstone, siltstone, shale	-	-	14	-	16	14	-	10	-	10	-	-	13	-	13	-	-	10
1864	33 07 37.1	71 17 44.8	Diorite, granite, sandstone	3	-	6	-	20	14	5	-	15	10	-	-	10	-	-	4	4	12
1872	33 13 59.3	71 22 56.9	Sandstone, shale, claystone	-	-	10	-	16	15	10		10	15	5	-	-	-	4	10	-	5
1875	33 10 37.6	71 21 07.5	Sandstone, limestone, shale	3	-	12	5	20	-	-	-	12	7	10	-	10	-	12	12	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Fluorite	Garnet	Zircon	Hornblende	Tremolite	Tourmaline	Amphibole	Rutile	Chlorite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1880	33 09 34.4	71 25 08.6	Sandstone, limestone, shale, diorite	-	-	14	-	16	12	-	4	-	20	10	4	-	-	4	14	-	-
2042	33 13 27.4	71 24 57.7	Sandstone, limestone, claystone	11	-	-	-	15	-	5	-	12	18	-	10	-	-	15	15	-	10
2050	33 12 46.9	71 16 59.8	Limestone, sandstone, siltstone	-	2	16	-	20	14	-	-	-	16	14	12	-	-	8	-	-	-
2056	33 19 13.0	71 12 56.1	Limestone, clay stone, sandstone, siltstone	-	-	6	4	15	12	10	-	-	18	-	5	-	-	5	15	10	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Olivine	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Pyroxene	Magnetite	Epidote	Chlorite	Ilmenite	Rock fragments
1598	32 56 08.3	70 36 17.0	Sandstone, limestone, granite, granodiorite, shale, dolomite	-	-	-	-	18	15	-	-	-	17	12	-	12	-	4	12	-	10	-
1701	32 49 51.3	70 36 22.3	Limestone, sandstone, quartz, dolomitic limestone	-	-	-	10	16	12	10	-	12	10	-	8	-	-	8	14	-	-	-
1702	32 52 05.7	70 38 19.3	Limestone, sandstone, gabbro, dolomite, granodiorite	7	-	-	-	24	18	-	-	-	20	12	-	-	12	-	-	-	14	-
1704	32 53 43.2	70 31 28.4	Quartz, limestone, sandstone	-	-	12	2	20	15	-	-	12	16	-	4	-	-	-	-	-	8	11
1705	32 57 24.9	70 34 26.6	Granitic rocks, limestone, sandstone, gabbro	-	-	-	-	18	12	-	-	10	18	-	-	-	8	4	12	-	8	10

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)																
				Colors <0.3mm	Specks 0.3-0.5mm	Olivine	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Hornblende	Topaz	Pyroxene	Magnetite	Epidote	Chlorite	Ilmenite	Rock fragments
1715	33 00 23.7	70 36 28.7	granite, sandstone, limestone, shale, quartz	9	-	-	-	20	-	6	-	15	12	-	-	-	4	-	15	10	12	6
1716	33 00 32.2	70 40 02.9	Shale, limestone, sandstone, granite	0	0	5	12	22	15	-	-	14	12	-	-	-	-	8	-	-	12	-
1729	33 03 08.1	70 47 12.5	Sandstone, granite, dolomite, quartz, quartzite	0	-	-	-	18	14	-	-	10	10	10	-	-	6	8	12	-	12	-
1732	32 59 40.6	70 38 14.6	Quartzite, granite, sandstone, limestone, shale	13	-	10	-	20	12	-	-	-	10	-	-	14	-	12	12	-	10	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)														
				Colors <0.3mm	Specks 0.3-0.5mm	Hornblende	Apatite	Garnet	Zircon	Hematite	Tremolite	Tourmaline	Amphibole	Rutile	Topaz	Pyroxene	Magnetite	Epidote	Ilmenite	Rock Fragments
1736	32 58 27.4	70 50 48.3	Sandstone, shale, granite, quartzite	-	-	8	-	15	16	-	4	-	12	10	3	-	10	14	-	8
1743	33 00 04.8	70 43 45.5	Granite, quartzite, sandstone, limestone, shale	-	-	-	12	16	15	2	-	15	-	12	-	10	4	12	2	-
1766	32 36 45.1	71 03 52.2	Sandstone, granite, limestone	9	-	-	-	16	18	12	-	14	16	10	-	-	2		12	-
1772	32 36 38.0	71 10 04.0	Sandstone, limestone, shale, granite, quartz	-	-	-	14	18	16	-	10	-	12	12	4	-	4	10	-	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Hornblende	Magnetite	Epidote	Hematite	Ilmenite	Pyroxene
1912	32 23 04.5	70 50 39.6	Sandstone, granite, quartz	-	-	-	12	20	16	-	12	18	10	-	-	12	-	-	-	-	-
1915	32 23 17.4	70 52 03.3	Siltstone, granite, sandstone, limestone	8	-	-	14	20	15	-	-	20	-	-	-	2	-	5	10	14	-
1930	32 40 59.4	70 46 32.2	Limestone, sandstone, shale	-	-	8	14	22	-	-	15	25	-	-	-	-	-	16	-	-	-
1935	32 37 17.6	70 54 14.1	Sandstone, limestone, granite, quartz	2	-	-	-	14	15	-	15	16	-	-	12	-	7	12	-	9	-

Table: 4.2. Continued

S. No	Latitude	Longitude	Float study	Visible Gold grains		Heavy minerals visual estimate (%)															
				Colors <0.3mm	Specks 0.3-0.5mm	Fluorite	Apatite	Garnet	Zircon	Tremolite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Hornblende	Magnetite	Epidote	Hematite	Ilmenite	Pyroxene
1941	32 41 23.7	70 54 29.6	Granite, quartz, quartzite, limestone, sandstone	3	-	-	8	15	12	-	16	16	14	12	-	-	7	-	-	-	-
1943	32 47 06.2	70 51 05.1	Granite, sandstone, limestone	5	-	-	10	25	15	-	-	15	-	-	-	-	15	15	-	-	5
1944	32 49 49.7	70 49 16.1	Sandstone, granite, quartz, quartzite	-	-	-	12	15	10	8	-	10	10	10	-	-	25	-	-	-	-
1958	32 37 59.1	70 58 43.2	Sandstone, limestone, granite, quartz	-	-	-	10	15	20	-	-	14	10	-	-	-	5	14	-	12	-

Plate 5

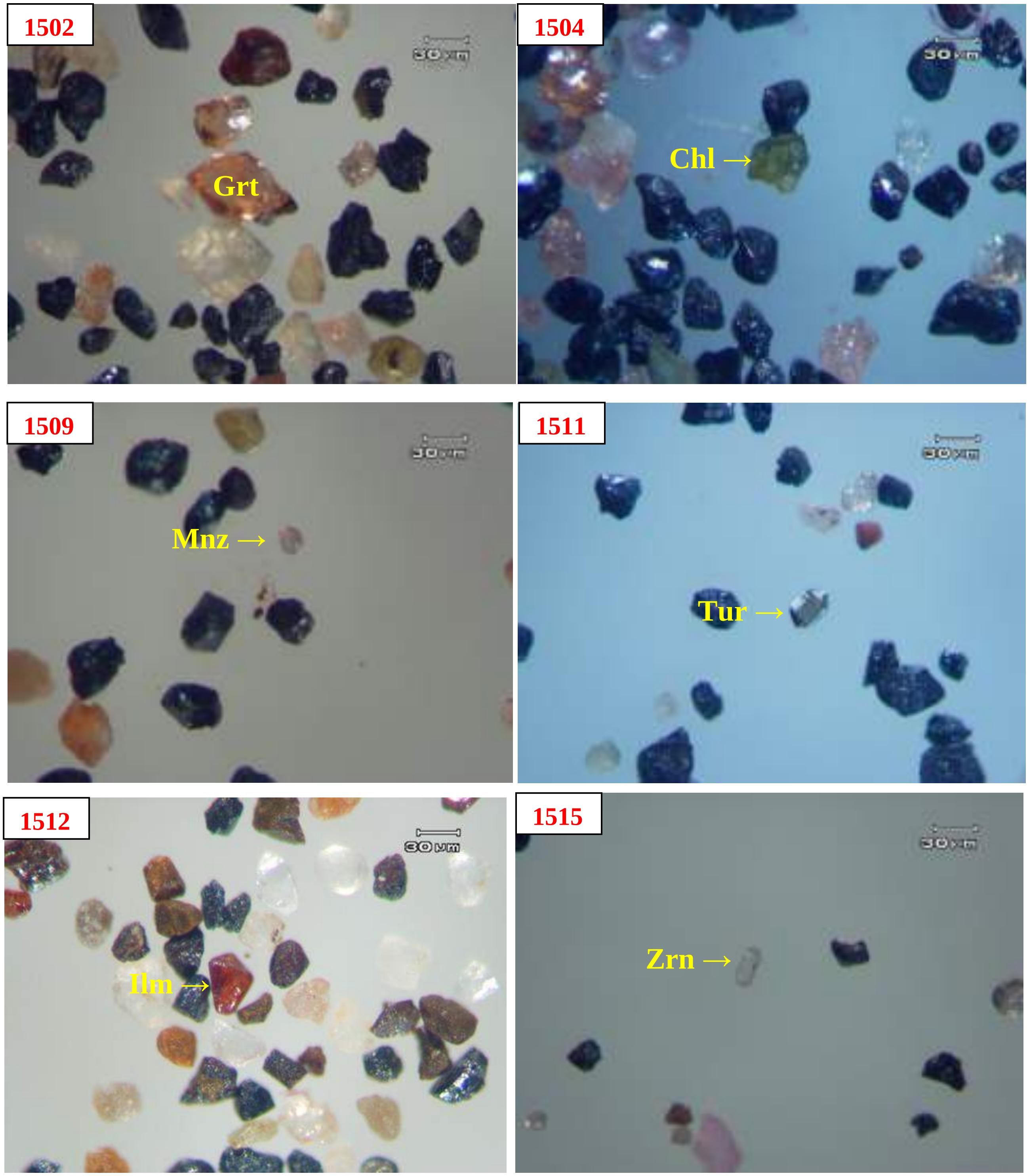


Plate 5. View of the Heavy minerals in the panned-concentrate samples from Kohat and Bannu divisions under stereomicroscope. Grt (garnet), Chl (chlorite), Tur (tourmaline), Mnz (monazite), Ilm (Ilmenite), Zrn (zircon).

Plate 6

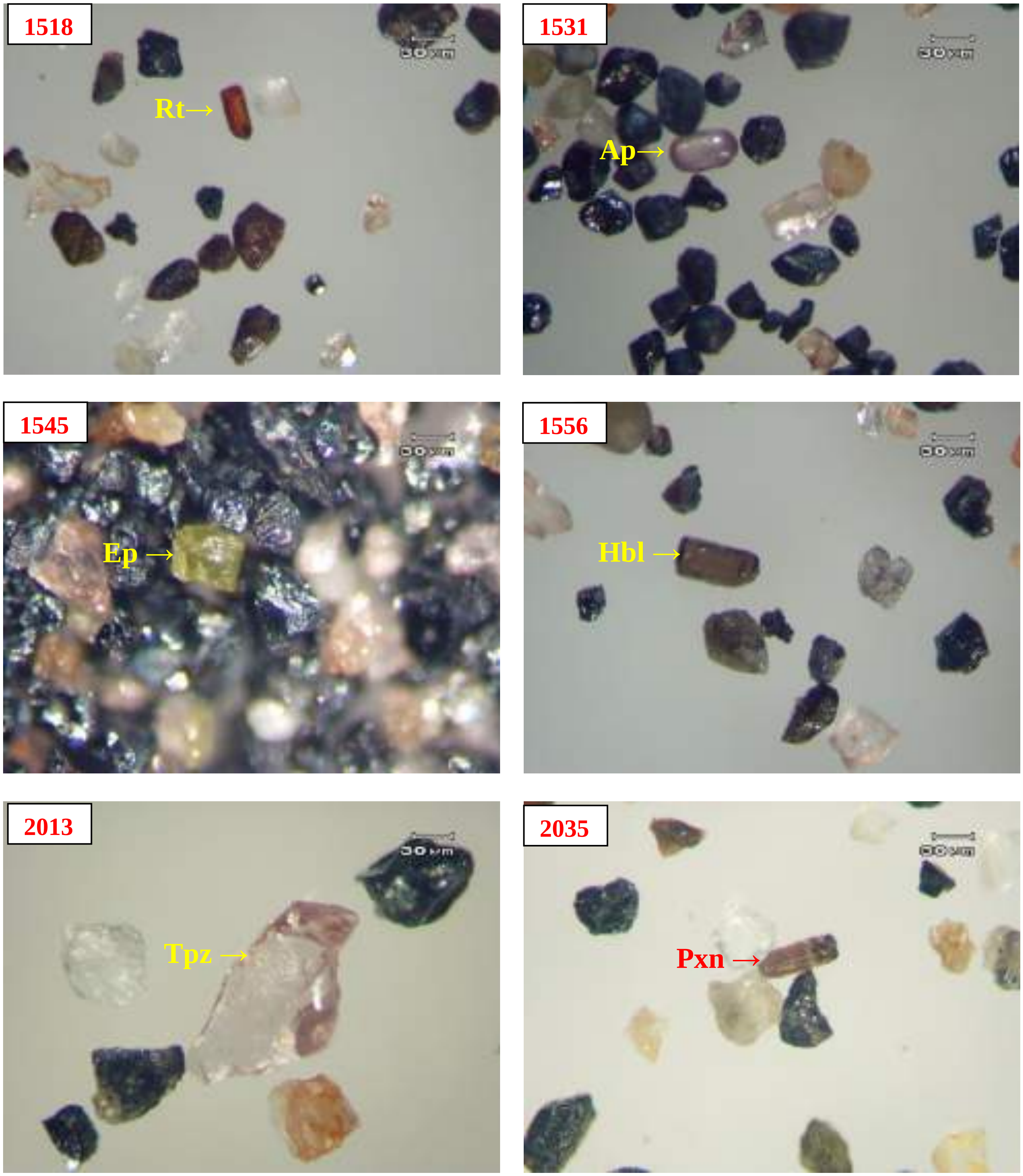


Plate 6. View of the Heavy minerals in the panned-concentrate samples from Kohat and Bannu divisions under stereomicroscope. Rt (rutile), Ap (apatite), Ep (epidote), Hbl (hornblende), Tpz (topaz), Pxn (pyroxene).

Plate 7

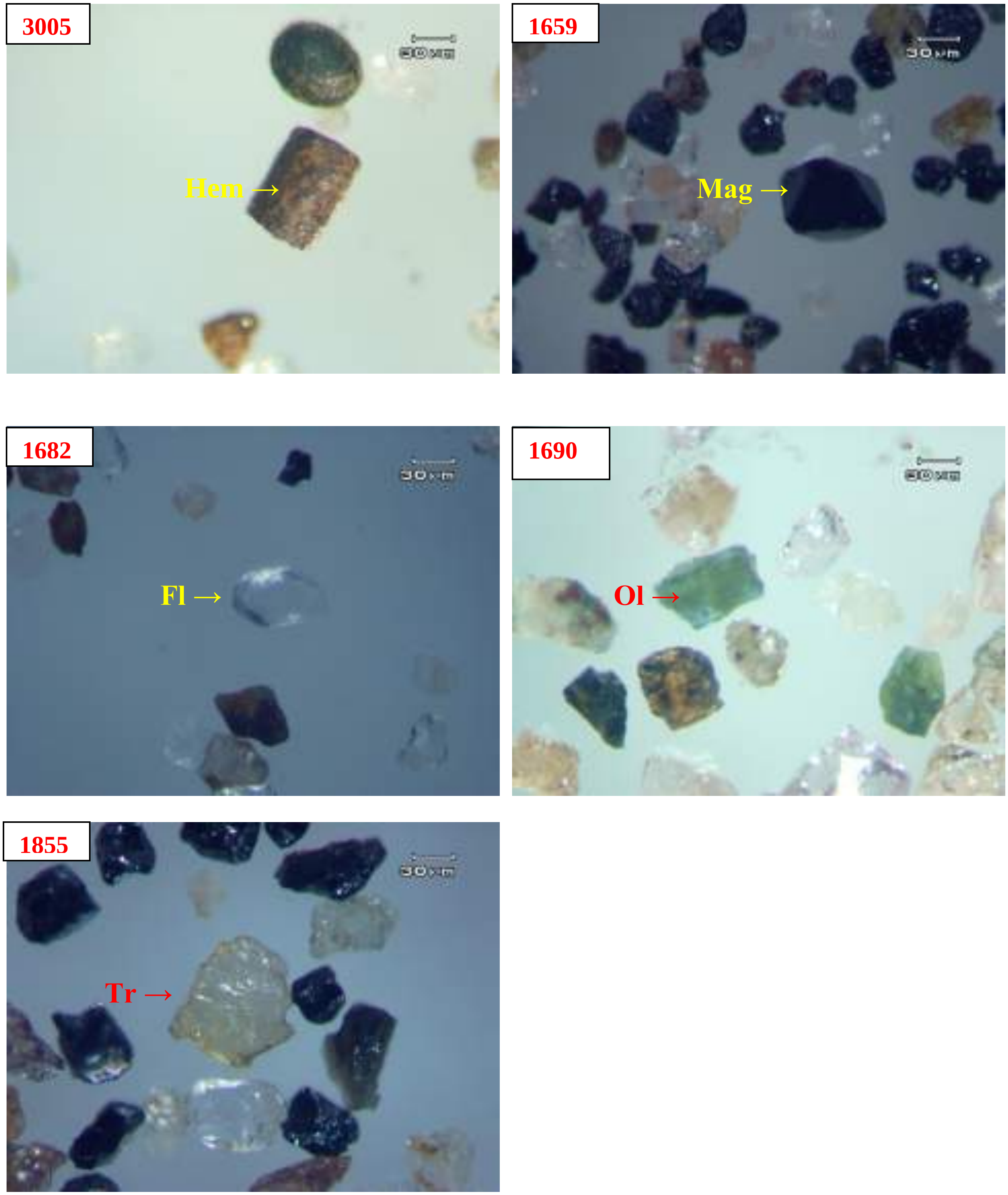


Plate 7. View of the Heavy minerals in the pan-concentrate samples from Kohat and Bannu divisions under stereomicroscope. Hem (hematite), Mag (magnetite), Fl (fluorite), Ol (olivine), Tr (tremolite).

Table: 4.3. Visible gold and heavy minerals studies of pan-concentrate samples from D.I.Khan Division.

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2111	32.24783	70.86972	2	-	-	35	10	5	10	-	-	-	-	-	15	10	-	-
2112	32.24580	70.87355	-	-	5	30	15	5	5	-	-	-	-	-	-	-	-	-
2113	32.24511	70.86941	-	-	-	25	20	5	10	-	-	-	-	-	15	-	-	5
2174	31.88727	70.94194	-	-	-	15	10	25	10	-	-	-	-	-	20	-	-	-
2206	31.73908	70.32822	-	-	-	20	10	-	-	10	-	-	-	-	10	20	-	-

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2210	31.70941	70.33936	-	-	-	15	10	5	5	-	-	-	-	-	15	15	5	5
2255	31.63472	70.82119	-	-	-	25	15	5	5	-	-	-	-	-	15	-	-	-
2256	31.55477	70.81655	-	-	5	20	15	10	15	-	-	-	-	-	15	5	-	-
2281	31.7525	70.93647	-	-	5	25	15	5	5	-	-	-	-	-	20	-	-	-
2282	31.37097	70.71875	-	-	5	20	35	10	5	-	-	-	-	-	10	5	-	-
2342	32.25205	70.88330	-	-	-	25	15	5	10	5	-	-	-	-	15	5	-	-

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2365	32.23497	70.74213	-	-	-	20	15	5	10	-	-	-	-	15	15	10	-	10
2369	31.87499	70.7128	-	-		25	15	5	15	-	-	-	-	5	10	10	-	15
2370	31.77292	70.70880	-	-		25	20	10	10	-	-	-	-	8	2	5	-	20
2371	31.98233	70.83753	-	-	-	30	15	20	10	-	-	-	-	10	5	-	-	10
2372	32.00853	70.97569	-	-	-	25	15	10	15	-	-	-	-	8	2	10	-	15
2373	32.25234	71.15786	-	-	-	30	15	-	15	-	-	-	-	10	5	10	-	15

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2375	31.72924	70.83087	-	-	-	20	15	10	15	-	-	-	-	15	5	10	-	15
2376	31.63701	70.76698	-	-	-	25	20	5	15	-	-	-	-	10	5	10	-	10
2377	31.67045	70.79493	-	-	-	20	25	10	5	-	-	-	-	12	15	5	-	8
2378	31.53368	70.74491	-	-	-	30	15	5	15	-	-	-	-	8	2	5	-	20
2379	31.58472	70.77709	-	-	-	25	20	5	10	-	-	-	-	12	3	5	-	20
2380	31.44388	70.74730	-	-	-	25	15	10	15	-	-	-	-	5	5	10	-	15

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2431	31.81144	70.92002	-	-	-	30	15	10	10	-	-	-	-	10	5	5	-	15
2432	31.77261	70.93372	-	-	-	25	10	15	12	-	-	-	-	12	3	8	-	15
2501	32.45423	70.5198	2	-	6	18	20	10	6	-	-	-	-	8	6	-	10	10
2502	32.45399	70.50906	-	-	-	16	18	12	14	-	-	-	-	6	14	-	6	14
2503	32.46251	70.49282	4	-	-	20	20	6	10	-	-	-	-	10	5	10	-	15

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2505	32.45391	70.53265	2	-	-	20	18	-	15	-	-	-	-	10	8	12	-	15
2515	32.31677	70.43136	-	-	-	20	15	15	15	5		-	-	10	3	10		7
2516	32.31764	70.43038	-	-	12	18	12	10	20	-	-		-	5	5	10		8
2517	32.3167	70.4325	-	-	12	20	10	10	15	2	-		-	10	8	8		5

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2519	32.284	70.4287	2	-	-	15	15	5	10	5		-	-	10	10	10		18
2538	32.43518	70.44341	-	-	-	20	15	-	15	5		-	-	10	10	10		15
2539	32.42612	70.45187	-	-	5	20	15	5	10	-		-		10	10	10		15
2547	32.28461	70.35082	-	-	-	16	14	-	20	10	-	-		10-	5	10	5	10
2548	32.27728	70.32365	-	-	-	20	18	14	26	-	-	-		12	5	5		-

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)													
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments
2549	32.27831	70.32586	-	-	12	22	18	15	15	10	-	-		8	-	-		-
2550	32.27455	70.37707	-	-	5	15	10	5	10	-	-	-		10-	10	25		10
2553	32.10298	70.28867	-	-	12	20	16	-	24	12		-	-	8	-	8	-	-
2560	32.13145	70.28398	-	-	-	20	14	16	28	2	-	-	-	8	4	10	-	-
2561	32.15311	70.25418	-	-	8	16	18	-	18	-	-	-		10	10	-	12	8

Table: 4.3. Continued

S.No	Latitude	Longitude	Visible Gold grains		Heavy minerals visual estimate (%)														
			Colors <0.3mm	Specks 0.3-0.5mm	Apatite	Garnet	Zircon	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Rock Fragments	Chlorite
2564	32.07553	70.32563	-	-	-	20	20	5	10	-	-	-	-	10-	10	10	-	10	-
2565	32.03432	70.19608	-	-	22	18	10	-	-	10	-	-	-	10	8	12	-	10	-
2567	32.13854	70.21137	-	-	12	20	22	-	15	10		-	-	8	-	3	10	-	-
2570	32.10856	70.15405	-	-	-	25	10	16	10	-		-	-	8	18	3	-	10	-
2572	32.14352	70.12108	-	-	-	-	20	-	10	12		-	-	10	16	8	-	14	10

Table: 4.4. Float, visible gold and heavy minerals studies of pan-concentrates from bulk samples of various Districts.

S.No	Latitude	Longitude	Float study	District	Visible Gold grains			Heavy minerals visual estimate (%)															
					Colors <0.3mm	Specks 0.3-0.5mm	Piece >0.5mm	Fluorite	Apatite	Garnet	Zircon	Goethite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite	Beryl
1110BK	34.011	72.55541	Gabbro, diorite, volcanic, Granite, granodiorite.	Swabi	20	6		-	-	20	15	10	12	12	-	5	-	5	13				8
1201BK	34.36831	71.69733	Garnet, gneiss, schist, gabbro, pyroxinite	Charsadda	12	1		-	-	16	4			12	8		12		18	12	8	10	
1216BK	33.87003	72.234861	Slate, limestone	Nowshehra	8	-		-	8	20	3		9	10	7		10		13	12		8	
1219BK	33.84714	72.232694	Slate, limestone	Nowshehra	-	-			10	18	15		10	16	5				8	11			5
1230BK	33.78553	72.014306	Quartzite, limestone	Nowshehra	-	-		-	12	18	4			14	10	8		9		14		5	

Table: 4.4. Continued

S.No	Latitude	Longitude	Float study	District	Visible Gold grains			Heavy minerals visual estimate (%)														
					Colors <0.3mm	Specks 0.3-0.5mm	Piece >0.5mm	Fluorite	Apatite	Garnet	Zircon	Chlorite	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1234BK	33.99408	72.10972	Granite, gneiss, braccia, slate, quartz, schist	Nowshehra	17	5		-	7	14	13		10	14			16			12		10
1238BK	33.98775	72.09580	Slate, granite, limestone, quartzite	Nowshehra	11	5		-	12	20	14		11	13			12	7		11		
1240BK	33.96369	72.157667	Granite, garnet bearing schist, slate, limestone, sandstone, quartz	Nowshehra	11	12				21	13	5		14	11		13		10	14		
1245BK	33.99156	72.138667	Granite, quartzite, slate, limestone	Nowshehra	10	6	1			22	15			14			15		10	13	12	
1247BK	33.9865	72.143389	Granite, limestone, slate, quartzite, braccia, schist	Nowshehra	11	6	1	9	3	17	14		8	14		5	10		8	11		

Table: 4.4. Continued

S.No	Latitude	Longitude	Float study	District	Visible Gold grains			Heavy minerals visual estimate (%)														
					Colors <0.3mm	Specks 0.3-0.5mm	Piece >0.5mm	Fluorite	Apatite	Garnet	Zircon	Hornblende	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
1604BK	33.14442	71.15080	Sandstone, gypsum, shale, clay	Karak	24	3		-	13	19	15			15	10		8			16		
1836BK	33.08053	71.09547	Sandstone, quartz, shale.	Karak	21	2			5	20	15		7	16	10					12		10
2007BK	33.20572	71.578583	Sandstone, granite, limestone, shale.	Kohat	13	1			4	16	10		9	20	6		3		10	14		8
2013BK	33.19772	71.598972	Granite, quartz, quartzite, sandstone, limestone	Kohat	12	2			10	17	10	9	13	22						14		4
2027BK	33.29842	71.448778	Sandstone, limestone, shale, claystone	Kohat	24	-			11	18	14	8	12	20	5					12		

Table: 4.4. Continued

S.No	Latitude	Longitude	Float study	District	Visible Gold grains			Heavy minerals visual estimate (%)														
					Colors <0.3mm	Specks 0.3-0.5mm	Piece >0.5mm	Fluorite	Apatite	Garnet	Zircon	Hornblende	Tourmaline	Amphibole	Rutile	Monazite	Topaz	Pyroxene	Magnetite	Epidote	Hematite	Ilmenite
2050BK	33.21303	71.28327	Limestone, sandstone, siltstone	Karak	15	3		-	8	18	14	5	10	17	7					12		8

Plate 8

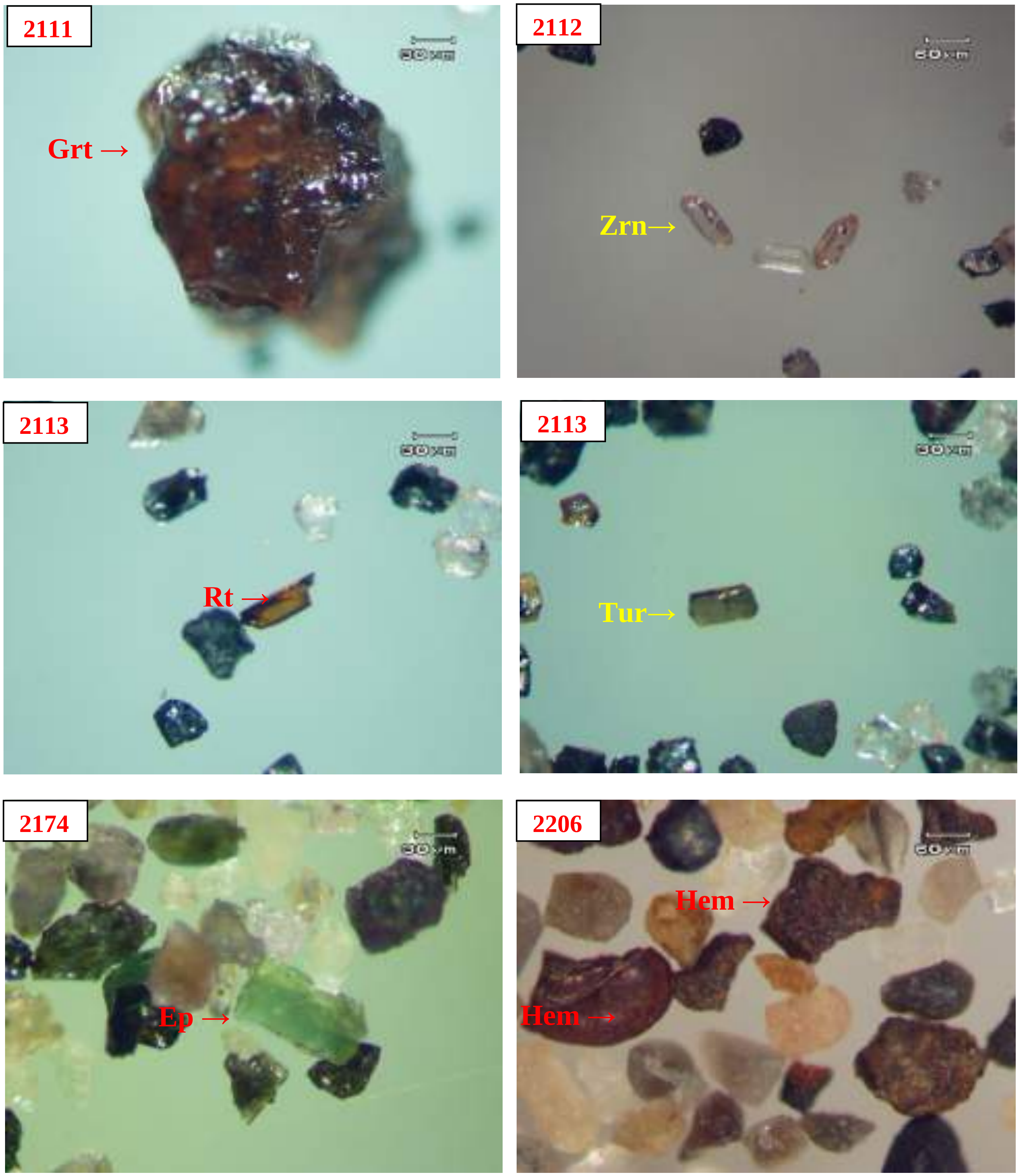


Plate 8. View of the heavy minerals in the pan-concentrate samples from D. I. Khan Division under stereomicroscope Grt (Garnet), Zrn (Zircon), Rt (Rutile), Tur (Tourmaline), Ep (Epidote),Hem (Hematite),.

Plate 9

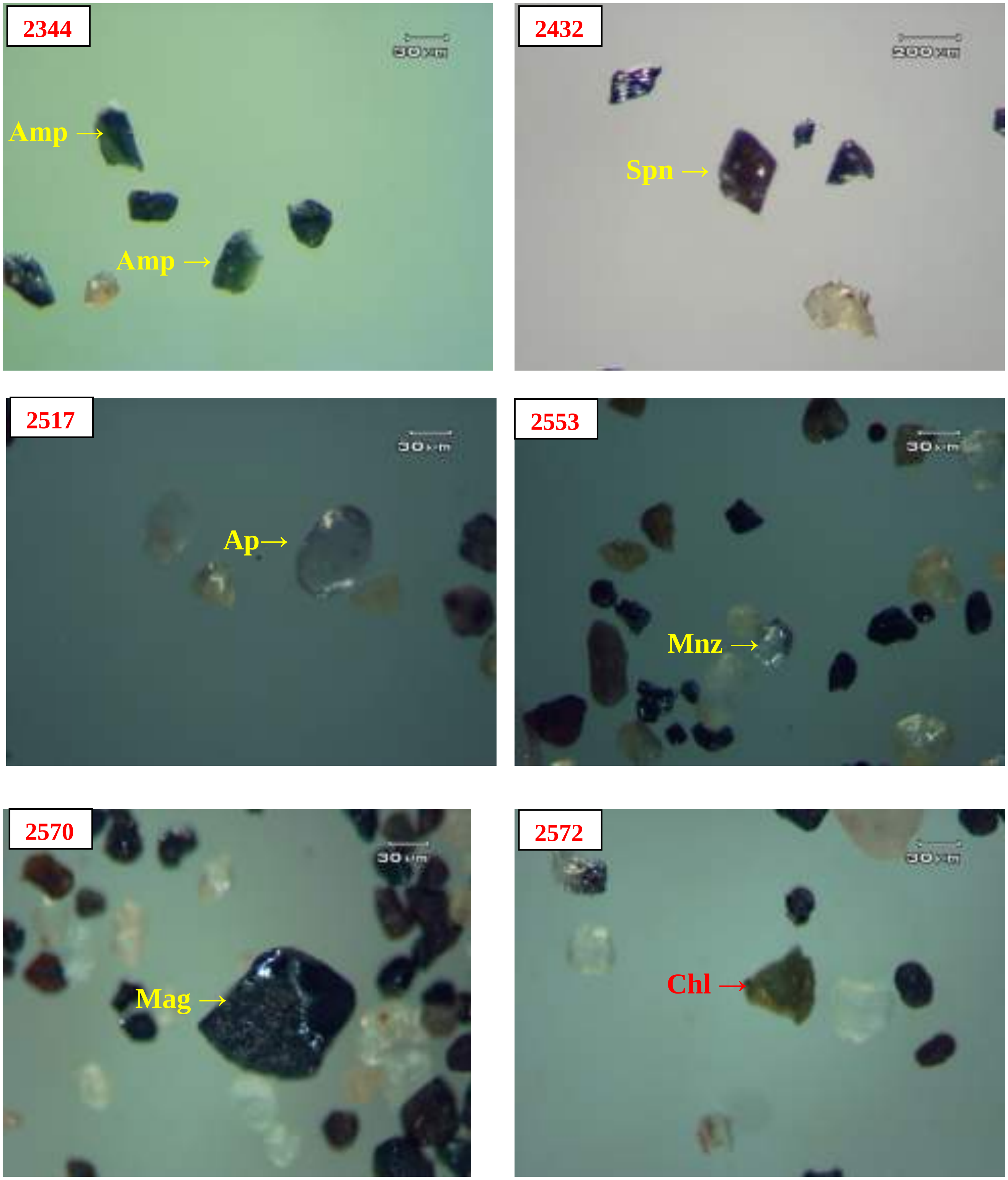


Plate9. View of the Heavy minerals in the pan-concentrate samples from D.I. Khan Division under stereomicroscope. Amp (Amphibole), Spn (Sphene), Ap (Apatite), Mnz (Monazite), Mag (Magnetite), Chl (Chlorite)

4.5. Morphological Features of Gold Grains

The gold grains especially specks collected in the pan-concentrates from the project area have been studied under the Scanning Electron microscope for morphological and textural features. It has been found that most of the gold grains have morphological features like roundness, flatness and flaky. These have porous appearance with groves and pits on the surface and folding along the margins. There is no mineral inclusion found in the studied gold grains. All these features have been show in the Plate10. The deformation and the highly eroded nature of the gold grains suggest that these have been transported from a distal source of hundreds of kilometers away.

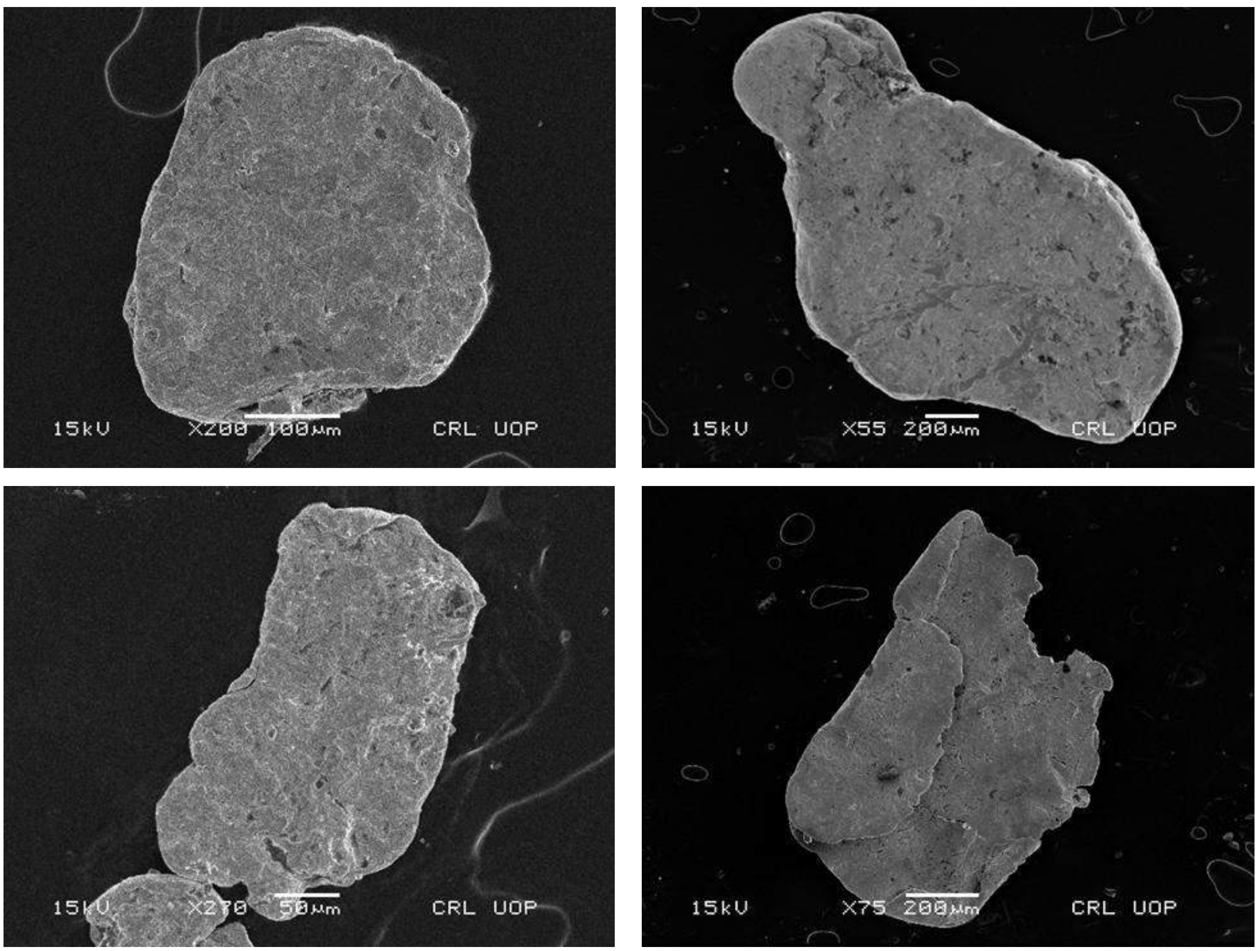


Plate 10. Scanning Electron Microscope images of representative gold grains.

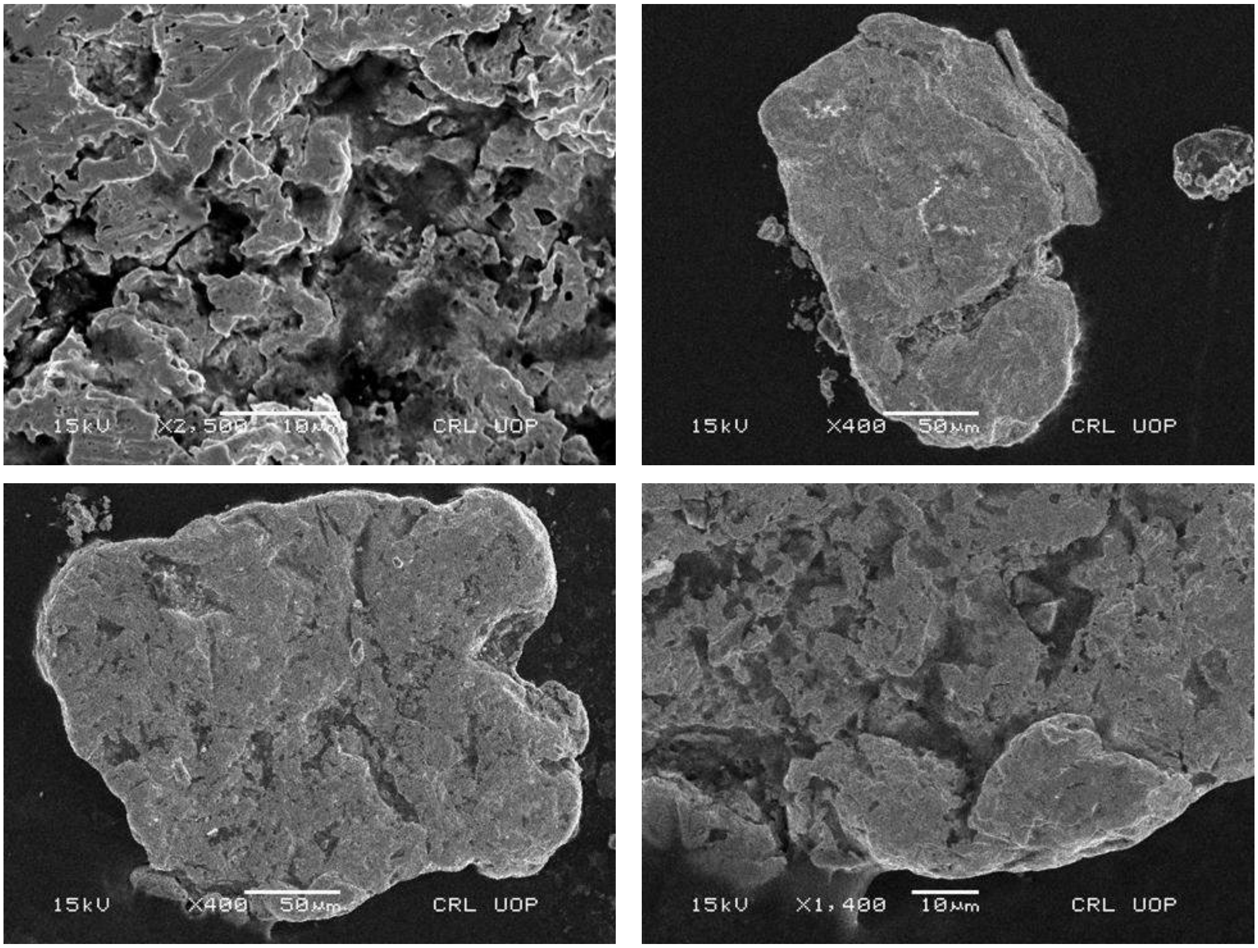


Plate 10. Continue

4.6. Petrographic study of the selected rock samples from Peshawar Basin

Petrographic study of the rock samples of an area can give valuable information about their mineralogy, petrogenesis and texture. Petrographic explanations initiate with the field notes at the outcrop and consist of megascopic description of hand specimens. However, the most imperative means for the petrographer is the petrographic microscope. The detailed analysis of minerals by optical mineralogy in thin section and the micro-texture and structure are vital to understanding the origin of the rock.

Petrographic study of the host rock samples collected from different sites within the Peshawar Basin (Peshawar, Charsadda, Nowshera, Swabi and Mardan districts) was conducted in the petrographic laboratory of the National Centre of Excellence, in Geology, University of Peshawar. Sixteen representative samples were selected and their thin sections were prepared. These thin sections were studied in detail under the Nikon polarized light microscope. The constituent minerals were identified and their relative abundance was determined on the basis of visual estimation. Grain sizes, shapes and their mutual relationship were determined. The rock samples were classified and named on the basis of their mineralogy and texture. Description of the petrographic study of the individual samples has been given below.

Sample No: 1144

Location: Shahbazgarhi area, Swabi

Grid reference: N 34 14 33.5, E 72, 14, 27.2

Brief Description: In hand specimen the sample is whitish brown in color and appears to have porphyritic texture (large phenocrysts embedded in the fine grained ground mass). Microscopic observation confirms the presence of porphyritic texture. Quartz (Plate 11), alkali feldspar, plagioclase, biotite and hornblende were identified in the sample microscopically on the basis of their optical properties. Quartz, alkali feldspar and plagioclase are the dominant mineral phases occurring as phenocrysts. The fine grained cryptocrystalline ground mass covers maximum part of the thin section.

Model composition:

Minerals	Percentage
Quartz	13
Alkali feldspar	10
Plagioclase	06
Biotite	01
Hornblende	Tr
Ground mass	70
Total	**100**

Rock type identified: **Rhyolite**

Sample No: 1147

Location: Teacher Colony along main Shahbazgarhi - Rustam Road Swabi.

Grid reference: N 34 14 06.2, E 72 10 12.6

Brief Description: In hand specimen the sample is greyish white in color with porphyritic texture. The dominant minerals visible under microscope are usually quartz, alkali feldspar (Plate 12) and plagioclase occurring in the decreasing order of abundance as phenocrysts. Amphibole is also present in the thin section in minor amount. The fine grained ground mass is cryptocrystalline in nature.

Model composition:

Minerals	Percentage
Quartz	12
Alkali feldspar	09
Plagioclase	04
Amphibole	Tr
Ground mass	75
Total	**100**

Rock type identified: **Rhyolite**

Sample No: 1156

Location: Along Dag Ismail Khel and Safari village, Nowshera.

Grid reference: N 33 49 56.8, E 71 51 10.0

Brief Description: In hand specimen it is light grey to gray in color, fine grained and easily attacked by hydrochloric acid (HCl). The thin section study reveals that the main minerals present in this sample are of quartz, calcite (Plate 13) and opaque minerals.

Model composition:

Minerals	Percentage
Quartz	35
Calcite	60
Opaque	03
Clay	02
Total	**100**

Rock type identified: Siliceous Limestone

Sample No: 1160

Location: Along main Mardan-Nowshera Road at Polytechnic College.

Grid reference: N 34 01 48.2, E 71 59 55.0

Description: The rock sample is fine grained, pinkish white in color and is showing vigorous reaction with HCl. Calcite (Plate 14) and quartz grains are present as the dominant minerals in thin section. Chlorite grains are also present but in minor amount. The grain boundaries between calcite grainsare filled with iron oxide of brown color.

Model composition:

Minerals	Percentage
Calcite	55
Quartz	43
Chlorite	02
Total	**100**

Rock type identified: Crystalline limestone

Sample No: 1173

Location: Payo Pull village, Jamrud, Warsak Road Peshawar.

Grid reference: N 34 07 38.7, E 71 24 51.7

The sample appears fine grained and Greyish white in hand specimen. It is clear from the thin section study that the rock contains quartz, alkali feldspar (Plate 15), plagioclase and amphibole minerals. The grains are subhedral to anhedral in shape. The sample is from a granite body which appears to be an extension of the Warsak Alkaline Granite. Kempe & Jan (1970, 1980) correlated these granites with peralkaline granites of Shewa-Shabazgarhi, Tarbela, and Ambela, and suggested that they formed an integral part of a Tertiary alkaline province located in and around the Peshawar plain.

Model composition:

Minerals	**Percentage**
Quartz	48
Plagioclase	25
Alkali feldspar	25
Amphibole	02
Total	**100**

Rock type identified: **Granite**

Sample No: 1185

Location: Bandaire area, Gadoon, Swabi.

Grid reference: N 34 05 45.0, E 72 39 30.1

Description: In hand specimen the sample is pinkish white in colour and medium to coarse grained. It shows no reaction with HCl. In thin section the constituent minerals have preferred orientation with schistose texture. In hand specimen it gives soapy feel and can be scratched with the finger nail. Talc and clinochlore (chlorite) are the dominant minerals phases present. Calcite, tremolite (Plate 16) and black opaque minerals are also present in this sample in minor amount. The presence of the mineral talc and clinochlore has also been confirmed with the X-Rays Diffraction (XRD) analysis of the powdered rock sample.

Model composition:

Minerals	Percentage
Talc	45
Clinochlore (Chlorite)	25
Calcite	10
Tremolite	10
Opaque minerals	10
Total	**100**

Rock type identified: **Talc Carbonate Schist**

Sample No: 1192

Location: Along Gandaf-Besak Road, Swabi.

Grid reference: N 34 08 25.6, E 72 40 49.6

Description: In hand specimen the sample is light grey in color and fine grained. Minerals identified in this thin section are of plagioclase, garnet, quartz (Plate17), feldspar and rock fragments. Grains in this sample are sub-rounded to sub angular and show well sorting. Iron oxide is present as a cementing material between grains boundaries along fractures.

Model composition:

Minerals	Percentage
Quartz	79
Feldspar	10
Rock fragments	10
Garnet	Tr
Ores	Tr
Plagioclase	01
Total	**100**

Rock type identified: **Quartz Arenite**

Sample No: 1203

Location: Prang Ghar outcrop, Charsadda, Mohmand Agency.

Grid reference: N 34 24 06.9, E 71 38 26.1

Description: In hand specimen the sample is light green in color and medium to fine grained. In this thin section the rock is displaying phaneritic texture. Pyroxene (both clinopyroxene (Plate 18) and orthopyroxene) is the essential mineral constituent in the studied sample. Other minerals identified are of olivine, serpentine and opaque ores. The sample seems to have been taken from the Dargai Klippe.

Model composition:

Minerals	**Percentage**
Orthopyroxene	20
Clinopyroxene	45
Olivine	05
Ores	05
Serpentine	25
Total	**100**

Rock type identified: **Altered Pyroxenite**

Sample No: 1205

Location: Prang Ghar, Charsadda, Mohmand Agency.

Grid reference: N 34 24 01.2 E 71 38 24.4

Description: In hand specimen the sample is black in color, very dense and fine grained rock. The main mineral present in this rock is chromite with minor serpentine (Plate 19). In thin section mineral grains are anhedral in shape. Fractures present along grains boundaries are filled with iron oxide of brown color. The sample seems to have been taken from the Dargai Melange Zone.

Model composition:

Minerals	**Percentage**
Chromite	90

Serpentine	10
Total	**100**

Rock type identified: **Chromite Ore**

Sample No: 1217

Location: Slate outcrop near Darwazai village Nowshehra.

Grid reference: N 33 52 12.8 E 72 14 07.3

Description: In hand specimen the sample is black in color and extremely fine grained. Petrographic study under microscope reveals that the rock is showing slaty texture and displays preferred orientation of micaceous minerals. Muscovite, quartz (Plate 20) and hematite are the dominant mineral phases identified.

Model composition:

Minerals	**Percentage**
Muscovite	60
Quartz	30
Ores	05
Fine clay	05
Total	**100**

Rock type identified: **Slate**

Sample No: 1273

Location: Pirono village, Nowshera.

Grid reference: N 33 44 31.8 E 71 58 52.2

Description: In hand specimen the sample is dark grey in color, medium to fine grained. It shows vigorous reaction with HCl. Fossils present in the sample can be seen both with the naked eyes as well as under microscope. The thin section under microscope shows that quartz and calcite are the main minerals present in the sample. Calcite is present as frame work grains as well as in the form of spary calcite cement between the quartz grains. Fractures stained with iron oxide are quite common.

Calcareous bioclasts (Plate 21) are also frequently present in the thin section under microscope.

Model composition:

Minerals	Percentage
Calcite	70
Quartz	25
Ores	02
Clay	03
Total	**100**

Rock type identified: Fossiliferous Limestone

Sample No: 1305

Location: Along Beqo Jando Road at Salag Dara village, Swabi.

Grid reference: N 34 08 40.3 E 72 33 18.7

Description: The sample is greyish white in color and medium grained in hand specimen. In thin section the grains of the sample are sub-angular to sub-rounded. Main minerals are quartz (Plate 22), biotite and ore minerals with minor amount of calcite (as cementing material) and clay. Quartz grains appear fused together and are bounded with each other with iron oxide cement.

Model composition:

Minerals	Percentage
Quartz	85
Biotite	07
Ores	05
Clay	03
Total	**100**

Rock type identified: Quartzite

Sample No: 1310

Location: Along Shahbazgarhi-Rustam Road, Teacher Colony, Swabi.

Grid reference: N 34 14 09.0 E 72 10 17.3

Description: In hand specimen the sample is greyish white and fine grained. In thin section it is showing porphyritic texture. Under microscope the sample is showing preferred orientation of micaceous grains. Phenocrysts of quartz, alkali feldspar (Plate 23) and plagioclase are present as the dominant mineral phases. Muscovite and biotite are present in minor amount. The ground mass is fine grained and cryptocrystalline.

Model composition:

Minerals	Percentage
Quartz	10
Alkali feldspar	07
Plagioclase	03
Mica	Tr
Ground mass	80
Total	**100**

Rock type identified: **Rhyolite**

Sample No: 1338

Location: Along Khukule Gate, Shahbazgarhi, Swabi.

Grid reference: N 34 13 27.9 E 72 09 56.0

Description: In hand specimen the sample is light grey to white in color and medium grained. In thin section the rock sample is showing glomero-porphyritic texture (large phenocrysts embedded in fine grained felsic ground mass (Plate24). Microscopic study of the thin section of the sample shows that alkali feldspar is present in the tabular form. Large quartz grains are present as phenocrysts. Muscovite and biotite are present in trace amount.

Model composition:

Minerals	Percentage
Quartz	10
Alkali feldspar	15

Plagioclase	04
Mica	01
Ores	02
Ground mass	68
Total	**100**

Rock type identified: **Rhyolite**

Sample No: 1342

Location: Ambar village, Swabi.

Grid reference: N 34 02 53.1 E 72 24 53.3

Description: The rock sample is light to dark grey in color and very fine grained in hand specimen. Mineral grains in thin section are well sorted medium to fine grained. Deformed and elongated quartz (Plate 25) and alkali feldspar grains are present. The amount of quartz is high as compared to alkali feldspar.

Model composition:

Minerals	**Percentage**
Quartz	80
Alkali feldspar	20
Total	**100**

Rock type identified: Feldspathic Quartzite

Sample No: 1372

Location: Jamal Garhi, Mardan.

Grid reference: N 34 19 13.4 E 72 03 37.1

Description: The sample in hand specimen is whitish brown and medium grained. The sample is soft with occasional banding and effervesces with HCl. The main mineral is usually calcite (Plate 26) with lesser amount of quartz. Calcite and quartz grains are well crystalline indicating that the rock sample has been metamorphosed. Calcite occurs in the form of spary calcite cement as well as frame work grains.

Model composition:

Minerals	Percentage
Calcite	80
Quartz	15
Ores	02
Clay	03
Total	**100**

Rock type identified: **Marble**

Plate11. (A= cross polarized light, B= plane polarized light): Photomicrograph of rhyolite showing quartz (Qz) phenocryst embedded in the fine grained ground mass (Sample No. 1144).

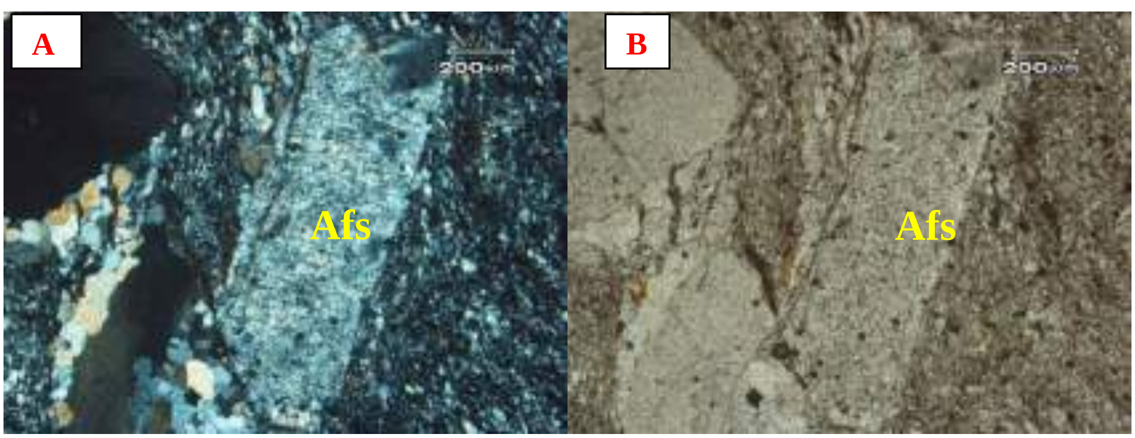


Plate12. (A= cross polarized light, B= plane polarized light): Photomicrograph of rhyolite showing alkali feldspar (Afs) phenocryst embedded in the fine grained cryptocrystalline ground mass (Sample No: 1147).

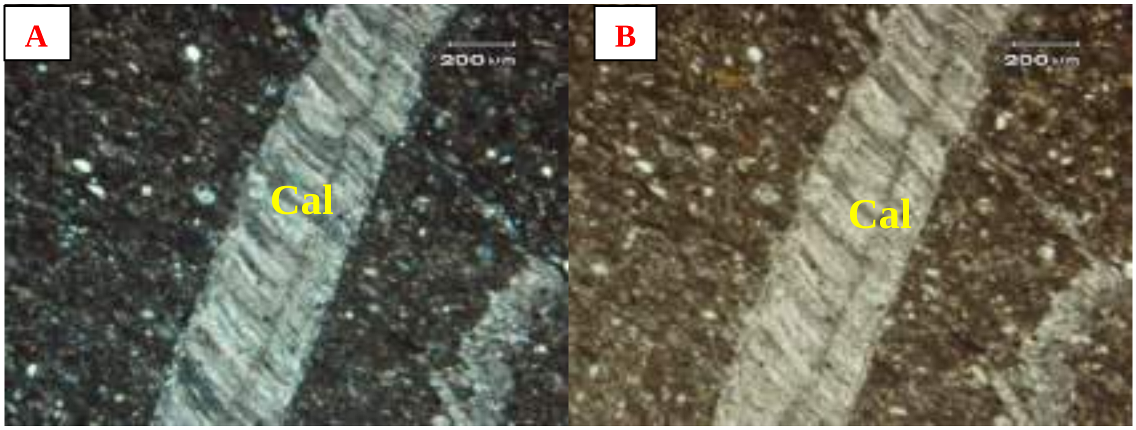


Plate13. (A= cross polarized light, B= plane polarized light): Photomicrograph of siliceous limestone showing fracture filled with calcite (Cal) (Sample No: 1156).

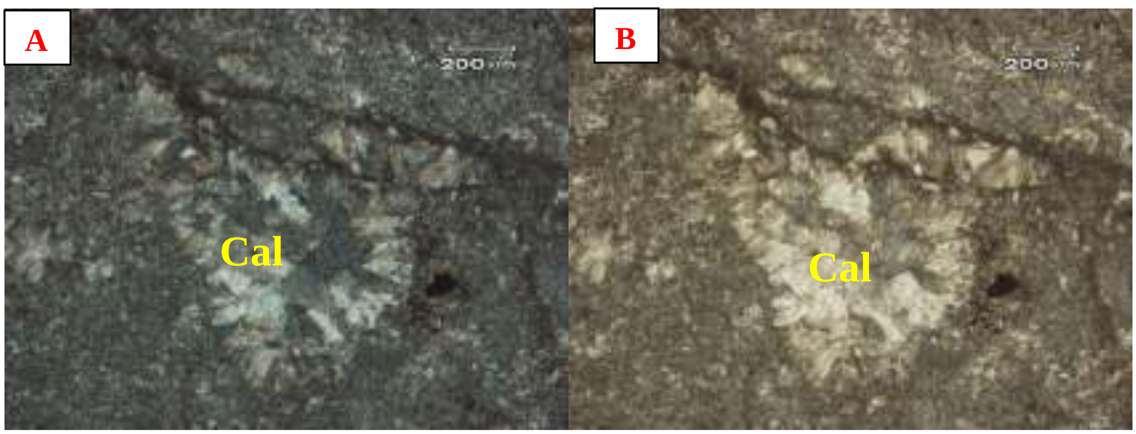


Plate 14. (A= cross polarized light, B= plane polarized light): Photomicrograph of limestone showing calcite (Cal) which is present in the form of clastic grain (Sample No: 1160).

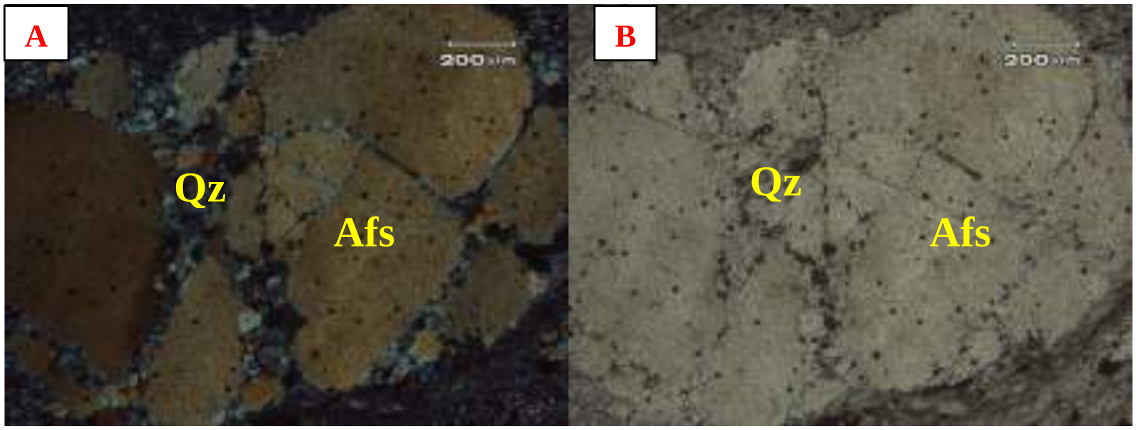


Plate15. (A= cross polarized light, B= plane polarized light):

Photomicrograph of granite showing fractured alkali feldspar (Afs) with the fractures filled with quartz (Qz) grains (Sample No: 1173).

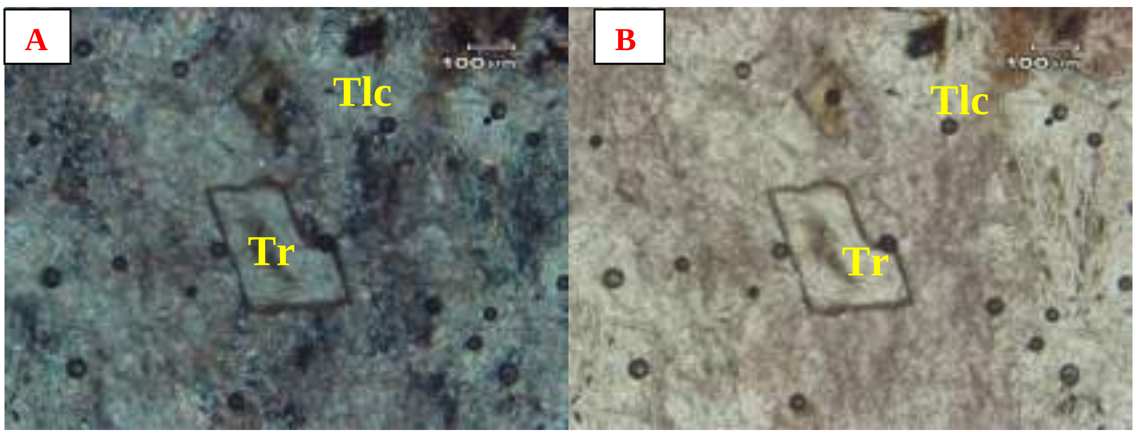


Plate16. (A= cross polarized light, B= plane polarized light):

Photomicrograph of talc schist showing talc (Tlc) and tremolite (Tr) minerals (Sample No: 1185).

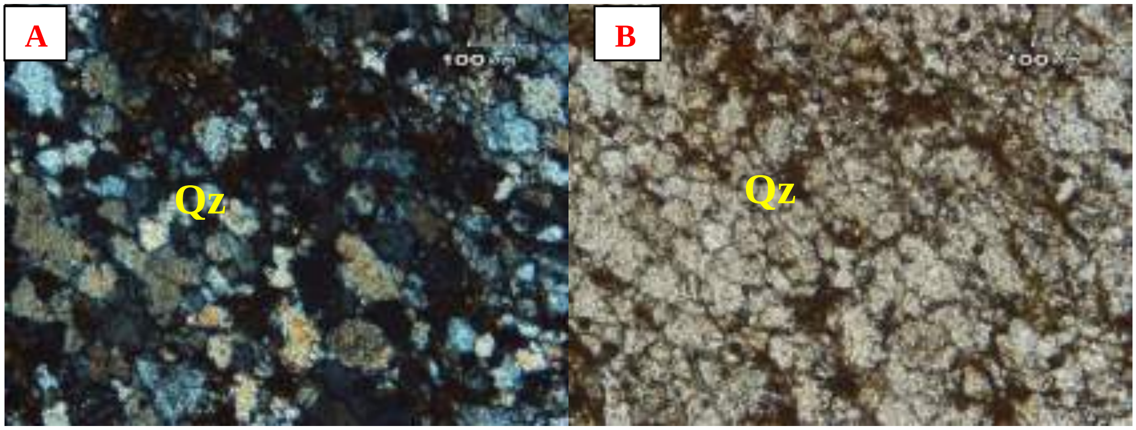


Plate17. (A= cross polarized light, B= plane polarized light):

Photomicrograph of quartz arenite showing iron oxide present as a cementing material along grain boundaries of quartz (Qz) grains (Sample No: 1192).

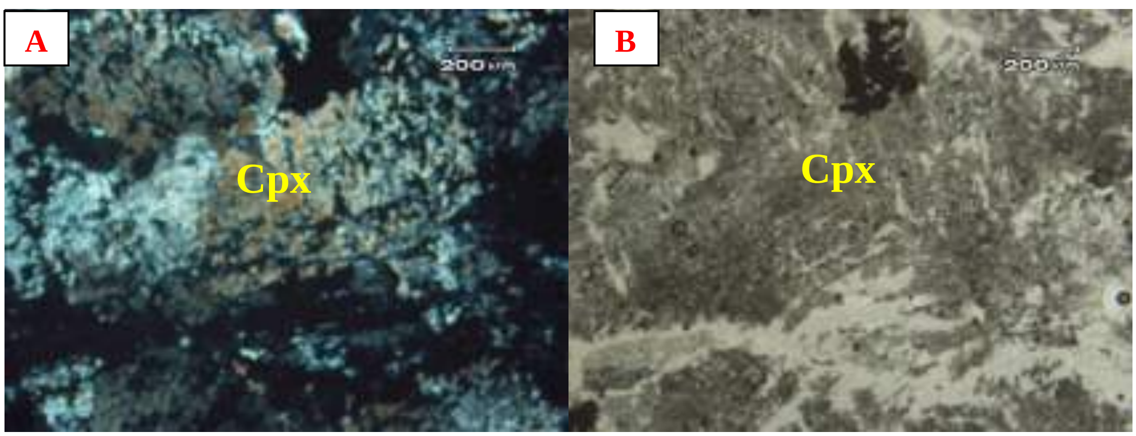


Plate18. (A= cross polarized light, B= plane polarized light):

Photomicrograph of altered pyroxenite showing clinopyroxene (Cpx) grains (Sample No: 1203).

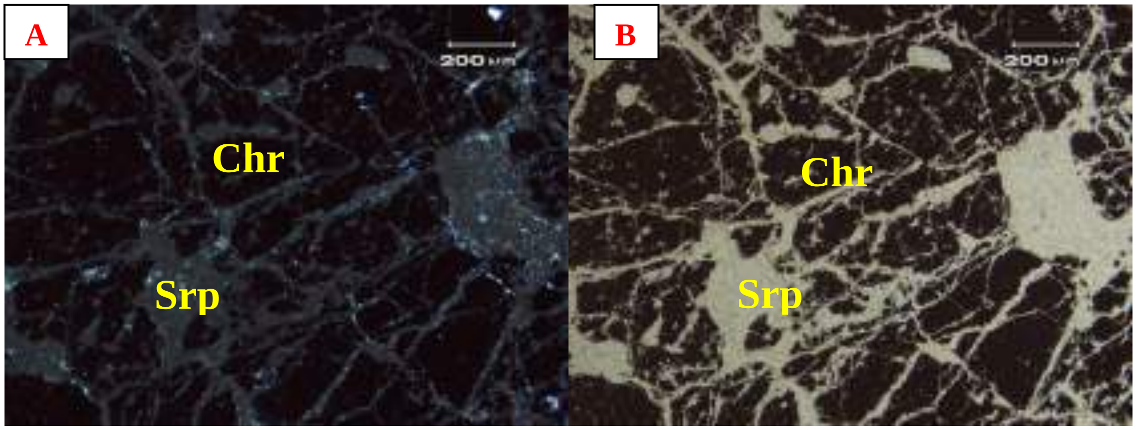


Plate19. (A= cross polarized light, B= plane polarized light):

Photomicrograph of chromite ore showing subhedral to anhedral grains of chromite (Chr) mineral while serpentine (Srp) is present along fractures in the chromite grains (Sample No: 1205).

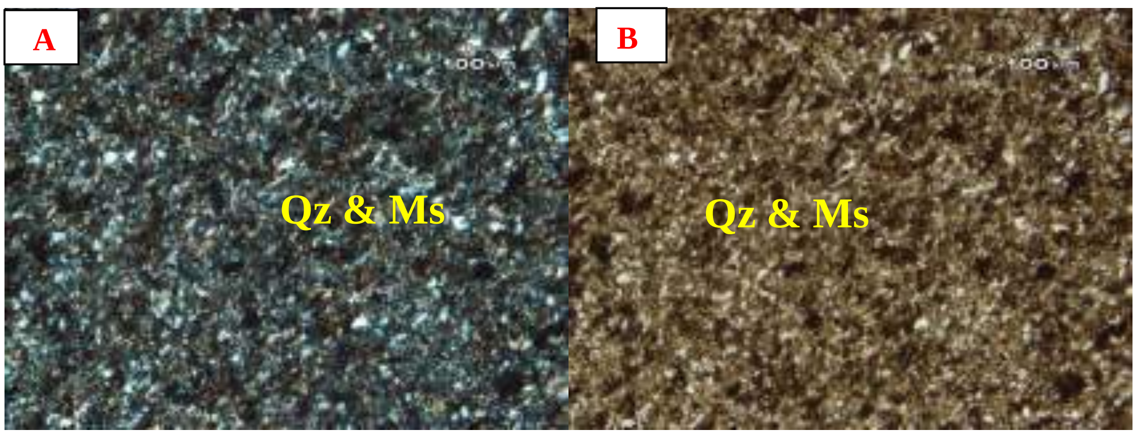


Plate20. (A= cross polarized light, B= plane polarized light):

Photomicrograph of slate showing preferred orientation displayed by muscovite (Ms) and quartz (Qz) grains (Sample No: 1217).

Plate 21. (A= cross polarized light, B= plane polarized light): Photomicrograph of fossiliferous limestone showing a foraminifera (Sample No: 1273).

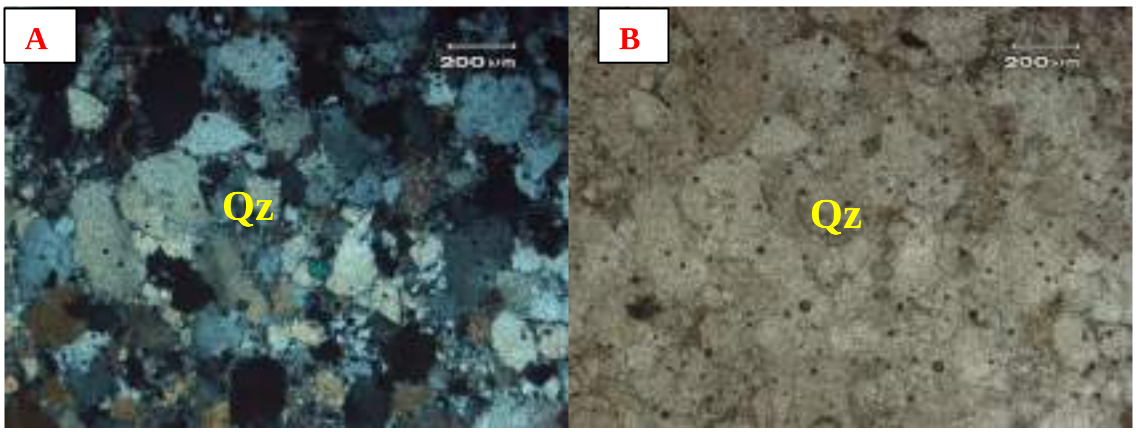


Plate22. (A= cross polarized light, B= plane polarized light): Photomicrograph of quartzite showing sub-angular to sub-rounded quartz (Qz) grains (Sample No: 1305**).**

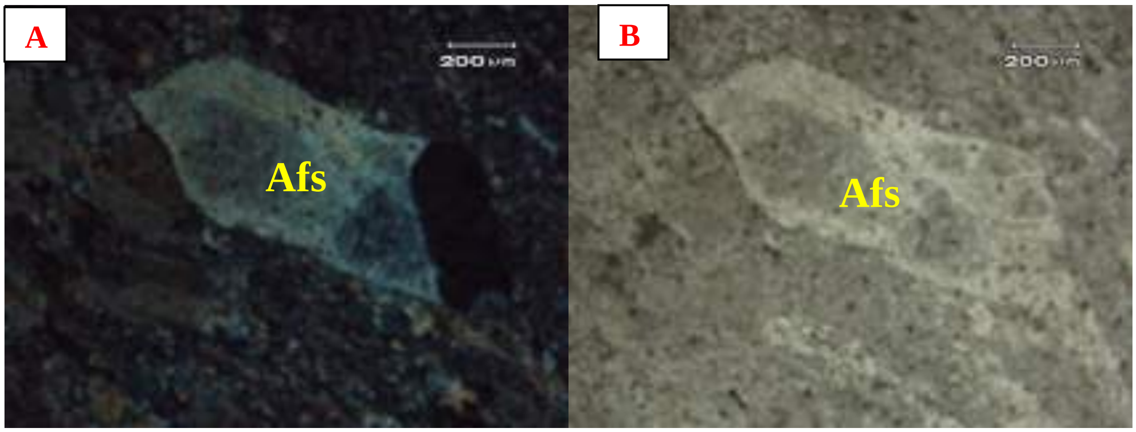


Plate23. (A= cross polarized light, B= plane polarized light): Photomicrograph of rhyolite showing phenocryst of alkali feldspar (Afs) embedded in fine grained ground mass (Sample No: 1310).

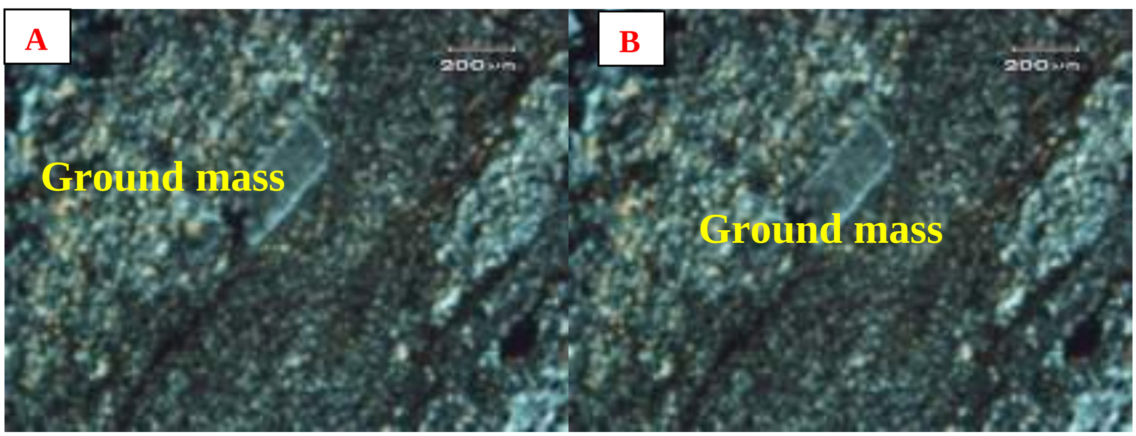


Plate24. (A= cross polarized light, B= plane polarized light): Photomicrograph of rhyolite showing fine grained felsic ground mass **(**Sample No: 1338)

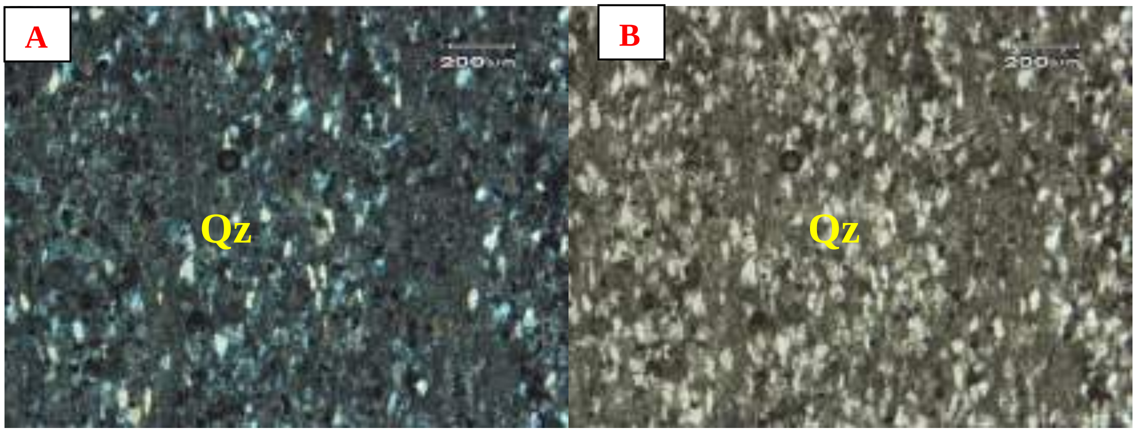


Plate25. (A= cross polarized light, B= plane polarized light): Photomicrograph of feldspathic quartzite showing deformed and elongated quartz (Qz) grains (Sample No: 1342).

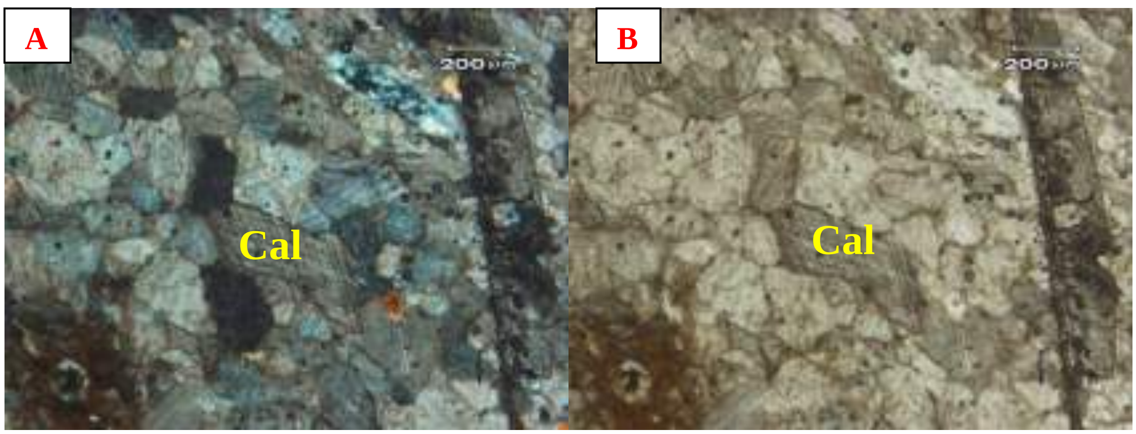


Plate26. (A= cross polarized light, B= plane polarized light): Photomicrograph of marble showing frame work grains of mineral calcite (Cal) (Sample No: 1372).

4.7. Petrography of the selected rock samples from Kohat Sub-Basin

Petrographic study of the sedimentary rock samples collected from different sites within the Kohat Sub-Basin has been discussed in this section. The technique of petrography is an important tool for the evaluation of provenance and depositional environment of the sedimentary rocks. Outcrop descriptions from the field provide the basis for petrography. The detail analysis of modal composition, fabric and allochemical constituents under microscope plays a vital role in the understanding of the origin of sedimentary rocks. According to Abid et al. (1983) the provenance of Lower Siwaliks (Chinji Formation) is from Eocene carbonates, the source for Middle Siwaliks (Nagri and Dhok Pathan formations) is from crystalline rocks of Himalayan Hinterland and the source for Upper Siwaliks (Soan Formation) is from both Lower and Middle Siwaliks. Description of the petrographic study of the individual samples has been given below:

Sample No: 1637RS (K-18)

Location: Shalam Pul, Bahadar Khel, Karak.

Grid reference: 33 12 07.9N, 70 54 21.8E

Description: The sample is from Chinji Formation. In hand specimen the rock sample is brown in color and gives effervescence with 5% HCl. Quartz is the dominant mineral followed by lithics and feldspar (Plate 27). Grain size varies from fine to medium and are sub angular in shape. The fabric is grain supported and shows moderate sorting. The rock is recognized as sub-mature both compositionally and texturally (Table 4.5). The rock is identified as Feldspathic litharenite (Fig. 4.1).

Model composition:

Minerals	**Percentage**
Quartz	35%
Feldspar	18%
Micas (*Chlorite,Muscovite, Biotite*)	*0*7%
Other detritals (Lithics) (*Clasts*)	25%

Matrix % (*Lime Mud, Clay*)	08%
Cement % (*Carbonate, Chlorite*)	*0*7%
Total	**100**

Rock Type Identified: **Feldspathic Litharenite**

Sample No: 1869RS (K-19)

Location: Nari Edal Khel, Sabir Abad, Karak

Grid reference: 33 13 26.2N, 71 22 27.4E

Description: This sample is from Chinji Formation. Quartz is the dominant mineral type followed by feldspar and lithics, minor constituents include different types of micas (such as chlorite, muscovite and biotite), matrix and cement (Plate 28). Grain size is medium and shape is sub-angular. The rock is grain supported and shows moderate sorting. It is recognized texturally and compositionally as an immature rock (Table 4.5). The rock is identified as feldspathic litharenite (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**
Quartz	28%
Feldspar	22%
Micas (*Chlorite,Muscovite, Biotite)*	10%
Other detritals (Lithics) (*Clasts*, *Carbonate, Glauconite*)	20%
Matrix % (*Clay*)	10%
Cement % (*Carbonate, Chlorite*)	10%
Total	**100%**

Rock Type Identified: **Feldspathic Litharenite**

Sample No: 1882RS (K-36)

Location: Wargha Banda, Sabir Abad, Karak

Grid reference: 33 09 32.7N, 71 25 09.3E

Description: This sample is from Nagri Formation. Petrographically, Quartz is the dominant mineral followed by lithics and feldspar, cement is present in significant amount, other constituents include micas and matrix (Plate 29). Grain size ranges from fine to medium and shape is variable from angular to sub angular. The fabric is both grain and cement supported and sorting is poor (Table 4.5). The rock is identified as feldspathic litharenite (Fig. 4.1).

Modal Composition:

Mineral	Percentage
Quartz	23%
Feldspar	18%
Micas (*Chlorite,Muscovite, Biotite)*	*0*8%
Other detritals (Lithics) (*Clasts*, *Carbonate, Glauconite*)	27%
Matrix % (*Lime Mud, Clay, Chlorite*)	06%
Cement % (*Carbonate, Chlorite*)	18%
Total	**100%**

Rock Type Identified: **Feldspathic Litharenite**

Sample No: 1870RS (K-23)

Location: Near Nari Edal Khel road, Sabir Abad, Karak

Grid reference: 33 13 34.0N, 71 22 44.9E

Description: The sample is from Nagri Formation. Feldspar is the dominant mineral followed by quartz and lithics, cement is present in significant amount, and other constituents include micas and matrix (Plate 30). Grain size is coarse and shape is variable ranging from angular to sub-angular. The fabric is grain cum cement supported and sorting is moderate. The rock is texturally and compositionally sub-mature (Table 4.5). The rock is identified as Feldspathic litharenite (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**
Quartz	20%
Feldspar	25%
Micas (*Muscovite, Biotite, Chlorite*)	09%
Other detritals (Lithics) (*Clasts*, *Carbonate, Glauconite*)	18%
Matrix % (*Lime Mud, Clay, Chlorite*)	05%
Cement % (*Carbonate*)	23%
Total	**100%**

Rock Type Identified: **Feldspathic Litharenite**

Sample No: 1831RS (K-5)

Location: Zarkai Kalay, Takht e Nusrati, Karak

Grid reference: 32 59 31.6N, 71 05 06.3E

Description: The sample is from Dhok Pathan Formation. Quartz is the dominant mineral followed by feldspar and lithics, other constituents include micas, matrix and cement (Plate 31). Grain size is medium and shape is sub angular, the fabric is grain supported and sorting is poor. The rock is texturally and compositionally sub-mature (Table 4.5). The rock is identified as Lithic arkose (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**

Quartz	33%
Feldspar	30%
Micas (*Chlorite,Muscovite, Biotite*)	08%
Other detritals (Lithics) (*Clasts*, *Garnet, amphiboles, Glauconite*)	18%
Matrix % (*Lime Mud, Clay, Chlorite*)	04%
Cement % (*Carbonate, Chlorite*)	07%
Total	**100%**

Rock Type Identified: **Lithic Arkose**

Sample No: 1853RS (K-15)

Location: Zebi Channi Khel Algada, Sabir Abad, Karak.

Grid reference: 33 06 07.4N, 71 20 42.4E

Description: This sample is from Dhok Pathan Formation. Quartz is the dominant mineral followed by feldspar, lithics and micas, other constituents include matrix and cement (Plate 32). Grain size is coarse and shape is sub-angular. The fabric is grain supported and sorting is moderate. The rock is texturally sub-mature and compositionally immature (Table 4.5). The rock is identified as Lithic arkose (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**
Quartz	30%
Feldspar	25%
Micas (*Chlorite,Muscovite, Biotite*)	15%
Other detritals (Lithics) (*Clasts, Glauconite, Garnet, amphiboles, Pyroxenes*)	16%
Matrix % (*Lime Mud, Clay, Chlorite*)	09%

Cement % (*Carbonate, Chlorite*)	05%
Total	**100%**

Rock Type Identified: Lithic Arkose

Sample No: 1838RS (K-7)

Grid reference: 33 06 11.7N, 71 06 09.1E

Location: Baji Khel Kanda, Karak.

Description: The sample is from Soan Formation. Lithics mostly carbonates are the dominant constituents followed by quartz and feldspar, other constituents include matrix, micas and cement (Plate 33). Grain size is coarse and shape is angular to sub-angular, the fabric is grain supported, sorting is poor. The rock is texturally sub-mature and compositionally immature (Table 4.5). The rock is identified as Litharenite (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**
Quartz	25%
Feldspar	18%
Micas (*Chlorite,Muscovite, Biotite*)	06%
Other detritals (Lithics) (*Carbonate fragments*)	40%
Matrix % (*Lime Mud, Clay, Chlorite*)	08%
Cement % (*Carbonate, Chlorite*)	03%
Total	**100%**

Rock Type Identified: Litharenite

Sample No: 1873RS (K-1)

Location: Dandi Edal Khel, Sabir Abad, Karak.

Grid reference: 33 14 00.2N, 71 22 51.1E

Description: The sample is from Saon Formation. Lithics are the dominant constituents followed by quartz and feldspar, other components include matrix, micas and cement (Plate 34). Grain size is coarse and shape is angular to sub-angular, the fabric is grain supported sorting is poor to moderate. The rock is texturally sub-mature and compositionally immature (Table 4.5). The rock is identified as Litharenite (Fig. 4.1).

Modal Composition:

Mineral	Percentage
Quartz	23%
Feldspar	20%
Micas (*Chlorite,Muscovite, Biotite)*	05%
Other detritals (Lithics) (*Clasts*, *Carbonate, Glauconite*)	40%
Matrix % (*Lime Mud, Clay, Chlorite*)	08%
Cement % (*Carbonate, Chlorite*)	04%
Total	**100%**

Rock Type Identified: **Litharenite**

Sample No: 1529

Location: Uraze Village, Kohat.

Grid reference: 33 30 07.4N, 71 39 49.6E

Description: The rock sample in hand specimen is red in color with burrows and calcitic veinlets and gives effervescence with 5% HCl. Matrix, mostly clay, is the dominant component followed by quartz, lithics, micas and feldspar, cement is lacking (Plate 35). The rock is very fine grained and grain shapes are mostly sub-angular, the fabric is matrix and grain supported and sorting is poor. The rock is texturally and compositionally immature to sub-mature (Table 4.5). The rock is identified as Lithic Graywacke.

Modal Composition:

Mineral	Percentage
Quartz	20 %
Feldspar	10%
Micas (*Chlorite,Muscovite, Biotite*)	15%
Other detritals (Lithics) (*Clasts*, *Carbonate, Glauconite*)	15 %
Matrix % (*Clay*)	40 %
Total	**100%**

Rock Type Identified: **Lithic Graywacke**

Sample No: 1615

Location: Shawa area, Nari Panos village, Karak.

Grid reference: 33 12 41.9N, 71 05 13.3E

Description: The sample represents Kamlial Formation. It is greyish to greenish in color and very friable. Quartz is dominant mineral followed by micas and feldspar, cement is present in significant amount, other constituents include lithics and matrix (Plate 36). Grain size is medium and shape is dominantly sub-angular, the fabric is grains supported and sorting is moderate. The rock is texturally and compositionally sub-mature (Table 4.5). The rock is identified as Lithic arkose (Fig. 4.1).

Modal Composition:

Mineral	Percentage
Quartz	35%
Feldspar	15%
Micas (*Chlorite,Muscovite, Biotite*)	20%

Other detritals (Lithics) (*Opaque)*	10%
Matrix % (*Lime Mud, Clay, Chlorite*)	05%
Cement % (*Carbonate, Chlorite*)	15%
Total	**100%**

Rock Type Identified: **Lithic Arkose**

Sample No: 1540RS

Location: Kandher Village, Nizampur Road, Kohat

Grid reference: 33 32 31.5N, 71 49 48.1E

Description: In hand specimen the sample is greenish sandstone and gives effervescence with HCl. Quartz and cement are the dominant components followed by micas, feldspar and matrix (Plate 37). Grain size is coarse and shapes are dominantly angular. The fabric is cement cum grain supported and moderately sorted. The rock is texturally sub-mature and compositionally immature (Table 4.5). The rock is identified as Lithic arkose (Fig. 4.1).

Modal Composition:

Mineral	**Percentage**
Quartz	30%
Feldspar	15%
Micas (*Chlorite,Muscovite, Biotite*)	15%
Other detritals (Lithics) (*Opaque*)	06%
Matrix (*Lime Mud, Clay, Chlorite*)	04%
Cement (*Carbonate*)	30%
Total	**100%**

Rock Type Identified: **Lithic Arkose**

Sample No: 1568

Location: Near Police Station, Jerma Village, Kohat

Grid reference: 33 31 51.1N, 71 27 39.1E

Description: The rock sample is from Kohat Formation of Eocene age. In hand sample the rock is white to greyish in color. The foraminifera (*Nummulites* sp.) can be seen with unaided eye. The rock gives strong effervescence with HCl. The rock is dominantly composed of micrite followed by skeletal allochems, non-skeletal allochem as intraclast is present as a minor constituent (Plate 38). The rock is identified as foraminiferal packstone.

Modal composition:

Components	**Percentage**
Skeletal allochem	45%
Intraclasts (non-skeletal)	05%
Cement (spar)	0%
Mud (micrite)	50%
Total	**100%**

Rock Type Identified: **Foraminiferal packstone**

Sample No: 1501

Location: Along Tunnel Kohat road, Kohat

Grid reference: 33 33 33.7N, 71 47 07.6E

Description: The sample represents Kohat Formation of Eocene age. The sample is dark grey in color in hand specimen and gives effervescence with 5% HCl. Peloid a non-skeletal allochem is the dominant component followed by skeletal allochem, spar as cement and micrite (Plate 39). The rock is identified as peloidal grainstone.

Modal Composition:

Component	**Percentage**

Skeletal allochem	22%
Peloids	50%
Cement (spar)	20%
Mud (micrite)	08%
Total	**100%**

Rock Type Identified: **Peloidal Grainstone**

Sample No: 1513

Location: Rock Sample at Jerma village Kohat

Grid reference: 33 31 18, 71 27 53.6

Description: The rock sample is collected from Kohat Formation. The sample is pervaded by calcite veins, with common micro-stylolite. Alveolina sp. can be seen with unaided eye. The rock gives effervescence with 5% HCl. Skeletal allochems and micrite are dominant and both are present in approximately equal proportions followed by spar as cement (Plate 40). The rock is identified as foraminiferal wacke-packstone.

Modal Composition:

Component	**Percentage**
Skeletal allochem	45%
Cement (spar)	10%
Mud (micrite)	45%
Total	**100%**

Rock Type Identified: **Foraminiferal Wacke-Packstone**

Sample No: 1583

Location: Near Kohat Pass, Kohat

Grid reference: 33 37 02.2N, 71 27 36.1E

Description: The rock sample is yellowish grey in hand specimen and gives effervescence with 5% HCl. Calcite is the dominant component followed by quartz and heavy (oqague) components (Plate 41). The rock is identified as quartzitic limestone.

Modal Composition:

Mineral	**Percentage**
Quartz	30%,
Calcite	60 %
Heavy /opaque	10%
Total	**100%**

Rock Type Identified: **Quartzitic Limestone**

Sample No: 1593

Location: Muslimabad Village, Kohat

Grid reference: 33 28 14.4N, 71 23 34.1E

Description: The rock sample belongs to Samana Suk Formation. The rock contains nodules which are visible with naked eyes. The color of the rock sample is dark brown with veins (filled with marl?), the sample gives effervescence with 5% HCl. Calcite nodules are dominant constituents of the rock followed by matrix (Plate 42). The rock is identified as nodular limestone.

Modal Composition:

Component	**Percentage**
Calcitic nodule	70%
Matrix (marl?)	20%
Matrix	10%

Total	**100%**

Rock Type Identified: **Nodular Limestone**

Sample No: 1605RS

Location: Gypsum exposure, Nari Panos road, Karak

Grid reference: 33 09 19.2N, 71 09 29.3E

Description: The sample is collected from Jatta Gypsum of Eocene age. The Sample has fine laminas of gypsum. It is yellowish white in color and does not give effervescence with 5% HCl. Dominant mineral is gypsum followed by anhydrite and clayey matrix in subordinate amount (Plate 43). The rock is interpreted as gypsum (Fig. 4.2).

Modal Composition:

Component	Percentage
Gypsum	85%
Anhydrite	05%
Clayey Matrix	10%
Total	**100%**

Rock Type Identified: **Gypsum Rock**

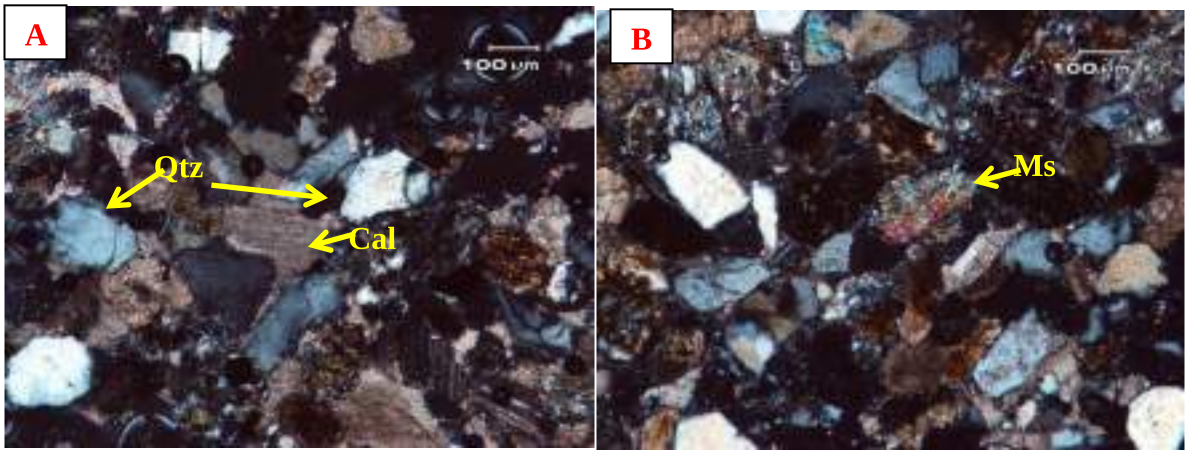


Plate27: Photomicrographs (CPL, 10X) of feldspathic litharenite (Chinji Formation), Sample No 1637RS (K-18), Quartz (Qtz), Calcite (Cal), Muscovite (Ms).

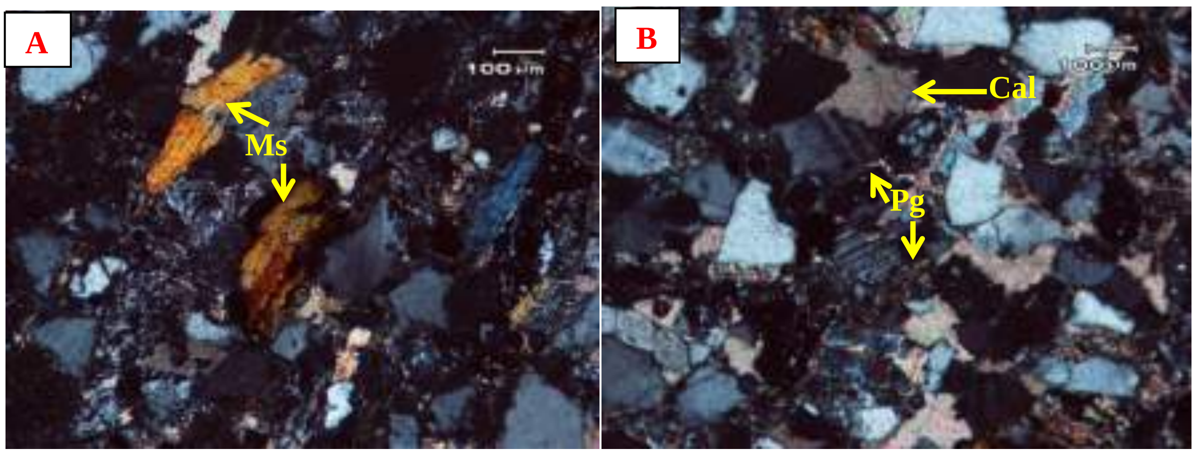


Plate28: Photomicrographs (CPL, 10X) of feldspathic litharenite (Chinji Formation), Sample No 1869RS (K-19), Muscovite (Ms), plagioclase (Pg) (twinned) Calcite, (Cal).

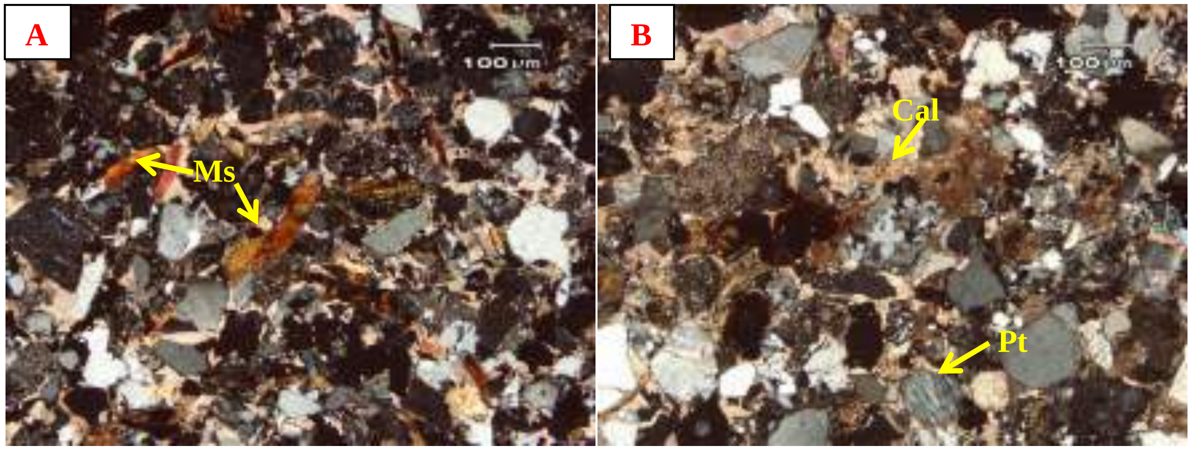


Plate29: Photomicrographs (CPL, 10X) of feldspathic litharenite (Nagri Formation), Sample No 1882RS (K-36), Muscovite (Ms), Perthite (Pt), Calcite Cement (Cal).

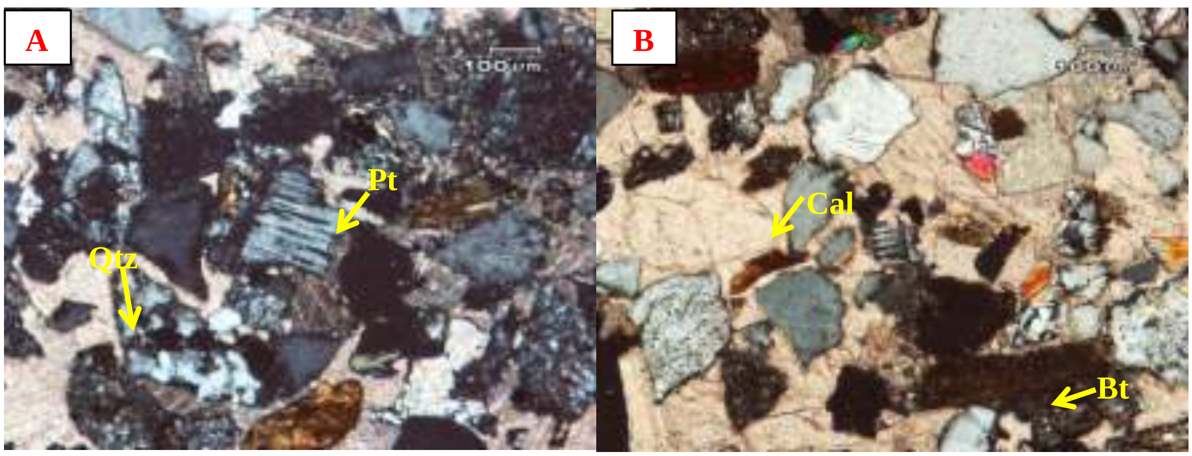


Plate30: Photomicrographs (CPL, 10X) of feldspathic litharenite (Nagri Formation), Sample No 1870RS (K-23), Quartz (Qtz), Perthite (Pt), Biotite (Bt), Calcite (Cal).

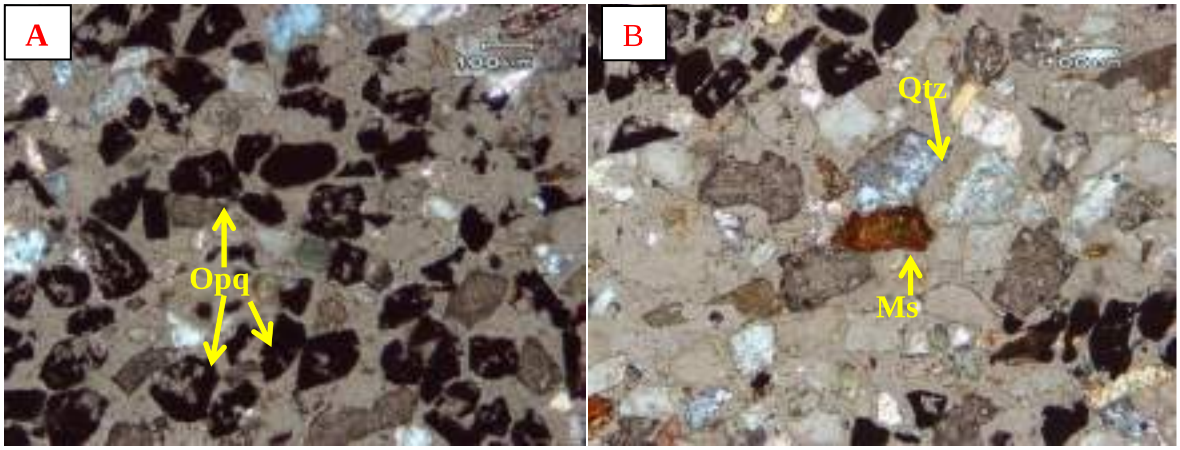


Plate31: Photomicrographs (CPL, 10X) of lithic arkose (Dhok Pathan Formation), Sample No: 1831RS (K-5), Opaque (Opq), Quartz (Qtz), Muscovite (Ms).

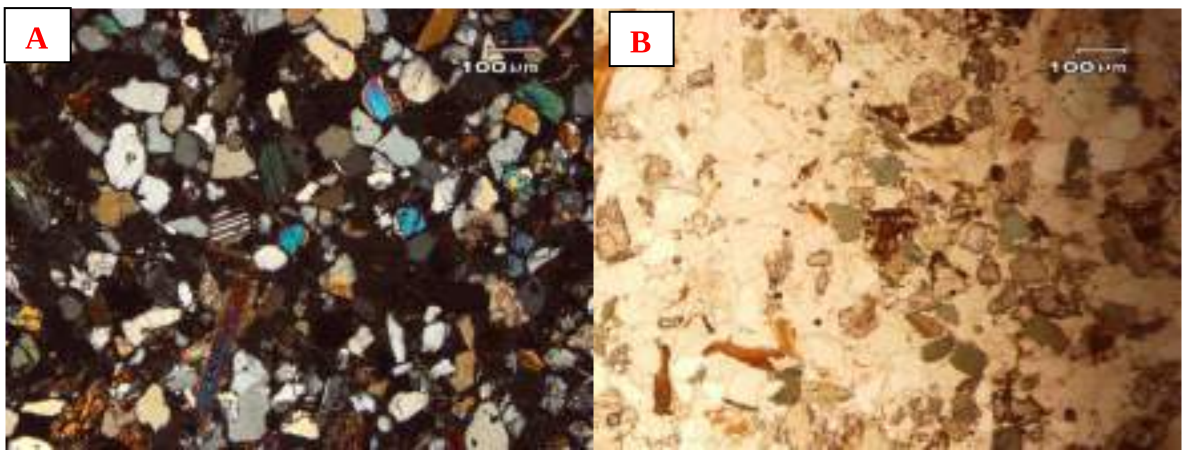


Plate32: Photomicrographs of lithic arkose (Dhok Pathan Formation), Sample No: 1853RS (K-15), (A: CPL and B: PPL, 10X).

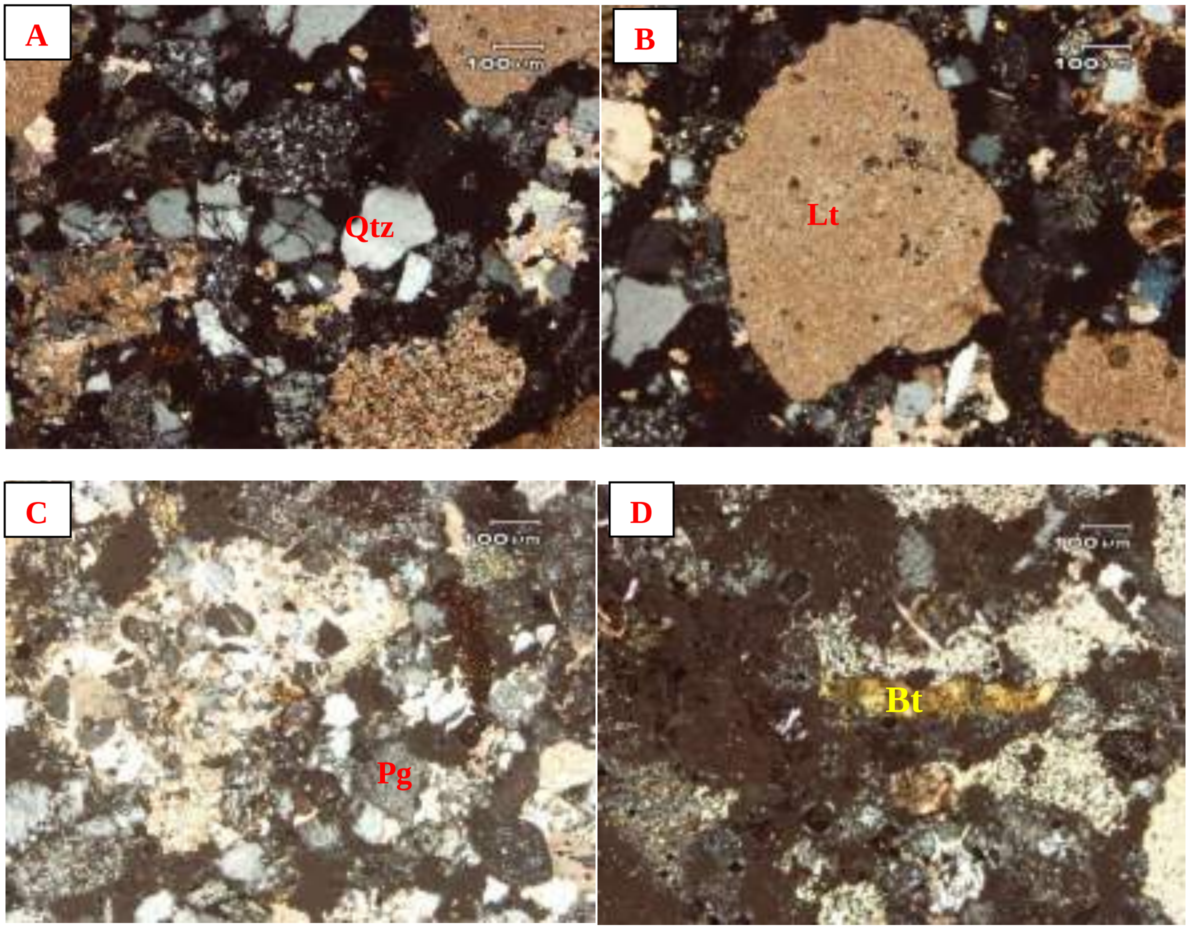


Plate 33: Photomicrographs (CPL, 10X) of litharenite (Soan Formation), Sample No: 1838RS (K-7), Quartz (Qtz), Lithic fragment (Lt), Twinned plagioclase (Pg), Biotite (Bt).

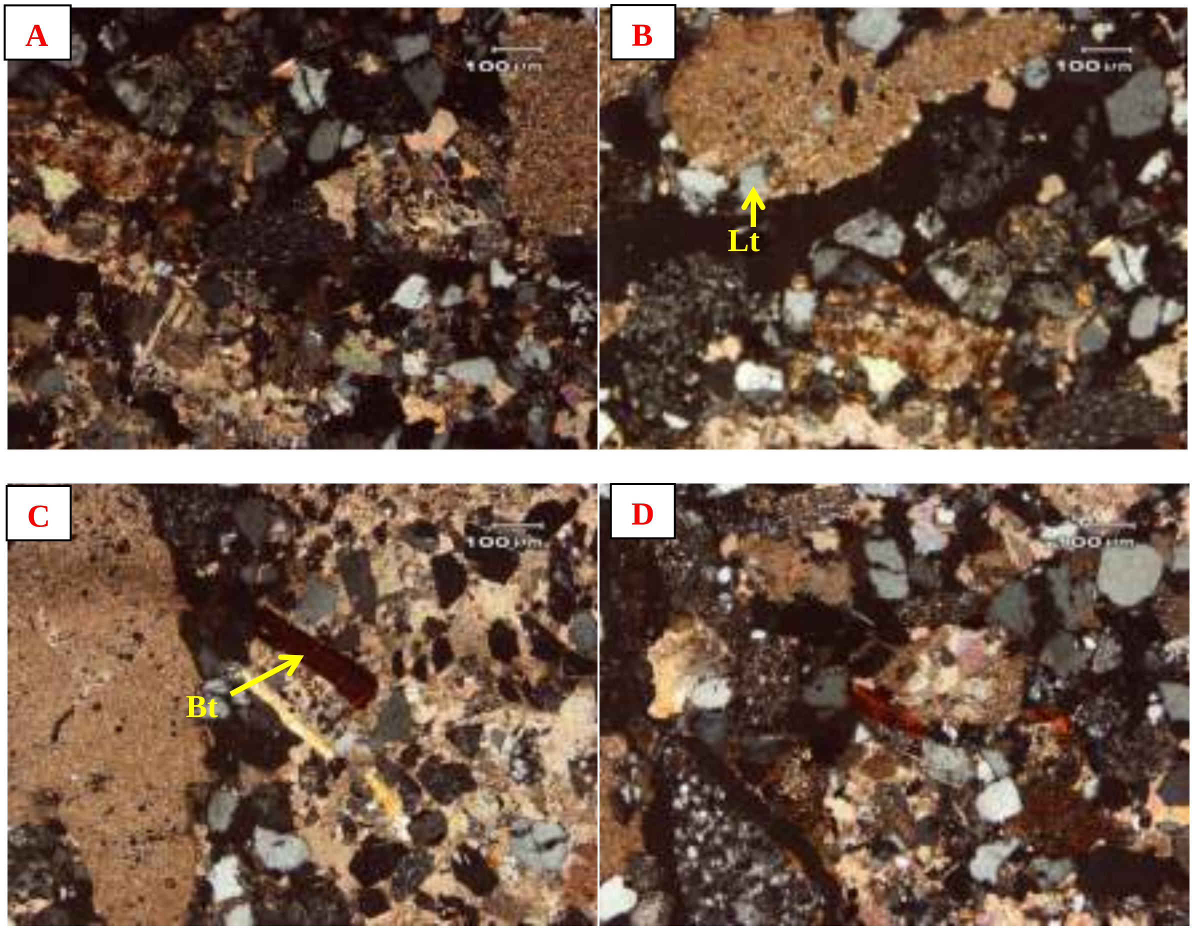


Plate34: Photomicrographs (CPL, 10X) of litharenite (Soan Formation), Sample No: 1873RS (K-1), Lithics (Lt), Biotite (Bt).

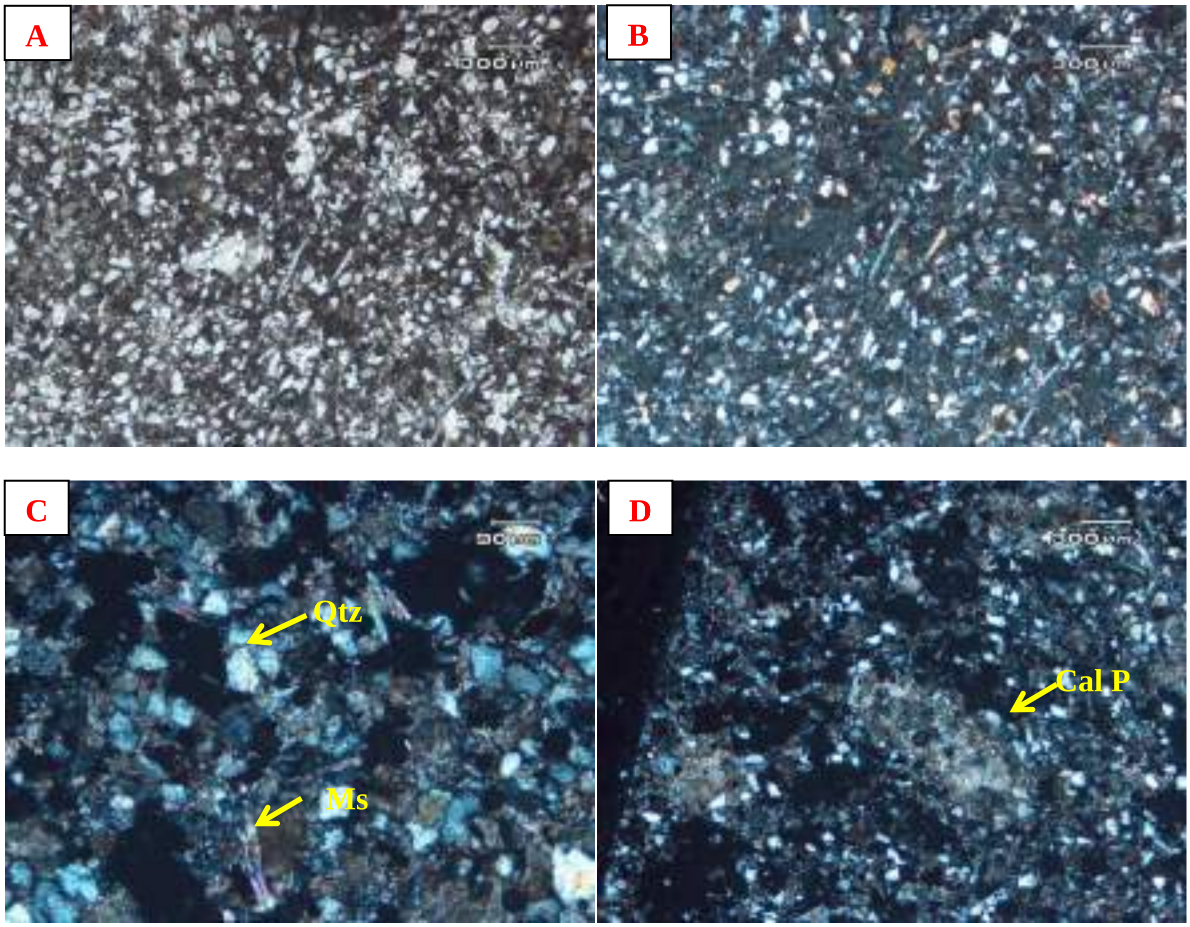


Plate 35: Photomicrographs of lithic graywacke from Sample No: 1529RS, Ms = Muscovite, Qtz = quartz, Cal P = caliche having calcite pockets (A: PPL, B, C, D: CPL) (A, B, D at 4X, C at 10X).

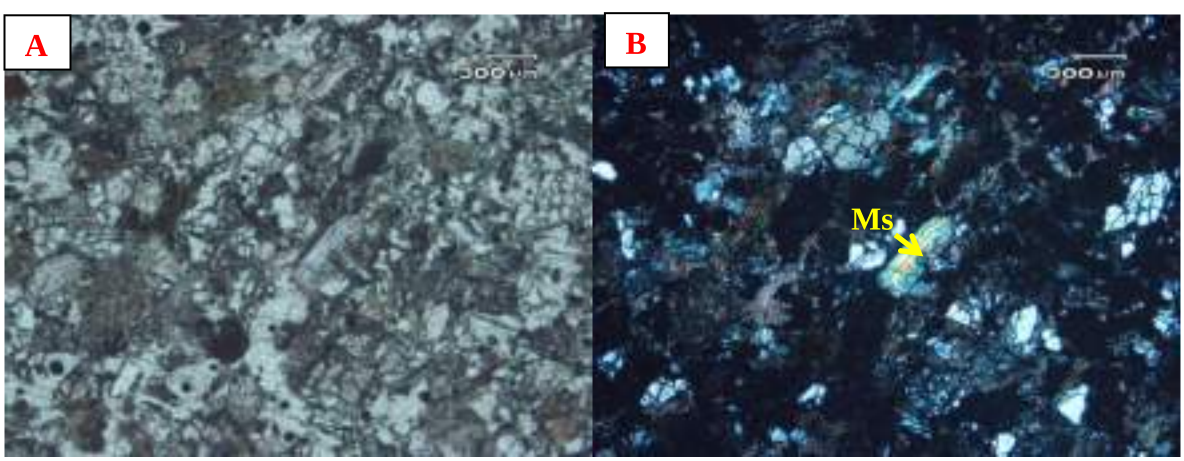


Plate 36: Photomicrographs of lithic arkose (Kamlial Formation), Sample No: 1615, Ms = Muscovite (A: PPL and B: CPL at 4X).

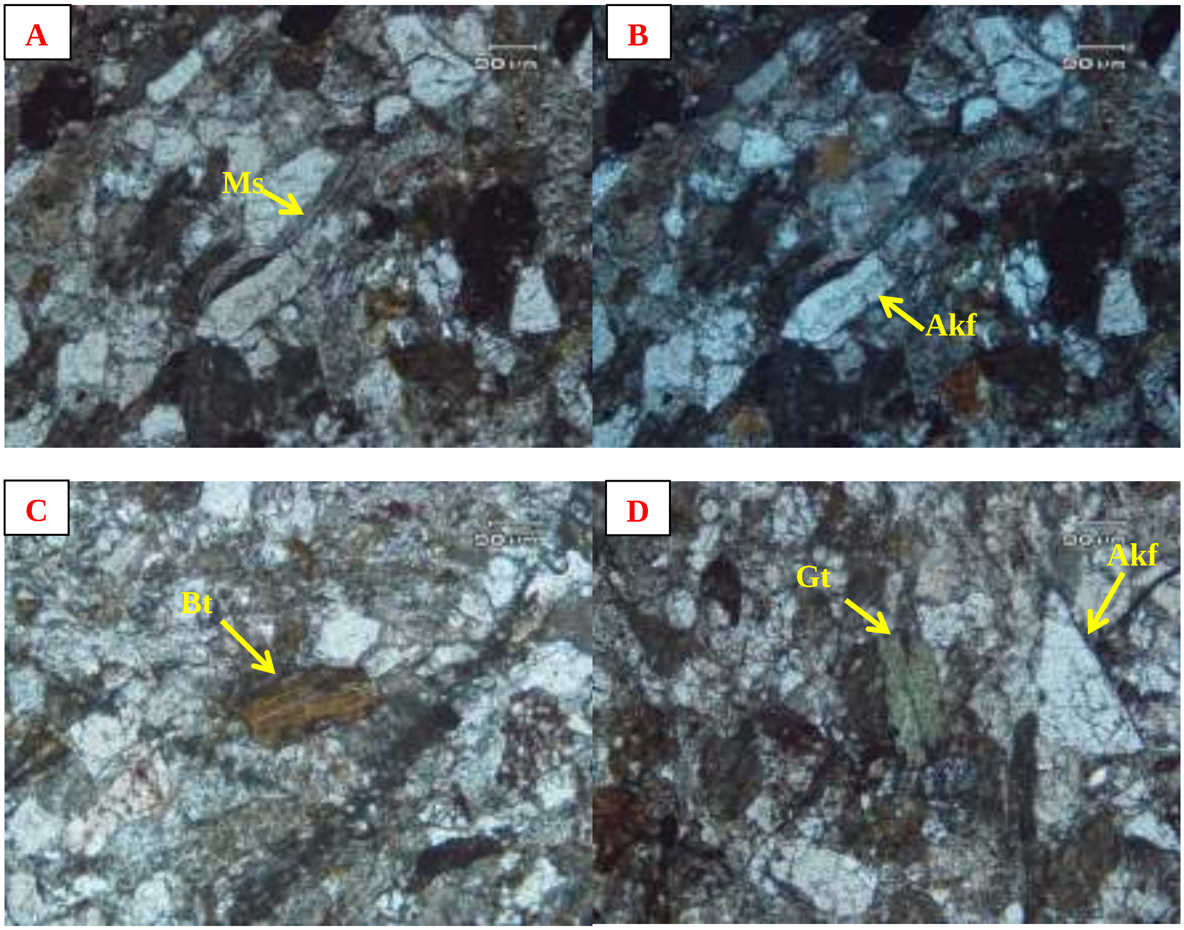


Plate37: Photomicrographs of lithic arkose from Sample No: 1540RS, Ms = Muscovite, Biotite (Bt), Glauconite (Gt) and Alkali Feldspar (Akf) (A, C, D: PPL, B: CPL, at 10X).

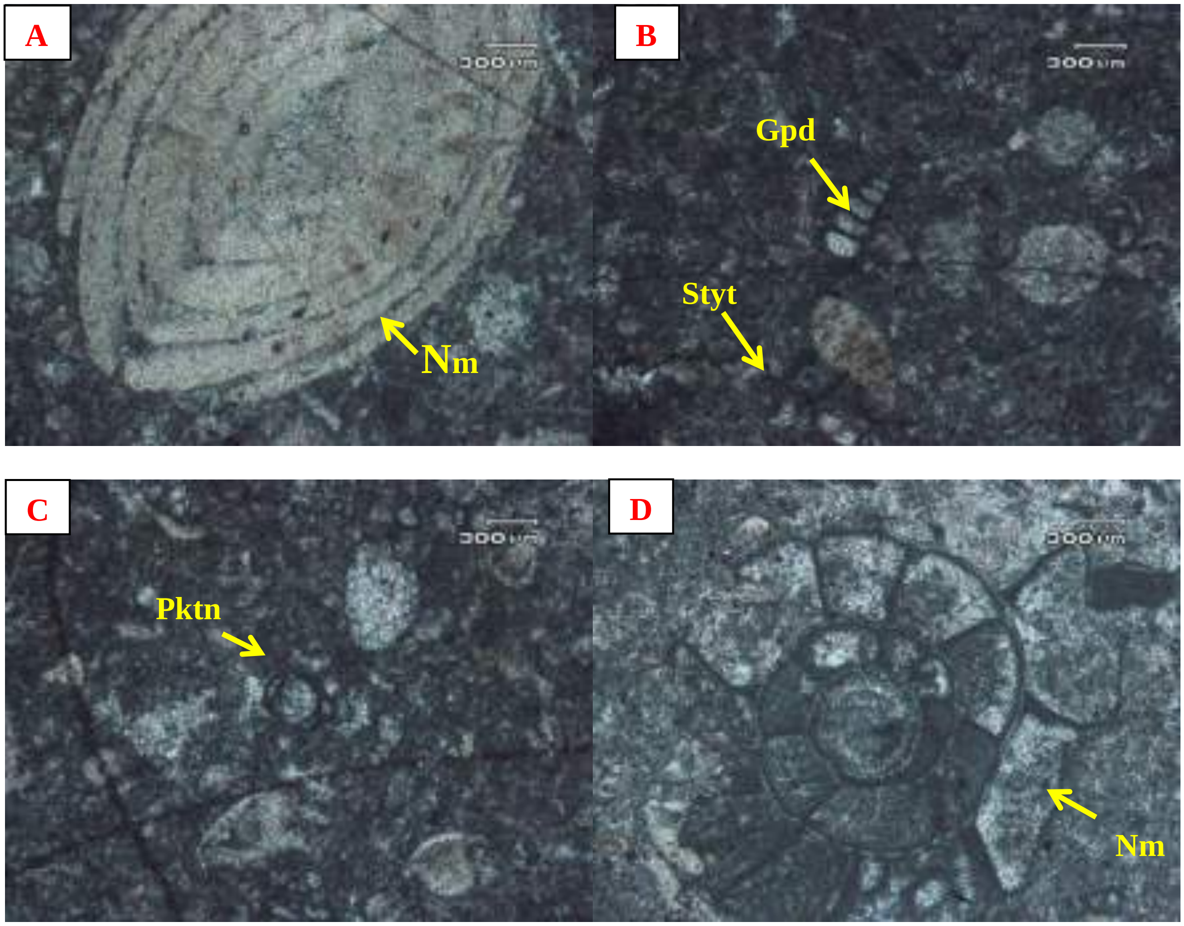


Plate38: Photomicrographs (PPL at 4X) of foraminiferal packstone (Kohat Formation), Sample No: 1568, Nummulite (Nm), Uniserial (Gpd) and stylolites (Styt), other skeletal allochem (Pktn).

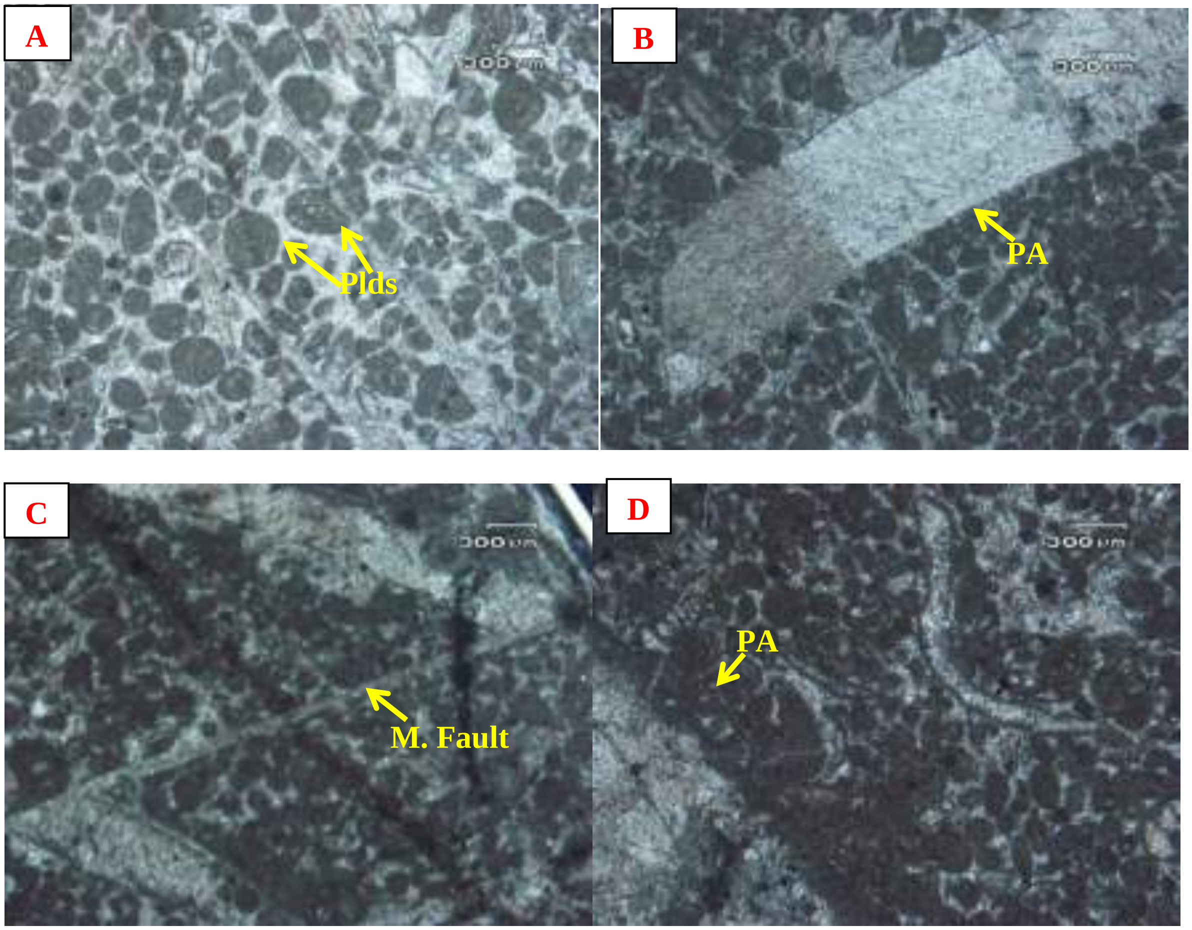


Plate39: Photomicrographs (PPL at 4X) of peloidal grainstone (Kohat Formation), Sample No: 1501, Microfault (M. Fault), Phylloid algae (PA), Peloids (Plds).

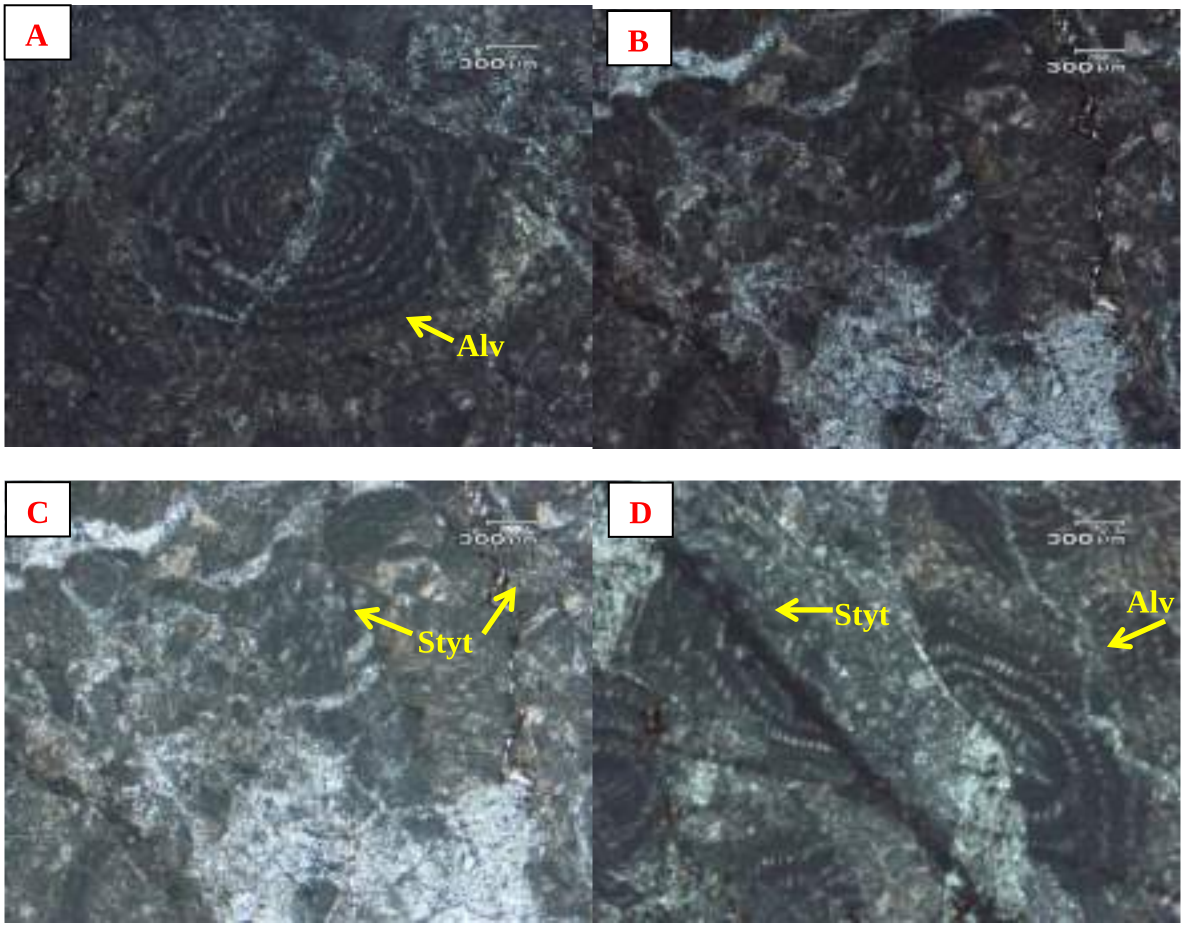


Plate 40: Photomicrographs (PPL at 4X) of foraminiferal wacke-packstone (Kohat Formation), Sample No: 1513, Alveolina (Alv), Microstylolites (Styt).

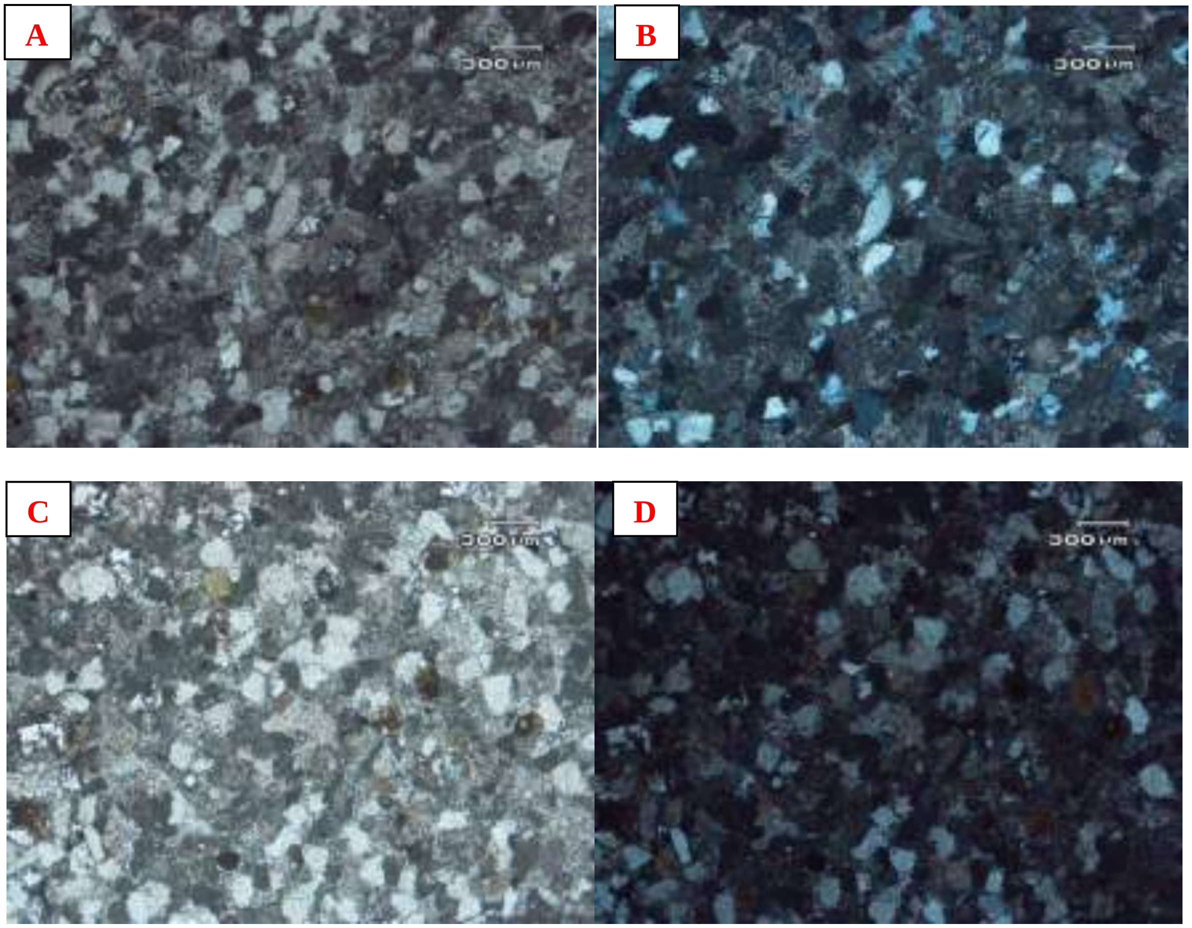


Plate 41: Photomicrographs of quartzitic limestone from Sample No: 1583 (A, C: PPL, B, D: CPL, at 4X).

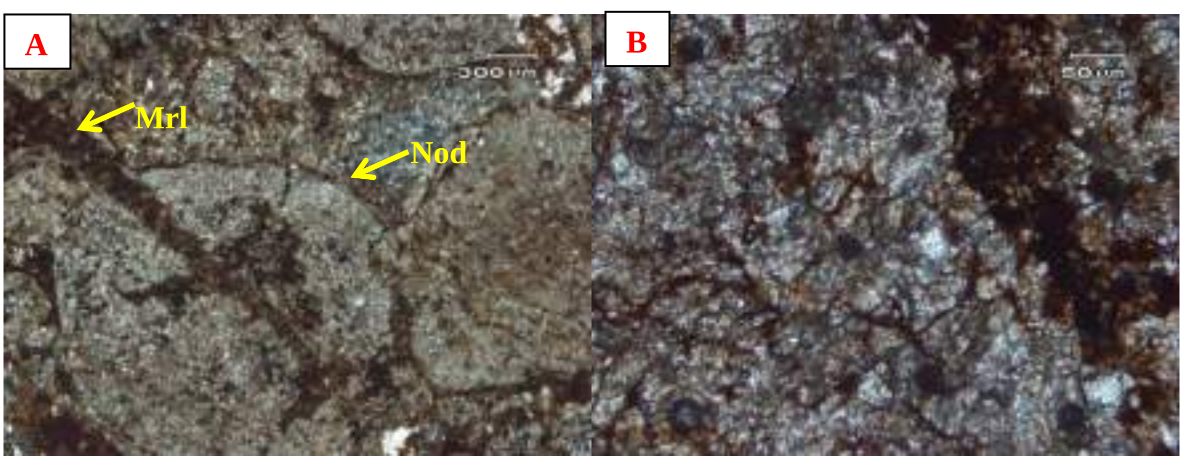


Plate42: Photomicrographs (CPL) of nodular limestone (Samana Suk Formation) from Sample No: 1593, micronodules (Nod) (A at 4X, B at 40X).

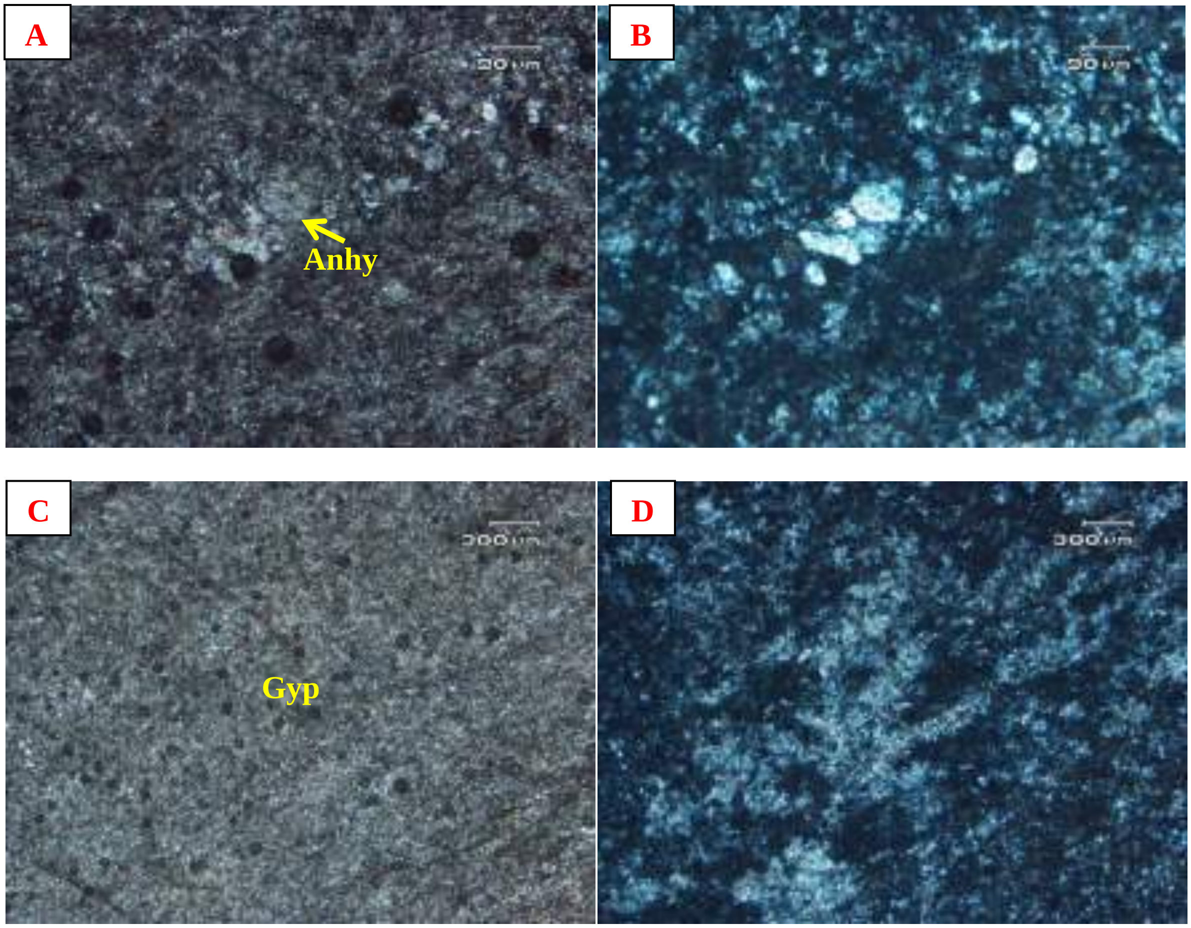
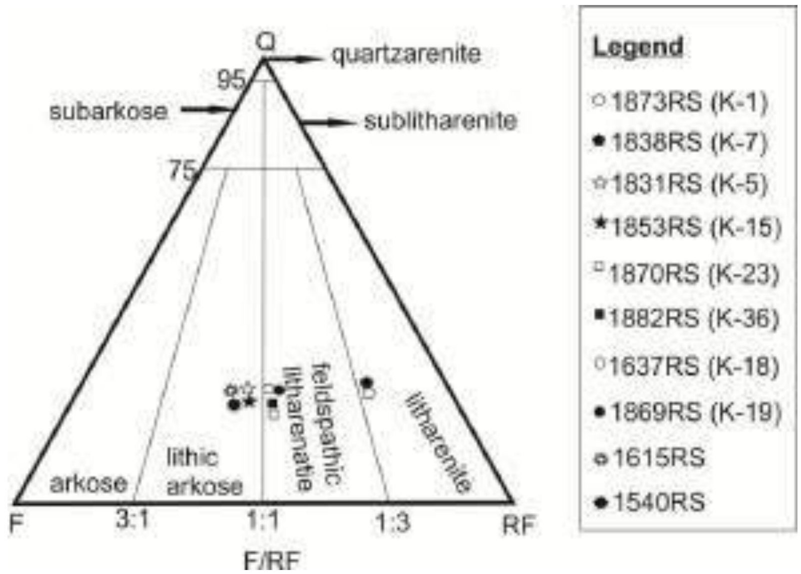


Plate43: Photomicrographs of gypsum rock (Jatta Gypsum), Sample No: 1605RS, Anhydrite (Anhy), Gypsum (Gyp) (A, C: PPL, B, D: CPL,) A, B at 10X, C, D at 4X.

Fig. 4.1: Classification of the sandstones according to Folk (1974), Q = Quartz, F = Feldspar, RF = Rock Fragment.



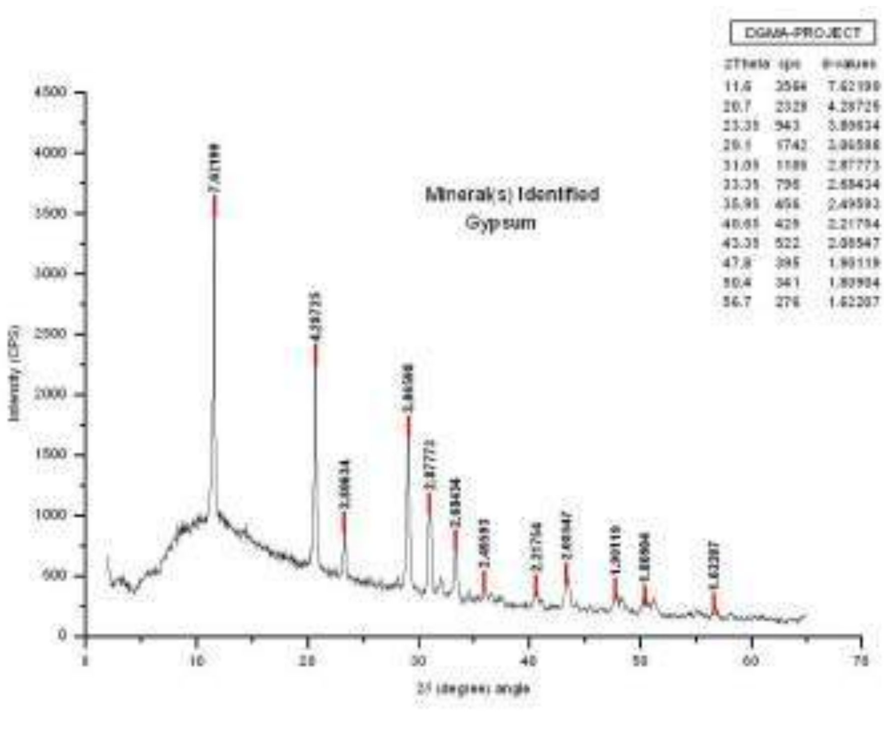


Fig.4.2: XRD analysis of the Sample No. 1605RS showing peaks for Gypsum.

Table 4.5. Petrographic data of the selected samples from Kohat Sub-Basin. Fine grained sand: 0.125-0.25 mm, Clay implies size descriptive term (Grains < 1/256 mm in size), Medium grained sand: 0.25-0.5mm, Coarse grained sand:. 0.5-2mm.

Rock Type		Litharenite	Litharenite	Lithic arkose	Lithic arkose	Feldspathic Litharenite	Feldspathic Litharenite	Feldspatc Litharenite	Feldspathic Litharenite	Lithic Graywacke	Lithic Arkose	Lithic Arkose
Compositional Maturity		Immature	Immature	Sub-mature	Immature	Sub-mature	Sub-mature	Sub-mature	Immature	Immature	Sub-mature	Immature
Textural Maturity		Submatur	=	=	=	=	=	=	=	Immature	Submatu	Submatur
Depositional Fabric	Sorting	Poor	=	=	Moderate	Moderate	Poor	Moderat	Moderate	Poor	Moderate	Moderate
	Packing	Grain supported	Grain supported	Grain supported	Grain supported	Cement and grain supported	Cement-grain supported	Grain supported	Grain supported	Matrix-grain supported	Grain supported	Cement and grain supported
	Sphericity	Low	=	=	=	=	=	=	=	=	=	=
	Roundness	Angular to Sub	Angular to	Sub angular	Sub angular	Angular to Sub	Angular to Sub	Sub angular	=	=	=	Angular
	Grain Shape	Variable	=	=	=	=	=	=	=	=	=	=
	Grain Size	Coarse grained	=	Medium Grained	Coarse Grained	Coarse grained	Fine-Coarse grained	Fine-Medium grained	Medium grained	Very Fine grained	Medium grained	Coarse grained
Provenance of Detrital		Sedimentary, Metamorphic and Plutonic	Sedimentary, Metamorphic and Plutonic	Igneous and Metamorphic source	Igneous and Metamorphic source	Igneous and Metamorphic source	Igneous and Metamorphic source	Sedimentary source	Sedimentary, Metamorphic and Plutonic	Metamorphic and Plutonic source	=	=
Cement %		4	3	7	5	23	18	7	10	5	15	30
Matrix %		8	8	4	9	5	6	8	10	35	5	4
Terrigenous Grains %	Other detrital (Lithic)	40	40	18	16	18	27	25	20	15	10	06
	Micas	5	6	8	15	9	8	7	10	15	20	15
	Feldspar	20	18	30	25	25	18	18	22	10	15	11
	Quartz	23	25	33	30	20	23	35	28	20	35	30
Sample No.		1873RS (K-1)	1838RS (K-7)	1831RS (K-5)	1853RS (K-15)	1870RS (K-23)	1882RS (K-36)	1637RS	1869RS (K-19)	1529RS	1615RS	1540RS

4.8. Petrographic study of the selected rock samples from D.I.Khan

Appropriate representative samples from Dera Ismail Khan (D.I Khan) area were collected from different geologic formations for thin section preparation. Rock samples were collected from different formations described by Hemphill et al., 1973. These thin sections were then studied in detail under the Nikon polarized light microscope in the Petrography Lab of the National Centre of Excellence in Geology. The constituent minerals were identified and their relative abundance was determined on the basis of visual estimation. Grain sizes, shapes and their mutual relationship were determined. The rock samples were classified and named on the basis of their mineralogy and textural characters. Description of the petrographic study of the individual samples have been given below.

Sample No: 2108RS

Location: Pir Abad village, Sheikh Badin Hills, D.I Khan

Grid reference: 32 15 13.4N, 70 51 19.7E

Description: This sample is collected from an outcrop of Chinji Formation near Sheikh Badin Hills. In hand specimen the rock sample is reddish brown in color and gives effervescence with 5% HCl. Clay seems to be the dominant mineral (plate 44). The rock is identified as claystone.

Model composition:

Minerals	**Percentage**
Clays	90%
Silt (Quartz?)	10%
Total	**100**

Rock Type Identified: **claystone**

Sample No: 2133RS

Location: Bilout Area, near CRBC, Miawali-D.I Khan Road, D.I Khan

Grid reference: 32 14 11.8N, 71 09 18.5E

Description: This sample is from Nagri Formation. The rock sample is grayish-greenish colored in hand-specimen and fizzes with 5% HCl, indicating presence of calcite as cement. Quartz is the dominant mineral type followed by feldspar and lithics, minor constituents include different types of micas (such as chlorite, muscovite and biotite), matrix and cement (plate 45). Grain size is medium and shape is sub-angular. The rock is grain supported and it shows moderate sorting. It is recognized as texturally and compositionally an immature rock. The rock is identified as feldspathic litharenite.

Modal Composition:

Mineral	**Percentage**
Feldspar	22%
Quartz	28%
Micas	10%
Other detritals (Lithics)	20%
Matrix % (*Clay*)	10%
Cement % (*Carbonate*)	10%
Total	**100%**

Rock Type Identified: **Feldspathic Litharenite**

Sample No: 2140RS

Location: Mali Khel, D.I Khan

Grid reference: 32 25 54.8N, 71 18 19E

Description: This sample is from some Eocene limestone. The rock is grayish-blackish in color and fizzes strongly with HCl (plate 46). Some bio-clasts present are micritized and hard to identify. The fabric is mud-supported. The rock is identified as mudstone-wackestone.

Modal Composition:

Mineral	**Percentage**
Micrite (calcite)	90%
Micritized bioclasts	10%
Total	**100%**

Rock Type Identified: **Mudstone-wackestone**

Sample No: 2143RS

Location: Near Chashma Barrage (Along road), D.I Khan

Grid reference: 32 27 07.1N, 71 19 39.2E

Description:

Description: The rock sample is yellowish grey in hand specimen and gives effervescence with 5% HCl. Calcite is the dominant component followed by quartz and heavy (opaque) components (plate 47). Some broken bioclasts of brachiopods and bivalves are also present. The rock is identified as quartzitic limestone.

Modal Composition:

Mineral	**Percentage**
Quartz	30%,
Calcite	60 %
Heavy /opaque	10%
Total	**100%**

Rock Type Identified: **Quartzitic Limestone**

Sample No: 2345RS

Grid reference: 32 13 10.21N, 70 53 09.1E

Location: Near Panyala village (Sandstone from Nagri Formation) D.I Khan.

Description: The sample is from Nagri Formation of Miocene age. The rock weakly bubbles with 5% HCl, which indicates the presence of some calcite as cement. Lithics (mostly quartz and feldspar) are the dominant constituents followed by carbonates. Other constituents include matrix, micas and cement (plate 48). Grain size is medium-fine and shape is angular to sub-angular. The fabric is grain supported while sorting is poor. The rock is texturally sub-mature and compositionally immature. The rock is identified as Litharenite.

Modal Composition:

Mineral	**Percentage**
Quartz	25%

Feldspar	18%
Micas (*Chlorite,Muscovite, Biotite*)	06%
Other detritals (Lithics)	40%
Matrix % (*Lime Mud, Clay, Chlorite*)	08%
Cement % (*Carbonate, Chlorite*)	*0*3%
Total	**100%**

Rock Type Identified: **Litharenite**

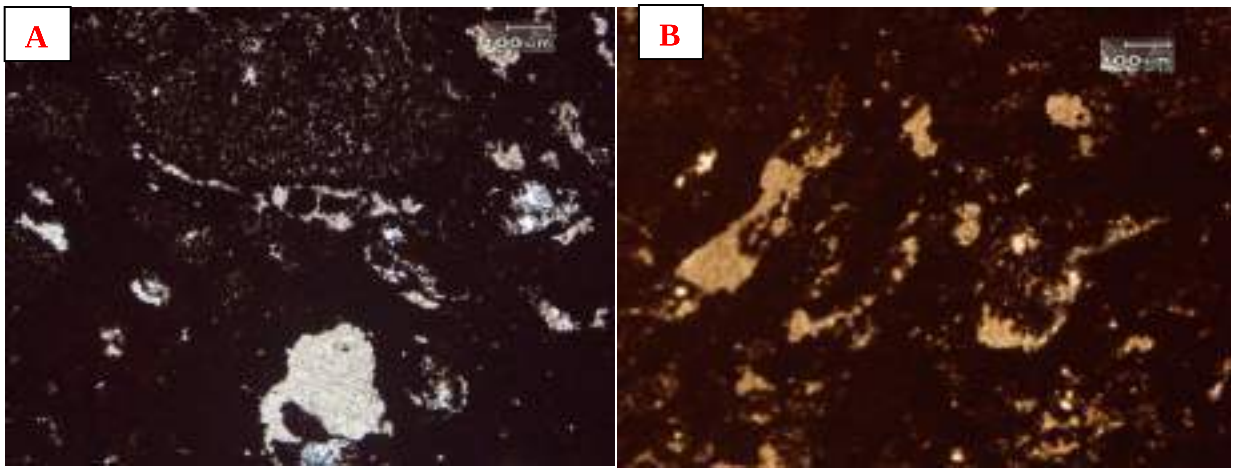


Plate 44: Photomicrographs of claystone (Chinji Formation), Sample No 2108RS, (A: CPL and B: PPL, 10X)

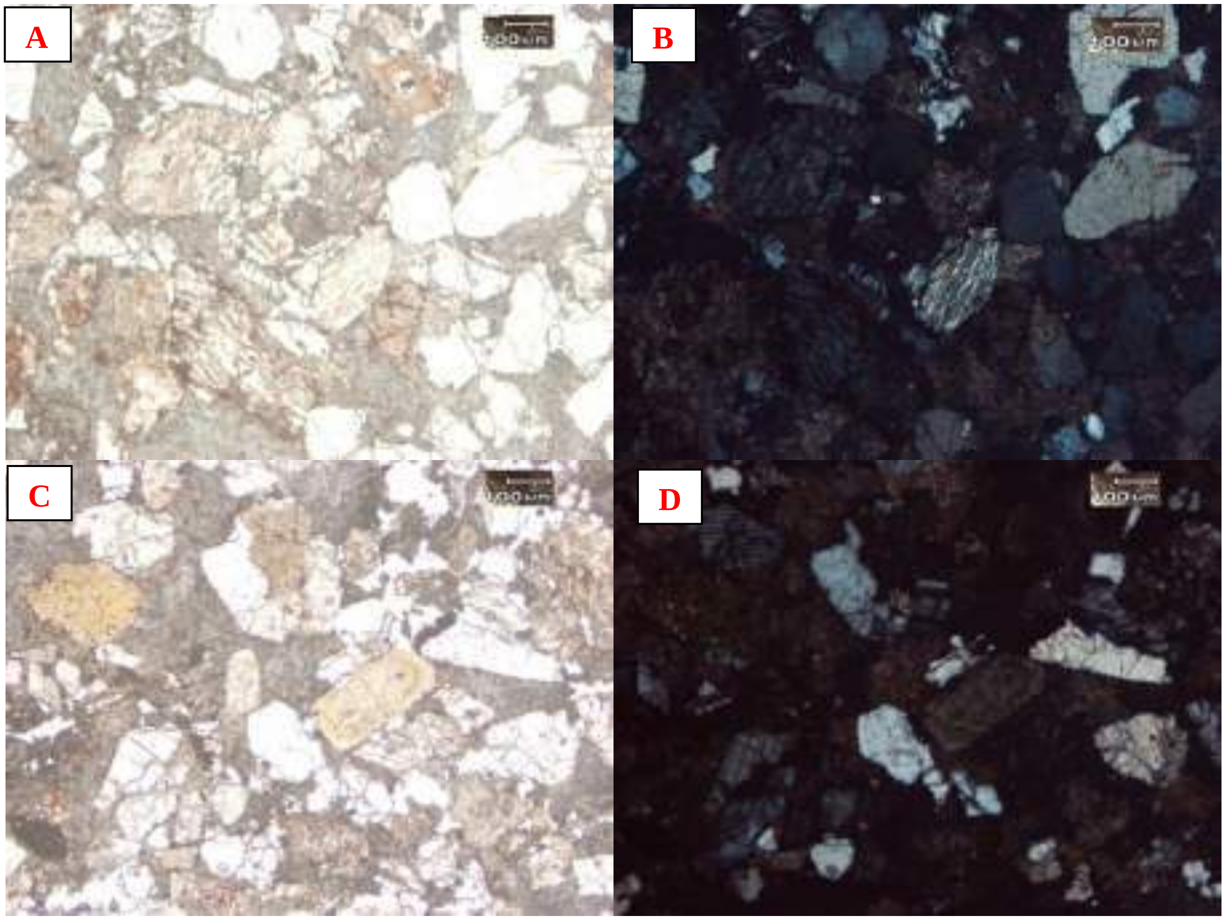


Plate 45: Photomicrographs of feldspathic litharenite (Nagri Formation), Sample No 2133RS. (A, C: PPL, B, D: CPL at 10X)

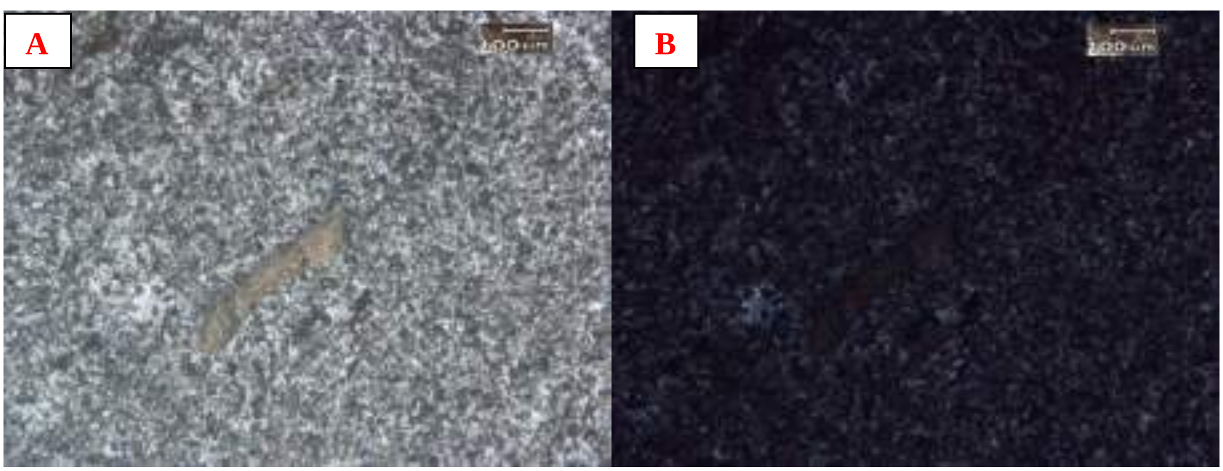


Plate 46: Photomicrographs of Mudstone, Sample No 2140RS (A: CPL and B: PPL, 10X)

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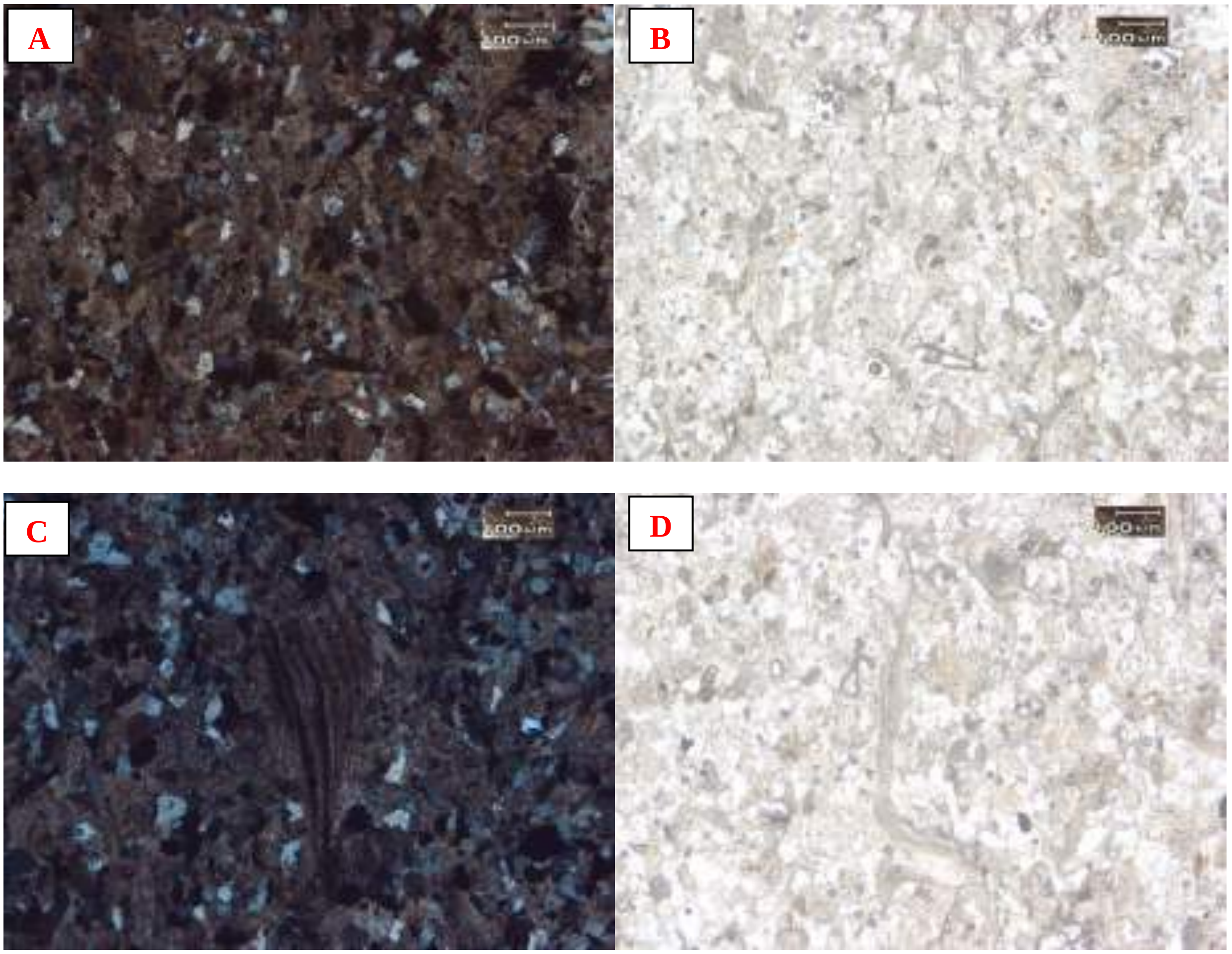


Plate 47: Photomicrographs of arenaceous limestone, Sample No: 2143RS (A, D: PPL, B, C: CPL, at 10X).

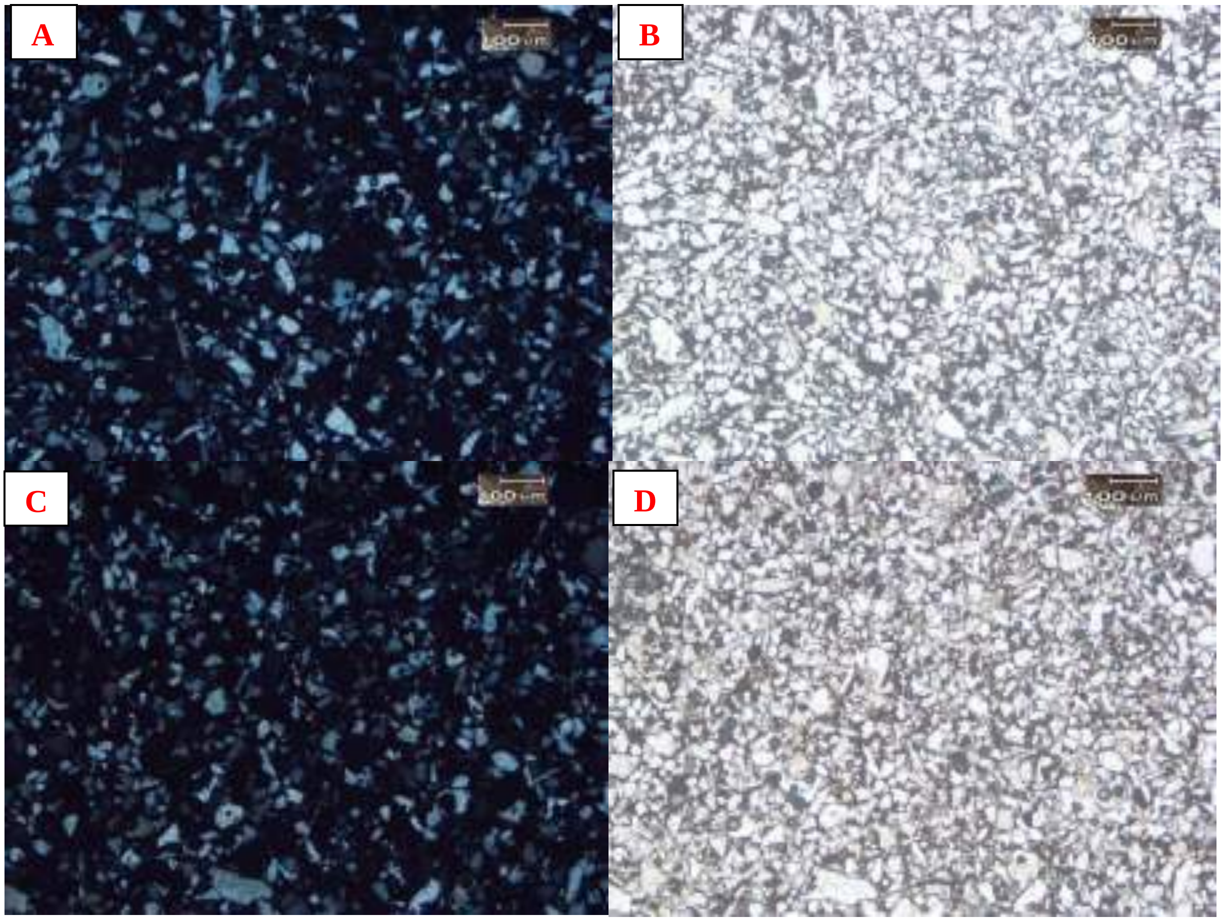


Plate 48: Photomicrographs of litharenite of Nagri Formation, Sample No: 2345RS (A, C: PPL and B, D: CPL, 10X).

CHAPTER 5

GEOCHEMICAL STUDIES

5.1. Geochemical survey

Geochemical surveys based on the chemical analysis of samples of active stream sediments from the drainage courses have long been used as an exploration tool worldwide. The fundamental premise is that stream sediments are composite products of erosion and weathering, and thus represent the source catchment area of the stream drainage network (Darnley, 1990; Cocker, 1996, 1999). Geochemical maps have been constructed using geochemical data of stream sediment all over the world to identify possible sources of anomalous element concentrations (Kautsky and Bølviken, 1986; Thalmann et al., 1988; Reid, 1993; Ohta et al., 2005). These maps also provide information on pollutant sources, weathering, and transport processes of the catchment area.The stream sediments can provide good results regarding mineral and ore exploration, especially in arid climates, where there are more stable anomalies due to less mobility of certain trace elements. Usually stream sediments include adsorbed elements, precipitated materials and unaltered primary minerals (Ramazanov and Ali, 2011).

This projectwas aimed at identifying the placer gold, silver and base metals mineralization in the southern parts of the Khyber Pakhtunkhwa Province, using stream sediments in the form of pan-concentrates, stream sediments (fine fraction) and Tallus. This part of the province does not have previous history of gold exploration; therefore, the current study was designed to investigate pan-concentrates, stream sediments and tallus for Au, Ag and base metals in order to correlate anomalies with any possible source in the area.

5.2. Statistical and GIS Data Analysis

Stream sediment geochemical data can be interpreted by using a variety of tools in order to extract an anomalous geochemical signature for mineral exploration. Statistical and spatial analysis are the two basic approaches that have been used to analyze regional geochemical data (Harris et al., 2000; Xu and Cheng, 2001; Grunsky, 2002).

Major statistical analysis of geochemical data from the project area includes univariate (Histograms), bivariate (element-element correlation) and multivariate analysis (factor analysis). These statistical analysesplay a key role in order to define significant geochemical trends in the data and to define background and anomalous signatures for large data sets (Figs 5.1 & 5.3). The combination of univariate, bivariate and multivariate statistical analyses can have great impact on the geochemical data interpretation. However, multi-element analysis has relatively strong influence on the results for regional data with broad variation (Ali et al., 2006).

The regional geochemical data from the project area is analyzed using variety of statistical methods in order to remove outliers. Histograms for different elements (Cu, Pb, Zn, Ni, Cr, Co, Cd, Mn, Ag and Au) were tested in order to account for background and anomalous concentrations.Statistical parameters such as Minimum, Maximum, Mean, Standard Deviation and division of geochemical data into 50^{th}, 75^{th}, 90^{th}, 95^{th} and 99^{th} percentile were determined. Bivariate analysis, such as correlation matrix, was also used for the whole data sets of the project area. All the statistical analyses for pan-concentrates, stream sediments and quaternary sediments were carried out in the SPSS 21.1.

Geochemical maps were produced for pan-concentrates, stream sediments and tallus by plotting the data on topographic sheets (1:50,000) and regional geological maps in Arc-GIS 10.1. All the data processing, including digitizing of geological maps, georeferencing and drainage pattern, were carried out in the Arc-GIS 10.1. The geological maps, topographic sheets, structures, geochemical data and drainage cells were added as a separate layer to GIS 10.1. The data was then plotted in the order of increasing concentration for Cu, Pb, Zn, Ni, Cr, Co, Cd, Mn, Ag and Au. A GIS data base was constructed on the basis of these information in order to view stream sediments geochemical data from the central and southern parts of Khyber Pakhtunkhwa. The spatial relationship of geochemical data for pan-concentrates, stream sediments and tallus with respect to geology and structures was integrated into

GIS. Results of the spatial geochemical maps are shown in Figs. 5.2 a-j, 5.4 a-j and 5.6 a-j.

5.3. Pan-concentrates geochemical study

Results of pan-concentrate samples are shown in Table 5.1. Statistical parameters of geochemical data are presented in Table 5.2, Correlation matrix in Table 5.3 and Factor analysis in Table 5.4. While Histograms for Cu, Pb, Zn, Ni, Cr, Co, Cd, Mn, Ag and Au are shown in Fig. 5.1 and spatial geochemical maps for Au and base metals are shown in Figs. 5.2 a-j.

The geochemical data of the pan-concentrates (Table 5.1) is highly variable. Cu ranges from <0.020 to 349.770 ppm, Pb from <0.020 to 203.45 ppm, Zn from <0.020 to 131.300 ppm, Ni from <0.020 to 699.350 ppm, Cr from <0.020 to 541.0 ppm, Co from <0.020 to 47.350 ppm, Cd from <0.020 to 6.350 ppm, Mn from <0.020 to 986.6 ppm, Ag from <0.05 to 20 ppm, and Au from <0.05 to 45.456 ppm, (see Table 5.1).

The threshold value of each element was estimated after considering the histograms (Fig. 5.1) and statistical parameters (Table 5.2). The threshold value of each element in pan-concentrates is found to be 80 ppm for Cu, 40 ppm for Pb, 65 ppm for Zn, 200 ppm for Ni, 160 ppm for Cr, 25 ppm for Co, 4.5 ppm for Cd, 450 ppm for Mn, 6.8 ppm for Ag and 2.5 ppm for Au.

The combination of geo-statistical parameters and various layers generated by using spatial data analysis through GIS, give very useful results for the geochemical data of pan-concentrates (Figs. 5.2 a-j). It is clear from these figures that the concentration of Au, Ag and base metals is much higher in Peshawar Basin as compared to all other parts of the project area. Anomalous concentrations of Au (24.33 ppm, 41.71 ppm, 18.06 ppm and 45.46 ppm) in pan-concentrate samples are present in Nowshehra district either in the quaternary deposits or in the channel bars of Indus River (Fig. 5.2j). Anomalous values of Au are also found in a sample from Charsadda (Girgichi Khwar) and Swabi (Bada Khwar) districts having catchments in the Dargai Ophiolites (Indus Suture Melange) and Undivided rocks of Korara complex and Gandaf Formation respectively (Fig. 5.2j). Beside this, high values of Au also occur in Chorlaki

(Kohat) Shakadara (Kohat), Tarkha algad (Karak) and Umer khel (Tank) areas. The streams of Shakadara, Targha algad and Umer khel areas are originating from the Siwalik sandstone and conglomerate while that of Chorlaki area is from the quaternaty flood plain deposits of River Indus. Anomalous values of Ag, Cu, Ni, Cr, Co, and Cd are found, showing a geochemical association of these elements, in the streams originating from Indus Suture Melange (Dargai Ophiolites). Besides these anomalous values of base metals (Ag, Cu, Ni, Cr, Co, and Cd) in streams originating from Melange zone, some anomalous or high background values of these elements occur in various other parts, mostly from Northwestern and Northeastern boundary, of Peshawar Basin (Fig. 5.2a,d,e,f,g). The rocks bounding the Peshawar Basin in the Northwest and Northeast are undivided Paleozoic rocks, Tanawal, Manglawar, Gandaf, Kashala, Nikani-ghar, and Saidu Formations and igneous complexes of Karoara, Shewa, Ambela and Warsak.Anomalously values of base metals (Pb and Cd) also occur at confluence area of Indus and Kabul Rivers (Fig. 5.2b,g). Anomalous concentration of Cd is also found in Shewa, Ghazi and Marghaz area of Swabi district (Fig. 5.2g). Co is anomalously high in pan-concentratestream sediments from marghaz area of Swabi district (Fig. 5.2f). Anomalous values of Zn are found in Qasamai, Mardan, in streams having catchments in the undivided rocks of Kashala, Nikani-ghar, and Saidu Formations (Fig. 5.2c).

Table 5.1 Geochemical data of gold, silver and base metals in pan-concentrates.

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1101A	Swabi	25.65	18.55	20.65	34	16.1	47.35	1.3	111.2	0.5	0.237
1102A	Swabi	41.2	11.8	28.1	<0.02	42.55	35.5	4.65	147.05	<0.05	0.098
1103A	Swabi	<0.02	4.4	25.6	1.2	21.4	3.75	0.05	108.8	<0.05	31.795
1105A	Swabi	31.95	16.35	23	34.5	49.4	8.4	0.05	184.6	1	0.187
1106A	Swabi	7.2	4.75	9.95	13.55	49.1	3.25	0.25	50.9	<0.05	0.454
1108A	Swabi	14.2	3.95	19.35	8.8	8.1	10.85	2.2	105.9	<0.05	0.4
1109A	Swabi	49.95	30.85	45.55	25.9	25.35	12.25	5.85	313.1	1.5	0.069
1110A	Swabi	12.6	7.75	15.85	24.95	68.65	15.4	0.95	101.35	1	9.239
1111A	Swabi	5.55	20.65	10.9	12.1	17.3	5.2	1.8	64.4	1.5	0.119
1112A	Swabi	20.05	1.95	3.8	8.4	33.9	3.75	1.2	58.65	0.5	1.32
1113A	Swabi	0.4	<0.02	2.25	7.3	<0.02	3.2	1.4	60.1	2	<0.05
1114A	Swabi	4.2	<0.02	35.45	<0.02	<0.02	<0.02	1.55	89.75	<0.05	<0.05
1115A	Swabi	349.55	6.65	62.7	<0.02	31.9	1.15	2.85	80.8	<0.05	0.172
1116A	Swabi	37.55	2.4	24.2	29.9	43.55	11.5	2.15	204.05	1	0.096
1117A	Swabi	4.95	18.55	44.1	23	27.15	6.7	5.5	199.7	4	2.632
1118A	Swabi	<0.02	<0.02	25.9	0.15	14.15	2.4	1.05	80.2	0.1	0.206
1119A	Swabi	0.75	6.35	28.15	<0.02	28.8	3	2.2	116.8	<0.05	0.21
1120A	Mardan	24.15	2.95	38.55	23.5	36.95	19.95	2.65	194.5	2	0.238
1121A	Mardan	9.25	3.9	11.6	14.3	17.9	4.95	1.7	49.2	1	<0.05
1122A	Mardan	16.25	7.15	19.9	<0.02	16.15	3.85	1.35	127.35	5.5	<0.05
1123A	Mardan	24.45	19.35	40.75	41.55	39.65	24.15	2.05	190.4	1.5	0.248
1124A	Mardan	5.6	<0.02	26.7	10.9	7.9	5.05	1.2	104.8	1.5	0.378
1125A	Mardan	8.85	6.55	41.85	7.7	0.65	6.6	0.85	986.6	2	0.135
1126A	Mardan	8.2	2.75	46.55	26.1	8.9	8.1	1.95	136.15	1.5	<0.05
1127A	Mardan	43.7	21.7	36.15	91.95	64.95	37.15	3.35	131.55	19.5	<0.05
1128A	Mardan	12.95	3.05	22.35	2.5	6.85	13.35	1.75	100.15	0.5	<0.05

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1129A	Mardan	13.4	19.75	26.35	18.45	29.6	17.4	3.45	139.5	3	0.524
1130A	Mardan	86.45	8.1	61	67.8	3.5	22.7	0.4	238	<0.05	0.082
1131A	Mardan	39.75	5.5	24.3	49.45	10.9	15.8	0.05	178.3	<0.05	<0.05
1132A	Mardan	22.1	13.4	30.35	32.3	1.25	13.35	2.5	124	3	<0.05
1133A	Mardan	96.2	12.05	131.3	89.65	56.35	29.95	2.35	283.45	3	0.137
1134A	Mardan	27.3	1.4	30.2	145.6	117.8	16.45	1.3	182.45	1	0.128
1135A	Mardan	31.75	2.85	22.05	134.2	126.25	15.45	0.2	124	1.5	<0.05
1137A	Charsadda	2.7	<0.02	4	43.6	74.6	4.75	0.05	33.05	2	<0.05
1138A	Charsadda	5	2.45	7.6	393.25	69.3	<0.02	2.15	116.8	1	0.069
1139A	Charsadda	<0.02	7.1	11.05	699.35	106.25	36.1	4.65	26.35	20	<0.05
1140A	Charsadda	<0.02	<0.02	0.85	<0.02	<0.02	<0.02	0.05	<0.02	1	<0.05
1141A	Charsadda	3.65	5.55	11.1	567.85	136.8	25.15	0.5	188.7	2	<0.05
1150A	Nowshehra	<0.02	<0.02	35	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1152A	Nowshehra	18.5	10.45	28.25	53.45	43.75	13.3	1.05	254.5	1.5	0.431
1153A	Nowshehra	72.15	10.35	46.85	108.55	83.2	18.4	1.75	421.5	<0.05	<0.05
1154A	Nowshehra	8.25	6.7	16.25	24.9	53.1	3.5	0.05	104.25	<0.5	0.125
1155A	Nowshehra	18.4	10.5	29.5	60.4	38.6	10.6	0.35	236.75	2	<0.05
1157A	Nowshehra	15.3	5.05	28.45	49.7	63.45	7.4	1.9	228.25	1	0.266
1158A	Nowshehra	18.9	7.6	31.9	98.7	70.55	14.6	1.55	21.1	1.5	<0.05
1159A	Nowshehra	19.75	14.6	32.35	58.45	84.8	12.1	1.15	204.85	1	3.025
1162A	Nowshehra	22.5	20.15	51.5	18.85	46.8	9.35	0.25	356	2.5	0.145
1164A	Nowshehra	26.75	16.95	54.75	44.75	10	11.7	1.5	514.1	1.5	<0.05
1165A	Nowshehra	16.8	8.95	33.9	27.3	27.85	6.5	1.25	345.8	8	<0.05
1167A	Nowshehra	29.9	11.95	29.3	54.2	79.7	9.7	1.45	195.2	2	0.755
1168A	Peshawar	4.9	<0.02	18.25	<0.02	15.55	2.7	2.5	190.5	<0.05	<0.05
1169A	Peshawar	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	0.184

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1170A	Peshawar	23.6	13.2	42.15	33.2	38.9	10.65	4.6	266.8	<0.05	<0.05
1172A	Peshawar	30.1	5.15	26.55	20.05	40.05	16.1	2.3	224.35	<0.05	<0.05
1174A	Peshawar	2.9	<0.02	4.8	9.65	10.9	<0.02	0.05	31.1	0.5	<0.05
1175A	Peshawar	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1176A	Peshawar	14.4	10.7	25.95	46.15	50.15	6.05	4.8	209	<0.05	0.099
1177A	Peshawar	33.55	14.05	64.2	21.9	58.9	17.75	3.3	<0.02	<0.05	0.095
1201A	Charsadda	6.45	5.7	7.15	44.8	92.35	5.25	0.5	54.65	1.5	4.243
1206A	Charsadda	1.7	<0.02	3.4	<0.02	58.55	1.5	0.75	46.7	<0.05	25.084
1207A	Charsadda	15.05	1.3	17.1	112	438.75	16.35	1.05	132.75	0.5	<0.05
1208A	Charsadda	32.6	2.95	32.45	155.75	541	34.2	0.7	<0.02	1.5	0.65
1210A	Charsadda	<0.02	4.8	12.45	27.7	72.05	13.85	0.95	120.25	2	<0.05
1212A	Charsadda	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1214A	Charsadda	130.25	9.2	18	26.75	34.45	13.7	2.7	140.8	2.5	0.098
1215A	Charsadda	7.9	<0.02	10.55	10.55	74.9	11.95	0.9	96.85	3.5	6.82
1216A	Nowshehra	37.5	5.7	16.15	16.55	<0.02	4.35	1.3	96.2	2	45.456
1219A	Nowshehra	36.5	203.45	40.05	16.1	59.9	14.4	1.65	606.1	1.5	<0.05
1220A	Nowshehra	22.85	12.75	31.25	15.25	54.2	10.55	1.05	293.7	0.5	<0.05
1221A	Nowshehra	12.35	2.9	12.25	<0.02	82.15	13.9	0.9	176.1	3	5.555
1222A	Nowshehra	11.95	12.5	13.35	12.55	58.7	7.8	0.05	140.25	1.5	<0.05
1224A	Nowshehra	12.15	1.7	13.8	5.7	27.15	6.95	4.45	135.05	<0.05	<0.05
1227A	Nowshehra	16.05	13.05	23.9	31.85	34.2	6.75	6.35	144.1	2.5	0.104
1229A	Nowshehra	6.4	11	10.15	0.1	<0.02	0.05	0.05	82	<0.05	<0.05
1230A	Nowshehra	21.1	21	32.2	43.25	28.1	8.55	1.55	241.6	6.5	<0.05
1231A	Nowshehra	13.95	<0.02	28.15	18.45	20.05	6.15	1.25	147.4	4	0.293
1232A	Nowshehra	9.65	<0.02	20.6	5.55	18.5	4.85	3.4	117.4	0.5	<0.05
1233A	Nowshehra	27.25	17.4	54.85	36.7	<0.02	11.75	0.85	325.7	2	<0.05
1234A	Nowshehra	13.95	3.2	23.05	29.4	31	8.5	1.2	166.65	2.5	18.065

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1235A	Nowshehra	8.75	6.15	<0.02	10.95	58.35	4.75	0.05	131.8	<0.05	<0.05
1236A	Nowshehra	10.25	33.55	24.7	13.75	<0.02	<0.02	0.05	131.3	<0.05	<0.05
1237A	Nowshehra	20.25	16.6	43.9	<0.02	29	4.2	6	335	1.5	0.18
1238A	Nowshehra	<0.02	3.55	34.6	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	0.26
1239A	Nowshehra	12.8	8.5	13.85	19.15	99.95	6.35	1.3	136.25	1	7.64
1240A	Nowshehra	10	4.3	19	<0.02	50.4	8.3	3.25	221.7	<0.05	41.706
1241A	Nowshehra	65.6	25.25	54.55	28.9	31.1	11.55	5.55	228.5	1.5	0.466
1242A	Nowshehra	32.85	24.45	49.3	23.6	19.95	9.65	2.6	408.4	1.5	<0.05
1243A	Nowshehra	7.65	4.05	11.45	4.9	12.55	1.75	4.8	161.85	<0.05	9.434
1244A	Nowshehra	30.2	14.95	54.15	38.7	19.6	10.45	0.25	332.7	0.5	<0.05
1245A	Nowshehra	10.3	3.9	13.55	13.4	12.5	2.45	2	118.1	1.5	<0.05
1246A	Nowshehra	18	15.65	32.05	25.35	19.35	5.95	2.75	297.75	1.5	0.334
1247A	Nowshehra	67.3	10.85	21.8	7.9	50.95	7.5	1.15	250.75	1	24.33
1502A	Kohat	0.101	0.026	0.519	0.226	1.379	0.06	0.006	5.828	0.07	0.176
1504A	Kohat	0.124	0.041	0.53	0.085	1.297	<0.02	<0.02	3.799	0.087	0.256
1506A	Kohat	0.65	3.363	0.614	0.186	1.621	0.042	<0.02	3.452	0.067	0.633
1509A	Kohat	0.241	0.03	0.427	0.113	0.523	0.06	<0.02	5.15	0.092	<0.05
1511A	Kohat	0.108	0.021	0.477	0.273	2.543	0.056	0.042	4.318	0.086	<0.05
1512A	Kohat	0.052	<0.02	0.321	0.036	0.515	0.039	0.052	1.851	0.08	<0.05
1515A	Kohat	0.114	0.186	0.317	0.229	0.116	<0.02	<0.02	10.78	0.131	<0.05
1518A	Kohat	0.064	0.03	0.166	0.116	0.885	0.25	<0.02	2.362	0.104	<0.05
1526A	Kohat	0.092	0.078	0.346	0.132	0.784	0.07	<0.02	2.535	0.08	1.116
1531A	Kohat	0.845	0.052	0.345	0.193	0.866	0.094	0.023	5.9	0.12	<0.05
1536A	Kohat	4.566	<0.02	0.445	0.502	2.87	0.183	<0.02	4.17	0.101	1.018
1541A	Kohat	0.083	<0.02	0.309	0.098	0.698	<0.02	<0.02	5.7	0.087	0.183
1542A	Kohat	0.104	0.085	0.446	0.084	0.212	0.088	<0.02	3.94	0.167	0.133
1545A	Kohat	0.155	<0.02	0.38	0.497	2.737	<0.02	<0.02	4.103	0.087	13.58

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1551A	Kohat	0.1	0.125	0.467	0.085	0.131	0.046	0.066	4.873	0.082	0.252
1553A	Kohat	0.158	0.156	0.327	0.174	0.2	0.047	0.047	12.89	0.102	<0.05
1556A	Kohat	0.108	<0.02	0.512	0.202	0.552	0.081	0.037	12.08	0.074	<0.05
1559A	Kohat	0.078	0.088	0.42	0.126	0.402	0.14	0.027	6.37	0.086	0.198
1567A	Kohat	0.05	<0.02	0.252	0.097	1.43	<0.02	0.051	1.944	0.101	0.5
1572A	Kohat	0.07	0.039	0.277	0.002	0.759	0.024	<0.02	2.304	0.104	<0.05
1573A	Kohat	0.171	0.023	0.809	0.257	0.033	0.032	<0.02	4.083	0.089	<0.05
1577A	Kohat	0.13	<0.02	0.371	0.182	0.156	0.046	<0.02	6.944	0.087	<0.05
2003A	Kohat	0.205	0.079	1.01	0.312	2.534	0.21	<0.02	4.081	0.083	1.59
2007A	Kohat	0.201	0.054	1.283	0.388	2.515	0.036	<0.02	5.285	0.082	1.023
2010A	Kohat	0.133	0.031	0.946	0.214	1.799	0.068	0.045	5.071	0.081	0.998
2013A	Kohat	0.146	0.078	1.454	0.34	2.002	0.076	<0.02	4.393	0.07	1.6185
2027A	Kohat	0.267	0.41	1.339	0.551	2.821	<0.02	0.025	5.54	0.096	2.191
2035A	Kohat	0.227	0.049	0.137	0.546	1.036	0.064	0.037	11.26	0.096	1.24
2040A	Kohat	0.403	0.075	0.952	0.167	2.313	<0.02	<0.02	4.234	0.081	1.305
1602A	Karak	0.096	0.068	0.327	<0.02	1.14	0.038	0.032	1.625	0.322	3.7515
1604A	Karak	<0.02	0.028	0.554	0.087	2.947	0.177	0.029	5.939	2.526	0.231
1606A	Karak	<0.02	<0.02	0.454	0.071	0.402	0.092	<0.02	5.302	0.244	0.127
1612A	Karak	0.025	<0.02	0.354	<0.02	0.612	0.115	0.038	2.822	<0.05	0.348
1617A	Karak	0.055	0.077	0.339	<0.02	0.572	0.058	0.04	2.335	1.521	0.057
1630A	Karak	0.642	0.112	0.517	0.156	1.414	0.176	0.091	9.683	1.071	
1632A	Karak	0.024	0.222	0.37	0.056	0.697	<0.02	0.071	3.011	1.013	0.135
1643A	Karak	<0.02	0.1	0.434	0.191	0.717	<0.02	<0.02	2.598	0.973	<0.05
1648A	Karak	0.039	0.029	0.548	0.105	2.513	0.1	<0.02	5.631	0.149	0.3875
1650A	Karak	0.03	0.049	0.432	0.08	2.064	<0.02	0.06	3.549	0.702	2.2665
1655A	Karak	<0.02	0.041	0.83	0.394	3.853	<0.02	0.036	3.472	0.125	<0.05
1659A	Karak	0.356	0.135	0.455	0.089	1.832	0.046	0.03	1.833	2.335	0.123

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1663A	Karak	0.057	0.028	0.45	0.028	0.218	0.095	0.029	2.231	0.113	<0.05
1665A	Karak	0.153	0.029	0.544	0.145	0.672	0.13	<0.02	3.357	0.121	0.234
1680A	Karak	<0.02	0.053	0.481	0.236	1.469	0.06	0.022	3.215	2.701	0.15
1682A	Karak	0.077	0.085	0.331	0.234	3.486	<0.02	0.037	2.878	1.048	<0.05
1684A	Karak	0.083	0.647	0.412	0.236	0.362	0.148	<0.02	3.44	0.278	0.204
1690A	Karak	0.072	0.105	0.401	0.034	1.778	0.056	<0.02	3.14	0.145	1.012
1695A	Karak	0.046	0.156	0.36	<0.02	2.17	0.108	0.072	4.744	0.541	0.2805
1697A	Karak	0.027	0.117	0.565	0.067	0.999	0.091	<0.02	2.445	1.811	2.877
1808A	Karak	<0.02	<0.02	0.227	0.031	0.283	0.041	0.057	4.304	1.161	0.225
1810A	Karak	0.028	0.196	0.288	0.031	1.111	0.067	<0.02	2.435	0.921	5.139
1820A	Karak	0.028	0.072	0.601	0.29	3.532	0.512	0.055	4.271	1.082	0.204
1822A	Karak	0.111	0.048	0.143	<0.02	1.234	0.116	<0.02	1.366	0.954	0.177
1824A	Karak	0.078	0.039	0.576	0.17	3.561	0.473	0.106	4.788	1.308	0.2565
1836A	Karak	<0.02	0.127	0.608	0.399	2.681	0.433	<0.02	8.887	1.126	<0.05
1841A	Karak	<0.02	<0.02	0.62	0.176	2.945	0.152	0.063	4.253	0.196	0.192
1845A	Karak	<0.02	0.047	0.457	0.125	2.396	0.189	0.064	3.356	0.863	4.832
1855A	Karak	<0.02	0.094	0.421	<0.02	1.137	0.042	0.066	3.451	0.345	<0.05
1864A	Karak	0.032	0.058	0.475	0.03	2.041	0.093	0.022	3.107	0.099	0.165
1872A	Karak	0.089	0.096	0.751	0.272	3.817	0.401	0.067	4.232	0.275	<0.05
1875A	Karak	0.203	<0.02	0.771	0.042	1.969	0.082	0.035	4.478	0.148	0.139
1878A	Karak	0.289	0.069	1.246	0.573	4.51	0.571	0.043	10.18	0.795	<0.05
1880A	Karak	<0.02	0.025	0.482	0.059	2.381	0.065	<0.02	3.873	0.192	<0.05
2042A	Karak	0.061	<0.02	1.058	0.06	2.078	0.064	0.086	2.647	0.735	0.7995
2050A	Karak	0.021	0.022	1.034	0.116	2.648	0.292	0.076	3.794	1.103	1.6485
2056A	Karak	0.052	0.035	1.135	0.208	3.097	0.066	0.038	5.227	0.413	<0.05
1598A	Bannu	0.229	<0.02	0.927	1.297	2.605	0.397	<0.02	10.03	0.115	0.056
1701A	Bannu	0.425	0.064	0.761	2.324	1.669	0.291	<0.02	21.45	0.087	0.0585

Table 5.1 continued

SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1702A	Bannu	0.293	0.043	0.524	1.05	2.222	0.271	<0.02	16.26	0.119	0.282
1704A	Bannu	0.299	0.101	0.452	1.637	1.247	0.152	<0.02	17.99	0.079	0.06
1705A	Bannu	0.304	0.056	0.615	0.826	0.575	0.215	<0.02	11.95	0.1	<0.05
1714A	Bannu	0.27	0.056	0.534	1.662	1.552	0.362	<0.02	11.22	0.172	<0.05
1715A	Bannu	2.463	0.099	0.742	1.234	1.283	0.175	0.023	8.004	0.099	0.654
1716A	Bannu	0.174	0.091	0.396	0.459	1.168	<0.02	<0.02	8.924	0.091	0.0855
1729A	Bannu	0.167	0.093	0.522	0.412	0.935	0.153	<0.02	15.08	0.093	<0.05
1732A	Bannu	0.567	<0.02	0.492	0.878	1.327	0.076	0.05	11.85	0.087	1.3485
1736A	Bannu	0.189	0.091	0.422	0.34	0.449	0.099	0.034	8.599	0.077	0.0525
1743A	Bannu	0.242	0.052	0.511	0.909	0.955	0.307	<0.02	13.43	0.083	0.0915
1766A	Lakki Marwat	0.152	0.057	0.898	0.718	2.277	0.395	<0.02	10.16	<0.05	0.707
1772A	Lakki Marwat	0.789	0.054	0.521	0.618	1.357	0.425	<0.02	8.494	0.062	<0.05
1912A	Lakki Marwat	0.091	0.028	0.458	0.18	0.687	0.235	<0.02	3.244	0.059	<0.05
1915A	Lakki Marwat	0.091	0.021	0.595	0.467	1.576	0.405	0.075	2.887	0.066	0.4395
1917A	Lakki Marwat	0.336	0.037	1.016	0.431	1.014	0.387	<0.02	8.979	0.083	0.0675
1930A	Lakki Marwat	0.268	0.032	0.621	1.703	2.381	0.264	0.061	8.233	0.072	0.4815
1935A	Lakki Marwat	0.12	<0.02	0.56	1.094	2.211	0.437	<0.02	6.69	0.059	0.198
1941A	Lakki Marwat	0.038	0.023	0.559	0.59	2.183	0.374	0.042	3.352	<0.05	0.2535
1943A	Lakki Marwat	0.083	0.074	0.922	1.1	3.784	0.63	<0.02	8.256	0.079	0.205
1958A	Lakki Marwat	0.147	0.035	1.094	1.049	1.498	0.412	<0.02	7.362	0.06	<0.05
3005A	Hangu	0.26	0.32	0.578	0.509	0.657	0.266	0.095	10.3	<0.05	0.346
3007A	Hangu	0.356	0.214	0.843	0.295	0.829	0.168	0.069	18.025	<0.05	0.093
3008A	Hangu	0.148	0.03	0.41	0.365	0.625	0.176	0.045	7.486	<0.05	0.275
3017A	Hangu	0.884	0.094	1.503	1.191	0.985	0.683	0.111	4.936	0.9	0.078
3030A	Hangu	0.209	0.102	0.843	0.459	0.771	0.265	0.055	7.454	0.734	<0.05
3042A	Hangu	<0.02	0.502	0.225	0.266	0.065	0.107	0.038	3.523	<0.05	0.488
3050A	Hangu	0.036	0.203	0.304	0.175	0.244	0.116	0.093	5.179	<0.05	0.531

Table 5.1 continued

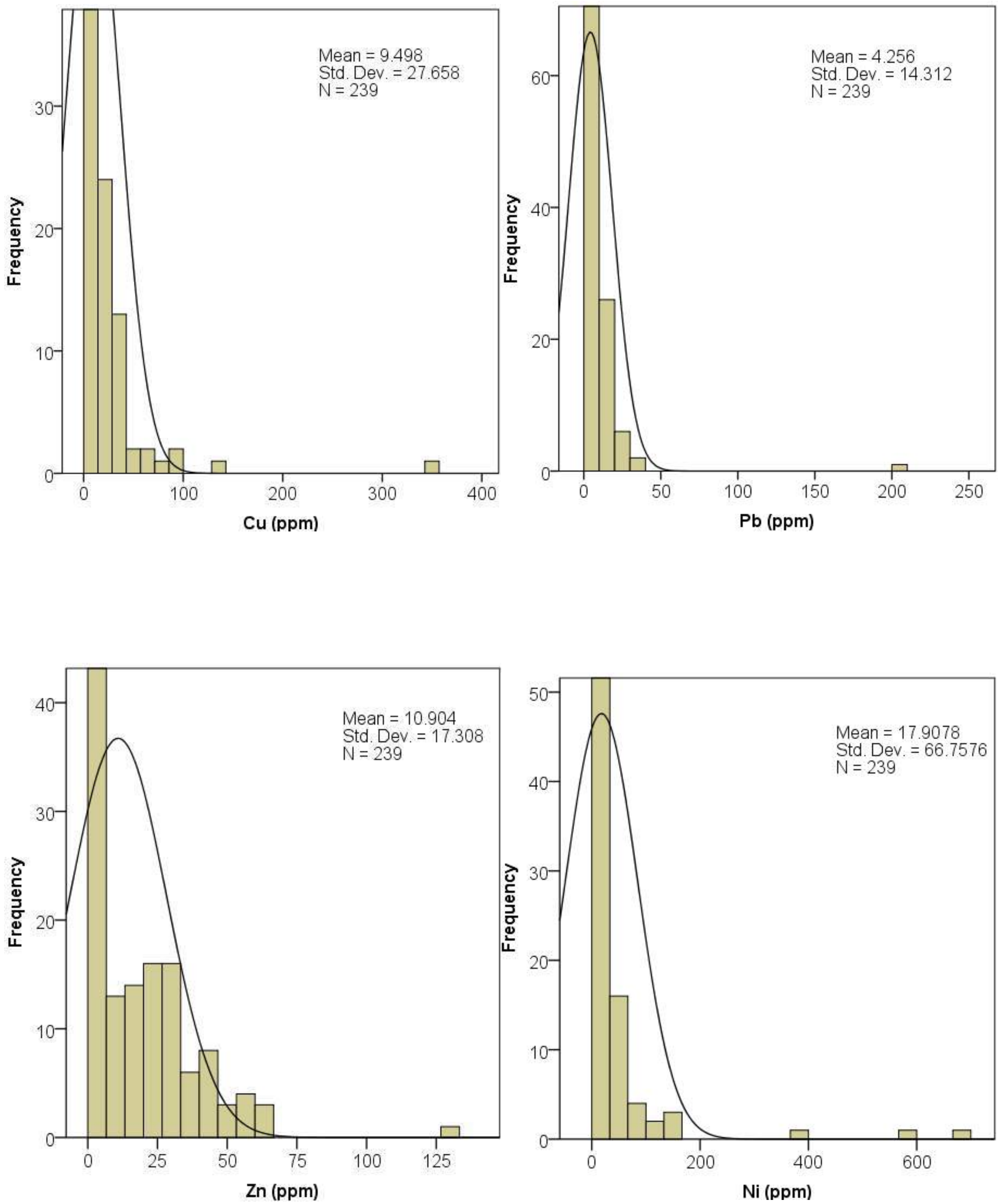
SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
3069A	Hangu	0.201	0.63	0.467	0.372	0.262	0.164	0.042	24.8	<0.05	<0.05
2111A	D.I.Khan	0.043	<0.02	1.457	0.214	<0.02	<0.02	0.246	0.054	0.06	4.322
2112A	D.I.Khan	0.11	0.524	2.421	0.244	<0.02	<0.02	0.585	0.043	0.209	<0.05
2113A	D.I.Khan	0.038	0.263	1.938	0.155	0.044	0.117	0.121	0.064	0.137	<0.05
2174A	D.I.Khan	0.141	0.752	2.446	0.315	<0.02	0.117	0.192	0.059	0.075	<0.05
2206A	D.I.Khan	1.647	0.606	13.8	1.487	1.163	0.133	0.651	1.475	0.094	<0.05
2210A	D.I.Khan	0.691	0.533	6.81	0.814	0.717	0.125	1.363	0.432	0.161	0.093
2255A	D.I.Khan	0.051	0.566	2.326	0.285	<0.02	0.119	0.465	0.051	<0.05	<0.05
2256A	D.I.Khan	0.076	0.616	2.487	0.473	0.09	0.119	0.884	0.15	0.13	<0.05
2281A	D.I.Khan	0.224	0.523	3.578	0.537	0.534	<0.02	2.213	0.318	0.199	<0.05
2282A	D.I.Khan	0.254	1.842	3.491	0.532	0.233	0.11	1.977	0.283	0.132	<0.05
2342A	D.I.Khan	0.024	<0.02	2.232	0.283	0.141	0.133	0.326	0.036	0.171	<0.05
2344A	D.I.Khan	0.059	0.683	2.39	0.154	<0.02	0.104	0.149	0.123	0.126	<0.05
2365A	D.I.Khan	13.77	0.785	1.725	0.857	0.03	0.115	0.246	0.045	0.198	0.247
2369A	D.I.Khan	0.113	0.081	0.259	0.47	0.439	0.259	<0.02	4.197	0.052	<0.05
2370A	D.I.Khan	0.1	0.08	0.221	0.46	0.813	0.221	<0.02	3.699	<0.05	<0.05
2371A	D.I.Khan	0.526	0.121	0.584	0.865	1.251	0.584	0.021	10.51	<0.05	0.051
2372A	D.I.Khan	0.789	0.182	0.744	1.284	1.519	0.744	0.036	12.85	<0.05	<0.05
2373A	D.I.Khan	0.207	0.288	0.233	0.635	0.414	0.233	<0.02	8.604	0.076	0.182
2374A	D.I.Khan	0.12	0.106	0.254	0.479	0.421	0.254	<0.02	4.063	0.062	<0.05
2375A	D.I.Khan	0.357	0.113	0.309	0.654	0.574	0.309	0.21	7.916	0.075	<0.05
2376A	D.I.Khan	0.17	0.147	0.486	0.765	2.803	0.486	<0.02	6.746	<0.05	<0.05
2377A	D.I.Khan	0.396	0.115	0.337	0.664	0.691	0.337	<0.02	8.466	0.051	<0.05
2378A	D.I.Khan	0.241	0.123	0.286	0.523	0.32	0.286	0.027	3.684	<0.05	0.061
2379A	D.I.Khan	1.007	0.12	0.253	0.683	0.458	0.253	0.023	6.873	<0.05	<0.05
2380A	D.I.Khan	0.362	0.118	0.577	0.781	2.31	0.577	0.028	6.367	0.063	<0.05
2381A	D.I.Khan	0.129	0.092	0.294	0.268	0.272	0.294	<0.02	4.868	<0.05	<0.05

Table 5.1 continued

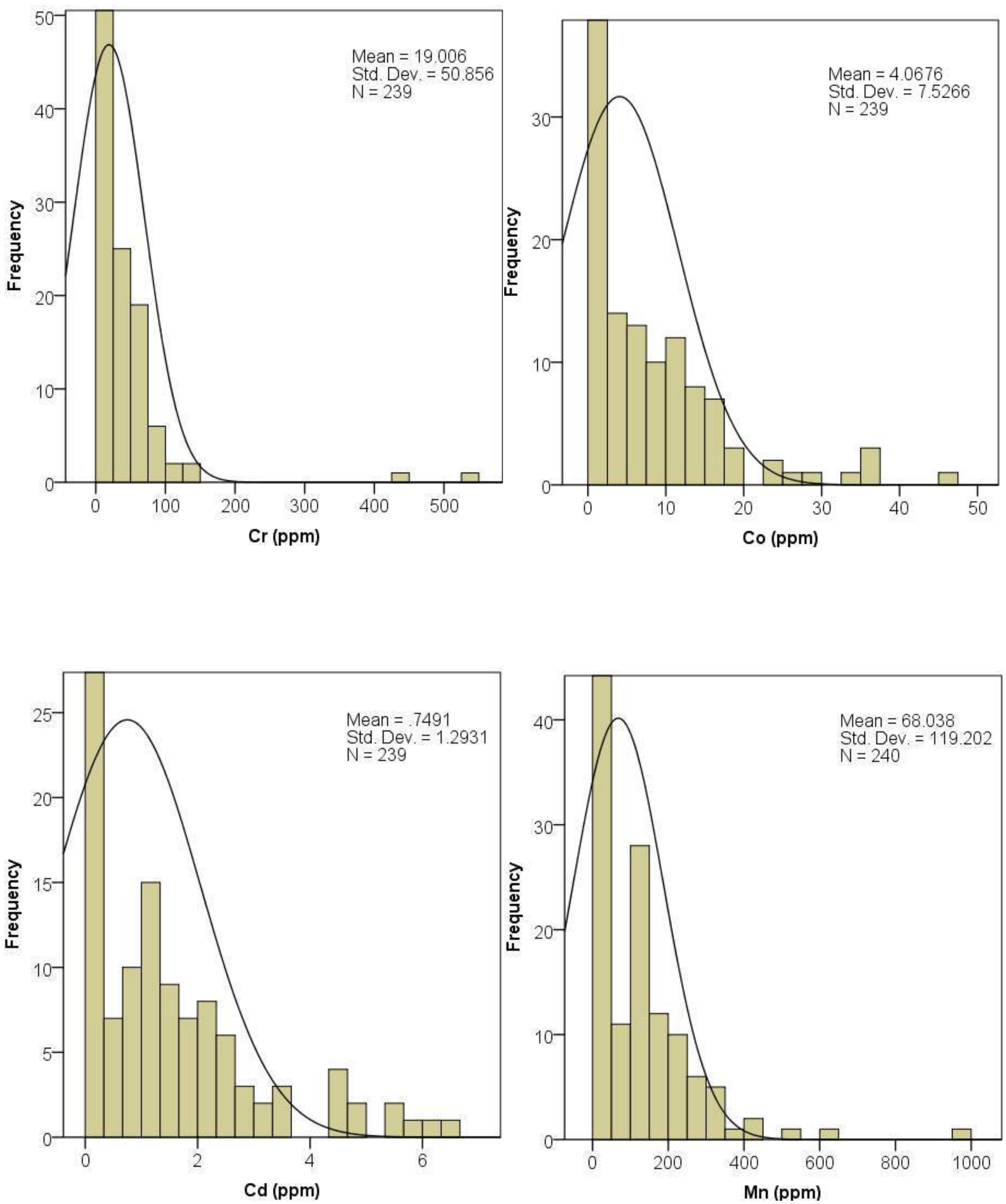
SampleNo.	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2431A	D.I.Khan	0.077	<0.02	2.896	0.265	0.092	0.125	0.955	0.106	0.092	<0.05
2432A	D.I.Khan	0.16	0.745	4.138	0.586	0.418	0.094	2.639	0.327	0.142	<0.05
2501A	Tank	0.039	0.758	0.577	0.126	1.838	0.359	0.075	4.568	<0.05	1.717
2502A	Tank	0.264	0.806	0.777	0.547	1.699	0.381	0.064	6.001	<0.05	<0.05
2503A	Tank	0.363	0.038	1.034	0.49	2.192	0.555	0.037	8.826	<0.05	5.863
2505A	Tank	0.41	1.142	0.428	<0.02	0.638	0.114	<0.02	2.489	<0.05	4.608
2515A	Tank	1.335	1.727	1.216	0.739	0.474	0.0338	0.095	0.801	<0.05	<0.05
2516A	Tank	0.037	0.279	0.207	<0.02	<0.02	0.028	0.021	2.145	<0.05	<0.05
2517A	Tank	0.841	0.799	1.045	0.058	<0.02	0.348	0.033	0.56	<0.05	<0.05
2519A	Tank	1.236	1.537	1.235	0.292	1.471	0.484	<0.02	0.577	<0.05	1.51
2538A	Tank	0.867	0.744	1.078	0.586	0.896	0.433	<0.02	10.26	0.102	0.313
2539A	Tank	0.875	1.745	1.537	0.968	1.589	0.718	0.044	0.613	<0.05	0.59
2546A	Tank	2.052	2.068	1.801	2.03	1.664	0.833	<0.02	3.712	0.128	0.118
2547A	Tank	8.942	1.123	1.149	1.265	0.923	0.502	<0.02	2.309	<0.05	<0.05
2548A	Tank	1.698	0.174	1.461	1.01	0.975	0.542	0.057	2.784	0.086	<0.05
2549A	Tank	1.537	0.6	1.455	1.479	1.707	0.645	0.078	3.164	0.096	<0.05
2550A	Tank	1.077	1.527	1.091	0.754	0.989	0.491	0.052	2.071	<0.05	0.06
2558A	Tank	0.748	1.445	0.995	0.943	0.419	0.473	0.025	0.66	<0.05	<0.05
2560A	Tank	1.578	2.327	1.669	1.456	0.951	0.91	0.05	0.961	<0.05	<0.05
2561A	Tank	0.913	1.545	1.251	0.731	1.269	0.612	<0.02	0.786	<0.05	<0.05
2564A	Tank	0.853	1.442	1.173	1.27	1.9	0.522	0.063	10.69	<0.05	<0.05
2565A	Tank	1.239	0.658	1.29	0.747	1	0.532	0.047	0.525	0.111	<0.05
2567A	Tank	1.249	1.823	1.163	0.939	<0.02	0.725	0.072	0.567	<0.05	0.055
2570A	Tank	1.355	1.304	1.747	0.613	0.659	0.458	0.094	0.645	<0.05	<0.05
2572A	Tank	2.056	2.257	2.356	1.336	0.612	0.764	0.067	0.979	<0.05	<0.05

Table 5.2. Statistical parameters of gold, silver and base metals in pan-concentrates.

		Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
N	**Valid**	239	239	239	239	239	239	239	240	239	240
	Missing	2	2	2	2	2	2	2	1	2	1
Mean		9.498	4.256	10.904	17.908	19.006	4.068	.749	68.038	.823	1.380
Median		.362	.196	1.163	.573	1.778	.359	.057	7.489	.104	.084
Std. Deviation		27.658	14.312	17.308	66.758	50.856	7.527	1.293	119.202	2.047	5.265
Minimum		.020	.020	.020	.002	.020	.020	.006	.020	.050	.050
Maximum		349.550	203.450	131.300	699.350	541.000	47.350	6.350	986.600	20.000	45.456
Percentiles	**50**	.362	.196	1.163	.573	1.778	.359	.057	7.489	.104	.084
	75	10.000	3.950	19.000	12.100	19.600	5.250	1.150	115.400	1.000	.329
	90	27.250	13.050	34.600	41.550	58.550	13.700	2.500	220.430	2.000	2.144
	95	37.550	18.550	46.550	67.800	79.700	17.750	3.450	297.548	3.000	5.848
	99	116.630	32.470	63.600	498.010	317.970	36.730	5.940	568.380	14.900	37.642



Continuation of Fig. 5.1



Continuation of Fig. 5.1

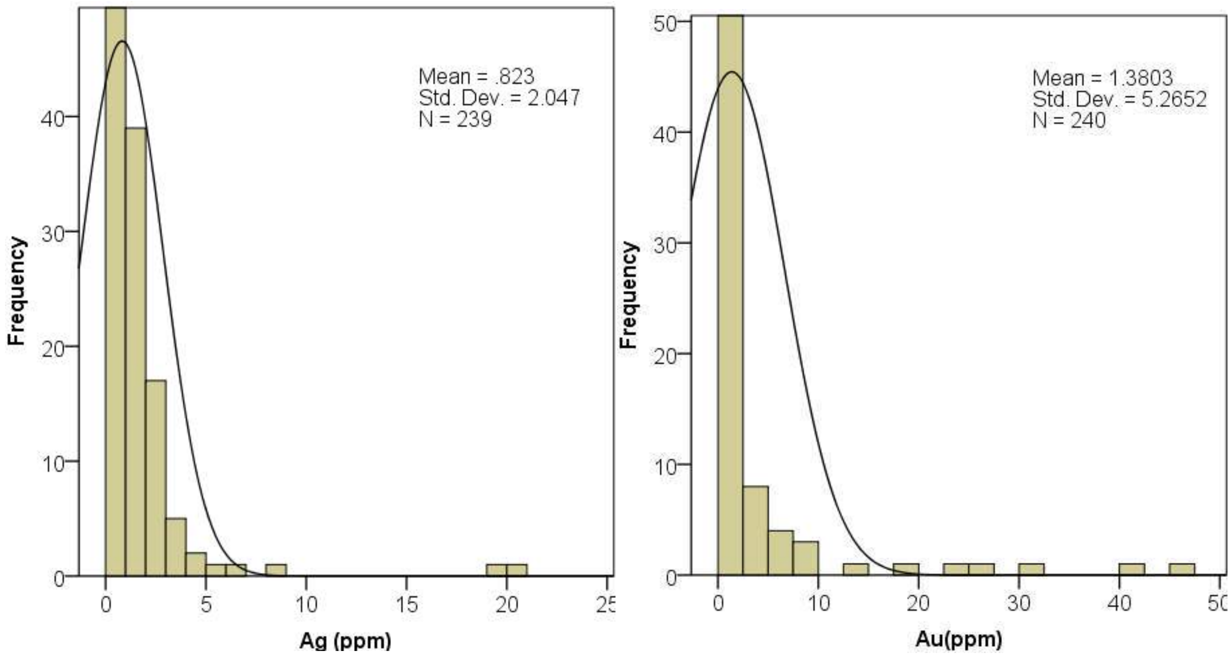


Fig. 5.1. Histograms of gold, silver and base metals in pan-concentrates.

Table 5.3. Correlation matrix for gold, silver and base metals in Pan-concentrates.

		LogCu	LogPb	LogZn	LogNi	LogCr	LogCo	LogCd	LogMn	LogAg	LogAu
LogCu	**Pearson Correlation**	1									
	Sig. (2-tailed)										
	N	239									
LogPb	**Pearson Correlation**	.746**	1								
	Sig. (2-tailed)	.000									
	N	239	239								
LogZn	**Pearson Correlation**	.772**	.731**	1							
	Sig. (2-tailed)	.000	.000								
	N	239	239	239							
LogNi	**Pearson Correlation**	.703**	.632**	.656**	1						
	Sig. (2-tailed)	.000	.000	.000							
	N	239	239	239	239						
LogCr	**Pearson Correlation**	.596**	.474**	.573**	.606**	1					
	Sig. (2-tailed)	.000	.000	.000	.000						
	N	239	239	239	239	239					
LogCo	**Pearson Correlation**	.778**	.700**	.761**	.747**	.734**	1				
	Sig. (2-tailed)	.000	.000	.000	.000	.000					
	N	239	239	239	239	239	239				
LogCd	**Pearson Correlation**	.672**	.639**	.816**	.550**	.509**	.695**	1			

	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000				
	N	239	239	239	239	239	239	239			
LogMn	**Pearson Correlation**	.659**	.509**	.596**	.578**	.681**	.688**	.490**	1		
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000			
	N	239	239	239	239	239	239	239	240		
LogAg	**Pearson Correlation**	.331**	.341**	.452**	.449**	.462**	.463**	.477**	.423**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		
	N	239	239	239	239	239	239	239	239	239	
LogAu	**Pearson Correlation**	.027	.007	.050	-.061	.209**	.058	.056	.112	.082	1
	Sig. (2-tailed)	.681	.909	.438	.347	.001	.374	.387	.083	.205	
	N	238	238	238	238	238	238	238	239	238	240

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.4. Factor Analysis for gold, silver and base metals in Pan-concentrates.

	Factor 1	**Factor 2**
LogCu	.874	-.128
LogPb	.804	-.196
LogZn	.884	-.094
LogNi	.818	-.159
LogCr	.776	.299
LogCo	.912	-.011
LogCd	.810	-.070
LogMn	.775	.160
LogAg	.582	.195
LogAu	.086	.923

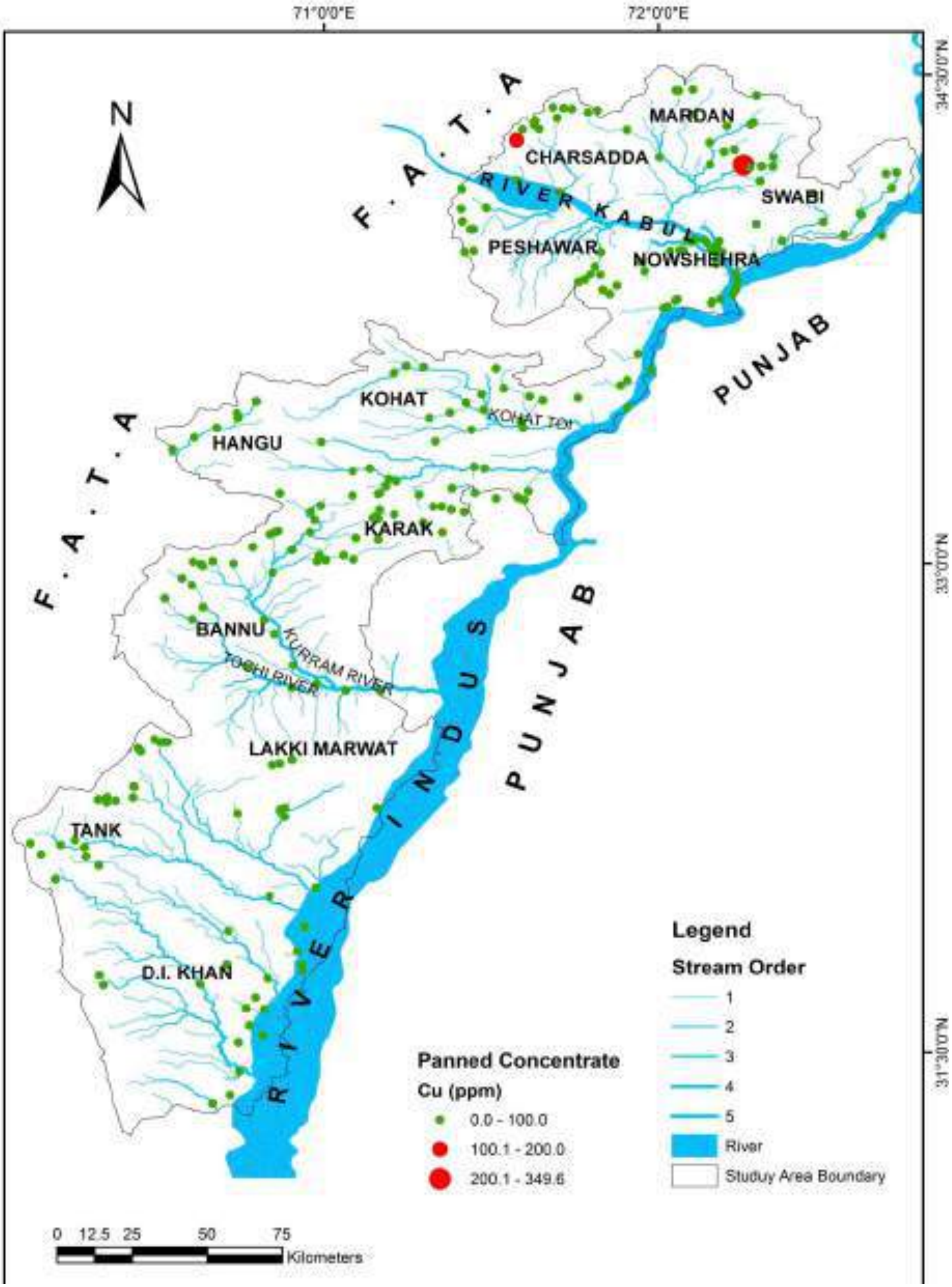


Fig. 5.2a. Geochemical map of Cu in pan-concentrates.

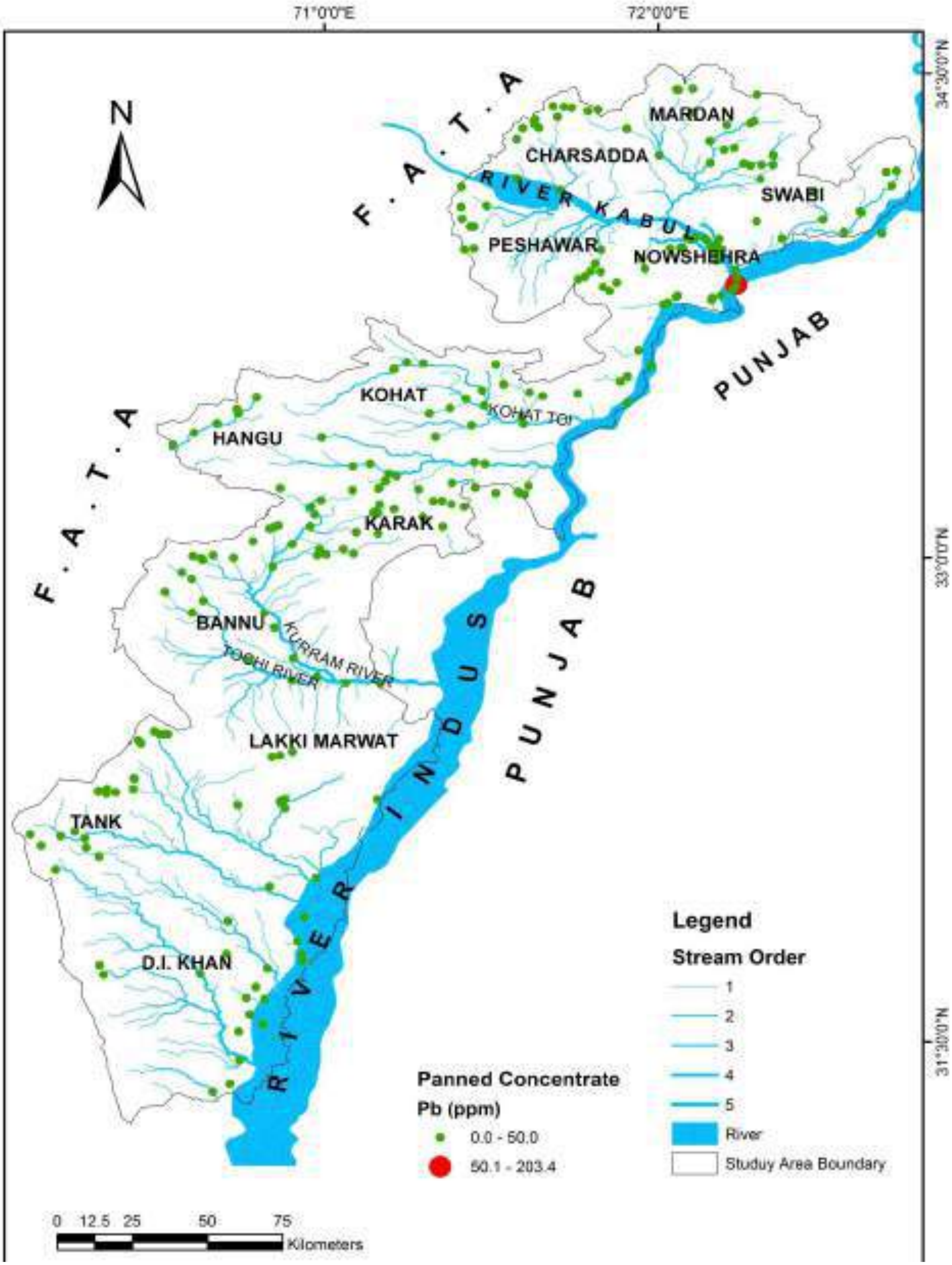


Fig. 5.2b. Geochemical map of Pb in pan-concentrates.

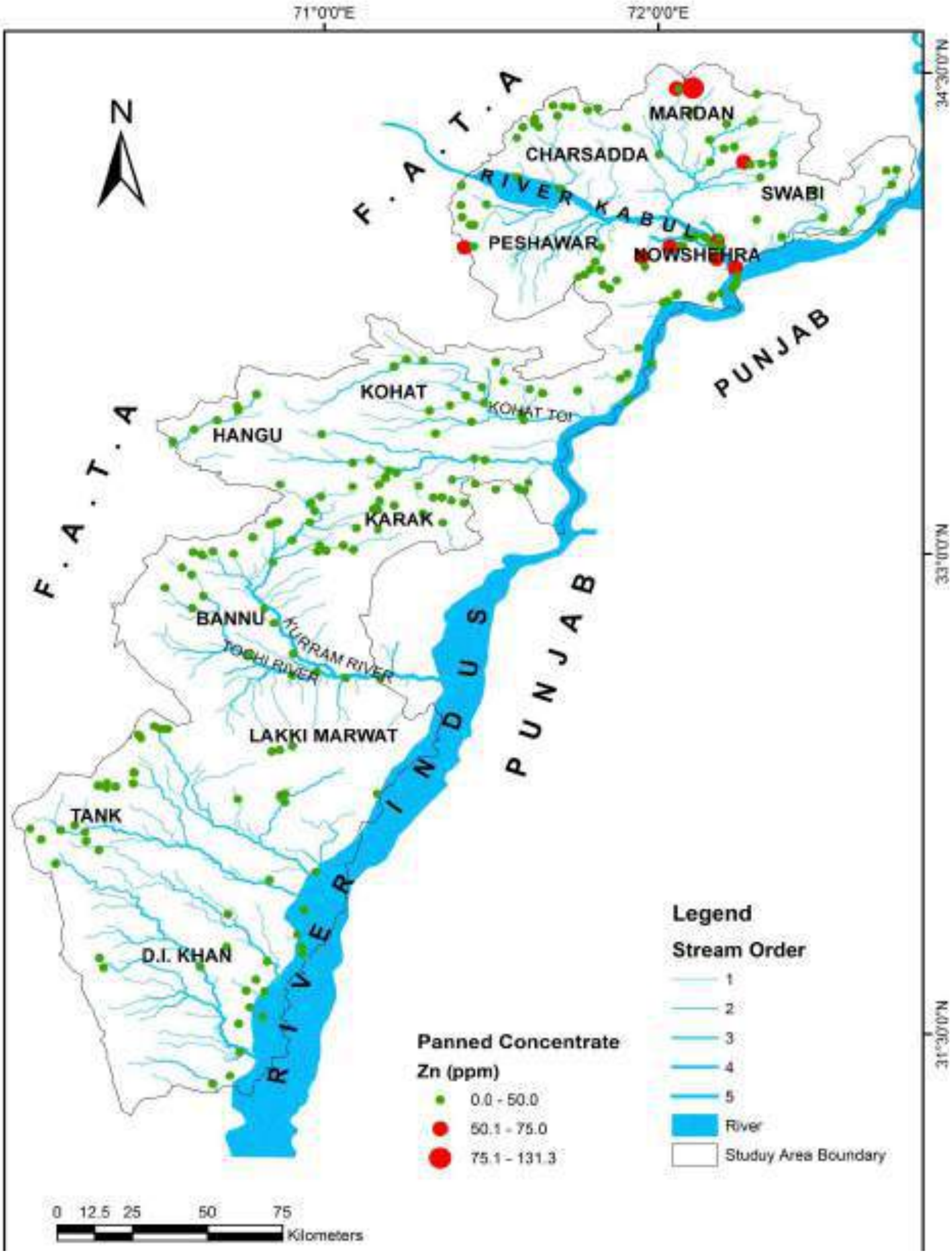


Fig. 5.2c. Geochemical map of Zn in pan-concentrates.

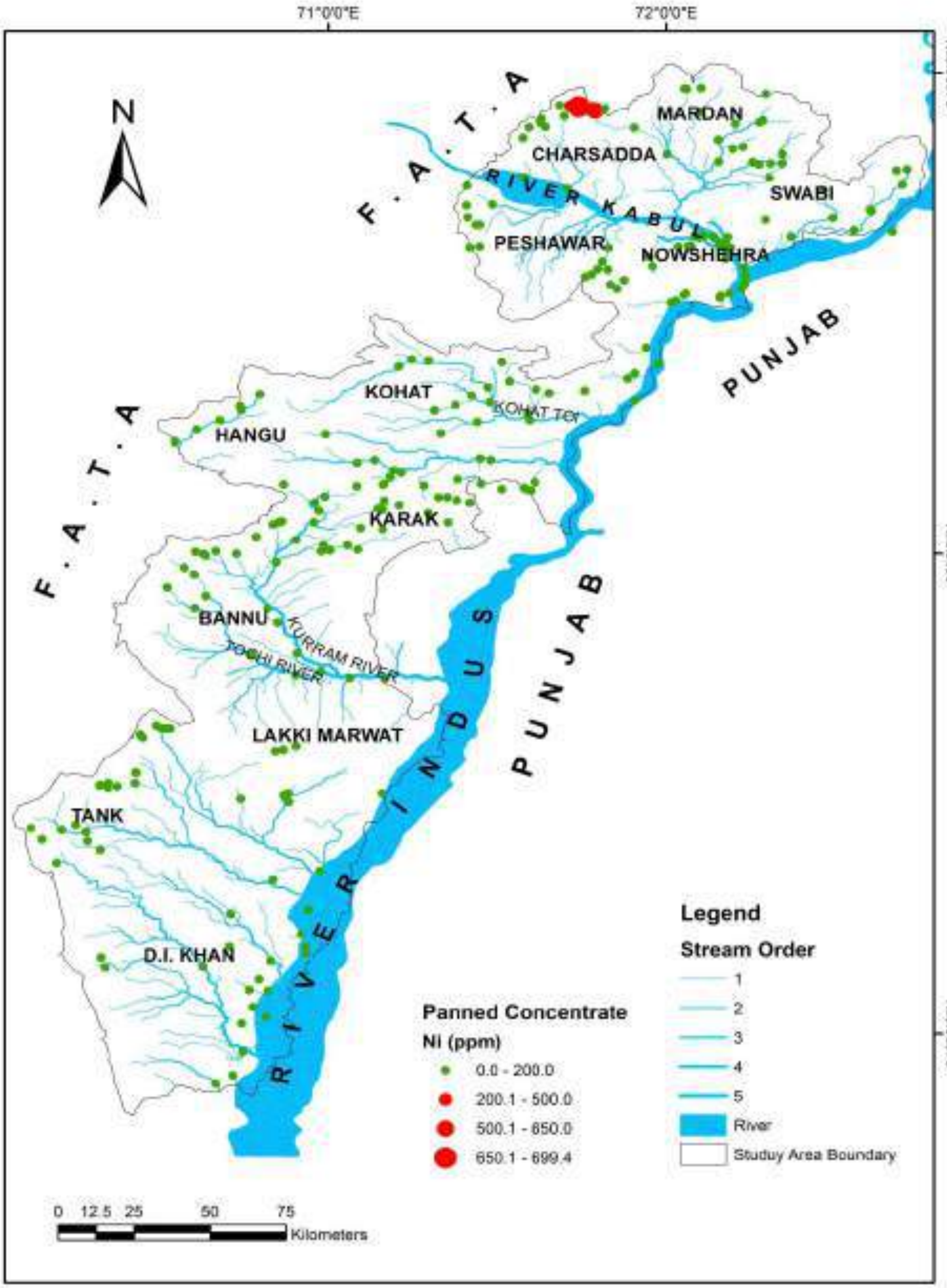


Fig. 5.2d. Geochemical map of Ni in pan-concentrates.

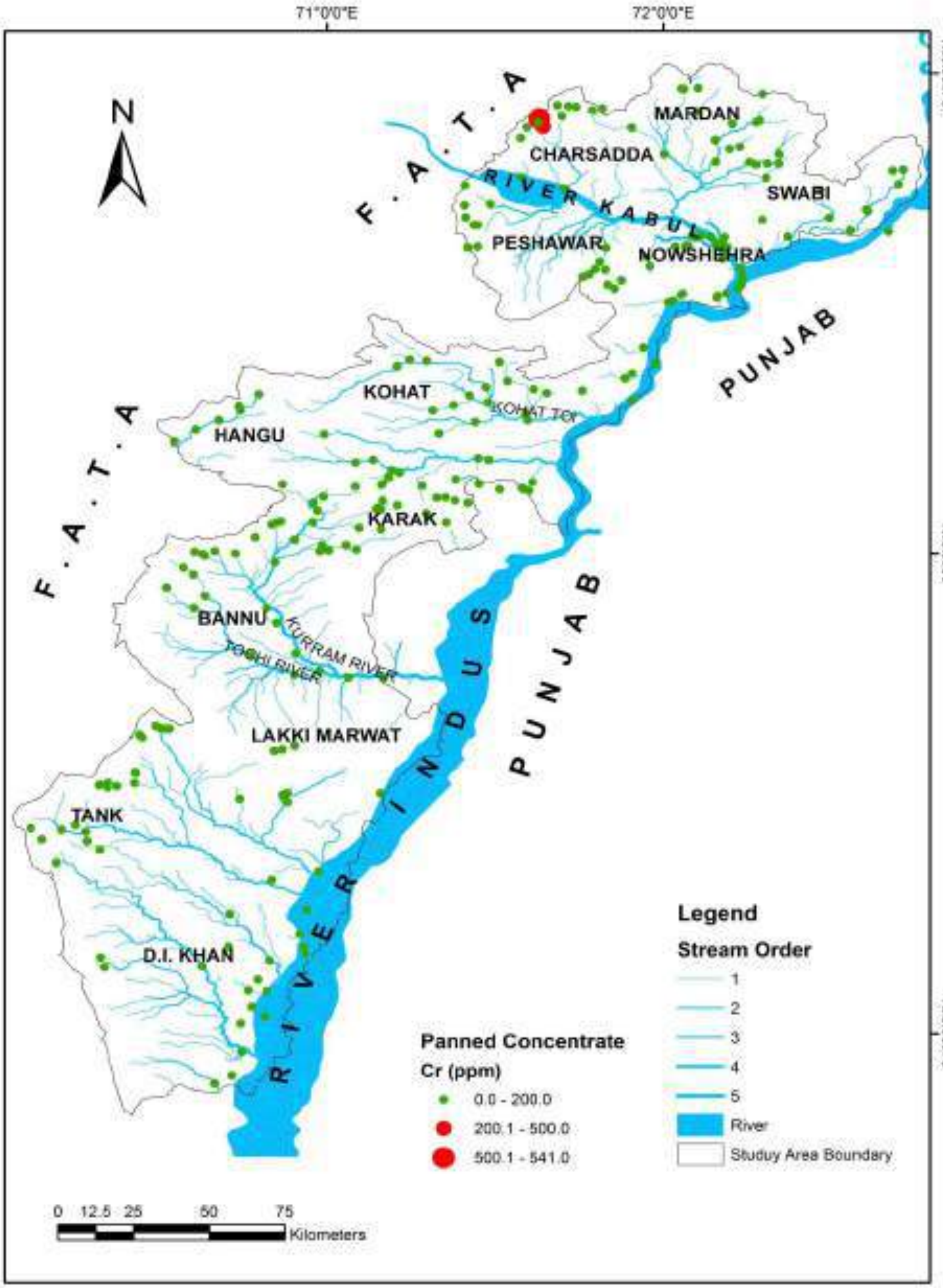


Fig. 5.2e. Geochemical map of Cr in pan-concentrates.

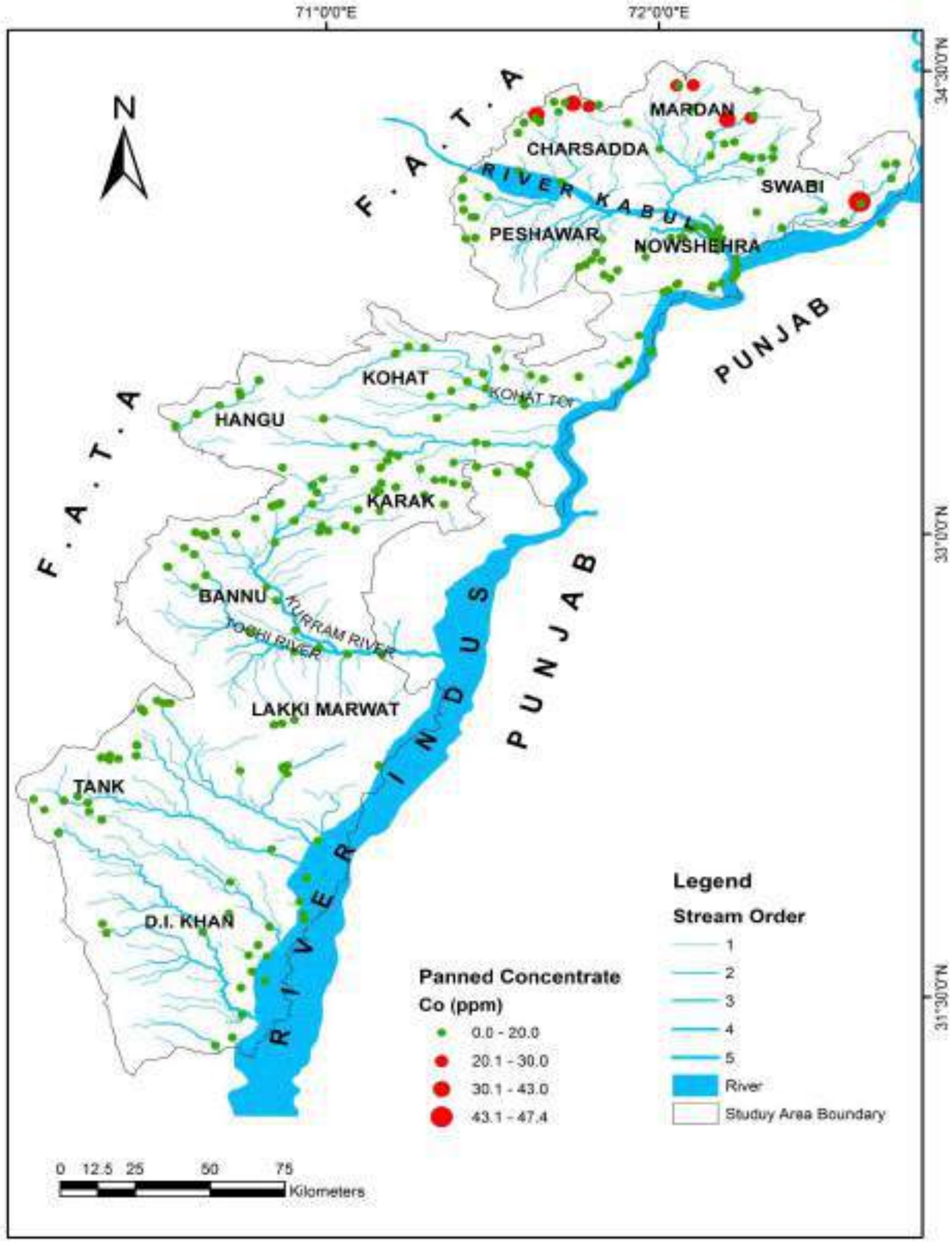


Fig. 5.2f. Geochemical map of Co in pan-concentrates.

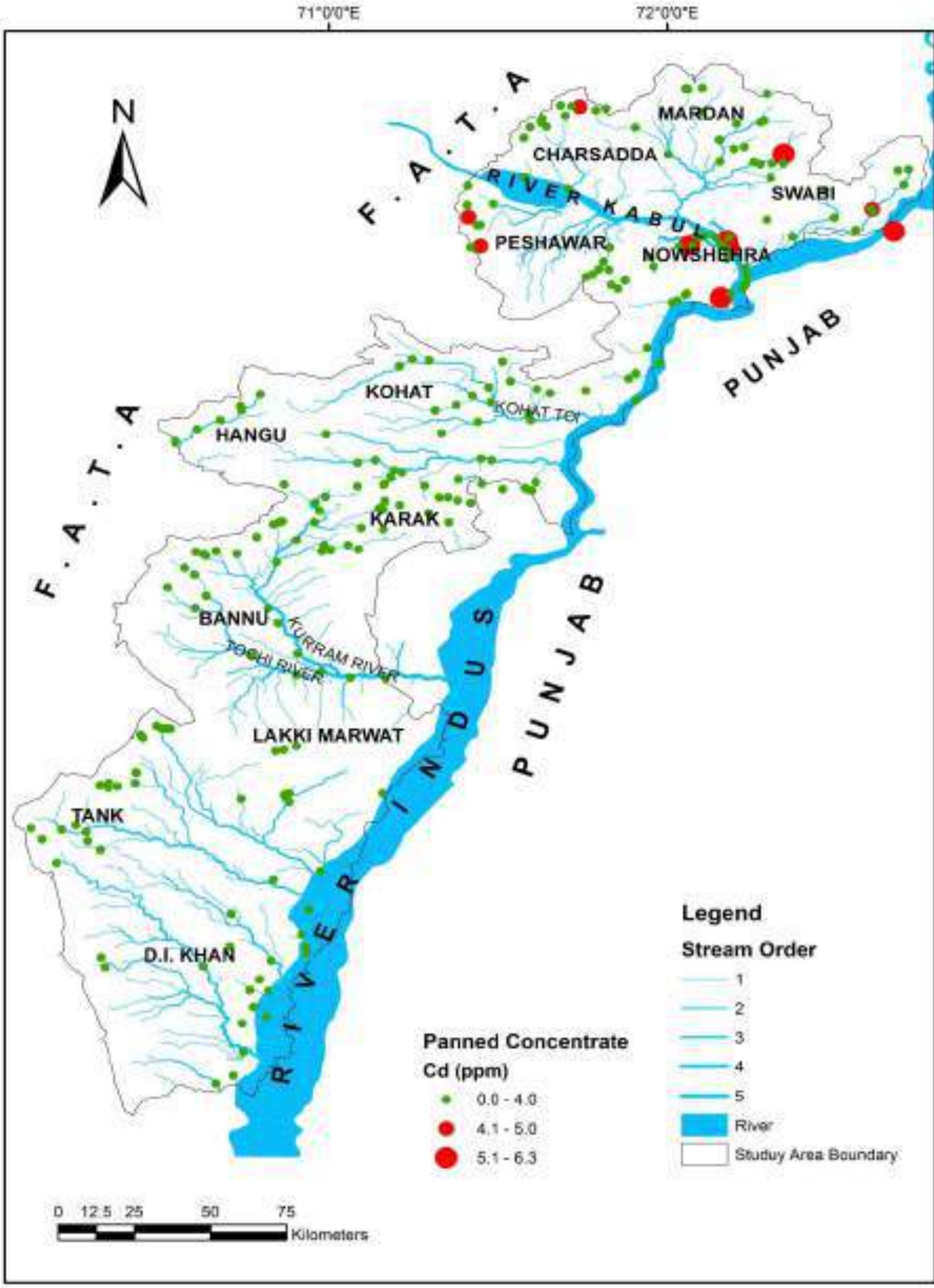


Fig. 5.2g. Geochemical map of Cd in pan-concentrates.

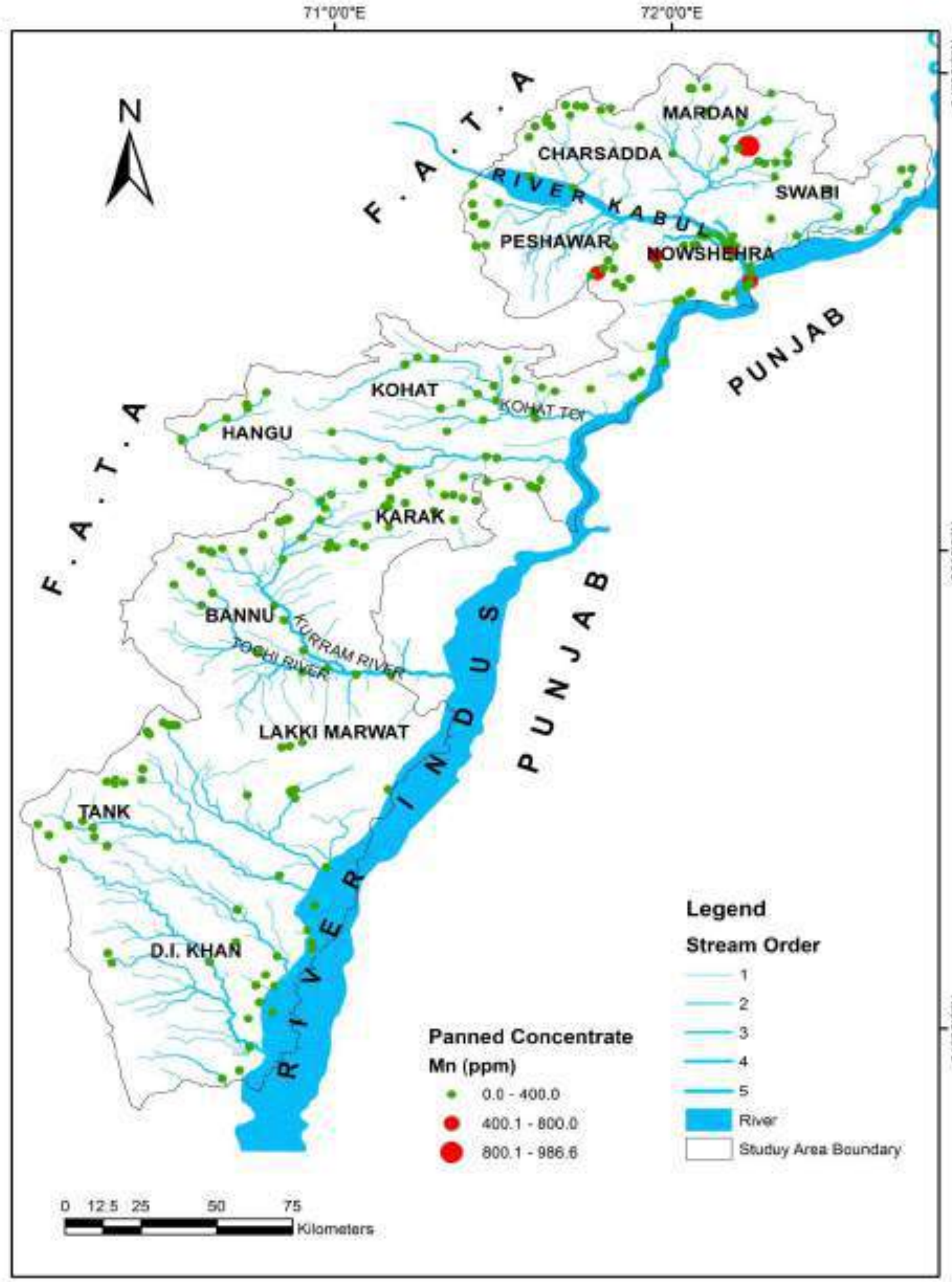


Fig. 5.2h. Geochemical map of Mn in pan-concentrates.

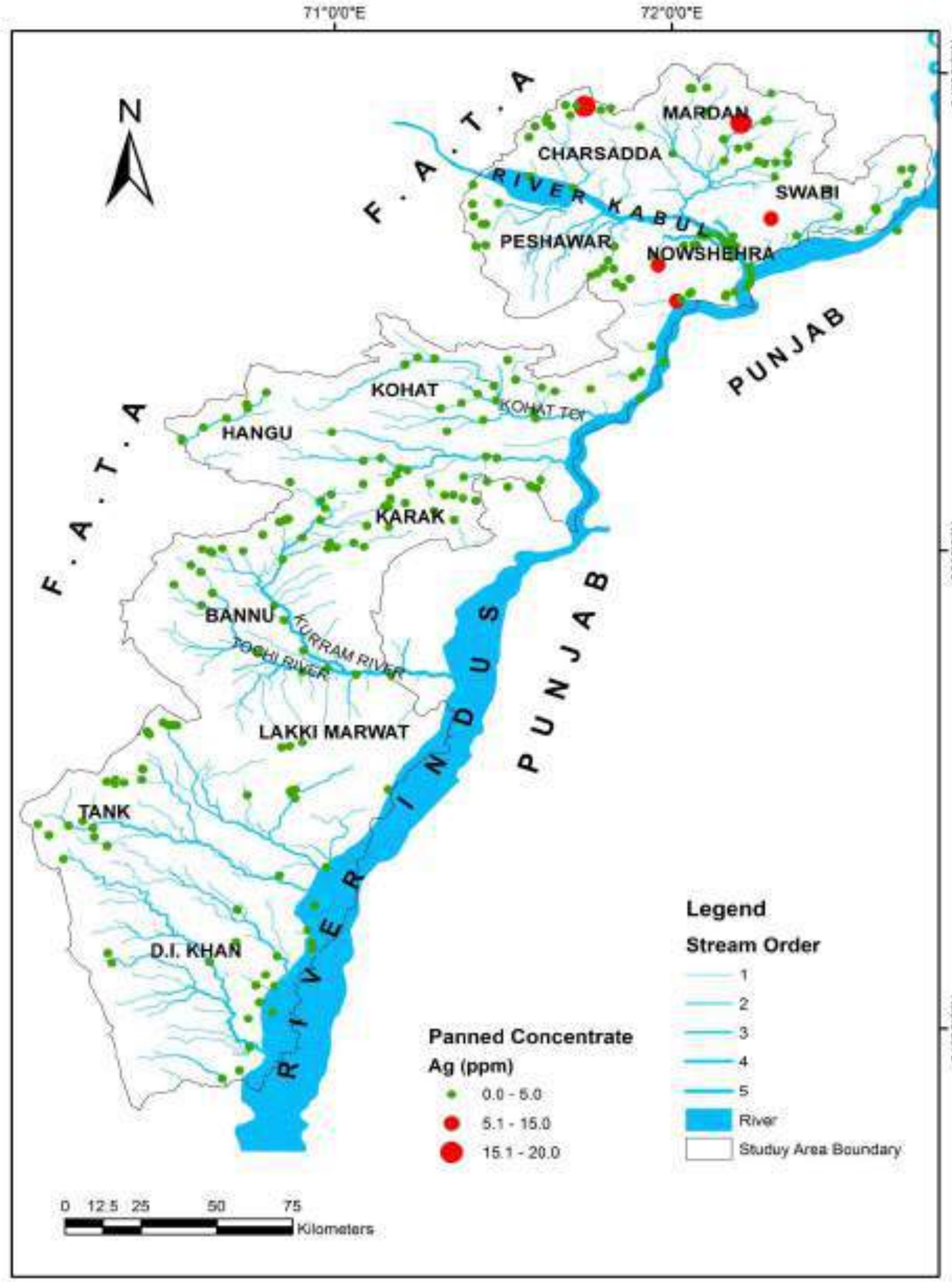


Fig. 5.2i. Geochemical map of Ag in pan-concentrates.

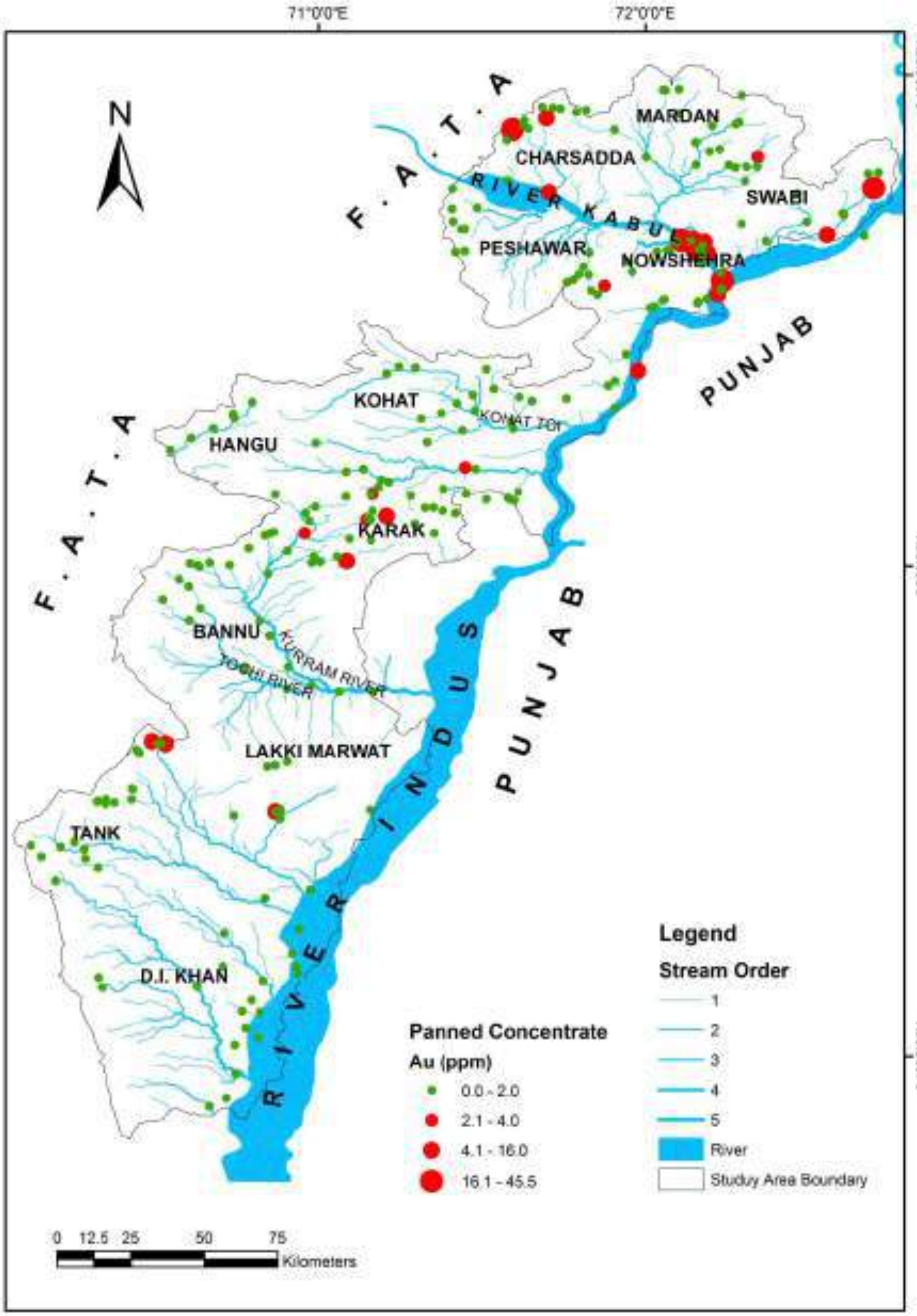


Fig. 5.2j. Geochemical map of Au in pan-concentrates.

5.4. Stream sediments geochemical study

Results of the geochemical analyses of the stream sediments (-80 mesh fine fraction) from project area are given in Table 5.5. Statistical parameters are presented in Table 5.6, Correlation matrix in Table 5.7 and Factor analysis in Table 5.8. The geochemical data for Au, Ag and base metals have been synthesized through geo-statistical and GIS softwares and the resultant histograms and spatial geochemical maps are shown in Fig. 5.3 and Figs. 5.4 a-j respectively.

The geochemical data of the stream sediments shown in Table 5.5 clearly indicate that there is much variation in the data. Concentrations of Cu ranges from <0.02 to 133.5 ppm, Pb from <0.02 to 53.55 ppm, Zn from <0.02 to 59.55 ppm, Ni from <0.02 to 732.5 ppm, Cr from <0.02 to 201.85 ppm, Co from <0.02 to 38.15 ppm, Cd from <0.02 to 11.0 ppm, Mn from <0.02 to 780.4 ppm, Ag from <0.05 to 16.0 ppm and Au from <0.05 to 10.61 ppm (Table 5.5).

The threshold values were estimated after considering the histograms (Fig. 5.3) and also statistical parameters. The threshold values are set as: 45 ppm for Cu, 17 ppm for Pb, 46 ppm for Zn, 200 ppm for Ni, 75 ppm for Cr, 12 ppm for Co, 5 ppm for Cd, 400 ppm for Mn, 3.2 ppm for Ag and 1 ppm for Au.

Geochemical data of stream sediments were evaluated by using statistical methods and GIS softwares by considering the lithological variations. Geochemical maps generated in GIS for Au, Ag and base metals are shown in figures 5.4a-j. Like in pan-concentrates the concentrations of elements in stream sediments is also much higher in Peshawar Basin as compared to all other parts of the project area. As compared to pan-concentrates majority of the elements (Cu, Pb, Zn, Ni, Cr, Co, Cd, Mn, Ag and Au) are showing low concentration in stream sediments (fine fraction). It is evident from figure 5.4j that the stream sediment geochemical distribution for gold is showing anomalous values at the confluence of Kabul and Indus Rivers that is also detected in pan-concentrate samples and in a stream in Bahadur khel, Karak, having catchment in the Siwalik sandstone (Nagri Formation). High Cu values are spread out in stream sediments of Peshawar Basin with consistently high values all along the Kabul River (Fig. 5.4a). High Cu is also found in stream sediments originating from murree formation in southern Peshawar district and from rocks of Shewa, Ambela and Warsak complexes in Mardan district (Fig. 5.4a). Anomalous concentration of Pb and Zn is associated in the stream sediments of Dargai Ophiolites (Indus Suture Melange), undivided rocks of Kashala, Nikani ghar and Saidu formations in Mardan district and Shagai, Dakhnair and Hazara formation in Nowshehra district (Fig. 5.4b,c). Similarly anomalous values of Ni, Cr and Co are found in the stream sediments originating from Dargai Ophiolits (Fig. 5.4d,e,f). High values of Cr and Co in stream sediments of Murree Formation in Peshawar district and Ni from Karora complex in Mardan district are also found (Fig. 5.4d,ef). Anomalous concentrations of Cd and Mn occur in stream sediments of Paleozoic rocks in Mardan and Nowshehra districts (Fig. 5.4g,h).

Table 5.5. Results of geochemical data for gold, silver and base metals in stream sediments.

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1101B	Swabi	8.35	14.5	22.3	10.8	21.85	3.2	4.15	148.05	0.5	<0.05
1102B	Swabi	9.4	6.65	17.95	16.8	14.55	1.7	2.65	130.4	<0.05	0.277
1103B	Swabi	7.6	4.55	54.9	17.65	<0.02	<0.02	4.15	100.65	<0.05	<0.05
1105B	Swabi	6.5	9.7	15.45	8.75	12.6	0.15	4.05	106.85	<0.05	<0.05
1106B	Swabi	18.3	4	30.4	8	17.1	2.6	1.05	127.1	<0.05	0.23
1108B	Swabi	3.5	6.9	15.05	10.6	38.75	0.55	0.6	72.6	<0.05	0.621
1109B	Swabi	11.75	8.75	27.4	26.45	5.1	<0.02	0.05	203.15	<0.05	0.594
1110B	Swabi	9.25	10.55	14.25	18.35	8.65	2.85	1.6	83.65	<0.05	0.994
1111B	Swabi	4.5	21.75	29.85	23.3	20.75	3.15	1.7	208.1	0.5	0.298
1112B	Swabi	3.3	15.95	15.2	12.95	22.65	<0.02	3.6	153.2	<0.05	0.152
1113B	Swabi	16.55	12.65	22.2	43.35	25.95	8.9	0.05	85.65	<0.05	<0.05
1114B	Swabi	7.8	9.4	44.1	20.55	<0.02	5.2	4.2	297.7	<0.05	0.133
1115B	Swabi	25.9	11.55	57.1	13.7	5.4	7.75	1.3	418.95	2	<0.05
1116B	Swabi	20.15	3.9	33.95	27.95	1.3	6.55	4.05	234.75	0.5	<0.05
1117B	Swabi	5.25	13.15	32.15	19.2	1.85	1.8	1.25	206.85	<0.05	0.161
1118B	Swabi	4.75	13.6	15.55	5.4	<0.02	3.55	4.6	103.7	0.1	<0.05
1119B	Swabi	7.1	11.45	31.75	47.4	26.45	<0.02	0.05	259.4	<0.05	<0.05
1120B	Mardan	2.85	10.4	41.15	22.8	20.55	6.65	1.35	279.75	<0.05	0.757
1121B	Mardan	6	12.6	38.7	14.9	19.05	5.05	1.1	194.75	1	0.142
1122B	Mardan	6	2.55	39.8	29	11.05	3.45	0.05	183.6	<.05	0.21
1123B	Mardan	2.3	11.6	29.15	13	14.1	3.75	2.8	172.75	2.5	<0.05
1124B	Mardan	6.1	10.55	42.05	22.05	13.55	0.9	2.25	92.95	1	0.261
1125B	Mardan	6.4	12.55	44.9	58.35	54.4	1.65	1.95	309.5	<0.05	0.199
1126B	Mardan	6.3	<0.02	29.2	18.6	43.4	4.1	4.6	237.05	2	0.141
1127B	Mardan	2.85	8.7	25.1	10.1	13.25	4.95	0.8	144.65	3.5	0.077
1128B	Mardan	2.15	8.15	<0.02	24.4	<0.02	<0.02	0.05	64.8	<0.05	<0.05
1130B	Mardan	3.6	6.15	12.65	12.85	52.8	<0.02	1.35	106.75	0.5	<0.05
1131B	Mardan	11.35	15	27.95	27.5	24.35	3.6	2.8	220.3	1	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1132B	Mardan	1.8	2.45	12.95	11.2	13.4	1.1	3.1	30.8	<0.05	0.249
1133B	Mardan	9.7	<0.02	31.5	50.75	22	2.2	2.05	156.4	0.5	<0.05
1134B	Mardan	<0.02	<0.02	<0.02	<0.02	8.5	<0.02	1.35	<0.02	<0.05	0.236
1137B	Charsadda	<0.02	9.45	27.15	116.55	64.3	15.05	1.4	254.4	<0.05	<0.05
1138B	Charsadda	5.65	8.4	9.8	222.8	53.6	12.2	2.45	154.3	4.5	0.094
1139B	Charsadda	9.35	14.55	39.6	682.45	105.1	36.75	2.6	291.3	2.5	0.228
1140B	Charsadda	8.95	4.05	15.4	289.8	83.3	16.15	4.55	216.85	<0.05	0.234
1141B	Charsadda	5.25	11.55	25	732.5	154.7	14.2	3.45	339.8	4.5	0.12
1145B	Swabi	10.1	9.8	59.55	<0.02	4.05	6.7	2.5	602.5	0.5	0.291
1151B	Nowshehra	8.15	13.25	32.25	81.5	53.5	5.65	4.4	285.6	1.5	0.702
1152B	Nowshehra	5.05	12.2	25.95	12.25	45.4	9.25	4.15	258.4	5.5	0.168
1153B	Nowshehra	17.05	2.7	35	63.45	73.45	10.65	1.1	359.25	<0.05	0.254
1154B	Nowshehra	12.85	<0.02	36.95	47.65	6.75	10.6	2.4	330.55	0.15	0.162
1155B	Nowshehra	4.8	11.6	32.05	59.75	35.65	9.45	3.05	294.45	7	0.227
1157B	Nowshehra	10.95	14.35	34.45	58.4	32.35	<0.02	3.9	317.75	<0.05	<0.05
1158B	Nowshehra	4.5	9.25	23.5	30.4	29.25	5.6	3.6	203.6	0.5	0.091
1159B	Nowshehra	7.6	7.75	30.6	47.2	42.95	5.35	3.45	230.5	<0.05	0.941
1162B	Nowshehra	12.15	20	58.85	65.65	34	8.35	2.4	433.45	<0.05	<0.05
1164B	Nowshehra	18.2	10.05	<0.02	33.9	31.2	<0.02	1.7	198.15	1.5	<0.05
1165B	Nowshehra	0.9	53.55	<0.02	35.6	<0.02	<0.02	0.05	84.7	<0.05	<0.05
1167B	Nowshehra	6.65	15.05	28.45	70.2	14.8	1.3	4.1	245.15	<0.05	<0.05
1169B	Peshawar	10.35	8.2	18.85	21	<0.02	7.05	0.75	207.7	0.5	0.137
1170B	Peshawar	11.55	13.85	41.95	68	32.45	9.2	4.5	272.35	0.15	<0.05
1171B	Peshawar	17.45	11.5	22.9	27.3	34.85	4.8	0.55	280.05	2.5	0.123
1172B	Peshawar	<0.02	9.7	<0.02	24.05	10.7	5.75	0.05	193.95	2	<0.05
1174B	Peshawar	<0.02	5.35	22.9	6.8	<0.02	<0.02	3.65	147.6	<0.05	0.271
1175B	Peshawar	8.95	<0.02	17.85	21.6	53.4	2.75	0.95	210.7	2	<0.05
1176B	Peshawar	9.65	4.45	11.1	18.2	47.2	4.8	2.8	159.8	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1177B	Peshawar	6.2	9.45	30.2	31.25	24.2	9	0.05	254.9	3	0.153
1178B	Swabi	4.9	8.7	16.25	13.7	0.4	<0.02	7.75	144.65	2	<0.05
1179B	Swabi	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1180B	Swabi	2.75	3.9	12.45	<0.02	<0.02	9.1	0.05	104.75	1	0.27
1182B	Swabi	14.6	3.2	<0.02	30.55	33.35	<0.02	1.85	157.25	<0.05	<0.05
1184B	Swabi	4	0.5	3.1	0.7	13.95	0.8	2.45	<0.02	3	<0.05
1186B	Swabi	11.8	10.4	23.95	24.15	45.7	9.3	2.7	<0.02	<0.05	0.379
1188B	Swabi	104.35	0.8	38.7	53.4	45.15	9.05	0.75	233.9	1	0.488
1191B	Swabi	1.1	2.55	13.6	653	13.35	0.2	3.6	343.5	<0.05	<0.05
1194B	Swabi	7.25	0.05	24.3	9	22.95	1.7	0.05	117.75	2	<0.05
1195B	Swabi	<0.02	<0.02	<0.02	23.7	<0.02	<0.02	0.05	<0.02	<0.05	0.067
1196B	Swabi	10	<0.02	6.7	1.1	12	<0.02	2.7	54.15	<0.05	<0.05
1197B	Swabi	9.55	6.55	26.95	26.9	8.7	2.6	2.9	114.55	<0.05	0.28
1199B	Swabi	7.35	<0.02	16.05	8.35	26.2	2.55	1.05	85.75	2.5	<0.05
1200B	Swabi	2.45	<0.02	0.1	<0.02	9.6	<0.02	0.45	<0.02	1	0.339
1201B	Charsadda	12.7	5.65	25.3	111.15	59.55	8.3	0.05	286.9	<0.05	0.236
1202B	Charsadda	10.6	10.5	25.7	51.3	97.8	4	1.4	298.55	1.5	0.157
1206B	Charsadda	4.9	<0.02	13.75	20.95	<0.02	3.5	1.55	148.35	3.5	0.329
1207B	Charsadda	7.05	5.6	<0.02	18.15	71.25	0.15	1.65	176.55	<0.05	0.225
1208B	Charsadda	9.15	4.55	18.05	67.5	201.85	4.1	3.45	239.75	<0.05	0.673
1209B	Charsadda	5.25	11.6	12.5	35.55	<0.02	1.05	0.95	148	<0.05	<0.05
1210B	Charsadda	12.05	22.05	50.65	26.1	18.7	5.65	4.65	462.75	3	0.074
1211B	Charsadda	11.15	<0.02	25.55	40.35	122.45	7.75	4.3	268.25	0.05	0.488
1212B	Charsadda	6.05	9.5	<0.02	40.2	16.55	<0.02	0.05	127.15	0.5	<0.05
1213B	Charsadda	7.2	1.8	24.35	28.8	0.8	2.25	3.6	190.95	<0.05	<0.05
1214B	Charsadda	4.1	<0.02	26.55	12.5	15.6	6.3	2.9	161.95	0.2	<0.05
1215B	Charsadda	2.45	5.2	19.9	17.25	42.45	7.1	3.2	184.1	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1216B	Nowshehra	9.8	17.2	25.65	49.5	40.4	4.4	5.15	271.1	0.5	<0.05
1218B	Nowshehra	7.15	6.8	21.9	52.6	43.9	5.15	1.85	204.6	<0.05	0.085
1219B	Nowshehra	6.4	19.95	23.35	30.05	42.9	4.1	6.45	171.55	<0.05	<0.05
1220B	Nowshehra	<0.02	8.9	<0.02	19.6	21.5	<0.02	0.05	<0.02	<0.05	<0.05
1221B	Nowshehra	4.7	5.3	16.5	24.6	39.65	<0.02	1.6	149.3	<0.05	10.61
1222B	Nowshehra	6.25	11.7	20.4	24.5	57.25	3.5	5.5	152.2	<0.05	0.313
1223B	Nowshehra	7.65	8.5	<0.02	<0.02	53.9	<0.02	3.2	<0.02	<0.05	0.12
1224B	Nowshehra	15.05	23.15	30.15	80.35	92.05	<0.02	2.85	300.5	<0.05	0.416
1225B	Nowshehra	2.4	0.85	11.65	13.05	8.15	<0.02	1.7	44.5	<0.05	<0.05
1227B	Nowshehra	2.05	7.35	14.3	16.75	10.9	<0.02	2.3	94.05	1	<0.05
1229B	Nowshehra	16.4	5.4	49	13.7	27.1	7.25	0.85	380.45	<0.05	<0.05
1230B	Nowshehra	14.5	10.45	25.95	14.3	16.1	10	2.4	189.85	1	<0.05
1231B	Nowshehra	6.55	21.7	31.7	24.7	27	<0.02	6.05	250.3	0.1	<0.05
1232B	Nowshehra	13.4	<0.02	42.15	11.2	13.35	5.45	1.8	334.05	0.5	<0.05
1233B	Nowshehra	20.05	4.05	42.5	12.3	6.3	8.5	2.15	380.15	1.5	0.061
1234B	Nowshehra	10.75	7	1.7	10	51.85	6.3	1.75	249.1	<0.05	0.215
1235B	Nowshehra	17.6	3.95	48.4	13.25	28.5	<0.02	1.35	444.05	<0.05	<0.05
1236B	Nowshehra	24.5	6.05	34.15	220.25	13.45	18.2	1.85	396.2	1.5	0.132
1237B	Nowshehra	13.4	21.45	45.45	50.85	<0.02	10.75	0.05	399.25	<0.05	<0.05
1238B	Nowshehra	16.8	1.95	<0.02	30.6	19.8	9.3	0.6	279.3	<0.05	0.083
1239B	Nowshehra	3	1.25	10.8	1.75	12.4	2.7	0.7	103.6	<0.05	<0.05
1240B	Nowshehra	8.4	11.5	29.3	12.9	23.45	10.5	1.85	274.95	3	<0.05
1241B	Nowshehra	9.45	14.9	41.9	48.95	31.4	3.05	5.4	<0.02	0.2	<0.05
1242B	Nowshehra	16.75	2.45	44	29.05	11.9	9.05	2	294.1	<0.05	<0.05
1243B	Nowshehra	4.85	5.35	22.25	12.4	56	5.55	1.8	189.3	0.15	0.171
1244B	Nowshehra	16.05	20	56.5	68.35	14.35	6.7	0.05	475.1	<0.05	0.308
1245B	Nowshehra	20.05	5.15	45.7	19.05	29.45	10.15	0.05	277.65	<0.05	0.262

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1246B	Nowshehra	<0.02	13.8	46.9	46.5	4	8.2	0.05	495.15	<0.05	0.065
1247B	Nowshehra	12.1	<0.02	<0.02	7.9	25.5	6.95	0.5	157	<0.05	0.288
1249B	Nowshehra	10.6	8.65	27.9	46.5	40.25	2	0.05	146.1	<0.05	<0.05
1251B	Nowshehra	12.8	16.65	38.4	64.5	70	8.35	4.05	392.1	<0.05	<0.05
1252B	Nowshehra	7.85	16.55	30.6	82.3	32.5	7.1	0.05	272.75	<0.05	<0.05
1253B	Nowshehra	0.6	4.05	8.2	6.8	<0.02	<0.02	7.45	55.55	<0.05	<0.05
1254B	Nowshehra	10	4	<0.02	65.4	60	10.75	3.6	270.65	<0.05	<0.05
1255B	Nowshehra	4.8	0.4	13.1	54.8	6.1	<0.02	0.05	156.9	3	<0.05
1256B	Nowshehra	19.5	9.25	19.3	46.15	27.85	8.75	4.4	408.15	<0.05	0.109
1257B	Nowshehra	5.85	10.15	<0.02	22.65	24.15	<0.02	2.75	168.35	<0.05	<0.05
1258B	Nowshehra	8.3	10.6	31.5	37.6	51.45	3.6	2	299.35	<0.05	<0.05
1259B	Nowshehra	7.2	15.05	27.85	28.1	10.2	9.5	0.05	194.5	<0.05	<0.05
1260B	Nowshehra	<0.02	3.7	19.1	26.75	<0.02	<0.02	0.05	102.25	<0.05	<0.05
1261B	Nowshehra	2.35	3.5	15.35	8.9	19.65	<0.02	1.9	105.85	<0.05	<0.05
1262B	Nowshehra	7.55	<0.02	20.55	10.15	72.85	6.35	1.35	194	<0.05	0.318
1263B	Nowshehra	3.1	<0.02	12.05	21.8	12.4	10.65	2.15	76.15	<0.05	<0.05
1264B	Nowshehra	5.5	14.55	25.95	27.75	<0.02	4.45	5.35	212.8	<0.05	<0.05
1266B	Nowshehra	4.55	9.45	30.05	16.4	42.85	1.4	2.95	142.25	1	<0.05
1267B	Nowshehra	3.8	6.2	13.7	51.75	2.2	1.15	0.05	210.9	<0.05	<0.05
1268B	Nowshehra	7.65	15.2	37.4	44	16.3	4.15	0.05	325.55	<0.05	<0.05
1279B	Nowshehra	4.8	<0.02	<0.02	21.6	25.95	<0.02	4.3	131.9	<0.05	<0.05
1282B	Nowshehra	18.05	<0.02	<0.02	18.1	41.3	9.45	2.15	309.8	<0.05	<0.05
1283B	Nowshehra	10.05	19.95	20.2	24.4	43.35	9.4	5	340.9	0.5	<0.05
1284B	Nowshehra	7.65	20.1	28.2	22.7	44.3	5	5.75	269.55	<0.05	<0.05
1285B	Nowshehra	7.45	<0.02	<0.02	<0.02	54.3	<0.02	0.05	<0.02	<0.05	<0.05
1286B	Nowshehra	2.4	2.75	12.45	32.05	1.65	<0.02	0.05	65.95	<0.05	<0.05
1287B	Nowshehra	3.6	<0.02	16.6	11.2	21.55	4.35	3.3	79.05	<0.05	<0.05
1288B	Nowshehra	8.1	<0.02	21.45	22.75	62.2	12.15	2.9	220.3	0.2	0.236
1289B	Nowshehra	2.15	0.4	9.4	30.2	<0.02	<0.02	0.05	70.05	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1290B	Nowshehra	7.9	3.45	22.4	19.25	45.1	2.55	0.05	165.45	<0.05	<0.05
1291B	Nowshehra	7.35	17.35	23.95	30.65	41.3	1.2	5.2	221.6	3.5	0.067
1292B	Nowshehra	2.85	1.55	12.3	<0.02	13.4	<0.02	3.95	78.6	<0.05	<0.05
1293B	Nowshehra	7.45	0.35	26.7	39.2	20.3	11.7	0.05	239.55	2.5	<0.05
1294B	Nowshehra	5.95	14.1	30.8	13.25	33.6	<0.02	5.05	286.25	<0.05	<0.05
1295B	Nowshehra	8.45	19.1	40.15	15.15	15.25	4.55	0.05	563	0.5	<0.05
1296B	Nowshehra	11.2	16.7	32.55	28.9	14.2	3.35	3.7	359.1	3	<0.05
1298B	Nowshehra	10.3	5.05	14.3	10	3.5	4.1	2.05	156.2	5.5	<0.05
1301B	Swabi	0.8	1.6	6.15	0.55	8.95	1.85	0.8	34.15	<0.05	0.106
1302B	Swabi	5.65	6.95	23.4	13.6	8	<0.02	3.75	187.9	<0.05	0.179
1303B	Swabi	6.8	11.15	20.35	18.4	14.35	<0.02	0.05	203.4	0.5	<0.05
1304B	Swabi	10.7	<0.02	14.85	6.4	26.55	3.05	0.05	205.55	4	<0.05
1306B	Swabi	3.2	5.9	14.95	15.45	14.55	<0.02	0.05	226.4	3	0.14
1307B	Swabi	<0.02	1.7	0.1	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	0.409
1308B	Swabi	11.8	0.95	14.25	9.7	30.05	2.1	0.4	153.45	<0.05	0.267
1312B	Mardan	0.7	0.9	12.5	8.85	12.55	1.25	0.05	60.5	0.5	0.078
1313B	Mardan	0.45	1.25	13.35	6.8	<0.02	<0.02	11	109.75	0.5	0.32
1314B	Mardan	12.7	<0.02	17.95	11.75	40.9	0.2	0.05	149.75	<0.05	<0.05
1315B	Mardan	2.15	1.75	15.85	8.35	<0.02	1.6	0.05	124.35	<0.05	0.305
1318B	Mardan	3.45	14.45	46.1	13.05	7.8	3.4	4.25	226.75	2	<0.05
1319B	Mardan	<0.02	5.2	31.45	8.5	<0.02	<0.02	8.75	84.55	0.5	<0.05
1320B	Mardan	2.2	<0.02	19.2	4.1	16.15	2.3	0.8	115.05	<0.05	<0.05
1321B	Mardan	13.8	1.1	8.6	8.55	36.3	4.45	1.55	155.2	<0.05	<0.05
1322B	Mardan	3.1	<0.02	18.85	3.85	21.1	<0.02	1.2	122.35	2.5	0.142
1323B	Mardan	2.7	12.55	45.1	13.15	34.5	0.3	3.55	245.55	4.5	0.069
1324B	Mardan	7.65	<0.02	29.9	7	22.9	2.1	0.75	220.55	16	0.132
1325B	Mardan	10.65	<0.02	14.25	21.7	23.9	2.85	2.5	118.65	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1327B	Mardan	1.75	<0.02	15.8	14.6	21.95	2.3	0.05	126.3	3	<0.05
1328B	Mardan	5.15	<0.02	9.2	4.3	26.2	0.4	0.15	89.15	6.5	<0.05
1329B	Mardan	9.35	1.15	16.5	15.1	35.9	3.2	1.1	79.1	0.15	0.326
1330B	Swabi	3.95	4.4	14	10.1	11.15	<0.02	0.05	125.05	<0.05	0.331
1331B	Swabi	13.4	<0.02	14.6	8.95	29.5	4.2	0.05	146.5	3.5	<0.05
1332B	Swabi	16.25	17.05	39.2	50.55	79.05	5.3	6	309.95	0.2	0.218
1333B	Swabi	8.15	1.05	13.55	0.65	20.4	<0.02	1.55	<0.02	<0.05	<0.05
1334B	Swabi	8.3	3.5	12.4	9.15	39.15	0.05	1.95	142.35	<0.05	<0.05
1335B	Swabi	9.35	2.95	19	17.25	4.05	0.15	0.05	209.55	0.5	<0.05
1336B	Swabi	1.55	13.1	12.85	12.4	16.25	<0.02	2.55	99.05	2.5	<0.05
1339B	Swabi	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1343B	Swabi	3.9	10.15	21.55	23.15	<0.02	<0.02	4.9	146.8	<0.05	<0.05
1344B	Swabi	<0.02	<0.02	<0.02	<0.02	<<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1350B	Swabi	13.5	<0.02	28.25	43.45	46.5	4.1	3.4	274.5	<0.05	0.507
1351B	Mardan	12.65	2.35	22.4	43.25	27.3	7.4	0.05	211.4	<0.05	0.153
1352B	Mardan	<0.02	<0.02	<0.02	55.3	46.2	4.25	0.05	<0.02	<0.05	<0.05
1356B	Mardan	3.35	<0.02	9.75	10.8	2.8	<0.02	0.05	105.45	<0.05	<0.05
1358B	Mardan	18.45	7.5	22.15	32.95	25.3	10.7	3.55	274.75	<0.05	0.488
1359B	Mardan	18.05	6.65	15.85	8.55	21.05	6.8	2.2	149.75	<0.05	<0.05
1360B	Mardan	18.55	8.2	33.75	25.75	29.9	5.85	0.05	275.5	<0.05	<0.05
1362B	Mardan	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	0.25
1365B	Mardan	28.2	4.65	36.1	23.2	0.4	0.65	0.05	303.75	3	<0.05
1366B	Mardan	11.95	9.1	7.9	113.05	11.85	2.7	0.05	228.15	3	<0.05
1367B	Mardan	0.65	<0.02	<0.02	5.2	11.85	<0.02	0.05	65.6	<0.05	<0.05
1369B	Mardan	6.15	<0.02	<0.02	<0.02	<0.02	<0.02	0.95	<0.02	<0.05	0.061
1371B	Mardan	60.25	36.4	14.85	36.15	57.15	17.5	4.6	780.4	<0.05	0.057
1373B	Peshawar	92.9	1.25	33.6	41.05	38.3	14	2.4	255.65	<0.05	0.11
1374B	Peshawar	71.45	<0.02	38.7	45.15	50.05	6.45	4.2	247.5	1.5	<0.05
1375B	Mardan	50.15	3.1	29.6	29.7	35.45	2.25	1.65	190.3	<0.05	0.102

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1376B	Peshawar	42.6	4.35	29.75	24.2	15.75	0.1	3.45	183.2	0.5	<0.05
1377B	Charsadda	37.95	<0.02	16.2	30.5	24.5	7.25	3.65	177.6	<0.05	<0.05
1378B	Charsadda	39.3	9.6	18.3	20.95	15.05	3.2	2.15	149.8	1	0.381
1379B	Charsadda	8.4	<0.02	4.25	5.4	<0.02	<0.02	3	28.05	<0.05	0.171
1380B	Charsadda	72.5	5.75	31.3	52.8	71.35	6.15	2.25	256.95	<0.05	0.238
1381B	Charsadda	59.15	1.25	24.6	6.45	63.45	9.7	1.8	207.9	<0.05	<0.05
1382B	Charsadda	60.95	0.95	35.55	50.9	70.8	7.1	3.85	224.75	1	<0.05
1383B	Nowshehra	89.05	9.55	46.8	56.45	61.75	12.5	1.1	362.2	<0.05	0.403
1384B	Nowshehra	67.6	2	39	51.05	64.7	<0.02	1.95	298.75	<0.05	<0.05
1387B	Charsadda	38.9	<0.02	19.05	30.75	42.25	12.4	2.4	173.25	<0.05	0.294
1388B	Charsadda	<0.02	9.95	27.75	33.65	39.1	2.6	0.25	199.55	<0.05	0.05
1389B	Peshawar	<0.02	<0.02	<0.02	53.15	<0.02	<0.02	5.25	<0.02	<0.05	<0.05
1390B	Peshawar	61.8	1.65	33.1	45.7	66.45	10.6	0.95	224.95	<0.05	<0.05
1391B	Peshawar	48.4	4	27.75	42.35	27.05	6.2	2.9	215.55	1.5	<0.05
1392B	Peshawar	47.4	4.75	25.9	30.8	28.55	9	2.65	196.6	<0.05	<0.05
1393B	Charsadda	52.55	0.75	32.5	32.85	34.5	2.35	2.85	241.75	<0.05	<0.05
1394B	Charsadda	48.05	<0.02	27	34	38.1	23.7	3.25	203.75	<0.05	<0.05
1395B	Mardan	52.4	0.45	28.7	55.3	28	2	1.7	279.5	<0.05	<0.05
1396B	Mardan	45.6	3.2	41.55	29.9	43.2	0.9	0.85	227.35	<0.05	0.258
1397B	Mardan	61.75	6.35	33.3	65.65	50.35	5.55	1.3	224.3	<0.05	0.081
1398B	Mardan	49.7	1.55	32.9	27.25	15.7	<0.02	2.2	253.15	<0.05	0.09
1399B	Mardan	65.5	3.5	47.1	58.25	75.7	14	1.6	304.25	14.5	<0.05
1400B	Nowshehra	71.15	7.35	48.2	41.45	58.75	5.05	2.45	323.2	<0.05	0.062
1402B	Nowshehra	19.1	7.7	41.45	91.55	109.65	2.65	0.05	243.95	1.5	<0.05
1405B	Nowshehra	6.05	9.45	23.7	21.1	10.3	2.9	5.5	174.5	2	0.288
1407B	Nowshehra	15.25	10.6	<0.02	57.55	24.55	9.4	9	387.65	0.5	<0.05
1410B	Nowshehra	6	25.8	27.05	17.45	7.2	2.3	0.05	267.85	<0.05	0.088

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1411B	Nowshehra	21.1	5.9	33.6	18.75	16	4.35	0.5	280.2	2	<0.05
1413B	Nowshehra	19.4	10.1	35.5	28.7	71.05	12.15	0.05	467.5	<0.05	<0.05
1414B	Nowshehra	13.1	20.95	53.75	44.45	15.65	8.1	0.05	330.75	<0.05	<0.05
1415B	Nowshehra	12.2	<0.02	41.45	66.05	59.7	2.85	4.9	281.95	<0.15	0.141
1416B	Nowshehra	<0.02	<0.02	0.3	<0.02	12.75	<0.02	0.75	<0.02	1	<0.05
1418B	Nowshehra	13.75	13.15	39.4	40.15	30.4	3.35	0.8	245.15	<0.05	<0.05
1419B	Nowshehra	9.95	5.75	21.15	33.6	42.15	<0.02	2.7	168.4	<0.05	<0.05
1420B	Nowshehra	4.65	5.3	20.05	24.05	12.7	<0.02	0.05	130.5	<0.05	<0.05
1421B	Nowshehra	6	15.5	19.35	23.45	<0.02	0.8	4.4	173.5	<0.05	<0.05
1422B	Nowshehra	10.75	17.95	53.1	47.05	<0.02	6.45	1.45	371.65	<0.05	<0.05
1423B	Nowshehra	14.75	2.85	37.7	16.35	36.7	6.5	1.05	225	1.5	<0.05
1424B	Nowshehra	<0.02	6.2	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1425B	Charsadda	8	10.2	28	<0.02	26.2	3.05	4.7	170.8	1.5	<0.05
1426B	Charsadda	20.15	6.6	22.85	11.85	35.2	10.8	1.3	249	<0.05	0.171
1427B	Charsadda	19.6	5.45	25.7	32.5	65.1	6.55	0.05	<0.02	8.5	0.344
1429B	Charsadda	17.6	<0.02	26.65	58.65	95.95	<0.02	2.35	255.5	<0.05	<.05
1430B	Charsadda	5.75	3.5	15.1	64.5	62	1.9	0.05	197.75	0.05	<0.05
1431B	Charsadda	<0.02	1.55	33	463.3	80.1	29.4	5	418.95	0.5	0.445
1432B	Charsadda	<0.02	5.15	10.15	152	42.3	5.55	1.6	74.95	<0.05	<0.05
1433B	Charsadda	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	0.05	0.311
1434B	Charsadda	0.95	<0.02	<0.02	192.6	60.2	8	0.55	143.55	<0.05	<0.05
1435B	Charsadda	<0.02	17.65	31	71.3	19.4	1.7	0.05	268.9	2.5	0.368
1436B	Charsadda	5.75	<0.02	19.55	569.05	56.6	31.55	0.05	385.8	0.5	<0.05
1437B	Charsadda	2.1	9.2	16.85	714.55	<0.02	38.15	0.05	343.65	<0.05	0.09
1438B	Nowshehra	56.75	3.8	31.6	43.9	49.4	3.5	0.05	210.2	<0.05	0.081
1439B	Nowshehra	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.05	<0.05
1440B	Nowshehra	67.25	<0.02	39.35	50.95	42.95	10.5	2.05	264.45	<0.05	<0.05
1441B	Nowshehra	54.75	<0.02	<0.02	41.55	35.5	<0.02	2.6	238.85	<0.05	<0.05
1442B	Peshawar	35.15	7.75	22.9	32.7	27.95	11.45	2.75	265.35	<0.05	0.639

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1443B	Peshawar	56.75	14.3	23.65	49.55	36.1	6.15	2.5	251.25	<0.05	<0.05
1444B	Peshawar	47.4	<0.02	33.6	61.55	64	14.95	3.15	255.65	4	0.405
1445B	Peshawar	46.15	1.2	28.85	49.55	32.45	7.45	3.55	254.55	0.5	0.305
1446B	Peshawar	60.65	14.5	35.7	97.45	104.25	5.4	0.35	330.9	1	<0.05
1447B	Peshawar	60.65	5.2	38.3	80.1	88.8	12.75	0.05	9.1	1	<0.05
1448B	Peshawar	<0.02	7.35	44.9	49.2	77.3	7	3.2	264.75	<0.05	<0.05
1449B	Peshawar	45.15	2.05	19.9	58.65	48.15	5.9	2.2	154.95	<0.05	0.171
1450B	Nowshehra	56.4	8	35.55	56.9	65.55	5.55	3.35	6.8	<0.05	0.413
1451B	Nowshehra	42.2	7.35	21.45	28.4	20.45	4.7	1.15	165.25	<0.05	0.114
1452B	Nowshehra	57.1	6.05	33.15	36.15	33.3	10.35	3.15	250	<0.05	0.081
1453B	Nowshehra	<0.02	7.4	45.65	53.45	76.65	7.7	2.05	366.1	0.5	<0.05
1454B	Nowshehra	68.2	7.1	33.85	47.95	72.15	4.85	3.6	331.75	2.5	0.108
1455B	Nowshehra	133.5	8.8	28.2	27.6	28.7	8.65	2.6	208.75	<0.05	0.453
1456B	Peshawar	26.45	13.85	23.1	32.6	26.45	4.4	2.05	246.95	0.5	0.269
1457B	Peshawar	59.9	3.3	31.55	89.05	80.6	15.05	2.45	344.5	<0.05	<0.05
1458B	Peshawar	49.3	7.7	38.85	80.2	92.55	10.2	4.8	328.35	<0.05	<0.05
1459B	Peshawar	47.95	3.4	28.45	60.4	83.25	6.1	2.9	316.85	<0.05	<0.05
1460B	Peshawar	47.15	<0.02	23.4	47.7	37.25	9.6	1.95	448.3	0.15	0.195
1461B	Peshawar	45.45	0.2	33	58.45	52.05	12	3.05	271.2	<0.05	0.074
1462B	Peshawar	50.55	11.1	34.6	<0.02	73.4	5.4	1.1	269.3	<0.05	0.214
1463B	Peshawar	27.95	<0.02	15.4	25.6	11.9	0.8	3.45	174.5	<0.05	0.117
1502B	Kohat	0.218	0.26	0.42	0.35	0.79	0.14	0.04	5.26	<0.05	<0.05
1503B	Kohat	0.321	<0.02	0.29	0.12	0.49	0.09	0.03	5.36	<0.05	<0.05
1504B	Kohat	0.184	0.43	0.75	0.66	0.14	0.03	0.1	7.68	<0.05	<0.05
1506B	Kohat	0.391	0.05	0.64	0.32	0.09	0.15	0.1	5.58	0.06	<0.05
1508B	Kohat	0.287	0.05	0.47	0.14	0.14	0.13	0.1	5.74	0.07	0.18
1509B	Kohat	0.038	<0.02	0.27	0.08	0.61	0.05	0.12	2.59	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1511B	Kohat	<0.02	0.05	0.23	0.04	0.04	0.12	<0.02	3.57	<0.05	0.29
1512B	Kohat	0.156	0.07	0.35	0.07	0.62	0.19	0.05	5.04	<0.05	0.2
1515B	Kohat	0.23	<0.02	0.41	0.21	0.29	0.15	0.07	5.8	<0.05	0.4
1516B	Kohat	0.524	0.24	0.53	0.39	0.63	0.11	0.06	6.57	<0.05	0.26
1518B	Kohat	0.556	0.24	0.64	0.41	0.03	0.17	0.16	9.52	<0.05	0.2
1523B	Kohat	0.11	0.04	0.47	0.25	0.06	0.18	0.03	5.14	<0.05	0.17
1524B	Kohat	<0.02	<0.02	0.17	<0.02	0.08	0.05	0.09	6.22	<0.05	0.26
1525B	Kohat	0.146	0.23	0.51	0.3	0.22	0.14	0.12	6.24	<0.05	0.22
1526B	Kohat	0.341	0.07	0.58	0.32	0.53	0.22	0.15	7.09	<0.05	<0.05
1528B	Kohat	<0.02	0.05	0.25	0.06	<0.02	0.12	0.1	3.21	<0.05	0.17
1531B	Kohat	0.17	<0.02	0.4	0.35	0.23	0.14	<0.02	3.22	<0.05	0.24
1533B	Kohat	1.18	<0.02	0.25	0.04	0.78	<0.02	0.06	2.8	<0.05	0.18
1535B	Kohat	0.141	0.31	0.53	0.2	0.84	0.09	0.05	5.68	<0.05	0.24
1536B	Kohat	0.05	0.19	0.26	0.12	0.16	0.1	0.04	2.41	<0.05	0.18
1538B	Kohat	0.477	<0.02	0.44	0.2	0.76	0.2	<0.02	4.03	<0.05	0.26
1541B	Kohat	0.236	<0.02	0.41	0.15	0.3	0.12	<0.02	4.46	<0.05	0.37
1542B	Kohat	0.038	<0.02	0.17	<0.02	0.13	0.09	<0.02	1.86	<0.05	0.07
1543B	Kohat	0.21	<0.02	0.38	0.21	0.83	0.13	0.11	6.98	<0.05	0.19
1544B	Kohat	0.724	0.37	0.58	0.31	0.77	0.15	0.1	5.43	<0.05	0.32
1545B	Kohat	0.21	0.43	0.41	0.24	0.35	0.16	0.04	3.61	<0.05	0.24
1546B	Kohat	0.055	<0.02	0.34	0.2	0.11	0.14	0.1	4.13	<0.05	0.16
1547B	Kohat	0.161	0.11	0.38	0.3	0.12	0.11	0.06	3.79	<0.05	<0.05
1549B	Kohat	<0.02	<0.02	0.29	0.09	0.05	0.1	0.08	2.41	0.18	0.07
1550B	Kohat	0.64	<0.02	0.81	0.6	0.16	0.19	0.05	4.11	<0.05	<0.05
1551B	Kohat	<0.02	<0.02	0.24	0.23	0.04	0.11	<0.02	3.35	<0.05	<0.05
1553B	Kohat	0.178	0.18	0.41	0.14	0.62	0.05	0.04	5.15	<0.05	<0.05
1556B	Kohat	0.464	0.07	0.58	0.32	0.82	0.19	0.06	5.18	0.06	<0.05
1557B	Kohat	0.117	<0.02	0.32	<0.02	<0.02	0.07	0.11	3.43	<0.05	0.1
1558B	Kohat	0.082	0.17	0.35	0.12	0.84	0.9	0.12	5.48	0.15	0.07

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1559B	Kohat	0.067	<0.02	0.31	0.36	0.2	0.12	0.11	4.29	<0.05	<0.05
1560B	Kohat	1.313	0.13	0.31	0.28	0.85	0.13	0.04	4.04	<0.05	0.25
1562B	Kohat	0.391	0.22	0.39	0.57	1.03	0.12	0.11	6.13	<0.05	<0.05
1564B	Kohat	<0.02	<0.02	0.16	<0.02	0.53	0.67	0.03	1.69	<0.05	0.21
1565B	Kohat	0.131	<0.02	0.36	0.16	0.09	0.12	0.05	3.83	<0.05	0.08
1567B	Kohat	0.022	<0.02	0.12	0.08	0.37	0.08	0.11	1.47	<0.05	0.09
1570B	Kohat	0.212	0.91	0.52	0.16	0.7	0.11	0.03	1.81	<0.05	0.08
1571B	Kohat	<0.02	0.05	0.11	<0.02	0.65	<0.02	0.04	0.67	0.05	<0.05
1572B	Kohat	0.381	0.23	0.55	0.35	0.56	0.19	0.1	6.33	<0.05	0.08
1573B	Kohat	0.174	0.04	0.17	<0.02	0.07	0.08	0.03	0.83	<0.05	<0.05
1577B	Kohat	0.42	0.67	0.87	0.75	0.82	0.12	0.04	16.53	<0.05	0.06
1579B	Kohat	0.495	0.53	0.75	0.11	0.67	0.06	0.05	2.59	<0.05	<0.05
1580B	Kohat	<0.02	0.06	0.09	<0.02	0.06	<0.02	0.1	0.4	<0.05	0.05
1586B	Kohat	0.242	0.08	0.47	0.2	0.35	0.18	0.06	3.99	<0.05	<0.05
1588B	Kohat	0.079	0.04	0.36	0.18	0.72	0.13	0.09	3.85	<0.05	<0.05
2001B	Kohat	<0.02	0.1	0.67	0.13	0.04	<0.02	<0.02	4.54	0.39	0.11
2002B	Kohat	0.037	0.08	0.33	0.25	<0.02	0.03	0.05	4.89	0.05	0.11
2004B	Kohat	0.023	0.05	0.48	0.46	0.51	0.06	<0.02	5.73	0.07	0.05
2005B	Kohat	0.123	0.09	0.64	0.41	<0.02	0.03	0.03	5.12	0.21	<0.05
2006B	Kohat	0.122	0.07	0.85	0.72	0.16	0.04	0.05	6.69	<0.05	0.42
2008B	Kohat	0.027	0.05	0.25	0.23	0.28	<0.02	<0.02	4.02	<0.05	0.47
2009B	Kohat	0.069	0.07	0.32	0.26	<0.02	<0.02	0.04	5	<0.05	0.56
2011B	Kohat	0.026	<0.02	0.59	0.23	0.35	<0.02	0.04	4.32	<0.05	0.24
2012B	Kohat	0.03	0.06	0.68	0.35	0.27	<0.02	<0.02	5.11	<0.05	0.12
2014B	Kohat	0.247	0.42	0.91	0.76	1.23	0.31	0.05	10.14	0.43	0.4
2015B	Kohat	0.066	0.1	0.57	0.03	<0.02	<0.02	<0.02	4.89	0.12	0.08
2016B	Kohat	0.085	<0.02	0.47	0.34	0.25	0.09	0.06	5.64	0.1	0.12

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2017B	Kohat	0.078	0.03	0.34	0.19	0.05	0.14	<0.02	5.92	<0.05	0.39
2018B	Kohat	0.065	0.09	0.71	0.17	0.03	<0.02	0.06	5.76	0.1	<0.05
2021B	Kohat	0.036	0.03	0.98	0.39	0.06	<0.02	<0.02	5.36	0.06	0.2
2022B	Kohat	0.078	0.09	0.9	0.55	0.47	<0.02	<0.02	7.5	<0.05	0.06
2023B	Kohat	0.09	0.08	0.9	0.58	0.06	0.03	<0.02	7.11	0.12	0.39
2024B	Kohat	0.184	0.03	0.81	0.9	0.26	0.23	0.04	30.3	0.06	<0.05
2025B	Kohat	0.047	0.28	0.66	0.34	0.06	0.09	0.06	3.3	0.05	0.3
2026B	Kohat	0.072	0.08	0.64	0.47	0.07	<0.02	<0.02	6.26	<0.05	<0.05
2028B	Kohat	0.071	0.06	0.52	0.37	0.11	0.04	0.03	6.47	<0.05	0.1
2029B	Kohat	0.126	0.07	0.97	0.87	0.31	0.15	0.04	5.93	0.08	<0.05
2030B	Kohat	<0.02	0.04	0.45	0.21	0.21	<0.02	0.03	7.57	<0.05	0.09
2031B	Kohat	<0.02	0.33	0.28	0.47	<0.02	0.03	0.09	6.19	0.05	<0.05
2032B	Kohat	0.033	0.05	0.44	0.29	0.47	0.03	0.04	6.16	<0.05	0.41
2034B	Kohat	0.087	0.06	0.66	0.29	0.05	<0.02	0.03	4.86	<0.05	0.17
2037B	Kohat	0.13	0.14	0.6	0.33	0.04	0.07	0.04	5.61	0.12	0.22
2039B	Kohat	0.156	0.08	0.46	0.41	<0.02	<0.02	<0.02	4.52	0.11	<0.05
2046B	Kohat	0.116	0.43	0.6	0.47	0.37	0.16	0.08	6.95	0.07	0.44
2061B	Kohat	0.299	0.09	0.9	0.33	0.08	0.04	0.06	10.61	0.43	<0.05
2062B	Kohat	0.077	0.03	0.92	0.06	<0.02	0.06	0.04	4.61	0.07	0.05
2063B	Kohat	0.083	0.06	0.36	0.09	<0.02	0.07	<0.02	4.9	<0.05	<0.05
2064B	Kohat	<0.02	0.05	0.09	<0.02	0.57	0.06	0.05	1.24	0.06	0.51
2065B	Kohat	0.066	0.03	0.9	0.32	<0.02	<0.02	<0.02	5.43	0.05	0.64
2066B	Kohat	0.268	<0.02	1.03	0.49	0.26	<0.02	<0.02	7.3	0.25	0.13
2067B	Kohat	0.186	<0.02	0.9	0.4	0.2	0.03	0.06	6.96	0.06	1
2068B	Kohat	0.33	0.05	0.95	0.45	0.06	<0.02	0.06	13.66	<0.05	0.08
2069B	Kohat	0.135	0.09	0.57	0.22	<0.02	<0.02	<0.02	5.75	0.08	<0.05
2070B	Kohat	0.034	0.03	0.78	0.82	1.18	0.05	0.07	25.65	0.08	0.48
2071B	Kohat	0.154	<0.02	0.49	0.36	<0.02	0.07	0.03	10.31	<0.05	0.3
2072B	Kohat	0.124	0.04	0.63	0.51	0.07	0.03	0.03	5.73	0.12	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2073B	Kohat	0.821	0.08	0.7	0.4	<0.02	0.04	0.04	5.41	0.09	0.09
1601B	Karak	0.073	0.04	0.19	0.04	0.48	0.33	0.04	3.72	0.06	0.47
1603B	Karak	0.229	0.06	0.38	0.37	0.94	0.31	0.03	5.01	0.06	<0.05
1607B	Karak	0.259	0.07	0.44	0.17	0.26	0.2	0.06	6.24	0.05	0.09
1608B	Karak	0.162	<0.02	0.3	<0.02	0.24	0.14	0.04	6.02	0.05	0.06
1609B	Karak	0.199	0.09	0.32	0.26	0.33	0.03	0.06	6.45	<0.05	<0.05
1610B	Karak	0.128	0.04	0.41	0.43	0.6	0.36	0.03	5.06	0.06	0.08
1611B	Karak	0.021	0.03	<0.02	0.22	0.13	0.24	<0.02	1.19	0.05	<0.05
1613B	Karak	0.133	0.05	0.36	0.41	0.25	0.07	0.05	6.2	<0.05	<0.05
1614B	Karak	0.191	0.07	0.27	0.41	0.32	0.55	0.03	5.27	<0.05	0.06
1616B	Karak	0.227	<0.02	0.41	0.55	0.14	0.06	0.03	6.29	0.11	0.1
1618B	Karak	<0.02	0.09	0.18	<0.02	<0.02	0.2	0.05	3.58	0.05	<0.05
1619B	Karak	0.094	0.12	0.48	0.17	0.48	0.34	<0.02	7.02	0.09	<0.05
1620B	Karak	0.097	0.13	0.28	0.27	0.51	0.36	0.06	5.04	<0.05	0.14
1621B	Karak	0.1	0.2	0.17	0.47	0.37	0.17	0.05	3.37	0.06	0.21
1623B	Karak	0.041	0.1	0.17	<0.02	0.28	0.19	<0.02	3.78	0.14	0.21
1624B	Karak	0.232	0.05	0.07	0.44	<0.02	0.12	0.04	6.44	0.14	<0.05
1625B	Karak	0.206	<0.02	0.23	0.47	0.38	0.07	0.03	3.7	0.05	0.36
1626B	Karak	0.143	0.03	0.42	0.8	0.35	0.48	<0.02	6.43	0.1	0.66
1627B	Karak	0.171	0.07	0.31	0.24	0.36	0.15	<0.02	6.19	0.06	0.07
1629B	Karak	0.209	<0.02	0.33	0.65	0.53	0.14	<0.02	4.91	0.1	<0.05
1631B	Karak	0.174	0.12	0.39	<0.02	0.93	0.1	0.07	7.62	0.05	0.2
1633B	Karak	0.102	0.05	0.28	0.2	1.84	0.27	0.03	5	<0.05	0.05
1634B	Karak	1.128	0.18	0.08	<0.02	0.06	0.03	<0.02	1.84	0.06	0.15
1635B	Karak	0.16	0.05	0.31	0.3	0.06	0.23	0.04	4.93	0.07	<0.05
1638B	Karak	0.056	0.06	0.32	0.34	0.5	0.03	0.06	5.23	<0.05	1.91
1640B	Karak	0.164	0.06	0.35	0.35	0.49	0.23	0.05	6.43	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1642B	Karak	0.077	0.05	0.14	<0.02	<0.02	<0.02	0.04	3.62	0.07	0.06
1645B	Karak	0.224	0.03	0.41	0.95	0.27	0.12	<0.02	5	0.14	<0.05
1646B	Karak	0.064	0.06	0.24	<0.02	0.42	0.17	0.06	4.22	<0.05	0.08
1649B	Karak	0.158	0.04	0.28	0.36	0.32	0.23	0.06	5.73	<0.05	0.09
1651B	Karak	<0.02	<0.02	0.1	<0.02	0.28	0.14	<0.02	2.5	0.15	<0.05
1652B	Karak	<0.02	<0.02	<0.02	<0.02	0.08	0.1	<0.02	0.75	<0.05	0.09
1653B	Karak	0.085	<0.02	0.18	<0.02	0.46	0.03	0.05	4.47	<0.05	0.05
1656B	Karak	0.023	0.23	0.44	0.1	0.57	<0.02	0.04	5.95	0.08	0.08
1658B	Karak	0.023	0.03	0.33	0.08	0.54	0.15	0.06	6.68	0.11	0.07
1660B	Karak	<0.02	<0.02	0.12	<0.02	0.38	0.45	0.03	2.52	0.05	
1661B	Karak	0.033	0.09	0.17	0.23	0.35	0.36	<0.02	3.67	0.05	
1662B	Karak	0.091	0.08	0.28	<0.02	0.43	0.48	0.06	5.14	0.08	<0.05
1664B	Karak	<0.02	0.12	0.23	<0.02	0.43	0.38	0.07	5.24	0.07	0.4
1668B	Karak	0.083	0.09	0.26	0.21	0.4	0.25	0.03	4.35	<0.05	0.06
1669B	Karak	0.021	<0.02	<0.02	0.23	0.34	0.36	0.04	3.33	0.08	<0.05
1670B	Karak	0.044	<0.02	0.26	<0.02	0.44	0.57	0.03	4.05	<0.05	0.05
1671B	Karak	0.168	<0.02	0.39	0.21	0.19	0.07	0.07	6.21	<0.05	<0.05
1672B	Karak	0.366	0.03	0.66	0.62	0.34	0.65	0.08	6.68	<0.05	<0.05
1674B	Karak	0.061	<0.02	0.16	0.19	0.33	0.04	0.05	4.96	0.05	
1675B	Karak	0.056	<0.02	0.09	0.26	0.03	0.53	0.04	2.48	<0.05	<0.05
1676B	Karak	<0.02	0.07	0.06	<0.02	<0.02	<0.02	0.05	1.92	<0.05	0.06
1678B	Karak	0.345	0.05	0.51	0.66	1.29	0.59	<0.02	7.05	0.1	<0.05
1679B	Karak	0.116	<0.02	0.32	0.49	0.52	0.19	0.03	6.33	0.06	0.1
1683B	Karak	<0.02	<0.02	0.13	<0.02	0.09	0.25	<0.02	2.65	<0.05	<0.05
1685B	Karak	0.194	0.16	0.27	<0.02	0.71	0.05	0.04	5.95	<0.05	<0.05
1687B	Karak	0.226	0.06	0.28	<0.02	0.58	<0.02	0.04	5.79	0.08	0.1
1688B	Karak	0.07	0.08	0.24	0.11	0.76	0.28	0.07	5.84	0.08	0.09
1689B	Karak	0.093	<0.02	0.24	0.42	0.27	0.1	<0.02	5.06	0.11	<0.05
1691B	Karak	0.135	<0.02	0.27	0.21	0.44	0.13	0.04	4.42	0.07	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1692B	Karak	0.167	0.04	0.22	<0.02	0.21	0.28	<0.02	4.51	0.16	0.13
1693B	Karak	0.031	0.06	<0.02	<0.02	<0.02	<0.02	0.05	0.48	<0.05	<0.05
1694B	Karak	0.081	<0.02	0.31	<0.02	0.55	0.57	0.03	4.11	0.06	0.08
1696B	Karak	0.133	<0.02	0.35	0.15	0.49	0.54	0.04	4.47	0.05	<0.05
1698B	Karak	0.181	0.09	0.44	0.1	0.52	0.53	0.08	5.3	0.1	<0.05
1700B	Karak	0.206	0.08	0.46	0.42	0.24	<0.02	<0.02	6.33	0.06	
1801B	Karak	0.175	<0.02	0.22	0.06	0.26	0.1	0.04	6.81	<0.05	0.06
1802B	Karak	0.127	0.08	0.32	0.39	0.4	<0.02	0.04	5.52	0.08	0.05
1804B	Karak	0.09	0.03	0.31	0.44	0.33	0.13	0.05	6.45	0.05	
1805B	Karak	0.148	0.2	0.46	0.67	0.41	0.19	<0.02	6.12	0.32	<0.05
1806B	Karak	0.153	0.09	0.33	0.35	0.4	0.1	0.03	4.16	0.1	0.58
1809B	Karak	0.108	0.09	0.25	<0.02	0.43	0.15	0.03	4.44	0.07	<0.05
1811B	Karak	0.561	0.05	0.28	<0.02	0.39	<0.02	<0.02	3.79	0.08	<0.05
1812B	Karak	0.251	<0.02	0.6	0.3	0.58	0.09	0.03	7.41	0.08	<0.05
1813B	Karak	<0.02	0.07	0.16	<0.02	0.23	0.06	<0.02	2.49	0.08	<0.05
1814B	Karak	0.126	0.09	0.34	<0.02	0.29	<0.02	0.04	3.65	0.12	0.08
1815B	Karak	0.038	<0.02	0.05	<0.02	0.25	0.09	0.04	1.19	<0.05	<0.05
1817B	Karak	0.067	0.06	0.22	0.12	0.27	<0.02	0.04	2.84	<0.05	<0.05
1818B	Karak	0.236	0.08	0.45	0.04	0.29	0.06	0.03	4.43	<0.05	0.07
1819B	Karak	0.083	0.09	0.28	0.24	0.38	0.06	<0.02	4.32	0.07	<0.05
1821B	Karak	0.059	0.06	0.34	0.15	0.18	0.04	0.03	3.98	<0.05	<0.05
1823B	Karak	0.052	0.11	0.29	<0.02	0.33	<0.02	0.03	4.01	0.08	0.27
1825B	Karak	0.074	0.03	0.22	0.43	0.38	<0.02	0.04	2.63	<0.05	0.08
1826B	Karak	0.057	0.05	0.25	<0.02	0.41	0.07	<0.02	3.48	0.06	0.06
1827B	Karak	0.057	0.06	0.16	0.07	0.19	0.03	0.04	2.97	<0.05	<0.05
1828B	Karak	0.232	0.05	0.37	0.32	0.16	0.03	0.03	5.18	0.07	<0.05
1829B	Karak	0.035	0.07	0.09	0.04	0.24	0.03	0.04	1.7	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1830B	Karak	0.098	0.06	0.35	<0.02	0.43	0.04	0.05	4.19	0.05	<0.05
1833B	Karak	<0.02	0.05	0.15	<0.02	0.26	0.04	<0.02	2.04	0.06	0.07
1835B	Karak	0.04	0.07	0.27	0.24	0.33	0.04	0.04	4.45	0.13	0.33
1837B	Karak	0.16	<0.02	0.22	<0.02	0.48	0.06	0.06	3.8	0.06	0.08
1839B	Karak	0.181	0.08	0.39	0.06	0.35	0.09	0.04	4.58	<0.05	0.07
1840B	Karak	0.111	0.09	0.3	0.39	0.46	0.1	<0.02	4.16	0.1	<0.05
1842B	Karak	0.093	0.06	0.41	0.11	0.69	0.12	0.04	5.95	<0.05	<0.05
1844B	Karak	0.079	0.03	0.32	<0.02	0.34	0.32	0.03	4	0.08	<0.05
1846B	Karak	0.191	0.2	0.24	0.08	0.79	<0.02	<0.02	4.03	0.29	0.22
1847B	Karak	0.036	0.07	0.06	<0.02	0.28	0.08	<0.02	1.41	<0.05	<0.05
1848B	Karak	<0.02	0.04	0.19	<0.02	<0.02	<0.02	<0.02	2.92	0.05	<0.05
1849B	Karak	0.235	0.03	0.38	<0.02	0.31	0.06	<0.02	3.63	0.09	0.6
1850B	Karak	0.036	0.08	0.26	<0.02	0.13	0.03	<0.02	2	0.08	0.12
1852B	Karak	0.079	0.05	0.14	<0.02	0.2	0.1	<0.02	3.52	<0.05	<0.05
1854B	Karak	0.142	0.05	0.16	<0.02	0.39	0.05	0.03	3.01	0.1	0.09
1856B	Karak	0.196	<0.02	0.44	0.38	0.38	0.09	0.03	4	0.16	<0.05
1857B	Karak	0.211	0.09	0.22	<0.02	<0.02	0.04	0.04	1.13	0.05	<0.05
1858B	Karak	0.033	0.03	0.35	0.09	0.28	0.07	0.03	1.9	0.13	<0.05
1860B	Karak	0.206	<0.02	0.35	0.19	0.09	<0.02	0.04	3.5	<0.05	0.06
1861B	Karak	0.155	<0.02	0.32	0.1	0.13	<0.02	<0.02	3.16	<0.05	<0.05
1862B	Karak	0.272	0.04	0.26	<0.02	0.27	0.06	<0.02	4.74	<0.05	<0.05
1863B	Karak	0.183	0.07	0.29	<0.02	0.24	0.1	<0.02	3.32	0.09	<0.05
1865B	Karak	0.254	<0.02	0.36	0.03	0.15	0.44	0.05	4.2	<0.05	0.15
1866B	Karak	0.109	<0.02	0.17	<0.02	0.29	0.04	0.05	3.8	0.1	<0.05
1867B	Karak	0.132	<0.02	0.4	0.1	0.46	<0.02	<0.02	4.86	0.16	<0.05
1868B	Karak	0.062	0.03	0.41	<0.02	0.38	<0.02	0.03	3.74	0.13	0.08
1871B	Karak	0.096	0.1	0.21	<0.02	0.04	0.05	0.03	3.95	0.06	<0.05
1874B	Karak	0.153	<0.02	0.32	0.24	0.21	<0.02	0.05	5.02	0.07	0.07
1876B	Karak	0.169	0.06	0.48	0.38	0.21	0.03	0.04	6.03	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1877B	Karak	<0.02	<0.02	0.06	<0.02	0.11	<0.02	0.06	1.3	0.06	0.3
1879B	Karak	0.231	0.06	0.42	0.11	0.4	0.15	<0.02	6.96	0.12	<0.05
1881B	Karak	0.117	0.09	0.43	0.16	0.91	0.1	<0.02	4.9	0.26	0.07
1884B	Karak	0.106	0.04	0.32	<0.02	0.67	0.05	0.04	4.72	0.1	<0.05
1885B	Karak	<0.02	0.05	0.1	<0.02	0.2	<0.02	0.04	1.58	<0.05	<0.05
1887B	Karak	0.036	0.04	0.05	0.03	0.14	<0.02	0.04	1.32	<0.05	0.1
1889B	Karak	0.147	<0.02	0.56	0.65	1.1	0.04	<0.02	8.03	0.19	0.09
1890B	Karak	0.186	0.07	0.33	0.28	<0.02	0.07	0.04	4.25	0.07	<0.05
2041B	Karak	0.167	0.08	0.49	0.47	<0.02	0.08	0.07	4.2	<0.05	<0.05
2043B	Karak	0.126	0.07	0.95	0.25	0.04	0.04	0.06	4.02	0.07	0.22
2044B	Karak	0.122	0.07	0.66	0.29	0.22	0.2	<0.02	3.9	0.06	0.06
2045B	Karak	0.079	0.09	0.4	<0.02	0.04		0.05	2.1	<0.05	<0.05
2047B	Karak	0.176	0.03	1.35	0.54	1.33	0.32	0.09	17.74	0.06	<0.05
2048B	Karak	0.204	0.31	0.87	0.62	0.31	0.32	0.1	9.09	0.07	0.1
2049B	Karak	0.102	0.04	0.53	0.49	<0.02	<0.02	0.05	3.9	0.06	<0.05
2051B	Karak	0.133	0.25	0.41	0.42	0.29	0.04	<0.02	4.9	0.14	0.29
2052B	Karak	0.044	0.09	0.99	0.34	0.37	<0.02	<0.02	5.1	0.1	0.23
2053B	Karak	0.088	0.05	1.1	0.58	0.04	0.04	<0.02	3.8	0.09	<0.05
2054B	Karak	0.022	<0.02	0.91	<0.02	<0.02	0.06	0.06	6.4	0.18	0.05
2055B	Karak	0.042	0.08	1.15	0.36	0.07	0.05	0.04	4.3	0.06	<0.05
2057B	Karak	0.093	<0.02	0.98	0.34	0.34	0.06	0.03	3.6	<0.05	0.42
2058B	Karak	0.15	<0.02	1.04	0.36	0.22	0.09	0.03	4.6	<0.05	<0.05
2059B	Karak	0.026	<0.02	0.88	0.39	0.05	0.05	0.03	5.1	0.07	0.07
2060B	Karak	0.138	<0.02	0.47	0.95	1.52	0.03	0.04	4.9	0.06	<0.05
1598B	Bannu	0.282	0.18	0.7	0.1	0.7	0.07	0.04	10.03	<0.05	<0.05
1599B	Bannu	0.379	<0.02	0.55	2.19	0.83	0.08	0.13	6.82	<0.05	0.1
1701B	Bannu	1.035	0.63	1	9.11	3.38	0.95	0.14	12.45	0.15	0.06

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1702B	Bannu	0.391	0.23	1.06	2.3	0.74	0.33	0.11	16.26	0.11	0.06
1703B	Bannu	0.314	0.2	0.74	2.43	0.69	0.08	0.1	8.06	<0.05	<0.05
1704B	Bannu	0.931	0.6	1.75	8.88	3.32	0.86	0.1	17.99	0.12	<0.05
1705B	Bannu	0.379	0.23	0.9	1.16	0.39	<0.02	0.07	11.95	<0.05	<0.05
1706B	Bannu	0.223	0.27	0.82	1.08	0.58	0.13	0.11	8.88	<0.05	<0.05
1709B	Bannu	0.325	<0.02	0.99	1.13	1.12	0.33	0.09	13.2	0.07	<0.05
1710B	Bannu	0.424	0.37	1.27	2.16	1.58	0.4	0.09	14.3	0.12	<0.05
1713B	Bannu	0.315	0.12	0.81	1.22	0.41	0.14	0.12	9.5	<0.05	<0.05
1714B	Bannu	0.371	<0.02	0.93	1.63	1.21	0.24	0.16	11.22	0.08	0.17
1715B	Bannu	0.29	0.06	0.74	1.12	0.15	0.07	0.13	8	<0.05	0.08
1716B	Bannu	0.162	0.09	0.67	0.69	1.01	0.12	0.08	8.92	<0.05	0.1
1718B	Bannu	0.128	0.03	0.45	0.44	0.63	0.14	0.14	17.66	<0.05	0.25
1720B	Bannu	0.164	0.13	0.77	0.91	0.82	0.22	0.06	11.4	<0.05	<0.05
1722B	Bannu	0.172	0.39	0.72	1.12	0.75	0.07	0.13	11.05	0.08	<0.05
1723B	Bannu	0.231	0.16	1.01	1.6	2.36	0.29	0.06	14.26	0.09	<0.05
1725B	Bannu	0.062	<0.02	0.14	<0.02	0.04	<0.02	0.09	2.55	<0.05	<0.05
1727B	Bannu	0.229	<0.02	0.78	0.79	1.09	0.19	<0.02	12.05	0.06	0.07
1729B	Bannu	0.304	0.57	1.58	1.89	0.96	0.33	0.06	15.08	0.08	0.39
1730B	Bannu	0.251	0.57	1.2	1.63	2.95	0.41	0.1	13.78	0.08	<0.05
1731B	Bannu	0.162	0.06	0.73	1.12	0.15	0.14	0.15	9.51	0.18	<0.05
1732B	Bannu	0.392	0.16	0.9	0.16	1.12	0.23	0.11	11.85	0.09	<0.05
1733B	Bannu	0.29	0.53	1.14	1.68	0.64	0.31	0.12	15.24	0.07	<0.05
1734B	Bannu	0.211	0.27	0.88	1.2	1.7	0.29	0.08	12.68	0.07	0.15
1735B	Bannu	0.31	0.4	1.19	1.91	1.12	0.36	0.13	15.75	0.09	0.05
1736B	Bannu	0.176	<0.02	0.53	0.69	0.34	0.04	0.12	8.6	<0.05	<0.05
1738B	Bannu	0.166	0.11	0.37	0.31	0.29	<0.02	0.12	11.7	<0.05	<0.05
1741B	Bannu	0.195	0.32	0.6	0.07	0.85	0.11	0.09	6.73	<0.05	0.1
1742B	Bannu	0.117	<0.02	0.53	0.71	<0.02	0.07	0.13	8.51	0.07	0.21
1743B	Bannu	0.513	0.43	1.39	2.83	0.11	0.41	0.09	15.17	0.06	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1745B	Bannu	0.199	0.26	0.93	0.95	2.1	0.24	0.04	13.59	<0.05	<0.05
1747B	Bannu	0.222	0.15	0.86	0.56	1.31	0.2	<0.02	9.03	0.18	<0.05
1748B	Bannu	0.199	0.26	0.73	0.43	0.85	0.13	<0.02	8.16	<0.05	0.28
1749B	Bannu	0.226	<0.02	0.66	0.38	0.54	0.11	0.07	7.08	<0.05	<0.05
1751B	Bannu	0.256	0.2	0.28	0.2	0.15	0.1	0.42	3.5	0.07	0.05
1752B	Bannu	0.318	0.32	0.95	0.56	0.62	0.22	0.1	10.47	0.06	<0.05
1754B	Lakki Marwat	0.063	0.12	0.41	0.21	0.32	0.07	0.05	3.67	0.05	
1756B	Lakki Marwat	<0.02	<0.02	0.18	<0.02	0.06	0.1	0.17	2.37	<0.05	0.57
1758B	Lakki Marwat	0.06	<0.02	0.13	0.07	0.61	<0.02	<0.02	1.97	<0.05	<0.05
1759B	Lakki Marwat	0.046	0.05	0.28	0.21	0.67	<0.02	0.11	4.27	<0.05	
1761B	Lakki Marwat	0.101	0.05	0.09	0.05	0.28	0.07	0.06	4.23	<0.05	
1763B	Lakki Marwat	0.082	<0.02	0.42	0.21	0.42	<0.02	0.11	3.57	<0.05	0.05
1766B	Lakki Marwat	0.189	0.08	0.49	1.47	0.05	0.05	0.06	8.49	<0.05	
1767B	Lakki Marwat	0.025	0.04	0.33	0.03	0.49	<0.02	0.03	3.24	<0.05	
1768B	Lakki Marwat	0.167	0.24	0.2	0.4	0.41	<0.02	0.12	3.88	<0.05	0.06
1770B	Lakki Marwat	0.033	0.03	0.19	0.29	0.07	0.1	<0.02	3.39	<0.05	
1772B	Lakki Marwat	0.182	0.14	0.37	0.73	0.23	<0.02	0.05	6.19	<0.05	<0.05
1776B	Lakki Marwat	0.102	0.23	0.32	0.29	0.54	0.05	0.07	2.97	<0.05	<0.05
1778B	Lakki Marwat	0.038	0.05	0.29	0.42	0.69	0.07	0.13	4.22	<0.05	
1779B	Lakki Marwat	0.181	1.71	0.36	0.3	0.83	0.03	<0.02	3.36	0.07	<0.05
1780B	Lakki Marwat	0.09	0.83	0.16	0.12	0.2	0.2	0.05	2.97	<0.05	<0.05
1782B	Lakki Marwat	0.089	0.03	0.28	0.25	0.48	0.15	0.44	3.63	<0.05	<0.05
1783B	Lakki Marwat	0.039	0.04	0.21	0.06	0.03	0.03	0.03	4.61	<0.05	
1784B	Lakki Marwat	<0.02	<0.02	0.28	0.19	1.17	0.06	0.08	3.21	0.08	<0.05
1786B	Lakki Marwat	0.052	0.03	0.35	0.25	<0.02	0.06	0.15	4.04	<0.05	0.06
1787B	Lakki Marwat	0.026	<0.02	0.07	0.25	1	0.07	0.12	3.67	<0.05	0.05
1789B	Lakki Marwat	0.094	0.37	0.17	0.11	0.53	0.03	0.17	2.68	<0.05	

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1790B	Lakki Marwat	0.105	0.08	0.18	0.12	0.06	0.04	0.1	2.26	0.22	
1791B	Lakki Marwat	<0.02	0.04	0.24	0.04	0.85	<0.02	0.03	2.33	<0.05	<0.05
1792B	Lakki Marwat	0.46	<0.02	0.42	0.26	0.73	<0.02	0.06	2.43	<0.05	0.27
1794B	Lakki Marwat	0.189	0.05	<0.02	0.11	<0.02	0.04	<0.02	1.66	<0.05	<0.05
1795B	Lakki Marwat	0.19	0.07	0.42	0.38	0.07	0.04	0.06	7.79	0.06	<0.05
1799B	Lakki Marwat	0.116	0.03	0.34	0.29	0.17	0.04	0.17	7.23	<0.05	<0.05
1902B	Lakki Marwat	<0.02	0.06	0.16	0.05	<0.02	0.05	0.15	2.25	<0.05	0.09
1903B	Lakki Marwat	0.085	0.04	0.23	0.32	0.04	0.05	0.07	3.51	<0.05	<0.05
1904B	Lakki Marwat	0.082	0.27	0.27	0.31	0.83	0.03	0.05	3.67	<0.05	0.2
1905B	Lakki Marwat	0.143	0.04	0.24	0.31	0.67	0.06	0.04	3.38	<0.05	<0.05
1906B	Lakki Marwat	0.234	0.09	0.27	0.13	0.5	<0.02	0.09	3.75	<0.05	<0.05
1907B	Lakki Marwat	0.083	0.26	0.23	0.46	0.97	<0.02	0.06	3.9	0.06	<0.05
1909B	Lakki Marwat	0.056	0.07	0.23	0.05	0.11	0.06	<0.02	3.41	0.05	<0.05
1911B	Lakki Marwat	0.04	0.1	0.34	0.27	0.22	<0.02	0.1	4.08	<0.05	<0.05
1912B	Lakki Marwat	0.129	0.04	0.19	<0.02	0.9	0.04	0.08	3.86	<0.05	<0.05
1913B	Lakki Marwat	0.062	0.44	0.1	0.23	0.25	0.04	0.07	3.39	<0.05	<0.05
1915B	Lakki Marwat	0.03	0.22	0.13	0.35	0.45	0.09	0.11	2.99	<0.05	<0.05
1916B	Lakki Marwat	0.133	0.26	0.23	0.27	0.47	<0.02	0.1	3.34	<0.05	0.35
1917B	Lakki Marwat	0.037	<0.02	0.3	0.08	0.17	0.07	0.21	3.4	<0.05	<0.05
1918B	Lakki Marwat	<0.02	0.05	0.18	0.05	0.05	<0.02	0.2	3.63	<0.05	<0.05
1919B	Lakki Marwat	0.039	<0.02	0.21	0.03	0.04	0.07	<0.02	3.18	<0.05	0.14
1920B	Lakki Marwat	0.067	<0.02	0.23	0.19	0.95	<0.02	0.06	2.59	<0.05	0.07
1922B	Lakki Marwat	0.097	0.42	0.23	0.36	0.81	0.04	0.09	3.19	0.07	<0.05
1924B	Lakki Marwat	0.126	0.3	0.21	0.19	0.7	<0.02	0.1	2.45	<0.05	0.39
1927B	Lakki Marwat	0.407	0.21	0.72	0.61	<0.02	0.2	<0.02	8.88	0.05	<0.05
1933B	Lakki Marwat	0.132	0.25	0.39	0.64	<0.02	0.03	<0.02	6.07	0.05	<0.05
1934B	Lakki Marwat	0.162	<0.02	0.18	0.05	0.06	<0.02	0.11	3.47	0.05	<0.05
1935B	Lakki Marwat	0.243	0.05	0.07	1.44	0.42	0.05	0.2	9.5	<0.05	<0.05
1937B	Lakki Marwat	0.04	0.07	0.27	<0.02	0.05	<0.02	0.08	3.25	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1938B	Lakki Marwat	0.156	<0.02	0.67	0.88	<0.02	0.04	0.16	7.88	<0.05	<0.05
1940B	Lakki Marwat	<0.02	0.03	0.51	0.9	0.67	0.08	<0.02	6.61	0.05	<0.05
1941B	Lakki Marwat	0.368	0.03	0.2	0.42	<0.02	0.11	0.09	6.89	<0.05	<0.05
1944B	Lakki Marwat	0.118	0.04	1.38	0.48	0.03	0.12	0.05	7.57	0.06	<0.05
1945B	Lakki Marwat	0.234	0.25	0.3	1.09	0.71	0.28	<0.02	7.92	<0.05	<0.05
1946B	Lakki Marwat	0.055	0.03	0.28	0.32	0.39	0.1	0.07	2.96	<0.05	<0.05
1948B	Lakki Marwat	0.085	0.04	0.22	0.26	0.29	0.09	0.04	3.03	0.06	<0.05
1949B	Lakki Marwat	0.116	0.46	0.23	0.19	0.51	<0.02	0.08	2.89	<0.05	<0.05
1951B	Lakki Marwat	0.052	0.08	0.29	0.14	0.07	0.06	0.16	3.63		0.22
1952B	Lakki Marwat	0.156	0.17	0.35	0.31	0.63	<0.02	0.1	3.99	<0.05	0.06
1953B	Lakki Marwat	0.04	0.1	0.24	0.22	0.04	<0.02	0.16	4.29	<0.05	<0.05
1955B	Lakki Marwat	0.057	<0.02	0.2	0.13	0.64	<0.02	0.13	2.33	0.07	<0.05
1956B	Lakki Marwat	0.136	0.13	0.34	1.13	0.53	0.09	0.2	8.36	<0.05	<0.05
1957B	Lakki Marwat	0.095	<0.02	0.26	0.22	0.06	0.09	0.14	3.46	<0.05	<0.05
1958B	Lakki Marwat	0.172	0.11	0.47	1.46	0.76	0.07	0.03	8.84	0.06	<0.05
3002B	Hangu	0.3	0.43	0.63	0.42	0.68	0.06	0.09	8.98	0.22	<0.05
3003B	Hangu	0.25	0.46	0.84	0.94	1.38	0.08	0.14	9.67	0.05	<0.05
3005B	Hangu	0.265	0.08	0.68	0.41	0.92	0.05	0.07	9.89	<0.05	<0.05
3006B	Hangu	0.4	0.54	0.95	0.6	0.77	0.04	0.06	8.45	<0.05	<0.05
3007B	Hangu	0.586	1.03	1.26	0.85	1	0.14	0.1	18.4	<0.05	<0.05
3008B	Hangu	0.284	0.49	0.72	0.79	0.91	0.09	0.06	8.36	<0.05	<0.05
3010B	Hangu	0.276	0.06	0.92	0.36	0.66	0.07	0.11	7.78	<0.05	<0.05
3011B	Hangu	0.308	0.54	0.61	0.91	1.05	0.06	0.05	7.63	<0.05	<0.05
3015B	Hangu	0.184	0.03	0.67	0.47	0.78	0.07	0.07	8.63	<0.05	0.08
3016B	Hangu	0.213	0.03	0.73	0.65	0.84	0.08	0.07	8.77	<0.05	0.06
3017B	Hangu	0.263	0.08	0.64	0.52	0.73	0.08	0.09	12.48	<0.05	0.05
3018B	Hangu	0.143	0.05	0.67	1.07	1.45	0.08	0.12	8.31	0.41	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
3020B	Hangu	0.119	0.48	0.6	2.28	1.77	0.04	<0.02	10.21	0.23	<0.05
3021B	Hangu	0.47	1.18	1.24	1.09	1.22	0.09	0.09	7.53	0.44	0.06
3022B	Hangu	0.091	0.41	0.47	1.23	1.24	<0.02	0.05	6.39	0.23	<0.05
3024B	Hangu	0.103	0.43	0.56	1.82	0.42	0.06	0.05	7.45	0.14	<0.05
3026B	Hangu	0.416	0.56	0.74	0.76	0.94	0.05	0.12	9.45	0.38	<0.05
3029B	Hangu	<0.02	0.19	0.91	0.45	0.56	0.1	0.12	7.31	0.23	<0.05
3030B	Hangu	0.267	0.68	0.56	0.41	0.47	0.04	0.06	5.12	0.06	<0.05
3031B	Hangu	0.393	0.23	0.75	0.57	0.44	0.05	<0.02	9.6	0.27	0.06
3033B	Hangu	0.134	0.11	0.73	0.96	0.41	<0.02	0.12	11.3	0.09	0.16
3035B	Hangu	0.579	0.47	1.15	0.96	0.67	0.06	0.15	28.07	0.35	0.1
3036B	Hangu	0.375	0.05	0.78	0.66	0.38	0.07	0.12	16.35	0.06	0.05
3037B	Hangu	0.558	0.25	0.7	0.87	0.27	0.1	0.11	21.05	0.22	<0.05
3038B	Hangu	0.151	0.69	0.56	0.55	0.5	0.09	0.15	3.09	<0.05	0.05
3040B	Hangu	0.144	0.56	0.64	0.65	0.68	0.06	0.1	6.66	<0.05	0.17
3042B	Hangu	0.253	0.39	0.92	1.34	0.87	0.07	0.07	11.69	<0.05	0.14
3043B	Hangu	0.389	0.03	0.93	0.5	0.09	0.08	0.17	7.02	<0.05	<0.05
3045B	Hangu	0.197	0.51	0.93	0.71	0.59	0.03	0.11	9.55	<0.05	0.08
3046B	Hangu	0.719	0.12	1.04	0.76	0.13	0.08	0.08	18.1	<0.05	<0.05
3048B	Hangu	0.112	0.39	0.88	0.67	0.33	<0.02	0.13	10.49	<0.05	0.08
3049B	Hangu	0.327	0.06	0.73	0.5	0.43	0.07	0.04	6.87	<0.05	<0.05
3050B	Hangu	0.287	0.13	0.62	0.42	0.51	0.08	0.11	0.9	<0.05	<0.05
3052B	Hangu	0.27	0.13	0.88	0.79	0.19	0.06	0.1	15.7	<0.05	<0.05
3053B	Hangu	0.221	0.09	0.79	0.86	0.28	0.05	0.08	9.31	<0.05	0.08
3054B	Hangu	0.116	0.06	0.74	0.77	0.24	0.06	0.11	9.55	<0.05	<0.05
3055B	Hangu	0.329	<0.02	0.86	0.62	0.54	0.13	0.03	12.09	<0.05	<0.05
3056B	Hangu	0.148	0.09	0.77	0.52	0.4	<0.02	0.09	10.85	<0.05	<0.05
3057B	Hangu	0.391	0.08	0.88	0.69	0.37	0.13	0.06	36.45	<0.05	<0.05
3060B	Hangu	0.311	0.34	1.04	0.94	0.76	0.07	0.08	44.07	<0.05	0.09
3062B	Hangu	0.258	0.07	0.86	0.56	0.4	0.03	0.03	11.95	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
3063B	Hangu	0.3	0.09	0.81	0.65	0.52	0.06	<0.02	6.9	<0.05	<0.05
3064B	Hangu	0.245	0.03	0.8	0.58	0.11	0.05	0.09	6.77	<0.05	<0.05
3065B	Hangu	0.42	0.9	0.93	1.06	0.13	<0.02	0.04	8.34	<0.05	0.15
3066B	Hangu	0.369	1.17	0.2	1.53	0.77	<0.02	0.18	13.82	<0.05	<0.05
3067B	Hangu	0.612	0.72	0.96	0.79	0.3	0.13	0.03	24.35	<0.05	0.06
3068B	Hangu	0.328	0.15	0.65	0.44	0.48	0.07	0.03	7.19	<0.05	<0.05
3069B	Hangu	0.23	0.29	0.71	0.42	0.37	0.03	0.09	4.75	<0.05	<0.05
3070B	Hangu	<0.02	0.53	0.71	0.77	0.12	0.05	0.11	6.84	<0.05	<0.05
3071B	Hangu	0.389	0.06	0.61	0.42	0.17	<0.02	0.04	5.67	<0.05	<0.05
2101B	D.I.Khan	0.31	0.521	0.641	0.526	4.951	0.095	0.042	7.568	0.093	<0.05
2109B	D.I.Khan	0.439	0.443	0.726	0.638	0.345	0.314	0.078	10.61	0.097	<0.05
2111B	D.I.Khan	0.193	0.492	0.583	0.467	4.153	0.13	0.083	5.966	0.068	<0.05
2112B	D.I.Khan	0.124	0.243	0.338	0.169	3.174	0.107	0.041	4.269	0.064	<0.05
2113B	D.I.Khan	0.146	0.438	0.802	0.059	2.325	<0.02	0.052	3.772	0.075	<0.05
2114B	D.I.Khan	0.158	0.418	0.145	0.491	2.618	0.045	<0.02	6.364	0.053	<0.05
2114B	D.I.Khan	0.145	0.414	1.242	0.236	1.136	0.162	<0.02	3.923	0.089	0.077
2116B	D.I.Khan	0.202	0.277	0.71	0.431	1.849	0.122	0.032	4.746	0.054	0.217
2117B	D.I.Khan	0.289	0.396	0.517	0.269	3.715	0.225	0.098	5.549	0.072	<0.05
2118B	D.I.Khan	0.273	0.415	0.361	0.331	3.802	0.17	0.043	3.528	0.09	0.061
2119B	D.I.Khan	0.258	0.432	2.966	0.056	2.333	0.081	<0.02	5.794	<0.05	0.079
2120B	D.I.Khan	0.403	0.615	0.676	0.717	1.701	0.113	0.085	7.486	0.073	<0.05
2121B	D.I.Khan	0.162	0.386	0.442	0.218	2.531	0.082	0.05	5.059	0.104	<0.05
2122B	D.I.Khan	0.834	0.331	0.502	0.137	0.75	0.131	0.021	5.109	<0.05	<0.05
2125B	D.I.Khan	0.123	0.423	0.544	0.037	2.382	0.192	0.078	5.467	0.063	<0.05
2127B	D.I.Khan	<0.02	0.027	0.17	0.235	2.23	0.321	0.056	1.581	<0.05	<0.05
2131B	D.I.Khan	0.226	0.433	0.531	0.342	5.379	0.166	0.067	5.401	0.086	0.17
2135B	D.I.Khan	0.274	<0.02	0.826	0.113	0.31	0.321	<0.02	3.854	0.069	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2136B	D.I.Khan	0.114	0.422	0.316	0.127	2.719	0.076	<0.02	4.729	0.07	<0.05
2137B	D.I.Khan	0.111	0.433	0.71	<0.02	2.349	0.078	0.065	4.483	0.091	0.182
2138B	D.I.Khan	0.167	0.506	0.853	0.052	2.245	0.021	0.038	4.485	0.069	<0.05
2139B	D.I.Khan	0.346	0.567	0.391	0.391	2.66	0.253	0.044	4.526	0.061	<0.05
2144B	D.I.Khan	0.283	0.574	0.505	0.491	1.981	0.233	0.04	4.782	0.079	<0.05
2145B	D.I.Khan	0.452	0.624	0.597	0.41	2.494	0.315	0.046	5.301	<0.05	<0.05
2146B	D.I.Khan	0.335	0.656	0.628	0.508	1.533	0.157	0.053	6.87	0.094	0.091
2148B	D.I.Khan	0.295	0.553	0.479	0.636	1.159	0.07	0.056	5.018	0.059	<0.05
2149B	D.I.Khan	0.335	0.532	0.421	0.308	1.569	0.035	0.062	3.085	0.066	0.148
2150B	D.I.Khan	0.145	0.403	0.396	0.098	4.294	0.03	0.046	3.883	0.058	<0.05
2152B	D.I.Khan	0.313	0.612	0.698	0.633	2.763	0.077	0.088	7.807	0.083	<0.05
2153B	D.I.Khan	0.247	1.039	0.34	0.474	0.965	0.027	0.04	2.552	0.089	<0.05
2154B	D.I.Khan	0.095	0.258	0.429	<0.02	0.47	0.052	0.082	4.868	0.064	<0.05
2155B	D.I.Khan	0.189	0.247	0.043	0.04	1.422	0.119	0.036	5.829	0.091	<0.05
2157B	D.I.Khan	0.257	0.619	0.818	0.047	3.672	0.101	0.046	9.355	0.096	<0.05
2158B	D.I.Khan	0.31	0.591	0.658	0.054	2.385	0.048	<0.02	7.823	0.097	<0.05
2159B	D.I.Khan	0.198	0.309	0.437	0.023	1.149	0.076	0.044	3.932	0.062	<0.05
2160B	D.I.Khan	0.12	0.333	0.437	0.228	4.826	0.278	0.067	4.733	0.062	<0.05
2161B	D.I.Khan	0.263	0.36	0.343	0.061	4.471	0.389	0.072	4.092	0.077	<0.05
2162B	D.I.Khan	0.111	0.103	0.387	0.204	0.888	0.064	0.032	3.76	0.061	<0.05
2163B	D.I.Khan	0.667	0.929	1.432	0.413	4.589	0.487	<0.02	14.44	0.113	<0.05
2164B	D.I.Khan	0.256	0.584	0.834	0.117	3.523	0.308	<0.02	9.355	0.079	0.119
2165B	D.I.Khan	0.192	0.267	0.491	0.141	0.987	0.04	0.049	5.55	0.06	<0.05
2167B	D.I.Khan	0.325	0.186	0.34	<0.02	2.628	0.174	0.045	4.514	0.105	0.056
2168B	D.I.Khan	0.262	0.537	0.37	0.575	3.214	0.775	0.115	9.391	<0.05	<0.05
2169B	D.I.Khan	0.108	0.414	0.268	0.339	2.066	0.204	0.072	3.81	0.068	<0.05
2170B	D.I.Khan	0.289	0.423	0.619	0.688	1.092	0.202	0.054	4.254	0.076	0.09
2171B	D.I.Khan	0.227	0.21	0.51	0.361	1.765	0.119	0.072	5.845	0.087	0.223
2172B	D.I.Khan	0.173	0.308	0.495	0.209	6.544	<0.02	0.057	4.429	0.079	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2174B	D.I.Khan	0.365	0.423	0.327	0.391	3.563	0.251	<0.02	6.542	<0.05	<0.05
2176B	D.I.Khan	0.173	0.373	0.423	0.193	2.607	<0.02	0.036	5.082	0.076	<0.05
2177B	D.I.Khan	0.139	0.124	0.424	0.196	3.667	0.175	0.057	4.953	0.106	<0.05
2178B	D.I.Khan	0.221	0.431	0.339	0.535	0.558	0.073	0.057	4.074	0.083	<0.05
2181B	D.I.Khan	0.244	0.552	0.574	0.241	0.714	0.029	0.04	5.359	0.091	<0.05
2183B	D.I.Khan	0.165	0.541	0.541	0.346	0.521	0.31	0.085	5.475	0.096	<0.05
2184B	D.I.Khan	0.874	0.372	1.895	0.209	5.897	0.149	0.024	4.815	0.085	<0.05
2185B	D.I.Khan	0.117	0.095	0.309	0.043	0.784	0.112	<0.02	4.293	0.103	<0.05
2186B	D.I.Khan	0.155	0.333	1.405	0.374	1.533	1.231	0.04	5.556	<0.05	<0.05
2189B	D.I.Khan	0.335	0.793	0.738	0.439	0.589	0.247	<0.02	6.4	0.09	<0.05
2190B	D.I.Khan	0.089	0.094	0.366	<0.02	2.949	0.025	0.064	3.885	<0.05	<0.05
2201B	D.I.Khan	0.439	<0.02	0.699	0.349	6.321	0.336	0.055	8.085	0.055	0.087
2202B	D.I.Khan	0.364	0.112	0.641	0.457	5.5	0.358	0.082	9.098	<0.05	0.201
2203B	D.I.Khan	0.483	0.433	0.649	0.752	0.707	0.351	0.092	7.2	0.074	0.05
2204B	D.I.Khan	0.43	0.35	0.853	0.403	9.808	0.304	0.086	9.111	0.054	<0.05
2205B	D.I.Khan	0.482	0.42	0.771	0.564	0.782	0.413	0.096	8.565	<0.05	0.068
2207B	D.I.Khan	0.505	0.257	0.895	0.336	0.555	0.43	0.089	9.956	0.067	<0.05
2208B	D.I.Khan	0.482	0.336	0.784	0.419	1.369	0.378	0.058	9.031	0.068	<0.05
2209B	D.I.Khan	0.398	0.346	0.647	0.391	3.68	0.339	0.087	9.452	0.068	<0.05
2211B	D.I.Khan	0.55	0.142	0.826	0.297	2.112	0.199	0.067	8.72	0.057	<0.05
2212B	D.I.Khan	0.603	0.105	0.942	0.352	3.304	0.381	0.085	8.202	0.06	0.05
2213B	D.I.Khan	0.508	0.064	1.032	0.316	8.453	0.178	0.095	8.874	0.065	<0.05
2214B	D.I.Khan	0.46	0.208	0.644	0.489	4.985	0.336	0.069	9.223	0.062	0.089
2215B	D.I.Khan	0.413	0.418	0.56	0.489	1.103	0.397	0.079	9.142	0.075	<0.05
2216B	D.I.Khan	0.403	0.064	0.712	0.521	3.242	0.215	0.097	8.215	0.073	0.064
2217B	D.I.Khan	0.394	0.159	0.689	0.62	5.42	0.426	0.062	9.494	0.06	0.079
2218B	D.I.Khan	0.331	0.584	0.69	0.868	1.264	0.391	0.084	7.945	0.051	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2219B	D.I.Khan	0.535	0.328	0.695	0.745	6.622	0.45	0.077	8.37	<0.05	<0.05
2220B	D.I.Khan	0.42	0.1	0.697	0.67	4.203	0.215	0.074	6.543	<0.05	<0.05
2221B	D.I.Khan	0.393	0.177	0.596	0.315	3.798	<0.02	0.067	9.305	0.059	0.09
2222B	D.I.Khan	0.429	0.521	0.784	0.673	3.852	0.306	0.096	9.273	0.07	<0.05
2223B	D.I.Khan	0.278	0.542	0.839	0.535	0.374	0.239	0.096	9.048	<0.05	<0.05
2224B	D.I.Khan	0.349	0.487	0.666	0.122	0.499	0.33	0.092	8.326	0.053	0.103
2225B	D.I.Khan	0.54	0.195	0.683	0.529	7.714	0.35	0.09	7.979	<0.05	<0.05
2226B	D.I.Khan	0.521	0.454	0.988	1.111	0.389	0.338	0.082	9.85	<0.05	<0.05
2227B	D.I.Khan	0.538	0.468	0.861	0.874	1.885	0.393	0.066	10.56	0.069	0.095
2228B	D.I.Khan	0.517	0.491	0.883	0.599	5.068	0.224	0.1	9.442	<0.05	0.156
2229B	D.I.Khan	0.367	0.459	0.73	0.816	8.056	0.334	0.079	8.419	<0.05	<0.05
2231B	D.I.Khan	0.521	0.41	0.897	0.412	2.609	0.356	0.069	8.344	0.062	0.071
2232B	D.I.Khan	0.563	0.367	0.865	0.502	2.451	0.315	0.091	8.656	0.074	<0.05
2233B	D.I.Khan	0.435	0.667	0.676	0.964	6.535	0.07	0.055	8.889	<0.05	<0.05
2234B	D.I.Khan	0.438	0.092	0.761	0.957	1.536	0.338	0.1	8.666	<0.05	<0.05
2235B	D.I.Khan	0.404	0.574	0.729	0.381	3.141	0.281	0.121	8.65	0.073	0.195
2236B	D.I.Khan	0.385	0.256	0.71	0.935	1.331	0.337	0.083	8.796	<0.05	0.057
2237B	D.I.Khan	0.345	0.1	0.648	0.436	1.665	0.241	0.094	8.262	0.07	<0.05
2238B	D.I.Khan	0.774	<0.02	0.954	0.331	0.198	0.379	0.093	9.262	0.066	<0.05
2239B	D.I.Khan	0.444	<0.02	0.768	0.35	1.939	0.343	0.094	9.529	0.055	<0.05
2240B	D.I.Khan	0.484	0.17	0.778	0.646	3.596	0.448	0.074	9.943	0.062	<0.05
2241B	D.I.Khan	0.437	0.148	0.83	0.654	3.881	0.217	0.069	9.447	0.068	0.059
2242B	D.I.Khan	0.612	0.267	1.039	0.718	10.54	0.222	0.094	10.6	0.067	<0.05
2243B	D.I.Khan	0.523	0.35	0.796	0.652	5.231	0.421	0.081	9.562	0.062	<0.05
2244B	D.I.Khan	0.558	0.305	0.979	0.968	9.174	0.389	0.082	9.295	<0.05	0.085
2245B	D.I.Khan	0.601	0.1	0.771	0.983	1.051	0.494	0.073	10.2	0.07	<0.05
2246B	D.I.Khan	0.485	0.429	0.757	0.481	1.388	0.297	0.076	7.236	0.063	0.075
2247B	D.I.Khan	0.58	0.596	0.996	1.138	8.942	0.35	0.101	11.01	0.051	0.057
2248B	D.I.Khan	0.423	0.3	0.907	0.477	4.594	0.111	0.084	8.397	0.068	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2249B	D.I.Khan	0.679	0.47	0.97	0.874	6.324	0.114	0.096	9.171	0.051	<0.05
2251B	D.I.Khan	0.591	0.395	0.973	0.312	6.98	0.383	0.082	10.99	0.059	<0.05
2252B	D.I.Khan	0.231	0.221	0.54	0.449	1.762	0.163	0.067	4.483	<0.05	<0.05
2253B	D.I.Khan	0.197	<0.02	0.47	0.21	3.9	0.361	0.089	4.05	<0.05	<0.05
2254B	D.I.Khan	0.179	<0.02	0.344	0.103	5.926	0.126	0.092	3.629	0.052	0.197
2257B	D.I.Khan	0.498	0.025	1.173	0.371	5.752	0.152	0.058	8.102	0.064	0.167
2258B	D.I.Khan	0.47	0.048	0.71	0.257	0.999	0.197	0.086	8.44	0.058	<0.05
2259B	D.I.Khan	0.295	0.311	0.516	0.073	3.935	0.186	0.062	4.573	<0.05	<0.05
2260B	D.I.Khan	0.264	0.057	0.572	<0.02	0.53	0.222	0.096	5.379	0.054	<0.05
2261B	D.I.Khan	0.189	0.03	0.479	0.118	3.243	0.236	0.079	5.309	0.067	<0.05
2262B	D.I.Khan	0.244	0.249	0.546	0.412	6.335	0.594	0.068	4.31	0.055	0.212
2263B	D.I.Khan	0.183	0.191	0.39	0.303	0.454	0.175	0.084	4.254	<0.05	<0.05
2264B	D.I.Khan	0.226	0.201	0.558	0.24	1.541	0.171	0.093	3.822	0.056	<0.05
2268B	D.I.Khan	0.258	0.357	0.44	0.346	2.912	0.361	0.089	4.279	<0.05	0.052
2269B	D.I.Khan	0.183	0.186	0.469	0.131	2.299	0.233	0.052	4.787	<0.05	<0.05
2271B	D.I.Khan	0.459	0.536	0.755	0.283	1.851	0.421	0.171	9.61	0.07	<0.05
2272B	D.I.Khan	0.549	0.061	1.08	0.39	8.398	0.301	0.077	9.269	0.071	<0.05
2273B	D.I.Khan	0.193	0.074	0.451	0.204	5.067	0.025	0.07	3.473	<0.05	0.229
2274B	D.I.Khan	0.173	0.099	0.368	0.207	1.815	0.291	0.075	2.982	<0.05	0.083
2275B	D.I.Khan	0.245	0.062	0.449	0.201	4.028	0.03	0.06	3.264	<0.05	0.079
2276B	D.I.Khan	0.311	0.228	0.532	0.2	2.169	0.194	0.079	4.754	0.059	0.064
2277B	D.I.Khan	0.287	0.362	0.514	0.299	0.664	0.193	0.089	4.037	<0.05	<0.05
2278B	D.I.Khan	0.139	0.362	0.467	0.293	1.23	0.067	0.064	5.235	0.061	0.056
2279B	D.I.Khan	0.152	0.381	0.627	0.1	0.521	0.143	<0.02	4.236	<0.05	<0.05
2280B	D.I.Khan	0.272	0.378	0.781	0.032	0.666	0.264	0.074	4.885	<0.05	<0.05
2286B	D.I.Khan	0.256	0.072	0.538	0.567	2.964	0.213	0.096	8.698	0.061	<0.05
2287B	D.I.Khan	0.227	0.422	0.838	0.525	7.829	<0.02	0.06	6.347	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2288B	D.I.Khan	0.194	0.059	0.426	0.429	5.551	0.035	0.067	5.044	0.078	<0.05
2289B	D.I.Khan	0.283	0.228	0.571	0.307	7.623	0.265	0.082	6.868	<0.05	<0.05
2291B	D.I.Khan	0.056	<0.02	0.341	0.339	6.352	0.178	0.063	4.102	<0.05	0.063
2292B	D.I.Khan	0.308	0.027	0.53	0.302	1.852	0.406	0.057	9.398	0.061	<0.05
2293B	D.I.Khan	0.253	0.474	0.71	0.665	7.438	0.52	0.058	8.594	0.052	<0.05
2294B	D.I.Khan	0.329	0.026	0.722	0.487	4.731	0.299	0.084	8.5	0.058	<0.05
2295B	D.I.Khan	0.439	0.295	0.917	0.7	0.743	0.35	0.095	8.794	0.056	0.055
2296B	D.I.Khan	0.198	0.134	0.418	0.372	0.931	0.09	0.071	3.979	<0.05	0.189
2297B	D.I.Khan	0.34	0.499	0.742	0.161	7.97	0.392	0.074	7.638	0.055	<0.05
2300B	D.I.Khan	0.593	0.325	0.362	0.436	8.641	0.22	0.021	7.798	<0.05	<0.05
2303B	D.I.Khan	0.57	0.028	0.661	0.664	0.392	0.144	<0.02	8.02	<0.05	<0.05
2305B	D.I.Khan	0.637	0.354	0.741	0.399	5.581	0.141	<0.02	6.4	0.056	0.194
2308B	D.I.Khan	0.42	0.403	0.549	0.38	4.82	0.128	<0.02	7.82	0.052	<0.05
2309B	D.I.Khan	0.551	0.767	0.284	0.874	6.071	0.269	<0.02	8.373	0.059	<0.05
2310B	D.I.Khan	0.562	0.087	0.784	0.952	6.39	0.417	<0.02	7.991	0.06	<0.05
2311B	D.I.Khan	0.481	0.588	0.897	0.683	6.735	0.154	0.029	7.881	0.062	<0.05
2312B	D.I.Khan	0.4	0.237	0.744	0.6	0.705	0.188	<0.02	7.466	0.054	<0.05
2314B	D.I.Khan	0.492	0.385	0.478	0.532	1.508	0.281	0.026	7.234	<0.05	<0.05
2315B	D.I.Khan	0.736	0.215	0.639	0.414	9.224	0.34	<0.02	8.912	0.055	<0.05
2316B	D.I.Khan	0.69	0.195	0.518	0.551	8.629	0.165	<0.02	8.703	0.062	<0.05
2318B	D.I.Khan	0.382	0.294	0.543	0.518	0.838	0.196	<0.02	5.286	0.056	<0.05
2321B	D.I.Khan	0.594	0.426	0.769	<0.02	5.749	0.142	0.029	6.037	<0.05	0.216
2326B	D.I.Khan	0.616	0.599	0.862	0.411	0.238	<0.02	0.024	8.098	0.059	<0.05
2327B	D.I.Khan	0.633	0.4	0.626	0.365	5.958	0.257	<0.02	11.1	0.062	<0.05
2328B	D.I.Khan	0.708	0.539	0.59	0.14	7.196	0.222	<0.02	7.752	0.053	<0.05
2330B	D.I.Khan	0.486	0.3	0.369	0.295	5.083	0.242	<0.02	9.183	0.059	<0.05
2331B	D.I.Khan	0.352	0.178	0.613	0.084	2.391	0.092	<0.02	3.949	0.067	<0.05
2332B	D.I.Khan	0.385	0.097	0.624	0.022	6.199	0.15	<0.02	4.949	0.058	<0.05
2333B	D.I.Khan	0.312	0.386	0.737	0.032	1.136	0.506	0.027	4.821	0.068	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2334B	D.I.Khan	0.381	0.252	0.933	0.037	1.204	0.111	<0.02	5.642	0.08	<0.05
2335B	D.I.Khan	0.636	0.266	0.672	0.208	0.712	0.219	<0.02	9.58	0.062	0.121
2336B	D.I.Khan	1.226	<0.02	0.765	0.353	4.747	0.17	0.022	8.905	0.069	0.198
2337B	D.I.Khan	0.536	0.357	0.725	0.409	0.136	0.189	<0.02	7.517	0.063	<0.05
2338B	D.I.Khan	1.184	0.453	0.857	0.252	9.671	0.201	0.023	10.39	0.061	<0.05
2339B	D.I.Khan	1.327	0.292	0.847	0.67	2.786	0.45	<0.02	9.839	0.061	<0.05
2340B	D.I.Khan	0.334	0.139	0.546	0.269	3.749	0.288	<0.02	3.917	<0.05	<0.05
2341B	D.I.Khan	0.184	0.107	0.222	0.028	4.574	0.176	<0.02	2.926	<0.05	<0.05
2342B	D.I.Khan	0.125	0.24	0.474	0.112	1.029	0.174	<0.02	2.779	0.062	<0.05
2343B	D.I.Khan	0.201	0.333	0.408	0.246	0.243	0.039	0.03	3.587	<0.05	0.06
2344B	D.I.Khan	0.316	0.181	0.553	0.218	1.46	0.237	<0.02	4.012	0.059	0.08
2346B	D.I.Khan	0.444	0.09	0.739	0.175	22.75	0.241	<0.02	6.478	<0.05	0.076
2347B	D.I.Khan	0.678	0.137	0.357	0.047	1.067	0.111	0.021	3.895	0.07	<0.05
2348B	D.I.Khan	0.18	0.409	0.486	0.086	4.94	0.169	0.023	3.873	0.058	<0.05
2352B	D.I.Khan	0.375	0.029	0.63	0.263	1.589	0.199	<0.02	4.452	0.058	<0.05
2353B	D.I.Khan	0.327	0.092	0.521	0.176	1.236	0.046	<0.02	5.235	0.092	<0.05
2354B	D.I.Khan	0.361	0.125	0.488	0.056	6.214	0.136	<0.02	4.608	0.055	<0.05
2355B	D.I.Khan	0.085	0.129	0.234	0.038	3.298	0.093	0.021	3.369	<0.05	0.631
2356B	D.I.Khan	0.405	0.34	0.638	0.27	5.658	0.163	0.027	5.07	0.06	0.097
2358B	D.I.Khan	0.256	0.135	0.462	0.16	4.547	0.028	<0.02	8.251	<0.05	<0.05
2361B	D.I.Khan	0.229	0.529	0.565	0.154	4.778	0.024	0.031	3.818	0.052	<0.05
2362B	D.I.Khan	0.175	0.281	0.469	0.021	3.125	0.196	<0.02	3.666	0.063	<0.05
2363B	D.I.Khan	0.279	0.12	0.486	0.037	5.61	0.072	0.026	3.299	0.054	<0.05
2365B	D.I.Khan	0.184	0.129	0.32	0.162	5.933	0.108	<0.02	2.827	<0.05	0.072
2367B	D.I.Khan	0.099	0.031	0.233	0.231	0.36	0.031	<0.02	2.226	0.056	0.061
2401B	D.I.Khan	0.419	0.332	0.432	0.559	6.744	0.291	0.062	7.592	<0.05	<0.05
2411B	D.I.Khan	0.484	0.209	0.429	0.721	8.041	0.195	0.076	6.892	<0.05	<0.05

Table 5.5 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2414B	D.I.Khan	0.57	0.107	0.56	0.496	7.236	0.167	0.092	6.146	<0.05	0.301
2415B	D.I.Khan	0.476	0.364	0.258	0.479	3.13	0.307	0.076	5.761	0.06	<0.05
2416B	D.I.Khan	0.53	0.377	0.369	0.504	8.602	0.265	0.1	6.041	<0.05	0.089
2417B	D.I.Khan	0.509	0.138	0.852	0.49	7.875	0.365	0.092	6.297	0.085	<0.05
2418B	D.I.Khan	0.52	0.068	0.958	0.506	8.265	0.244	0.089	6.184	<0.05	<0.05
2419B	D.I.Khan	0.455	0.145	0.763	0.526	6.325	0.197	0.072	6.146	0.062	<0.05
2420B	D.I.Khan	0.499	0.286	0.658	0.522	7.784	0.375	0.03	5.718	<0.05	<0.05
2421B	D.I.Khan	0.715	0.58	0.523	0.714	10.01	0.343	0.068	7.85	<0.05	<0.05
2422B	D.I.Khan	0.418	0.507	0.432	0.489	7.11	0.232	0.1	5.428	<0.05	<0.05
2423B	D.I.Khan	0.235	0.049	0.462	0.258	5.785	0.193	0.07	4.074	<0.05	<0.05
2424B	D.I.Khan	0.621	0.256	0.69	0.551	8.351	0.156	0.082	5.7	<0.05	0.178
2425B	D.I.Khan	0.561	0.038	0.85	0.466	2.639	0.264	0.094	7.006	0.052	0.151
2426B	D.I.Khan	0.626	0.49	0.236	0.604	1.989	0.32	0.046	6.824	0.071	0.087
2427B	D.I.Khan	0.592	0.374	0.546	0.572	9.007	0.231	0.056	6.521	0.063	<0.05
2428B	D.I.Khan	0.365	0.113	0.556	0.392	6.441	0.157	0.052	3.827	<0.05	0<0.05
2429B	D.I.Khan	0.556	0.24	0.265	0.571	5.787	0.261	0.098	6.307	<0.05	<0.05
2430B	D.I.Khan	0.416	0.081	0.536	0.308	6.783	0.214	0.059	5.51	0.052	<0.05
2441B	D.I.Khan	0.367	0.122	0.429	0.352	0.176	0.352	<0.02	4.386	<0.05	<0.05
2442B	D.I.Khan	0.399	0.343	0.343	0.172	0.841	0.245	<0.02	4.49	<0.05	<0.05
2443B	D.I.Khan	0.576	0.242	0.935	0.781	3.898	0.317	0.096	7.757	<0.05	<0.05
2444B	D.I.Khan	0.104	0.192	0.725	0.358	1.236	0.234	0.097	9.251	<0.05	0.052
2445B	D.I.Khan	0.205	0.167	0.581	0.1	3.26	0.054	0.078	3.531	0.059	<0.05
2446B	D.I.Khan	0.239	<0.02	0.462	0.223	6.937	0.157	0.093	4.604	<0.05	<0.05
2447B	D.I.Khan	0.305	0.021	0.532	0.341	5.84	0.029	0.085	4.605	<0.05	0.074
2501B	Tank	0.418	0.227	1.169	0.078	0.678	0.479	0.076	11.68	0.813	0.091
2502B	Tank	0.385	1.042	0.903	1.154	0.487	0.301	0.137	10.21	0.147	<0.05
2503B	Tank	0.386	1.006	0.789	0.023	0.435	0.33	0.083	11.54	0.119	<0.05
2504B	Tank	0.428	0.785	0.845	0.054	0.972	0.263	0.082	7.987	<0.05	<0.05
2505B	Tank	0.574	0.795	1.205	0.245	0.314	0.398	0.06	10.38	1.625	0.06

Table 5.5 continued

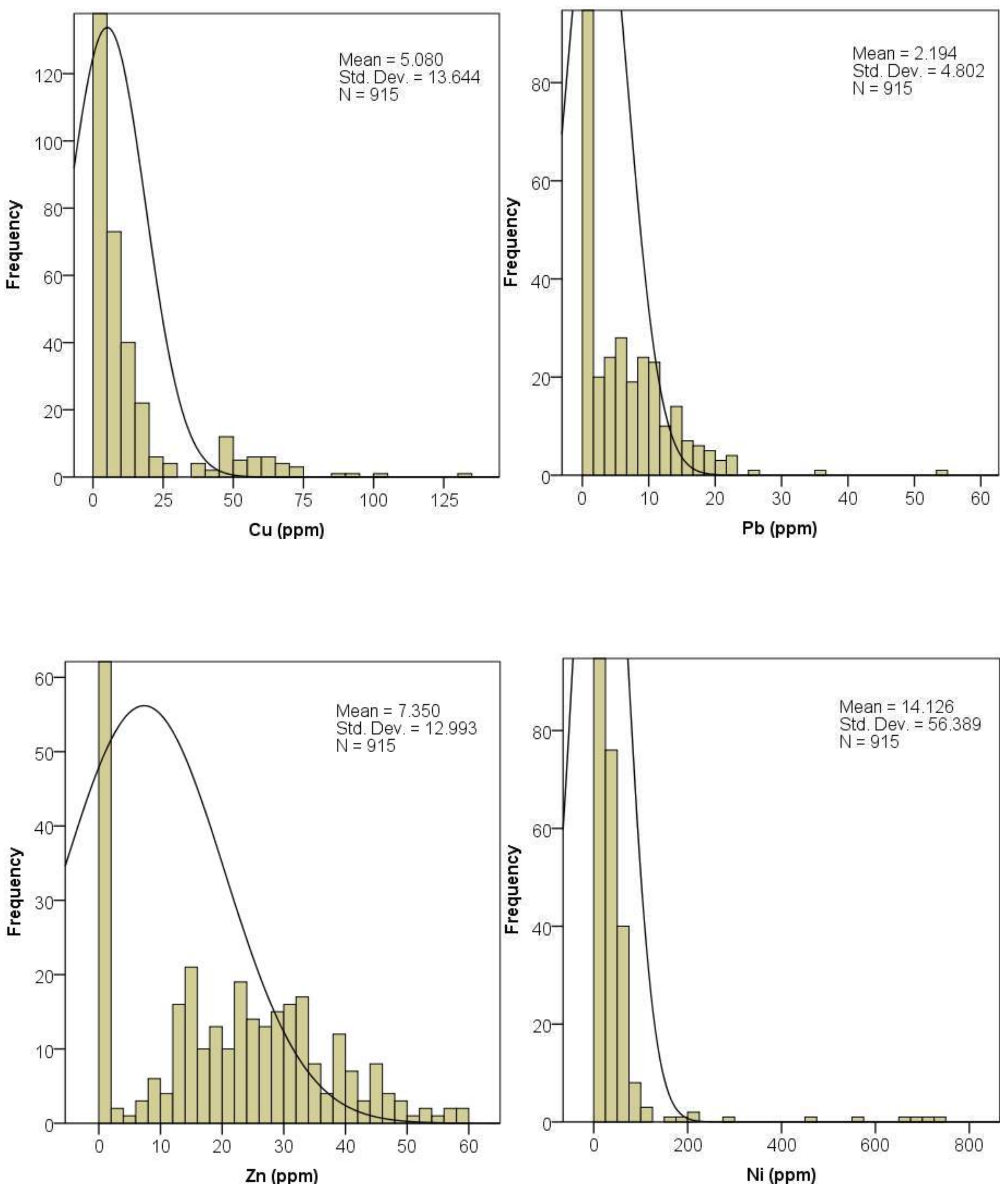
Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2506B	Tank	0.527	0.316	0.996	0.084	0.709	0.431	0.085	10.14	0.364	<0.05
2509B	Tank	0.294	0.885	0.77	0.193	0.811	0.421	0.108	7.741	<0.05	<0.05
2510B	Tank	0.341	1.146	0.811	0.025	0.528	0.231	0.141	10.51	0.164	<0.05
2511B	Tank	0.35	0.77	0.761	0.081	0.639	0.294	0.037	9.22	<0.05	<0.05
2514B	Tank	0.459	0.324	0.877	0.89	0.049	0.356	0.131	0.548	0.13	<0.05
2515B	Tank	0.604	0.659	0.816	0.059	0.772	0.255	0.107	0.676	<0.05	<0.05
2516B	Tank	0.665	0.706	1.132	0.559	0.818	0.317	0.119	0.584	<0.05	<0.05
2517B	Tank	0.616	0.153	1.102	0.022	0.25	0.334	0.172	0.593	0.173	<0.05
2519B	Tank	0.537	0.936	0.839	0.634	0.442	0.117	0.085	0.664	<0.05	<0.05
2521B	Tank	0.518	0.621	0.88	0.083	0.308	0.26	0.06	11.44	0.662	0.064
2522B	Tank	0.217	0.53	1.425	0.065	0.796	0.251	0.085	5.141	<0.05	<0.05
2523B	Tank	0.188	0.482	0.672	0.797	0.236	0.215	0.1	5.014	0.113	<0.05
2525B	Tank	0.129	0.435	0.454	0.065	0.848	0.141	0.165	3.908	<0.05	<0.05
2526B	Tank	0.143	0.891	0.586	<0.02	0.255	0.159	0.096	4.527	0.155	<0.05
2527B	Tank	0.321	0.888	0.855	<0.02	0.362	0.196	0.149	8.337	0.159	<0.05
2528B	Tank	0.131	0.675	0.554	0.999	0.368	0.228	0.072	4.846	0.106	0.083
2529B	Tank	0.181	0.226	0.576	0.791	0.77	0.34	0.05	6.2	<0.05	<0.05
2530T	Tank	0.291	0.64	0.826	0.801	0.99	0.198	0.125	6.848	<0.05	<0.05
2531B	Tank	0.382	0.977	0.685	0.083	0.496	0.177	0.034	10.37	0.196	<0.05
2532B	Tank	0.164	0.837	0.47	0.06	0.51	0.163	0.159	5.325	0.204	<0.05
2533B	Tank	0.236	0.991	0.703	1.207	0.468	0.171	0.172	5.994	0.186	0.052
2534B	Tank	0.213	0.323	0.493	0.092	0.817	0.252	0.089	6.433	<0.05	<0.05
2535B	Tank	0.209	0.631	0.506	<0.02	0.903	0.298	0.068	5.826	<0.05	0.053
2536B	Tank	0.18	0.708	0.489	0.722	0.676	0.302	0.119	5.677	0.149	<0.05
2538B	Tank	0.361	0.929	0.605	0.847	0.728	0.2	0.056	10.37	0.091	<0.05
2539B	Tank	0.472	0.808	0.702	0.142	0.219	0.343	0.07	10.49	0.939	<0.05
2541B	Tank	0.58	1.085	0.873	0.202	0.464	0.293	0.104	0.544	0.597	<0.05

Table 5.5 continued

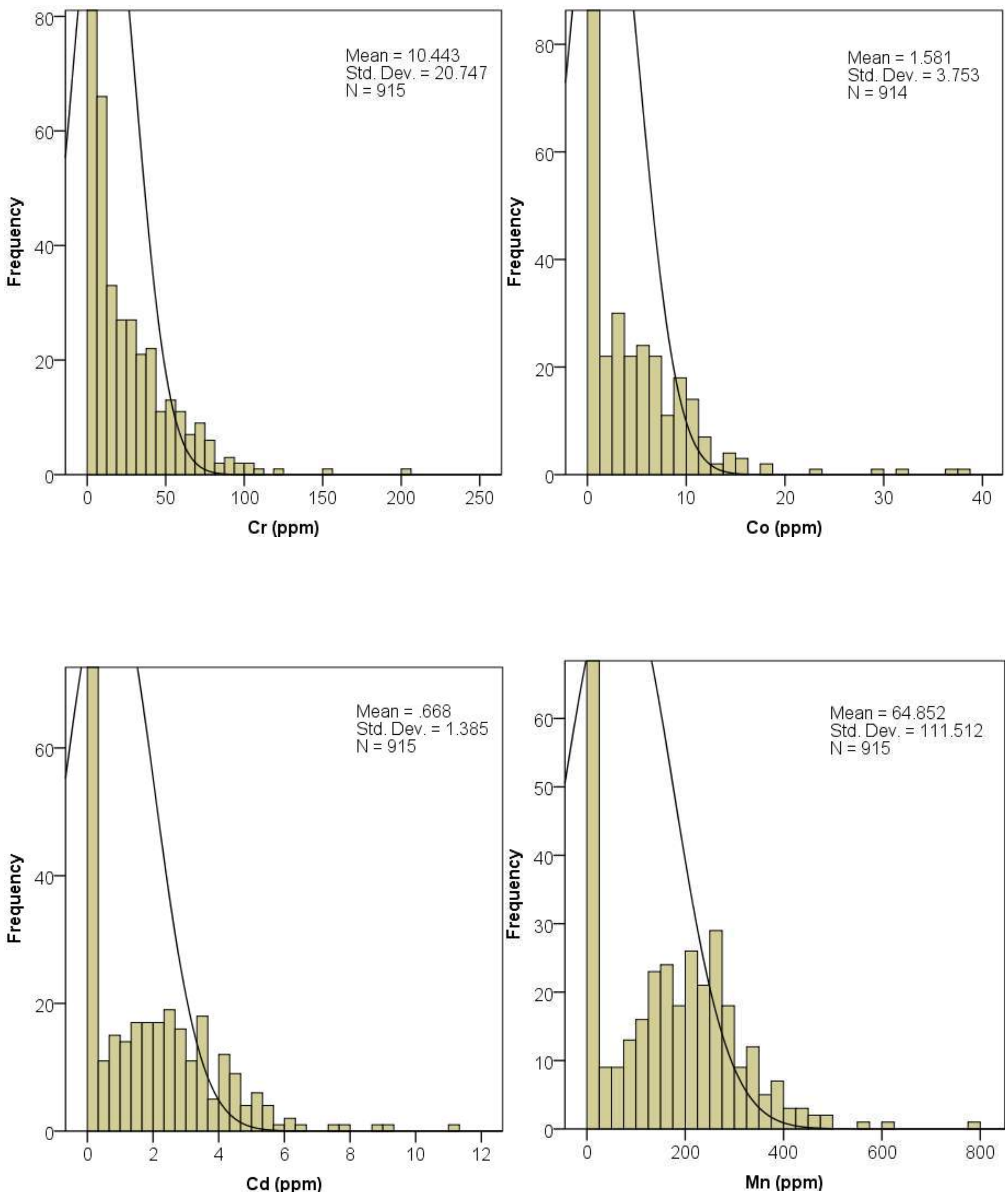
Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2542B	Tank	1.068	0.984	1.054	<0.02	0.798	0.233	0.094	10.64	0.149	0.074
2543B	Tank	0.569	1.068	0.945	0.205	0.673	0.454	0.11	0.779	0.169	<0.05
2544B	Tank	0.514	1.074	1.029	0.941	0.315	0.331	0.057	0.552	0.125	<0.05
2545B	Tank	0.634	0.945	0.378	0.655	0.157	0.355	0.095	11.34	0.096	<0.05
2546B	Tank	0.638	0.799	0.864	1.044	0.115	0.367	0.112	0.689	0.117	<0.05
2548B	Tank	0.546	1.062	0.841	0.309	0.539	0.354	0.105	0.665	0.244	<0.05
2549B	Tank	0.461	0.953	0.264	1.719	0.456	0.352	0.091	0.654	0.836	0.069
2550B	Tank	0.532	1.19	0.929	0.811	0.394	0.249	0.035	0.766	0.282	<0.05
2552B	Tank	0.495	0.853	0.826	0.514	0.564	0.231	0.114	10.82	<0.05	<0.05
2555B	Tank	0.488	1.033	0.726	0.829	0.681	0.354	0.055	0.502	<0.05	<0.05
2558B	Tank	0.478	0.405	0.828	0.676	0.212	0.283	0.118	7.788	0.117	<0.05
2560B	Tank	0.497	0.717	0.842	0.05	0.324	0.222	0.043	9.752	0.614	<0.05
2561B	Tank	0.429	0.529	0.844	0.106	0.157	0.283	0.108	10.27	0.156	<0.05
2562B	Tank	0.315	0.784	0.725	0.961	0.787	0.44	0.098	0.488	0.166	<0.05
2564B	Tank	0.47	1.005	0.666	<0.02	0.447	0.196	0.108	3.216	0.145	<0.05
2565B	Tank	0.557	1.104	1.015	1.291	0.475	0.388	0.056	0.621	1.096	<0.05
2567B	Tank	0.447	0.802	1.126	<0.02	0.254	0.401	0.178	0.542	0.14	<0.05
2568B	Tank	0.868	0.771	1.18	0.786	0.323	0.383	0.105	0.714	0.144	<0.05
2569B	Tank	0.615	0.446	1.049	0.714	0.481	0.466	0.073	10.43	0.804	<0.05
2570B	Tank	0.435	0.417	1.178	1.146	1.231	0.404	0.12	0.454	0.177	<0.05
2572B	Tank	0.345	0.802	0.821	0.086	0.743	0.384	0.122	0.62	<0.05	<0.05

Table 5.6. Statistical parameters of gold, silver and base metals in stream sediments.

		Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
N	**Valid**	915	915	915	915	915	914	915	915	914	901
	Missing	1	1	1	1	1	2	1	1	2	15
Mean		5.080	2.194	7.350	14.126	10.443	1.581	.668	64.852	.303	.120
Median		.315	.240	.676	.470	.888	.170	.070	7.090	.050	.050
Std. Deviation		13.644	4.802	12.993	56.389	20.747	3.753	1.385	111.512	1.040	.375
Minimum		.020	.020	.020	.020	.020	.020	.020	.020	.050	.050
Maximum		133.500	53.550	59.550	732.500	201.850	38.150	11.000	780.400	16.000	10.610
Percentiles	**50**	.315	.240	.676	.470	.888	.170	.070	7.090	.050	.050
	75	2.300	.910	9.200	8.880	8.500	.430	.150	84.550	.090	.090
	90	12.700	8.980	29.870	39.580	38.180	6.125	2.720	250.680	.500	.257
	95	35.710	13.110	37.820	56.540	56.710	9.300	3.910	301.150	1.531	.381
	99	67.544	20.814	48.904	215.826	92.470	15.050	5.710	442.354	4.500	.660



Continuation of Fig. 5.3



Continuation of Fig. 5.3

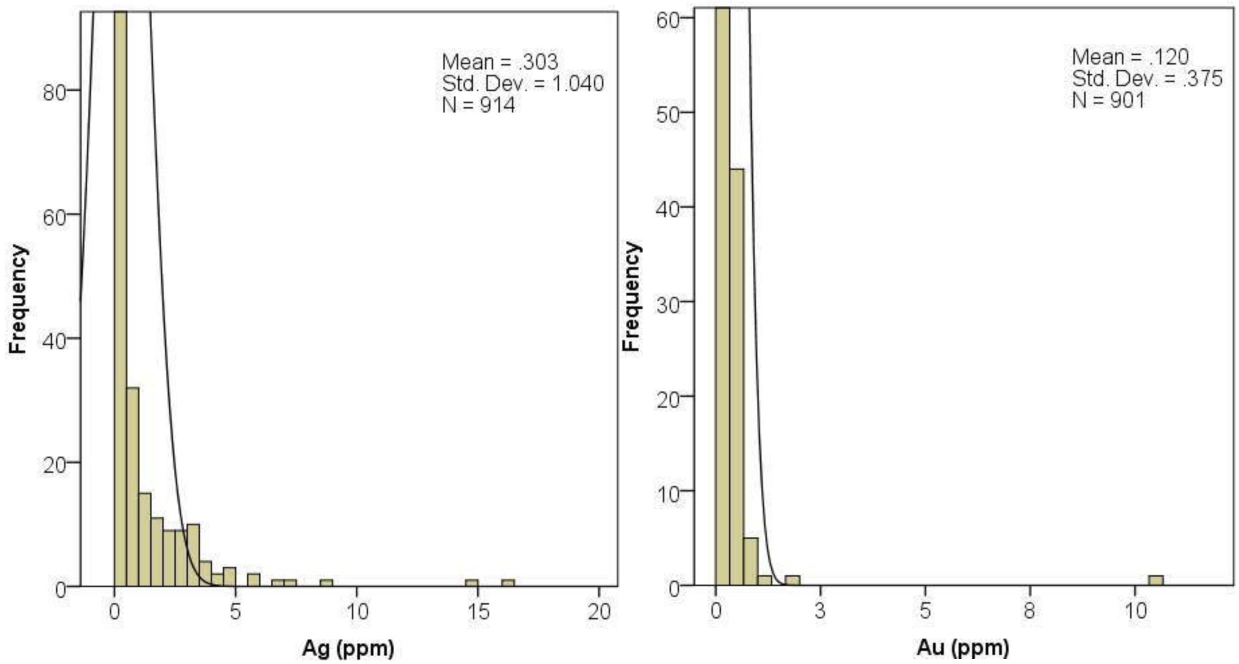


Fig. 5.3. Histograms of gold, silver and base metals in stream sediments.

Table 5.7. Correlation matrix for gold, silver and base metals in stream sediments.

		logCu	logPb	logZn	logNi	logCr	logCo	logCd	logMn	logAg	logAu
logCu	**Pearson Correlation**	1									
	Sig. (2-tailed)										
	N	915									
logPb	**Pearson Correlation**	.576**	1								
	Sig. (2-tailed)	.000									
	N	915	915								
logZn	**Pearson Correlation**	.746**	.610**	1							
	Sig. (2-tailed)	.000	.000								
	N	915	915	915							
logNi	**Pearson Correlation**	.740**	.594**	.738**	1						
	Sig. (2-tailed)	.000	.000	.000							
	N	915	915	915	915						
logCr	**Pearson Correlation**	.680**	.469**	.567**	.603**	1					
	Sig. (2-tailed)	.000	.000	.000	.000						
	N	915	915	915	915	915					
logCo	**Pearson Correlation**	.644**	.462**	.640**	.616**	.590**	1				
	Sig. (2-tailed)	.000	.000	.000	.000	.000					
	N	914	914	914	914	914	914				
logCd	**Pearson Correlation**	.670**	.509**	.635**	.667**	.521**	.512**	1			

	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000				
	N	915	915	915	915	915	914	915			
logMn	**Pearson Correlation**	.715**	.544**	.767**	.761**	.557**	.597**	.593**	1		
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000			
	N	915	915	915	915	915	914	915	915		
logAg	**Pearson Correlation**	.327**	.278**	.383**	.320**	.269**	.331**	.293**	.303**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.
	N	914	914	914	914	914	913	914	914	914	
logAu	**Pearson Correlation**	.104**	.055	.159**	.118**	.085*	.113**	.154**	.115**	.029	1
	Sig. (2-tailed)	.002	.099	.000	.000	.011	.001	.000	.001	.390	
	N	900	900	900	900	900	899	900	900	899	901
**. Correlation is significant at the 0.01 level (2-tailed).											
*. Correlation is significant at the 0.05 level (2-tailed).											

Table 5.8. Factor Analysis for gold, silver and base metals in stream sediments.

	Factor 1	Factor 2
logCu	.881	-.029
logPb	.714	-.100
logZn	.879	.025
logNi	.875	-.009
logCr	.751	-.042
logCo	.772	-.013
logCd	.779	.070
logMn	.847	-.004
logAg	.448	-.200
logAu	.168	.967
Total	5.539	0.994
% of Variance	55.387	9.937
Cumulative %	55.387	65.324

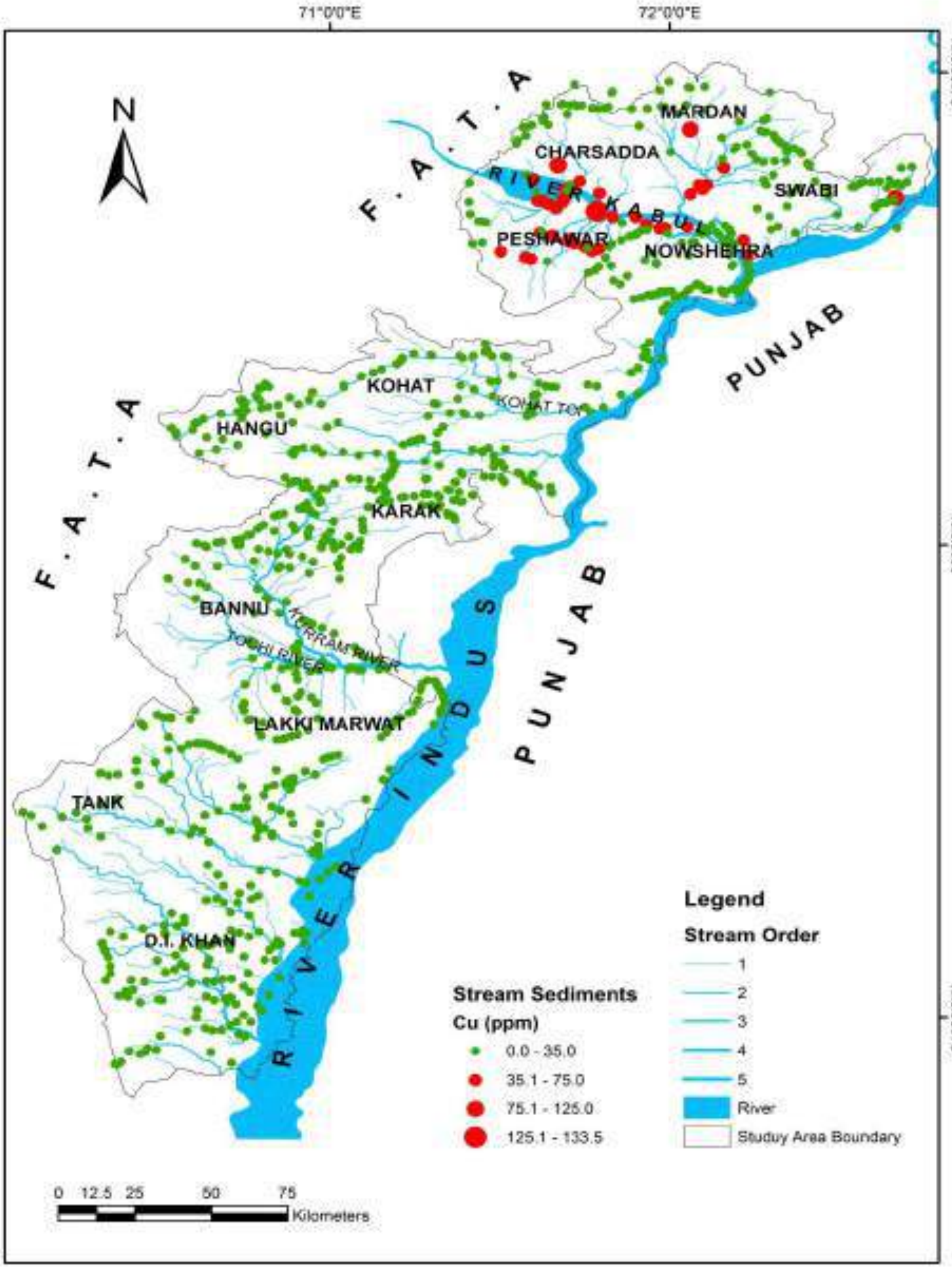


Fig. 5.4(a). Geochemical map of Cu in stream sediments (-80 mesh).

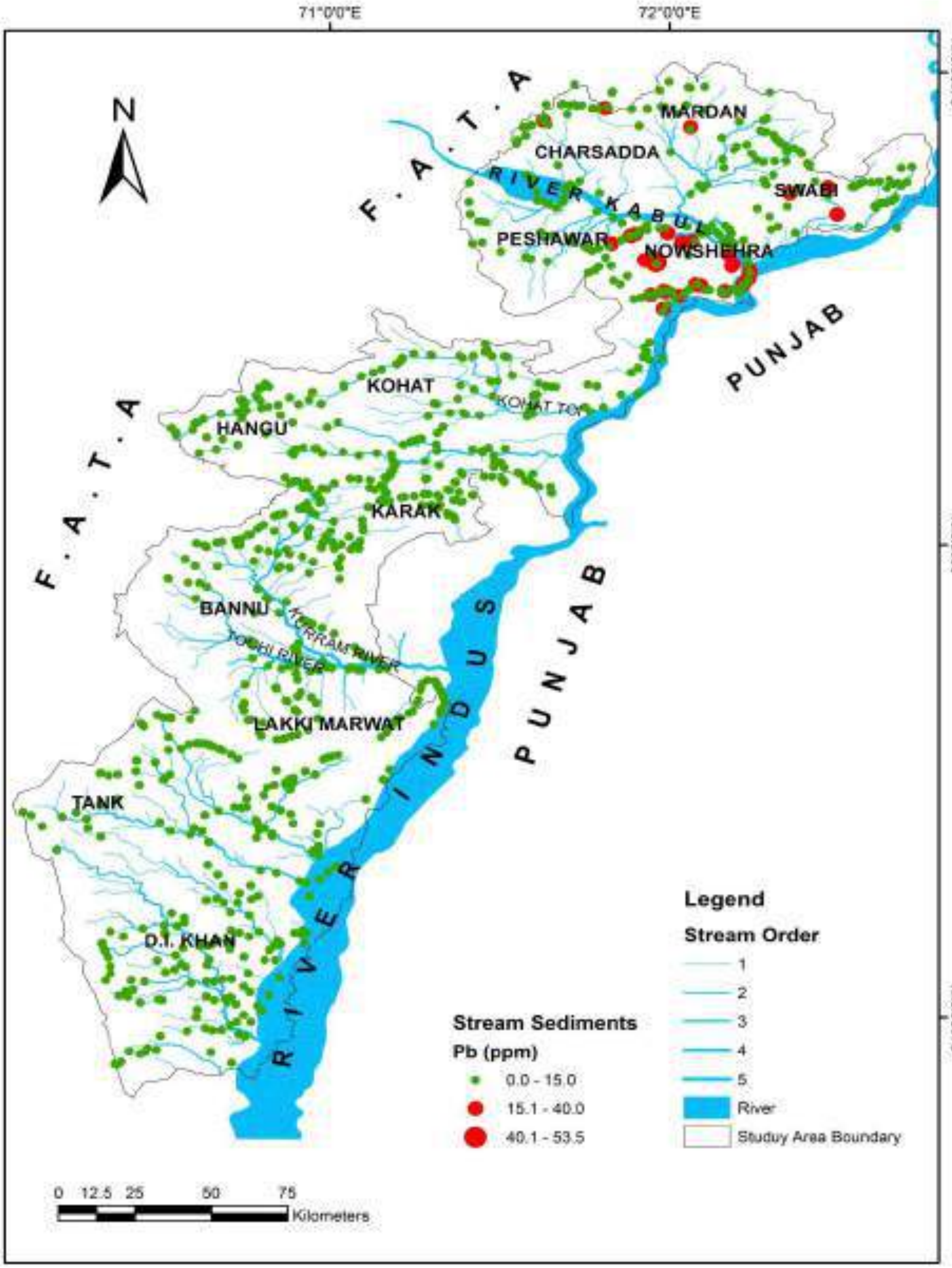


Fig. 5.4(b). Geochemical map of Pb in stream sediments (-80 mesh).

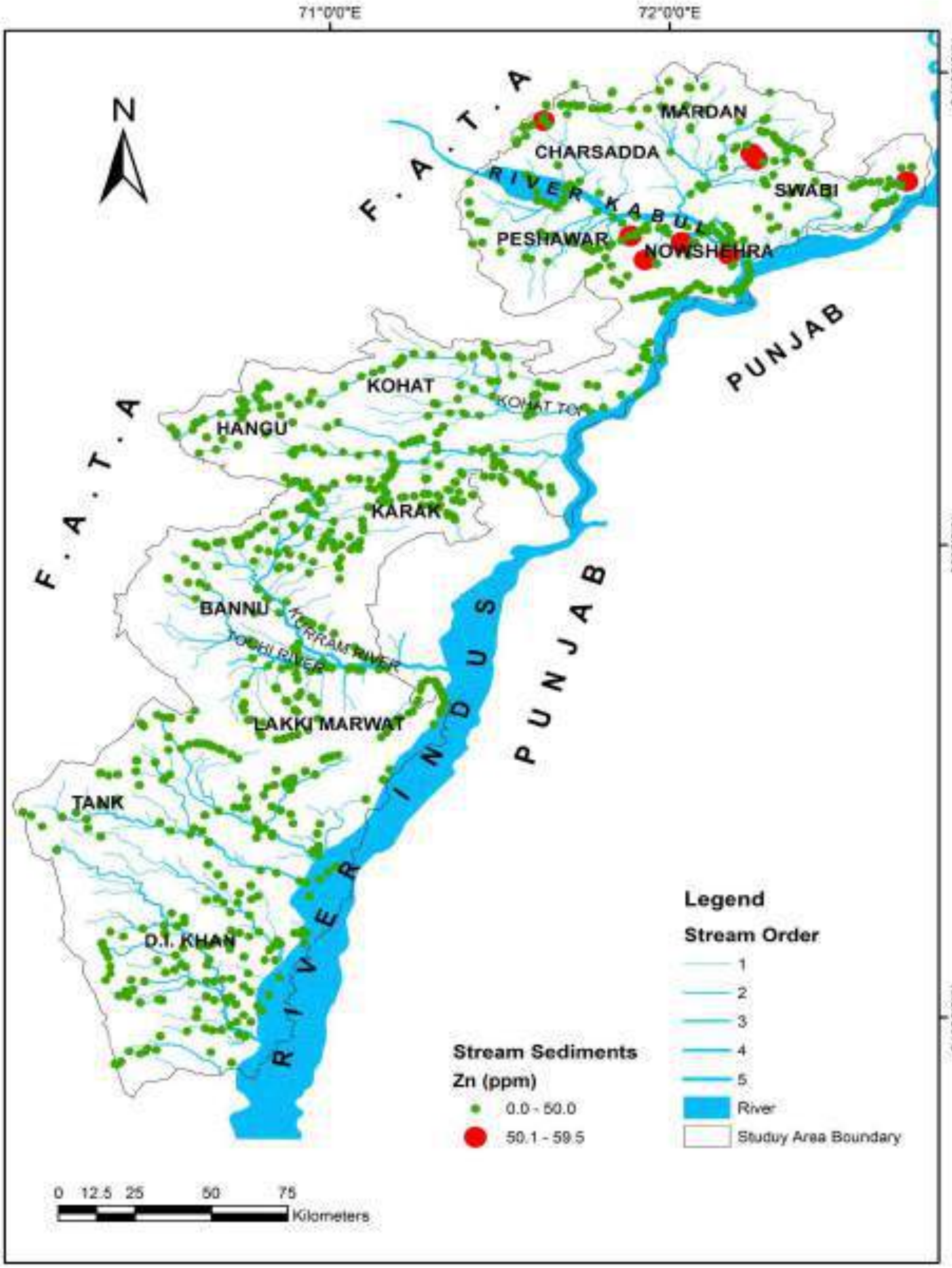


Fig. 5.4(c). Geochemical map of Zn in stream sediments (-80 mesh).

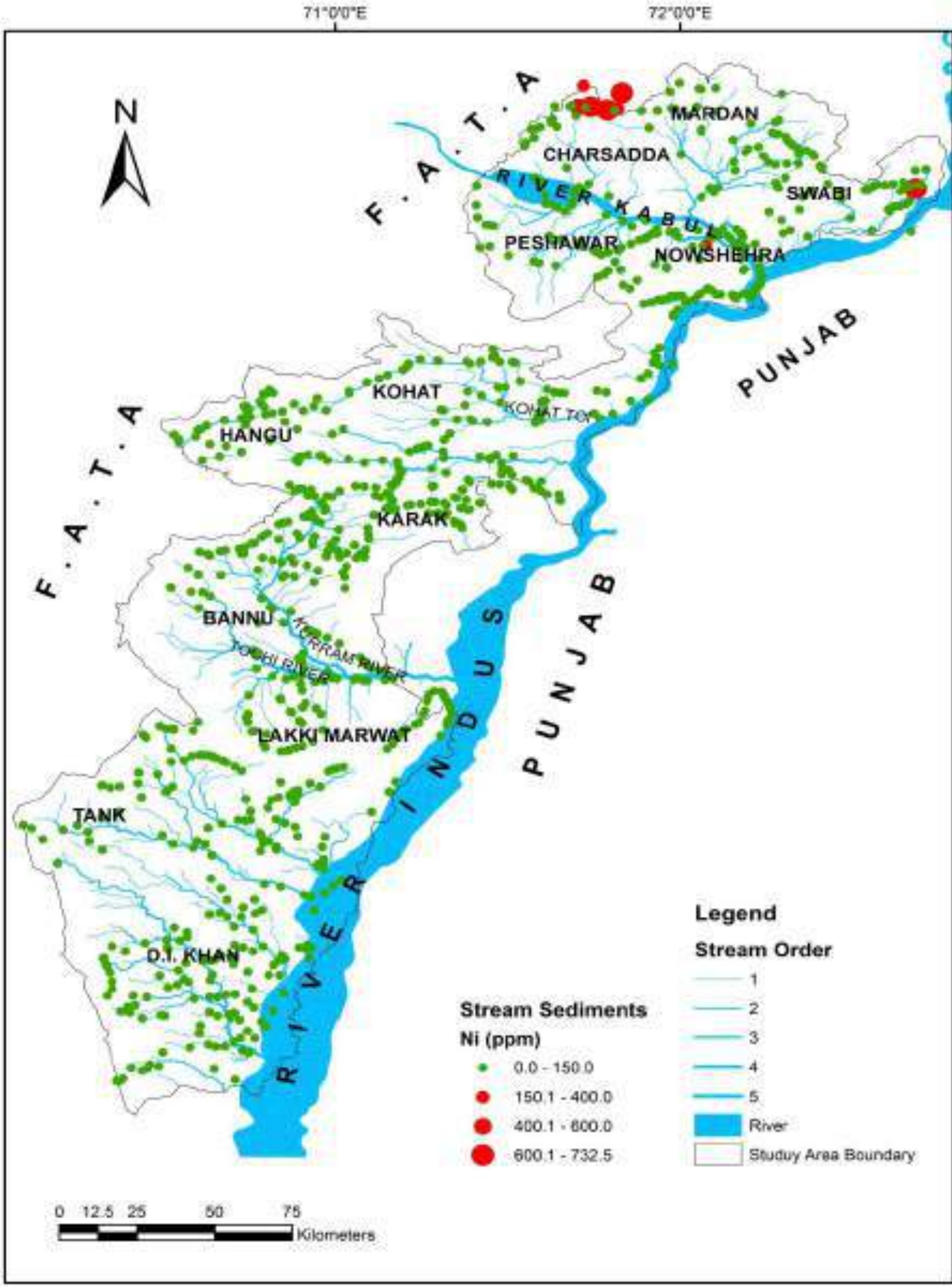


Fig. 5.4(d). Geochemical map of Ni in stream sediments (-80 mesh).

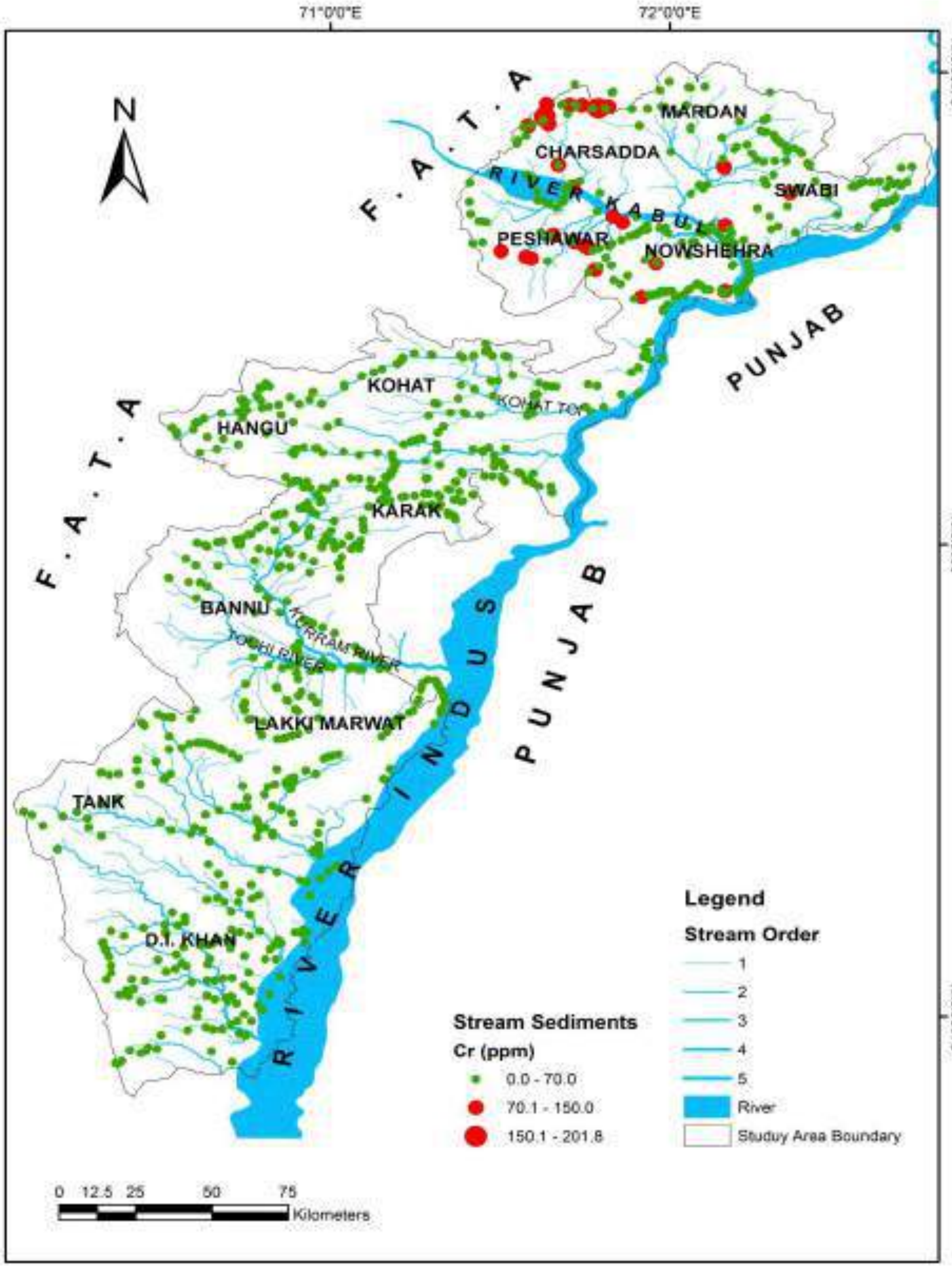


Fig. 5.4(e). Geochemical map of Cr in stream sediments (-80 mesh).

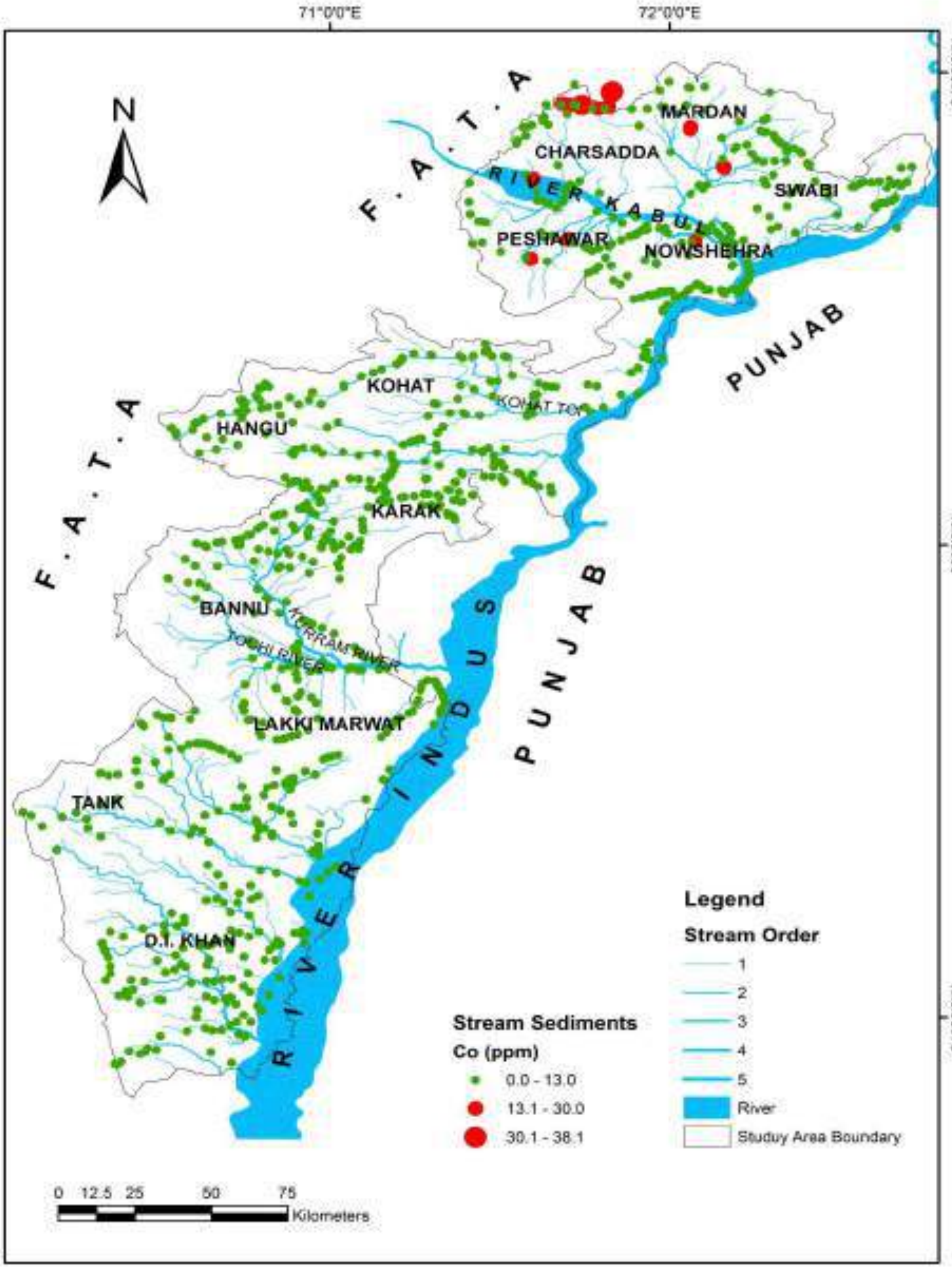


Fig. 5.4(f). Geochemical map of Co in stream sediments (-80 mesh).

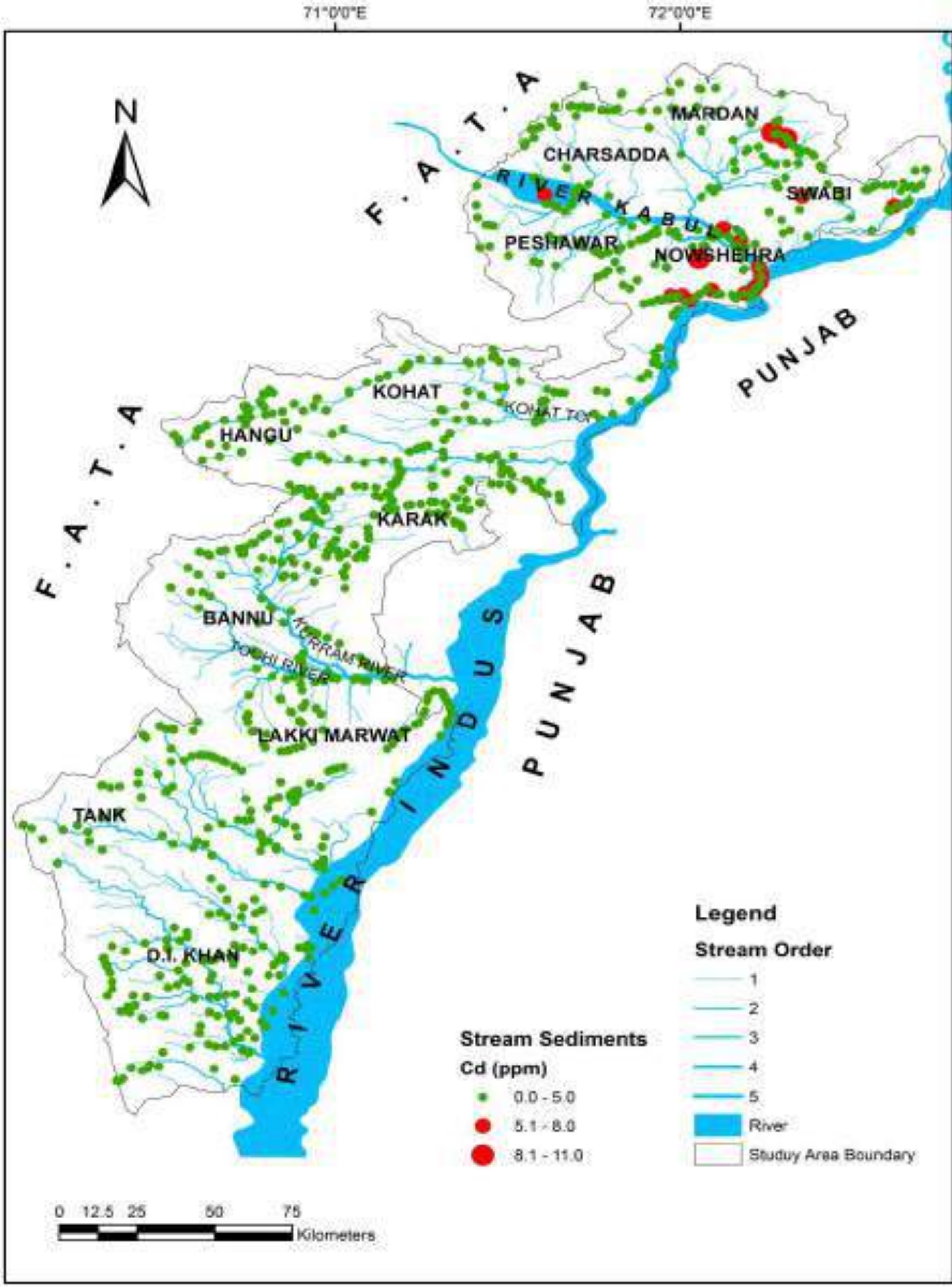


Fig. 5.4(g). Geochemical map of Cd in stream sediments (-80 mesh).

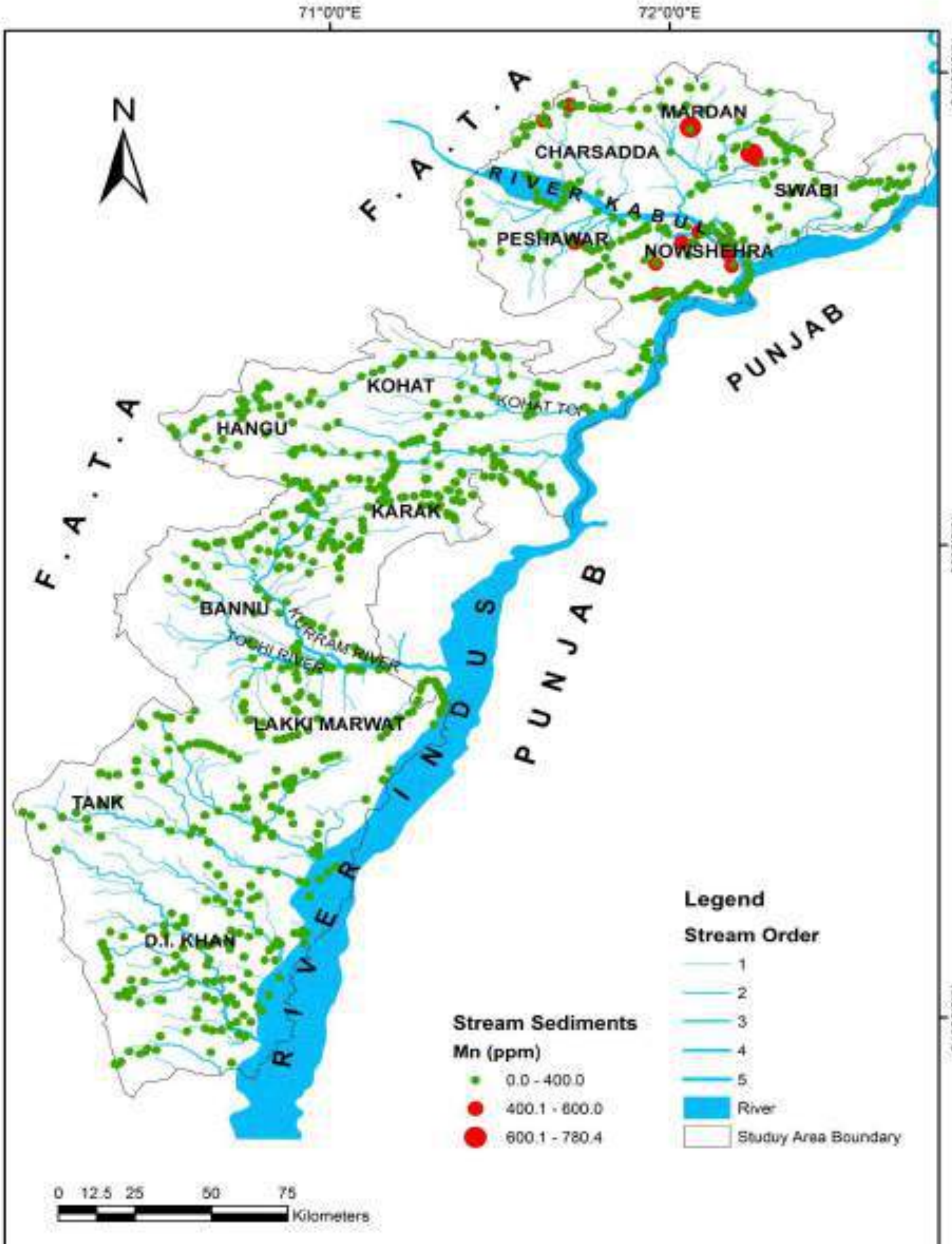


Fig. 5.4(h). Geochemical map of Mn in stream sediments (-80 mesh).

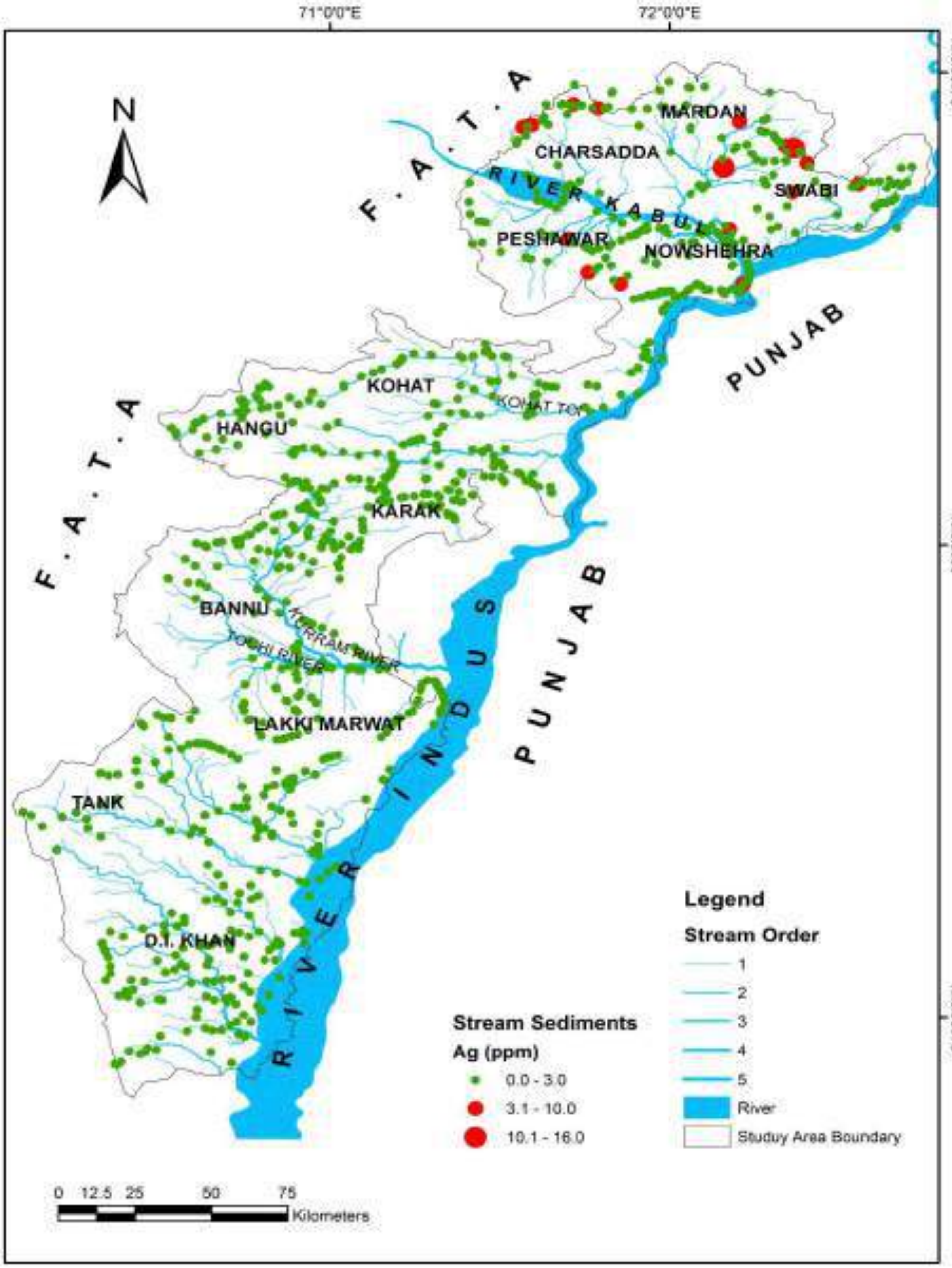


Fig. 5.4(i). Geochemical map of Ag in stream sediments (-80 mesh).

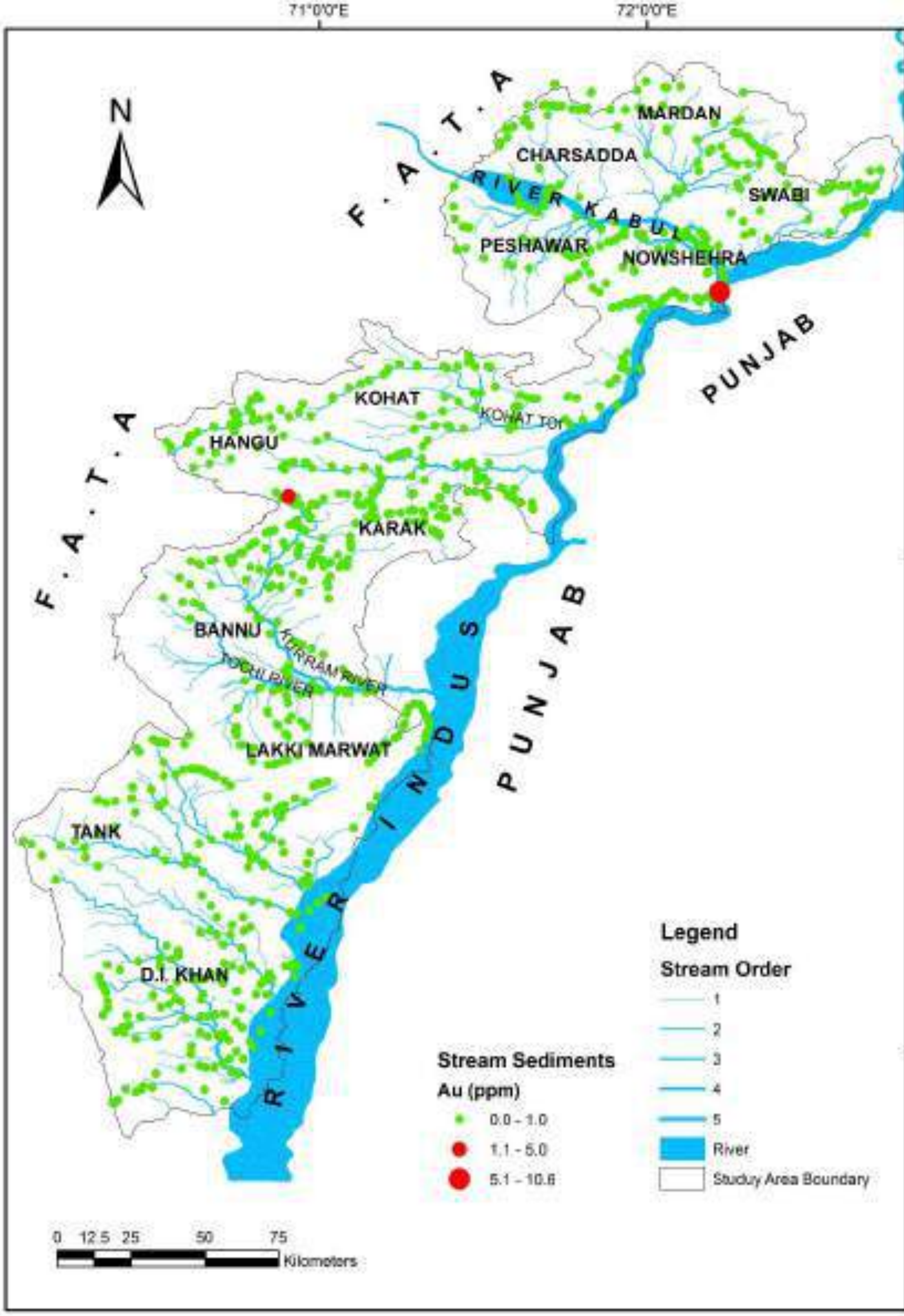


Fig. 5.4(j). Geochemical map of Au in stream sediments (-80 mesh).

5.5. Tallus Samples geochemical study

Result of Au, Ag and base metals in Tallus samples are presented in Table 5.9. Statistical parameters are given in Table 5.10 and correlation matrix in Table 5.11. The data have been treated with statistical and GIS softwares and the histograms and spatial geochemical maps have been constructed in Figure 5.5 and 5.6 a-j respectively.

Greater variation was found in the geochemical data of Tallus samples(Table 5.9). Cu is ranging from <0.02 to 100.5 ppm, Pb from <0.02 to 26.7 ppm, Zn from <0.02 to 77.5 ppm, Ni from <0.02 to 988 ppm, Cr from <0.02 to 157.45 ppm, Co from <0.02 to 82.55 ppm, Cd from <0.02 to 6.3 ppm, Mn from <0.02 to 766.5 ppm, Ag from <0.05 to 11.5 ppm and Aufrom <0.05 to 5.31 ppm (Table 5.9).

The threshold value of each element was estimated after considering the histograms (Fig. 5.5) and statistical parameters (Table 5.10). The threshold values of are found to be 30 ppm for Cu, 11 ppm for Pb, 40 ppm for Zn, 200 ppm for Ni, 60 ppm for Cr, 20 ppm for Co, 3 ppm for Cd, 375 ppm for Mn, 3 ppm for Ag and 1 ppm for Au.

The correlation of the geochemical data of tallus with the lithologies of the project area are shown in Fig 5.6. The spatial geochemical map of gold (Fig.5.6j) shows high concentration in the quaternary sediments of Nowshehra district also detected in stream sediment samples and pan-concentrate samples in the same area (Fig. 5.2j and 5.4j) and in the quaternary boulder fan deposits of Siwaliks in Bannu district. High Cu values are found in alluvial fan sediments of Indus Suture Melange in Charsadda district and in the quaternary sediments of Swabi district (Fig.5.6a). Similarly anomalous concentrations of Ni, Cr and Co are found in the alluvial fan sediments of Indus Suture Melange (Fig.5.6d,e,f) and anomalous concentrations of Pb and Zn occur in the alluvial fan sediments of Attock-Cherat ranges (Fig.5.6b,c). Cadmium (Cd) and Manganese (Mn) is found in higher concentrations in tallus samples from Attock-Cherat ranges while anomalous concentrations of Mn is also found from Indus Suture Melange (Fig.5.6g,h).

Table 5.9. Results of geochemical data for gold, silver and base metals in Tallus.

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1208T	Charsadda	18.5	13.35	32.4	233.85	157.45	17.7	2.9	<0.02	<0.05	0.069
1226T	Nowshehra	13.1	7.6	26.75	26.85	62.26	9.7	3.45	282.6	<0.05	5.307
1234T	Nowshehra	13.95	2.75	26.55	18.65	50.45	9.8	0.95	26.65	0.5	<0.05
1254T	Nowshehra	11.65	8.4	<0.02	45.75	59.55	6.05	5.35	317.8	5.5	<0.05
1256T	Nowshehra	3.2	17.8	20.9	33.5	45.45	<0.02	0.65	105.85	<0.05	<0.05
1261T	Nowshehra	13.7	26.7	36.6	43.5	49	9.65	0.05	405	11.5	<0.05
1262T	Nowshehra	12.35	22.45	35.45	31.25	33.2	8.8	3.55	378.7	<0.05	<0.05
1263T	Nowshehra	9.9	<0.02	<0.02	6.3	49.65	<0.02	2.7	265.4	6.5	<0.05
1264T	Nowshehra	16.3	3.3	27.35	33.5	11.35	0.75	1.7	204.3	<0.05	<0.05
1271T	Nowshehra	<0.02	0.35	3.55	12.7	7	<0.02	0.05	18.35	<0.05	<0.05
1272T	Nowshehra	1.7	8.75	13.7	10.2	7.9	<0.02	0.05	96.2	<0.05	<0.05
1275T	Nowshehra	4.25	7.05	<0.02	16.6	13.2	0.95	0.05	139.8	<0.05	0.21
1277T	Nowshehra	10.05	10.55	<0.02	23.1	30.6	1.05	3.6	<0.02	<0.05	<0.05
1282T	Nowshehra	14.9	<0.02	32.25	15.4	19.25	6.45	1.95	438.65	1	<0.05
1284T	Nowshehra	9.35	<0.02	36.55	17.2	24.65	13.45	2.4	509.5	1.5	<0.05
1289T	Nowshehra	4.2	10.5	9.65	15.65	33.05	2.35	5.25	146.4	<0.05	0.262
1291T	Nowshehra	10.95	2.35	30.35	49.6	39.5	7	0.05	291.1	<0.05	<0.05
1292T	Nowshehra	10.1	4.5	23.7	23.05	11.15	<0.02	0.05	217.9	<0.05	<0.05
1296T	Nowshehra	9.8	13.95	22.45	24.8	46.5	7.15	1.15	409.1	<0.05	<0.05
1299T	Nowshehra	6.15	4.15	21.3	14.7	34.05	9.5	5.9	156.35	1.5	<0.05
1347T	Swabi	7.15	10.85	<0.02	48.5	19.4	6.5	0.05	248.35	<0.05	<0.05
1348T	Mardan	100.5	5.55	27.9	20.7	27.75	8.35	4.45	204.2	<0.05	<0.05
1349T	Mardan	10.8	2.15	28.95	27.3	48.75	4.6	0.05	128.4	<0.05	<0.05
1353T	Mardan	78.15	6.55	<0.02	22.9	53.85	8.45	1.4	396.4	<0.05	0.315
1355T	Mardan	10.4	7.75	17.25	44.1	6	<0.02	2.35	179.35	<0.05	0.749
1357T	Mardan	13.95	9.3	28	22.75	18.95	<0.02	2.35	183.25	<0.05	0.217

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1361T	Mardan	<0.02	6.25	0.05	0.95	<0.02	<0.02	4.1	<0.02	<0.05	<0.05
1368T	Mardan	66.75	2.65	37.05	38.2	67.25	4.15	0.05	321.05	<0.05	0.087
1403T	Nowshehra	11.7	<0.02	14.9	7.3	31.55	2.3	1.05	177.3	<0.05	<0.05
1407T	Nowshehra	9.15	<0.02	77.5	28.35	42.95	<0.02	6.3	<0.02	<0.05	<0.05
1408T	Nowshehra	21.1	<0.02	76.75	25.65	42.95	6.55	4.35	751.5	<0.05	<0.05
1409T	Nowshehra	7.8	19	50.6	14.4	54.3	9.7	2	384.95	3.5	<0.05
1413T	Nowshehra	9.7	26.1	39.85	28.3	20.65	11.35	0.4	381.05	3	<0.05
1414T	Nowshehra	<0.02	<0.02	<0.02	<0.02	16	<0.02	0.05	<0.02	<0.05	<0.05
1417T	Nowshehra	<0.02	5.25	32.5	78.5	<0.02	6.1	0.05	185.7	<0.05	<0.05
1436T	Charsadda	13	<0.02	36.25	988	65.95	82.55	1.3	766.5	1	<0.05
1527T	Kohat	0.186	<0.02	0.302	0.17	<0.02	0.097	0.022	5.798	<0.05	<0.05
1581T	Kohat	0.139	<0.02	0.319	0.179	0.025	0.128	0.038	3.314	<0.05	0.099
1584T	Kohat	0.189	<0.02	0.397	0.262	<0.02	0.192	0.042	2.719	<0.05	0.074
1590T	Kohat	0.109	0.422	0.307	0.31	0.107	0.119	0.059	2.143	<0.05	<0.05
1591T	Kohat	0.594	0.315	0.468	0.433	0.568	0.202	<0.02	4.803	<0.05	0.099
1592T	Kohat	0.467	0.549	0.835	0.744	0.228	0.042	0.074	14.15	<0.05	<0.05
1594T	Kohat	0.111	<0.02	0.312	0.163	0.464	0.082	0.095	2.765	<0.05	<0.05
1596T	Kohat	0.213	0.049	0.586	0.656	1.189	0.182	0.048	4.988	<0.05	0.065
1641T	Karak	0.341	0.031	0.253	0.291	0.471	0.308	0.027	4.678	<0.05	0.062
1644T	Karak	0.088	0.033	0.288	0.47	0.56	0.126	<0.02	5.214	0.06	0.063
1667T	Karak	0.22	0.199	0.425	0.609	0.692	0.067	0.077	7.867	<0.05	<0.05
1677T	Karak	0.102	<0.02	0.189	<0.02	0.399	0.307	0.031	4.015	0.059	<0.05
1686T	Karak	0.153	0.032	0.08	0.211	0.25	0.31	0.038	6.415	0.098	0.09
1699T	Karak	0.978	0.064	0.302	0.233	0.362	0.09	0.038	5.725	<0.05	<0.05
1707T	Bannu	0.579	0.2	1.538	1.942	1.153	0.303	0.097	15.19	0.053	0.095
1708T	Bannu	0.4	0.633	1.154	1.572	1.659	0.504	0.149	14.86	0.06	<0.05
1711T	Bannu	0.38	0.115	1.213	1.317	1.131	0.31	0.116	12.79	<0.05	<0.05

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1712T	Bannu	0.396	0.369	2.02	1.25	1.5	0.354	0.091	13.46	0.076	<0.05
1717T	Bannu	0.533	0.555	1.671	2.463	1.42	0.397	0.118	15.78	0.083	<0.05
1719T	Bannu	0.431	0.586	1.565	2.784	1.93	0.513	0.179	18.98	0.084	<0.05
1721T	Bannu	0.187	0.157	0.755	1.127	0.319	0.125	0.15	11.74	<0.05	<0.05
1724T	Bannu	0.188	0.245	0.696	0.769	0.966	0.167	0.082	10.09	0.07	<0.05
1726T	Bannu	0.282	0.324	0.825	1.156	0.281	0.094	0.149	10.24	<0.05	<0.05
1728T	Bannu	0.387	0.271	1.039	1.048	0.916	0.281	0.149	9.807	<0.05	<0.05
1737T	Bannu	0.287	0.299	0.959	0.645	0.368	0.127	0.074	10.6	<0.05	0.057
1739T	Bannu	0.239	0.08	0.838	0.747	0.198	0.119	0.13	9.465	0.296	<0.05
1740T	Bannu	0.25	0.213	0.844	0.0922	0.711	0.114	0.132	12.08	0.0811	<0.05
1744T	Bannu	0.359	0.369	0.985	1.568	1.063	0.136	0.187	13.43	<0.05	0.093
1746T	Bannu	0.148	0.114	0.421	0.676	0.517	0.074	0.17	6.295	<0.05	<0.05
1750T	Bannu	0.305	0.083	0.837	0.728	0.54	0.077	0.118	8.38	0.068	0.069
1753T	Bannu	0.347	0.204	1.175	0.901	0.212	0.305	0.101	12.35	0.434	0.084
1755T	Lakki Marwat	0.091	0.065	0.249	0.343	0.054	0.066	0.095	3.475	<0.05	0.051
1757T	Lakki Marwat	0.111	0.092	0.22	0.88	0.53	0.035	0.044	6.957	<0.05	<0.05
1760T	Lakki Marwat	0.057	0.084	0.363	0.175	0.022	<0.02	0.088	3.775	<0.05	0.056
1762T	Lakki Marwat	0.11	0.067	0.116	0.294	0.189	<0.02	0.079	4.105	<0.05	
1764T	Lakki Marwat	0.076	0.066	0.284	0.238	0.677	0.08	0.059	2.898	<0.05	
1765T	Lakki Marwat	0.226	0.183	0.145	0.15	0.599	0.064	0.031	2.825	<0.05	<0.05
1769T	Lakki Marwat	0.132	0.079	0.831	0.223	0.554	0.03	0.04	3.09	<0.05	0.072
1771T	Lakki Marwat	0.117	0.106	0.024	<0.02	0.163	0.036	0.024	3.052	<0.05	<0.05
1775T	Lakki Marwat	0.129	<0.02	0.185	0.346	0.259	0.05	<0.02	3.539	<0.05	0.055
1777T	Lakki Marwat	0.091	0.054	0.264	0.326	0.304	0.057	0.036	3.666	0.093	0.088
1781T	Lakki Marwat	0.08	0.26	0.273	0.505	0.781	0.026	0.063	8.133	<0.05	0.329
1785T	Lakki Marwat	0.093	0.064	0.111	0.03	0.045	0.035	0.082	1.673	<0.05	0.07
1788T	Lakki Marwat	0.051	0.0243	<0.02	0.169	0.65	0.072	<0.02	3.458	<0.05	0.091

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1793T	Lakki Marwat	0.03	<0.02	0.641	<0.02	0.038	0.079	<0.02	1.627	<0.05	<0.05
1796T	Lakki Marwat	0.149	0.061	0.251	0.166	0.055	0.029	0.031	5.962	<0.05	<0.05
1797T	Lakki Marwat	0.276	0.229	0.503	0.553	1.026	0.073	<0.02	10.32	<0.05	0.267
1798T	Lakki Marwat	0.342	0.384	0.441	0.842	1.273	<0.02	0.095	8.404	<0.05	<0.05
1807T	Karak	0.081	<0.02	0.171	0.025	0.498	0.043	0.031	4.42	<0.05	<0.05
1834T	Karak	0.081	0.043	0.305	0.077	0.408	0.087	0.059	3.771	0.102	<0.05
1843T	Karak	0.194	0.053	0.297	<0.02	<0.02	0.03	0.054	3.409	<0.05	<0.05
1851T	Karak	0.272	0.05	0.459	0.433	<0.02	0.048	0.038	4.632	<0.05	0.094
1888T	Karak	0.268	0.095	0.052	0.419	0.347	0.035	0.026	5.658	0.061	0.056
1901T	Lakki Marwat	0.113	0.297	0.274	0.231	0.11	0.039	0.072	3.805	<0.05	<0.05
1908T	Lakki Marwat	0.062	0.18	0.31	0.225	0.045	0.07	0.122	3.991	0.051	
1910T	Lakki Marwat	<0.02	0.386	0.222	0.356	0.849	<0.02	0.049	3.638	<0.05	
1914T	Lakki Marwat	0.183	<0.02	0.22	0.449	0.086	0.083	<0.02	4.887	<0.05	0.061
1921T	Lakki Marwat	<0.02	<0.02	0.546	0.349			<0.02	4.47	<0.05	
1923T	Lakki Marwat	0.075	0.182	0.028	0.261	0.315	0.088	0.027	1.89	<0.05	
1925T	Lakki Marwat	0.156	0.022	0.525	0.481	0.075	0.133	0.098	11.03	0.227	
1926T	Lakki Marwat	0.204	0.139	0.666	0.84	0.055	0.041	0.025	8.522	<0.05	
1928T	Lakki Marwat	0.528	0.224	1.043	0.74	0.521	0.267	0.045	9.96	0.057	<0.05
1929T	Lakki Marwat	0.269	0.246	0.627	0.767	0.321	<0.02	0.061	9.486	0.07	0.115
1931T	Lakki Marwat	0.235	0.1	0.609	1.114	1.295	<0.02	0.112	11.04	<0.05	<0.05
1932T	Lakki Marwat	0.499	0.352	1.402	1.592	1.641	<0.02	0.059	9.395	<0.05	0.502
1936T	Lakki Marwat	0.468	0.337	0.439	1.348	0.236	0.022	0.048	8.822	0.083	
1939T	Lakki Marwat	0.195	0.368	0.655	0.813	0.685	<0.02	0.096	7.883	<0.05	
1942T	Lakki Marwat	<0.02	<0.02	0.323	1.002	0.089	0.049	0.126	5.768	0.057	<0.05
1947T	Lakki Marwat	0.187	0.248	0.379	0.524	0.192	0.022	0.03	5.064	<0.05	
1950T	Lakki Marwat	0.187	<0.02	0.181	0.157	0.094	<0.02	0.065	4.671	<0.05	<0.05
1954T	Lakki Marwat	0.083	0.062	0.543	0.566	0.089	0.0213	0.078	5.724	<0.05	<0.05

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1959T	Lakki Marwat	0.298	0.77	0.578	1.336	0.599	0.047	0.141	9.641	<0.05	<0.05
2019T	Kohat	0.199	0.09	0.297	0.18	0.367	0.069	0.026	3.898	<0.05	0.058
2038T	Kohat	0.136	0.091	0.549	0.747	0.029	<0.02	0.055	6.358	0.087	<0.05
2102T	D.I.Khan	0.41	0.362	0.445	0.554	0.499	0.169	<0.02	8.379	<0.05	<0.05
2103T	D.I.Khan	0.475	0.205	0.619	0.371	4.871	<0.02	0.025	6.905	0.055	<0.05
2106T	D.I.Khan	0.625	0.208	0.473	0.151	0.326	0.158	<0.02	7.945	<0.05	<0.05
2107T	D.I.Khan	0.116	0.039	0.247	0.054	7.682	0.323	<0.02	2.793	<0.05	<0.05
2110T	D.I.Khan	0.67	0.223	0.419	0.163	5.059	0.174	<0.02	4.413	<0.05	<0.05
2115T	D.I.Khan	0.18	0.078	0.332	0.137	4.626	0.229	<0.02	3.708	<0.05	0.056
2115T	D.I.Khan	0.095	0.257	0.418	0.338	2.424	<0.02	0.062	4.767	0.087	<0.05
2123T	D.I.Khan	0.278	0.089	0.7	0.632	5.049	0.212	0.032	2.62	<0.05	<0.05
2124T	D.I.Khan	0.369	0.023	0.254	0.137	2.659	0.08	0.028	3.086	<0.05	<0.05
2126T	D.I.Khan	0.21	0.169	0.423	0.228	5.138	0.571	<0.02	3.16	<0.05	0.195
2128T	D.I.Khan	0.637	0.254	0.257	0.402	3.224	0.306	<0.02	7.758	<0.05	<0.05
2129T	D.I.Khan	0.555	0.241	0.46	0.391	3.301	0.277	<0.02	5.889	<0.05	0.073
2130T	D.I.Khan	0.754	0.56	0.62	0.542	1.441	0.365	<0.02	4.616	<0.05	<0.05
2132T	D.I.Khan	0.443	0.425	0.23	0.391	3.968	0.199	<0.02	5.016	<0.05	<0.05
2134T	D.I.Khan	0.441	0.028	0.426	0.218	<0.02	0.207	<0.02	2.996	<0.05	0.069
2141T	D.I.Khan	0.404	0.16	0.214	0.522	3.967	0.589	<0.02	3.979	0.059	<0.05
2142T	D.I.Khan	0.496	0.267	0.37	0.466	3.854	0.31	<0.02	5.609	<0.05	<0.05
2156T	D.I.Khan	0.229	0.04	0.425	0.247	1.991	0.538	0.021	3.902	<0.05	<0.05
2166T	D.I.Khan	0.096	0.252	0.268	0.123	8.965	0.557	<0.02	4.121	<0.05	0.067
2173T	D.I.Khan	0.321	0.424	0.296	0.367	5.777	0.505	0.024	5.445	0.073	<0.05
2175T	D.I.Khan	0.593	0.216	0.206	0.237	0.27	0.406	<0.02	7.162	<0.05	<0.05
2179T	D.I.Khan	0.531	0.2	0.395	0.352	0.05	0.252	0.023	5.22	<0.05	<0.05
2180T	D.I.Khan	0.476	0.411	0.425	0.26	5.892	0.423	<0.02	5.836	<0.05	<0.05
2182T	D.I.Khan	0.466	0.131	0.321	0.648	0.613	0.403	0.031	6.062	0.052	<0.05
2187T	D.I.Khan	0.587	0.373	0.429	0.36	0.264	0.462	<0.02	6.282	<0.05	<0.05

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2188T	D.I.Khan	0.129	0.05	0.163	0.313	1.12	0.429	<0.02	2.708	<0.05	0.12
2191T	D.I.Khan	0.628	0.144	0.48	0.326	1.23	0.342	<0.02	4.495	<0.05	0.068
2192T	D.I.Khan	0.273	0.509	0.631	0.237	3.129	0.295	0.083	3.838	<0.05	<0.05
2193T	D.I.Khan	0.309	0.585	0.352	0.536	0.102	0.211	0.02	2.67	<0.05	<0.05
2194T	D.I.Khan	0.907	0.736	0.406	0.453	9.581	0.459	<0.02	9.488	<0.05	<0.05
2195T	D.I.Khan	0.261	0.698	0.651	0.907	0.103	0.715	<0.02	8.256	<0.05	<0.05
2196T	D.I.Khan	0.576	0.474	0.331	0.385	3.829	0.392	<0.02	5.108	<0.05	<0.05
2197T	D.I.Khan	0.435	0.074	0.263	0.11	3.076	0.337	<0.02	6.152	<0.05	<0.05
2198T	D.I.Khan	0.424	0.433	0.334	0.523	2.432	0.297	<0.02	3.154	<0.05	<0.05
2199T	D.I.Khan	0.422	0.021	0.399	0.157	4.239	0.423	<0.02	5.85	<0.05	<0.05
2200T	D.I.Khan	0.513	0.53	0.591	0.406	7.606	0.786	<0.02	6.063	<0.05	<0.05
2230T	D.I.Khan	0.491	0.456	0.625	0.743	1.733	0.427	0.07	6.634	<0.05	<0.05
2250T	D.I.Khan	0.549	0.331	1.063	0.847	3.462	0.262	0.067	9.852	0.066	<0.05
2265T	D.I.Khan	0.58	0.189	0.63	0.563	1.034	0.549	0.053	6.57	<0.05	<0.05
2266T	D.I.Khan	0.412	0.754	0.213	0.989	3.767	0.419	0.021	4.121	<0.05	<0.05
2267T	D.I.Khan	0.393	0.148	0.356	0.457	0.235	0.433	0.024	5.995	<0.05	<0.05
2270T	D.I.Khan	0.579	0.102	0.741	0.565	7.661	0.315	0.02	5.646	<0.05	<0.05
2283T	D.I.Khan	0.316	0.133	0.213	0.613	4.25	0.482	0.09	6.736	<0.05	<0.05
2284T	D.I.Khan	0.326	0.216	0.547	0.612	3.213	0.165	0.085	3.235	<0.05	0.073
2285T	D.I.Khan	0.386	0.016	0.622	0.458	5.084	0.262	0.052	6.866	0.065	0.071
2290T	D.I.Khan	0.142	0.015	0.695	0.364	5.362	0.365	0.075	7.235	0.067	<0.05
2298T	D.I.Khan	0.412	0.034	0.852	0.684	0.718	0.444	<0.02	6.186	<0.05	<0.05
2299T	D.I.Khan	0.346	0.136	0.279	0.034	1.09	0.473	<0.02	4.158	<0.05	0.096
2301T	D.I.Khan	0.4	0.093	0.39	0.147	0.627	0.312	<0.02	4.122	<0.05	<0.05
2302T	D.I.Khan	0.431	<0.02	0.362	0.683	0.773	0.542	<0.02	4.823	<0.05	<0.05
2304T	D.I.Khan	0.46	0.166	0.272	0.489	5.547	0.621	<0.02	7.254	<0.05	<0.05
2306T	D.I.Khan	0.545	0.299	0.523	0.359	6.77	0.36	<0.02	8.308	<0.05	<0.05
2307T	D.I.Khan	0.82	0.456	0.44	0.787	5.945	0.323	0.022	7.317	<0.05	<0.05
2313T	D.I.Khan	0.37	0.26	0.539	0.213	9.123	<0.02	<0.02	3.666	<0.05	0.055
2317T	D.I.Khan	0.609	0.694	0.494	0.861	0.794	0.725	0.025	8.157	<0.05	0.077

Table 5.9 continued

Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2319T	D.I.Khan	0.56	0.118	0.425	0.417	3.66	0.485	<0.02	5.853	<0.05	<0.05
2320T	D.I.Khan	0.532	0.283	0.952	0.667	1.48	0.353	<0.02	7.789	<0.05	<0.05
2322T	D.I.Khan	0.802	0.105	0.589	0.168	5.806	0.268	<0.02	7.201	<0.05	<0.05
2323T	D.I.Khan	0.652	0.354	0.423	0.318	0.038	0.303	<0.02	6.932	<0.05	0.082
2324T	D.I.Khan	0.6	0.445	0.542	0.604	1.291	0.351	0.023	6.909	<0.05	<0.05
2325T	D.I.Khan	0.712	0.583	0.685	0.608	6.268	0.307	0.02	7.563	<0.05	0.058
2329T	D.I.Khan	0.673	0.526	0.22	0.753	0.592	0.591	<0.02	6.326	<0.05	<0.05
2349T	D.I.Khan	0.45	0.24	0.288	0.158	6.321	0.534	<0.02	4.237	<0.05	<0.05
2350T	D.I.Khan	0.314	0.19	0.327	0.325	1.783	0.346	<0.02	4.456	<0.05	<0.05
2351T	D.I.Khan	0.482	0.449	0.338	0.417	1.019	0.283	<0.02	5.453	<0.05	<0.05
2357T	D.I.Khan	0.142	0.066	0.249	0.223	3.6	0.082	<0.02	2.594	<0.05	0.084
2359T	D.I.Khan	0.183	0.182	0.536	0.184	4.23	<0.02	<0.02	2.995	<0.05	0.054
2360T	D.I.Khan	0.085	0.228	0.216	0.314	0.302	0.142	0.024	2.435	<0.05	0.063
2364T	D.I.Khan	0.275	0.173	0.684	0.045	2.648	0.282	<0.02	2.264	<0.05	<0.05
2366T	D.I.Khan	0.145	0.131	0.781	0.181	0.325	0.361	<0.02	2.687	<0.05	<0.05
2368T	D.I.Khan	0.125	0.095	0.22	0.081	0.421	0.227	<0.02	1.386	<0.05	<0.05
2402T	D.I.Khan	0.421	0.093	0.342	0.573	4.318	0.351	<0.02	5.92	<0.05	<0.05
2403T	D.I.Khan	0.45	0.298	0.268	0.116	4.894	0.671	<0.02	5.242	<0.05	<0.05
2404T	D.I.Khan	0.445	0.049	0.38	0.734	2.358	0.481	<0.02	6.008	<0.05	0.056
2405T	D.I.Khan	0.296	0.361	0.854	0.317	1.853	0.334	<0.02	5.122	<0.05	<0.05
2406T	D.I.Khan	0.342	0.055	0.494	0.07	4.76	0.308	<0.02	4.405	<0.05	<0.05
2407T	D.I.Khan	0.702	0.626	0.482	0.961	0.537	0.75	0.028	7.166	0.051	<0.05
2408T	D.I.Khan	0.546	0.324	0.237	0.424	0.508	0.387	<0.02	6.529	<0.05	<0.05
2409T	D.I.Khan	0.453	0.381	0.415	0.709	1.057	0.569	0.004	6.436	<0.05	<0.05
2410T	D.I.Khan	0.296	0.03	0.266	0.331	4.122	0.426	0.006	3.547	<0.05	0.084
2412T	D.I.Khan	0.467	0.105	0.279	0.633	<0.02	0.412	0.0008	5.235	<0.05	<0.05
2413T	D.I.Khan	0.484	0.102	0.722	0.561	0.345	0.127	0.084	6.739	<0.05	<0.05
2433T	D.I.Khan	0.426	0.026	0.123	0.566	1.696	0.215	0.022	4.641	0.074	<0.05
2434T	D.I.Khan	0.62	0.368	0.535	0.511	3.637	0.391	0.025	5.924	<0.05	<0.05
2435T	D.I.Khan	0.273	0.259	0.394	0.398	1.865	0.24	0.01	3.331	0.087	<0.05
2436T	D.I.Khan	0.243	0.139	0.224	0.274	0.03	0.562	0.0008	2.784	<0.05	0.085

Table 5.9 continued

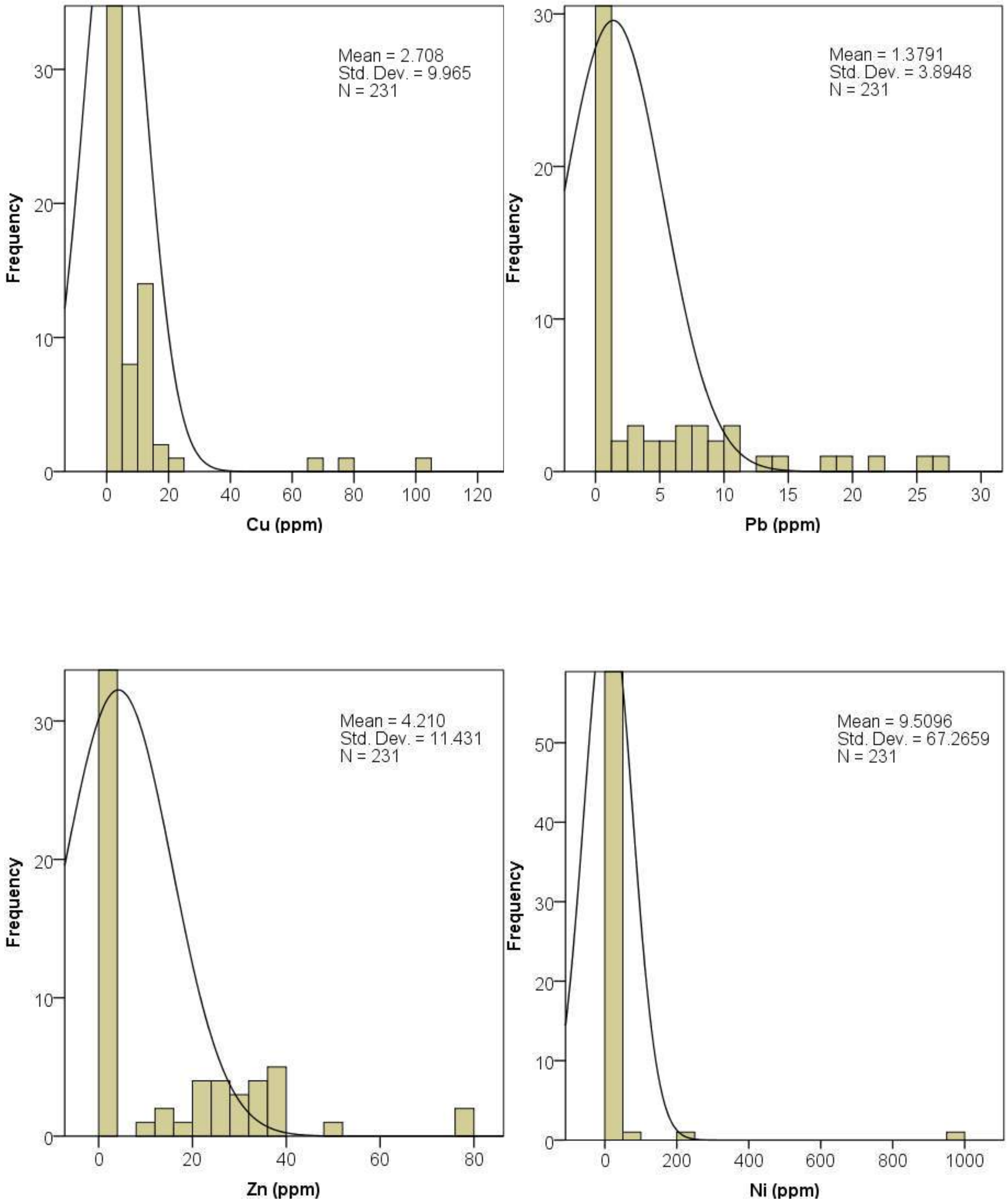
Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
2437T	D.I.Khan	0.212	0.067	0.251	0.303	0.995	0.038	<0.02	3.389	<0.05	<0.05
2438T	D.I.Khan	0.272	0.062	0.623	0.36	3.779	0.428	0.02	3.495	<0.05	0.083
2439T	D.I.Khan	0.583	0.281	0.527	0.61	7.19	0.306	<0.02	6.111	<0.05	<0.05
2440T	D.I.Khan	0.468	0.245	0.629	0.407	0.544	0.413	<0.02	4.405	<0.05	<0.05
2507T	Tank	0.559	1.085	0.867	0.673	0.22	0.313	0.086	10.68	<0.05	0.082
2508T	Tank	0.417	1.13	0.962	0.57	0.031	0.236	0.067	0.541	<0.05	<0.05
2512T	Tank	0.41	0.794	0.843	0.35	0.763	0.264	0.058	8.665	0.652	<0.05
2513T	Tank	0.532	0.711	0.62	0.834	0.09	0.246	0.166	9.991	0.335	<0.05
2518T	Tank	0.415	0.57	0.682	0.146	0.79	0.346	0.135	11.44	<0.05	0.091
2520T	Tank	0.441	0.736	0.754	0.254	0.854	0.223	0.117	0.552	<0.05	<0.05
2524T	Tank	0.549	0.414	0.945	0.079	0.152	0.373	0.136	11.06	0.132	0.061
2537T	Tank	0.339	0.602	0.662	0.677	0.354	0.183	0.13	7.6	<0.05	<0.05
2540T	Tank	0.623	0.778	0.688	0.539	0.135	0.252	0.039	9.045	<0.05	<0.05
2553T	Tank	0.784	1.035	0.769	0.577	0.899	0.242	0.047	9.596	0.137	<0.05
2554T	Tank	4.004	0.164	1.114	0.666	0.223	0.316	0.114	0.593	0.058	<0.05
2557T	Tank	0.315	0.785	0.911	0.338	0.99	0.252	0.162	11.02	<0.05	<0.05
2559T	Tank	0.379	1.052	0.694	0.308	0.838	0.268	0.169	0.56	<0.05	<0.05
2563T	Tank	0.694	0.86	0.883	0.287	0.824	0.172	0.108	7.915	<0.05	0.069
2566T	Tank	0.732	0.694	0.727	0.528	0.104	0.271	0.128	11.19	<0.05	<0.05
2571T	Tank	0.54	0.294	0.892	0.952	0.12	0.423	0.051	10.98	0.401	<0.05
2573T	Tank	0.326	0.314	0.748	0.701	0.976	0.247	0.127	6.081	<0.05	<0.05
3001T	Hangu	0.415	0.81	0.937	0.746	1.345	<0.02	0.136	9.787	<0.05	<0.05
3004T	Hangu	0.216	0.833	1.016	0.853	0.782	0.172	0.116	4.625	0.065	<0.05
3009T	Hangu	0.373	0.496	1.176	0.892	1.167	0.083	0.097	8.844	<0.05	0.155
3012T	Hangu	0.456	0.355	0.815	0.517	0.772	0.048	0.048	6.972	<0.05	<0.05
3014T	Hangu	0.117	0.536	0.866	0.498	1.148	<0.02	0.137	10.27	<0.05	<0.05
3023T	Hangu	0.12	0.239	0.732	0.911	1.232	0.021	0.082	7.627	0.381	<0.05
3028T	Hangu	0.378	0.384	0.984	3.118	0.695	0.219	0.098	7.312	0.491	0.102
3034T	Hangu	0.335	0.073	0.801	0.912	0.549	0.069	0.023	9.044	0.7	0.065
3041T	Hangu	0.126	0.443	0.702	0.759	1.065	0.022	0.09	7.918	<0.05	<0.05

Table 5.9 continued

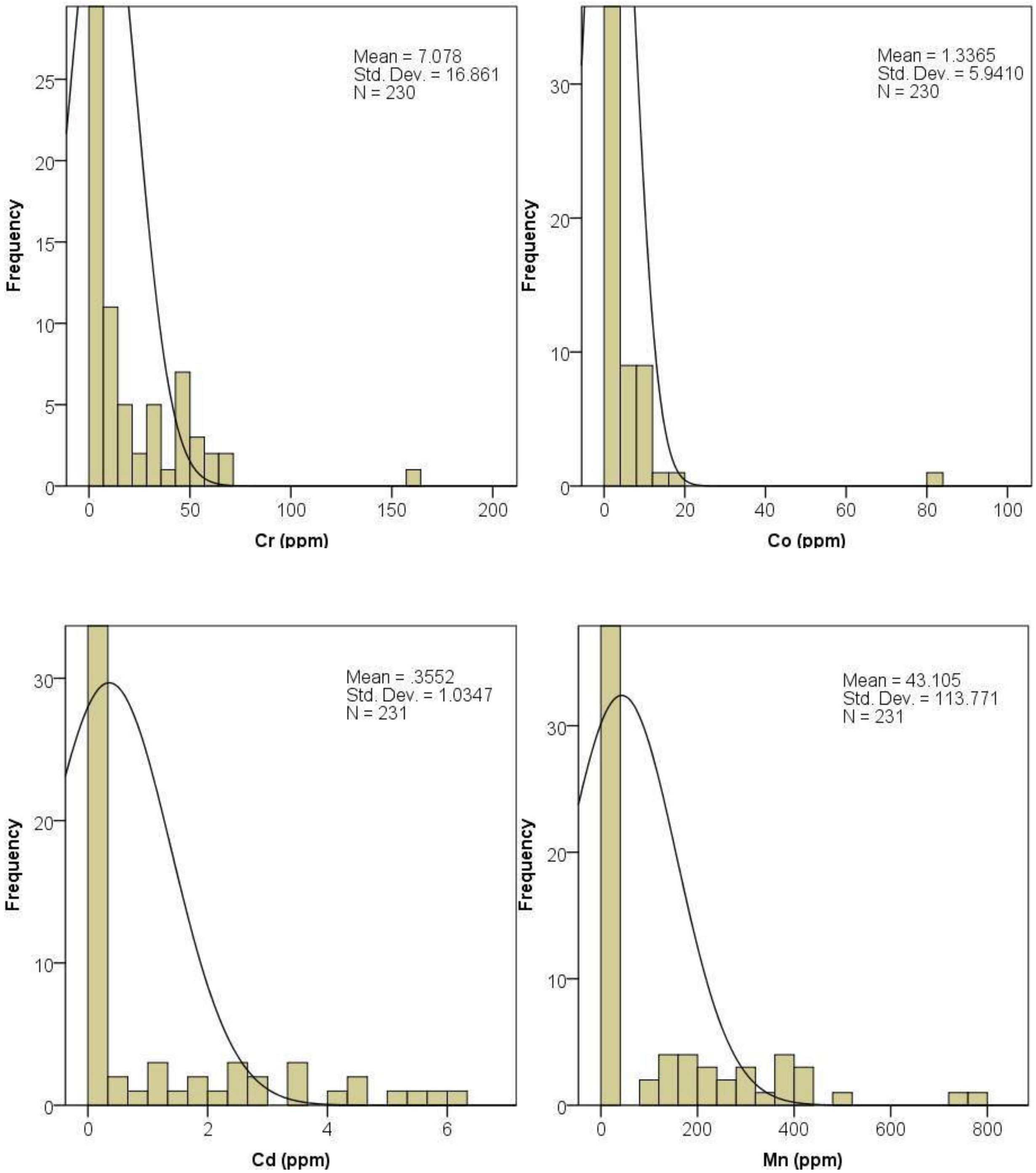
Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
3047T	Hangu	0.158	0.196	0.75	0.642	0.59	0.04	<0.02	9.006	<0.05	0.144
3051T	Hangu	0.19	0.084	0.598	0.5	0.405	0.076	<0.02	6.687	<0.05	<0.05
3058T	Hangu	0.338	0.059	0.842	0.808	0.873	<0.02	0.062	5.05	<0.05	0.06
3061T	Hangu	0.299	0.226	0.822	0.911	0.343	0.034	0.08	13.2	<0.05	0.075
3072T	Hangu	0.294	0.416	0.686	0.809	0.685	0.118	0.065	10.78	<0.05	<0.05

Table 5.10. Statistical parameters of gold, silver and base metals in Tallus.

		Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
N	**Valid**	231	231	231	231	230	230	231	231	231	220
	Missing	0	0	0	0	1	1	0	0	0	11
Mean		2.708	1.379	4.210	9.510	7.078	1.337	.355	43.105	.220	.093
Median		.387	.239	.535	.539	1.007	.252	.048	6.295	.050	.050
Std. Deviation		9.965	3.895	11.431	67.266	16.861	5.941	1.035	113.771	.987	.360
Minimum		.020	.0.020	.020	.020	.020	.020	.020	.020	.050	.050
Maximum		100.500	26.700	77.500	988.000	157.450	82.550	6.300	766.500	11.500	5.307
Percentiles	**50**	.387	.239	.535	.539	1.007	.252	.048	6.295	.050	.050
	75	.580	.526	.843	.907	4.660	.424	.098	9.991	.050	.060
	90	9.630	3.190	20.170	20.290	24.250	2.175	.890	173.110	.097	.091
	95	13.040	8.970	32.310	32.150	47.513	8.395	2.780	319.100	.561	.154
	99	74.502	24.932	68.382	184.138	66.847	16.383	5.724	674.060	6.180	.697



Continuation of Fig. 5.5



Continuation of Fig. 5.5

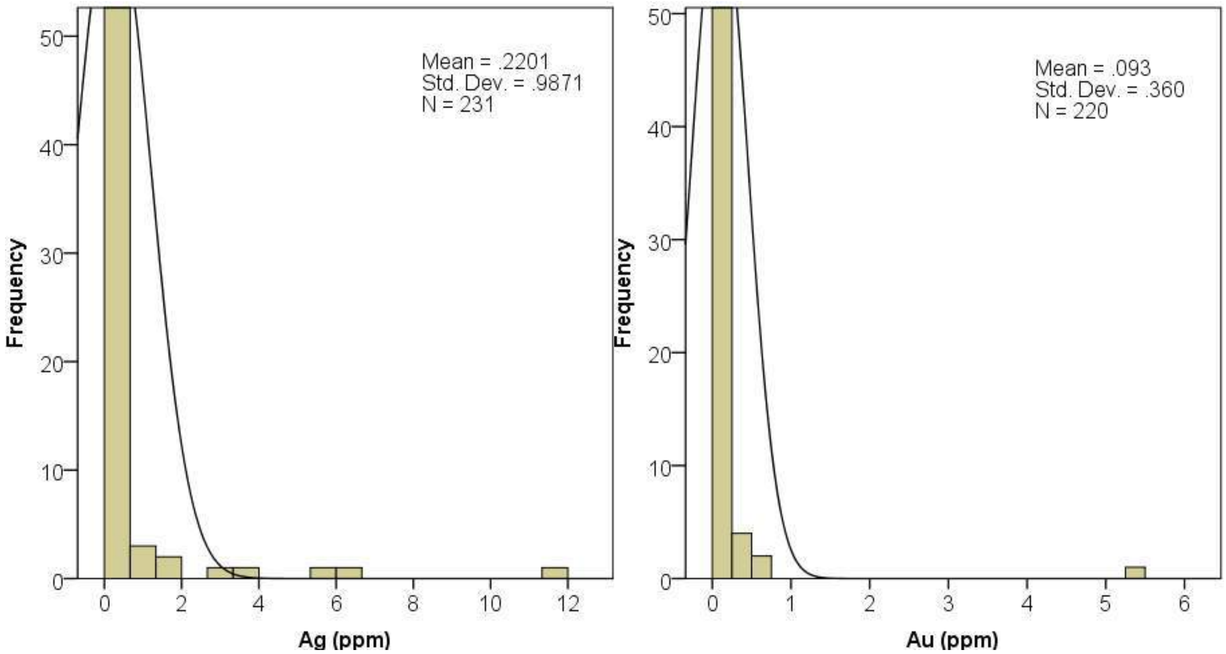


Fig. 5.5. Histograms of gold, silver and base metals in Tallus.

Table 5.11. Correlation matrix for gold, silver and base metals in Tallus.

		logCu	logPb	logZn	logNi	logCr	logCo	logCd	logMn	logAg	logAu
logCu	**Pearson Correlation**	1									
	Sig. (2-tailed)										
	N	231									
logPb	**Pearson Correlation**	.529**	1								
	Sig. (2-tailed)	.000									
	N	231	231								
logZn	**Pearson Correlation**	.568**	.386**	1							
	Sig. (2-tailed)	.000	.000								
	N	231	231	231							
logNi	**Pearson Correlation**	.739**	.590**	.656**	1						
	Sig. (2-tailed)	.000	.000	.000							
	N	231	231	231	231						
logCr	**Pearson Correlation**	.672**	.387**	.414**	.559**	1					
	Sig. (2-tailed)	.000	.000	.000	.000						
	N	230	230	230	230	230					
logCo	**Pearson Correlation**	.631**	.350**	.401**	.501**	.497**	1				
	Sig. (2-tailed)	.000	.000	.000	.000	.000					
	N	230	230	230	230	230	230				
logCd	**Pearson Correlation**	.455**	.348**	.453**	.593**	.297**	.177**	1			

	Sig. (2-tailed)	.000	.000	.000	.000	.000	.007				
	N	231	231	231	231	230	230	231			
logMn	**Pearson Correlation**	.589**	.371**	.527**	.614**	.405**	.442**	.339**	1		
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000			
	N	231	231	231	231	230	230	231	231		
logAg	**Pearson Correlation**	.339**	.154*	.247**	.373**	.255**	.327**	.354**	.417**	1	
	Sig. (2-tailed)	.000	.019	.000	.000	.000	.000	.000	.000		
	N	231	231	231	231	230	230	231	231	231	
logAu	**Pearson Correlation**	.170*	.186**	.090	.189**	.117	.014	.195**	.194**	-.085	1
	Sig. (2-tailed)	.011	.006	.185	.005	.083	.840	.004	.004	.212	
	N	220	220	220	220	220	220	220	220	220	220

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5.12. Factor Analysis for gold, silver and base metals in Tallus.

	Factor 1	Factor 2
logCu	.879	-.016
logPb	.648	.247
logZn	.730	.023
logNi	.894	.076
logCr	.706	-.062
logCo	.668	-.308
logCd	.629	.187
logMn	.739	-.044
logAg	.495	-.503
logAu	.221	.829
Total	4.704	1.143
% of Variance	47.041	11.427
Cumulative %	47.041	58.468

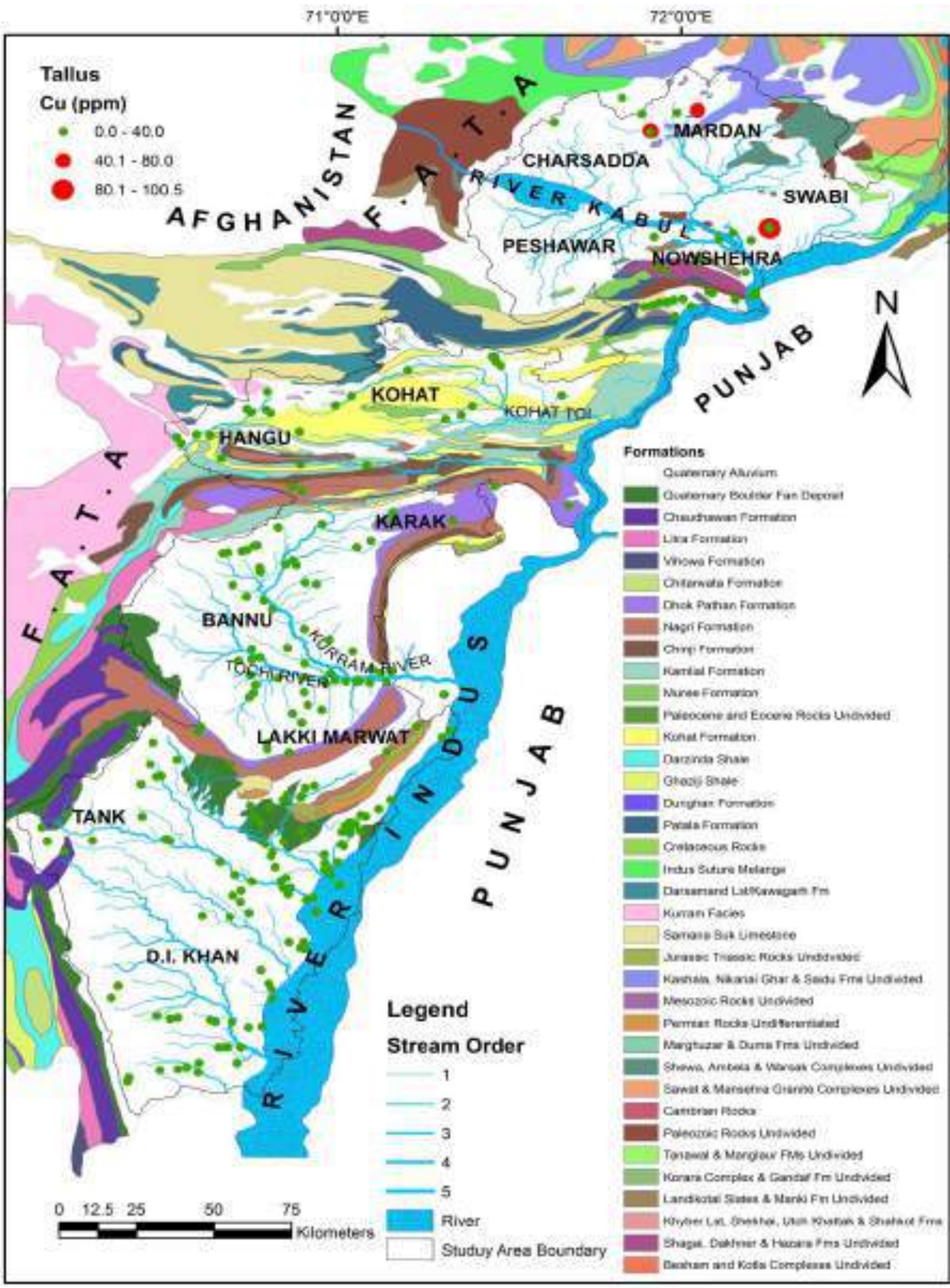


Fig. 5.6(a). Geochemical map of Cu in Tallus (After Aslam et al., 2006).

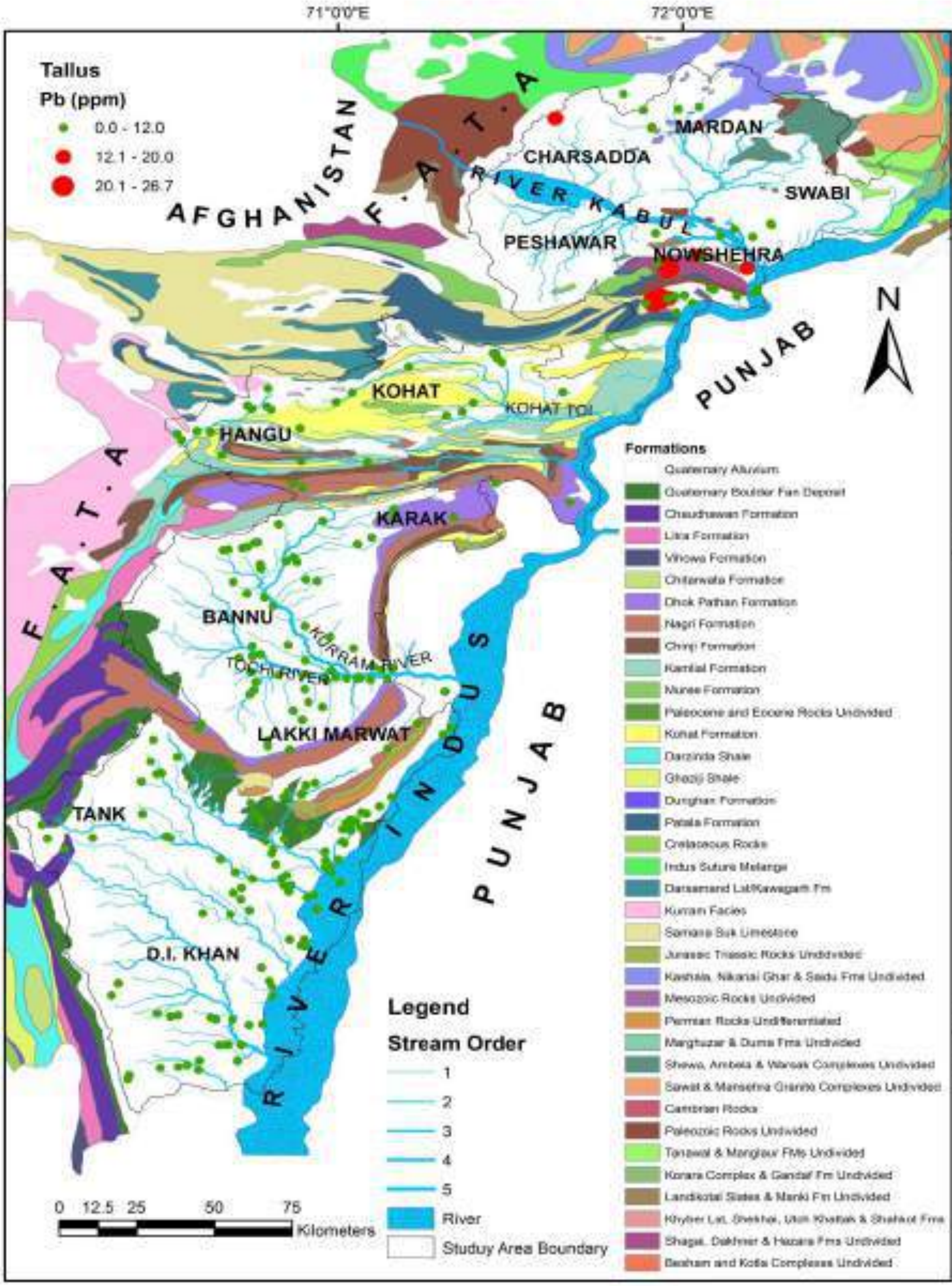


Fig. 5.6(b). Geochemical map of Pb in Tallus (After Aslam et al., 2006).

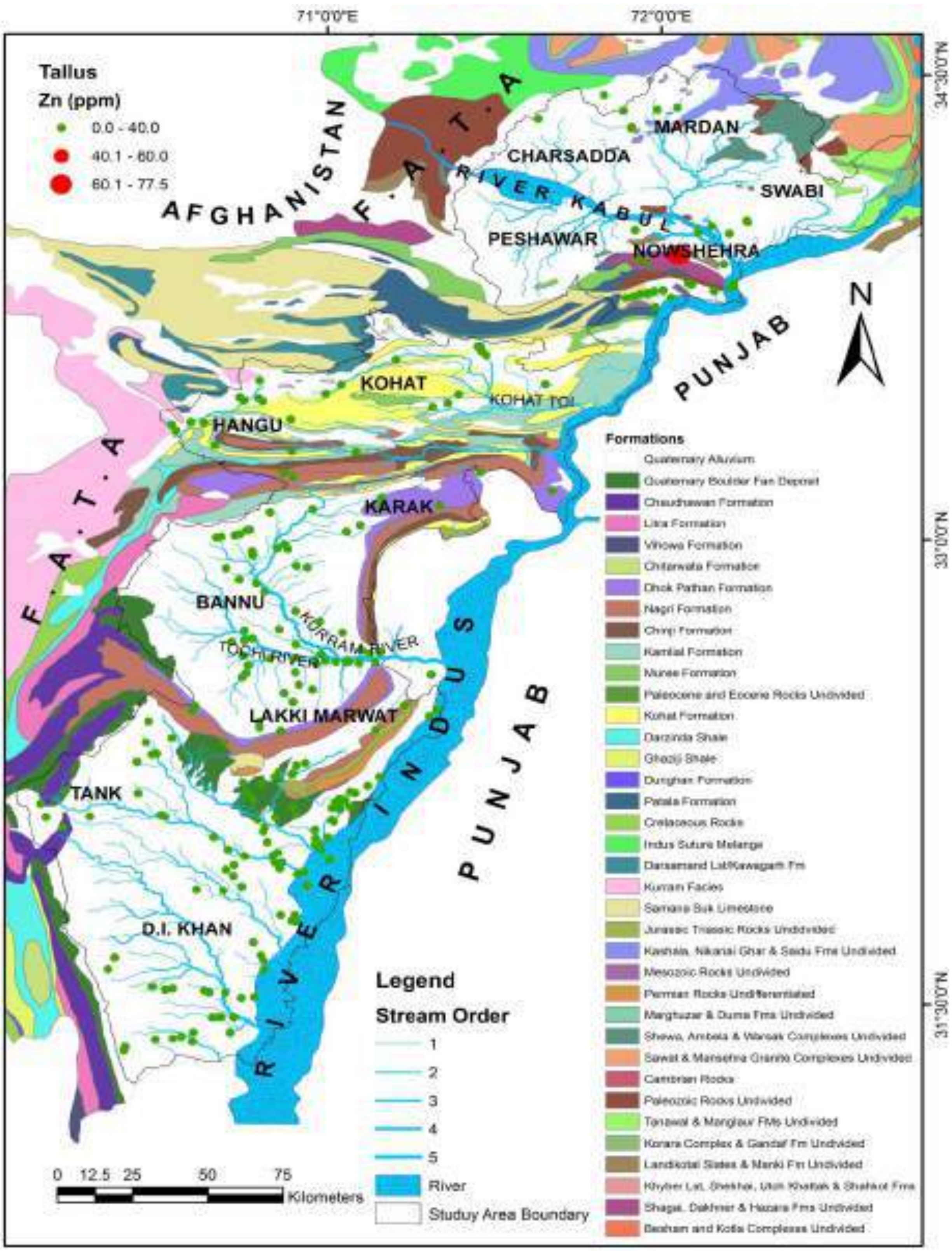


Fig. 5.6(c). Geochemical map of Zn in Tallus (After Aslam et al., 2006).

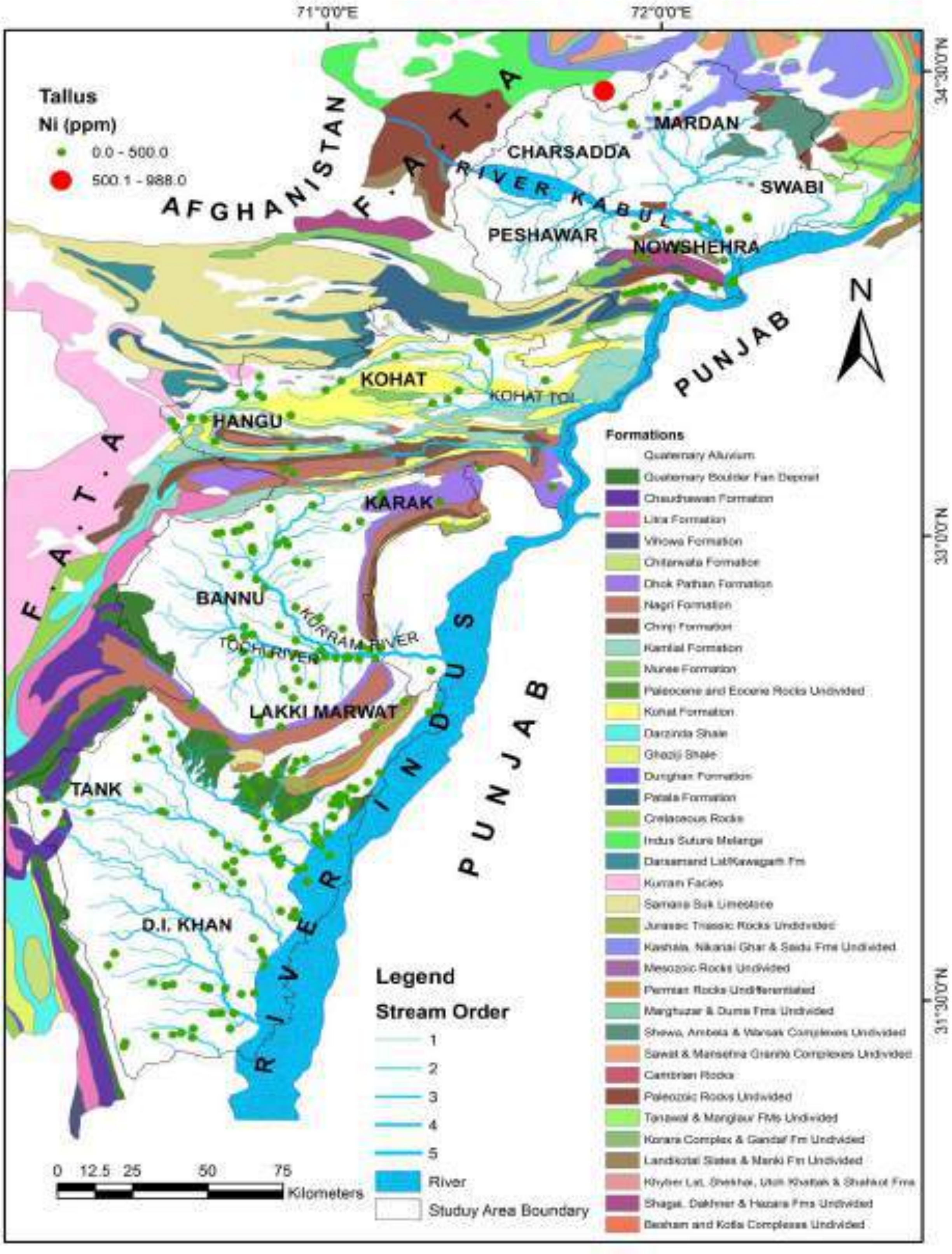


Fig. 5.6(d). Geochemical map of Ni in Tallus (After Aslam et al., 2006).

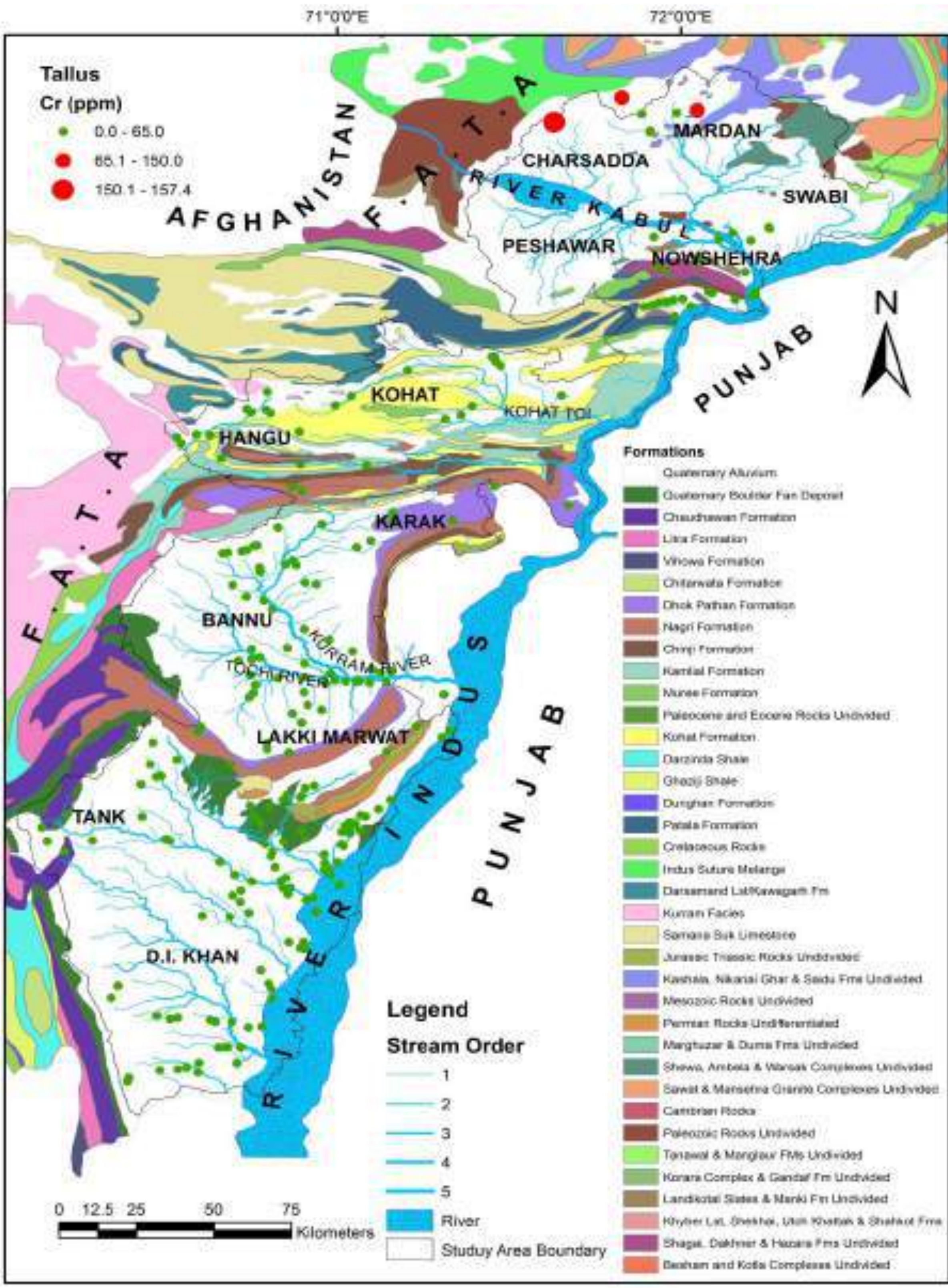


Fig. 5.6(e). Geochemical map of Cr in Tallus (After Aslam et al., 2006).

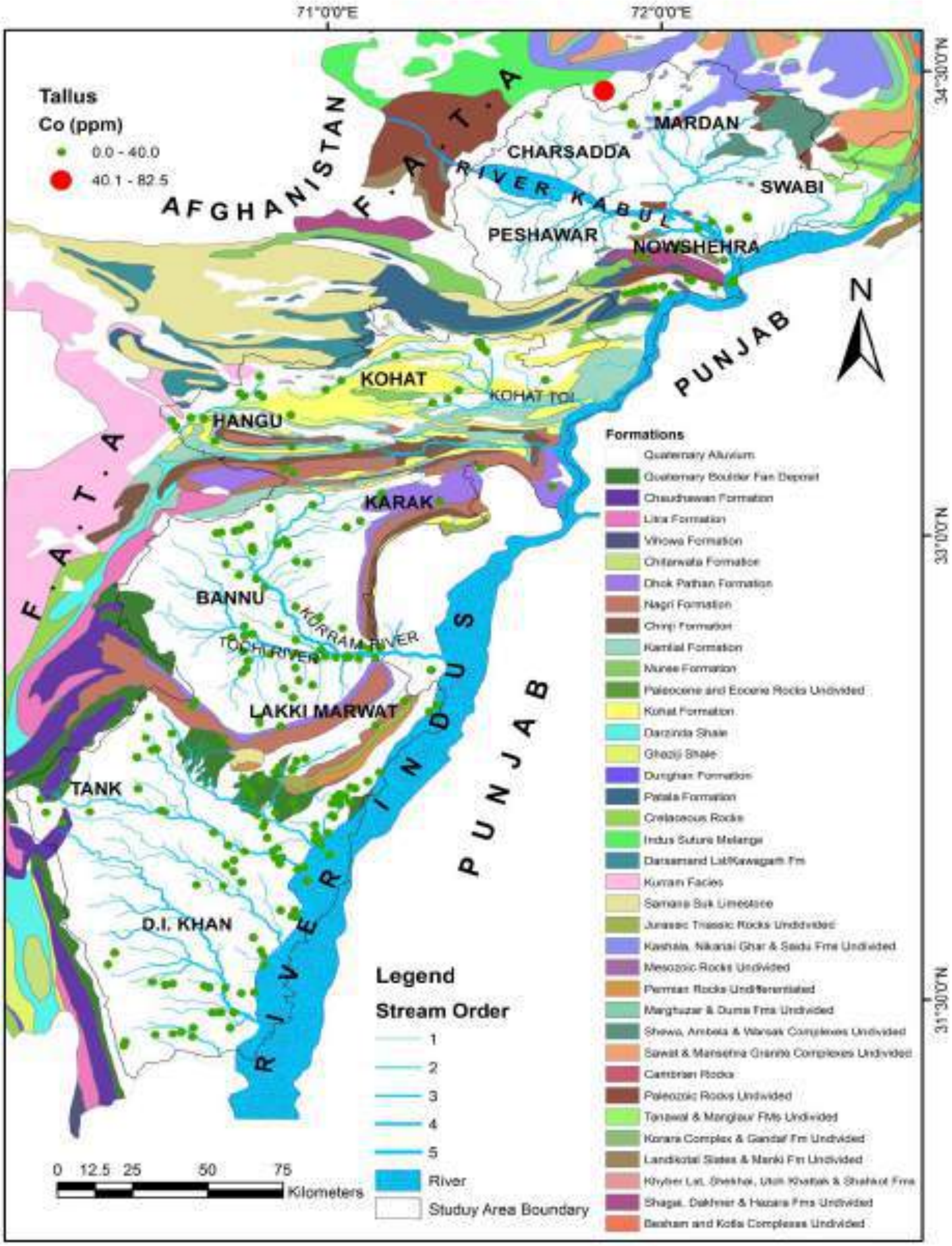


Fig. 5.6(f). Geochemical map of Co in Tallus (After Aslam et al., 2006).

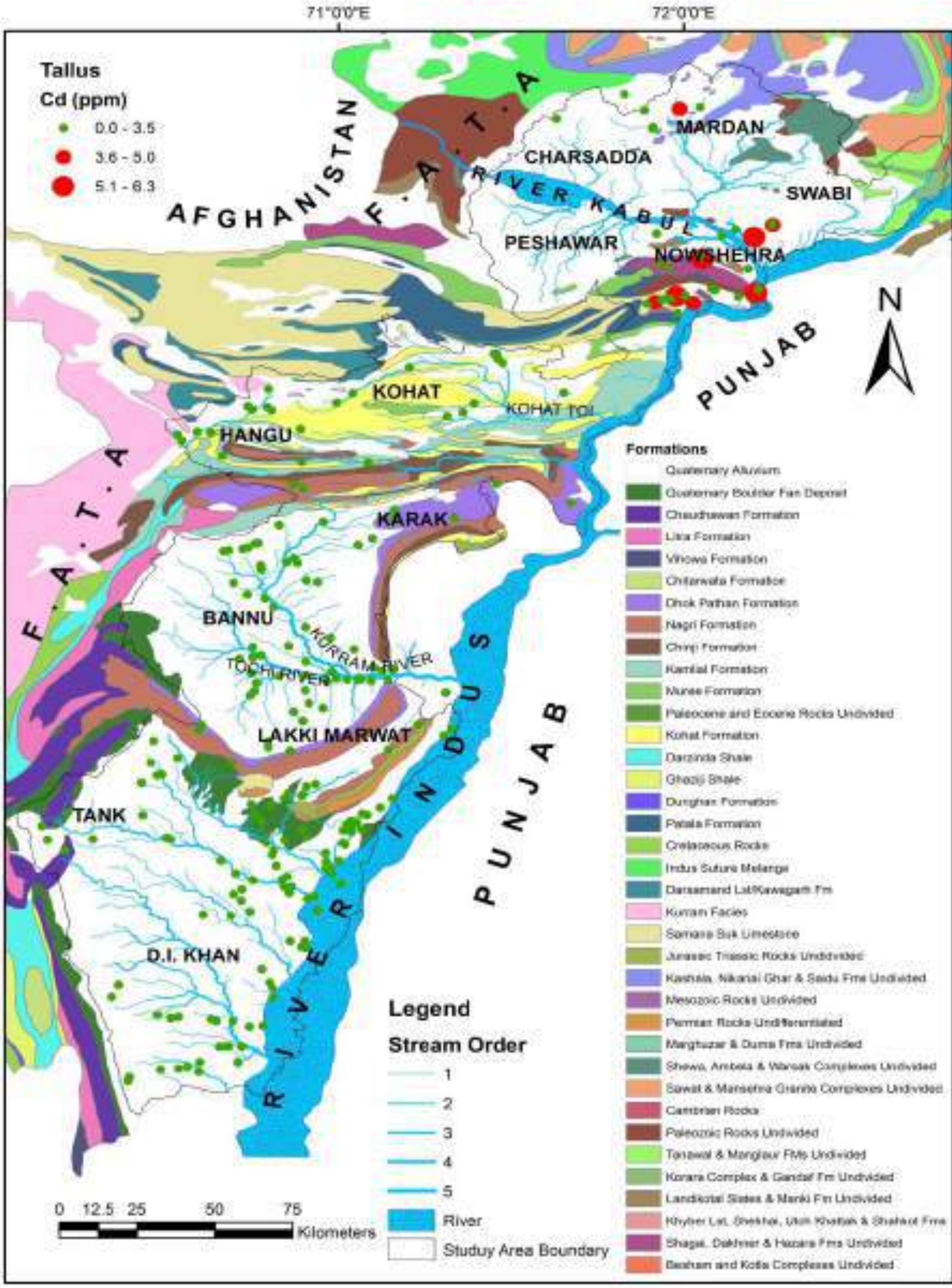


Fig. 5.46(g). Geochemical map of Cd in Tallus (After Aslam et al., 2006).

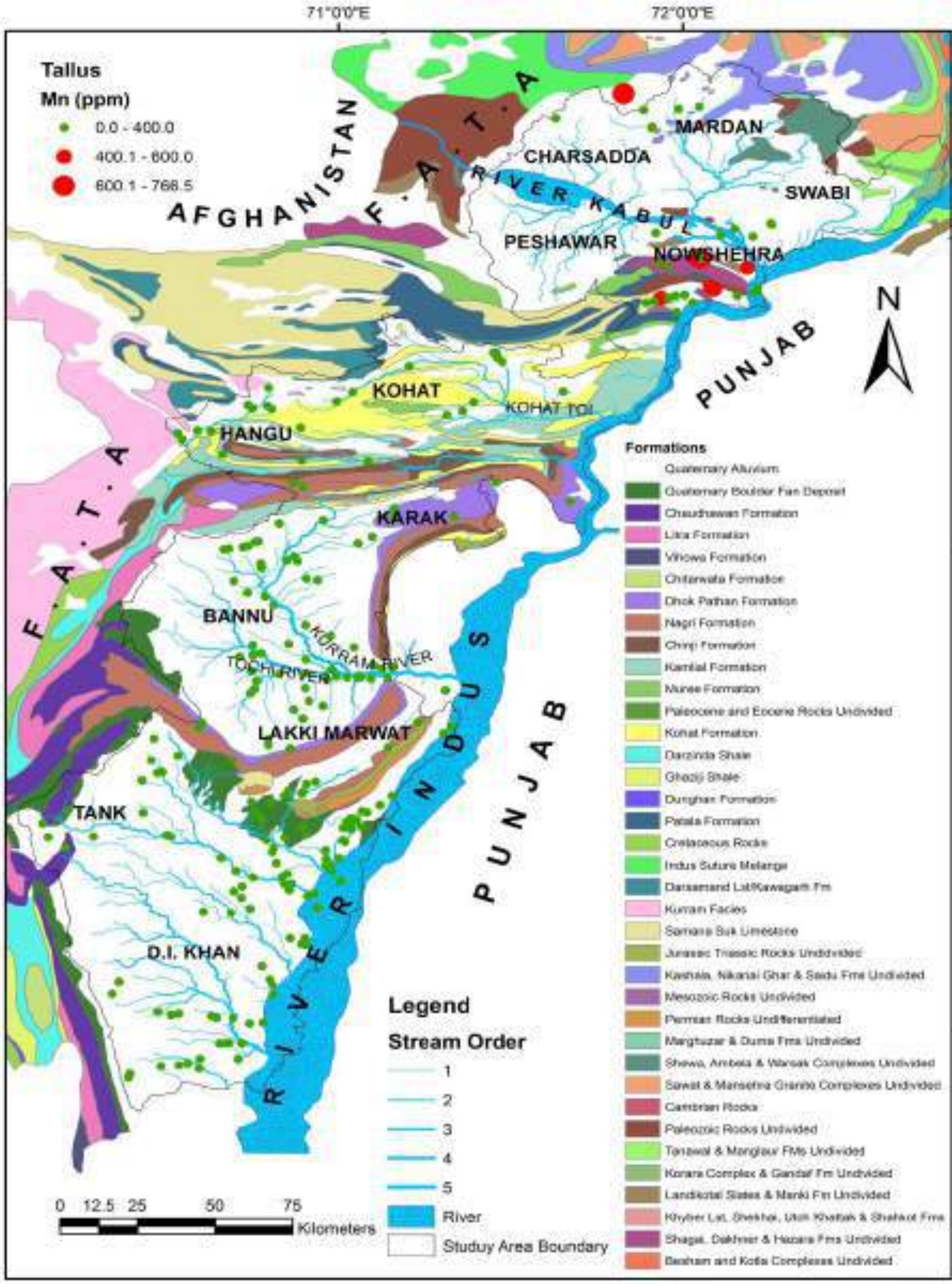


Fig. 5.6(h). Geochemical map of Mn in Tallus (After Aslam et al., 2006).

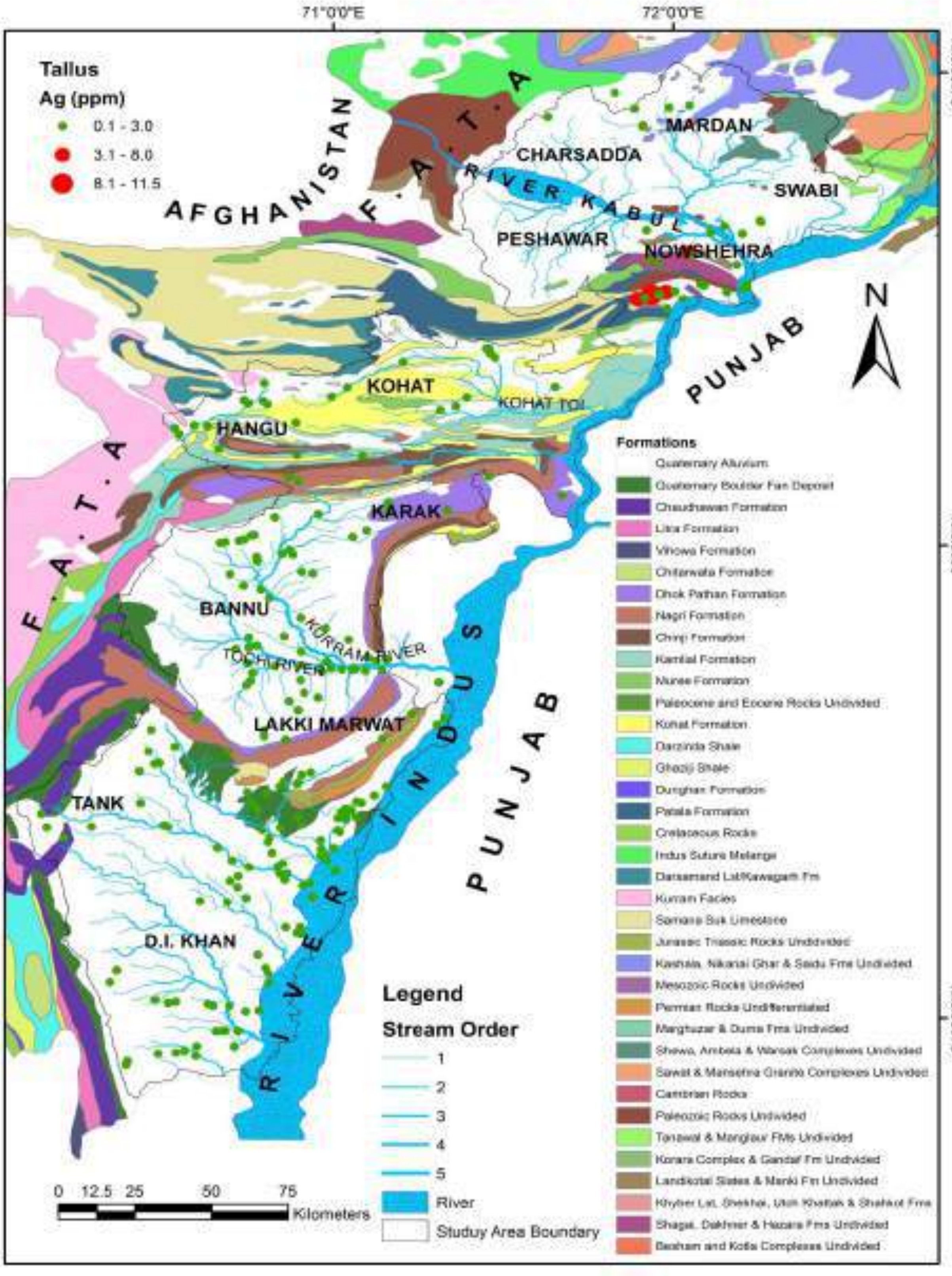


Fig. 5.6(i). Geochemical map of Ag in Tallus (After Aslam et al., 2006).

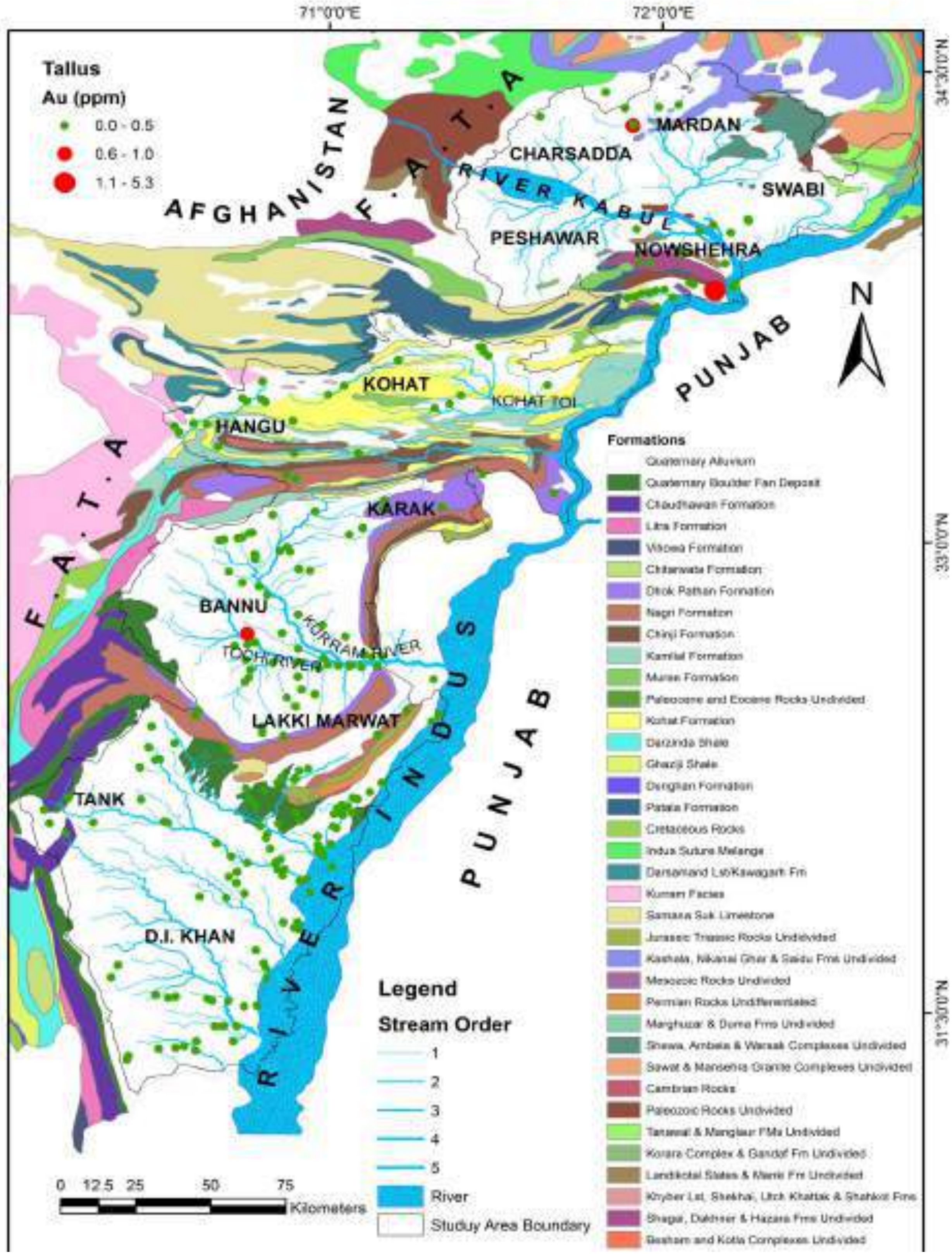


Fig. 5.6(j). Geochemical map of Au in Tallus (After Aslam et al., 2006).

5.6. Bulk samples geochemical study

Results of geochemical study of bulk samples are shown in Table 5.13. Statistical parameters of geochemical data are presented in Table 5.14, Correlation matrix in Table 5.15 and Factor analysis in Table 5.16. While Histograms for Cu, Pb, Zn, Ni, Cr, Co, Cd, Mn, Ag and Au are shown in Fig. 5.7 and spatial geochemical maps for Au and base metals are shown in Figs. 5.8 a-j.

The geochemical data of the bulk samples (Table 5.13) did not show any major variation. Cu is ranging from 0.28 to 14.72 ppm, Pb from 0.138 to 4.789 ppm, Zn from 0.476 to 6.678 ppm, Ni from 0.036 to 4.993 ppm, Cr from 0.894 to 12.180 ppm, Co from 0.382 to 0.903 ppm, Cd from 0.020 to 0.202 ppm, Mn from 2.576 to 12.960 ppm, Ag from 0.029 to 0.260 ppm, and Au from 0.020 to 20.970 ppm, (Table 5.14).

The threshold value of each element was estimated after considering the histograms (Fig. 5.7) and statistical parameters (Table 5.14). The threshold value of each element in bulk samples is found to be 11 ppm for Cu, 3.5 ppm for Pb, 5 ppm for Zn, 3.5 ppm for Ni, 9.5 ppm for Cr, 0.9 ppm for Co, 0.25 ppm for Cd, 12 ppm for Mn, 0.2 ppm for Ag and 2.5 ppm for Au.

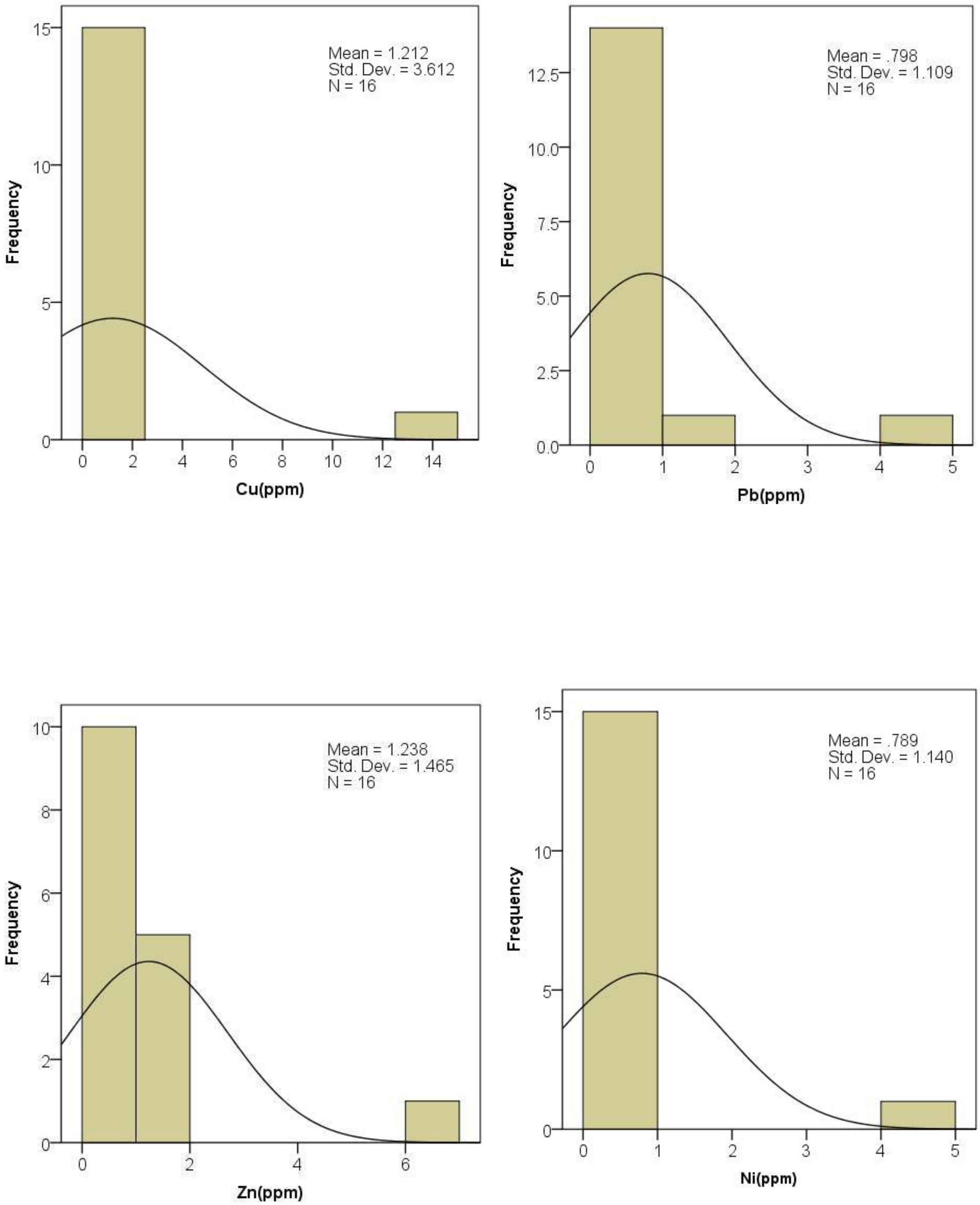
The geochemical maps of pan-concentrate bulk samples shows anomalous concentrations of Au (20.24 ppm) in Zarobai village (Swabi), 19.74 ppm in Ganderi Khwar (Charsadda), 12.97 ppm, 18.39 ppm, 20.09 ppm, 20.97 ppm and 19.48 ppm in Wuch Khwar, Warmando (Shnay Wannay Khwar), Chashmai Khwar, (Shaidu, Nowshehra), Narai Khwar and Ghat Khwar, respectively, in Nowshehra district (Figs. 5.7 j). In the southern parts of Khyber Pakhtunkhwa anomalous values of Au are found in the Tarkha algada (17.4 ppm), balangzin algada (12.87 ppm) and Thoya algada lack kora (14.2 ppm) in Karak district and in Hindu algada spara (14.02 ppm), Lagorai algada Kacho (16.91 ppm) and Main Tarhalay algada (16.18 ppm) in Shakardara Kohat district.All of the bulk samples from Karak and Kohat district have catchments in the Siwalik sandstone and conglomerates (Figs. 5.7 j). High value of Cu, Zn, Co, and Cd are foun in the bulk samples of Warmando (Shnay Wannay Khwar) (Figs. 5.7a,c,f,g), Nowshehra, while anamolous Pb, Mn and Ag are found at the confluence of Kabul and Indus Rivers (Figs. 5.7b,h,i). Anamolous values of Ni, Cr and Cd are found in the bulk samples having catchment area in Indus suture mélange in Charsadda district ((Figs. 5.7d,e,f). on the basis of the pan-concentrate stream sediments and the bulk concentrates studies of the samples collected from the project, various anamolous zones have been delineated as blocks No. 1,2,3,4 and 5 (Fig.5.8) for further detail exploration and exploitation work for proving these areas to be economically viable.

Table 5.13. Geochemical data of gold, silver and base metals in bulk samples (130kg/sample).

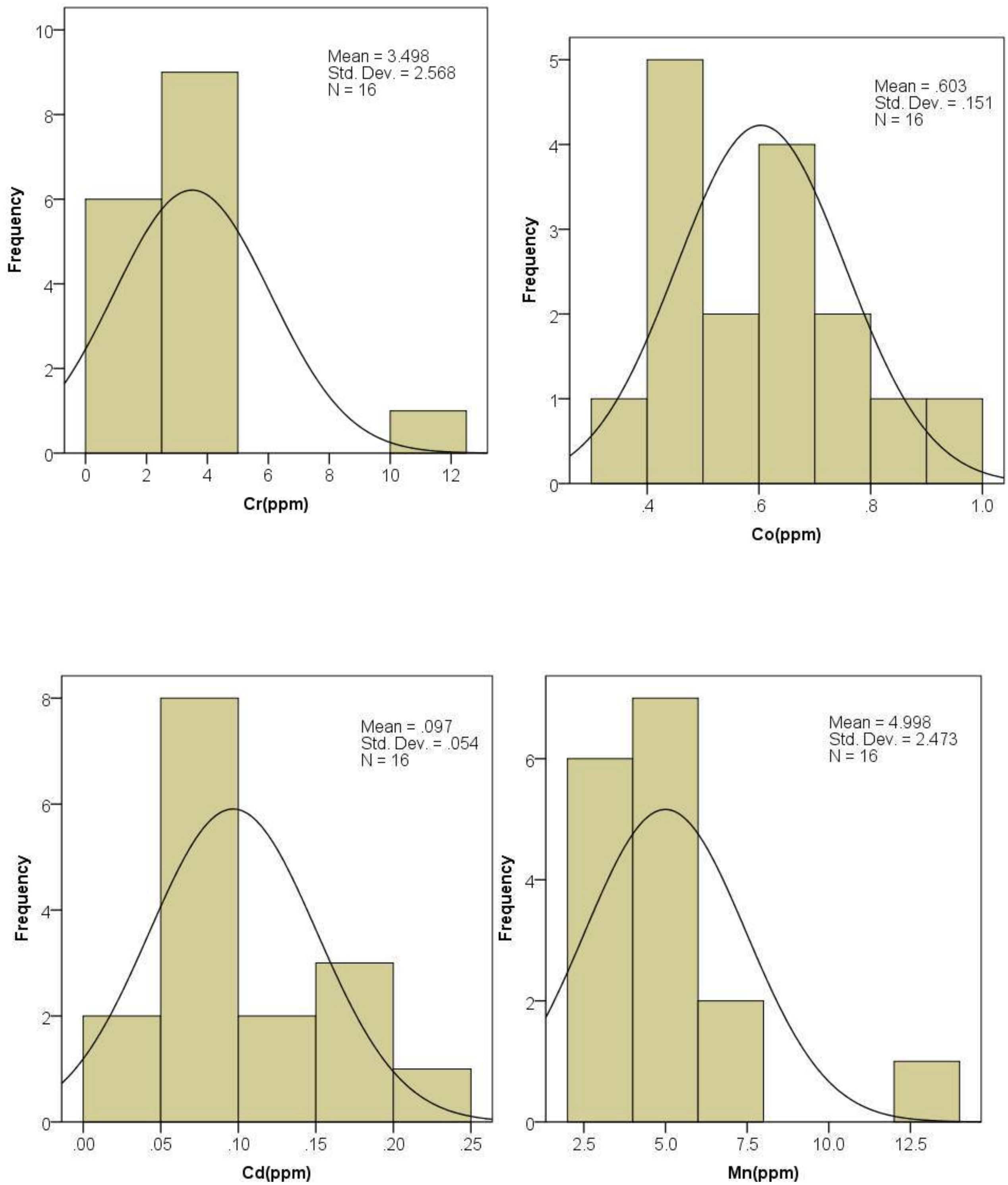
Sample No	District	Cu(ppm)	Pb(ppm)	Zn(ppm)	Ni(ppm)	Cr(ppm)	Co(ppm)	Cd(ppm)	Mn(ppm)	Ag(ppm)	Au(ppm)
1110BK	Swabi	0.303	0.19	0.97	0.701	3.444	0.859	0.095	4.322	0.128	20.24
1201BK	Charsadda	0.098	0.138	1.017	4.993	12.18	0.459	0.154	2.884	0.035	19.74
1216BK	Nowshehra	0.696	0.592	1.003	0.386	1.324	0.442	0.109	4.341	0.03	1.405
1219BK	Nowshehra	0.964	4.789	1.308	0.036	1.656	0.548	0.057	12.96	0.26	0.02
1230BK	Nowshehra	0.314	0.522	1.157	0.645	0.894	0.481	0.077	3.607	0.031	0.05
1234BK	Nowshehra	14.72	1.317	6.678	0.737	3.898	0.676	0.139	7.149	0.075	18.39
1238BK	Nowshehra	0.489	0.722	0.806	0.868	3.035	0.529	0.02	5.401	0.034	2.271
1240BK	Nowshehra	0.254	0.468	0.784	0.515	2.457	0.903	0.065	6.153	0.04	20.09
1245BK	Nowshehra	0.24	0.355	1.04	0.212	2.124	0.382	0.071	5.102	0.033	20.97
1247BK	Nowshehra	0.174	0.649	0.949	0.475	3.245	0.629	0.177	5.298	0.035	19.48
1604BK	Karak	0.1	0.428	0.759	0.629	4.539	0.649	0.051	4.341	0.036	17.4
1836BK	Karak	0.028	0.187	0.476	0.362	2.219	0.49	0.152	3.929	0.029	12.87
2007BK	Kohat	0.049	0.228	0.682	0.584	4.391	0.72	0.202	2.576	0.031	14.02
2013BK	Kohat	0.251	0.955	0.753	0.661	4.551	0.655	0.068	5.574	0.093	16.91
2027BK	Kohat	0.04	0.777	0.728	0.381	3.244	0.494	0.087	3.576	0.044	16.18
2050BK	Karak	0.672	0.453	0.69	0.445	2.773	0.739	0.023	2.754	0.047	14.2

Table 5.14. Statistical parameters of gold, silver and base metals in bulk samples (130kg/sample).

		Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
N	Valid	16	16	16	16	16	16	16	16	16	16
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		1.212	.798	1.237	.789	3.498	.603	.097	4.998	.061	13.389
Std. Deviation		3.612	1.108	1.465	1.140	2.568	.151	.054	2.473	.060	7.803
Minimum		.028	.138	.476	.036	.894	.382	.020	2.576	.029	.020
Maximum		14.720	4.789	6.678	4.993	12.180	.903	.202	12.960	.260	20.970
Percentiles	50	.253	.495	.877	.549	3.139	.588	.082	4.341	.035	16.545
	75	.626	.763	1.034	.691	4.268	.709	.149	5.530	.068	19.675
	90	5.091	2.359	2.919	2.105	6.840	.872	.184	8.892	.168	20.459
	95	.	.	.	.	.	.	.	.	.	.
	99	.	.	.	.	.	.	.	.	.	.



Continuation of Fig. 5.7



Continuation of Fig. 5.7

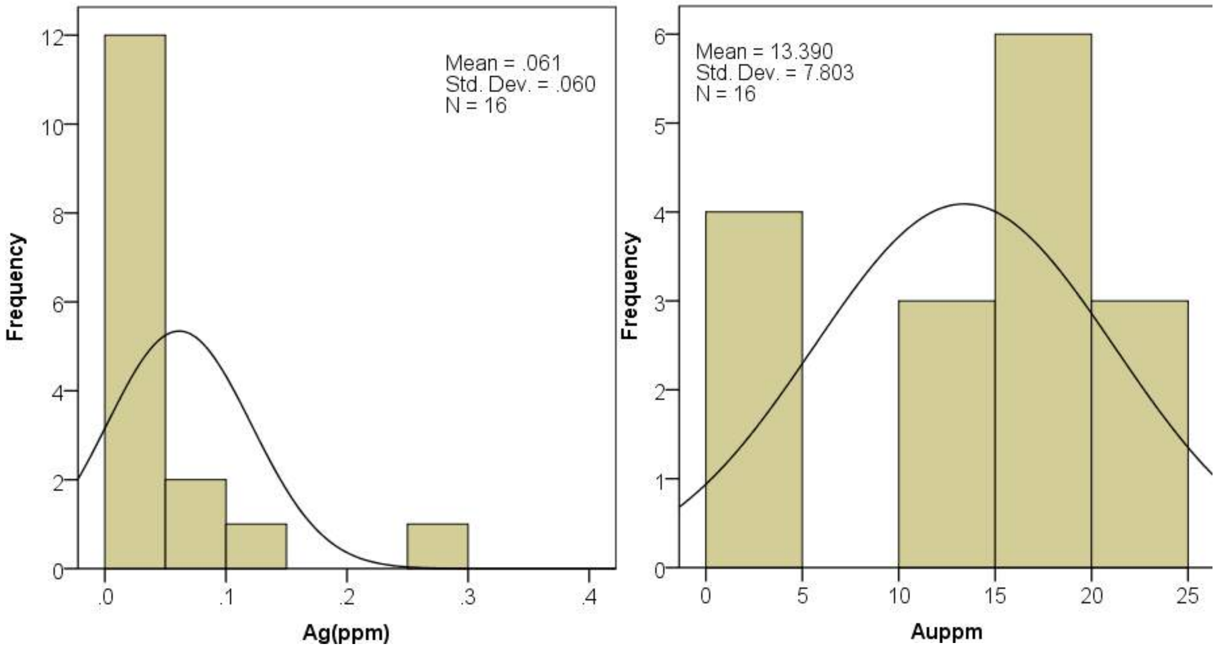


Fig. 5.7. Histograms of gold, silver and base metals in bulk samples.

Table 5.15. Correlation matrix for gold, silver and base metals in bulk samples.

		logCu	logPb	logZn	logNi	logCr	logCo	logCd	logMn	logAg	logAu
logCu	**Pearson Correlation**	1									
	Sig. (2-tailed)										
	N	16									
logPb	**Pearson Correlation**	.567*	1								
	Sig. (2-tailed)	.022									
	N	16	16								
logZn	**Pearson Correlation**	.837**	.429	1							
	Sig. (2-tailed)	.000	.097								
	N	16	16	16							
logNi	**Pearson Correlation**	-.148	-.653**	.013	1						
	Sig. (2-tailed)	.584	.006	.962							
	N	16	16	16	16						
logCr	**Pearson Correlation**	-.202	-.364	.009	.638**	1					
	Sig. (2-tailed)	.454	.165	.975	.008						
	N	16	16	16	16	16					
logCo	**Pearson Correlation**	.161	-.017	.032	.085	.233	1				
	Sig. (2-tailed)	.550	.951	.907	.754	.385					
	N	16	16	16	16	16	16				

logCd	**Pearson Correlation**	-.240	-.310	.183	.185	.206	-.083	1			
	Sig. (2-tailed)	.370	.242	.497	.493	.443	.760				
	N	16	16	16	16	16	16	16			
logMn	**Pearson Correlation**	.539*	.794**	.446	-.612*	-.279	.048	-.160	1		
	Sig. (2-tailed)	.031	.000	.083	.012	.295	.860	.555			
	N	16	16	16	16	16	16	16	16		
logAg	**Pearson Correlation**	.435	.593*	.334	-.471	-.001	.332	-.139	.658**	1	
	Sig. (2-tailed)	.092	.016	.207	.066	.996	.209	.607	.006		
	N	16	16	16	16	16	16	16	16	16	
logAu	**Pearson Correlation**	-.257	-.565*	-.125	.508*	.659**	.312	.219	-.414	-.327	1
	Sig. (2-tailed)	.336	.023	.646	.045	.006	.240	.415	.111	.216	
	N	16	16	16	16	16	16	16	16	16	16

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5.16. Factor Analysis for gold, silver and base metals in bulk samples.

	Factor 1	Factor 2	Factor 3
logCu	.690	.502	.254
logPb	.907	.015	-.041
logZn	.507	.629	.550
logNi	-.726	.428	.214
logCr	-.534	.642	-.143
logCo	.004	.559	-.644
logCd	-.312	.197	.509
logMn	.859	.145	-.056
logAg	.694	.341	-.355
logAu	-.676	.485	-.173
Total	4.141	1.968	1.268
% of Variance	41.415	19.684	12.681
Cumulative %	41.415	61.099	73.781

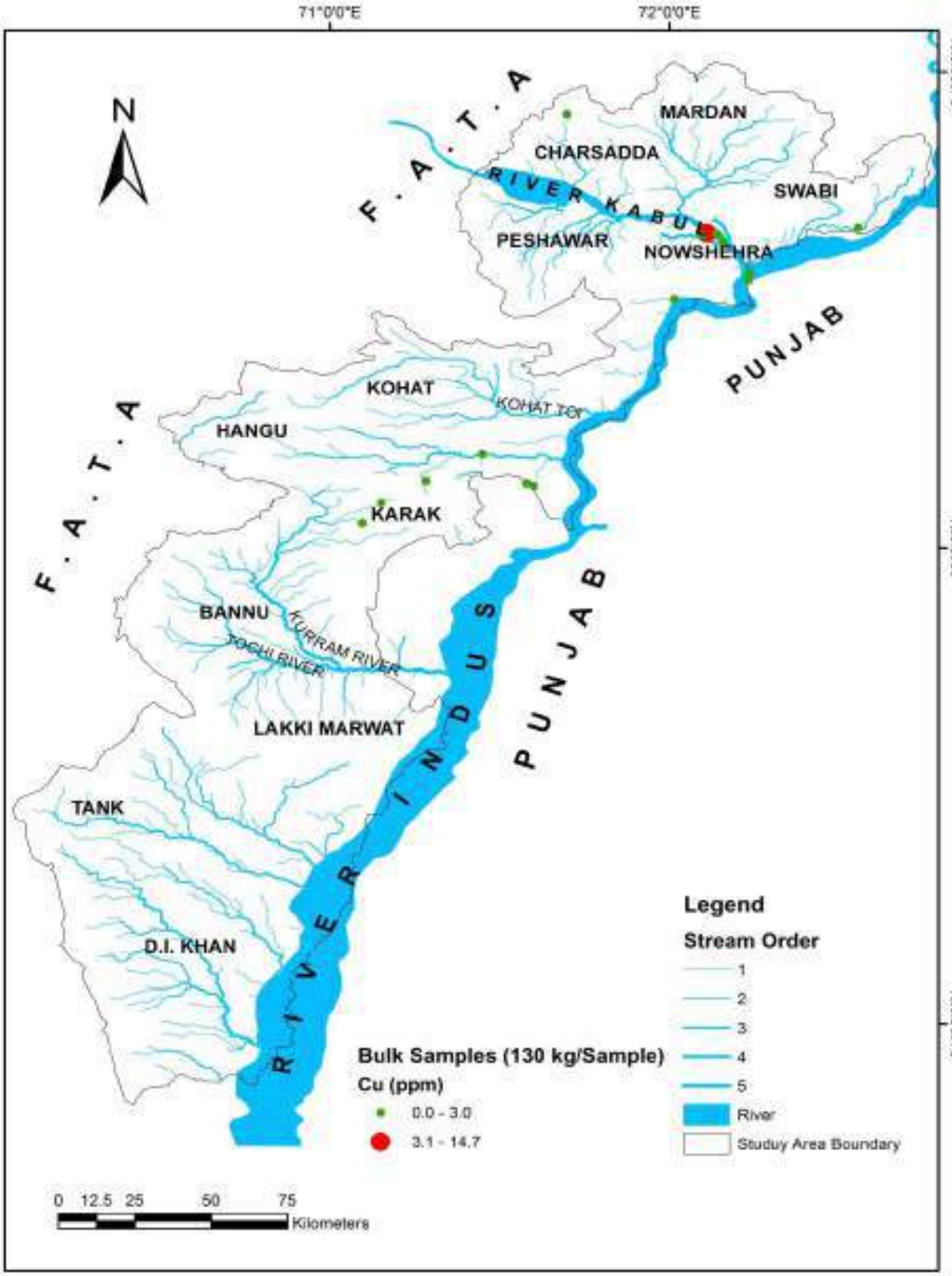


Fig. 5.7(a). Geochemical map of Cu in Bulk samples.

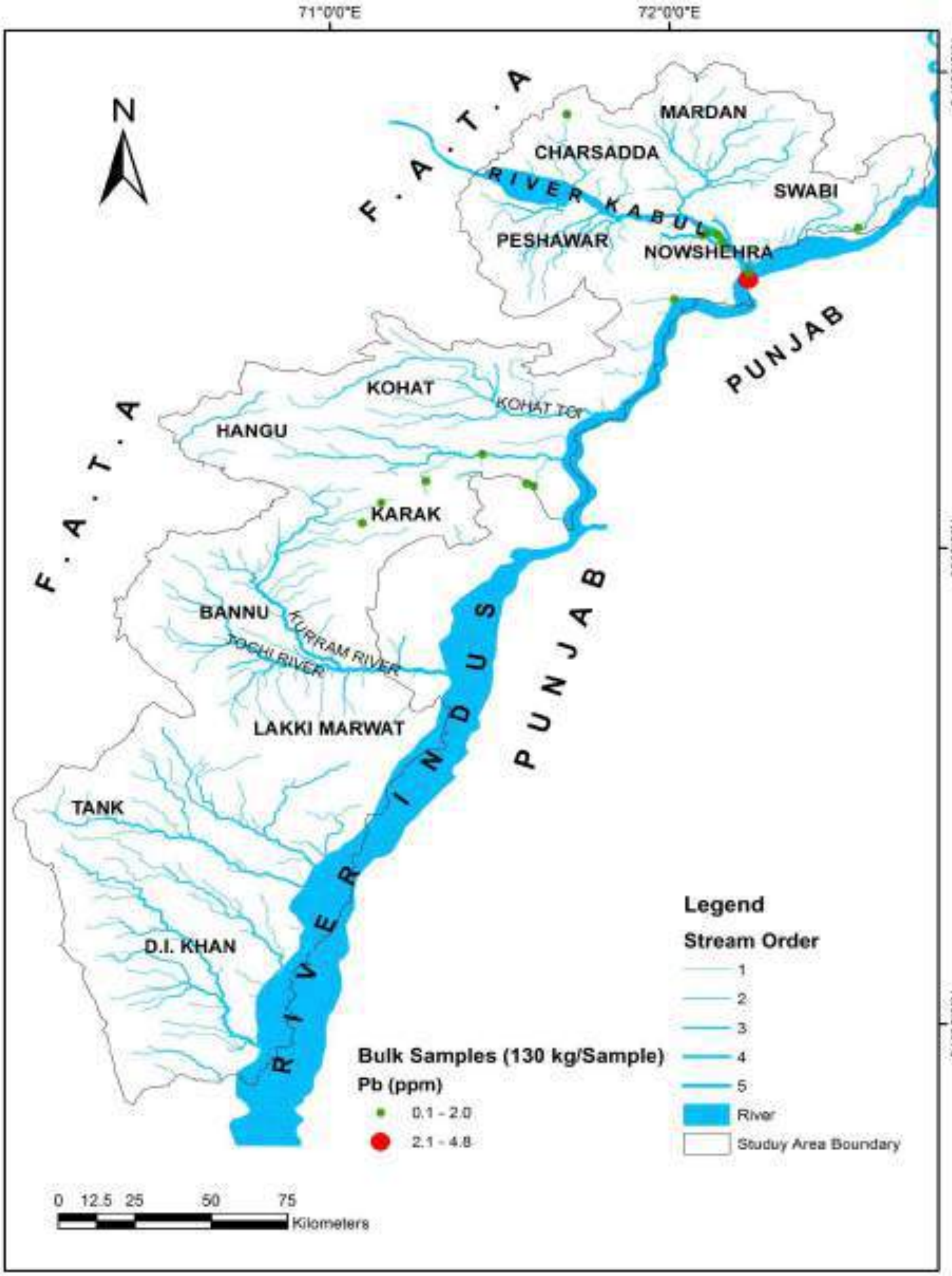


Fig. 5.7(b). Geochemical map of Pb in Bulk samples.

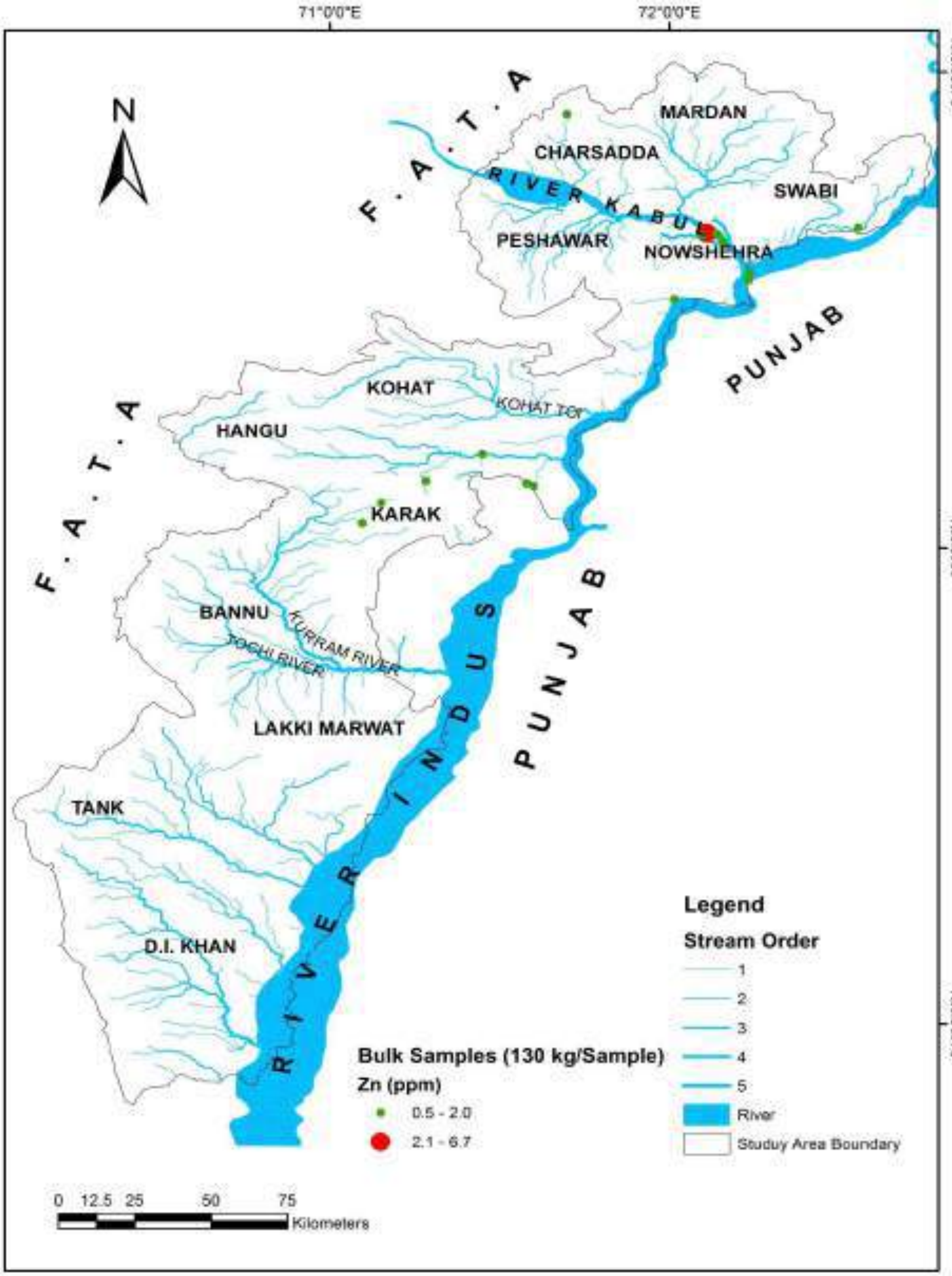


Fig. 5.7(c). Geochemical map of Zn in Bulk samples.

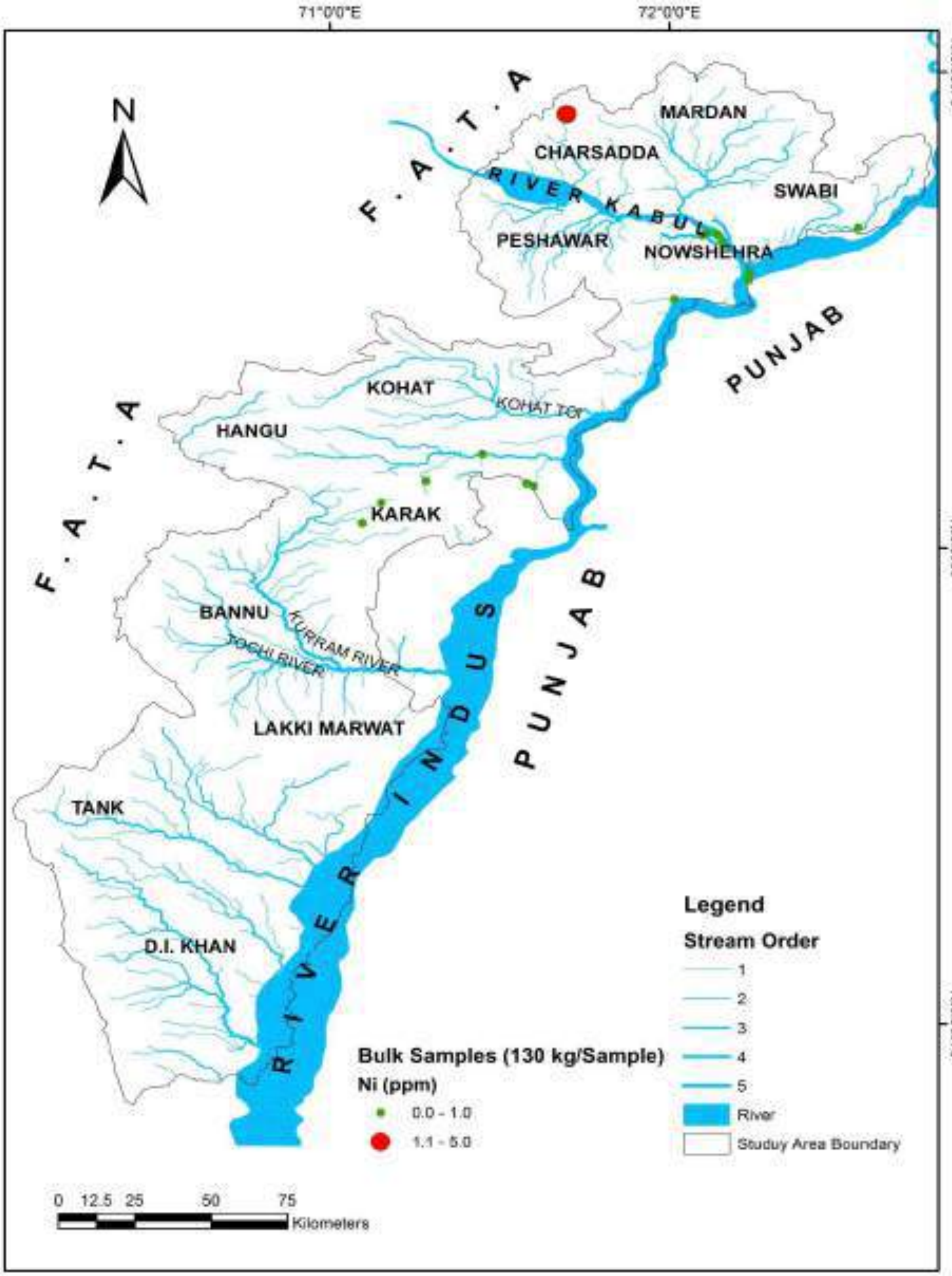


Fig. 5.7(d). Geochemical map of Ni in Bulk samples.

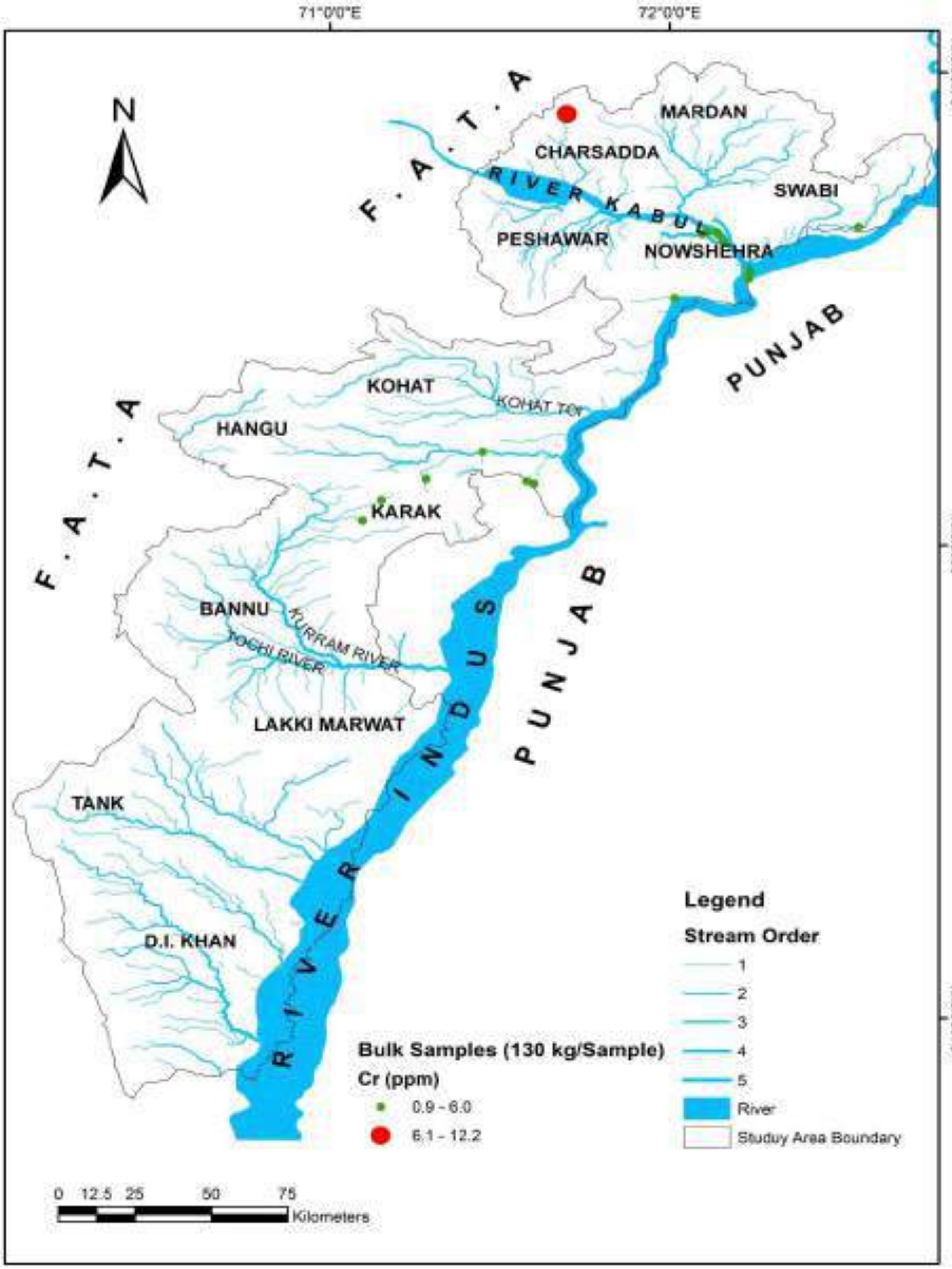


Fig. 5.7(e). Geochemical map of Cr in Bulk samples.

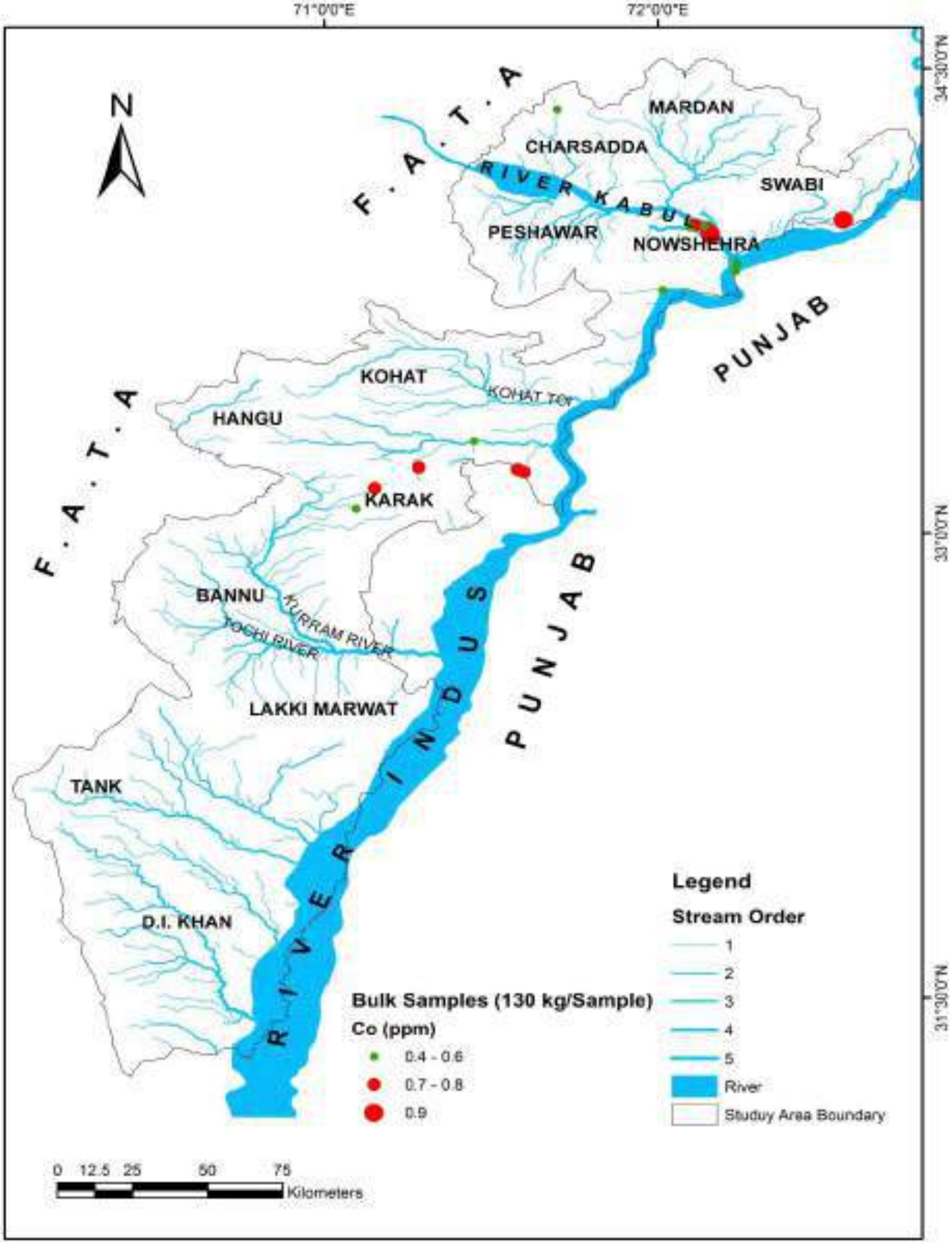


Fig. 5.7(f). Geochemical map of Co in Bulk samples.

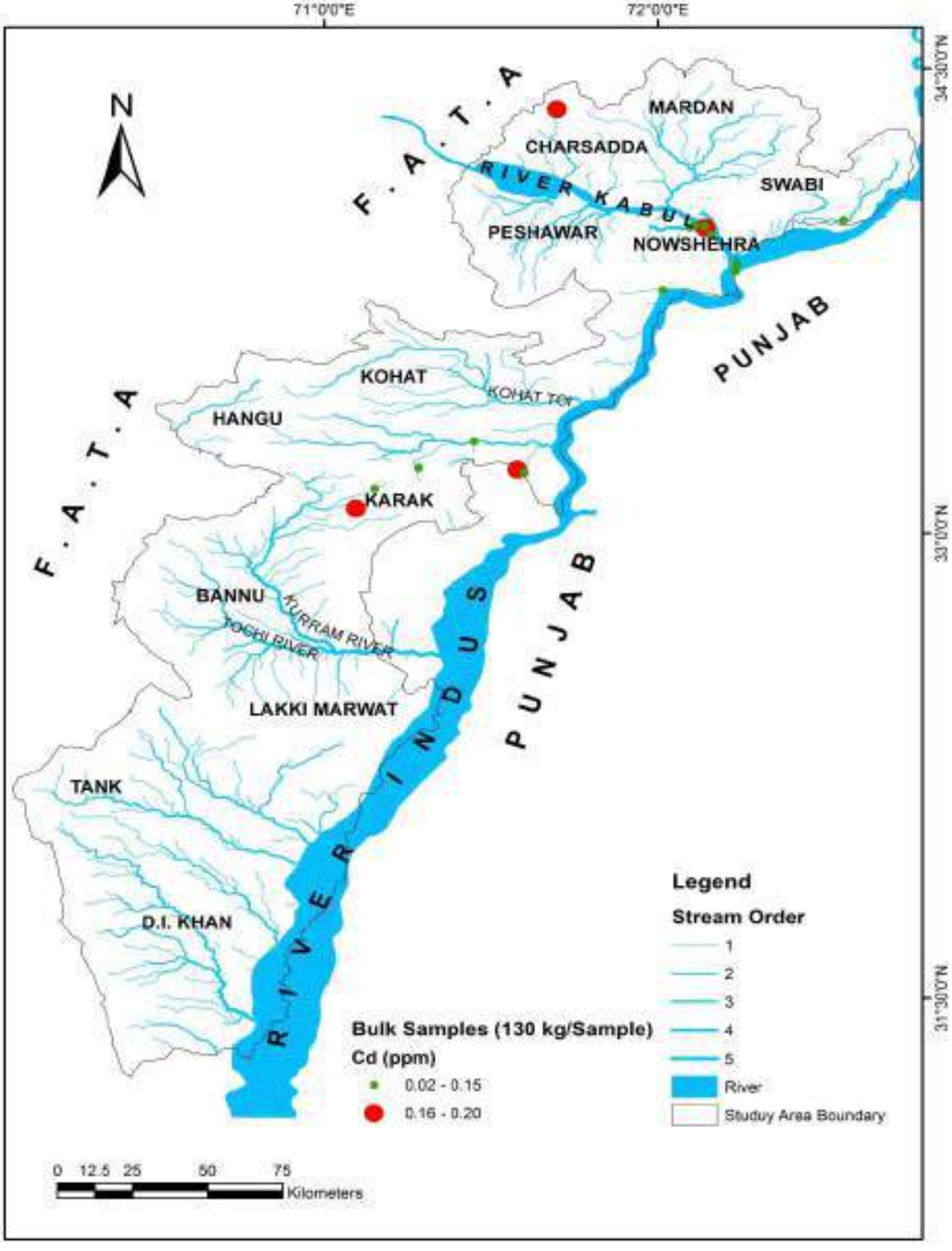


Fig. 5.7(g). Geochemical map of Cd in Bulk samples.

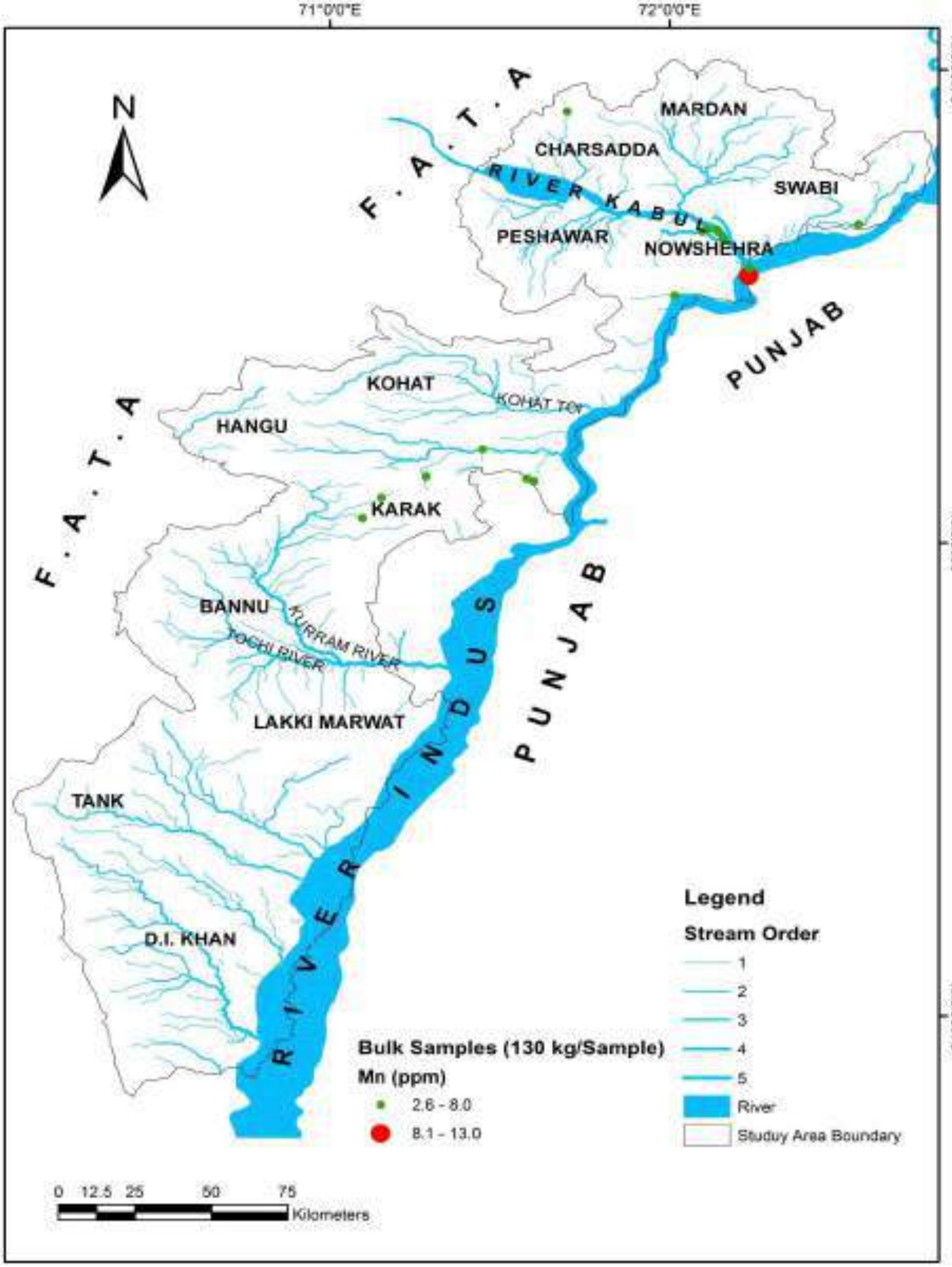


Fig. 5.7(h). Geochemical map of Mn in Bulk samples.

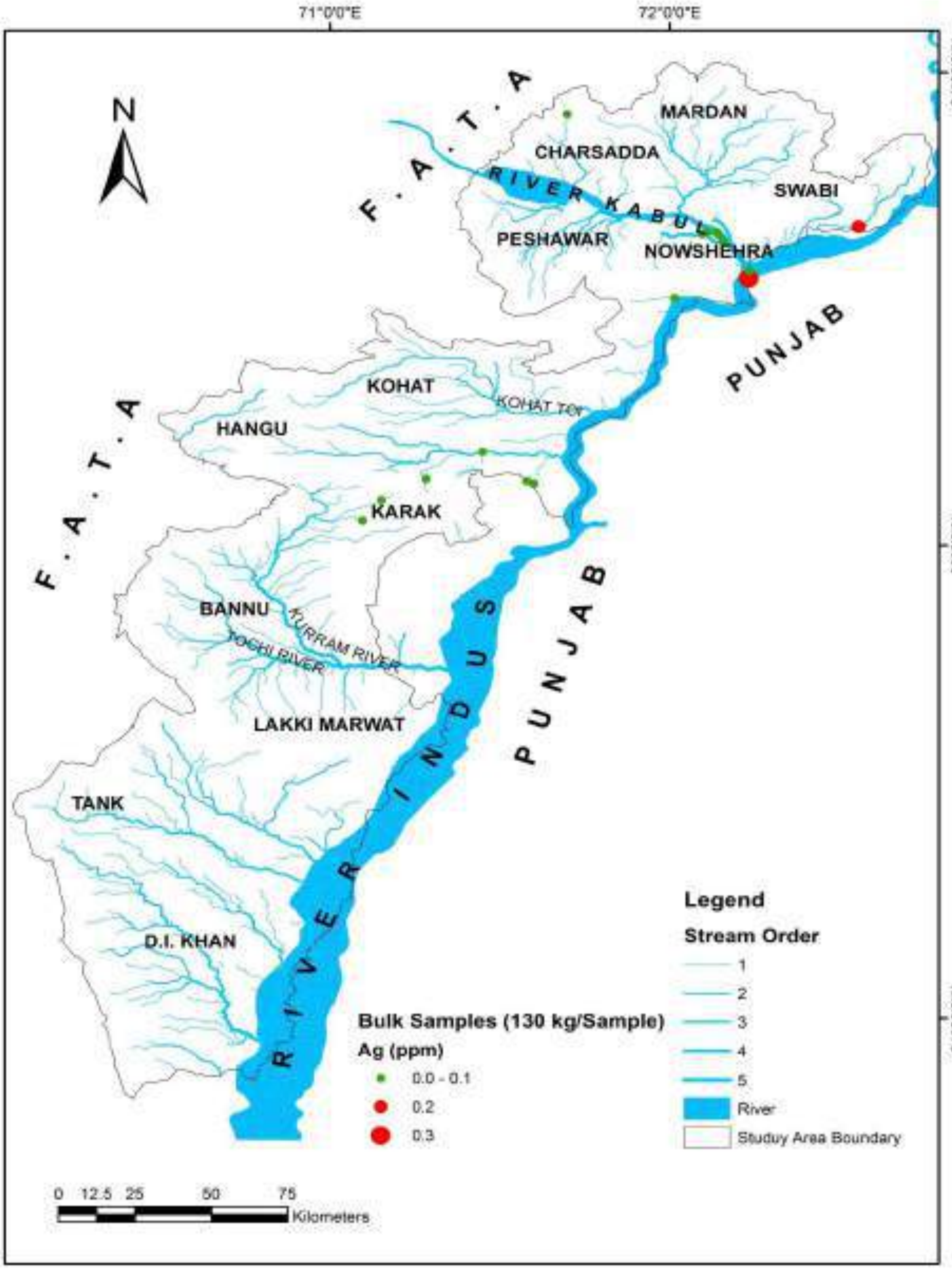


Fig. 5.7(i). Geochemical map of Ag in Bulk samples.

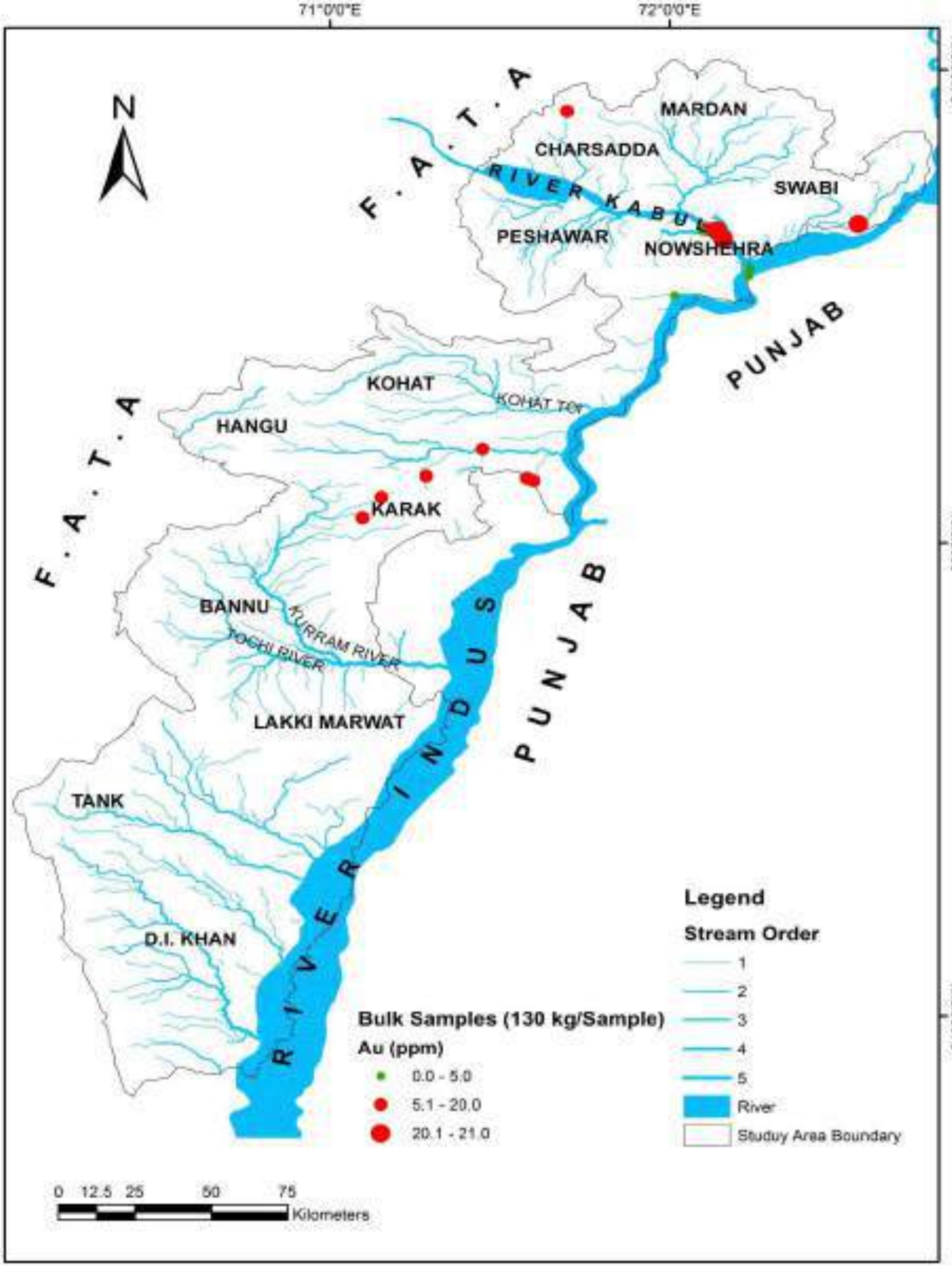


Fig. 5.7(j). Geochemical map of Au in Bulk samples.

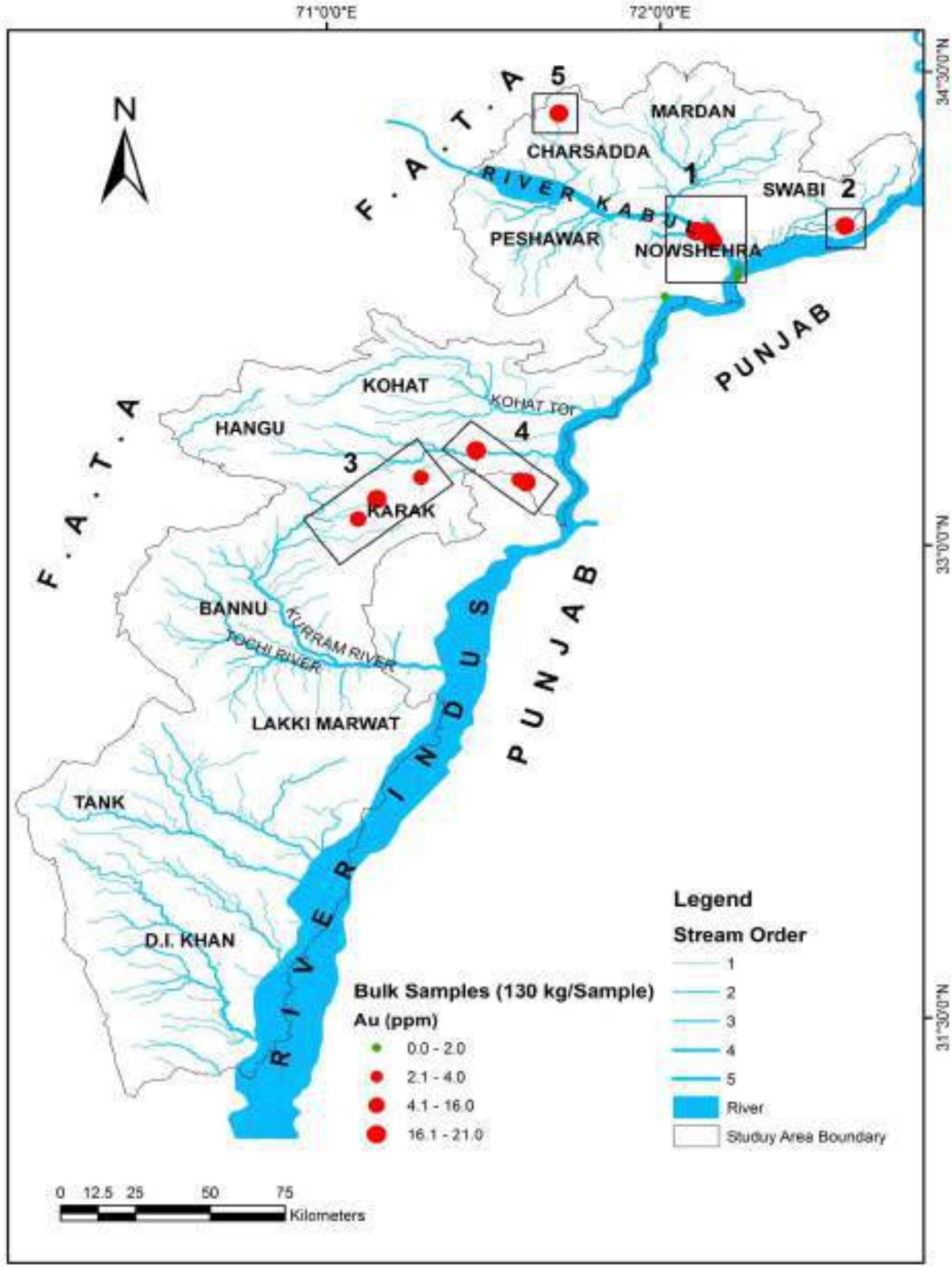


Fig. 5.8. Geochemical map showing various anamolous zones of Au.

CHAPTER 6

REMOTE SENSING AND GEOGRAPHIC INFORMATION STUDIES

6.1 Remote sensing for geological mapping and minerals identification

Satellite remote sensing is an emerging technology, to acquire the information about an exposed surface, without being is physical contact with the object. The electromagnetic energy, induced by sun is composed of varying wavelengths. When this energy passes through the atmosphere and interacts with the exposed ground features, some of the interacted energy is absorbed and remaining is reflected (Fig.6.1).

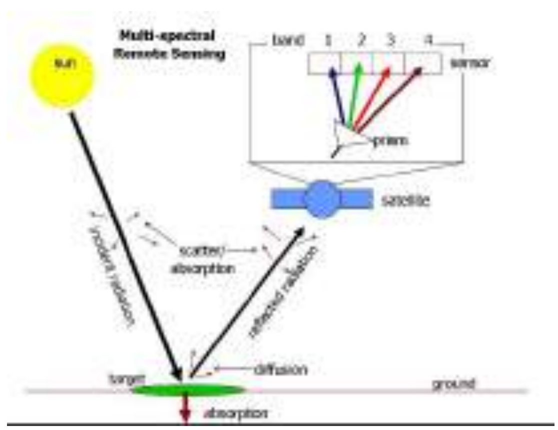


Fig.6.1. Process of satellite remote sensing to acquire multi-spectral image

The exact wavelengths of the sunlight absorbed and the degree of absorption of the energy both depends on the nature of the reflecting ground feature. The wavelength absorbed and the degree of absorption is unique to most of the minerals and lithological and stratigraphic units (Fig.6.2b). The reflected energy from the earth feature propagates again through the atmosphere and is being recorded by the sensors mounted on satellites. The sensors mounted on satellites record the reflected energy for a specific feature, indicating the wavelength and degree of absorbed energy, and provide these information's for a large area in the form of a satellite imagery (Fig.6.2c). For a specific rock or mineral the amount of reflected energy can be compared with it wavelength in the form of a spectral reflectance curves (Fig.6.2b). The spectral reflectance can be acquired from the field (Fig.6.2a) at the site of known rock or minerals using Spectrometer or directly from image knowing the exact location of the rock or minerals. Moreover, the unique spectral curve for different mineral and lithology are compiled in the spectral libraries that can be used carefully in other areas. Using the same concept, the spectral reflectance of the known rock and minerals can be applied to satellite images (Fig.6.2c) to discover similar minerals in any other locations (Fig.6.2d).

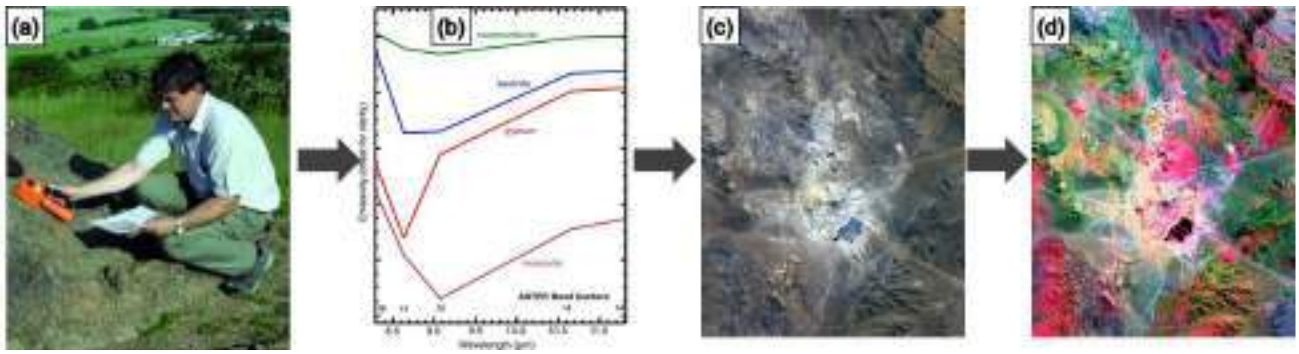


Fig.6.2. Methodology to use remote sensing for minerals exploration and lithological mapping

Modern technologies of GIS and satellite remote sensing, are effectively and efficiently used for seamless mapping of lithology and minerals over a large area (Hewson et al., 2005; Pour and Hashim 2011; van der Meer et al., 2012; Molan et al., 2014). Mapping surface mineralogy using remote sensing sensors provides an opportunity to improve the knowledge of regional lithology and initial steps of minerals exploration (Rowan and Mars, 2003; Fu et al., 2007; Gabr et al., 2010; Dalm et al., 2014; Salati et al., 2014). In the present study we have used the ASTER and Landsat 8 sensors to evaluate their applicability for geological mapping in the project area.

6.2 ASTER

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite sensor launched by NASA-USA presents unprecedented opportunities for lithological mapping and mineral exploration (Rowan et al., 2006; Caccetta et al., 2013; Rajendran and Nasir, 2014). ASTER sensor is a multispectral imaging system, launched during December 1999 travels in a near circular, sun-synchronous orbit with an inclination of approximately 98.2°,an altitude of 705 km and a repeat cycle of 16 days. It measures visible reflected radiation in three spectral bands (VNIR between 0.52 and 0.86 lm, with 15-m spatial resolution) and infrared reflected radiation in six spectral bands (SWIR between 1.6 and 2.43 lm, with 30-m spatial resolution) (Table 6.1). It records the data in band 3B (0.76–0.86 lm) with a backward looking angle that enables the calculation of digital elevation models (DEM). In addition, it measures emitted radiation in five spectral bands in the thermal infrared region between 8.125 and 11.65 lm, with 90-m spatial resolution (Table 6.1). The increase of spectral bands in the SWIR region (one spectral band for Landsat versus six spectral bands for ASTER) enhances the surface mineralogical and lithological mapping. The ASTER images of Level 1B were acquired for the project area from the ERDAC.

Table6.1. Bands characteristics of the ASTER sensor

Band	Label	Wavelength (µm)	Resolution (m)	Nadir or Backward	Description
B1	VNIR_Band1	0.520–0.600	15	Nadir	Visible green/yellow
B2	VNIR_Band2	0.630–0.690	15	Nadir	Visible red
B3	VNIR_Band3N	0.760–0.860	15	Nadir	Near infrared
B4	VNIR_Band3B	0.760–0.860	15	Backward	
B5	SWIR_Band4	1.600–1.700	30	Nadir	Short-wave infrared
B6	SWIR_Band5	2.145–2.185	30	Nadir	
B7	SWIR_Band6	2.185–2.225	30	Nadir	
B8	SWIR_Band7	2.235–2.285	30	Nadir	
B9	SWIR_Band8	2.295–2.365	30	Nadir	
B10	SWIR_Band9	2.360–2.430	30	Nadir	
B11	TIR_Band10	8.125–8.475	90	Nadir	Long-wave infrared or thermal IR
B12	TIR_Band11	8.475–8.825	90	Nadir	
B13	TIR_Band12	8.925–9.275	90	Nadir	
B14	TIR_Band13	10.250–10.950	90	Nadir	
B15	TIR_Band14	10.950–11.650	90	Nadir	

6.3 Landsat 8

Landsat 8 is an American Earth observation satellite launched on February 11, 2013. It is the eighth satellite in the Landsat program; the seventh to reach orbit successfully. Originally called the Landsat Data Continuity Mission (LDCM), it is a collaboration between NASA and the United States Geological Survey (USGS). NASA Goddard Space Flight Center provided development, mission systems engineering, and acquisition of the launch vehicle while the USGS provided for development of the ground systems and will conduct on-going mission operations. The Landsat 8 satellite images the entire Earth every 16 days in an 8-day offset from Landsat 7. Data collected by the instruments onboard the satellite are available to download at no charge from GloVis, Earth Explorer, or via the Landsat Look Viewer within 24 hours of reception. Landsat 8 carries two instruments: The Operational Land Imager (OLI) sensor includes refined heritage bands, along with three new bands: a deep blue band for coastal/aerosol studies, a shortwave infrared band for cirrus detection, and a Quality Assessment band (Table 6.2). The Thermal Infrared Sensor (TIRS) provides two thermal bands (Table 6.2). These sensors both provide improved signal-to-noise (SNR) radiometric performance quantized over a 12-bit dynamic range. (This translates into 4096 potential grey levels in an image compared with only 256 grey levels in previous 8-bit instruments.) Improved signal to noise performance enable better characterization of land cover state and condition. Products are delivered as 16-bit images (scaled to 55,000 grey levels).

Table6.2. Bands characteristics of the Landsat 8 sensor

Spectral Band	Wavelength	Resolution
Band 1 - Coastal / Aerosol	0.433 - 0.453 µm	30 m
Band 2 – Blue	0.450 - 0.515 µm	30 m
Band 3 – Green	0.525 - 0.600 µm	30 m
Band 4 – Red	0.630 - 0.680 µm	30 m
Band 5 - Near Infrared	0.845 - 0.885 µm	30 m
Band 6 - Short Wavelength Infrared	1.560 - 1.660 µm	30 m
Band 7 - Short Wavelength Infrared	2.100 - 2.300 µm	30 m
Band 8 – Panchromatic	0.500 - 0.680 µm	15 m
Band 9 – Cirrus	1.360 - 1.390 µm	30 m

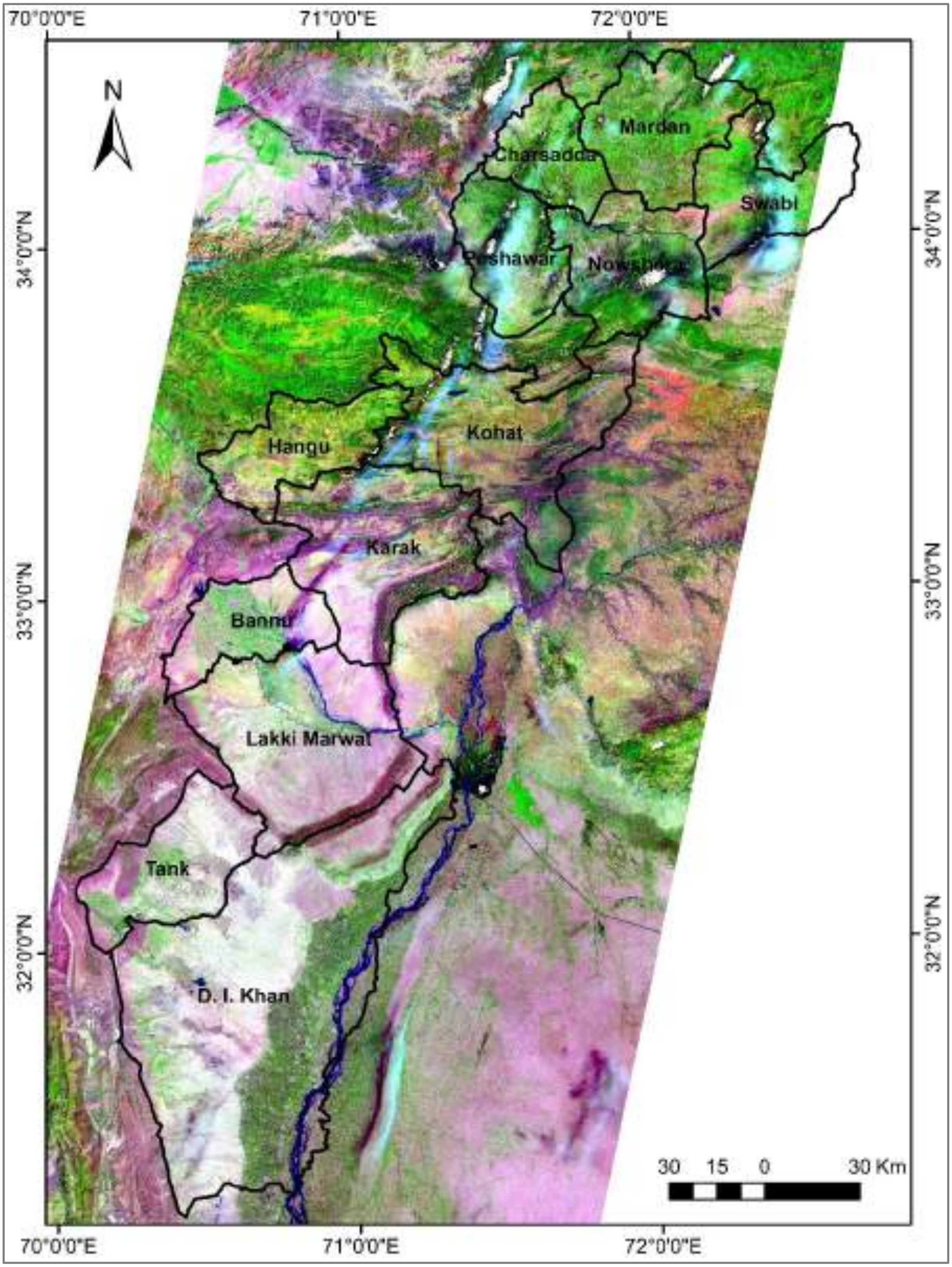


Fig. 6.3. Landsat 8 image of the study area. The image is RGB combination of 7, 5 and 4 bands, respectively.

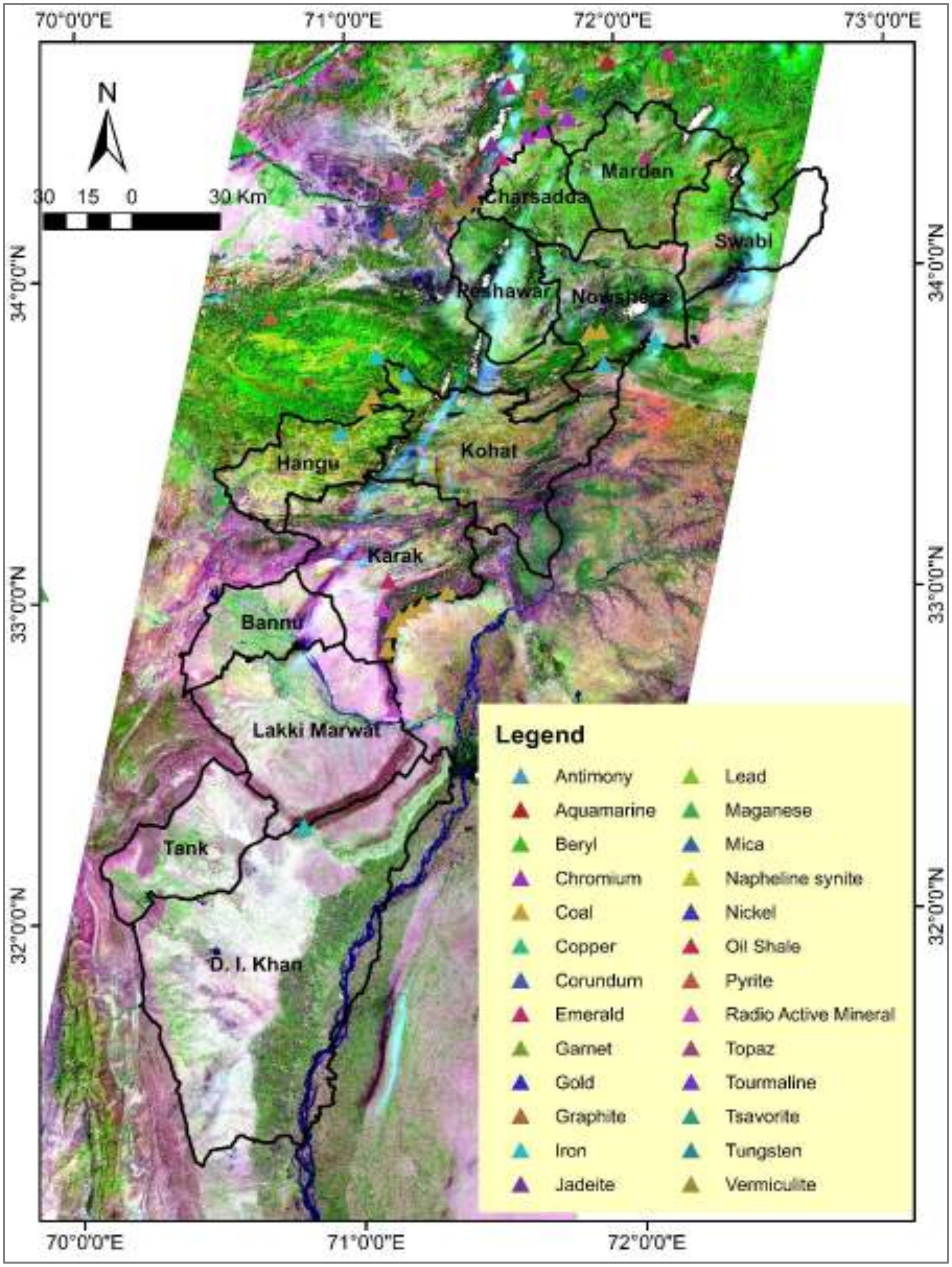


Fig. 6.4. The mapped minerals by Geological Survey of Pakistan are overlaid on the Landsat 8 image of the study area.

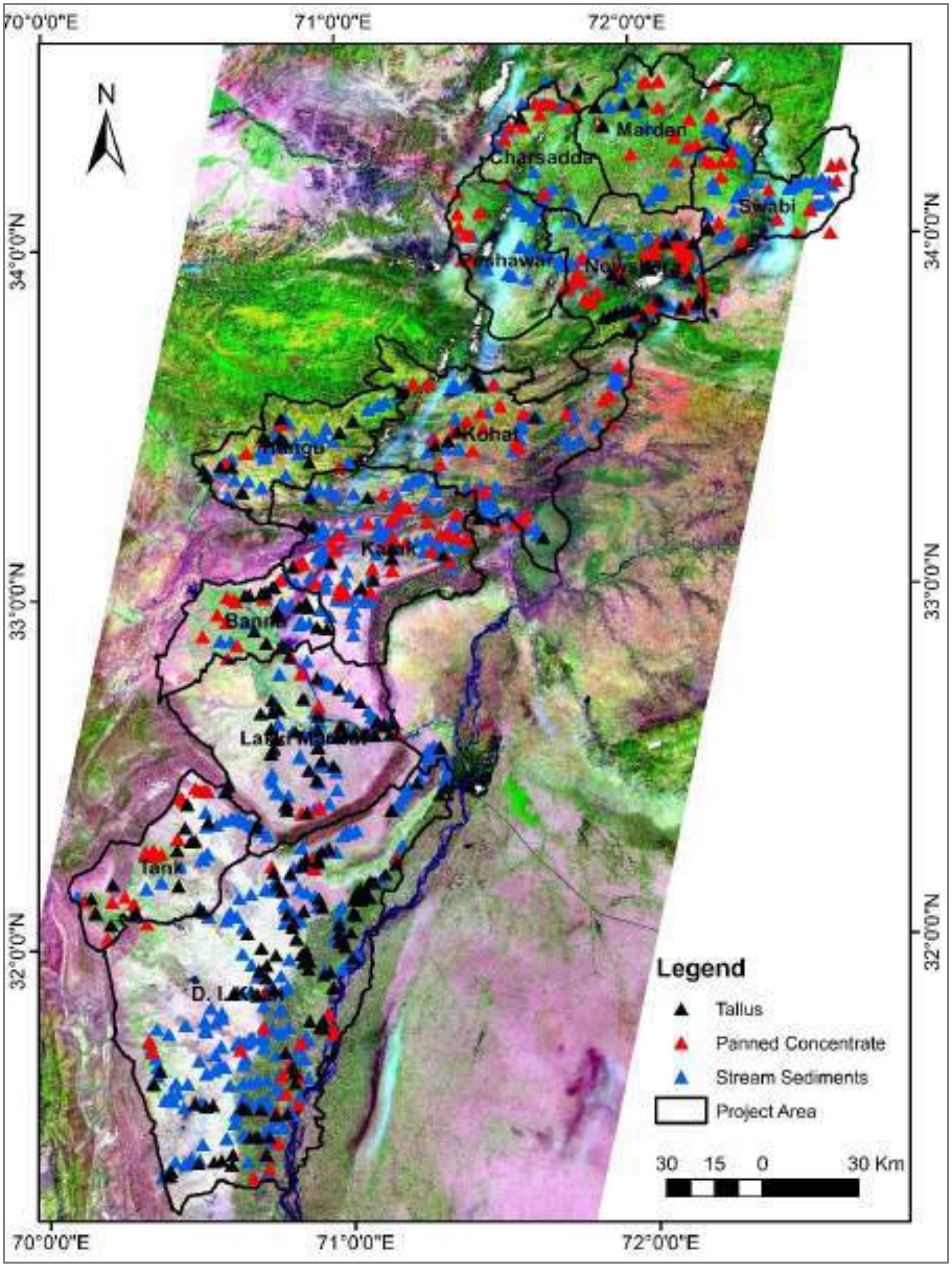


Fig. 6.5. The project collected samples locations are overlaid on the Landsat 8 image of the study area.

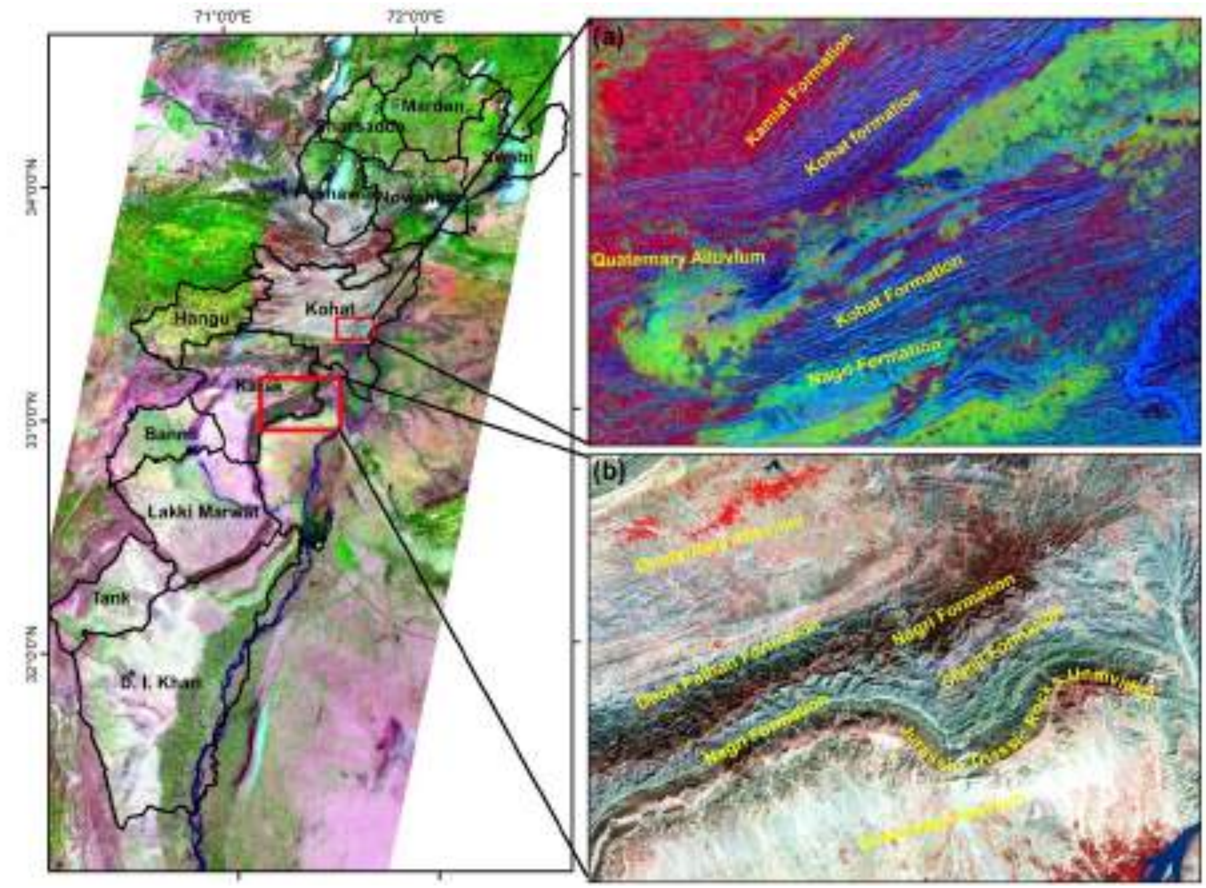


Fig. 6.6. Geological mapping using ASTER images, (a) band ratio of 9/1 (R) 6/8 (G) 1/2 (B) were used to highlight the limestone and other lithologies (b) the band combination of 3-2-1 as RGB discriminate between different geological formations

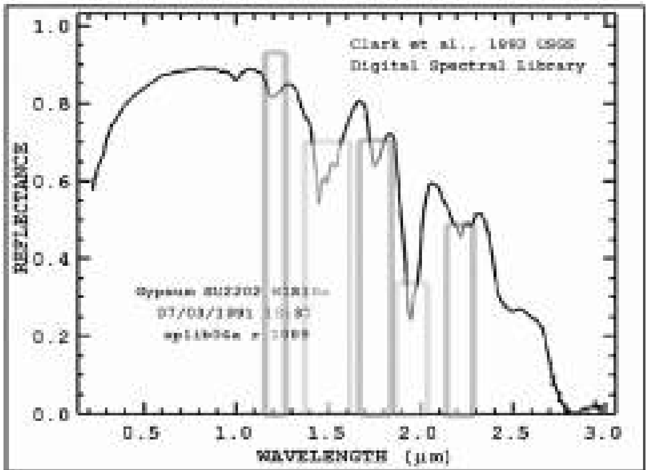
6.4 Remote sensing based Gypsum mapping

Evaporate minerals are very important raw materials in very different and broad industries. One of the extensively used evaporate mineral gypsum is very useful raw material in construction, agriculture, textile, dentistry and chemical industry. Since gypsum became important raw material especially in construction industry as plaster, demand to this mineral raises each following year. The aim of this preliminary work is to map out gypsum by using remote sensing techniques on ASTER images. The analyses are applied using different band ratios, decorrelation stretch and spectral indices through ENVI 5.1 software, to map gypsum and it is seen that it has a high success.

6.4.1 Spectral Properties of Gypsum

Many minerals show diagnostic absorption features in the visible to short-wave infrared range due to either electronic or vibrational processes (Hunt et al., 1971). The vibrational processes are more important in evaporate minerals like gypsum (Crowley, 1991). A sample of USGS Library spectrum of gypsum is shown in figure 6.7 and spectral curve of gypsum and location of different ASTER bands in figure 6.8. The spectrum of gypsum shows major absorption features in VNIR and SWIR regions.

When the spectral reflectance curve of the gypsum is considered according to the band intervals of ASTER image band 4 and band 8 gives high reflectance whereas band 6 and band 9 gives low reflectance (Fig. 6.8). Although the minimum reflectance is near 1.9-2.0 micrometer, there is no ASTER band covering that interval.



Interval	Reason
1.2 µm	H-O-H bending fundamental and the first overtones of the O-H stretch
1.4 - 1.6 µm	first overtone of the O-H stretching fundamental
1.74 µm	the fundamental H-O-H bend, fundamental O-H stretch, low frequency vibration modes of water.
1.9 µm	OH stretching, the H-O-H bending fundamentals
2.2 µm	fundamental O-H stretch, the first overtone of the water

Fig. 6.7. Spectral reflectance curve of Gypsum (USGS Digital Spectral Library) and the absorption intervals of the gypsum mineral (µm) and the causes of the absorption in these intervals.

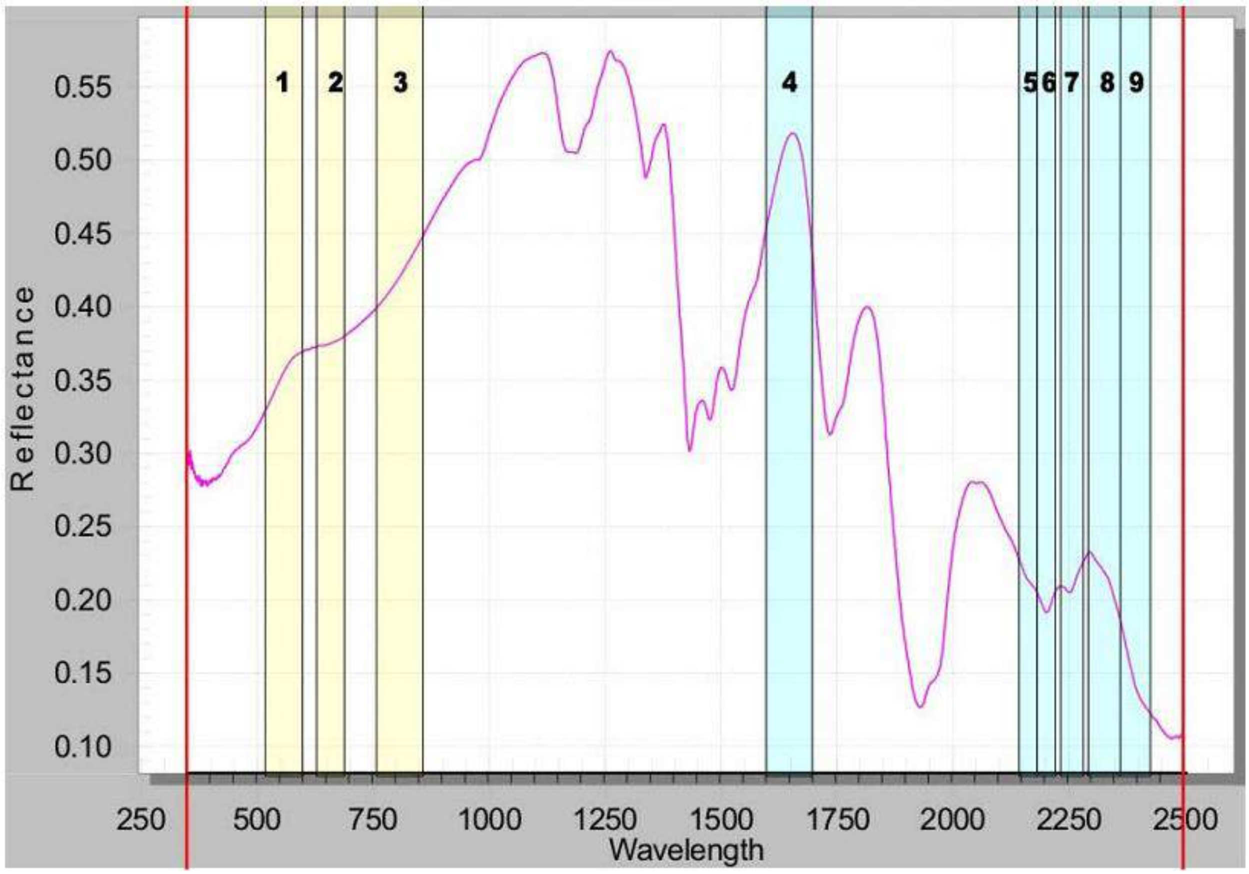


Fig. 6.8. Spectral curve of Gypsum and location of ASTER bands.

6.4.2Techniques of Remote Sensing for Gypsum Mapping

There are various methods for mineral mapping by remote sensing. The most common ones are; Band rationing (BR), principal component analysis (PCA), decorrelation stretch (DS) and spectral indices (SI) methods.

6.4.3 Band Rationing

Band rationing is simply dividing numerical values in one band by those in another for each pixel to produce ratio images and it is widely used technique for discriminating lithologies and other surface cover in a scene. Selection of the bands for band ratio depends on the spectral reflectance properties of the materials you want to distinguish. According to the spectral reflectance curve of gypsum mineral the high reflectance and low reflectance areas are considered so that 4/6, 4/9 and 8/9 band ratios are tried. Since ASTER bands 4 and 8 give high reflectance and bands 6 and 9 give low reflectance first dividing high reflectance bands to low ones are considered. Also using combination of the high reflectance bands 4+8 / 6 and 4+8 / 9 ratios are tried (Fig. 6.9-6.13).

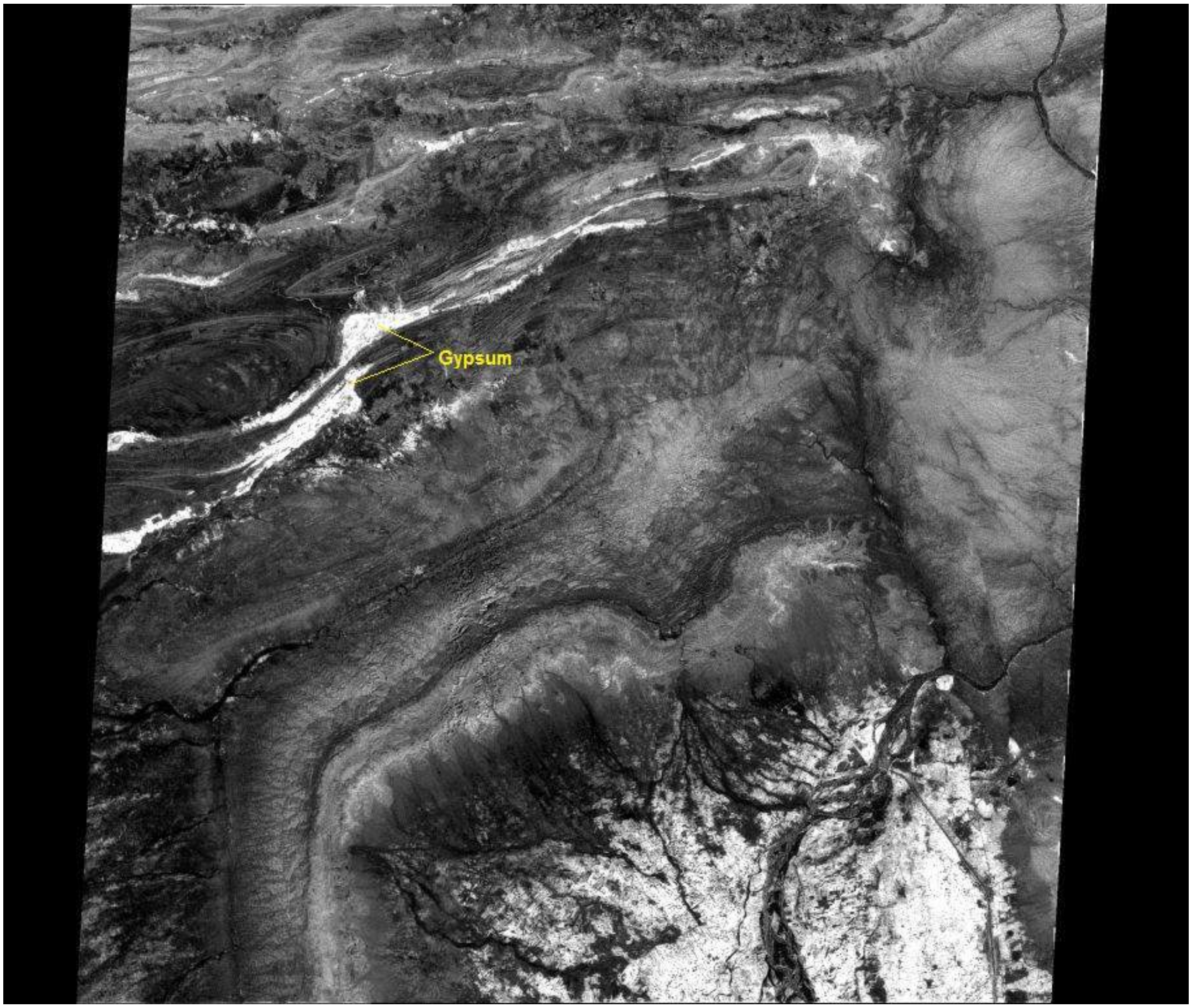


Fig. 6.9. Band ratio 4/6 applied on the image.

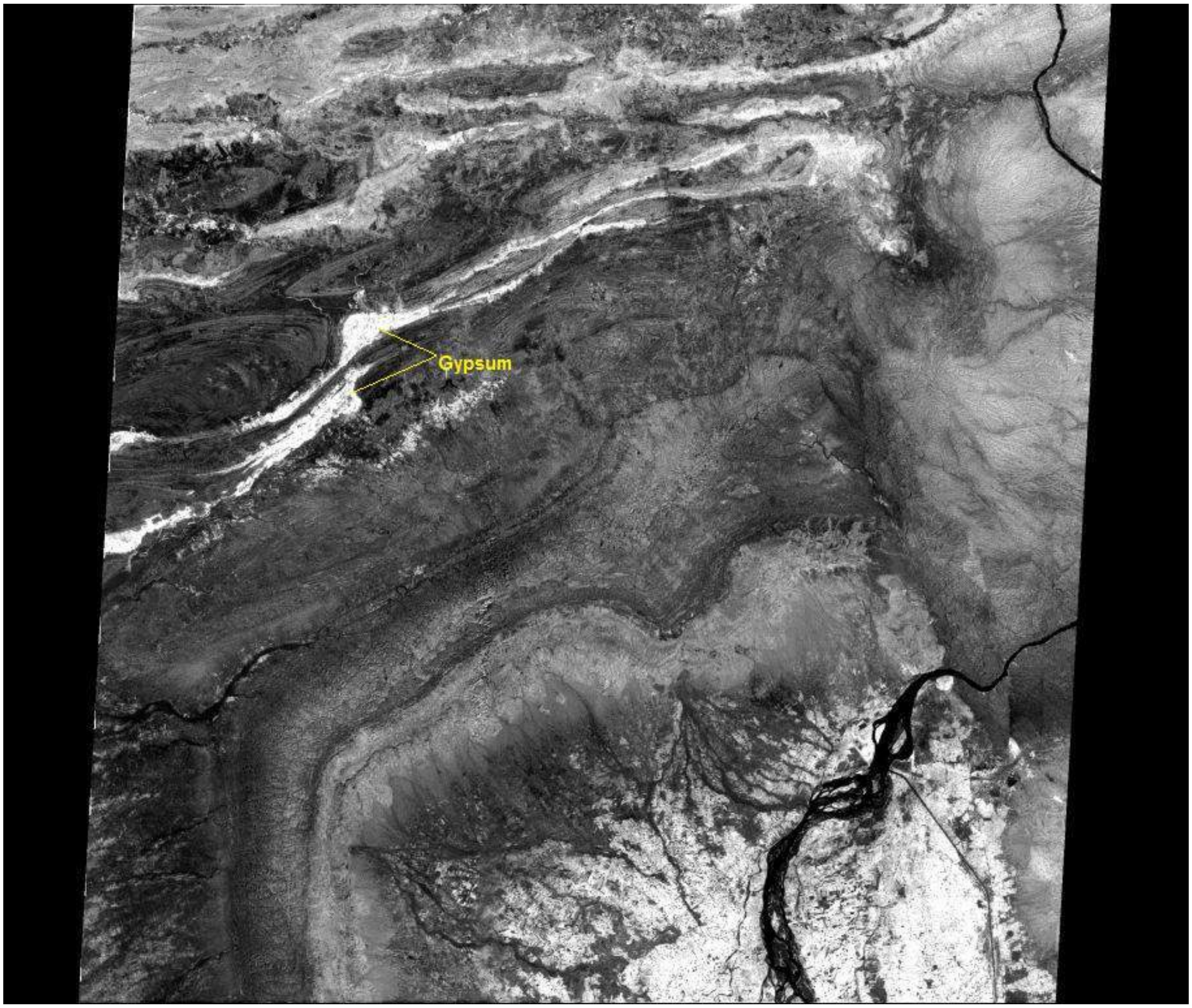


Fig. 6.10. Band ratio 4/9 applied on the image.

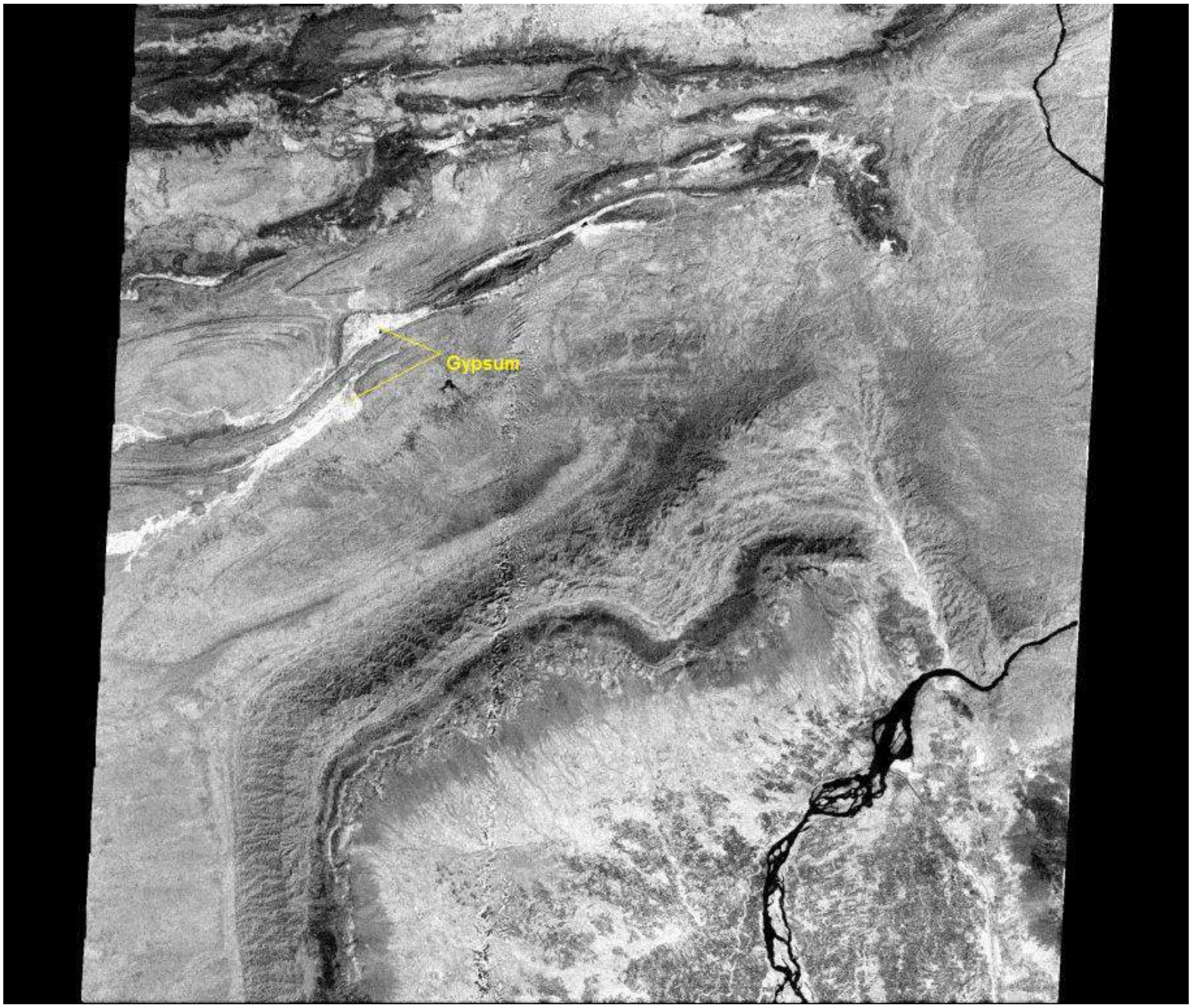


Fig. 6.11. Band ratio 8/ 9 applied on the image.

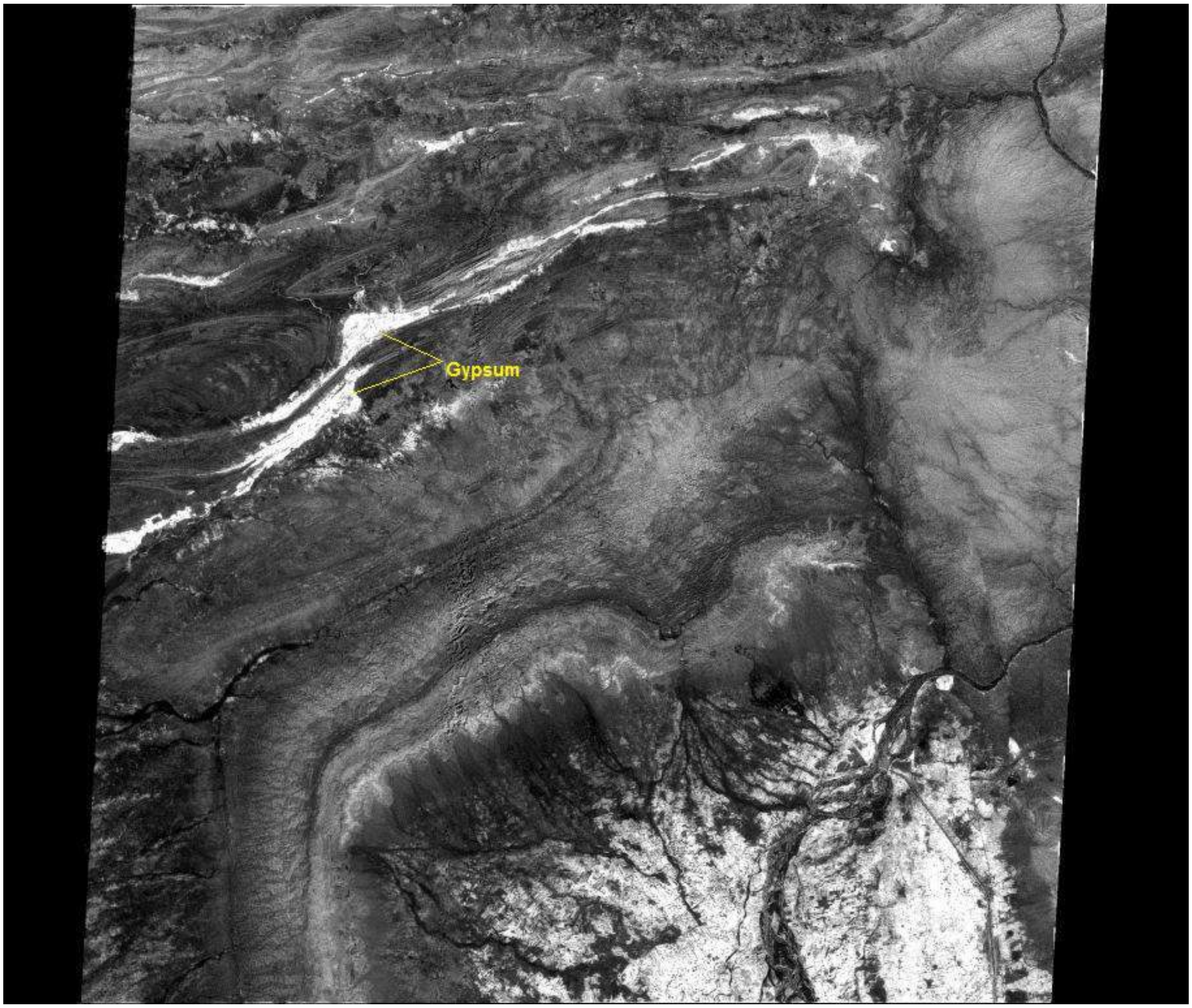


Fig. 6.12. Band ratio 4+8/ 6 applied on the image.

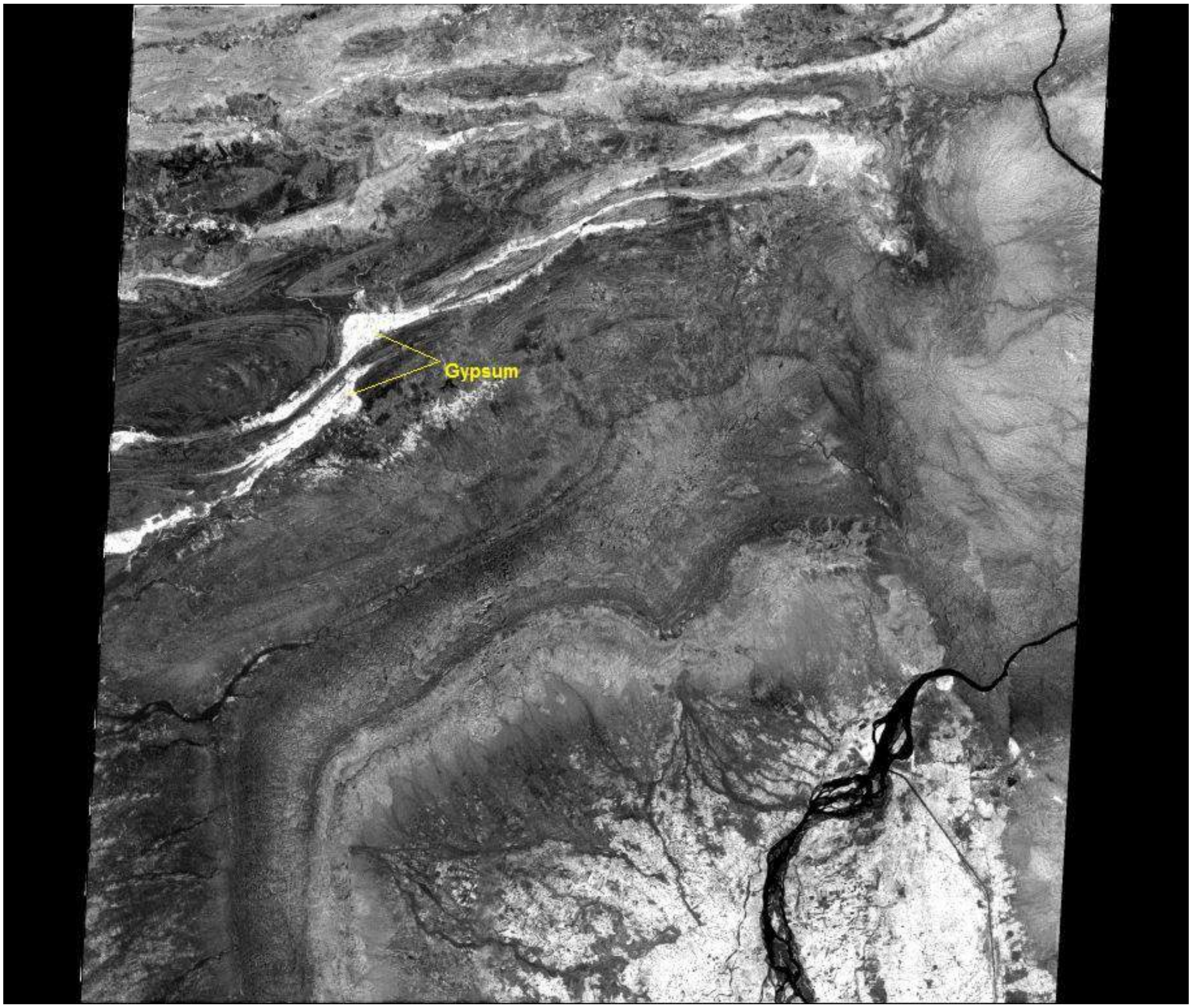


Fig. 6.13. Band ratio 4+8/ 9 applied on the image.

6.4.4 Decorrelation Stretch Analysis

Decorrelation stretch is applied to all bands of ASTER image. First it is applied to VNIR and SWIR bands (9 bands totally) and is applied to TIR bands (5 bands) separately. For the RGB band combination of decorrelated image band 1, 4, 8 combinations can be seen in Fig 6.14. In this combination the yellowish green parts in the middle of the scene most probably show gypsum rich parts since 1, 4, 8 bands gives the highest reflectance in the spectrum.

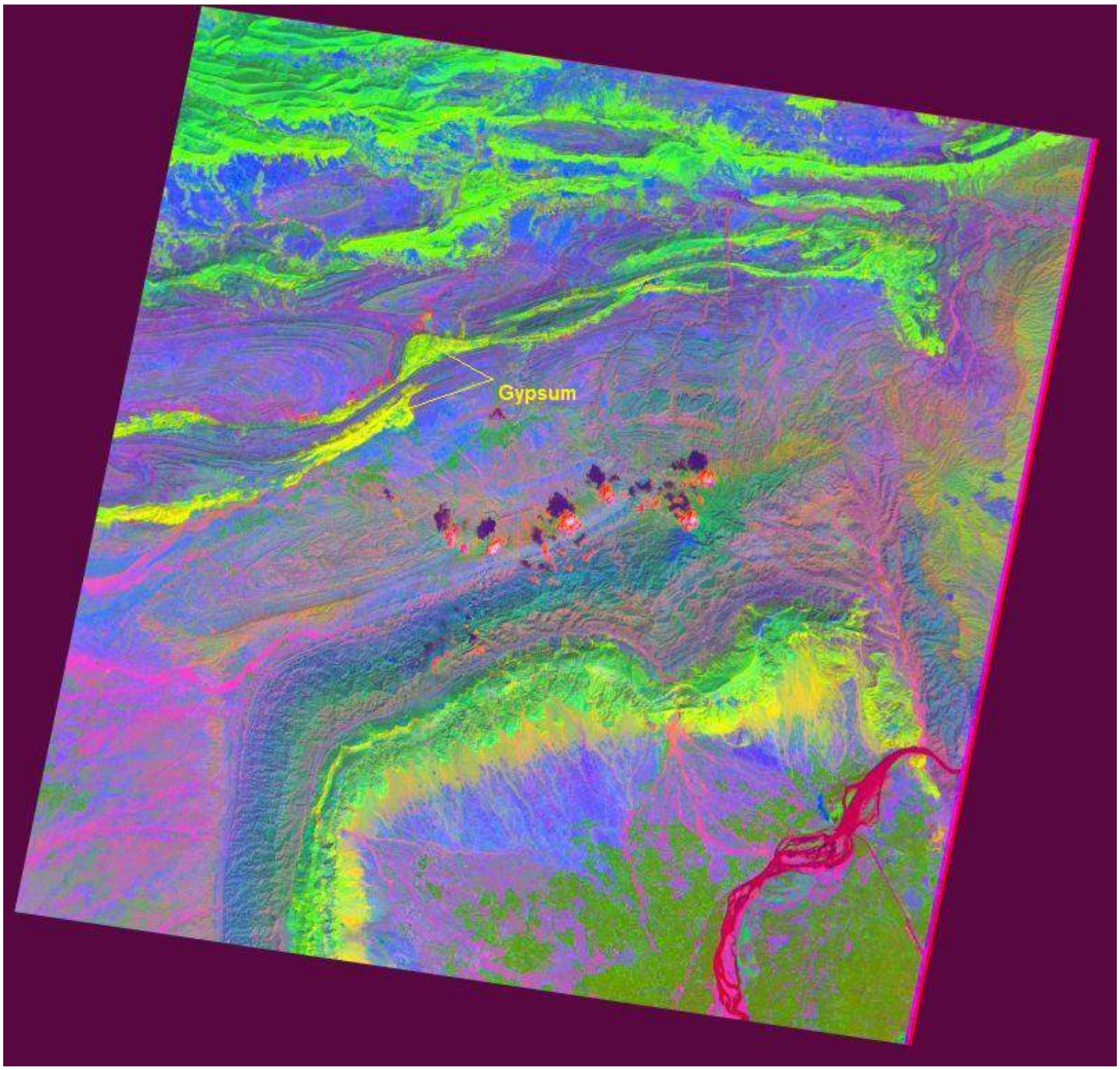


Fig. 6.14. Decorrelated image 1, 4, 8.

6.4.5 Spectral Indices

For ASTER images both for SWIR and TIR bands some indices are calculated by different researchers. Yamaguchi and Takeda (2003) defined alunite, kaolinite, calcite, brightness indices in SWIR region. Ninomiya (2002) defined quartz, carbonate and silica indices in TIR region of ASTER and discussed the possibility of mapping quartz, carbonate minerals and silicate rocks with them.

Spectral indices method is very useful method to get information about certain minerals from satellite imagery. Sulfate index defined by Öztan (2008) is:

$$\text{Sulfate Index} = \frac{\text{Band 10} * \text{Band 12}}{\text{Band 11} * \text{Band 11}}$$

The resultant image can be seen in Figure 6.15 in which the brighter parts show the gypsum minerals.

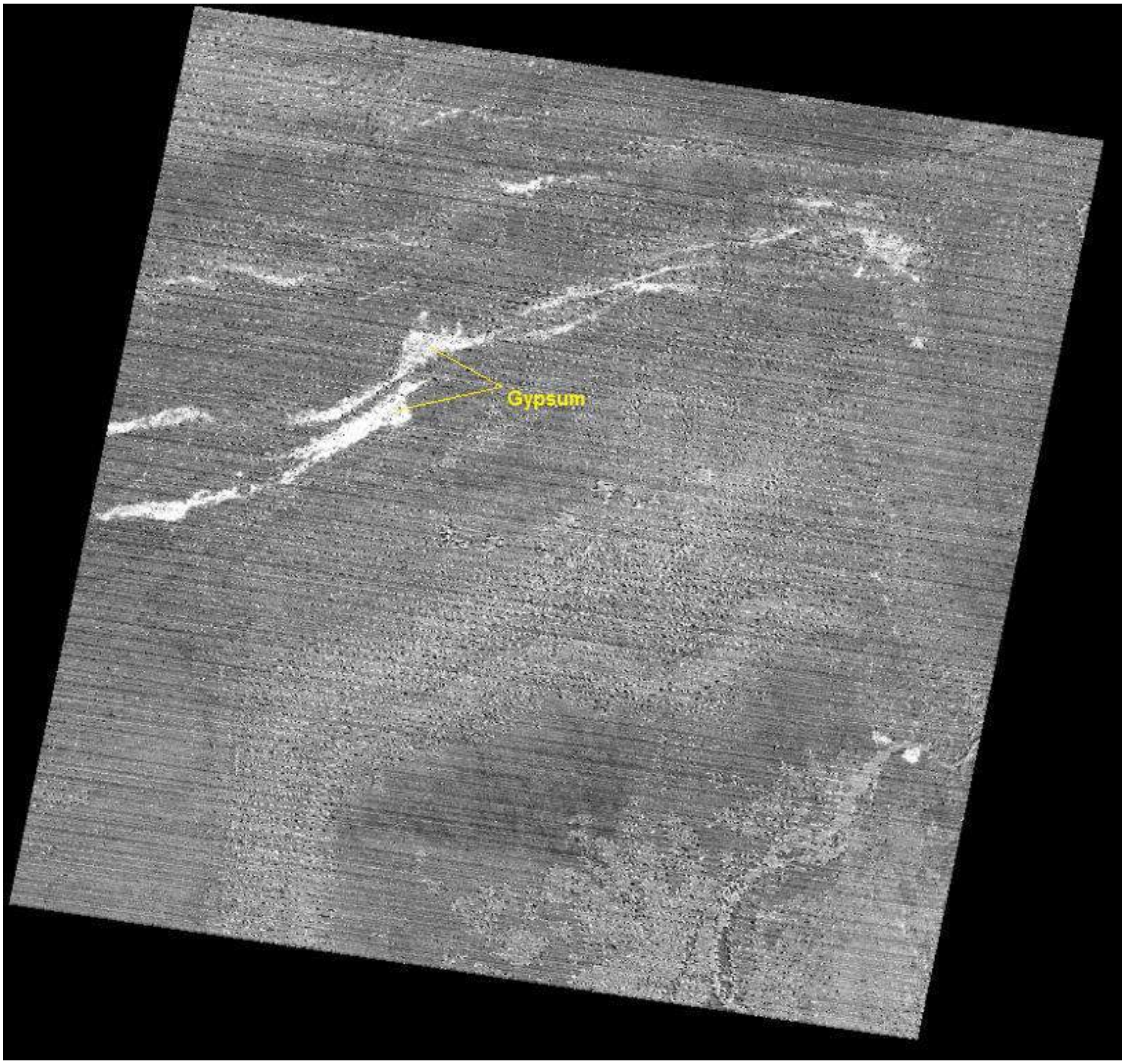


Fig. 6.15. The resultant image of Sulfate index method.

6.5 Discussion

The methods of band ratio, decorrelation stretch, and Sulfate index are cross-checked with the geological map of the area. For the recommended band ratios for gypsum mapping is 4\6 and 4+8/ 6. Also for decorrelation stretch method among all RGB combinations 1, 4, 8 combination somehow fits with the geological map. However the most successful method is Sulfate index which best fits with the geological map of the area.

CONCLUSIONS

The geochemical exploration survey was carried out during the PC-II scheme Project of Directorate General Mines and Minerals, Khyber Pakhtunkhwa. Whereby, total of 2,142 samples including 1,323 stream sediments (-80 mesh), 330 pan-concentrate, 318 tallus/quaternary sediments, 16 bulk samples of pan-concentrate and 155 rock samples were collected. The collected samples were studied for mineralogical study of heavy minerals concentrates and geochemical dispersion of gold, silver and base metals. The TOR based studies of the project area have been completed in five phases. These were 1) covering the orientation studies in the Phase 1, 2) carrying out exploration activities in Peshawar Basin, Kohat and Bannu Division, and Dera Ismail Khan Division in Phase 2, 3 and 4 respectively and 3) the compilation of the data in consolidated form and the submission of Final Report in Phase 5.The following conclusions have been drawn through this study:

- Peshawar Basin, comprising of Peshawar, Swabi, Nowshera, Charsada and Mardan districts, is located in the Lesser Himalayas and is surrounded by Attock-Cherat Ranges and Indus River to the south eastern side, metamorphic terrain to the north, sedimentary fold belt to the south and Gandghar Range lies to the east of Peshawar basin.
- The Kohat and Bannu divisions, comprising of five districts of Kohat, Hangu, Karak, Bannu and Lakki Marwat, are a part of the Kohat-Bannu Basin. This is mainly composed of Hill Ranges, Kuram-Waziristan Ranges, Trans Indus Ranges and the Kohat Plateau.
- The D.I. Khan Division is mainly composed of the rocks of Khisor, Marwat, Bhittanni and Waziristan-Sulaiman Ranges. The rocks of the Khisor, Marwat, and Bhittanni Ranges are mainly comprised of Siwalik Group rocks and other Cambrian to Triassic rocks, while the Waziristan-Sulaiman Range is composed of the sedimentary rocks of Quaternary to Jurassic age.

- The visible gold is generally found in the form of colors and specks in the central and southern parts of the project area in both the pan-concentrate and bulk concentrate samples.
- These gold grains are mainly platy (flattened), rounded to sub-rounded and are intensely grooved, pitted and folded which indicate that the source rock for gold is lying in the distal parts of the Himalayan regions.
- The gold particles present in the pan-concentrates samples of Peshawar Basin (mainly Peshawar and Mardan disvisions) have been contributed by the Quaternary sediments brought by the Indus and Kabul rivers. However, the gold particles found in the pan-concentrates of the Karak, Kohat, Tank and D.I. Khan Districts appear to have a source in the paleo-placers of Siwalik rocks of the Kohat Plateau, Khisor, Marwat, and Bhittanni Ranges. The ultimate source of the paleo-placers of Siwalik Molasses seems to be in the Hinterland areas of Himalayas and in the Kohistan Island Arc.
- Green colored amphiboles are commonly occurring in all the five districts of the Peshawar Basin. They indicate the uplifting and erosion of arc-type rocks and/or derivation from amphibolites, gneisses and granites of the Higher Himalayan rocks. Diagnostic and wide-ranging heavy minerals like garnet, topaz, zircon, tourmaline, amphiboles, epidote, rutile, ilmenite, hematite and magnetite etc. in the pan-concentrates from Peshawar Basin are indicative of erosion from complex sources, including high-grade to contact metamorphic rocks, and acidic to ultra-basic igneous rocks.
- The heavy minerals of Kohat-Bannu Basin including, garnet, zircon, tourmaline, amphiboles, pyroxenes, epidote, ilmenite, and rutile, blue-green hornblende, blue amphibole (glaucophane?), and rarely spinel etc. seem to have a source in the paleo-placers of Siwalik rocks of the Kohat Plateau. Occurrence of chemically unstable minerals like olivine, pyroxene and spinel (chrome?) in the stream sediments of Kurram and Tochi rivers flowing through Bannu Basin indicates

proximity to basic-ultrabasic source(s) in the Khost and the nearby Waziristan Agency (Waziristan Ophiolites).

- The mineralogical studies of heavy mineral concentrates of the various tributaries and other traps suggest that tourmaline, garnet, zircon, apatite, amphibole, magnetite, rutile, hematite, Ilmenite and rarely spinel are the typical heavy minerals of the alluvial sediments of the D. I. Khan Division having source areas in the western Sulaiman Range and in the paleo-placers of Siwalik Rocks of the Marwat, bhittanni and Khisor Ranges. The ultimate source of the paleo-placers of Siwalik Molasses is the Hinterland areas of Himalayas.
- Thin section study of the hosts rocks indicate presence of limestone, marble, quartzite, sandstone, rhyolite, granite, pyroxenite and chromite ore within the Peshawar Basin. These rocks may have contributed towards the deposition of placer gold within the basin. Petrographic study of the thin sections of the rocks indicates that the Lower Siwaliks (Chinji Formation) appear to have been derived from the reworked Eocene carbonates rocks within the region, the Middle Siwaliks (Nagri and Dhok Pathan formations) appears to have been derived from the crystalline rocks of Himalayan Hinterland and the Upper Siwaliks (Soan Formation) seems to have been derived from both the Lower and Middle Siwaliks of the region.
- Spatial data analysis together with statistical analysis was found very useful in the construction of predictive model for Au, Ag and base metal anomalies.Poor correlation between majority of the elements in both stream sediments and pan-concentrates indicate that the majority of the geochemical anomalies are of placer origin, and rarely associated with host rocks.
- The threshold value of each element in pan-concentrates are reported as 80 ppm for Cu, 40 ppm for Pb, 65 ppm for Zn, 200 ppm for Ni, 160 ppm for Cr, 25 ppm for Co, 4.5 ppm for Cd, 450 ppm for Mn, 6.8 ppm for Ag and 2.5 ppm for Au. While in stream sediments these threshold values are set as 45 ppm for Cu, 17 ppm for Pb, 46 ppm for Zn, 200 ppm for Ni, 75 ppm for Cr, 12 ppm for Co, 5 ppm for Cd, 400 ppm for Mn, 3.2 ppm for Ag and 1 ppm for Au.

- Prospective areas for gold on the basis of geochemical maps and statistical analysis includes Nowshera district, some part of Charsadda (Girgichi Khwar) and Swabi (Bada Khwar) districts having catchments in the Dargai Ophiolites (Indus Suture Melange) and Undivided rocks of Korara complex and Gandaf Formation respectively.
- Prospective areas for gold in Karak and Tank districts were also found which shows the potential of Siwalik sandstone and conglomerate for placer deposits.
- The strong anomalies of Cu in stream sediments along Kabul River give some clues about the relative high concentration of Cu may be derived from the upstream regions of the Pakistan and Afghanistan. Overall weak Cu anomalies are present in the study area, except some part of Swabi and Mardan.
- Pan-concentrates proved to be a powerful tool for delineating potential areas for Au, Ag and base metals as compared to stream sediments. In pan-concentrates anomalous values of Ag, Cu, Ni, Cr, Co, and Cd were found, showing a geochemical association of these elements, in the streams originating from Indus Suture Melange (Dargai Ophiolites). However, anomalous concentration of Pb, Zn, Ni, Cr and Co were associated in the stream sediments and alluvial fan sediments of Dargai Ophiolits (Indus Suture Melange) which clearly indicates known mineralization related to Indus Suture Zone in the area. Therefore, the combine effect of both sampling media proved to be an important tool for delineating anomalies.
- Follow up studies in the Prospective areas for gold and other heavy minerals may lead to the discoveries of placers and paleo-placer deposits of a marketable significance in the region.

RECOMENDATIONS

On the basis of the present Geochemical Exploration studies of the Central and southern districts of Khyber Pakhtunkhwa, the following recommendations are made for boosting the mining activities for placer gold in the region:

- Five blocks such as 1, 2, 3, 4 and 5 have been delineated, as discussed in Chapter 5 (Fig. 5.8), on the basis of present Geochemical Exploration studies in the project area where from the placer gold has been reported in economic concentration. Among these blocks, the Block-1 is more economical as compared to the other four blocks. These blocks can further be leased out for mining and extraction of gold by erecting the extraction plants in these blocks.
- With the completion of this Geochemical Exploration project, stream sediment geochemical scanning of the whole Khyber Pakhtunkhwa province has been completed which is an important step in the mineral exploration of the province. Due to this land mark achievement the areas of interest that have been delineated during these studies should be further studied in detail. For this purpose the national and international companies should be encouraged to locate the economic mineral deposits and converting these to be minable products.

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