Indira Gandhi National Open University
School of Sciences

BGYEL – 142
ORE GEOLOGY AND INDUSTRIAL MINERALS: LABORATORY



"शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।"

– इन्दिरा गांधी

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"Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances."

- Indira Gandhi

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IMPORTANT INSTRUCTIONS

- **Attendance** is compulsory in the Laboratory Course work held generally at the Study Centre.
- The Laboratory Course is worth **2 credits** to be completed over 7 **days** duration:
  - **6 days** of **Guided** Laboratory work
  - **1 day** for the **Unguided** Laboratory work
- To successfully complete the laboratory course you will have to pass (at least **35% marks**) in the Guided and Unguided components separately.

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ORE GEOLOGY AND INDUSTRIAL MINERALS: LABORATORY

The course titled **'Ore Geology and Industrial Minerals: Laboratory'** (**BGYEL-142**) is a laboratory-oriented course integrated to the theoretical aspects dealt in the **Ore Geology and Industrial Minerals** course (**BGYET-141**) of the B.Sc. (General) Programme with Geology as one subject. Some of the experiments of this course include activities that can be done in Geology laboratories and few can be done at your home. All the experiments have two or more activities that need to be written in your practical notebook and reported to the academic counsellor after completion. Some of the experiments of this course would require your hands-on involvement in Geology laboratory. The course comprises **11 Experiments** and is worth **2** credits. After performing these experiments, you will gain practical skills in observing, recording and solving various aspects related to ore geology and industrial minerals.

The experiments are based on **Block 3 and 4** of **BGYET-141** course that are related to megascopic and microscopic study of metallic, non-metallic and industrial minerals. **Experiment 1** deals with the megascopic study of common iron ores like hematite, magnetite, limonite, goethite and pyrite. It also deals with megascopic study of common manganese ores like psilomelane and pyrolusite; **Experiment 2** deals with the megascopic study of non-metallic minerals such as garnet, talc, magnesite and gypsum; **Experiment 3** deals with the megascopic study industrial minerals such as calcite, dolomite, asbestos and graphite; and **Experiment 4** also deals with the industrial minerals such as feldspar, quartz, beryl and tourmaline. **Experiment 5** deals with preparation of map showing distribution of metallic mineral deposits in India; **Experiment 6 deals** with the preparation of map showing distribution of non-metallic mineral deposits in India. **Experiment 7** deals with the preparation of map showing distribution of atomic minerals of India.

In addition, **Experiment 8** deals with the preparation of maps showing distribution of important coal and lignite deposits of India. **Experiment 9** deals with the preparation of map showing distribution of hydrocarbon basins of India. In **Experiment 10**, you will learn to recognise microscopic study of common sulphide ore minerals such as pyrite, chalcopyrite, galena and sphalerite. **Experiment 11** deals with the microscopic study of common oxide ore minerals such as hematite, goethite, magnetite, chromite, pyrolusite and psilomelane.

Expected Learning Skills

After performing the experiments of this course, you should be able to:

- identify the physical properties of common iron ores like hematite, magnetite, limonite, goethite and pyrite and manganese ores like psilomelane and pyrolusite.
- identify the physical properties of garnet, gypsum and talc and magnesite.
- recognise industrial minerals such as calcite, asbestos, graphite, dolomite, quartz, beryl, tourmaline and feldspar.
- list and plot spatial distribution of metallic and non-metallic deposits of India;
- list and plot spatial distribution of atomic minerals deposits on the map of India;
- list and plot spatial distribution of gondwana and tertiary coalfields and lignite deposits of India; and
- list and plot spatial distribution of sedimentary basins and important oilfields of India.

- identify the microscopic study of common sulphide ore minerals such as pyrite, chalcopyrite, galena and sphalerite
- know the microscopic study of common oxide ore minerals such as hematite, goethite, magnetite, chromite, pyrolusite and psilomelane

Guidelines for Performing the Experiments

While performing the experiments you must have the relevant blocks of the theory course with you for reference along with this laboratory manual. In many of the experiments, you will find references to the material given at the end.

The **eleven** experiments are to be completed in **six** days of laboratory sessions. Two sessions will be held each day. You will perform the experiments under the **guidance** of your counsellor. These experiments are called **Guided experiments**. The **seventh** day is for the **Term End Examination** in which the assigned experiment will not be guided by the counsellor. The experiment assigned for this purpose is called **Unguided experiment**. Details of the day, session and type of experiment for conduct of all the experiments are given in the table on next page.

Laboratory File / Practical Notebook

Maintaining a complete and up-to-date record of laboratory work is an important part of scientific training. You need to prepare and bring a laboratory file/practical notebook for writing and reporting the experiments you have performed in each practical session. You may use a 100 pages laboratory file / practical notebook for this purpose.

Instruction: Redraw the schematics/ diagrams/ tables given under the section Laboratory Exercises and their answers in your laboratory file/ practical notebook and submit the same to the academic counsellor for evaluation.

laboratory/ classroom/field. For each experiment, you should write down title of the experiment, date and time of the experiment, etc. along with the results obtained and your observations.

You need to submit your practical notebook and other required items, if any, to counsellor for evaluation. Marks will be allocated based on the successful completion of the experiments and recording the results and observations in your notebook in an appropriate manner.

Feedback form is given. Fill it up and send it back to us so that we know what you think about it to help us improve the course.

Your feedback pertaining to this block will help us undertake maintenance and timely revision of the block. Send your feedback to us to the address given below or e-mail to kakoligogoi@ignou.ac.in or mprashanth@ignou.ac.in:

The Course Coordinator BGYEL-142
Discipline of Geology
School of Sciences
IGNOU, Maidan Garhi
New Delhi – 110068 (India)

We hope that after studying and performing the experiments of this course you will acquire basic practical skills to observe, record and solve various problems related to ore geology.

Wishing you success in this endeavour!!

Table: Day, Session and Type for Experiments of BGYEL-141

Titles		Day	Session no.(s)	Type of Experiment
INTRODUCTION		1	I & II	Laboratory or Classroom
GUIDED EXPERIMENTS				
Experiment 1	Megascopic Study of Metallic Minerals			
Experiment 2	Megascopic Study of Non-Metallic Minerals		III	Laboratory or Classroom
Experiment 3	Megascopic Study of Industrial Minerals - I	2	IV	Laboratory or Classroom
Experiment 4	Megascopic Study of Industrial Minerals - II		V	Laboratory or Classroom
Experiment 5	Preparation of Map Showing Distribution of Metallic Mineral Deposits in India	3	VI	Laboratory/ Classroom or at Home
Experiment 6	Preparation of Map Showing Distribution of Non-Metallic Mineral Deposits in India		VII	Laboratory/ Classroom or at Home
Experiment 7	Preparation of Map Showing Distribution of Atomic Mineral Deposits of India	4	VIII	Laboratory/ Classroom or at Home
Experiment 8	Preparation of Map Showing Distribution of Coal and Lignite Deposits of India		IX	Laboratory/ Classroom or at Home
Experiment 9	Preparation of Map Showing Distribution of Hydrocarbon Basins of India	5	X	Laboratory/ Classroom or at Home
Experiment 10	Microscopic Study of Common Sulphide Ore Minerals		XI	Laboratory or Classroom
Experiment 11	Microscopic Study of Common Oxide Ore Minerals	6	XII	Laboratory or Classroom
ASSIGNED UNGUIDED EXPERIMENT		**7**	**XIII**	**Term End Examination**

List of audio / video materials related to this course

1. **Geology around us-Part I**

   Links: https://www.youtube.com/watch?v=F6cglc12wd0&t=301s

   http://egyankosh.ac.in//handle/123456789/65950

   SCAN the following QR Code to watch the video.



2. **Geology around us-Part II**

   Links: https://youtu.be/BtmJ8lOfxek

   http://egyankosh.ac.in//handle/123456789/65950

   SCAN the following QR Code to watch the video.



3. **Introduction to ore deposits**

   Link: http://egyankosh.ac.in//handle/123456789/53454

   https://www.youtube.com/watch?v=w2Pg6_V19G4

   SCAN the following QR Code to watch the video.



4. **Classification of ore deposits**

Link: http://egyankosh.ac.in//handle/123456789/53455

https://youtu.be/MVZ9_NhZB38

SCAN the following QR Code to watch the video.

5. **Early magmatic deposits**

Link: http://egyankosh.ac.in//handle/123456789/53456

https://www.youtube.com/watch?v=DQr0xMYRCLk

SCAN the following QR Code to watch the video.

6. **Hydrothermal mineralisation**

Link: http://egyankosh.ac.in//handle/123456789/53461

https://www.youtube.com/watch?v=Red8n1UOKx0

SCAN the following QR Code to watch the video.

7. **Contact metasomatic and contact metamorphic deposits**

Link: http://egyankosh.ac.in//handle/123456789/53458

https://www.youtube.com/watch?v=8uoDoJwNHCc

SCAN the following QR Code to watch the video.

8. **Late magmatic deposits**

Link: http://egyankosh.ac.in//handle/123456789/53457

https://www.youtube.com/watch?v=hJoZujIj3bs

SCAN the following QR Code to watch the video.

9. **Physical Properties of Minerals Depending on State of Aggregation-Specific Gravity and Sense**

Link: http://egyankosh.ac.in//handle/123456789/73673

https://youtu.be/UFXBMcMrQJc

SCAN the following QR Code to watch the video.

10. **Physical Properties of Minerals Depending on State of Aggregation : Hardness and Tenacity**

Link: http://egyankosh.ac.in//handle/123456789/73672

https://youtu.be/eUPWtaMeOAA

SCAN the following QR Code to watch the video.

11. **Physical Properties of Minerals Depending on Forces**

Link: http://egyankosh.ac.in//handle/123456789/73671

https://youtu.be/POWD1V85HyI

SCAN the following QR Code to watch the video.

12. **Physical Properties of Minerals Depending on State of Aggregation: Cleavage, Striations and Fracture**

Link: http://egyankosh.ac.in//handle/123456789/73670

https://youtu.be/DbJQE3RaQoM

SCAN the following QR Code to watch the video.

13. **Physical Properties of Minerals Depending on State of Aggregation: Form and Habit**

Link: http://egyankosh.ac.in//handle/123456789/73669

https://youtu.be/0SfrT76_IiA

SCAN the following QR Code to watch the video.

14. **Physical Properties of Minerals Depending on Light**

Link: http://egyankosh.ac.in//handle/123456789/73668

https://youtu.be/FjuZ-hn8Qyo

SCAN the following QR Code to watch the video.

15. **Basics of Petroleum**

Link: https://www.youtube.com/watch?v=xh-H6v4v08o

http://egyankosh.ac.in//handle/123456789/73675

SCAN the following QR Code to watch the video.

16. Hydrocarbon Source Rock

Link: https://www.youtube.com/watch?v=JyvDHOnawfA

http://egyankosh.ac.in//handle/123456789/73674

SCAN the following QR Code to watch the video.

17. Hydrocarbon Provinces

Link: https://www.youtube.com/watch?v=mfIs06Ehwsk

http://egyankosh.ac.in//handle/123456789/73677

SCAN the following QR Code to watch the video.

18. Petroleum Industry Value Chain

Link: https://www.youtube.com/watch?v=rlMIvHhb1OE

http://egyankosh.ac.in//handle/123456789/73676

SCAN the following QR Code to watch the video.

19. **Soil: Product of Weathering**

Link: https://www.youtube.com/watch?v=y-SENU4Abv8

SCAN the following QR Code to watch the video.

20. **Weathering its types and significance**

Link: https://www.youtube.com/watch?v=gBYijIPPVgc

SCAN the following QR Code to watch the video

Development of audio/video programmes is a continuous process. For recent materials pertaining to the course, you may visit YouTube page of the School of Sciences, IGNOU.

Alternatively, you can visit eGyankosh website at http://egyankosh.ac.in/handle/123456789/36575

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EXPERIMENT 1

MEGASCOPIC STUDY OF METALLIC MINERALS

Outline of Experiment

1.1 Introduction

Expected Learning Skills

1.2 Requirements

1.3 Basic Concepts

1.4 Physical Properties of Metallic Ores

Iron Ores

Manganese Ores

Chromium Ores

Copper Ores

1.5 Laboratory Exercises

1.6 References

1.7 Learning Resources

1.1 INTRODUCTION

The study of physical and optical properties of a mineral is not only useful in identifying the mineral in the field but also in the laboratory. Generally, any specific mineral is megascopically studied based on its several physical properties and along with its diagnostic properties exhibited by the mineral. In this experiment, you will get hands-on experience of identifying metallic minerals/ores in hand specimens. You will study the physical properties of some of the common ore minerals (iron, manganese, chromium and copper). You are advised to read the Section 4.3 of Experiment 9 of BGYCL-134 carefully in order to recall the physical properties for mineral identification.

Expected Learning Skills

After performing this experiment, you should be able to:

- identify the physical properties of common iron ores like hematite, magnetite, limonite, goethite and pyrite;

- ❖ recognise the physical properties of common manganese ores like psilomelane and pyrolusite;
- ❖ identify the physical properties of common chromium ores i.e., chromite;
- ❖ recognise the physical properties of common copper ores like chalcopyrite, malachite, cuprite and native copper; and
- ❖ learn about occurrences and uses of iron, manganese, chromium, copper and ores.

1.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Hand lens, pen knife, streak plate, coin, hardness box, glass plate
- Pen, pencil, eraser, scale, sharpener, coloured pencils and drawing compass
- Laboratory file
- Hand specimens of ores/minerals such as iron, manganese, copper and chromium.

Note:

- **Do not use pen/pencil/marker pen to mark the hand specimen of the mineral.**
- **Please do not attempt to cleave the minerals/ores in the laboratory. Many of the specimens you examine cannot be readily replaced.**
- **Do not break the mineral/orein order to see its cleavage. Cleavage is usually induced in the mineral when it is extracted from the rock it is found in, and is usually seen as planes running through the mineral.**

Instructions: You are required to study Unit 9 and 10, of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling session.

1.3 BASIC CONCEPTS

You have already studied about the physical/megascopic properties of minerals and based on them you have identified some of the metallic minerals in Experiments 4, 5 and 9 of BGYCL-134.

The minerals studied in hand specimen are called megascopic study of minerals. Every mineral display some physical properties and we can see these properties by holding the specimen in hand.

Some of the common physical properties of the minerals/ores are colour, streak, lustre/luster, hardness, form (habit), cleavage, fracture, specific gravity, magnetism, transparency, tenacity etc. Out of these properties, each mineral possesses two or three distinguishing properties also called diagnostic properties on the basis of which the mineral can be easily identified.

You will study the physical properties of minerals/ores as given in Table 1.1.

Table 1.1: Mineral Physical Properties Chart.

Sl. no.	Physical Property	Definition	Testing Method	Remarks
1.	**Colour**	The colour shown by a mineral depends upon the absorption and reflection of ordinary white light of visible wavelength. Minerals may display different colours depending on its varying chemical composition.	Look at the ore/mineral sample and determine its colour. For example, colours of ore/minerals can be white, green, blue, brilliant green, inky blue, steel grey, bright red, brass yellow, bronze yellow, yellowish brown, iron black, jet black, smoky white, transparent white etc.	
2.	**Streak**	Streak is the colour of the mineral in powdered form. It is quite different than the colour of the mineral.	The streak is determined by rubbing the mineral on a piece of unglazed porcelain, known as streak plate and determine the colour of the powder. The streak plate has a hardness of about 7.	
3.	**Cleavage**	Cleavage is defined as the property of a mineral to break along a definite plane surface.	Examine the mineral for area where the mineral is broken. Look for area where the light reflects from planar surfaces.	Take a print out of the cleavage goniometer given at the end of this experiment (Fig.1.13). Cut as asked and use it for measuring cleavage angles and identify the minerals/ores.
4.	**Fractures**	Fracture refers to rough broken irregular surfaces along which minerals break randomly	Examine the broken surfaces of the specimen and describe the breakage. It can be conchoidal, fibrous and splintery, hackly, uneven or irregular, earthy, even fracture.	Refer to basic concepts discussed in Experiment 4: Study of Physical Properties of Minerals-I; BGYCL-134 course.
5.	**Lustre/ Luster**	Luster refers to the general appearance of a mineral surface in the reflected light. There are two types of luster: metallic and non-metallic	Look at the ore/mineral samples to determine, if the mineral is metallic in appearance or non-metallic (Vitreous, Resinous, Pearly, Greasy, Silky, Waxy, Earthy, Adamantine).	

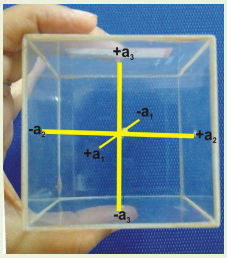
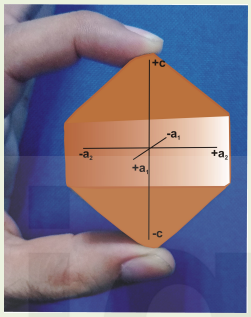
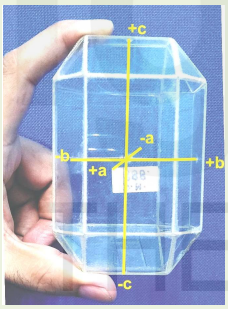
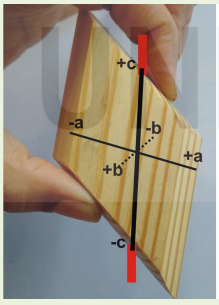
6.	**Hardness**	Hardness is the resistance offered by smooth surface of a mineral on scratching.	Hardness may be tested by rubbing the specimen over a fine cut file and noting the amount of powder formed and the degree of noise generated. A soft mineral yields more powder and little noise whereas a hard mineral yield less powder and more noise.	Use mineral of know hardness from the Mohs hardness Kits. Mohs scale of hardness (hardness box) is a sequence of the minerals arranged by Mohs in increasing order of hardness (Table 1.2).
7.	**Crystal System**	It is defined on the basis of the classification i.e., number of crystallographic axes; relative length or axial ratios of crystallographic axes; linear and angular relationships of crystallographic axes; elements of symmetry, i.e., plane, axis and centre.	Refer Table 1.3 and observe the specimen and you can classify as: Isometric (or cubic), Tetragonal, Orthorhombic, Hexagonal, Triclinic, Monoclinic, Rhombohedral (or trigonal)	Refer to Table 1.3
8.	**Crystal Forms/ Habit**	General shape or appearance of a mineral	Generally, it is not seen in most of the laboratory samples. However, determine it by examining the shape of a specimen.	
9.	**Magnetism**	Electromagnetic force generated by a mineral.	Use a magnet to check if it is attracted by the specimen.	For example, minerals/ores having magnetism: magnetite (strongly), chromite (weakly, ilmenite (weakly), and hematite (strongly).
10.	**Specific Gravity**	It determines how heavy a mineral is by its relative weight to water at 40o C. Water has a specific gravity of 1.0.	In this experiment, you will not determine this property in the Laboratory. You will write the already determined values of specific gravity of a particular mineral	

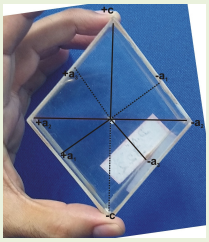
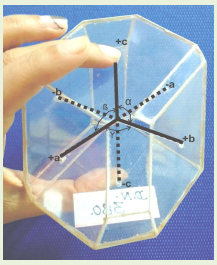
11.	**Transparency/ Diaphaneity**	It refers to the amount of light which is able to be pass through a mineral.	Observe the ore/mineral under ordinary white light. Ore/mineral can be transparent, translucent or opaque.	Light is able to pass through transparent minerals. Light passes through translucent minerals partially. The opaque minerals do not let any light through.
12.	**Tenacity**	Tenacity is the resistance of a mineral to breakage. Some minerals are very hard to break, whereas others are easily broken.	• Observe and touch the broken surface of ore/mineral. It can be: • Brittle - breaks or powders easily. • Malleable - can be hammered into thin sheets. • Sectile - can be cut into thin shavings with a knife. • Ductile - bends easily and does not return to its original shape. • Flexible - bends somewhat and does not return to its original shape. • Elastic - bends but does return to its original shape.	

Table 1.2: Mohs scale of hardness.

Hardness	Mineral	Mineral comparison with some common objects
1	**Talc**	
2	**Gypsum**	Finger nail (with hardness 2.2) May vary from person to person Copper coin (2.9)
3	**Calcite**	Brass (wood screw, washer) (with hardness 3.5)
4	**Fluorite**	Wire (iron) nail (with hardness 4.5)
5	**Apatite**	Steel nail, Steel Knife blade (with hardness 5-6.5) depending on the steel quality Glass plate (with hardness ~5.5)
6	**Orthoclase**	Steel file (with hardness ~6.5)
7	**Quartz**	Streak plate (with hardness ~7)
8	**Topaz**	Emery sandpaper
9	**Corundum**	Knife sharpener
10	**Diamond**	Masonry drill bit

Table 1.3: Seven crystal systems and their characteristics.

Crystal Systems		Crystallographic Axes and their designations
CUBIC/ ISOMETRIC SYSTEM		Three equal and mutually perpendicular axes [a_1, a_2 and a_3]
TETRAGONAL SYSTEM		Two equal horizontal, third vertical shorter or larger. All at right angles. 3 axes at right angles [a_1, a_2 and c]
ORTHORHOMBIC SYSTEM		Three unequal axes mutually perpendicular. All unequal. [a, b and c]
MONOCLINIC SYSTEM		Three unequal axes. b is at right angles to c. a is inclined. [a, b and c]
HEXAGONAL SYSTEM		4 Axes. 3 horizontal, a_1:a_2:a_3 at 120^0 fourth vertical at 90^0. [a_1, a_2, a_3 and c]

TRIGONAL / RHOMBOHEDRAL SYSTEM		4 Axes, 3 equal horizontal at 120^0 fourth vertical at 90^0. [a_1, a_2, a_3 and c]
TRICLINIC SYSTEM		3 unequal axes, a, b, c not at right angles. [a_1, a_2, a_3 and c]

Study all the given ores/minerals one by one and write down the physical properties of the metallic ore/mineral specimens in the manner as given below in Table 1.4. Further also write the diagnostic properties and mode of occurrence in the laboratory file.

Table 1.4: Format for describing ore/mineral specimen.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	
2.	**Crystal System**	
3.	**Colour**	
4.	**Streak**	
5.	**Lustre**	
6.	**Hardness**	
7.	**Form/Habit**	
8.	**Cleavage**	
9.	**Fracture**	
10.	**Specific Gravity**	
11.	**Magnetism**	
12.	**Transparency/ Diaphaneity**	
13.	**Tenacity**	
14.	**Special Property**	
15.	**Diagnostic Property**	
16.	**Inference/Name**	
Mode of Occurrence		

1.4 PHYSICAL PROPERTIES OF METALLIC ORES

Let us study the physical/ megascopic properties of metallic ores/minerals of iron, manganese and chromium.

1.4.1 Iron Ores

Iron is the most common metallic element present in the Earth's crust. It forms one of the important commodities in global trade because of its usage in day-to-day life. You have studied in Unit 9 of BGYET-141 that iron occurs in all the three types of rocks in the form of oxides, carbonates, hydroxides, sulphides and silicates. The minerals of iron that are mostly being used as ores are hematite, magnetite, siderite, and limonite. The other common ore mineral of iron are pyrite and goethite. You are advised to identify the hand specimens with the help of physical properties and photographs of the hand specimen as given in Table 1.5 for hematite (Fig. 1.1a and b); Table 1.6 for magnetite (Fig. 1.2); Table 1.7 for limonite (Fig.1.3); Table 1.8 for goethite (Fig.1.4); Table 1.9 for pyrite (Fig.1.5). Further also write the chemical composition, crystal system and diagnostic properties, mode of occurrence, distribution and uses of ores of iron.



Fig. 1.1: a) Hand specimen of hematite showing massive form and sub-metallic lustre; and b) Layered hematite.

Table 1.5: Physical properties of hematite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Compostion**	Fe_2O_3
2.	**Crystal System**	Hexagonal
3.	**Colour**	Red, brownish red (Fig. 1.1 b) or greyish brown (Fig. 1.1a)
4.	**Streak**	Cherry-red, red-brown
5.	**Lustre**	Metallic to sub-metallic
6.	**Hardness**	5-6
7.	**Form/Habit**	Earthy, granular, crystalline, oolitic, reinform, amorphous
8.	**Cleavage**	Absent

9.	**Fracture**	Uneven
10.	**Specific Gravity**	5.26
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Weakly magnetic
15.	**Diagnostic Property**	Weakly magnetic, form, hardness and streak. All forms of hematite have a characteristic reddish brown streak.
16.	**Inference/Name**	**HEMATITE**
Mode of Occurrence	Concentration of hematite occurs in Precambrian rocks throughout the world. It occurs in regionally metamorphosed siliceous Fe-rich sedimentary rocks.	



Fig. 1.2: Hand specimen of magnetite.

Table 1.6: Physical properties of magnetite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	Fe_3O_4
2.	**Crystal System**	Cubic/isometric
3.	**Colour**	Black to silver grey (Fig. 1.2)
4.	**Streak**	Black
5.	**Lustre**	Metallic to sub-metallic
6.	**Hardness**	5.5-6.5
7.	**Form/habit**	Crystalline,massive, granlar
8.	**Cleavage**	Absent
9.	**Fracture**	Uneven, Conchoidal to sub-conchoidal

10.	**Specific Gravity**	5.2
11.	**Magnetism**	Strongly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Strongly magnetic
15.	**Diagnostic Property**	Strongly magnetic, colour and streak
16.	**Inference/Name**	**MAGNETITE**
Mode of Occurrence	Magnetite occures in banded iron formations. It occurs as laminations, resulting from segregation, or by crystal settling in magmatic environment, e.g., Bushveld complex, South Africa. Magnetite is more common in mafic igneous rocks.	



Fig. 1.3: Hand specimen of limonite.

Table 1.7: Physical properties of limonite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	2 $Fe_2O_3.3H_2O$
2.	**Crystal System**	Amorphous to cryptocrystalline
3.	**Colour**	Light brown to brown (Fig. 1.3) and at places reddish-yellow
4.	**Streak**	Brownish yellow to yellow
5.	**Lustre**	Earthy to dull
6.	**Hardness**	4 to 5.5
7.	**Form/Habit**	Massive, botryoidal, layered, stalactitic
8.	**Cleavage**	Absent
9.	**Fracture**	Uneven

10.	**Specific Gravity**	2.7 to 4.3
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special/ Diagnostic Property**	Brown colour, brownish yellow streak and earthy luster
15.	**Inference/Name**	**LIMONITE**
Mode of Occurence	Limonite usually occurs as a secondary material, and formed from the weathering of hematite, magnetite, pyrite and other iron-bearing materials such as olivine, pyroxene, amphibole, and biotite.	

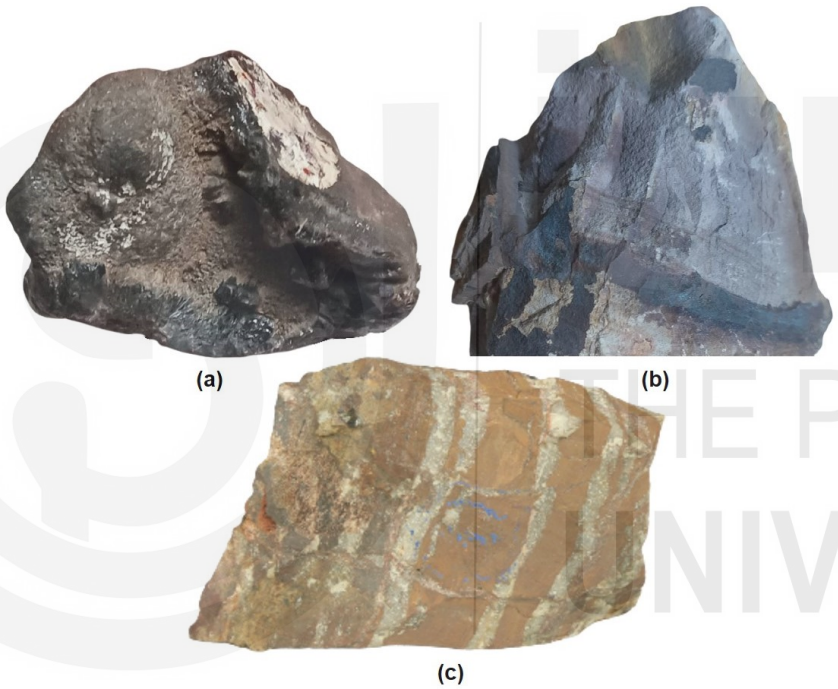


Fig. 1.4: Hand specimen of goethite showing brownish black colour.

Table 1.8: Physical properties of goethite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$Fe_2O_3.H_2O$
2.	**Crystal System**	Orthorhombic
3.	**Colour**	Brownish black
4.	**Streak**	Yellowish brown to orange-brown
5.	**Lustre**	Adamantine, silky, metallic, dull
6.	**Hardness**	5 to 5.5
7.	**Form/Habit**	Radial, acicular, massive, crystalline, botryoidal

8.	**Cleavage**	Perfect
9.	**Fracture**	Uneven
10.	**Specific Gravity**	3.3 to 4.3
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphanerity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Weakly magnetic
15.	**Diagnostic Property**	Weak magnetism and yellowish-brown to orange brown streak distinguish it from the brownish red streak of hematite.
16.	**Inference/Name**	**GOETHITE**
Mode of Occurrence		It forms under oxidizing conditions as a weathering product of iron-bearing minerals. It can precipitate in marine, lacustrine, and terrestrial environments and forms the weathered “gossan”.



Fig. 1.5: Hand specimen of pyrite showing its embedded crystal.

Table 1.9: Physical properties of pyrite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	FeS_2
2.	**Crystal System**	Cubic/Isometric
3.	**Colour**	Pale yellow to brass yellow
4.	**Streak**	Greenish black to brownish black
5.	**Lustre**	Metallic, splendid
6.	**Hardness**	6.0-6.5
7.	**Form/Habit**	Crystalline, cubic, massive, nodular, globular, radial-fibrous

8.	**Cleavage**	Absent
9.	**Fracture**	Conchoidal, uneven
10.	**Specific Gravity**	4.9 to 5.1
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Weakly magnetic
15.	**Diagnostic Property**	Pale yellow to brass yellow colour, greenish black to brownish black streak and hardness
16.	**Inference/Name**	**PYRITE**
Mode of Occurrence	Pyrite occurs as euhedral cubes and anhedral crystalline masses and colloform (radiating and concentric manner) bands of very fine grains. It forms at both high and low temperatures and occurs in hydrothermal veins, sedimentary, igneous and metamorphic rocks.	

- **Distribution in India**: Iron ores of maximum abundance are reported from the states of Odisha, Jharkhand, Chhattisgarh, Karnataka, Goa and Maharashtra. Minor occurrences are reported from West Bengal, Tamil Nadu, Kerala, Rajasthan, Madhya Pradesh, Uttaranchal, and Haryana.
- **Uses**: The important use of iron ore is the extraction of iron metal that is used for different purposes. Most of the extracted iron is used in the manufacture of steel. Some of the other uses of iron are in the manufacture of automobiles, rails, ships, construction industry, etc. besides in domestic applications.

1.4.2 Manganese Ores

Manganese is a transitional element and never occurs in native state. It occurs in association with iron and therefore used as an alloy of iron. It occurs in different forms of oxides, sulphides, silicates and carbonates. But the common manganese ores occur in the form of oxides such as psilomelane and pyrolusite. The other chief ores are manganite, rhodochrosite, braunite that you have read in Unit 9 of BGYET- 141 course. You are advised to identify the hand specimens with the help of physical properties and photographs of the hand specimen as given in Table 1.10 for psilomelane (Fig.1.6); Table 1.11 for pyrolusite (Fig. 1.7a and b). Further also write the chemical composition, crystal system, diagnostic properties, mode of occurrence, distribution and uses of ores of manganese.



Fig. 1.6: Hand specimen of Psilomelane.

Table 1.10: Physical properties of psilomelane.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$(Ba,H_2O)_2Mn_5O_{10}$
2.	**Crystal System**	Monoclinic
3.	**Colour**	Dark grey to black (Fig. 1.6)
4.	**Streak**	Black
5.	**Lustre**	Sub-metallic
6.	**Hardness**	5 to 6
7.	**Form/Habit**	Massive and commonly botryoidal
8.	**Cleavage**	Absent
9.	**Fracture**	Conchoidal to uneven
10.	**Magnetism**	Non magnetic
11.	**Transparency/ Diaphaneity**	Opaque
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	4.7
14.	**Diagnostic Property**	Hardness, botryoidal form and black streak
15.	**Inference/Name**	**PSILOMELANE**
Mode of Occurrence		Hydrothermal, sedimentary and residual concentration are the processes responsible for the formation of manganese deposits. Supergene deposits are also an important source of manganese.

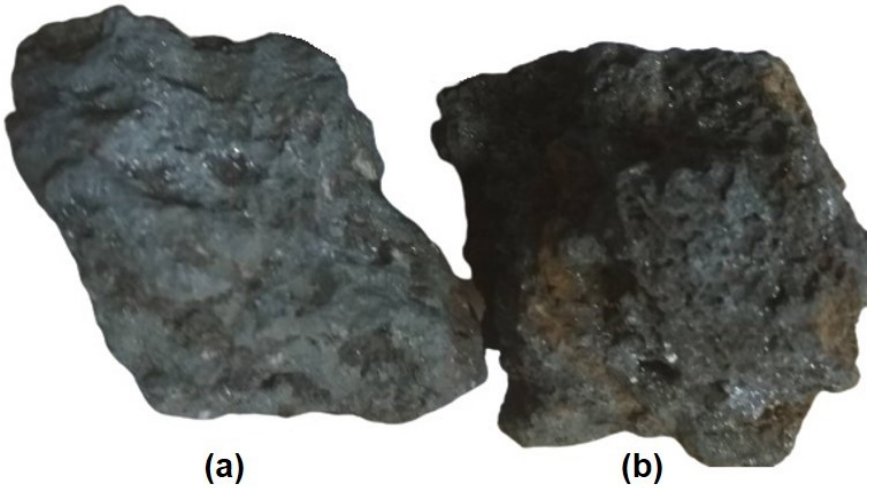


Fig. 1.7: a) Light; and b) dark steel grey colour pyrolusite in massive form.

Table 1.11: Physical properties of pyrolusite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	MnO_2
2.	**Crystal System**	Tetragonal
3.	**Colour**	Light (Fig. 1.7a) to dark steel-grey (Fig. 1.7b)
4.	**Streak**	Black, bluish black
5.	**Lustre**	Metallic
6.	**Hardness**	2-6.5
7.	**Form/Habit**	Massive, columnar or fibrous
8.	**Cleavage**	Perfect
9.	**Fracture**	Uneven
10.	**Specific Gravity**	4.5 to 5.06
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special/Diagnostic property**	Streak, colour and hardness
15.	**Inference/Name**	**PYROLUSITE**
Mode of Occurrence	Hydrothermal, sedimentary and residual concentration are the processes responsible for the formation of manganese deposits. Pyrolusite may also be formed from the alteration of rhodochrosite.	

- **Distribution in India**: Indian manganese ore deposits occur mainly in the the states of Madhya Pradesh, Odisha, Karnataka, and Maharashtra. Besides, minor occurrences are reported from Andhra Pradesh, Goa, Gujarat, Rajasthan, Jharkhand and Telangana.
- **Uses**: Manganese is used as an alloy of iron in the manufacture of various steels such as manganese-steel, carbon-steel, and special steels with specific properties. It is also used in the manufacture of dry cell batteries, glass, paint, dyes, leather, fertilizers and chemicals.

1.4.3 Chromium Ores

Chromium falls in the group of trace elements and forms an important alloy of iron like that of the manganese. Due to its non-corrosive and non-abrasive property, it is used in the manufacture of high-quality steel. You have read in Unit 9 of BGYET- 141 course that chromite is the only economic ore mineral of chromium and it is a mixture of oxides of iron and chromium with 32% FeO and 68% Cr_2O_3 content. You are advised to identify the hand specimens with the help of physical properties and photographs of the hand specimen as given in Table 1.12 for chromite (Fig.1.8). Further also write the chemical composition, crystal system, diagnostic properties, mode of occurrence, distribution and uses of ores of chromium.



Fig.1.8: Hand specimen of chromite exhibiting metallic to submetallic lustre.

Table 1.12: Physical properties of chromite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$FeCr_2O_4$
2.	**Crystal System**	Cubic
3.	**Colour**	Brownish black, yellowish red, dark brown

4.	**Streak**	Brown
5.	**Lustre**	Metallic to submetallic
6.	**Hardness**	5.5-6
7.	**Form/Habit**	Rarely crystalline, typically massive, fine granular to compact
8.	**Cleavage**	Absent
9.	**Fracture**	Uneven
10.	**Specific Gravity**	4.5 to 4.8
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special/Diagnostic Property**	Brown streak, lustre and common association with olivine and serpentine.
15.	**Inference/Name**	**CHROMITE**
Mode of Occurrence		Chromite is a common constituent of peridotites and other ultrabasic rocks. Large chromite ore are thought to have been derived by cumulate magmatic differentiation. Due to its resistance to erosion, chromite may accumulate in laterite and placer deposits.

- **Distribution in India**: Most of the chromite deposits are mainly concentrated in Odisha state. Minor occurrences are reported from the states of Manipur, Karnataka, Jharkhand, Maharashtra, Tamil Nadu and Andhra Pradesh.
- **Uses**: Chromium is used as an alloy because of its distinctive properties like hardness, toughness and high temperature bearing capacity. It is also used in refractories, and in the manufacture of leather, glass, and ammunition.

1.4.4 Copper Ores

Copper is a soft metallic element that occurs in native state and in other forms such as oxides, sulphides and carbonates. However, most of the copper produced is from sulphide ores. The commonly occuring ores of copper are chalcopyrite, malachite and cuprite. The other important ores are native copper, bornite and chrysocolla. You are advised to identify the hand specimens with the help of physical properties and photographs of the hand specimen as given in Table 1.13 for chalcopyrite (Fig. 1.9), Table 1.14 for malachite (Fig. 1.10) and Table 1.15 for cuprite (Fig. 1.11), Table 1.16 for native copper (Fig. 1.12). Further also write the chemical composition, crystal system, diagnostic properties, mode of occurrence, distribution and uses of ores of copper.



Fig.1.9: Hand specimen of chalcopyrite.

Table 1.13: Physical properties of chalcopyrite.

S.No.	Physical properties	Characteristics
1.	**Chemical Composition**	$CuFeS_2$
2.	**Crystal System**	Tetragonal
3.	**Colour**	Brass-yellow
4.	**Streak**	Greenish black
5.	**Lustre**	Metallic
6.	**Hardness**	3.5-4
7.	**Form/Habit**	Crystalline, massive compact, botryoidal
8.	**Cleavage**	Distinct
9.	**Fracture**	Uneven
10.	**Specific Gravity**	4.1-4.3
11.	**Magnetism**	Weakly magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Colour may resemble native gold, but chalcopyrite is much harder and dark greenish black streak. It is distinguished from pyrite by its hardness.
15.	**Diagnostic Property**	Crystals distinctive, golden yellow and greenish black streak.
16.	**Inference/Name**	**CHALCOPYRITE**
Mode of Occurrence		Chalcopyrite may be massive, crystalline disseminated, and/or intergrown. It forms in almost all ore forming environments.



Fig.1.10: Hand specimen of malachite.

Table 1.14: Physical properties of malachite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$CuCO_3.Cu(OH)_2$
2.	**Crystal System**	Monoclinic
3.	**Colour**	Bright green
4.	**Streak**	Pale or light green
5.	**Lustre**	Silky or dull
6.	**Hardness**	3.5-4
7.	**Form/Habit**	Rarely crystalline, massive, mammillary, botryoidal, fibrous
8.	**Cleavage**	Perfect
9.	**Fracture**	Uneven
10.	**Specific Gravity**	3.6-4.05
11.	**Magnetism**	Non magnetic
12.	**Transparency/ Diaphaneity**	Translucent to Opaque
13.	**Tenacity**	Brittle
14.	**Special Property**	Green colour and banding with pale green streak.
15.	**Diagnostic Property**	Bright green colour and botryoidal form.
16.	**Inference/Name**	**MALACHITE**
Mode of Occurrence	It may occur in any copper bearing deposits. It occurs as crystalline aggregates and growth-zoned, botryoidal clusters of radiating crystals.	



Fig.1.11: Photograph of cuprite hand specimen.
(Source:https://upload.wikimedia.org/wikipedia/commons/7/7c/CupriteUSGOV.jpg)

Table 1.15: Physical properties of cuprite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	Cu_2O
2.	**Crystal System**	Cubic
3.	**Colour**	Red, black
4.	**Streak**	Brownish red
5.	**Lustre**	Sub-metallic to adamantine or earthy
6.	**Hardness**	3.5-4
7.	**Form/Habit**	Crystalline, massive, granular, earthy
8.	**Cleavage**	Distinct
9.	**Fracture**	Conchoidal
10.	**Specific Gravity**	6.1
11.	**Magnetism**	Non-magnetic
12.	**Transparency/ Diaphaneity**	Transparent, translucent
13.	**Tenacity**	Brittle
14.	**Special/ Diagnostic Property**	Lustre, colour and form/habit
15.	**Inference/Name**	**CUPRITE**
Mode of Occurrence	It is a secondary mineral which forms in the oxidized zone of copper sulfide deposits. It frequently occurs in association with native copper, azurite, malachite and a variety of iron oxide minerals.	

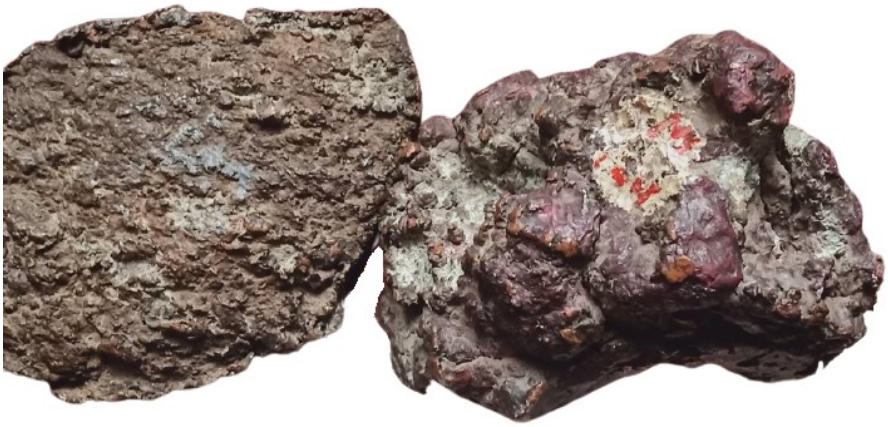


Fig. 1.12: Hand specimen of native copper.

Table 1.16: Physical properties of native copper.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	Cu
2.	**Crystal system**	Cubic
3.	**Colour**	Light rose on fresh surface, quickly changes to copper red and then to brown
4.	**Streak**	Copper red
5.	**Lustre**	Metallic
6.	**Hardness**	2.5-3
7.	**Form/Habit**	Rarely crystalline, massive
8.	**Cleavage**	Absent
9.	**Fracture**	Hackly
10.	**Specific Gravity**	8.9
11.	**Magnetism**	Non-magnetic
12.	**Transparency/ Diaphaneity**	Opaque
13.	**Tenacity**	Highly malleable and ductile
14.	**Special Property**	Copper-red streak, high specific gravity
15.	**Diagnostic Property**	Colour, lustre, specific gravity, malleability and ductility
16.	**Inference/Name**	**COPPER**
Mode of Occurrence	Deposits of native copper are associated with subaerial flood-basalt lavas. Occurs as coarse to fine grained aggregates, rarely as dendritic or spear-like crystals, wires, ore very rarely as individual crystals.	

- **Distribution in India**: The important distribution of copper deposits is reported from the states of Jharkhand, Rajasthan, Madhya Pradesh, and Chhattisgarh. Minor occurrences are reported from Karnataka, Andhra Pradesh, Tamil Nadu, Odisha, Madhya Pradesh, and Maharashtra.
- **Uses**: Copper is used as an alloy bronze, duralumin, and gun metal because of its distinctive properties. It is also used in the manufacture of coins, utensils, electrical appliances and ammunition.

1.5 LABORATORY EXERCISES

You have studied the physical/ megascopic properties of some of the common ores of iron, manganese, chromium and copper. Now, attempt the following exercises.

Exercise 1: Identify the given specimen/s of ores of iron by studying its physical/megascopic properties and write in your laboratory file as per Table 1.17.

Exercise 2: Identify the given specimen/s of ores of manganese by studying its physical/megascopic properties and write in your laboratory file as per Table 1.17.

Exercise 3: Identify the given specimen/s of ores of chromium by studying its physical/megascopic properties and write in your laboratory file as per Table 1.17.

Exercise 4: Identify the given specimen/s of ores of copper by studying its physical/megascopic properties and write in your laboratory file as per Table 1.17.

Guidelines: While performing these exercises, you will have to do the following activities:

1. Get the common ores of iron, manganese, chromium and copper from your academic counsellor.
2. Get hand lens, pen knife, streak plate, coin, hardness box and broken glass piece from your academic counsellor.
3. Draw the ore/mineral in your laboratory file as observed by naked eyes.
4. Study the physical properties of the ore by taking the specimen in hand and observe its properties by naked eyes very carefully.
5. Write down all the properties of the specimen that you have observed in the laboratory file and infer its diagnostic and special properties from the physical properties that you have examined.
6. From the physical properties and especially the diagnostic and special properties you have observed and known, identify the name of the ore and write it on the laboratory file.

7. Finally, write down the occurrences and uses of the ore from the knowledge you have gained while studying the theory and practical courses.

Note:

- Handle the mineral specimens and all the devices provide to you with great care and do not damage them.
- If you find any problem during the study of the mineral specimens do not hesitate to ask your counsellor.

The proforma i.e., Table 1.17 should be used for recording the physical/ megascopic properties of all the given specimens provided to you by your academic counsellor. You have to record all the exercises as Laboratory Exercise No.1, Exercise No.2, Exercise No.3 and so on. By following the above-mentioned procedures, you will have to describe all the given specimens of the minerals/ores one by one.

Table 1.17: Proforma for recording the physical properties.

Date: ……

Laboratory Exercise No.1……..:

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	
2.	**Crystal System**	
3.	**Colour**	
4.	**Streak**	
5.	**Lustre**	
6.	**Hardness**	
7.	**Form/Habit**	
8.	**Cleavage**	
9.	**Fracture**	
10.	**Specific gravity**	
11.	**Magnetism**	
12.	**Transparency**	
13.	**Special Property**	
14.	**Diagnostic Property**	
15.	**Inference/Name**	
16.	**Mode of Occurrence**	
17.	**Distribution**	
18.	**Uses**	

19.	**Sketch of the ore/ mineral**	

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- https://en.wikipedia.org/wiki/Cuprite

(Websites accessed between 10th to 25th July 2021)

1.7 LEARNING RESOURCES

1. **Physical Properties of Minerals Depending on State of Aggregation- Specific Gravity and Sense**

   Link: http://egyankosh.ac.in//handle/123456789/73673

   https://youtu.be/UFXBMcMrQJc

2. **Physical Properties of Minerals Depending on State of Aggregation : Hardness and Tenacity**

   Link: http://egyankosh.ac.in//handle/123456789/73672

   https://youtu.be/eUPWtaMeOAA

3. **Physical Properties of Minerals Depending on Forces**

   Link: http://egyankosh.ac.in//handle/123456789/73671

   https://youtu.be/POWD1V85HyI

4. **Physical Properties of Minerals Depending on State of Aggregation: Cleavage, Striations and Fracture**

   Link: http://egyankosh.ac.in//handle/123456789/73670

   https://youtu.be/DbJQE3RaQoM

5. **Physical Properties of Minerals Depending on State of Aggregation: Form and Habit**

   Link: http://egyankosh.ac.in//handle/123456789/73669

   https://youtu.be/0SfrT76_IiA

6. **Physical Properties of Minerals Depending on Light**

   Link: http://egyankosh.ac.in//handle/123456789/73668

   https://youtu.be/FjuZ-hn8Qyo

7. **Identifying Minerals**

   Link: https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-identifying-minerals/

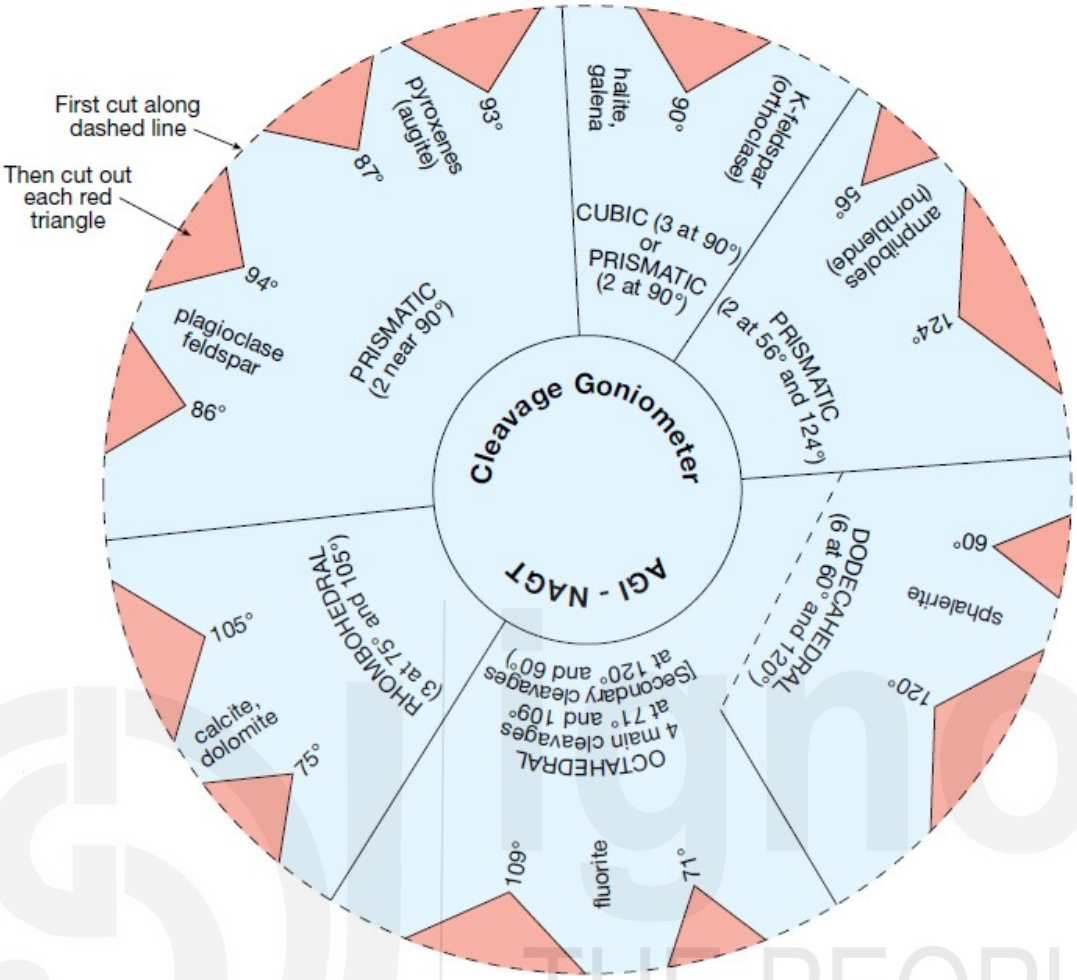


Fig.1.13: Use this cleavage goniometer for measuring cleavage angles.
(Source: Busch, R.M. (Ed.) (2015) Laboratory Manual in Physical Geology, 10th Edition, Pearson, Delhi)

EXPERIMENT 2

MEGASCOPIC STUDY OF NON-METALLIC MINERALS

Outline of Experiment

2.1 Introduction

Expected Learning Skills

2.2 Requirements

2.3 Physical Properties of Non-metallic minerals

Garnet

Gypsum

Talc

Magnesite

2.4 Laboratory Exercises

2.5 References

2.6 Learning Resources

2.1 INTRODUCTION

Generally, minerals are solid in nature but some minerals like native mercury are liquid in state. There are at least 4000 known minerals in nature. Out of them 100 minerals are common and in which 10 minerals are abundant.

In the previous Experiment 1, you have identified some of the common metallic minerals of iron, manganese, chromium and copper based on the physical properties. Similarly, in this experiment you will identify some non-metallic minerals such as garnet, gypsum, talc and magnesite by studying their physical properties.

Expected Learning Skills

- After performing this experiment, you should be able to:
- identify the physical properties of garnet and gypsum; and
- recognise non-metallic minerals such as talc and magnesite.

2.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Hand lens, pen knife, streak plate, coin, hardness box, glass plate
- Laboratory file, pen, pencil and eraser
- Hand specimens of garnet, gypsum, talc and magnesite

Note:

- **Do not use pen/pencil/marker pen to mark the hand specimen of the mineral.**
- **Please do not attempt to cleave the minerals in the laboratory. Many of the specimens you examine cannot be readily replaced.**
- **Do not break the mineral in order to see its cleavage. Cleavage is usually present in the mineral specimen and is usually seen as planes running through the mineral.**

Instructions: You are required to study Unit 11 of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling session.

You have read about the physical/ megascopic properties of minerals and based on them you have identified metallic minerals in Experiment 1. Each mineral displays some physical properties that can be recognised megascopically. Some of the common physical/megascopic properties are colour, streak, lustre, transparency, hardness, form (habit), cleavage, fracture and specific gravity. Each mineral possesses unique properties known as diagnostic properties based on which mineral can be easily identified.

2.3 PHYSICAL PROPERTIES OF NON-METALLIC MINERALS

In Section 1.3 of the previous Experiment 1 we have discussed about the common physical properties of the minerals/ores i.e., colour, streak, lustre, hardness, form (habit), cleavage, fracture, specific gravity, tenacity, magnetism, transparency, etc. Refer to Experiment 1 for description of physical / megascopic characters. Here, we will discuss about the physical properties of garnet, gypsum, talc and magnesite minerals, based on which these minerals can be identified.

2.3.1 Garnet

Garnet minerals have a nesosilicate structure with divalent and trivalent cations and crystallise in isometric system. They are equidimensional minerals and have the ability to occur as independent crystals. The general formula of garnet minerals being $X_3Y_2Si_3O_{12}$, where X = divalent ions such as Ca^{2+}, Mg, Fe, Mn, etc., and Y = trivalent ions such as Al^{3+}, Fe, Cr, Ti, etc.

The principal minerals of this group are given below:

Pyrope [$Mg_3Al_2(SiO_4)_3$]: magnesium-aluminium garnet.

Almandine [$Fe_3Al_2(SiO_4)_3$]: iron-aluminium garnet.

Spessartite [$Mn_3Al_2(SiO_4)_3$]: manganese-aluminium garnet.

Uvarovite [$Ca_3Cr_2(SiO_4)_3$]: calcium-chromium garnet.

Grossularite [$Ca_3Al_2(SiO_4)_3$]: calcium-aluminium garnet.

Andradite [$Ca_3Fe_2(SiO_4)_3$]: calcium-iron garnet.

The minerals pyrope, almandine, and spessartite form end-member series of one solid solution and the other minerals uvarovite, grossularite and andradite form the end-member of other solid solution series. You are advised to identify the hand specimens with the help of physical properties and photograph of the hand specimen as given in Table 2.1 (Fig.2.1). Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of garnet.



Fig. 2.1: Hand specimen of garnet crystals exhibiting rhomboherdal form.

Table 2.1: Physical properties of garnet.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$Fe_3Al_2(Sio_4)_3$ (almandine)
2.	**Crystal System**	Cubic (Isometric)
3.	**Colour**	Normally red or reddish brown, orange, pink colour. Emerald green, white, grey, pale brown, pale green colour
4.	**Streak**	White or grey
5.	**Lustre**	Vitreous to resinous
6.	**Hardness**	6.5-7.5
7.	**Form/Habit**	Crystals (rhombododecahedron form) common, also occurs as granular, massive and in fibrous form
8.	**Cleavage**	Absent
9.	**Fracture**	Conchoidal to uneven

10.	**Specific Gravity**	3.5-4.3
11.	**Magnetism**	Magnetic
12.	**Transparency/ Diaphaneity**	Transparent to opaque
13.	**Tenacity**	Brittle
14.	**Diagnostic Property**	Rhombododecahedron form, reddish brown colour, hardness, lack of cleavage
15.	**Inference/Name**	**GARNET**
Mode of Occurrence	Garnet is found in metamorphic rocks and in few igneous rocks, particularly granites and granitic pegmatites formed under conditions of high temperature and pressure. The mineral almandine is commonly present in metamorphic rocks and minerals such as pyrope and uvarovite are generally found in ultrabasic rocks like kimberlites and peridotites. They are rarely present in clastic sediments and sedimentary rocks.	

- **Distribution in India**: In India gem variety of garnets occurs in some places of Rajasthan, Telangana, Andhra Pradesh and Tamil Nadu. Garnet occurs as beach placer deposits along with ilmenite in coastal districts of Kerala, Tamil Nadu and Odisha.
- **Uses**: Garnet is used as a gemstone. Due to its hardness, absence of cleavage and affinity to break into uneven grains makes the mineral more suitable for using it as an abrasive.

2.3.2 Gypsum

Gypsum is a sulphate mineral and commonly occurs as evaporate deposit in layered sedimentary rocks. It occurs in association with other evaporite minerals such as anhydrite, halite, calcite, dolomite, etc. Gypsum ($CaSO_4.2H_2O$) is similar in composition to anhydrite ($CaSO_4$). But the difference is that gypsum is the hydrous form of anhydrite. You have read in Unit 11 of BGYET- 141 course that gypsum occurs in nature as gypsum rock, alabaster, gypsite, satin spar and selenite. You are advised to identify the hand specimens with the help of physical properties and photograph of the hand specimen as given in Table 2.2 (Fig.2.2). Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of gypsum.

Table 2.2: Physical properties of gypsum.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$CaSO_4.2H_2O$
2.	**Crystal System**	Monoclinic
3.	**Colour**	Colourless to white, sometimes yellow, tan, blue, pink, brown, reddish brown or grey due to impurities present
4.	**Streak**	White

5.	**Lustre**	Vitreous to silky, pearly
6.	**Hardness**	1.5 – 2
7.	**Form/Habit**	Crystalline, combination of prism and clinopinacoid, twinned crystals are of (a) swallow–tail and (b) arrow-head types
8.	**Cleavage**	Perfect, parallel to clinopinacoid
9.	**Fracture**	Subconchoidal
10.	**Specific Gravity**	2.31 to 2.33
11.	**Magnetism**	Non-magnetic (diamagnetic)
12.	**Transparency/ Diaphaneity**	Transparent to Translucent
13.	**Tenacity**	Flexible, inelastic
14.	**Diagnostic Property**	Perfect cleavage, low hardness, crystalline and massive form.
15.	**Inference/Name**	**GYPSUM**
Mode of Occurrence		Gypsum generally occurs in thick layers as evaporite deposits underlying beds of rock salt. It occurs in association with limestones and shales in sedimentary rocks. It is also found in clays and shales as tabular bodies or spread crystals. It occurs particularly in regions of volcanic activity where limestones are influenced by hot sulphur fumes.



Fig. 2.2: Hand specimen of gypsum showing twinning.

- **Distribution in India**: Gypsum deposits are concentrated in several parts of India. Selenite variety of gypsum occurs in coastal districts of Andhra Pradesh and Gujarat. High grade gypsum is found in Rajasthan. The occurrence of gypsum is also reported from the states of Himachal Pradesh, Uttarakhand, Karnataka, Madhya Pradesh and Tamil Nadu.
- **Uses**: Gypsum is used in the manufacture of many products. But it is mainly used in the manufacture of fertilizers, cement and plaster of paris. Pure

variety of gypsum is mostly used as filler in manufacture of textile, paints and paper. Impure variety of gypsum is used in the manufacture of insecticides and black board chalks.

2.3.3 Talc

Talc is a soft, non-metallic clay mineral having composition as that of a hydrous magnesium silicate. It is represented with a value of 1 (one) on Mohs scale of mineral hardness signifying its soft character. It is interesting to note that talc has almost similar physical properties as that of pyrophyllite mineral. Therefore, it is quite challenging to distinguish them in hand specimens. It occurs in foliated to fibrous forms and has the special properties of absorbing moisture, oils and odour. The different varieties of talc are soapstone or steatite, pot stone, french chalk, etc. You will identify the physical properties and write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of talc as given below (Table 2.3; Fig.2.3a-d).

Table 2.3: Physical properties of talc.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$Mg_3Si_4O_{10}(OH)_2$
2.	**Crystal System**	Monoclinic
3.	**Colour**	Off White (Fig.2.3a and Fig. 2.3d), pale yellow, green (Fig. 2.3b) or grey
4.	**Streak**	White
5.	**Lustre**	Pearly
6.	**Hardness**	1
7.	**Form/Habit**	Foliated, fibrous
8.	**Cleavage**	Present, one set
9.	**Fracture**	Uneven
10.	**Specific Gravity**	2.7
11.	**Magnetism**	Non-magnetic (diamagnetic)
12.	**Transparency / Diaphaneity**	Translucent along edges but not seen due to various reasons
13.	**Tenacity**	Sectile (ability of a mineral to be cut into thin pieces)
14.	**Diagnostic Property**	Softness and soapy feel
15.	**Inference/Name**	**TALC**
Mode of Occurrence		Talc occurs in metamorphic rocks such as talc schist. It is also formed by hydrothermal alteration of magnesium-bearing rocks such as peridotites and dolomites.

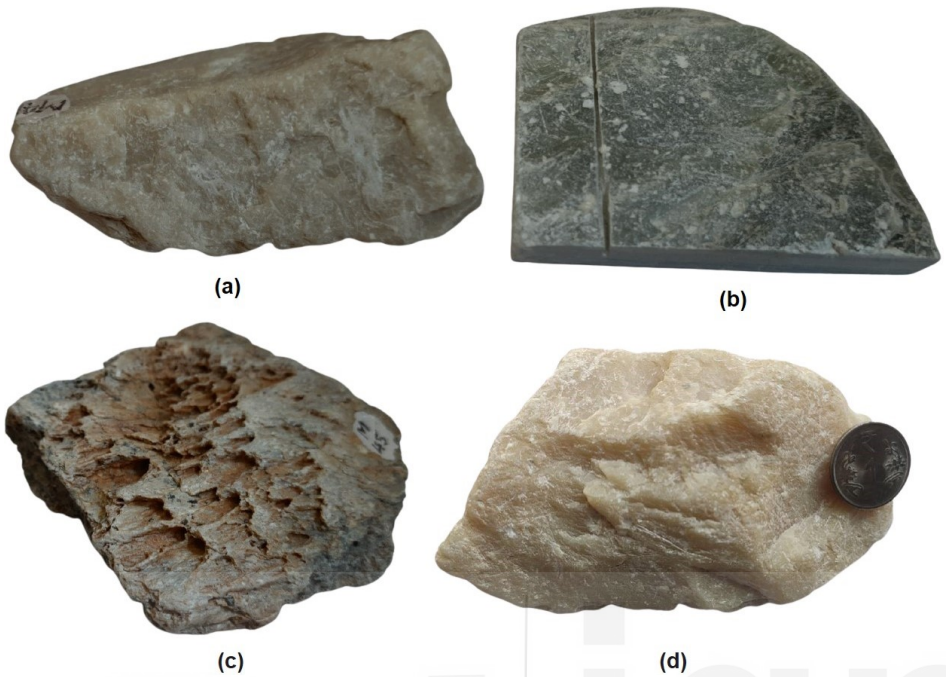


Fig. 2.3: Hand specimen of different varieties of talc.

- **Distribution in India**: In India, substantial mineral reserves of talc are reported from the states of Rajasthan and Uttarakhand. Minor reserves are found in the states of Bihar, Chhattisgarh, Andhra Pradesh, Odisha, Sikkim, Telangana Karnataka, Maharashtra, Kerala, Jharkhand and Sikkim.
- **Uses**: Talc mineral has many uses because of its special properties. It is used in the manufacture of talcum powder cosmetics, textile, paint, rubber and ceramics. It is used as filler in manufacture of paper. It is also used as a lubricant and in the manufacture of pesticides and insecticides.

2.3.4 Magnesite

Magnesite is a magnesium rich carbonate mineral and is named due to the occurrence of magnesium in its composition ($MgCO_3$). The mineral is generally formed by the metamorphic alteration of magnesium-rich rocks or carbonate rocks, or by the process of chemical weathering. It acts as the main source of raw material for the extraction of magnesium. In commercial terms, the magnesite is not only used to represent the mineral name, but also for various materials produced by calcining the natural carbonate, e.g., caustic magnesite and refractory magnesite. You are advised to identify the hand specimen with the help of physical properties and photograph of the hand specimen as given in Table 2.4 (Fig.2.4). Further write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of magnesite.

Table 2.4: Physical properties of magnesite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$MgCO_3$
2.	**Crystal System**	Hexagonal
3.	**Colour**	Mostly white colour, grey, yellow, brown

4.	**Transparency / Diaphaneity**	Opaque
5.	**Streak**	White
6.	**Lustre**	Dull
7.	**Hardness**	4-5
8.	**Form/Habit**	Commonly massive
9.	**Cleavage**	Absent
10.	**Fracture**	Even to uneven, sub-conchoidal
11.	**Specific Gravity**	3.0-3.2
12.	**Magnetism**	Non magnetic
13.	**Tenacity**	Brittle
14.	**Diagnostic Property**	White colour, dull lustre
15.	**Inference/Name**	**MAGNESITE**
Mode of Occurrence	Magnesite is generally formed when alteration of ultramafic rocks and other magnesium bearing rocks takes place. The replacement process of dolomite and dolomitic limestone are also responsible for the concentration of magnesite deposits. Interestingly, magnesite occurs as bedded sedimentary deposit.	



Fig. 2.4: Hand specimen of magnesite.

- **Distribution in India**: In India, considerably rich deposits of magnesite are reported from Almora and Pithoragarh districts of Uttarakhand; and Salem district of Tamilnadu. The other states from where magnesite deposits are reported are Himachal Pradesh, Rajasthan, Karnataka, and Union territory of Jammu and Kashmir.
- **Uses**: Magnesite is used in the manufacture of magnesium metal. It is used as an abrasive and also as a refractory material. It is used in the manufacture of steel and other alloys. Magnesite is used in chemical and fertilizer industry and in the production of rubber, glass, ceramics and textiles.

2.4 LABORATORY EXERCISES

You have studied chemical composition, crystal system and physical properties, occurrence, distribution and uses of some of the common non-metallic minerals i.e., garnet, gypsum, talc and magnesite. Now, attempt the following exercises.

Exercise 1: Identify the given specimen of garnet by studying its physical/megascopic properties and write in your laboratory file as per Table 2.5.

Exercise 2: Identify the given specimen of gypsum by studying its physical/megascopic properties and write in your laboratory file as per Table 2.5.

Exercise 3: Identify the given specimen of talc by studying its physical/megascopic properties and write in your laboratory file as per Table 2.5.

Exercise 4: Identify the given specimen of magnesite by studying its physical/megascopic properties and write in your laboratory file as per Table 2.5.

Guidelines: While performing these exercises, you will have to do the activities as listed in Section 1.5 under heading **Guidelines** of Experiment 1:

Note:

- Handle the mineral specimens and all the devices provide to you with great care and do not damage them.
- If you find any problem during the study of the mineral specimens do not hesitate to ask your counsellor.

The proforma i.e., Table 2.5 should be used for recording the physical/ megascopic properties of all the given specimens provided to you by your academic counsellor. You have to record all the exercises as Laboratory Exercise No.1, Exercise No.2, Exercise No.3 and so on. By following the procedures as mentioned in Section 1.5 under heading **Guidelines** of Experiment 1, you will have to describe all the given specimens of the minerals/ores one by one.

Table 2.5: Proforma for recording the physical properties.

Date: ……

Laboratory Exercise No.1……..:

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	
2.	**Crystal System**	
3.	**Colour**	
4.	**Streak**	
5.	**Lustre**	

6.	**Hardness**	
7.	**Form/Habit**	
8.	**Cleavage**	
9.	**Fracture**	
10.	**Specific Gravity**	
11.	**Magnetism**	
12.	**Transparency/ Diaphaneity**	
13.	**Special Property**	
14.	**Diagnostic Property**	
15.	**Inference/Name**	
16.	**Mode of Occurrence**	
17.	**Distribution**	
18.	**Uses**	
19.	**Sketch of the ore/ mineral**	

2.5 REFERENCES

- Farndon, J. (2016) Rocks, Minerals and Gems. Hermes House Anness Publishing Ltd, London.
- Marshall D., Anglin C.D. and Mumin H. (2004) Ore Mineral Atlas. Geological Association of Canada. Mineral deposits division, 126p.
- Prasad, U. (2011) Economic Geology, Economic Mineral Deposits. CBS Publishers, New Delhi. 319p.
- Read, H.H. (1988) Rutley's Elements of Mineralogy" (27th Edition), CBS Publications, (Rev. ed. C.D. Gribble).
- Unit-11: Industrial Minerals of BGYET-141 course.

2.6 LEARNING RESOURCES

1. **Physical Properties of Minerals Depending on State of Aggregation-Specific Gravity and Sense**

   Link: http://egyankosh.ac.in//handle/123456789/73673

   https://youtu.be/UFXBMcMrQJc

2. **Physical Properties of Minerals Depending on State of Aggregation : Hardness and Tenacity**

   Link: http://egyankosh.ac.in//handle/123456789/73672

   https://youtu.be/eUPWtaMeOAA

3. **Physical Properties of Minerals Depending on Forces**

   Link: http://egyankosh.ac.in//handle/123456789/73671

   https://youtu.be/POWD1V85HyI

4. **Physical Properties of Minerals Depending on State of Aggregation: Cleavage, Striations and Fracture**

   Link: http://egyankosh.ac.in//handle/123456789/73670

   https://youtu.be/DbJQE3RaQoM

5. **Physical Properties of Minerals Depending on State of Aggregation: Form and Habit**

   Link: http://egyankosh.ac.in//handle/123456789/73669

   https://youtu.be/0SfrT76_IiA

6. **Physical Properties of Minerals Depending on Light**

   Link: http://egyankosh.ac.in//handle/123456789/73668

   https://youtu.be/FjuZ-hn8Qyo

7. **Identifying Minerals**

   Link: https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-identifying-minerals/

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Experiment 3

MEGASCOPIC STUDY OF INDUSTRIAL MINERALS-I

Outline of Experiment

3.1 Introduction

Expected Learning Skills

3.2 Requirements

3.3 Physical Properties of Industrial Minerals

Calcite

Asbestos

Graphite

Dolomite

3.4 Laboratory Exercises

3.5 References

3.6 Learning Resources

3.1 INTRODUCTION

As you have already read in Unit 11, Block 3, BGYET -141 that non-metallic minerals and rocks are also called as industrial minerals. Non-metallic minerals, including industrial minerals, rocks and building stones are the major part of diverse natural resources that provide raw material for various industries and mostly used in day-to-day life. Interestingly, Indian subcontinent is bestowed with some of the important deposits of industrial minerals.

As defined by Bates in 1994 “an industrial mineral is any rock, mineral, or any other naturally occurring substance of economic value, exclusive of metallic ores, mineral fuels and gemstones”. In addition to the definitions given by previous researchers in economic geology, the recent definition by Scott in 2009 covers all the short comings in defining the industrial minerals. According to him “industrial minerals are a loose grouping of products made from Earth materials that are not a source of a metal or energy”.

In the previous Experiment 1 and Experiment 2) you have gained hands-on experience in identifying metallic and non-metallic minerals. In this experiment, you will get hands-on experience in identifying industrial minerals through megascopic study. You will also study the physical properties of some of the common industrial minerals such as calcite, asbestos, graphite, and dolomite.

Expected Learning Skills

After performing this experiment, you should be able to:

- ❖ identify the physical properties of calcite and asbestos; and
- ❖ recognise industrial minerals such as graphite and dolomite.

3.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Hand lens, pen knife, streak plate, coin, hardness box, glass plate
- Laboratory file pen, pencil and eraser
- Hand specimens of calcite, asbestos, graphite and dolomite

Note:

- **Do not use pen/pencil/marker pen to mark the hand specimen of the mineral.**
- **Please do not attempt to cleave the minerals in the laboratory. Many of the specimens you examine cannot be readily replaced.**
- **Do not break the mineral in order to see its cleavage. Cleavage is usually induced in the mineral when it is extracted from the rock it is found in, and is usually seen as planes running through the mineral.**

Instructions: You are required to study Unit 11, of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling session.

You have already studied about the physical properties of minerals and based on them you have identified metallic minerals in Experiment 1 and non-metallic minerals in Experiment 2.

Minerals show some of the common physical properties like colour, streak, lustre, hardness, form (habit), cleavage, fracture, specific gravity, tenacity, magnetism etc. Each mineral can be identified by some of the unique properties known as diagnostic properties.

3.3 PHYSICAL PROPERTIES OF INDUSTRIAL MINERALS

In Section 1.3 of Experiment 1 we have discussed about the common physical properties of the minerals/ores i.e., colour, streak, lustre, hardness, form (habit), cleavage, fracture, specific gravity etc. Refer to Experiment 1 for description of physical / megascopic characters. Here, we will discuss the physical properties

of some industrial minerals like- calcite, asbestos, graphite and dolomite, based on which these minerals can be identified.

3.3.1 Calcite

The most common carbonate minerals are calcite, aragonite, dolomite and siderite. Both calcite and aragonite have calcium carbonate ($CaCO_3$) composition, whereas the other carbonate minerals have different chemical composition. The minerals of the group are mostly present in sedimentary rocks, but they are also found in igneous and metamorphic rocks as primary or secondary minerals. You are advised to identify the hand specimens with the help of physical properties and photograph (Fig. 3.1) of the hand specimen as given in Table 3.1. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of calcite.

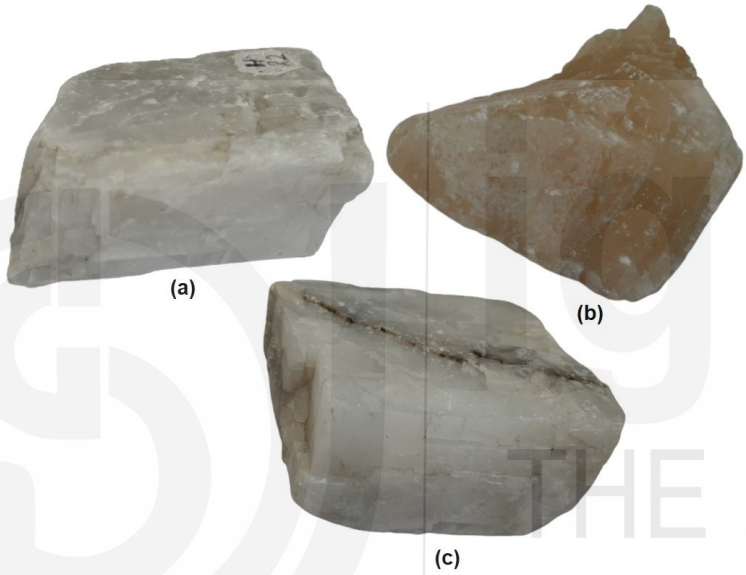


Fig. 3.1: (a – c) Hand specimens of calcite with vitreous lustre.

Table 3.1: Physical properties of calcite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$CaCO_3$
2.	**Crystal System**	Hexagonal
3.	**Colour**	Exceptionally variable but typically white or colourless (Fig. 3.1a and c) or with light shades of yellow, orange, blue, pink, red, brown (Fig. 3.1b), green, black and grey
4.	**Streak**	White
5.	**Lustre**	Vitreous
6.	**Hardness**	3
7.	**Form/Habit**	Crystalline, granular, stalactitic, oncretionary, massive, rhombohedral

8.	**Cleavage**	3 sets, perfect (rhombohedral)
9.	**Fracture**	Conchoidal to uneven
10.	**Magnetism**	Non-magnetic
11.	**Transparency/ Diaphaneity**	Transparent to translucent
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.7
14.	**Special Property**	It gives effervescence when reacted with dilute hydrochloric acid
15.	**Diagnostic Property**	Colour, hardness and rhombohedral cleavage
16.	**Inference/Name**	**CALCITE**
Mode of Occurrence	Calcite mostly occurs in pure form in nature as a cementing material in other sedimentary rocks. Calcite is richly found in stalactites and stalagmites which form the cave deposits. Marble, is a metamorphic rock where the mineral calcite is found almost in its pure from. It usually occupies the vesicular filings in basaltic rocks and rarely occurs in carbonatites of igneous rocks.	

- **Distribution in India**: Rajasthan stands first in hosting largest calcite resources in the country. The second largest state is Andhra Pradesh and followed by Madhya Pradesh. Minor occurrences are reported from the states of Karnataka, Gujarat, Uttar Pradesh, Haryana and Tamil Nadu.
- **Uses**: Calcite is used in the manufacture of ceramics, paint, cement, glass, fertilizers and chemicals. It is used as filler in rubber and textiles. 'Iceland spar' a best-known variety of calcite is used in the manufacture of nicol prism of polarizing microscopes.

3.3.2 Asbestos

Asbestos is a fibrous amphibole mineral consisting of useful properties such as high tensile strength, low electrical and heat conductivity, high flexibility, chemical stability and larger surface area. Commercial asbestos is grouped in to number of fibrous varieties such as:

i) Chrysotile, fibrous serpentine, ii) amosite, fibrous anthophyllite, iii) crocidolite iv) tremolite and actinolite asbestos.

Mostly all the varieties of asbestos are commercially used. However, chrysolite variety of asbestos is most commonly used and produced in different parts of the world. You are advised to identify the hand specimens with the help of physical properties and photograph (Fig. 3.2) of the hand specimen as given in Table 3.2. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of asbestos.



Fig. 3.2: Photograph of the hand specimen of asbestos with hackly fracture.

Table 3.2: Physical properties of asbestos.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$Mg_3Si_2O_5(OH)_4$ (Chrysotile)
2.	**Crystal System**	Monoclinic
3.	**Colour**	White/pale coloured
4.	**Streak**	White
5.	**Lustre**	Silky
6.	**Hardness**	2.5-4
7.	**Form/Habit**	Fibrous
8.	**Cleavage**	Present
9.	**Fracture**	Uneven to hackly
10.	**Magnetism**	Non-magnetic
11.	**Transparency/ Diaphaneity**	Thin fibres are translucent
12.	**Tenacity**	Flexible
13.	**Specific Gravity**	2.4-2.6
14.	**Diagnostic Property**	Silky lustre, fibrous form and cleavage
15.	**Inference/Name**	**ASBESTOS**
Mode of Occurrence	Chrysotile variety of asbestos occurs as an alteration product of ultrabasic igneous rocks rich in magnesium silicates. It is formed by the process of serpentinisation where molecular rearrangement and crystallisation occurs resulting in the formation of asbestos. It generally takes place along the fractures, fissures and shear zones. Mostly the other varieties of asbestos occur in association with schists and gneisses.	

- **Distribution in India**: Chrysotile variety of asbestos is found in Cuddapah in Andhra Pradesh and Singhbhum belt in Jharkhand. Minor occurrences are reported from Udaipur district of Rajasthan and Mysore district of Karnataka. Other varieties of asbestos mostly occur in Rajasthan and some other parts of the country.
- **Uses**: Asbestos is utilised due to its property of being spun into yarn and its resistance to heat and electricity, and fibrous tendency. It is used in

manufacture of break and clutch lining, gaskets, boilers covering, insulating material, fire proof textiles, paper, fillers and filters. It is basically used in the production of asbestos sheets and tiles.

3.3.3 Graphite

The word graphite is derived from Greek term 'graphein' that gives a meaning of writing. It is allotropic form of carbon and similar to diamond and wood charcoal. It occurs mainly in three forms- flakes, dusts, and lumps. Interestingly it displays the properties of a metal and a non-metal. The metallic properties are electrical and thermal conductivity, and non-metallic properties are electrical conductivity and lubrication. Hence, these properties make it more useful for industrial applications. Graphite occurs in two forms: i) Natural graphite which includes (a) crystalline and (b) amorphous varieties. ii) Artificial/manufactured graphite. You are advised to identify the hand specimens with the help of physical properties and photograph (Fig. 3.3) of the hand specimen as given in Table 3.3. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of graphite.



(a) (b)

Fig. 3.3: Hand specimen of graphite with massive from.

Table 3.3: Physical properties of graphite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	C
2.	**Crystal System**	Hexagonal
3.	**Colour**	Steel grey (Fig. 3.3b) to black (Fig. 3.3a)
4.	**Streak**	Black
5.	**Lustre**	Metallic, less probably submetallic and greasy
6.	**Hardness**	1-2
7.	**Form/Habit**	Massive, granular
8.	**Cleavage**	Perfect in one direction
9.	**Fracture**	Uneven
10.	**Magnetism**	Diamagnetic

11.	**Transparency/ Diaphaneity**	Opaque
12.	**Tenacity**	**Flexible, non-elastic, sectile**
13.	**Specific Gravity**	2.1-2.3
14.	**Diagnostic Property**	Steel grey to black colour, greasy feel and low specific gravity
15.	**Inference/Name**	**GRAPHITE**
Mode of Occurrence		Graphite mainly occurs in metamorphic rocks such as gneiss, schist, marble, quartzite and altered coal beds. It occurs in igneous rocks, veins and pegmatites. The crystalline variety of graphite mostly occurs in the form of flakes disseminated throughout the metamorphic rocks. Likewise, the amorphous variety occurs in the form of dust in which the ore content is normally high.

- **Distribution in India**: Graphite occurs in Palamau District of Jharkhand and East Godavari, West Godavari, Visakhapatnam and Srikakulam Districts of Andhra Pradesh. In Odisha the occurrence of the mineral is reported from the Districts of Bolangir, Dhenkanal, Kalahandi, Phulbani and Sambalpur. Graphite occurrences are also reported from the states of Kerala, Gujarat, Tamil Nadu, Arunachal Pradesh and Telangana.
- **Uses**: Graphite has diverse applications because of its high lubricity, refractoriness or ability to withstand high temperature, good electrical and heat conductivity, and resistance to reaction with ordinary chemical reagents. Thus, flaky graphite is used in the manufacture of crucibles for melting metals. It is used in the manufacture of lead in pencils, batteries, thermal and chemical resistant appliances. It is also used in nuclear reactors. The commercial graphite is graded based on its carbon content.

3.3.4 Dolomite

Dolomite is an anhydrous carbonate mineral that is similar to mineral calcite. It is a double carbonate of calcium ($CaCO_3$) and magnesium ($MgCO_3$) and also called as dolostone. Generally, the rock containing 40-45% $MgCO_3$ is called dolomite. Together with calcite and aragonite, dolomite forms about 2% of the Earth's crust. When magnesium of dolomite is replaced by iron or manganese and with lesser proportion of magnesium carbonate, it is known as dolomitic limestone. Dolomite can be differentiated from calcite by its hardness and reaction with the acid. Dolomite is slightly harder than calcite and it shows weak reaction with dilute HCl in comparison to calcite. You are advised to identify the hand specimens with the help of physical properties and photograph (Fig. 3.4) of the hand specimen as given in Table 3.4. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of dolomite.

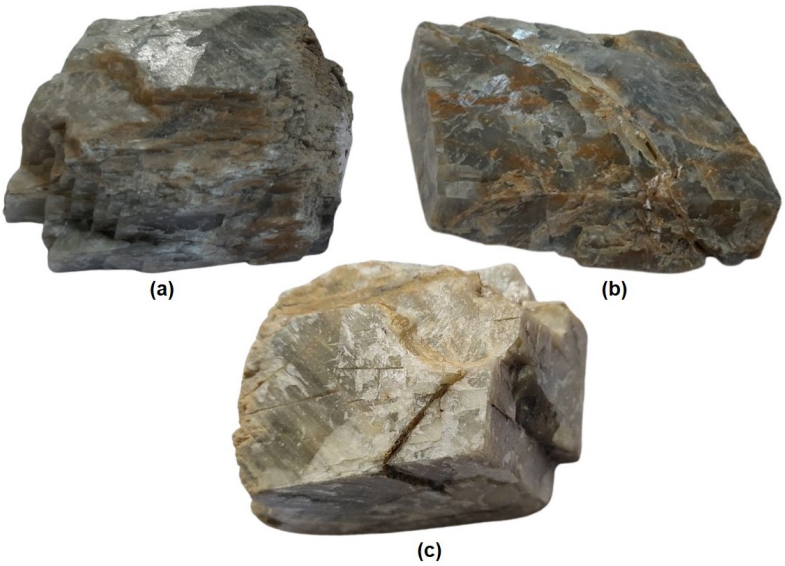


Fig. 3.4: Hand specimen of dolomite: (a-b) grey crystalline; and c) with rhombohedral cleavage.

Table 3.4: Physical properties of dolomite.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$CaMg(CO_3)_2$
2.	**Crystal System**	Hexagonal
3.	**Colour**	Grey or any other pale colour (Fig. 3.4a and b)
4.	**Streak**	White
5.	**Lustre**	Vitreous, pearly
6.	**Hardness**	3.5-4
7.	**Form/Habit**	Rhombic form, massive
8.	**Cleavage**	Perfect, rhombohedra l(three sets) (Fig. 3.4c)
9.	**Fracture**	Uneven to sub-conchoidal
10.	**Magnetism**	Diamagnetic
11.	**Transparency/ Diaphaneity**	Translucent along thin edges
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.8-2.9
14.	**Diagnostic Property**	Rhombohedral cleavage, hardness and weak reaction with dilute HCl
15.	**Inference/Name**	**DOLOMITE**
Mode of Occurrence	Dolomite occurs extensively as bedded strata in many geological formations often associated with the limestone, serpentine and other magnesium minerals. It occurs as a	

	common mineral in hydrothermal veins or as a pore-filling mineral in carbonate rocks. It also occurs as minor mineral component in igneous pegmatites or altered mafic igneous rocks and in metamorphic rocks in association with marble.

- **Distribution in India**: Dolomite mineral occurs in almost all parts of the country. Noted occurrences are reported in Jalpaiguri and Darjeeling districts of West Bengal, Anantapur District of Andhra Pradesh, and Mahendragarh District of Haryana. Similarly, the deposits are also found in Balaghat, Bastar, Ballarpur districts of Chhattisgarh; Chindwara and Mandla districts of Madhya Pradesh. Some occurrences are reported from districts of Maharashtra, Odisha, Tamil Nadu, Arunachal Pradesh and Rajasthan.
- **Uses**: Dolomite is mostly used as a refractory material in iron and steel industry and as a soft abrasive. It is used in the manufacture of ceramics, ferro alloys, glass, chemicals, pharmaceuticals and nickel plating. It is also used in the production of carbon dioxide, metallic magnesium and calcium.

3.4 LABORATORY EXERCISES

You have studied chemical composition, crystal system and physical properties of some of the common industrial minerals i.e., calcite, asbestos, graphite and dolomite. Now, attempt the following exercises.

Exercise 1: Identify the given specimen of calcite by studying its physical/megascopic properties and write in your laboratory file as per Table 3.5.

Exercise 2: Identify the given specimen of asbestos by studying its physical/megascopic properties and write in your laboratory file as per Table 3.5.

Exercise 3: Identify the given specimen of graphite by studying its physical/megascopic properties and write in your laboratory file as per Table 3.5.

Exercise 4: Identify the given specimen of dolomite by studying its physical/megascopic properties and write in your laboratory file as per Table 3.5.

Guidelines: While performing these exercises, you will have to do the activities as listed in Section 1.5 under heading **Guidelines** of Experiment 1:

Note:

- Handle the mineral specimens and all the devices provide to you with great care and do not damage them.
- If you find any problem during the study of the mineral specimens do not hesitate to ask your counsellor.

The proforma i.e., Table 3.5 should be used for recording the physical/ megascopic properties of all the given specimens provided to you by your academic counsellor. You have to record all the exercises as Laboratory Exercise No.1, Exercise No.2, Exercise No.3 and so on. By following the procedures as mentioned in Section 1.5 under heading **Guidelines** of

Experiment 1, you will have to describe all the given specimens of the minerals/ores one by one.

Table 3.5: Proforma for recording the physical properties.

Date: ……

Laboratory Exercise No.1……..:

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	
2.	**Crystal System**	
3.	**Colour**	
4.	**Streak**	
5.	**Lustre**	
6.	**Hardness**	
7.	**Form/Habit**	
8.	**Cleavage**	
9.	**Fracture**	
10.	**Specific gravity**	
11.	**Magnetism**	
12.	**Transparency / Diaphaneity**	
13.	**Special property**	
14.	**Diagnostic properties**	
15.	**Inference/Name**	
16.	**Mode of Occurrence**	
17.	**Distribution**	
18.	**Uses**	
19.	**Sketch of the ore/ mineral**	

3.5 REFERENCES

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- Prasad, U. (2011) Economic Geology, Economic Mineral Deposits. CBS Publishers, New Delhi. 319p.
- Read, H.H. (1988) Rutley's Elements of Mineralogy" (27th Edition), CBS Publications, (Rev. ed. C.D. Gribble).
- Unit-11: Industrial Minerals of BGYET-141 course.
- http://ibm.nic.in/writereaddata/files/11082017150414Calcite2016(AdvanceRelease).pdf

(Website accessed between 20/01/2021 and 21/05/2021)

3.6 LEARNING RESOURCES

1. **Physical Properties of Minerals Depending on State of Aggregation-Specific Gravity and Sense**

   Link: http://egyankosh.ac.in//handle/123456789/73673

   https://youtu.be/UFXBMcMrQJc

2. **Physical Properties of Minerals Depending on State of Aggregation : Hardness and Tenacity**

   Link: http://egyankosh.ac.in//handle/123456789/73672

   https://youtu.be/eUPWtaMeOAA

3. **Physical Properties of Minerals Depending on Forces**

   Link: http://egyankosh.ac.in//handle/123456789/73671

   https://youtu.be/POWD1V85HyI

4. **Physical Properties of Minerals Depending on State of Aggregation: Cleavage, Striations and Fracture**

   Link: http://egyankosh.ac.in//handle/123456789/73670

   https://youtu.be/DbJQE3RaQoM

5. **Physical Properties of Minerals Depending on State of Aggregation: Form and Habit**

   Link: http://egyankosh.ac.in//handle/123456789/73669

   https://youtu.be/0SfrT76_IiA

6. **Physical Properties of Minerals Depending on Light**

   Link: http://egyankosh.ac.in//handle/123456789/73668

   https://youtu.be/FjuZ-hn8Qyo

7. **Identifying Minerals**

   Link: https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-identifying-minerals/

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Experiment 4

MEGASCOPIC STUDY OF INDUSTIAL MINERALS-II

Outline of Experiment

4.1 Introduction

Expected Learning Skills

4.2 Requirements

4.3 Physical Properties of Industrial Minerals

Quartz

Beryl

Tourmaline

Feldspar

4.4 Laboratory Exercises

4.5 References

4.6 Learning Resources

4.1 INTRODUCTION

In the previous Experiment 3, you have gained hands-on experience in identifying some industrial minerals i.e., calcite, asbestos, graphite and dolomite. In this experiment, you will get hands-on experience of identifying some of other common industrial minerals like quartz, beryl, tourmaline and feldspar.

Expected Learning Skills

After performing this experiment, you should be able to:

- identify the physical properties of quartz and beryl; and
- recognise industrial minerals such as tourmaline and feldspar.

4.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Hand lens, pen knife, streak plate, coin, hardness box, glass plate
- Laboratory file, pen, pencil and eraser
- Hand specimens of quartz, beryl, tourmaline and feldspar

Note:

- **Do not use pen/pencil/marker pen to mark the hand specimen of the mineral.**
- **Please do not attempt to cleave the minerals in the laboratory. Many of the specimens you examine cannot be readily replaced.**
- **Do not break the mineral in order to see its cleavage. Cleavage is usually induced in the mineral when it is extracted from the rock it is found in, and is usually seen as planes running through the mineral.**

Instructions: You are required to study Unit 11, of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling session.

You have already studied about the physical properties of minerals and based on them you have identified industrial minerals in Experiment 3.

Minerals show some of the common physical properties like colour, streak, lustre, hardness, form (habit), cleavage, fracture, specific gravity, magnetism, transparency etc.

Each mineral can be identified by some of the unique properties known as diagnostic properties.

4.3 PHYSICAL PROPERTIES OF INDUSTRIAL MINERALS

In Section 1.3 of Experiment 1 we have discussed about the common physical properties of the minerals/ores i.e., colour, streak, lustre, hardness, form (habit), cleavage, fracture, specific gravity etc. Refer to Experiment 1 for description of physical / megascopic characters. Here, we will now discuss about the physical properties of some industrial minerals i.e., quartz, beryl, tourmaline and feldspar, based on which these minerals can be identified.

4.3.1 Quartz

Silica is one of the major groups of minerals that occur in Earth's crust with an abundance of nearly about 8%. Silica is dominantly present in all types of rocks like igneous, sedimentary and metamorphic. It occurs in nature as quartz, tridymite, cristobalite, coesite, stishovite, lechatelierite and opal. Silica occurs in different forms such as crystalline (e.g., quartz), cryptocrystalline (e.g., chalcedony, flint, chert) and amorphous (e.g., opal). Let us study the physical properties of quartz as it is the most commonly occurring mineral out of all the other minerals of silica. You are advised to identify the hand specimens with the

help of physical properties and photograph (Fig. 4.1a-f) of the hand specimen as given in Table 4.1. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of quartz.



Fig. 4.1: Hand specimen of: a) milky quartz; b) transparent quartz; c) rosy quartz; d) smoky quartz; e) grey coloured quartz; and f) crystalline quartz.

Table 4.1: Physical properties of quartz.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	SiO_2
2.	**Crystal System**	Hexagonal
3.	**Colour**	Almost it occurs in every colour - white, grey, purple, yellow, brown, black, pink, green, red
4.	**Streak**	Colourless and harder than the streak plate
5.	**Lustre**	Vitreous
6..	**Hardness**	7 (it is represented on Moh's scale) and cannot be scratched with knife
7	**Form/Habit**	Crystals commonly prismatic and it can also be massive, granular, acicular
8.	**Cleavage**	Absent

9.	**Fracture**	Conchoidal
10.	**Magnetism**	Diamagnetic
11.	**Transparency/ Diaphaneity**	Transparent to translucent and sometimes opaque
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.6-2.7
14.	**Diagnostic Property**	Conchoidal fracture, vitreous lustre, hardness of 7, and absence of cleavage
15.	**Inference/Name**	**QUARTZ**
Mode of Occurrence	Quartz is a common mineral occurring in igneous, sedimentary and metamorphic rocks. It is a major constituent of felsic igneous rock and commonly present in sedimentary rocks like sandstone and shale. It occurs in schist, gneiss, pegmatite and quartzite, and other related metamorphic rocks.	

- **Distribution in India**: Crystalline quartz occurs in Maharashtra, Andhra Pradesh and Madhya Pradesh. Transparent crystals of quartz occur in Rajasthan, West Bengal. Quartz also occurs in Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh and Tamil Nadu.
- **Uses:** Quartz is used in the manufacture of ceramics, glass, and toothpaste. Quartz crystals are used in making crystal oscillator, computers, watches, mobile phones and many other electronic devices. Due to its high durability, hardness and brilliant shine some varieties of quartz are used as a gemstone.

4.3.2 Beryl

Beryl falls in the category of cyclosilicate minerals and comprises of substantial amount of beryllium. It is the only ore of metal beryllium and is lighter than aluminium. It is considered as strategic mineral. It is one of the most significant gem minerals and occurs in different colours. Out of all the gem varieties of beryl, the transparent green coloured beryl, known as emerald is the most valuable. Greenish blue to blue coloured beryl is known as aquamarine and pink to orange coloured beryl is called as margonite. You are advised to identify the hand specimens with the help of physical properties and photograph (Fig. 4.2a and b) of the hand specimen as given in Table 4.2. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of beryl.

Table 4.2: Physical properties of beryl.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$Be_3Al_2(SiO_3)_6$
2.	**Crystal System**	Hexagonal

3.	**Colour**	Green, yellow, orange, pink, blue
4.	**Streak**	Colourless (harder than streak plate)
5.	**Lustre**	Vitreous to sub-vitreous
6.	**Hardness**	7-8
7.	**Form/Habit**	Hexagonal prisms
8.	**Cleavage**	1 set, basal, very poor
9.	**Fracture**	Conchoidal
10.	**Magnetism**	Green beryl are weakly magnetic, blue beryl are is more magnetic
11.	**Transparency / Diaphaneity**	Translucent to transparent
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.7
14.	**Diagnostic Property**	Hexagonal prismatic crystals, hardness and low specific gravity
15.	**Inference/ Name**	**BERYL**
Mode of Occurrence		Beryl occurs in intrusive rocks like granite, rhyolites, and mica pegmatites. It also occurs in metamorphic rocks, such as mica schists and crystalline limestones. It is found in veins and cavities formed by the hydrothermal alteration of rocks of granitic composition. Economically viable deposits of beryl are mostly confined to pegmatites.



(a) (b)

Fig. 4.2: Hand specimen of: a) green coloured crystalline beryl showing hexagonal form; and b) light brown coloured beryl.

- **Distribution in India**: India is one of the important producers of beryl and exploitable occurrences are mostly confined to the pegmatites of Dharwarian rocks. Gem varieties of beryl are found in Rajasthan, Himachal Pradesh, Tamil Nadu, and Jammu and Kashmir.
- **Uses**: The different gem varieties of beryl are used in making of ornaments. It is used in the manufacture of steel, casting of copper and very limitedly in manufacture of X-ray tubes. It is also used in the nuclear fission reactors.

4.3.3 Tourmaline

Tourmaline is categorised as semi-precious stone and is found in wide range of colours. The name 'tourmaline' is derived from Sinhalese language. It is a complex silicate mineral of aluminium and boron. However, due to isomorphous replacement it is compounded with elements like iron, magnesium, aluminium, lithium, potassium, sodium and some other elements. You are advised to identify the hand specimens with the help of physical properties and photograph of the hand specimen as given in Table 4.3 (Fig.4.3). Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of tourmaline.

Table 4.3: Physical properties of tourmaline.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$(Al,Fe,Li,Mg,Mn)_3(Al,Cr, Fe,V)_6(BO_3)_3(Si,Al,B)_6O_{18}(OH,F)_4$ (Complex silicate of boron and aluminium)
2.	**Crystal System**	Hexagonal
3.	**Colour**	Mostly black, but also in other colours such as purple, green, orange, blue, yellow, pink, red, brown, and colourless
4.	**Streak**	White or colourless
5.	**Lustre**	Vitreous
6.	**Hardness**	7-7.5
7.	**Form/Habit**	Parallel and elongated, acicular prisms, sometimes radiating, massive
8.	**Cleavage**	Indistinct
9.	**Fracture**	Uneven, small conchoidal, brittle
10.	**Magnetism**	magnetic
11.	**Transparency / Diaphaneity**	Transparent to translucent
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.8 to 3.3
14..	**Diagnostic properties**	Indistinct cleavage, prismatic crystals, vibrant colours
15	**Inference/ Name**	**TOURMALINE**
Mode of Occurrence	Tourmaline has a characteristic occurrence in granites, granitic pegmatites and pneumatolytic veins. It is found in some metamorphic and metasomatic rocks. It also occurs as detrital mineral in some sedimentary rocks.	



Fig. 4.3: Hand specimens of tourmaline crystals.

- **Distribution in India**: Tourmaline occurrences are reported from coastal districts of Andhra Pradesh. It is found in association with Bastar craton pegmatites of Chhattisgarh and East Singhbhum District of Jharkhand. It is also reported from states of Haryana, Karnataka, Rajasthan, Tamil Nadu, Odisha, Kerala, West Bengal and Madhya Pradesh.
- **Uses** : The different gem varieties of tourmaline are used in making of jewellery. In industry it is used in the manufacture of television and radio. It is also used in different therapies.

4.3.4 Feldspar

Feldspar is known to be one of the most widely available rock forming minerals. It includes a set of minerals composed of alumina silicates with potassium, calcium, sodium or barium as is omorphous series. The main minerals of this group are K- feldspar (orthoclase and microcline), Na-feldspar (albite), and Ca-feldspar (anorthite) which form the end-member series of plagioclase. K-feldspar and Na-feldspar are the commercially important varieties. They occur in different colours, but the most common colours are white, grey and pale red. You are advised to identify the hand specimens with the help of physical properties and photographs of the hand specimen as given in Table 4.4; (Fig. 4.4a and b) for orthoclase, Table 4.5 (Fig. 4.5) for microcline and Table 4.6; (Fig. 4.6a and b) for plagioclase. Further, write the chemical composition, crystal system, diagnostic properties, occurrence, distribution and uses of feldspar.

Table 4.4: Physical properties of orthoclase.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$KAlSi_3O_8$
2.	**Crystal System**	Monoclinic
3.	**Colour**	Shades of red and dark pink (Fig. 4.4b) such as flesh red, reddish white, light pink (Fig. 4.4a), colourless, white grey, rarely yellow or

		green
4.	**Streak**	white
5.	**Lustre**	Pearly on cleavage faces and vitreous on fractured faces
6.	**Hardness**	6 (represented on Mohs scale of hardness)
7.	**Form/Habit**	Tabular crystals, somewhat flattened crystals, massive
8.	**Cleavage**	Two set cleavage at 900
9.	**Fracture**	Conchoidal, hackly
10.	**Magnetism**	Non-magnetic
11..	**Transparency / Diaphaneity**	Translucent to opaque and rarely transparent
12	**Tenacity**	Brittle
13.	**Specific Gravity**	2.6
14.	**Diagnostic properties**	Flesh red colour, hardness of 6, perfect two set cleavage at 90^{o}, tabular habit
15.	**Inference/ Name**	**ORTHOCLASE**



(a) (b)

Fig. 4.4: Hand specimen of: a) light pink coloured; and b) dark pink coloured orthoclase.

Table 4.5: Physical properties of microcline.

S.No.	Physical Properties	Characteristics
1.	**Chemical composition**	$KAlSi_3O_8$
2.	**Crystal System**	Triclinic
3.	**Colour**	White, grey, greyish yellow, yellowish, pink, bluish green, green
4.	**Streak**	White
5.	**Lustre**	Vitreous to sub-vitreous

6.	**Hardness**	6-6.5
7.	**Form/Habit**	Tabular crystals, rather flattened crystals, massive
8.	**Cleavage**	Two set cleavage at 90^0
9.	**Fracture**	Conchoidal, uneven
10.	**Magnetism**	Non-magnetic
11.	**Transparency / Diaphaneity**	Translucent to opaque
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	2.55-2.63
14.	**Diagnostic Property**	Green colour, two set cleavage at 90^0, tabular to massive form; It is distinguished from orthoclase by its bright colour
15.	**Inference/ Name**	**MICROCLINE**



Fig. 4.5: Hand specimen of microcline.

Table 4.6: Physical properties of plagioclase.

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
2.	**Crystal System**	Triclinic
3.	**Colour**	Usually white, also colourless, cream (Fig.4.6a), grey (Fig. 4.6b), yellow, orange, pink, green, blue, red,brown, black
4.	**Streak**	White
5.	**Lustre**	Vitreous, pearly on cleavage surfaces
6.	**Hardness**	6-6.5
7.	**Form/Habit**	Massive, columnar, grainy, rosette, and

		rounded; crystals are tall prismatic and short, stubby tabular; crystals are also found as flat and bladed, and often striated
8.	**Cleavage**	Two set cleavage at 90^0
9.	**Fracture**	Conchoidal to uneven
10.	**Magnetism**	Non-magnetic
11.	**Transparency / Diaphaneity**	Transparent to translucent and opaque
12.	**Tenacity**	Brittle
13.	**Specific Gravity**	Striations on crystal faces
14.	**Diagnostic Property**	White colour; It is distinguished from quartz by its two visible cleavages; It is often difficult to distinguish from alkali feldspar when anhedral, however, the later is often pink
15.	**Inference/Name**	**PLAGIOCLASE**



Fig. 4.6: Hand specimen of (a) cream coloured crystalline and (b) grey coloured plagioclase.

- **Mode of Occurrence**: The alkali feldspars occur as the important constituents of acid igneous rocks like granite, syenite and diorite their hypabyssal and volcanic equivalents. Feldspars are common minerals in most of the sedimentary and metamorphic rocks. Feldspars also occur in the form of large crystals in pegmatites.
- **Distribution in India**: The mica rich pegmatites are the important sources of feldspar in states such as Rajasthan, Andhra Pradesh and Bihar. Maharashtra and Tamil Nadu are the other important states where the occurrence of workable deposits of feldspar is reported.
- **Uses**: Feldspar is used in the manufacture of glass, ceramics, pottery and vitrified tiles. It is also used as an abrasive, flux, refractory and in coal washeries.

4.4 LABORATORY EXERCISES

You have studied chemical composition, crystal system and physical properties of some of the common industrial minerals i.e., quartz, beryl, tourmaline and feldspar. Now, attempt the following exercises.

Exercise 1: Identify the given specimen of quartz by studying its physical/megascopic properties and write in your laboratory file as per Table 4.7.

Exercise 2: Identify the given specimen of beryl by studying its physical/megascopic properties and write in your laboratory file as per Table 4.7.

Exercise 3: Identify the given specimen of tourmaline by studying its physical/megascopic properties and write in your laboratory file as per Table 4.7.

Exercise 4: Identify the given specimen of feldspar (orthoclase, microcline, plagioclase) by studying its physical/megascopic properties and write in your laboratory file as per Table 4.7.

Guidelines: While performing these exercises, you will have to do the activities as listed in Section 1.5 under heading **Guidelines** of Experiment 1:

Note:

- Handle the mineral specimens and all the devices provide to you with great care and do not damage them.
- If you find any problem during the study of the mineral specimens do not hesitate to ask your counsellor.

The proforma i.e., Table 4.7 should be used for recording the physical/ megascopic properties of all the given specimens provided to you by your academic counsellor. You have to record all the exercises as Laboratory Exercise 1, Exercise 2, Exercise 3 and so on. By following the procedures as mentioned in Section 1.5 under heading **Guidelines** of Experiment 1, you will have to describe all the given specimens of the minerals/ores one by one.

Table 4.7: Proforma for recording the physical properties.

Date: ……

Laboratory Exercise No.1……..:

S.No.	Physical Properties	Characteristics
1.	**Chemical Composition**	
2.	**Crystal System**	
3.	**Colour**	
4.	**Streak**	
5.	**Lustre**	
6.	**Hardness**	
7.	**Form/Habit**	
8.	**Cleavage**	
9.	**Fracture**	

10.	**Specific gravity**	
11.	**Magnetism**	
12.	**Transparency / Diaphaneity**	
13.	**Special property**	
14.	**Diagnostic properties**	
15.	**Inference/Name**	
16.	**Mode of Occurrence**	
17.	**Distribution**	
18.	**Uses**	
19.	**Sketch of the ore/ mineral**	

4.5 REFERENCES

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- Unit-11: Industrial Minerals of BGYET-141 course.

4.6 LEARNING RESOURCES

1. **Physical Properties of Minerals Depending on State of Aggregation-Specific Gravity and Sense**

   Link: http://egyankosh.ac.in//handle/123456789/73673

   https://youtu.be/UFXBMcMrQJc

2. **Physical Properties of Minerals Depending on State of Aggregation : Hardness and Tenacity**

   Link: http://egyankosh.ac.in//handle/123456789/73672

   https://youtu.be/eUPWtaMeOAA

3. **Physical Properties of Minerals Depending on Forces**

   Link: http://egyankosh.ac.in//handle/123456789/73671

   https://youtu.be/POWD1V85HyI

4. **Physical Properties of Minerals Depending on State of Aggregation: Cleavage, Striations and Fracture**

   Link: http://egyankosh.ac.in//handle/123456789/73670

   https://youtu.be/DbJQE3RaQoM

5. **Physical Properties of Minerals Depending on State of Aggregation: Form and Habit**

   Link: http://egyankosh.ac.in//handle/123456789/73669

   https://youtu.be/0SfrT76_IiA

6. **Physical Properties of Minerals Depending on Light**

   Link: http://egyankosh.ac.in//handle/123456789/73668

   https://youtu.be/FjuZ-hn8Qyo

7. **Identifying Minerals**

   Link: https://courses.lumenlearning.com/wmopen-geology/chapter/outcome-identifying-minerals/

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EXPERIMENT 5

PREPARATION OF MAP SHOWING DISTRIBUTION OF METALLIC MINERAL DEPOSITS OF INDIA

Outline of Experiment

5.1 Introduction
Expected Learning Skills
5.2 Requirements
5.3 Iron Ore Deposits
5.4 Manganese Ore Deposits
5.5 Chromium Ore Deposits
5.6 Aluminium Ore Deposits
5.7 Copper Ore Deposits
5.8 Lead and Zinc Ore Deposits
5.9 Gold Deposits
5.10 Laboratory Exercises
5.11 References
5.12 Learning Resources

5.1 INTRODUCTION

You know that a mineral is a solid, naturally occurring combination of inorganic substances. You have already read in BGYET-141 course that an ore is defined as a naturally occurring mineral or aggregate of minerals from which metal/metals could be extracted with profit. It usually occurs with gangue mineral or mineral aggregates, substance or unwanted substance. The ore deposits represent a geochemically irregular concentration of elements in a very limited area of the earth's crust. The occurrence of metallic minerals is seen in all types of rocks. The most significant metallic minerals belong to the ores of iron, manganese, copper, chromium, aluminium, gold, silver, lead, zinc, cobalt, nickel, tungsten, molybdenum, vanadium, mercury, tin, magnesium, titanium and platinum. You have already studied those metals like iron, manganese, nickel and cobalt come under the category of ferrous metals. Copper, lead and zinc are grouped as base metals. Aluminium and magnesium are known as light metals and metals like gold and silver come under the category of precious metals. The ferrous metals such as the iron, manganese and chromium have a predominant place in the society due to their vital usage in day-to-day life.

In the previous experiment you have recognised the industrial minerals in hand specimen based on their physical properties. In this experiment, you will prepare different maps showing geographical or spatial distribution of some of the important metallic mineral such as iron, manganese, chromium, aluminium, copper, gold, lead and zinc depositsdeposits of India.

Expected Learning Skills

After completing this experiment, you would be able to:

- ❖ list spatial distribution of iron, manganese, chromium, aluminium, copper, gold, lead and zinc deposits of India;
- ❖ plot distribution of iron, manganese, chromium, aluminium, copper, gold, lead and zinc deposits on the map of India; and
- ❖ identify the regions, with the maximum concentration of iron, manganese, chromium, aluminium, copper, gold, lead and zinc deposits of India.

5.2 REQUIREMENTS

To perform this experiment successfully you require the following:

- Pen, pencil, eraser, scale, sharpener and coloured pencils
- Laboratory file
- Blank maps of India of A4 size (with demarcated states boundaries)
- Atlas of India (it will help you to plot the localities of economic minerals in the blank map of India)

[Instructions: You are required to study Unit -9 and 10 of BGYET-141course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling sessions.]

5.3 IRON ORE DEPOSITS

India is bestowed with large resource of iron ore. India ranks fourth in terms of quantity production in the world. Iron ore occurs in different geological formations. However, major economic deposits of iron ore are found associated with volcano-sedimentary Banded Iron Formation (BIF) of Precambrian age. Hematite and magnetite are the two iron oxides, which are commercially much useful that is found in India. Hematite is considered to be the most important iron ore because of its high-grade quality and lumpy nature. Hematite and magnetiteare consumed by a large number of steel and iron industries in the country. In India, major iron ore deposits are located in three belts (Fig. 5.1). These deposits are:

a) **Singhbhum-Mayurbhanj belt**: The important reserves of this belt are located in Noamundi- Thakurani (South Singhbhum district, Jharkhand), Joda- Barsua, Kalta, Kiriburu-Meghataburu-Gua-Bolani and Chiria (in Keonjhar, Bonai and Cuttack district, Odisha) and Gurumahisani- Sulaipeta-Badampahar (Mayurbhanj district, Odisha).

b) **Durg-Bastar-Chandrapur belt**: The important reserves of this belt are located in Dalli-Rajhara, Rowghat and Bailadila regions of Chhattisgarh.

c) **Bellary-Chitradurga-Chikmaglur-Tumkar belt**: The third important belt is from Bababudan Hills, Chikmagalur district, Karnataka and Sandur belt comprising Donimalai, Ramanadurg, and Kumar swami ranges in the Bellary-Hospet region of Karnataka and adjoining region of Andhra Pradesh.

The important iron ore producing states are Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh, Goa, and Karnataka (Fig. 5.2). The detailed distribution of iron ore deposits in India is given in Table 5.1.

Table 5.1: Distribution of iron ore deposits in different states of India.

States	District/Locality
Odisha	BIF's hosting high grade hematite deposits is reported from Keonjhar, Sundargarh, Mayurbhanj, Cuttack, and Koraput districts. Titaniferous magnetite ores are found in Bisoi-Rairangpur, Bisoi-Joshipur and Baripada-Udasa of Mayurbhang district.
Chhattisgarh	High grade hematite deposits of BIF is found in the Bailadila, Kanker, Parrekaro and Rowghat of Bastar district and Rajhara and Dhalli areas of the Durg District.
Jharkhand	Titaniferous-vanadiferous magnetite ore deposit occurs in the Noamundi, Notoburu, Jamda, and Gua areas. Apatite-magnetite ore is found in Pathargora, Kumaria and Singri of Singhbhum district. In Palamau district, magnetite deposits are found in the Gore Pahar and Biwabathan areas. Ironstone with siderite is found in the Rajabar, Balunagar and Mowai, Auranga coal field areas.
Karnataka	BIF with good hematite deposits are found in the Bellary, Hospet, Shimoga, Chitradurga, Chikmaglur districts. The rich magnetite deposits are also reported from the Kudramukh and Bababudan hills of Tumkur district.
Maharashtra	BIF exposures are enriched with iron content and are found in the Sindhudurg, Chandrapur, Gadchiroli, Bhandara and Ratnagiri districts.
Goa	Hematite ore is associated with the BIF and belongs to the Dharwar Supergroup. It is found in the Bicholim, Sirigao and Kosti areas. Minor occurrences of magnetite, limonite and goethite are also reported in the Goa.
Andhra Pradesh	The hematite deposits are found in the Kadapa, Kurnool, Anantapur and Nellore districts of Andhra Pradesh.
Telangana	The Warangal and Khammam districts of Telangana also host the hematite deposits.

5.4 MANGANESE ORE DEPOSITS

India is self-sufficient in manganese (Mn) ore reserves and exports almost three-fourths of the ore produced. More than 150 ores of manganese are presently known to occur in nature in different forms of oxides, sulphides, silicates and carbonates. Psilomelane and pyrolusite are the common oxide ores of manganese. In India Mn ore deposits occur in two different forms namely, Bedded (Syngenetic and Supergene) and Lateritoid or detrital. India is one of the largest producers of the manganese in the world. The states which are rich in manganese ore reserves are Madhya Pradesh, Odisha, Karnataka, and Maharashtra (Fig. 5.3). Minor occurrences are reported from Andhra Pradesh, Goa, Gujarat, Rajasthan, Jharkhand and Telangana. The detailed distribution of manganese ore deposits in India is given in Table 5.2.

Table 5.2: Distribution of manganese ore deposits in different states of India.

States	District/Locality
Madhya Pradesh	The high-grade manganese ore comes from the districts of Balaghat, Chhindwara, Jabalpur and Jhabua. The ores found in the Gondite Series are associated with the metamorphosed bedded sedimentary deposits.
Maharashtra	The weathering of gondite-bearing rocks has given rise to residual enrichment of the Mn ore deposits is usually found in the Bhandara and Nagpur districts.
Odisha	The Mn ore deposits are associated with the Kodurite Series in the Kalhandi, Bolangir, Ganjam and Koraput districts of Odisha. Lateritoid deposits are found in the Sundargarh, Keonjhar district.
Karnataka	Lateritoid deposits of Mn ore of the Dharwar Schist Belt are found in the Bellary, North Kanara, Sandur, Tumkur, Chitradurga and Shimoga districts. Minor occurrences of Mn ore deposits as veins, nodules, lenticles are also reported in the different places of Karnataka.
Andhra Pradesh	The Mn ore deposits are found in the Srikakulam and Visakhapatnam districts and are associated with the Kodurite rocks of the Khondalite Formation.
Gujarat	The Mn ores found in the Panchmahal and Vadodara districts are associated with the less metamorphosed Dharwar rocks.

5.5 CHROMIUM ORE DEPOSITS

Chromite is an oxide of chromium and iron. It is the only economic mineral of chromium. Chromite deposits of India amount to about 2% of the total world resources. The Odisha state accounts for more than 93% of the chromite deposits mostly in the Sukinda valley in Cuttack and Jajpur districts. Minor

deposits are scattered over Manipur, Nagaland, Karnataka, Jharkhand, Maharashtra, Tamil Nadu and Andhra Pradesh (Fig. 5.4). The detailed distribution of chromite deposits in India is given in Table 5.3.

Table 5.3: Distribution of Chromium in different states of India.

States	District/Locality
Odisha	Together with the nickel ore, the chromite occurs in bands and lenses in the Sukinda area of the Cuttack district, Katpal area in the Dhenkanal district. Nausahi locality of the Keonjhar district also host good chromite deposits.
Karnataka	The chromite deposit is associated with the ultrabasic rocks in the Dharwar schists reported from the Sindhuvalli in Mysore and the Byrarapur in Hassan districts. Minor deposits are reported from other districts.
Jharkhand	Important occurrences are found in Jojohatu near Chaibasa in Singhbhum district.
Tamil Nadu	The chromite occurs as lensoid body in charnockite rocks located in the Sittampundi anorthosite complex in the Salem district.
Maharashtra	The chromite ore is found in Pauni of Bhandara district and Byarapur of Ratnagiri district in ultramafic rocks.
Manipur	The deposits are known to occur in Ukhrul and east of Manipur.

5.6 ALUMINIUM ORE DEPOSITS

India occupies first position amongst top ten producers of aluminium in the world. It is considered as one of the most abundant metals present in the Earth's crust. It is relatively less abundant in the mantle. Aluminium is a valuable non-ferrous metal and gained importance due to its remarkable properties and capacity to form light alloys. You have studied in BGYET-141 course that bauxite is the only mineral of aluminium which has commercial importance. The bauxite occurs as blanket deposit in the Eastern Ghat region, that overlay as caps on Khondalites, whereas bauxite deposits on the Deccan Traps occur in the states of the Chhattisgarh, Maharashtra and Karnataka. In Jammu and Kashmir, the deposits are overlying the Permo-Carboniferous Sirban limestone; in Tamil Nadu, they overlie the Charnockites; the deposits overlie the Tertiary and Archaean rocks in the Kerala and granite gneisses in the Jharkhand areas. Bauxite also occurs as pocket deposits in the coastal areas of Odisha lying above the Upper Gondwanan rocks, particularly sandstones. The chief aluminium producing states are Odisha, Gujarat, Andhra Pradesh, Jharkhand, Maharashtra, Chhattisgarh, Tamil Nadu and Madhya Pradesh (Fig. 5.5). The detailed distribution of aluminiumore deposits in India is given in Table 5.4.

Table 5.4: Distribution of Aluminiumores in different states of India.

States	District/Locality
Odisha	High grade bauxite deposits are reported from Kalahandi and Sambalpur districts. The other districts which host bauxite deposits are Koraput, Bolangir, Kalahandi, Keonjhar, Sundergarh and Kandhamal.
Andhra Pradesh	The famous aluminous laterite occurrences are reported from the Eastern Ghat belt extending from Vishakhapatnam to East Godavari district. The bauxite capping in Anantagiri hills in Vishakhapatnam district cover a large area.
Gujarat	The state is bestowed with all grades of bauxite ore. The deposits are found in the districts of Kutch, Junagadh, Kheda, Amreli, Bhavnagar, Valsad, Jamnagar and Sabarkantha.
Jharkhand	High grade ores are reported from the district of Lohardaga and its adjoining areas. Extensive deposits of bauxite ore are found in the districts of Palamu, Ranchi and Gumla. Small occurrences are also known from the Dumka and Munger areas.
Maharashtra	Rich deposits that cap the Deccan basalt are reported from the surrounding areas of the Kolhapur district. The otherdistricts where aluminium deposits are reported include, Satara, Ratnagiri and Thane.
Chhattisgarh	Bauxite deposits are located in the districts of Kanker, Korba, Surguja, Bastar, Jashpur and Kabirdham.
Tamil Nadu	Salem, Nilgiri and Madurai are the main districts that produce metallurgical and low-grade bauxite ores.
Madhya Pradesh	Maikala range covering Mandla, Shahdol and Balagat districts and some areas of the Jabalpur (Katni) district are important producers of bauxite in the state.
Karnataka	Bauxite deposits with high grade of alumina are reported from the Deccan Traps of the Belgaum, Chikmangalur, North and South Kannad districts.

5.7 COPPER ORE DEPOSITS

Copper is a soft metal, which occurs in native form as-well-as in other mineral forms such as oxides, sulphides and carbonates. Copper deposits in India occur in association with various types of rocks, particularly with the Precambrian rocks. The copper lodes generally occur in the form of veins, fracture-fillings, cleavage -fillings and dissiminations. Besides copper, other metals are also associated with the copper deposits such as gold, silver, lead and zinc. Fairly, large number of copper deposits have orignated from the

hydrothermal solutions. The major copper reserves are present in four copper belts (Fig. 5.6). These are:

1) **The Khetri Copper Belt**: The important copper deposits are mainly found in Neem Ka Thana of Sikar district Rajasthan, and in other regions of Jhunjhunu and Bhilwara districts.

2) **Malanjkhand Copper Belt**: The significant deposits are found in Malanjkhand, Shitalpani, Gidori Dhorli, Jatta and GarhiDongri of Balaghat district in Madhya Pradesh.

3) **Singhbhum copper belt**: The deposits are found in Musabani, Rakha Ram ChandarPahar, Pathargora, Turamdih and some other places singhbhum copper belt, Jharkhand.

4) **Agnigundala Copper-Lead belt**: The ore mineralisation is noticed in northeastern part of Cuddapah Group. The copper and lead deposits of this belt are reported from Agnigudala area in Guntur District of Andhra Pradesh.

The important copper producing states are Jharkhand, Rajasthan, Madhya Pradesh and Chhattisgarh (Fig. 5.7). The detailed distribution of copper ore deposits in India is given in Table 5.5.

Table 5.5: Distribution of copper ore in different states of India.

States	District/Locality
Jharkhand and Bihar	The Singhbhum copper belt: the potential areas are Mosbani,Ghatshila, Pathargora,Rakha,Roam-Sidheswar, Ram chandrapahar, Tamapahar and Turamdih. Hesatu-Belbathan belt: the potential areas are Ganganpur, Jalakdiha, Baraganda, Damgi, Baghmari, Chandio, Pirrah and Toolsitanr.
Rajasthan	The Madhan-Kudan, Kolihan and Chandmari areas within the Khetri copper belt of the Jhunjhunu district. Potential copper deposit is noticed at Dariba, Alwar district. Isolated occurrences are also reported from the Pali, Sirohi, Udaipur, Churu and Nagaur districts.
Chhattisgarh	The major open pit base metal mine in India is located at Malanjkhand region of Balaghat district. Some occurrences are also reported from Rajnandgaon, Mahasamund and Dantewara districts.
Karnataka	Copper occurrences are reported from the Chitradurga and Hassan districts.
Andhra Pradesh	Copper occurrences are also known from Kurnool and Guntur districts.
Telangana	Khammam district.
Tamil Nadu	Chingleput, South Arcot, Tiruchirappalli, Madurai districts.

5.8 LEAD AND ZINC ORE DEPOSITS

You have already studied in BGYET-141 course that lead and zinc are the two base metals that normally occur in close association with each other. In India, economically viable lead and zinc deposits are found mainly in the western, central and southern parts of the country, hosted in the Precambrian rocks. The scattered deposits in a lesser quantity are also present in the northern and eastern parts of the country. In the western region, the deposits are hosted in, Aravalli and Delhi Supergroups of rocks.

The important lead and zinc occurrences are reported from the states of Rajasthan, Odisha, Jharkhand, Andhra Pradesh, Maharashtra, Gujarat and West Bengal (Fig. 5.8). The ore deposits are also reported from the states of Assam, Madhya Pradesh, Uttaranchal, Maharashtra, and Tamil Nadu, and Jammu and Kashmir (Fig. 5.8). The detailed distribution of lead and zinc deposits in India is given in Table 5.6.

Table 5.6: Distribution of lead and zinc deposits in India.

States	District/Locality
Rajasthan	Ajmer, Bhilwara, Udiapur (Zawar) and Sirohi districts. Minor occurrences are also reported from Pali, Banswara and Sawai Madhopur districts.
Andhra Pradesh	Guntur (Agnigundala), Cuddapah and Kurnool districts.
Bihar	Bhagalpur andMonghyr districts.
Jharkhand	Hazaribagh, Ranchi, Singhbhum and Palamu districts.
West Bengal	Jalpaiguri, Darjeeling, Midnapur and Purullia districts.
Karnataka	Mysore, Bellary and Chitaldurgadistricts.
Gujarat	Banaskantha and Vadodara districts.

5.9 GOLD DEPOSITS

You are already aware that the important ore of gold is the 'Native Gold'. It occurs as nuggets and small flakes in the alluvial placer deposits. In India, most of the gold deposits are load deposits and a very few are of placer type. The important gold occurrences are reported from the states of Karnataka, Andhra Pradesh, Jharkhand, Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Rajasthan and Kerala (Fig. 5.9). The geographical distribution of Indian gold deposits is given in Table 5.7.

Table 5.7: Distribution of gold in India.

States	District/Locality
Karnataka	The important gold producing districts are Kolar gold fields, Raichur (Hutti gold field). The other districts which host gold deposits are Shimoga, Dharward, Gulberga, Bellary, Mysore and Hassan.

Andhra Pradesh	Ramagiri, Anantapur district. Gold occurrences are also reported fromBisanatham and Palachchur in Chittoor district and Jonnagiri in Kurnool district.
Jharkhand	The state hosts both load and placer deposits. The deposits are found in Singhbhum district and other regions of the Chota Nagpur plateau.
Chhattisgarh	The gold placers are concentrated in the Sonakhan primary ore and in Ib river placer deposits.

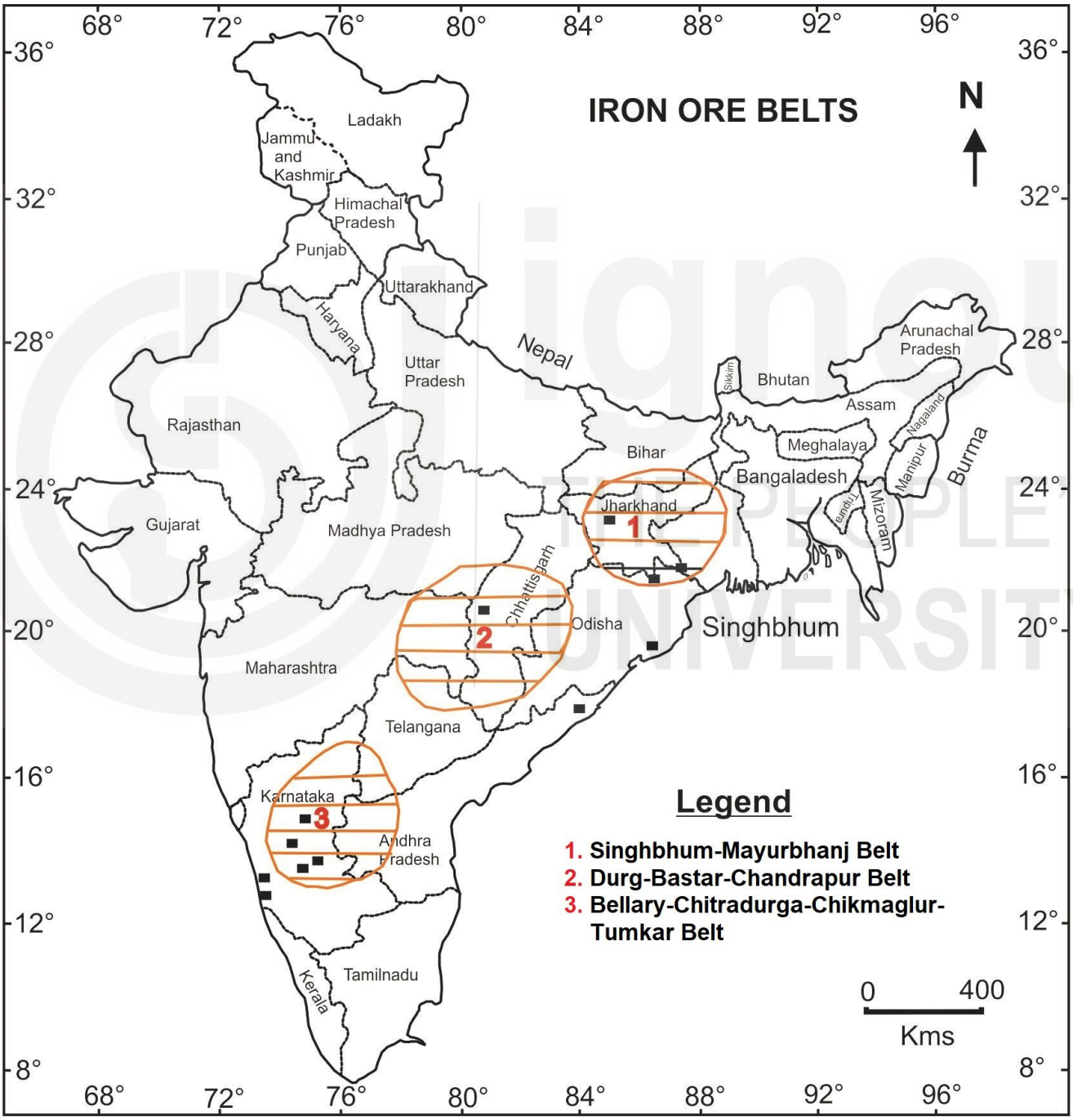


Fig.5.1: Map showing the distribution of iron ore reserves in India; Area inside the polygons showing important iron ore belts. (Source: Redrawn from https://neostencil.com/uploads1/2018/01/iron-ore.png)

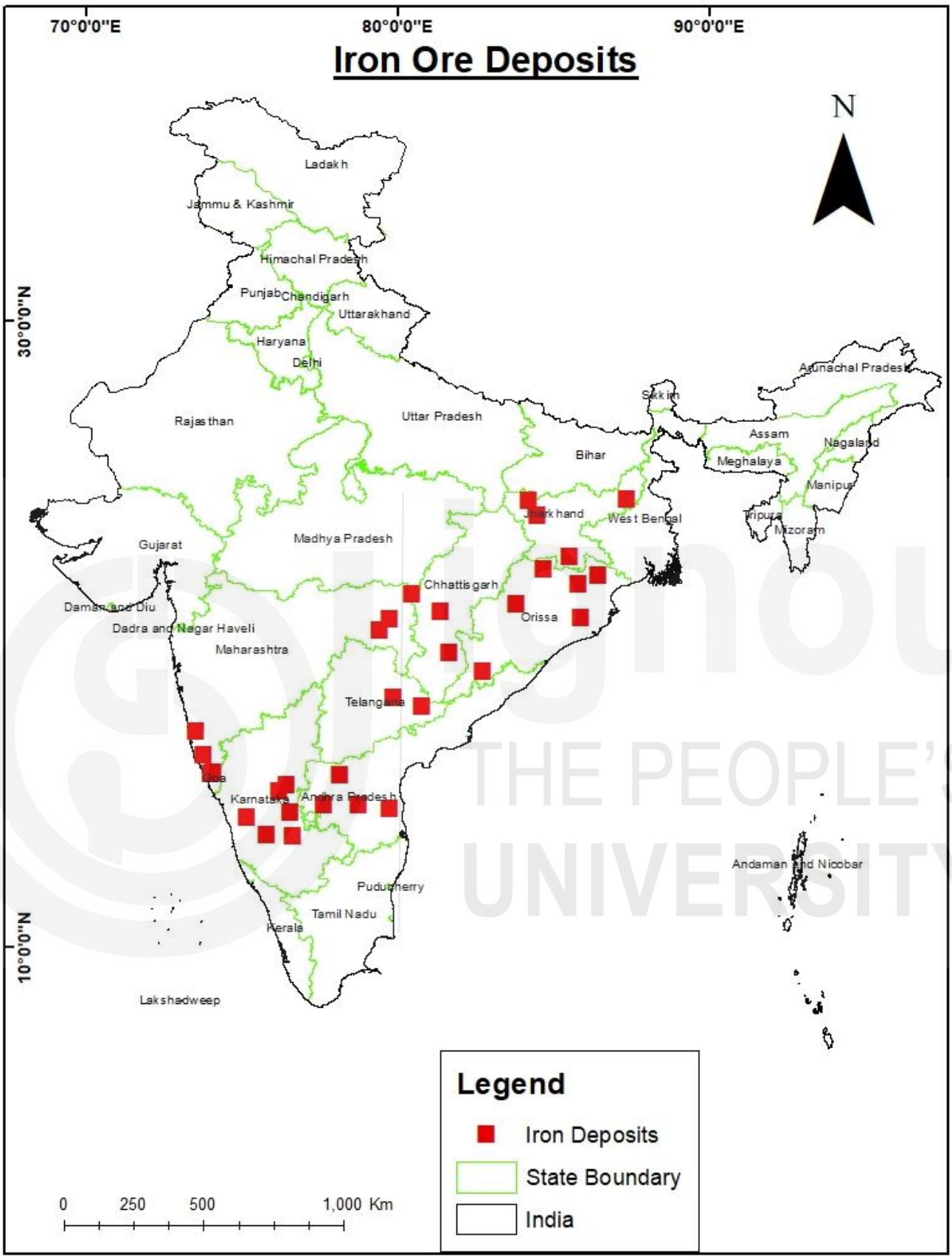


Fig. 5.2: Map of India showing spatial distribution of iron ore deposits.

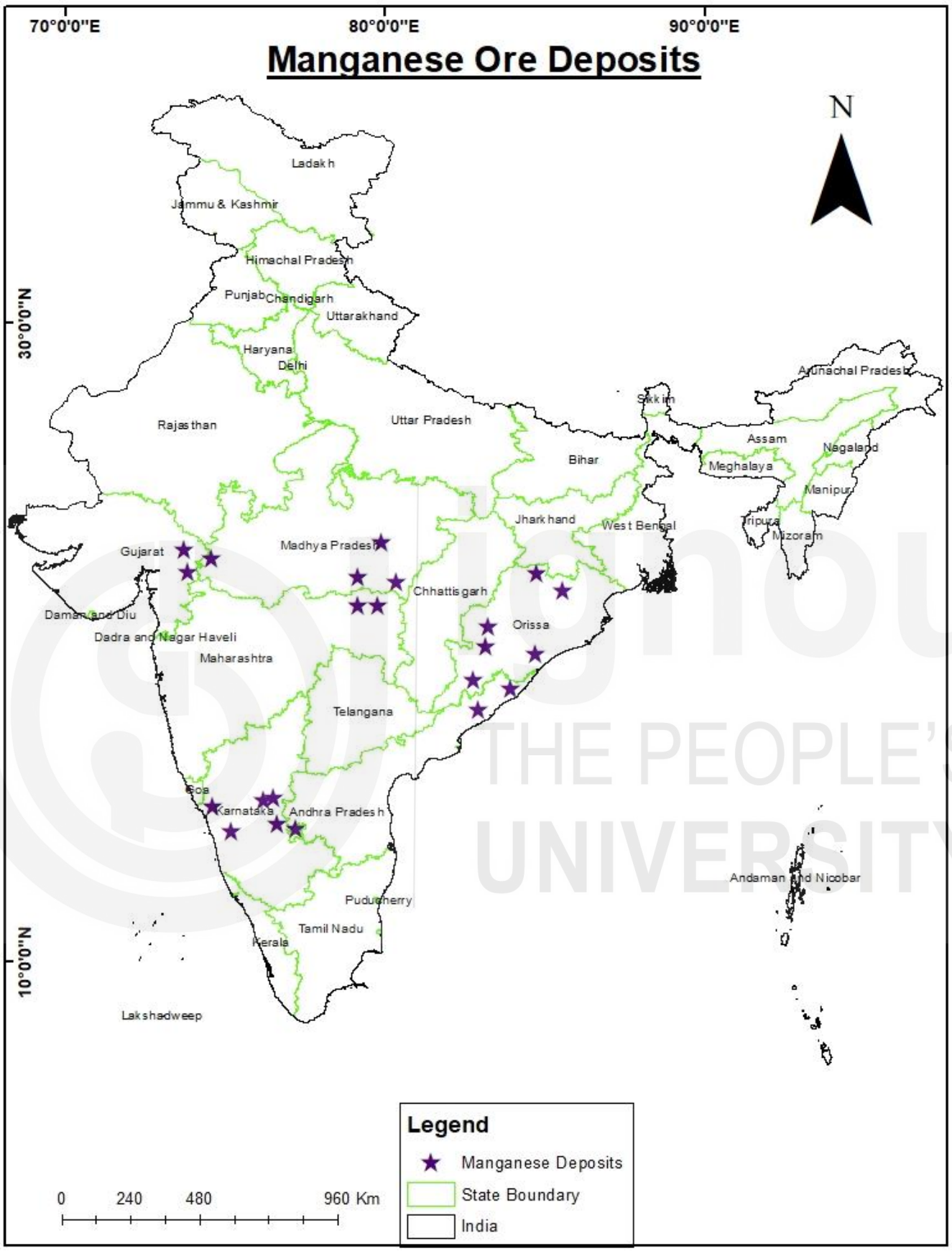


Fig. 5.3: Map showing spatial distribution of manganese ore deposits.

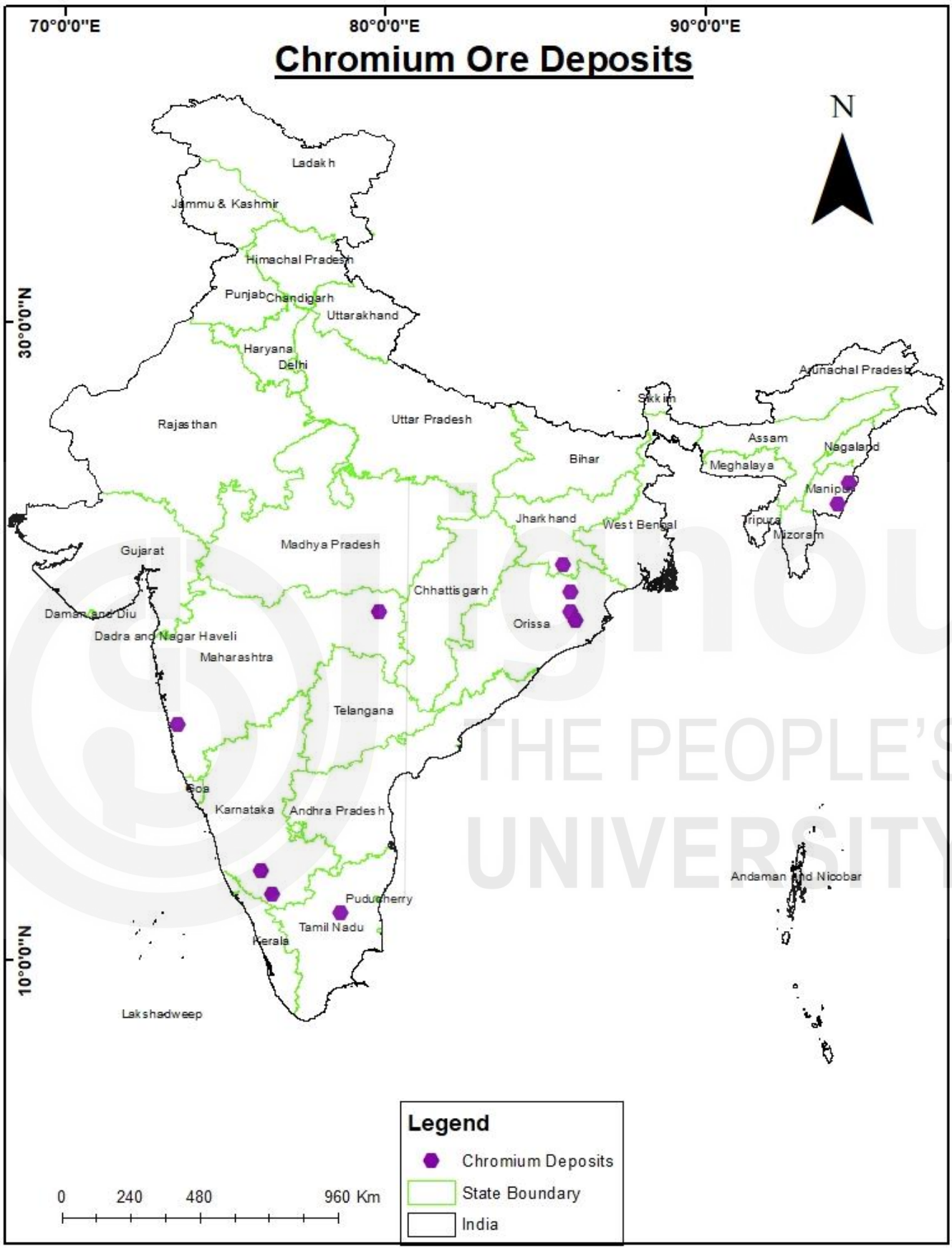


Fig. 5.4: Map showing spatial distribution of chromimum ore deposits.

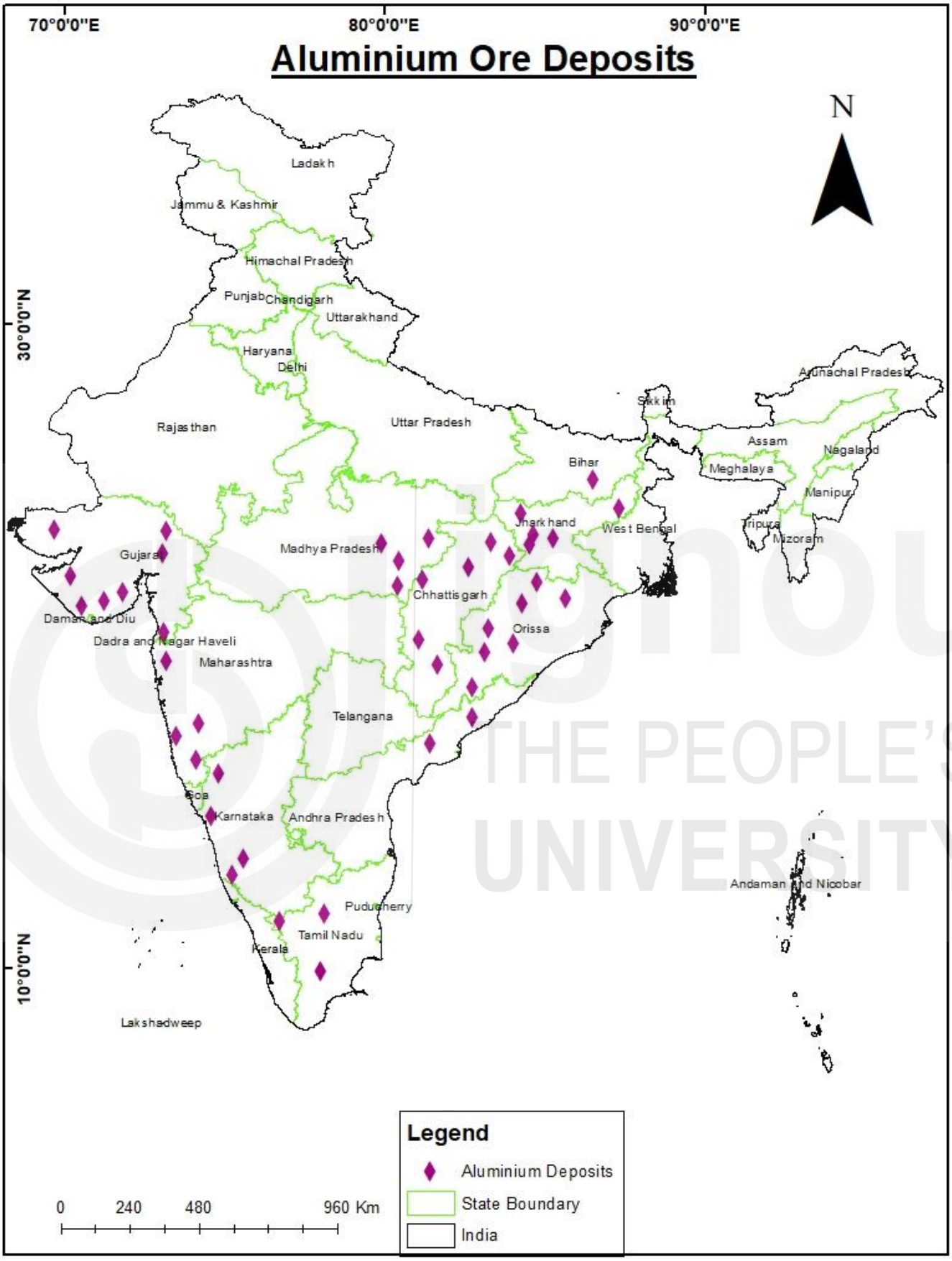


Fig. 5.5: Map showing spatial distribution of aluminium ore deposits in India.

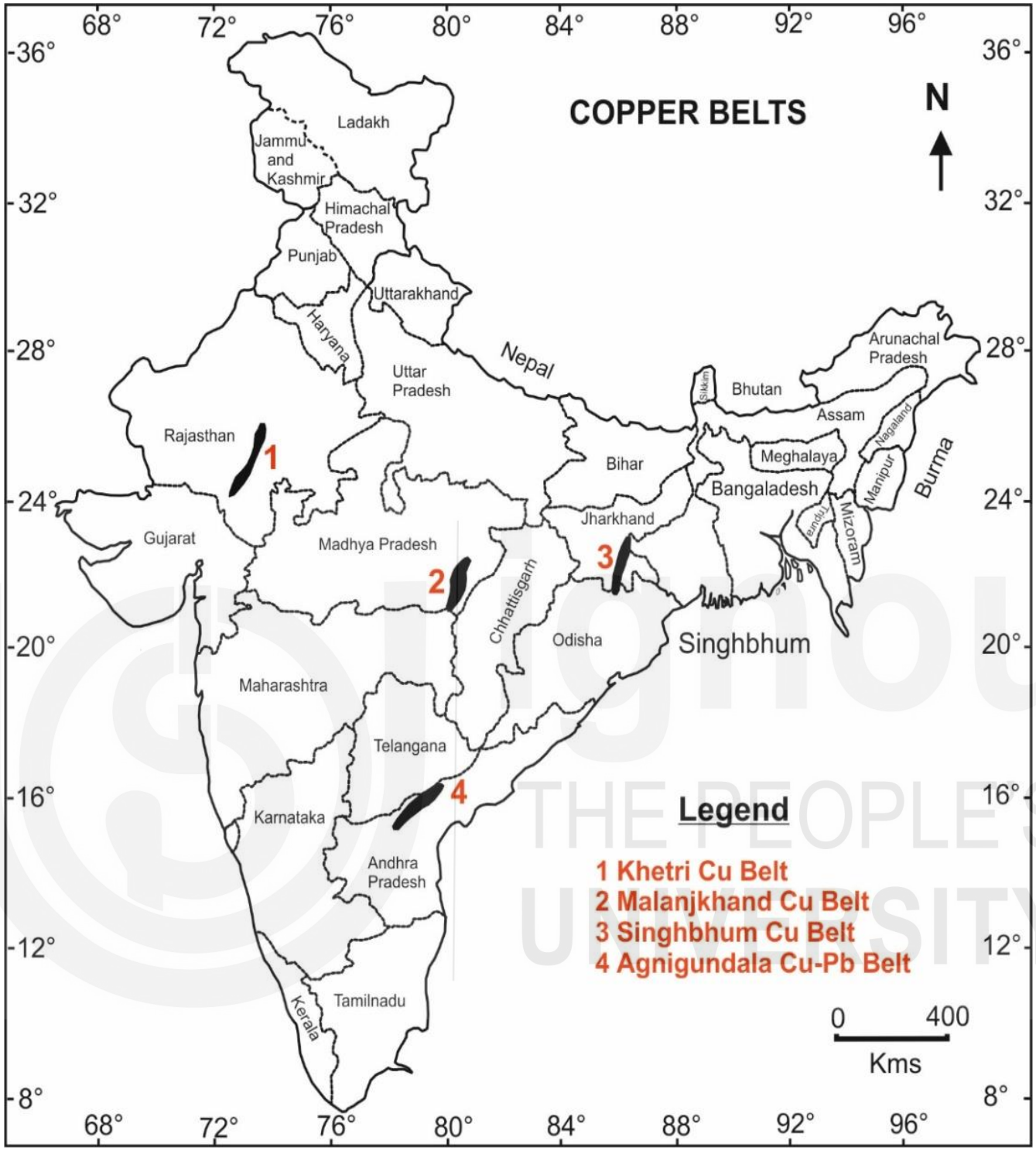


Fig. 5.6: Map showing the distribution of significant copper belts of India.

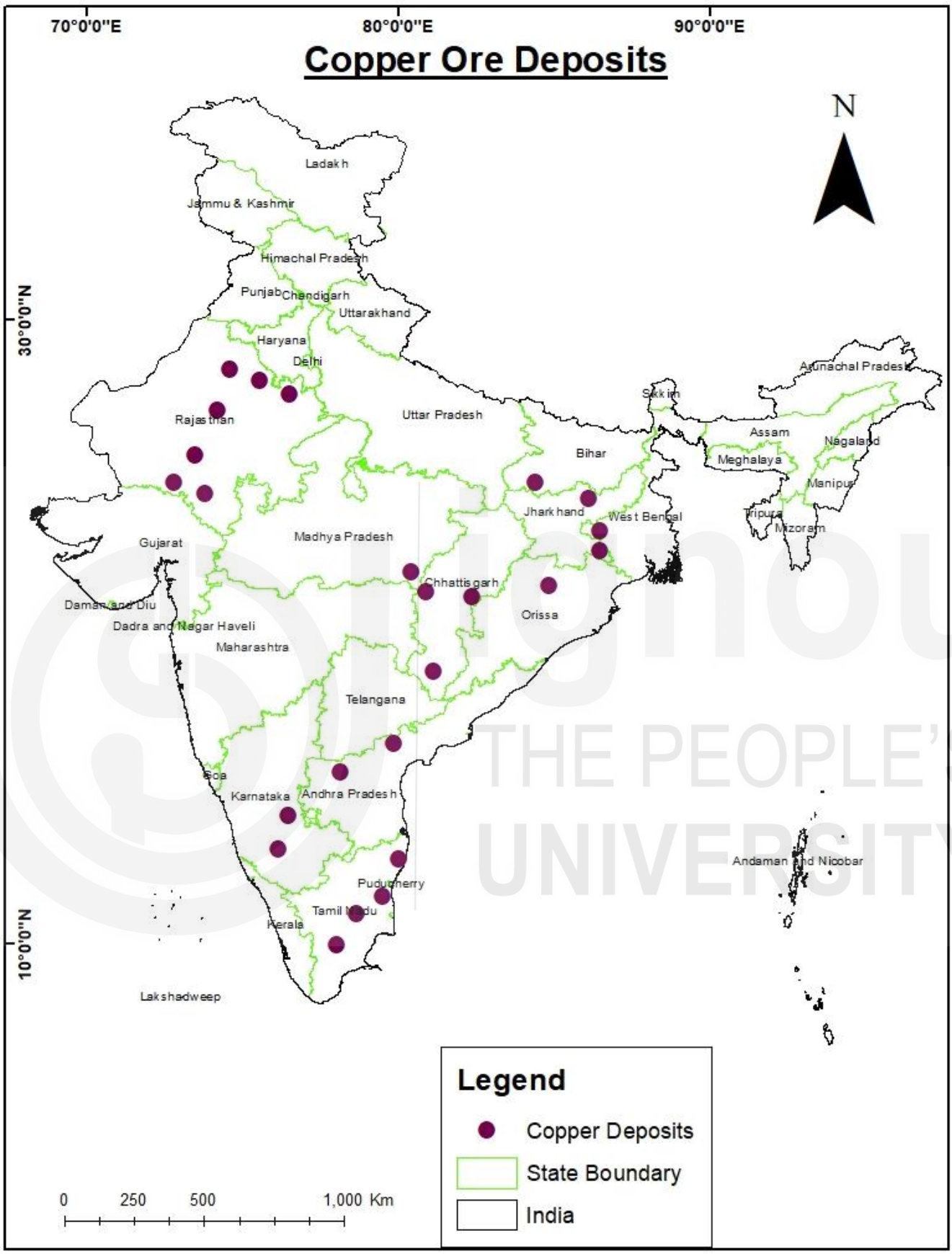


Fig. 5.7: Map showing spatial distribution of copper deposits in India.

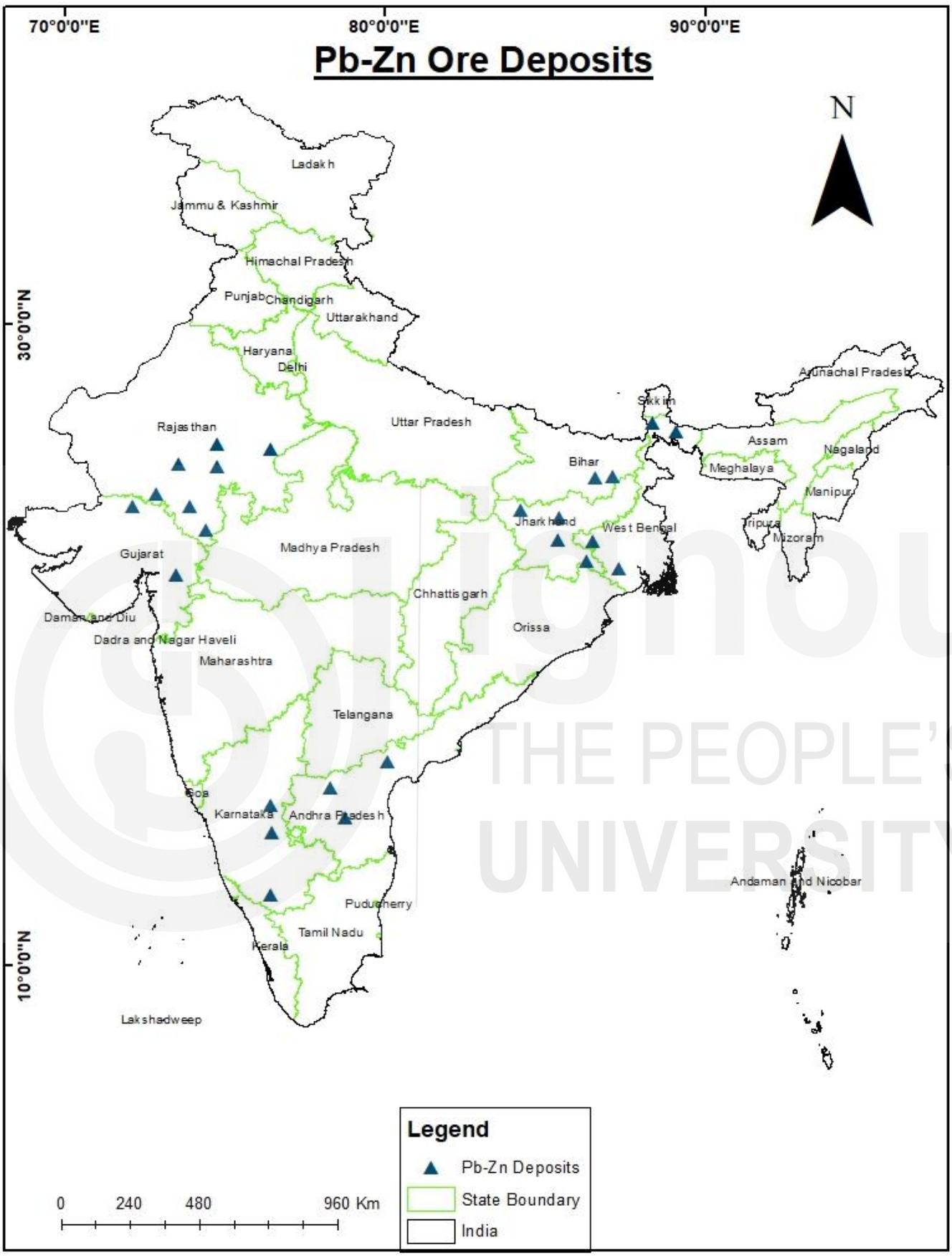


Fig. 5.8: Distribution of lead-zinc deposits in India.

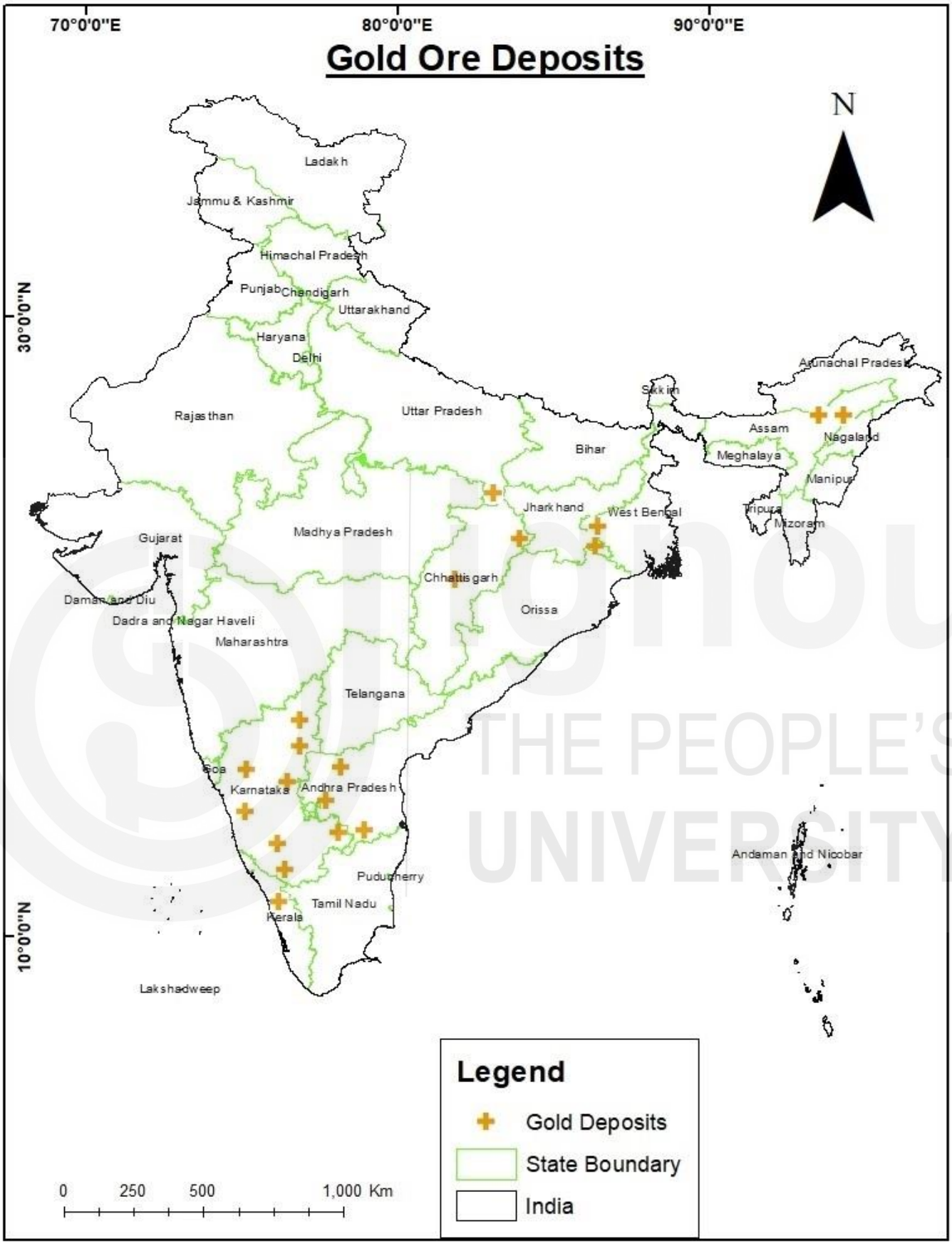


Fig. 5.9: Distribution of primary gold deposits in India.

5.10 LABORATORY EXERCISES

A blank map of India is given below (Fig. 5.10). You can make zerox copies of the India map and paste it on your laboratory file or draw neatoutline map of India showing the political boundaries of the states. Plot the geographical distribution of various metallic mineral deposits on the map of India. You can use coloured pencil for marking the places. **Give answers of the following exercises in your laboratory file and submit it to your Academic Counsellor.**

Exercise 1: List the three major iron ore belts of India. Plot them in the blank outline map of India.

Exercise 2: List the localities or districts where iron ore deposits are found in India. Plot them in the blank outline map of India.

Exercise 3: List the localities or districts where manganese ore deposits are found in India. Plot them in the blank outline map of India.

Exercise 4: List the localities or districts where chromium ore deposits are found in India. Plot them in the blank outline map of India.

Exercise 5: List the localities or districts where aluminium ore deposits are found in India. Plot them in the blank outline map of India.

Exercise 6: List the four major copper ore belts of India. Plot them in the blank outline map of India.

Exercise 7: List the localities or districts where copper ore deposits are found in India. Plot them in the blank outline map of India.

Exercise 8: List the localities or districts where gold deposits are found in India. Plot them in the blank outline map of India.

Exercise 9: List the localities or districts where lead and zinc deposits are found in India. Plot them in the blank outline map of India.

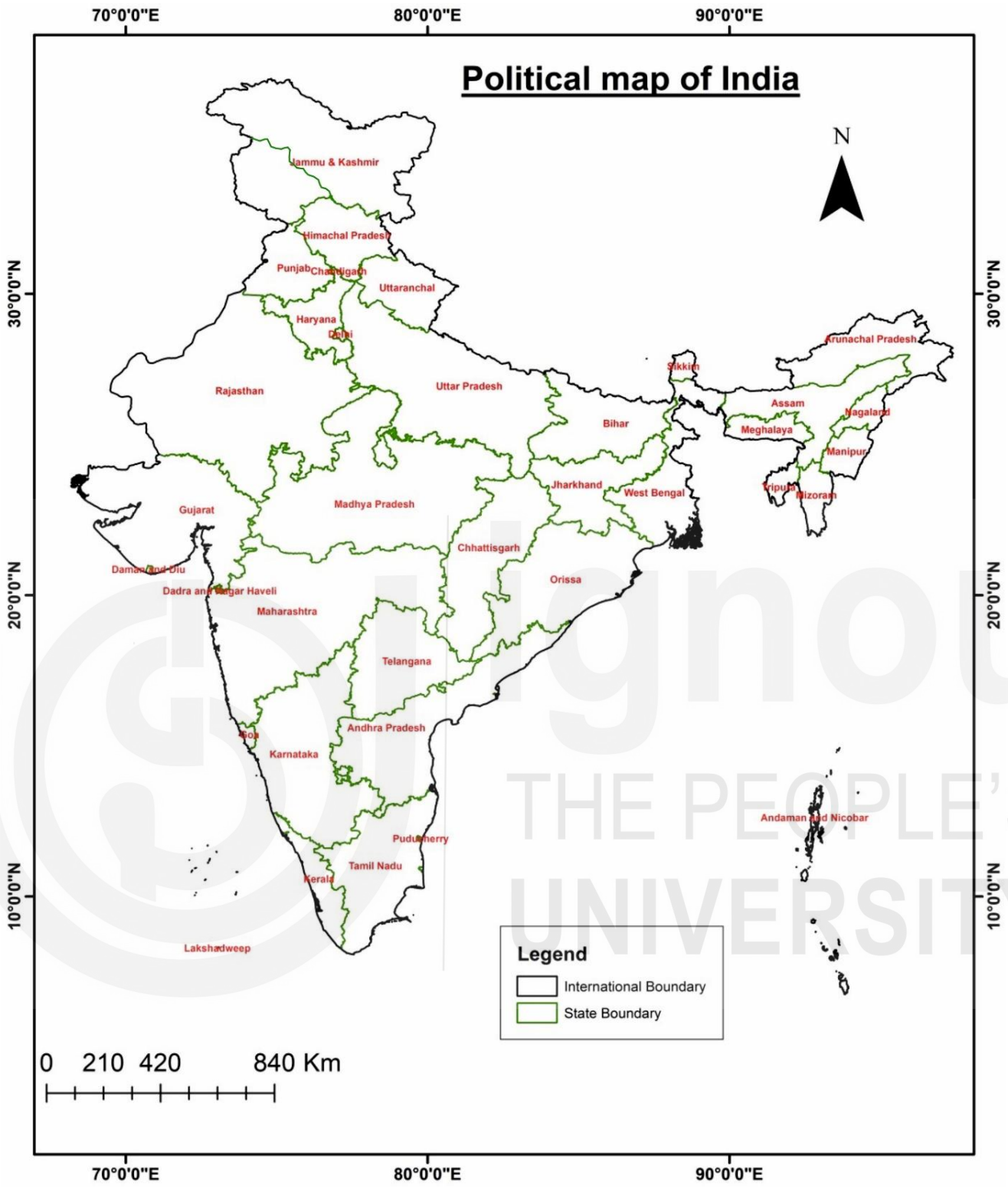


Fig. 5.10: Political map of India.

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(All the websites accessed between 1st April 2021 and 31st May 2021).

5.12 LEARNING RESOURCES

- **Minerals in India**

  Link: https://www.youtube.com/watch?v=YoN06_j4EJE
- **Distribution of minerals in India**

  Link: https://www.youtube.com/watch?v=aJ45TdtKQck

EXPERIMENT 6

PREPARATION OF MAP SHOWING DISTRIBUTION OF NON-METALLIC MINERAL DEPOSITS OF INDIA

Outline of Experiment

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Expected Learning Skills
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6.3 Limestone Deposits
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6.1 INTRODUCTION

Non-metallic minerals form the backbone of several industries such as chemical, ceramic, fertiliser, refractory, etc. The non-metallic minerals e.g., baryte, halite, dolomite, asbestos, barite, mica, dolomite, feldspar, gemstones, gypsum, quartz, magnesite etc. lack some of the properties of the metallic minerals such as a bright metallic luster and good conduction of heat and electricity. Some of the non-metallic minerals and rocks which are used in the industries are called industrial minerals.

These minerals are used in refractory, fertiliser, ceramic and glass manufacturing, chemical and paints, abrasive and gemstone industries. India is endowed with some of the largest deposits of these industrial minerals.

In the previous experiment, you have prepared different maps showing the geographical or spatial distribution of some of the important metallic minerals such as iron, manganese, chromium, aluminium, copper, gold, lead and zinc deposits of India. In this experiment, you will prepare different maps showing the geographical or spatial distribution of some of the important non-metallic minerals such as limestone, sandstone, quartz/silica sand, granite, marble, dolomite, magnesite, fireclay, garnet, gypsum, phosphate, corundum and diamond deposits of India.

Expected Learning Skills

After completing this experiment, you would be able to:

- ❖ list spatial distribution of limestone, sandstone, quartz/silica sand, granite, marble, dolomite, magnesite, fireclay, garnet, gypsum, phosphate, corundum and diamond deposits of India;
- ❖ plot distribution of limestone, sandstone, quartz/silica sand, granite, marble, dolomite, magnesite, fireclay, garnet, gypsum, phosphate, corundum and diamond deposits on the map of India; and
- ❖ identify the regions, with the maximum concentration of limestone, sandstone, quartz/silica sand, granite, marble, dolomite, magnesite, fireclay, garnet, gypsum, phosphate, corundum and diamond deposits of India.

6.2 REQUIREMENTS

To perform this experiment successfully you require the following:

- Pen, pencil, eraser, scale, sharpener and coloured pencils
- Laboratory file
- Blank maps of India of A4 size (with demarcated states boundaries)
- Atlas of India (it will help you to plot the localities of economic minerals in the blank map of India)

[Instructions: You are required to study Unit -11 of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling sessions.]

6.3 LIMESTONE DEPOSITS

Limestone is a sedimentary rock mainly composed of calcium carbonate. It is used as a building material, in cement industries, as a raw material for the production of lime etc. India has abundant deposits of limestone and is widely distributed in Telangana, Andhra Pradesh, Karnataka, Assam, Jharkhand, Gujarat, Haryana, Himachal Pradesh, Uttar Pradesh, Rajasthan, Uttarakhand,

Jammu & Kashmir, Chhattisgarh and Madhya Pradesh (Fig. 6.1). The detailed distribution of limestone deposits in India is given in Table 6.1.

Table: 6.1: Distribution of limestone deposits in different states of India.

State	District/Locality
Andhra Pradesh	Cuddapah, Guntur, Kurnool, East Godavari and West Godavari, Anantapuramu, Krishna, Nellore, Srikakulam, Visakhapatnam and Vizianagaram districts.
Telangana	Adilabad, Mahabubnagar, Nalgonda, Rangareddy, Hyderabad and Karimnagar districts.
Gujarat	Amreli, Banaskantha, Bhavnagar, Bharuch, Jamnagar, Junagadh, Kheda, Kachchh, Panchmahals, Porbandar, Rajkot, Sabarkantha, Surat, Vadodara and Valsad districts.
Jharkhand	Hazaribag, Palamu, Dhanbad, Bokaro, Garhwa, Giridih, Ranchi, East & West Singhbhum districts.
Karnataka	Belgaum, Chitradurga, Shimoga, Tumkur, Bagalkot, Bellary, Bijapur, Chickmagalur, Davangere, Gadag, Gulbarga, Hassan, Mysore, Uttar and Dakshin Kannad and Udupi districts.
Madhya Pradesh	Damoh, Hoshangabad, Mandsaur, Narsinghpur, Rewa, Satna, Panna, Katni, Sagar, Dhar, Khargone, Jhabua, Balaghat, Sidhi, Morena, Chhindwara, Jabalpur, Sehore and Shahdol districts.
Maharashtra	Ahmednagar, Chandrapur, Dhule, Gadchiroli, Nagpur, Nanded, Sangli and Yavatmal districts.
Odisha	Bargarh, Kalahandi, Koraput, Malkangiri, Nuapada, Sambalpur and Sundergarh districts.
Rajasthan	Ajmer, Alwar, Banswara, Chittorgarh, Jaipur, Jaisalmer, Jodhpur, Nagaur, Bhilwara, Bikaner, Bundi, Churu, Dungarpur, Jhunjhunu, Kota, Pali, Sawai Madhopur, Sikar, Sirohi and Udaipur districts.
Tamil Nadu	Coimbatore, Cuddalore, Dindigul, Kanchipuram, Karur, Madurai, Nagapattinam, Namakkal, Perambalur, Salem, Thiruvallur, Tiruchirappalli, Tirunel-veli, Vellore, Villupuram and Virudhunagar districts.
Chhattisgarh	Good deposits of cement grade limestone are available in Raipur, Baloda-bazar, Durg, Bemetara, Rajnandgaon, Kawardha, Raigarh, Janjgir-Champa, Bastar, Bilaspur, Mungeli, Sukma districts.
Jammu and Kashmir	Anantnag, Baramula, Doda and Kathua districts.
Uttar Pradesh	Sonbhadra district.

Himachal Pradesh	Bilaspur, Chamba, Kangra and Shimla districts
Uttarakhand	Almora, Pithoragarh and Dehradun districts
Assam	Karbi-Anglong, Lakhimpur and Nagaon districts
Haryana	Ambala, Bhiwani and Mahendragarh districts

6.4 SANDSTONE DEPOSITS

Sandstone is a sedimentary rock composed mainly of sand-sized (0.0625 to 2 mm) mineral particles or rock fragments. It contains the framework grains dominantly of quartz or feldspar because they are the most resistant minerals to weathering processes at the Earth's surface. Sandstones are extensively used as a building material since ancient times. The famous Sanchi Stupa and stupas of Sarnath and Barhut are built of Vindhyan sandstones. The famous Fatehpur Sikri fort used pink Vindhyan sandstones. The Delhi Secretariat and Rashtrapati Bhawan of New Delhi are made of red sandstone. It is well distributed in Rajasthan, Madhya Pradesh, Bihar, Uttar Pradesh, Son valley in Bihar and Uttar Pradesh, Andhra Pradesh, Assam, Gujarat, Haryana, Meghalaya, Mizoram, Karnataka, Odisha, Punjab, Tamil Nadu and West Bengal. (Fig. 6.2). The detailed distribution of sandstone deposits in India is given in Table 6.2.

Table 6.2: D**istribution of sandstone deposits in different states of India.**

State	District/Locality
Madhya Pradesh	The Vindhyan and Satpura Mountains have vast resources of sandstone. The red, cream and white sandstone are being quarried extensively in Panna and Shivpuri districts and many areas near Hoshangabad, Rewa and Jabalpur districts.
Rajasthan	Huge deposits of sandstone are associated with Vindhyan and Trans-Aravalli Formations covering districts of Dholpur, Bharatpur, Karauli, Sawai Madhopur, Tonk, Udaipur, Ajmer, Jhalawar, Kota, Bhilwara and Chittorgarh. It is also found scattered in the districts of Jodhpur, Churu, Bikaner and Nagaur.
Gujarat	Fine to medium-grained sandstone of varying colours are found in the district of Kachchh. A brownish-yellow sandstone occurs near Chabari and Mainapara in Bhachau tehsil. The sandstone at Rampur, Katada-Roha and Rajoda Dungar near Mangwana in Nakhtrana tehsil is cream coloured and is fairly hard. Extensive deposits are found around Songir, Naswadi, Ghautoli, Namaria and Lachharas in Vadodara district.
Bihar	Rohtas, Munger and Gaya districts and Son valley in Bihar.
Maharastra	The Kamthi Sandstone occurring in and around Saoner tehsil, district Nagpur is used as building stone.
Uttar	Sandstones suitable for making slabs and tiles are located in

Pradesh	Agra, Mirzapur, Lalitpur, Allahabad and Sonbhadra districts. The sandstone occurs in Madanpur and Rampura areas in Lalitpur district. Red and mottled sandstone in Tatpur area of Agra is used for interior as well as exterior flooring and cladding. Good quality sandstone is also available in Mirzapur and Sonbhadra areas.
Andhra Pradesh and Telangana	Guntur district of Andhra Pradesh and Komaram Bheem districts of Telangana

6.5 QUARTZ/ SILICA SAND DEPOSITS

Quartz occurs in form of veins and as a major mineral in many acidic igneous rocks like granites and pegmatites and metamorphic rock like quartzite. Silica sand is a trade name for sand rich in quartz. Quartz/silica sands have a wide application in the industries like glass industries, electrical industries gemstones etc. There are many varieties of quartz: Rock crystal, Amethyst, Citrine, Milky quartz, Rose quartz, Smoky quartz, Flint, Jasper etc. Crystalline quartz occurs in Maharashtra, Andhra Pradesh and Madhya Pradesh. Transparent crystals of quartz occur in pegmatites of Rajasthan and West Bengal. Occurrence of amethyst quartz have been reported in and around Shansabad, Palment, Nagunpally in Hyderabad and from the river bed of Godavari as placer in Warangal (Telangana) district. Quartz also occurs in Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh and Tamil Nadu. Silica-sand has been reported from Nellore and Prakasam districts of Andhra Pradesh; Junagadh, Rajkot, Kuchch districts of Gujarat. They also occur in Bihar, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh and Tamil Nadu (Fig. 6.3). The detailed distribution of quartz deposits in India is given in Table 6.3.

Table 6.3: Distribution of Quartz deposits in different states of India.

State	District/Locality
Andhra Pradesh	Anantapur, Chittoor, Cuddapah, West Godavari, Guntur, Krishna, Kurnool, Nellore, Prakasam, Srikakulam, Visakhapatnam and Vizianagaram districts.
Telangana	Mahabubnagar, Nalgonda, Rangareddy, Hyderabad, Khammam, Medak, Warangal, Bhadradri-Kothagudem, Jogulamba-Gadwal, Kamareddy, Karimnagar, Medchal, Nagarkurnool, Nirmal, Nizamabad, Sangareddy, Suryapet, Vikarabad, Wanaparthy and Yadadri districts.
Gujarat	Bharuch, Bhavnagar, Dahod, Kheda, Kachchh, Panchmahals, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara and Valsad districts.
Jharkhand	Deoghar, Dhanbad, Dumka, Giridih, Godda, Hazaribagh, Koderma, Palamau, Ranchi, Sahebganj, East & West Singhbhum districts.

Karnataka	Bagalkot, Bangalore, Belgaum, Bellary, Chickmagalur, Chitradurga, Davangere, Dharwad, Gulbarga, Hassan, Haveri, Kolar, Koppal, Mandya, Mysore, Uttar & Dakshin Kannad, Raichur, Shimoga, Tumkur and Udupi districts.
Madhya Pradesh	Balaghat, Dewas, Dhar, Jabalpur, Khandwa, Khargone, Morena, Rewa and Shahdol districts.
Maharashtra	Bhandara, Gadchiroli, Gondia, Kolhapur, Nagpur, Ratnagiri and Sindhudurg districts.
Odisha	Boudh, Bolangir, Kalahandi, Sambalpur and Sundergarh districts.
Rajasthan	Ajmer, Alwar, Bharatpur, Bhilwara, Bikaner, Bundi, Dausa, Jaipur, Jaisalmer, Jhunjhunu, Jodhpur, Kota, Pali, Rajsamand, Sawai Madhopur, Sikar, Sirohi, Tonk and Udaipur districts.
Tamil Nadu	Chengai-Anna, Chennai, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kanchipuram, Karur, Madurai, Namakkal, Periyar, Perambalur, Salem, Thiruvallur, Thiruvarur, Nagapattinam, Tiruchirapalli, Villupuram, Virudhunagar and Vellore districts.
Chhattisgarh	Durg, Raigarh, Raipur and Rajnandgaon districts.

6.6 GRANITE DEPOSITS

Granite is hard, strong and compact rock, occurring in the form of very large igneous bodies such as batholiths, stocks. It is widely exposed in almost all parts of India such as Telangana, Andhra Pradesh, Karnataka, Rajasthan, Tamil Nadu and Jharkhand (Fig. 6.4). The detailed distribution of granite deposits in India is given in Table 6.4.

Table 6.4: Distribution of granite deposits in different states of India.

State	District/Locality
Andhra Pradesh	Anantapur, Chittoor, Cuddapah, Guntur, Nellore, Prakasam, Srikakulam and Vizianagaram districts.
Telangana	Jagityal, Jangaon, Jayashankar, Jogulamba-Gadwal, Kamareddy, Khammam, Mahabubabad, Nizamabad, Peddapalli, Medak, Nalgonda, Rangareddy and Warangal districts.
Gujarat	Banaskantha, Mehesana and Sabarkantha districts.
Jharkhand	Deogarh, Dhanbad, Dumka, Giridih, Godda, Gumla, Hazaribagh, Koderma, Lohardaga, Palamau, Ranchi and East Singhbhum districts.
Karnataka	Bagalkot, Bangalore, Bellary, Bijapur, Chamrajanagar, Hassan, Kolar, Koppal, Uttara Kannada, Raichur and Tumkur districts
Madhya	Betul, Chhatarpur, Chhindwara, Datia, Jhabua, Panna, Seoni

Pradesh	and Shivpuri districts.
Maharashtra	Bhandra, Chandrapur, Dhule, Gadchiroli, Nagpur, Nanded, Nasik, Sindhudurg and Thane districts.
Odisha	Angul, Boudh, Bolangir, Cuttack, Deogarh, Dhenkanal, Ganjam, Keonjhar, Khurda, Koraput, Mayurbhanj, Nuapada, Rayagada and Sambalpur districts.
Rajasthan	Ajmer, Alwar, Banswara, Barmer, Bhilwara, Chittorgarh, Jaipur, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Pali, Rajsamand, Sawai Madhopur, Sikar, Sirohi, Tonk and Udaipur districts
Tamil Nadu	Coimbatore, Dharampuri, Salem districts.
Chhattisgarh	Bastar, Kanker and Raipur districts.
Bihar	Deogarh, Banka

6.7 MARBLE DEPOSITS

Marble is considered one of the oldest building materials used in monuments, decoration and building construction. Marble is a carbonate metamorphic rock. In India marble is mined from Rajasthan, Gujarat, Haryana, Telangana, Andhra Pradesh, Jharkhand, Uttarakhand and Uttar Pradesh (Fig.6.5). The detailed distribution of marble deposits in India is given in Table 6.5.

Table 6.5: Distribution of marble deposits in different states of India.

State	District/Locality
Gujarat	Banaskantha, Kachchh and Vadodara districts.
Jharkhand	Garhwal district.
Maharashtra	Bhandara and Nagpur districts.
Rajasthan	Makrana area is world famous centre for marble mining. marble is also mined from Ajmer, Pali, Banswara, Bhilwara, Alwar, Bundi, Chittorgarh, Dungarpur, Jaipur, Nagaur, Sikar, Sirohi and Udaipur districts.
Andhra Pradesh	Guntur district.
Telangana	Khammam, Bhadradri-Kothagudem districts.
Chhattisgarh	Bastar district.
Uttar Pradesh	Mirzapur district.
Uttarakhand	Dehradun, Tehri and Nainital districts.
Haryana	Mahendragarh district.

6.8 DOLOMITE DEPOSITS

Dolomite or dolostone is an anhydrous carbonate mineral. It occurs as sedimentary bedded strata/. The deposits are found in West Bengal, Andhra Pradesh, Jharkhand, Haryana, Chhattisgarh, Madhya Pradesh, Maharashtra,

Odisha and Rajasthan (Fig.6.6). The detailed distribution of dolomite deposits in India is given in Table 6.6.

Table 6.6: Distribution of dolomite deposits in different states of India.

State	District/Locality
Andhra Pradesh	Anantapur and Kurnool districts.
Telangana	Khammam, Warangal, Jayashankar districts.
Gujarat	Bhavnagar, Panchmahals and Vadodara districts.
Jharkhand	Garhwa and Palamau districts.
Karnataka	Bagalkot, Bijapur, Chitradurga, Mysore, Uttara Kannada and Tumkur districts
Madhya Pradesh	Balaghat, Chhatarpur, Khandwa, Sidhi, Betul, Chhindwara, Damoh, Dewas, Hoshangabad, Jabalpur, Jhabua, Katni, Mandla, Narsinghpur, Sagar and Seoni districts
Maharashtra	Chandrapur, Nagpur and Yavatmal districts
West Bengal	Jalpaiguri and Darjeeling districts
Odisha	Keonjhar, Koraput, Sambalpur and Sundergarh districts
Rajasthan	Ajmer, Alwar, Banswara, Bhilwara, Chittorgarh, Jaipur, Jaisalmer, Jhunjhunu, Jodhpur, Sikar and Udaipur districts
Tamil Nadu	Salem and Tirunelveli districts
Chhattisgarh	Bilaspur, Durg, Raigarh, Raipur, Bastar and Bilaspur districts

6.9 MAGNESITE DEPOSITS

Commercially, the term 'magnesite' refers not only to the mineral, but also to many products obtained by calcining the natural carbonate.. Magnesite deposits in India, generally occur as crystalline, amorphous and massive. In India magnesite deposits are found in Uttarakhand, Himachal Pradesh, Jammu and Kashmir, Karnataka and Tamil Nadu. (Fig. 6.7). The detailed distribution of magnesite deposits in India is given in Table 6.7.

Table 6.7: Distribution of magnesite deposits in different states of India.

State	District/Locality
Andhra Pradesh	Cuddapah district.
Karnataka	Mandya and Mysore districts.
Rajasthan	Ajmer, Dungarpur, Pali and Udaipur districts.
Tamil Nadu	Arcot, Coimbatore, Dharmapuri, Karur, Namakkal, Nilgiri, Salem, Tiruchirappalli, Tirunelveli and Vellore districts.
Jammu and Kashmir	Kargil, Ladakh and Udhampur districts.

Uttarakhand	Almora and Pithoragarh districts.
Himachal Pradesh	Brahmani and Pangi districts.

6.10 FIRECLAY DEPOSITS

Fireclays are sedimentary mudstones that occur as the 'seatearths' and underlie almost all the coal seams. In India the best deposits occur in association with the coal seams in the Lower Gondwana coalfields of Andhra Pradesh; Jharia and Raniganj coal fields of Jharkhand and West Bengal; Korba coalfields of Chhattisgarh and Neyveli lignite fields in Tamil Nadu. Fireclays that are not associated with coal measures are reported from Gujarat, Jabalpur region of Madhya Pradesh and Belpahar-Sundergarh areas of Odisha (Fig. 6.8). Fireclays are also found in Jammu and Kashmir, Assam and Meghalaya and Uttar Pradesh. The detailed distribution of fireclay deposits in India is given in Table 6.8.

Table 6.8: Distribution of fireclay deposits in different states of India.

State	District/Locality
Andhra Pradesh	Chittoor, Cuddapah, East Godavari, West Godavari, Kurnool and Srikakulam districts.
Telangana	Adilabad and Nalgonda districts.
Gujarat	Bharuch, Kachchh, Mehsana, Rajkot, Sabarkantha, Surat and Surendranagar districts.
Jharkhand	Dhanbad, Dumka, Giridih, Godda, Hazaribagh, Palamau, Ranchi and West Singhbhum districts.
Karnataka	Bangalore, Chitradurga, Dharwad, Hassan, Kolar, Shimoga and Tumkur districts.
Madhya Pradesh	Betul, Chhindwara, Gwalior, Jabalpur, Katni, Narsinghpur, Panna, Sagar, Shahdol and Sidhi districts.
Maharashtra	Amravati, Chandrapur, Nagpur and Ratnagiri districts.
Odisha	Angul, Bhubaneswar, Cuttack, Dhenkanal, Jharsuguda, Khurda, Puri, Sambalpur and Sundergarh districts.
Rajasthan	Alwar, Barmer, Bharatpur, Bikaner, Jaisalmer, Jhunjhunu and Sawai Madhopur districts.
Tamil Nadu	Cuddalore, Kanchipuram, Perambalur, Pudukottai, Sivaganga, Thiruvallur, Tiruchirapalli, Vellore and Villupuram districts.

6.11 GARNET DEPOSITS

Garnet is a collective term used for a group of minerals having similar physical properties. The common iron-rich garnet variety, almandite (Fe-Al garnet) is generally utilised as an abrasive. Other varieties are pyrope, spessartite, andradite, grossular, uvarovite. In India, the gem variety of garnet occurs in Rajasthan, Telangana, Andhra Pradesh and Tamil Nadu. Garnet occurs in beach sands along with ilmenite, rutile, sillimanite, etc. in the states of Kerala,

Odisha and Tamil Nadu (Fig. 6.9). The detailed distribution of garnet deposits in India is given in Table 6.9.

Table 6.9: Distribution of garnet deposits in different states of India.

State	District/Locality
Andhra Pradesh	Krishna, East Godavari and Nellore districts.
Telangana	Warangal and Khammam, Bhadradri-Kothagudem districts.
Jharkhand	Hazaribagh district.
Odisha	Ganjam and Sambalpur districts.
Rajasthan	Ajmer, Jaipur, Kishangarh (Ajmer district), Tonk, Bhilwara, Jhunjhunu, Sikar and Udaipur districts.
Tamil Nadu	Coimbatore, Nilgiri, Tirunelveli, Kanyakumari, Madurai, Tiruchirappalli, Chidambaram, Thanjavur, Kottabomman, Thoothukudi and Salem districts districts.
Chhattisgarh	Bastar district.

6.12 GYPSUM DEPOSITS

Gypsum is a hydrated soft mineral composed of calcium sulphate. Gypsum occurs as evaporite deposit and is a common mineral widely distributed in sedimentary rocks. It is often found in layered sedimentary deposits associated with the minerals halite, sulphur, and calcite. It frequently occurs interstratified with limestones and shales and is usually found as a layer underlying beds of rock salt.

Gypsum deposits occur in several parts of India. Selenite variety occurs in Nellore, Guntur and Prakasham districts of Andhra Pradesh. High-grade gypsum is mostly mined from Rajasthan. It occurs in Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Tamil Nadu and Uttarakhand (Fig. 6.10). The detailed distribution of gypsum deposits in India is given in Table 6.10.

Table 6.10: Distribution of gypsum deposits in different states of India.

State	District/Locality
Andhra Pradesh	Guntur, Nellore and Prakasam districts.
Gujarat	Bhavnagar, Jamnagar, Junagadh, Kachchh and Surendranagar districts.
Karnataka	Gulbarga district.
Madhya Pradesh	Shahdol district.
Rajasthan	Barmer, Bikaner, Churu, Sri Ganganagar, Hanumangarh, Jaisalmer, Jalore, Nagaur and Pali districts.
Tamil Nadu	Coimbatore and Tiruchirapalli district.

Himachal Pradesh	Sirmaur and Chamba areas.
Uttarakhand	Tehri Garhwal, Dehradun and Nainital districts.

6.13 PHOSPHATE DEPOSITS

Phosphorite or rock phosphate constitutes an essential plant food and are utilised in agriculture. The rocks may be fragmental, pelletal, nodular, oolitic, pisolitic, lenticular, platy, granular and massive form. Phosphatic limestone is mostly of low grade and found in Palamu district of Jharkhand and Pithoragarh district of Uttaranchal. They are also distributed in Himachal Pradesh, Jammu and Kashmir, Meghalaya, Madhya Pradesh, Odisha, Rajasthan, Uttarakhand and Uttar Pradesh (Fig. 6.11). The detailed distribution of rock phosphate in India is given in Table 6.11.

Table 6.11: Distribution of phosphate deposits in different states of India.

State	District/Locality
Gujarat	Panchmahals districts.
Jharkhand	low grade phosphatic limestone are mostly found in Palamau district.
Madhya Pradesh	Chhatarpur, Jhabua and Sagar districts.
Odisha	Ib coalfield.
Rajasthan	Alwar, Banswara, Jaipur, Jaisalmer and Udaipur districts.
Jammu and Kashmir	Pir Panjal Range.
Uttar Pradesh	Lalitpur district.
Himachal Pradesh	Shimla, Solan, Sirmaur and Mahasu districts.
Uttarakhand	Pithoragarh, Dehradun and Tehri districts.
Meghalaya	East Khasi, Garo and Jayantia Hills.

6.14 CORUNDUM DEPOSITS

Corundum is a crystalline form of aluminium oxide and is the hardest mineral next to diamond**.** According to colour, corundum is named as Ruby (red coloured transparent), Sapphire (blue), Amethyst (purple sapphire), White sapphire (colourless), Topaz (yellow sapphire), Emerald (green) and Emery (dark grey or black). In India, corundum occurs in Tamil Nadu, Karnataka. It is found associated with sillimanite or kyanite as observed in the Khasi and Jaintia hills of Meghalaya and Singhbhum district of Jharkhand. Other varieties occur in Madhya Pradesh, Maharastra, Jammu and Kashmir, West Bengal and Odisha (Fig. 6.12). The detailed distribution of corundum deposits in India is given in Table 6.12.

Table 6.12: Distribution of corundum deposits in different states of India.

State	District/Locality
Andhra Pradesh	Anantapur district.
Telengana	Khammam district.
Jharkhand	It is found associated with sillimanite or kyanite in Singhbhum district.
Karnataka	Kolar, Kanara, Mysore, Kudur, Tumakuru, Bangalore, Bellary, Chitradurga, Hassan and Mandya districts.
Madhya Pradesh	Sidhi district.
Maharashtra	Bhandara district.
Odisha	Cuttack district.
Rajasthan	Tonk district.
Tamil Nadu	Salem, Dharmapuri and Coimbatore districts.
Chhattisgarh	Bhopalpatnam, Uloor of Bijapur district and Sonakukanar areas of Dantewada district.
Jammu and Kashmir	Udhampur district.
Meghalaya	It is found associated with sillimanite or kyanite in Khasi and Jaintia Hills.
West Bengal	Puruliya district.

6.15 DIAMOND DEPOSITS

Diamond is the solid form of pure carbon with its atoms arranged in a crystal. Diamonds occur in kimberlite and lamproid pipes; stratified conglomerate and as alluvial placer deposits. Diamond deposits may be classified into three types based upon their geological settings such as kimberlite, conglomerate and alluvial gravels. The main diamond-bearing areas in India are the Panna belt in Madhya Pradesh (Fig. 6.13); Wajrakarur kimberlite pipe in Anantapur district; Munimadugu-Banganapalie conglomerate in Kurnool district; Krishna river basin in Andhra Pradesh and kimberlite in Raipur (Fig. 6.13). Potential diamondiferous kimberlites have been identified in Behradih-Payalikhand area of Gariaband districts in Chhattisgarh. Other diamond bearing areas are Bastar, Mahasamund, Dhamtari and Raigarh districts in Chhattisgarh (Fig. 6.13).

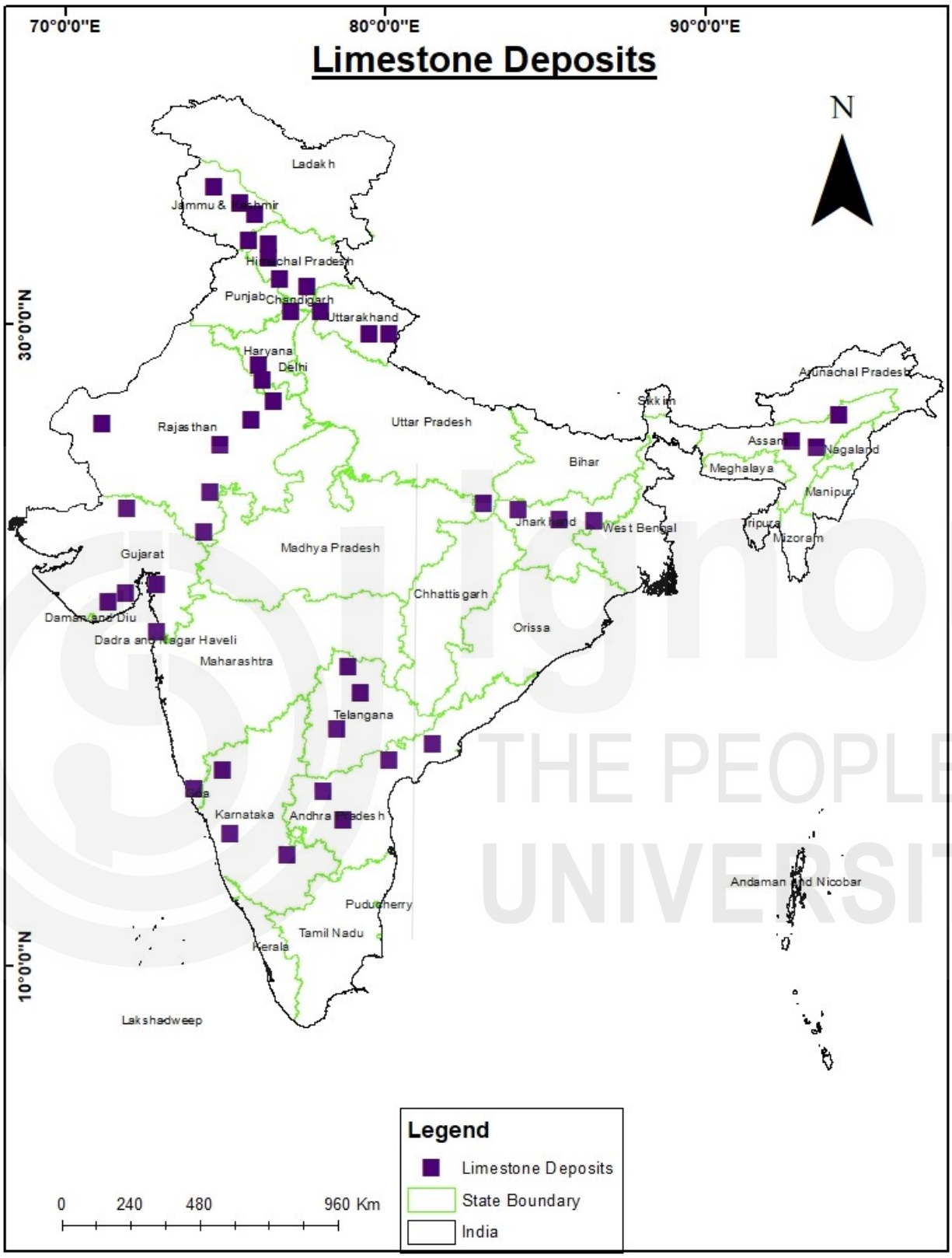


Fig. 6.1: Map showing the spatial distribution of some of the limestone deposits of India.

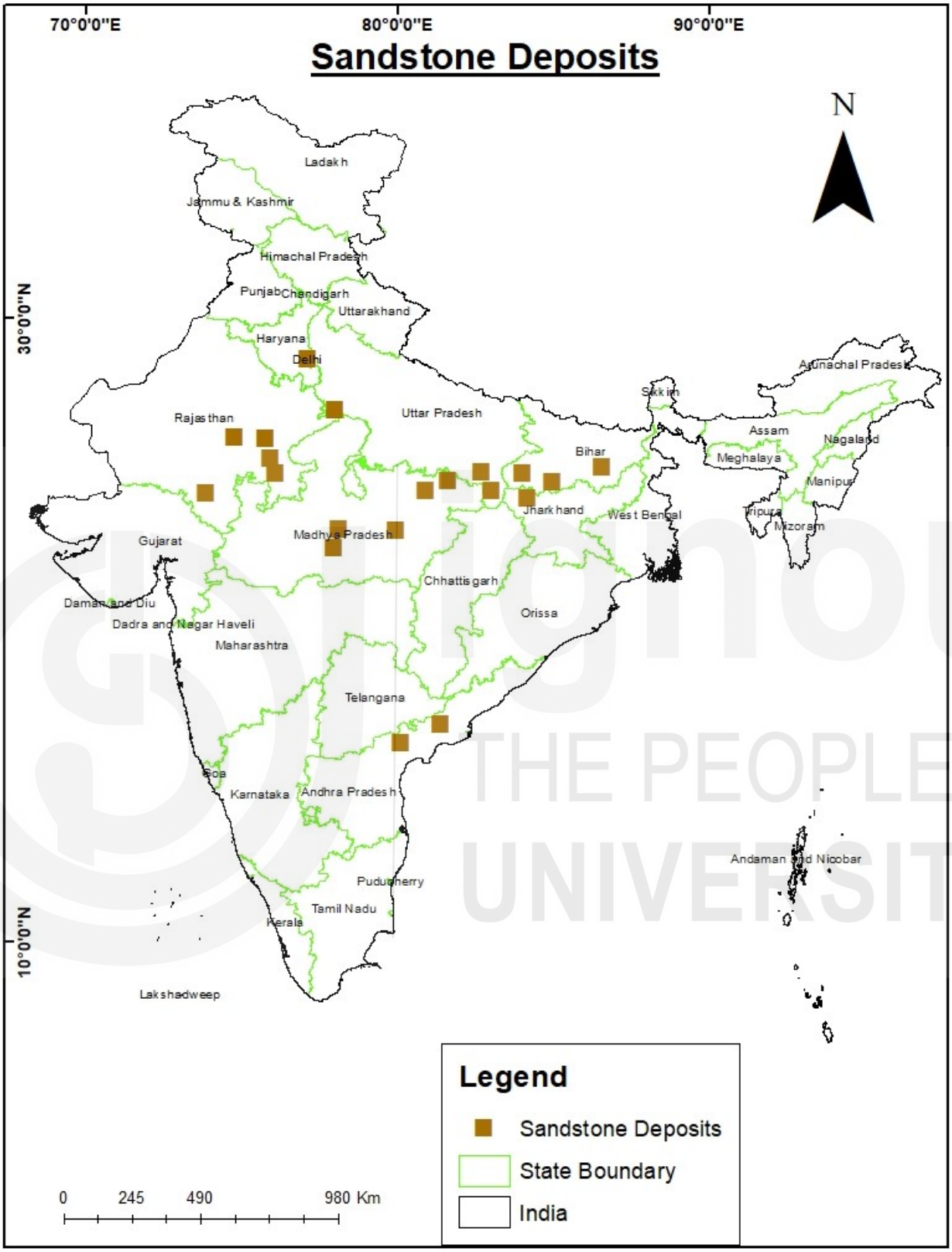


Fig. 6.2: Map showing the spatial distribution of some of the sandstone deposits of India.

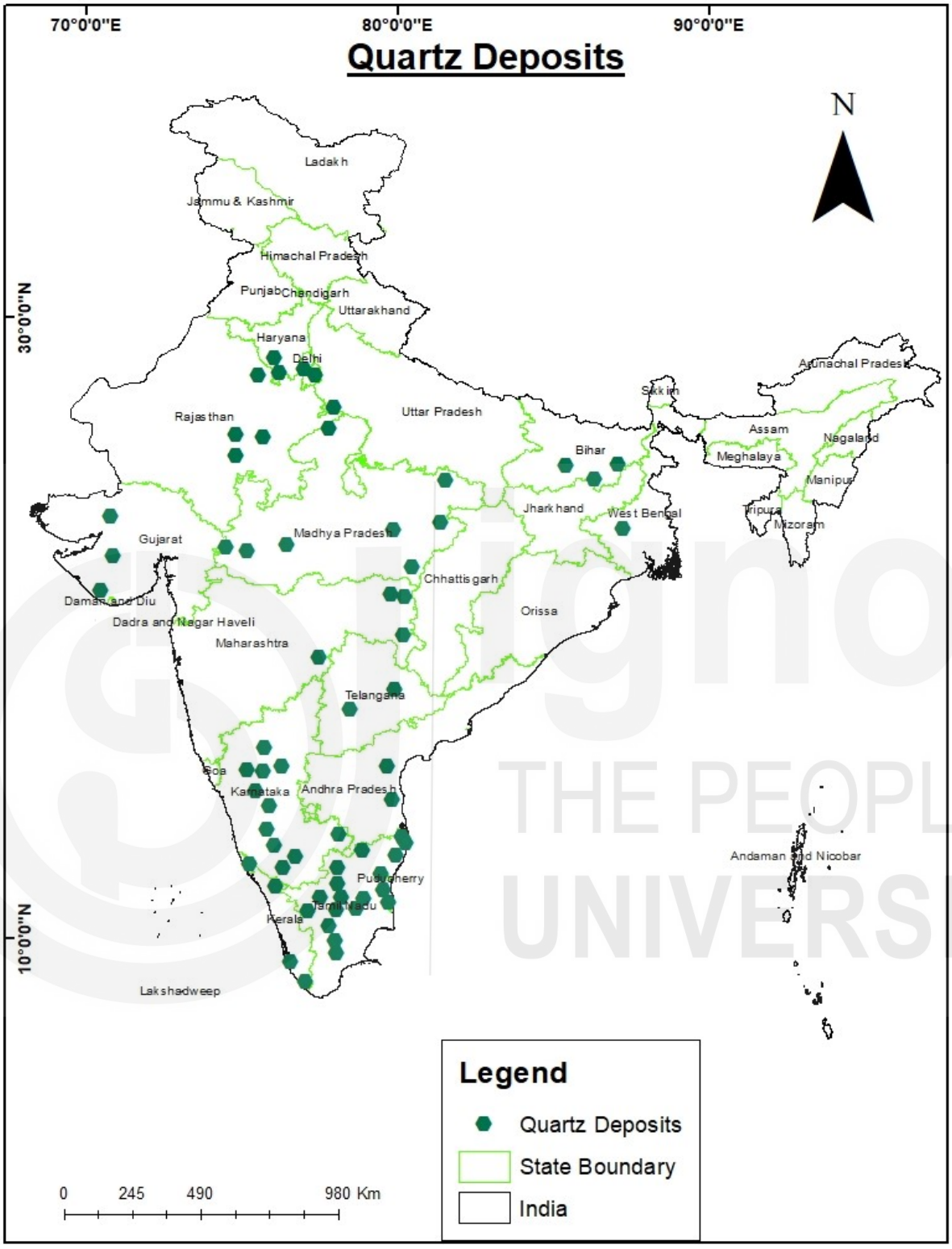


Fig. 6.3: Map showing the spatial distribution of some of the quartz deposits of India.

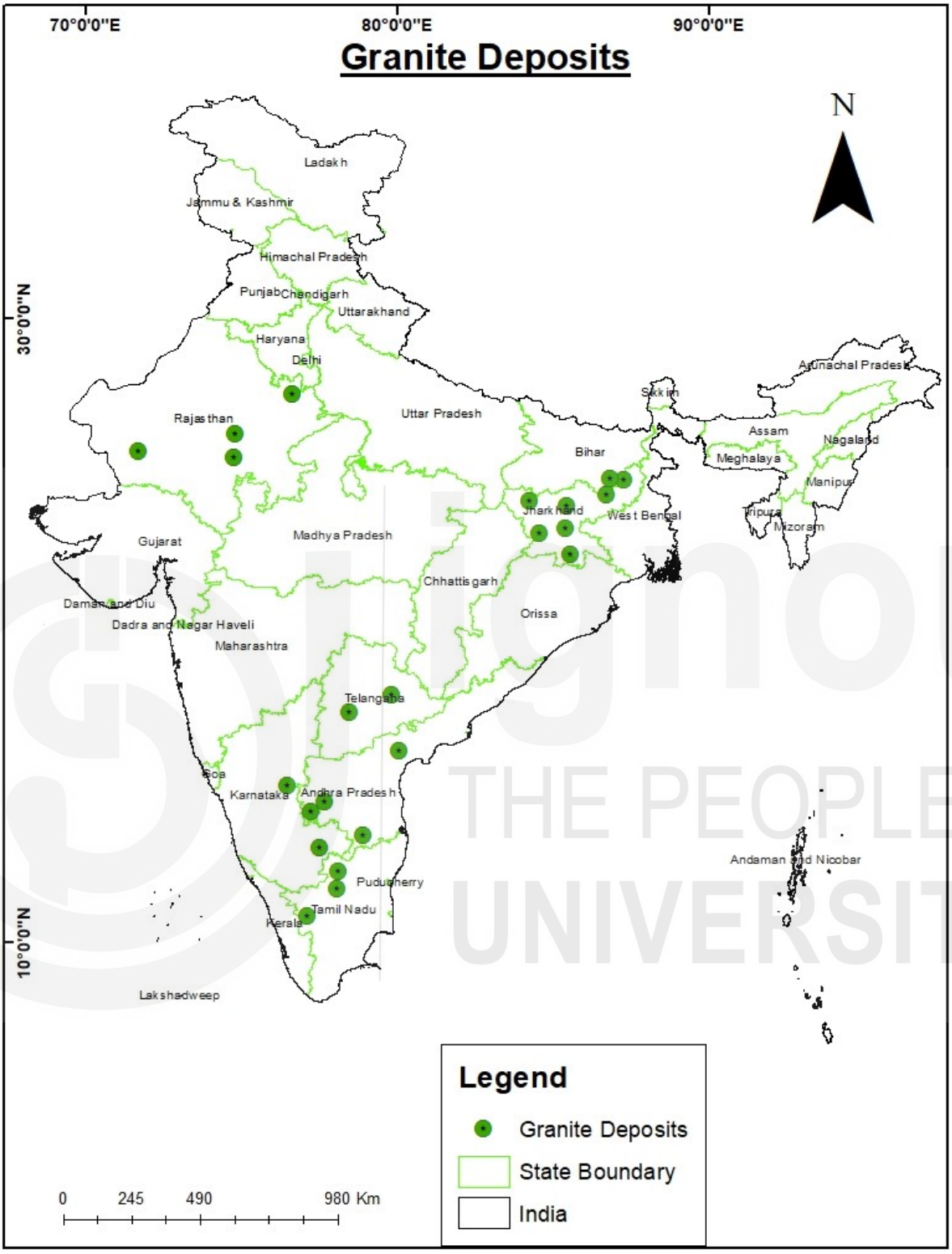


Fig. 6.4: Map showing the spatial distribution of some of the granite deposits of India.

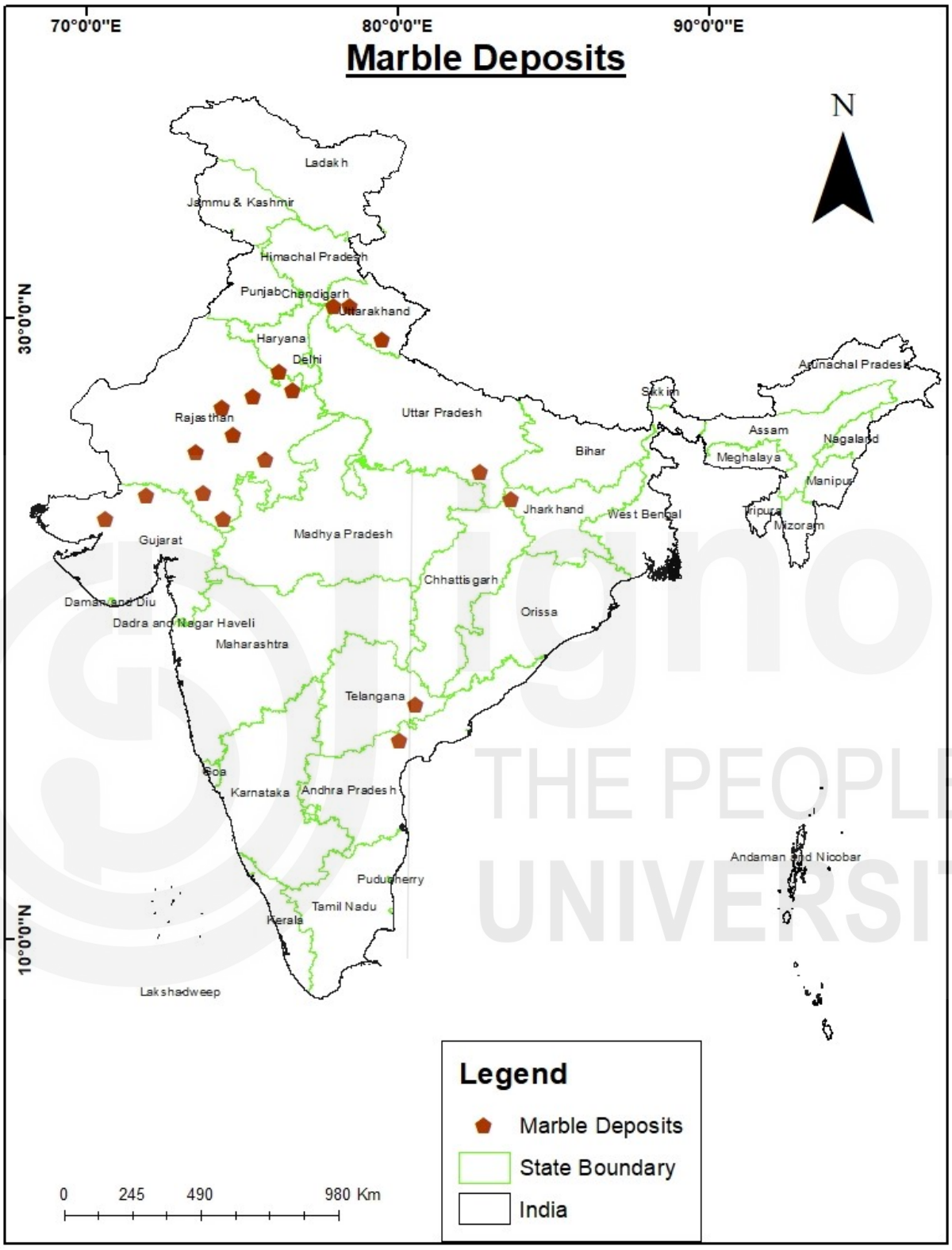


Fig. 6.5: Map showing the spatial distribution of some of the marble deposits of India.

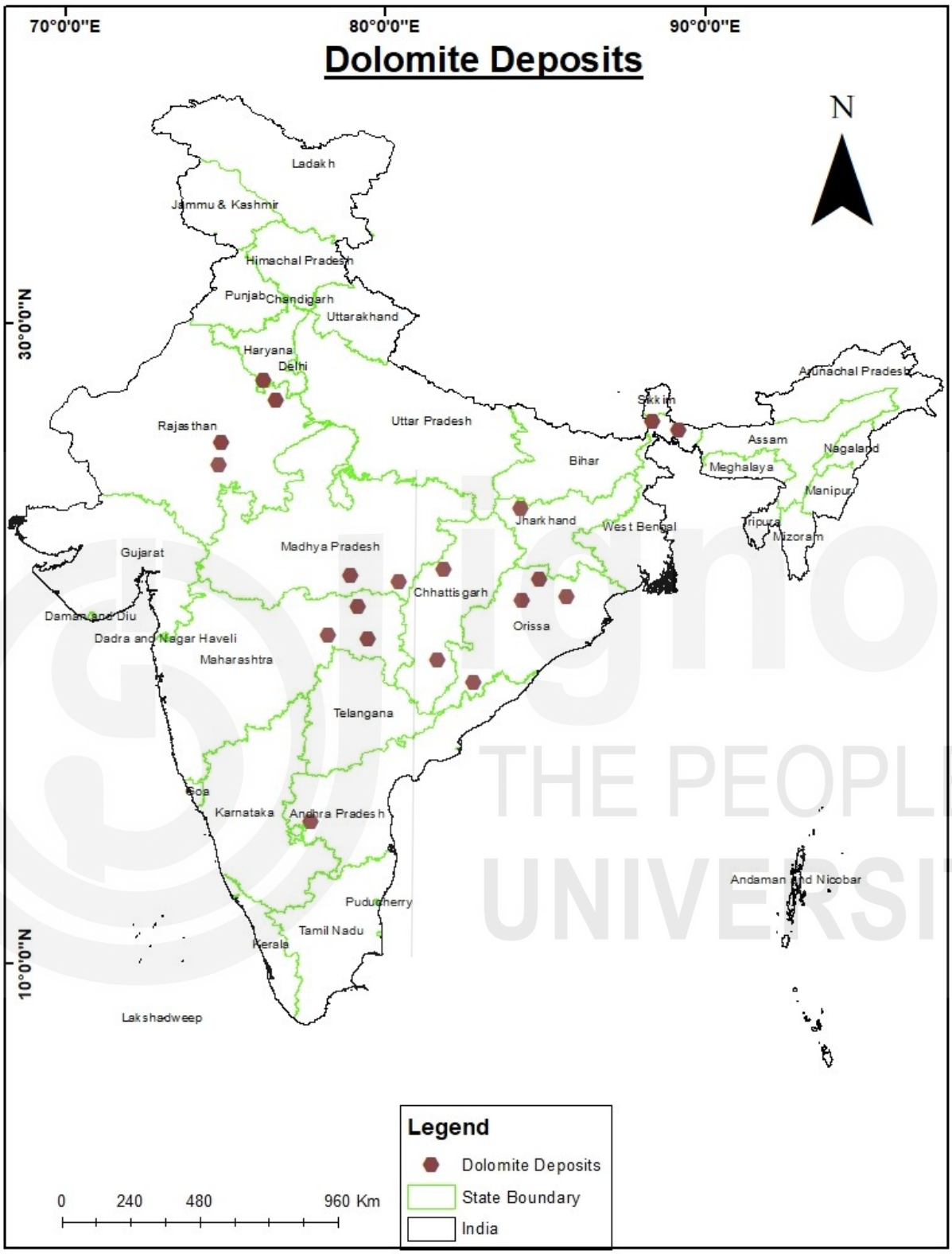


Fig. 6.6: Map showing the spatial distribution of some of the dolomite deposits of India.

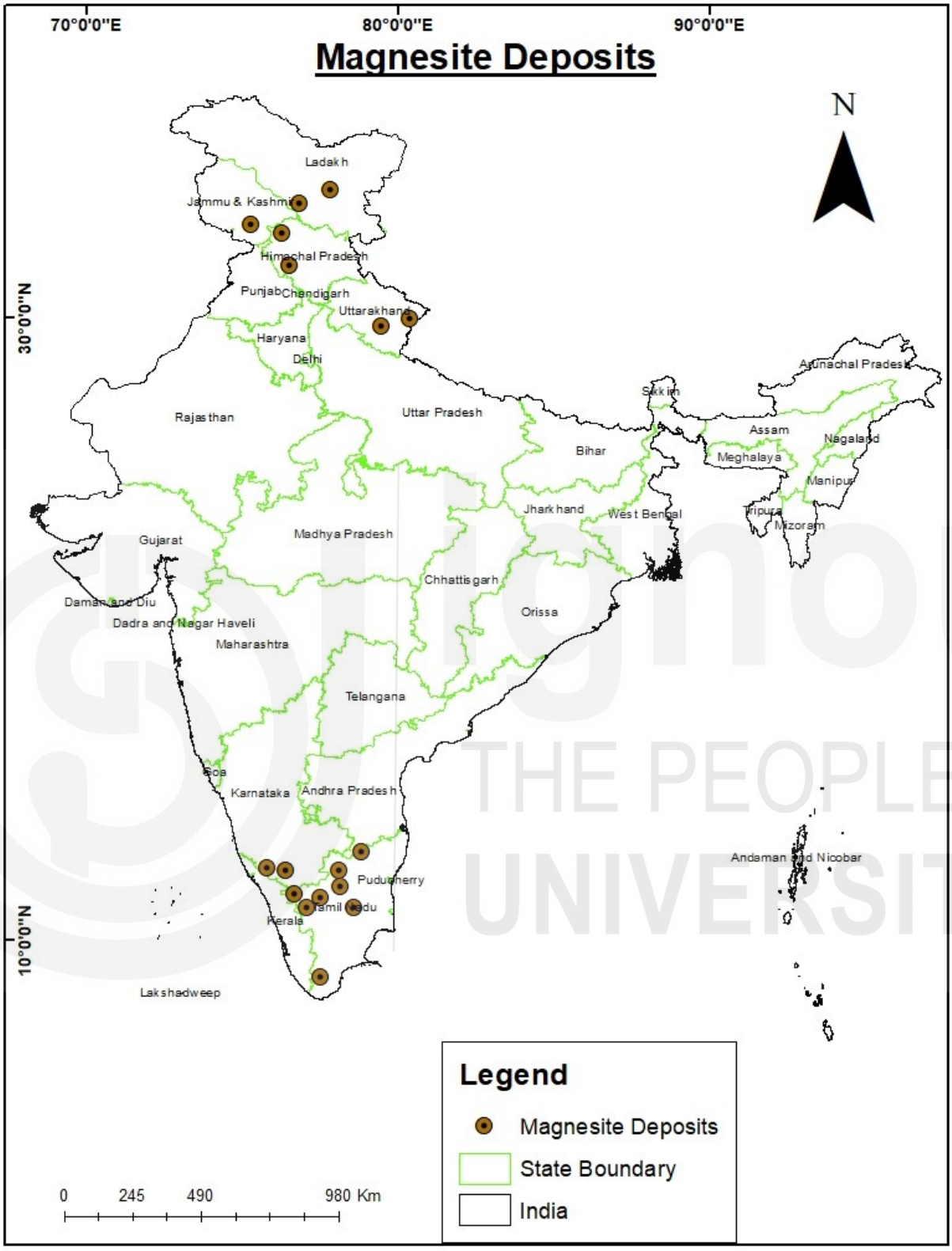


Fig. 6.7: Map showing the spatial distribution of some of the magnesite deposits of India.

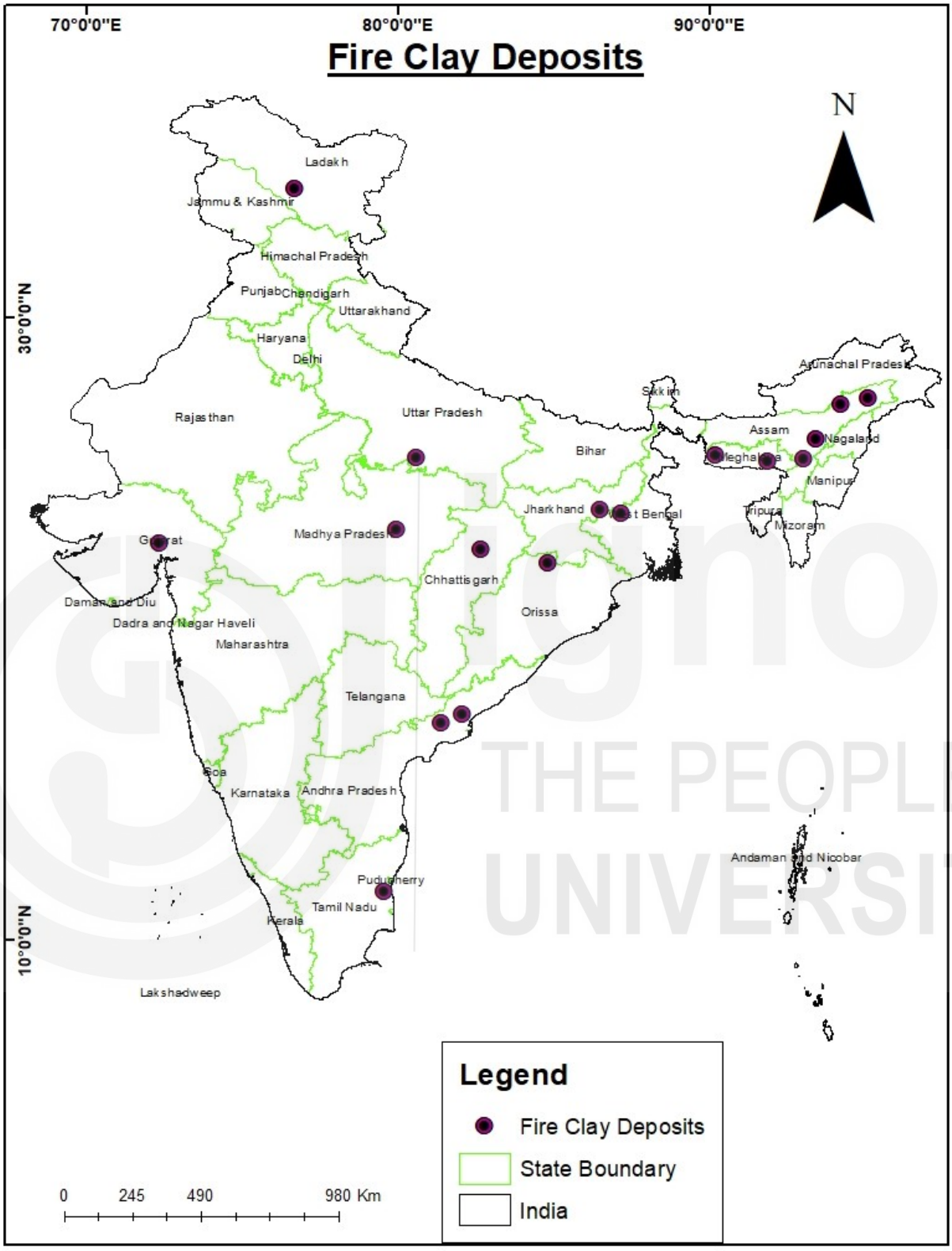


Fig. 6.8: Map showing the spatial distribution of some of the fireclay deposits of India.

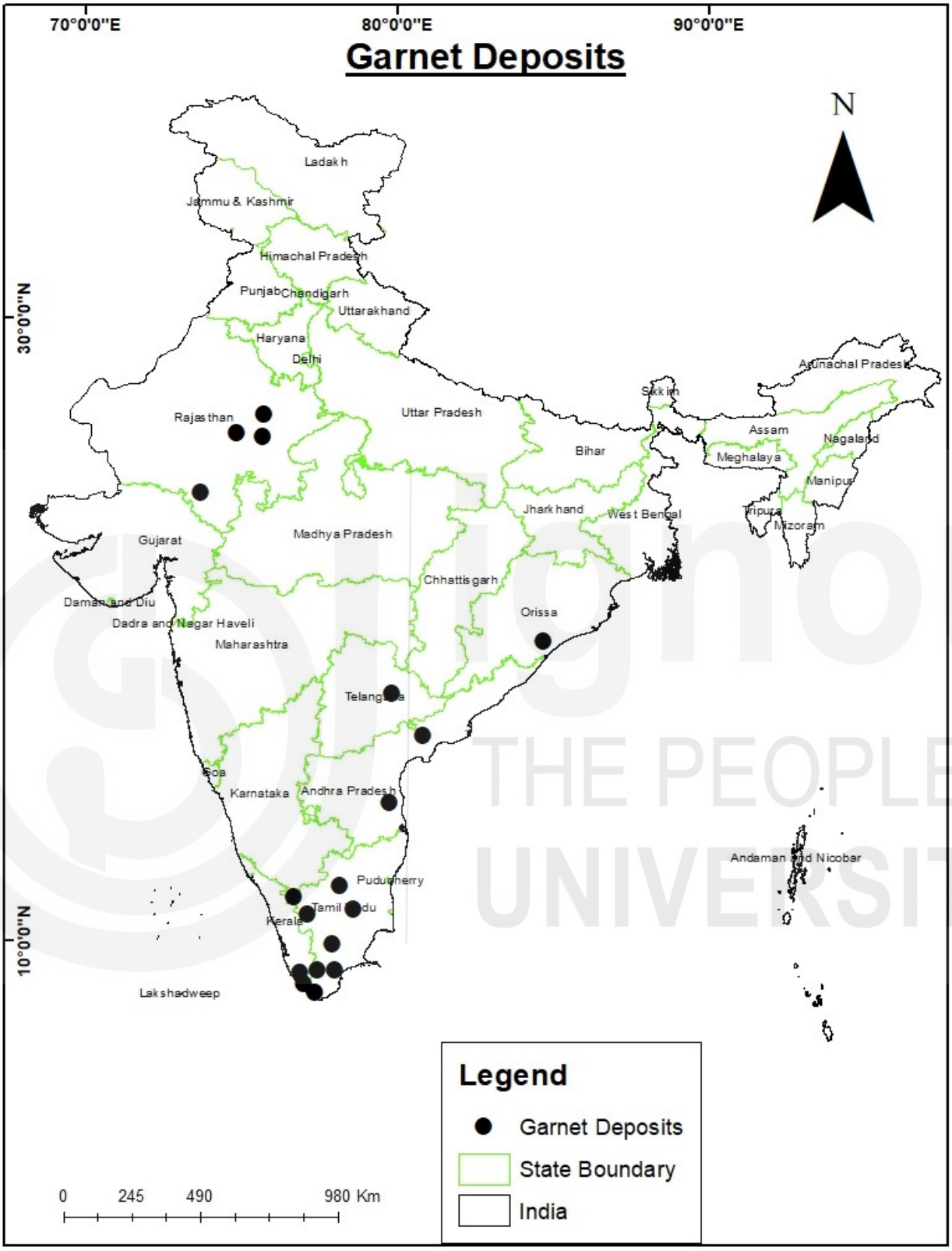


Fig. 6.9: Map showing the spatial distribution of some of the garnet deposits of India.

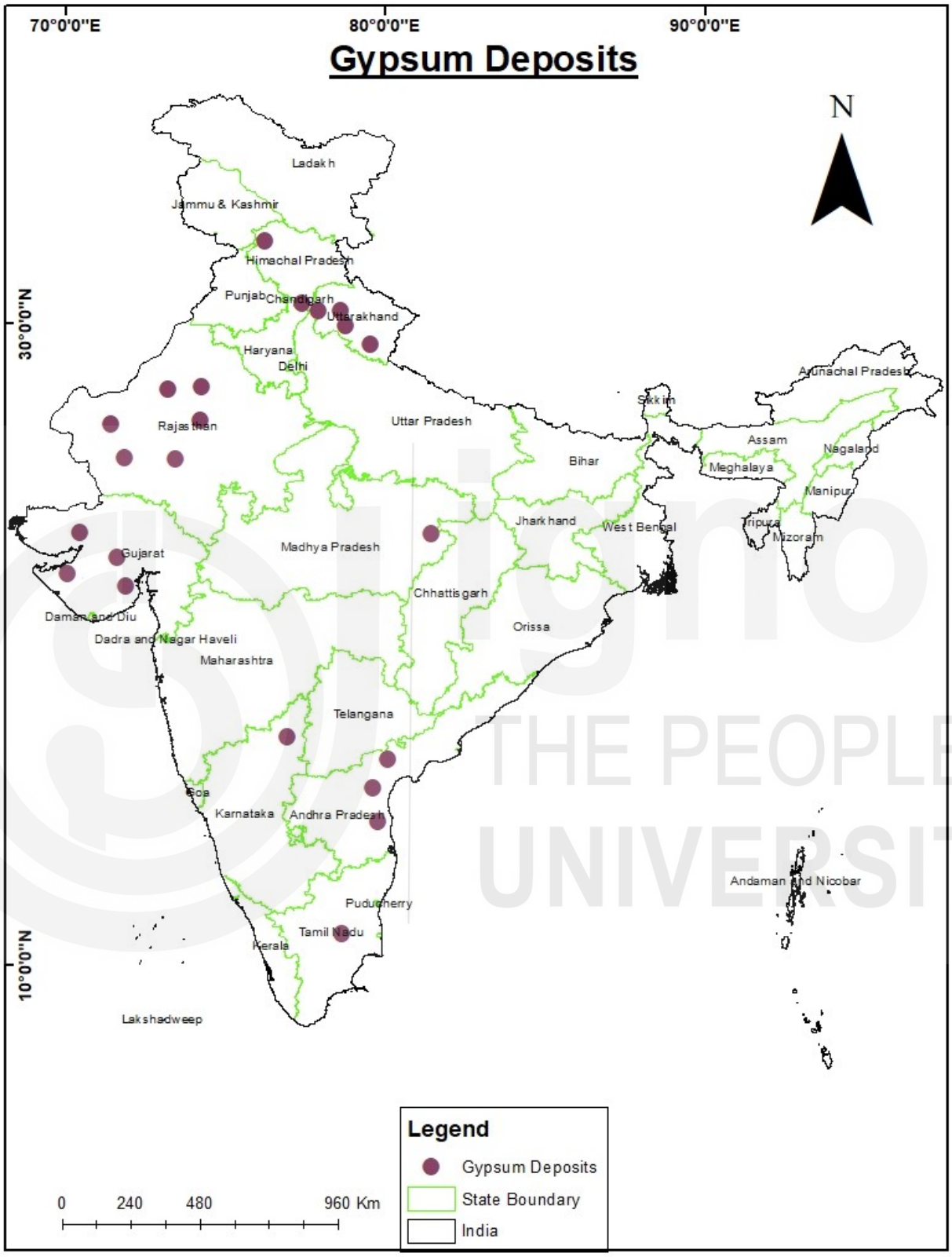


Fig. 6.10: Map showing the spatial distribution of some of the gypsum deposits of India.

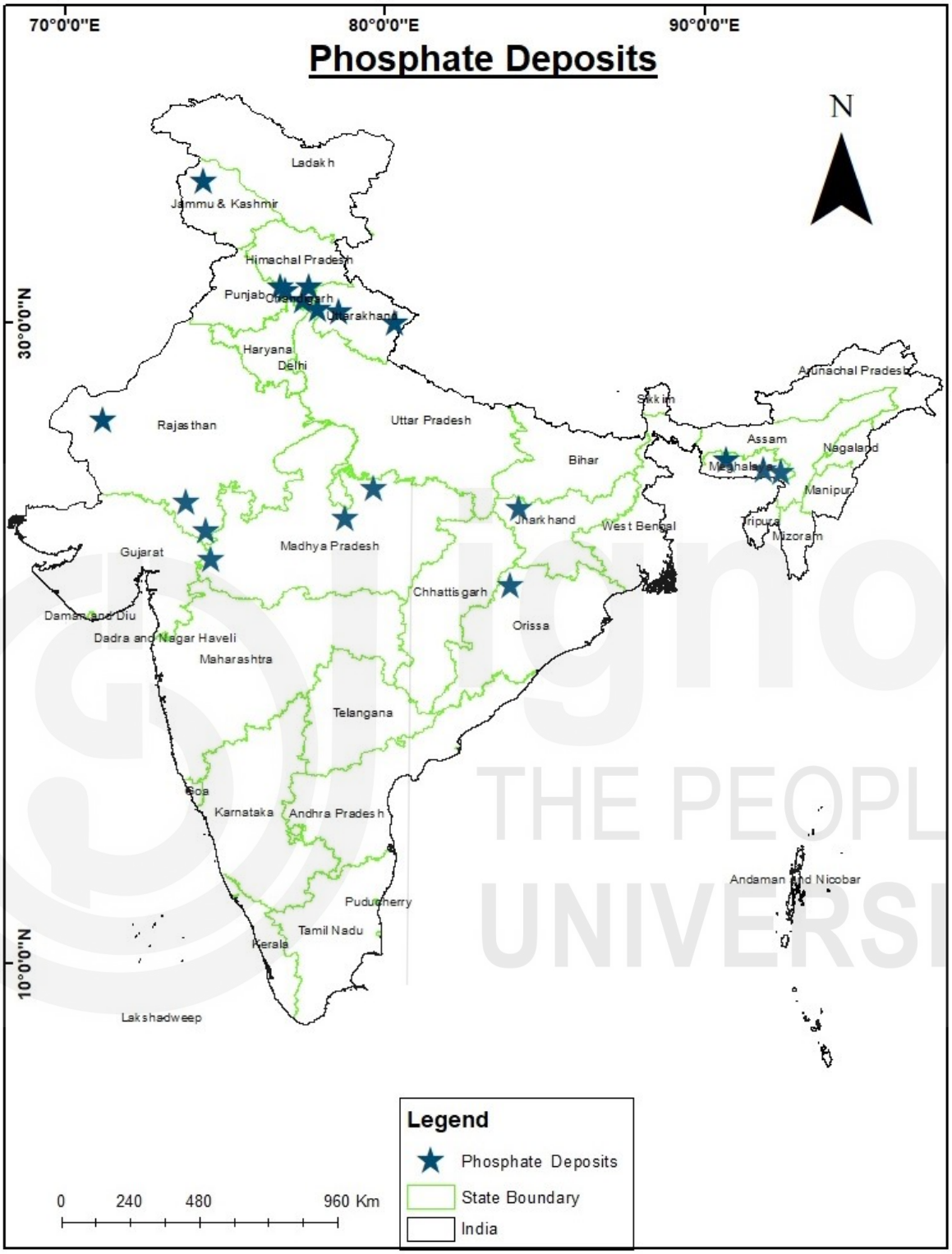


Fig. 6.11: Map showing the spatial distribution of some of the rock phosphate deposits of India.

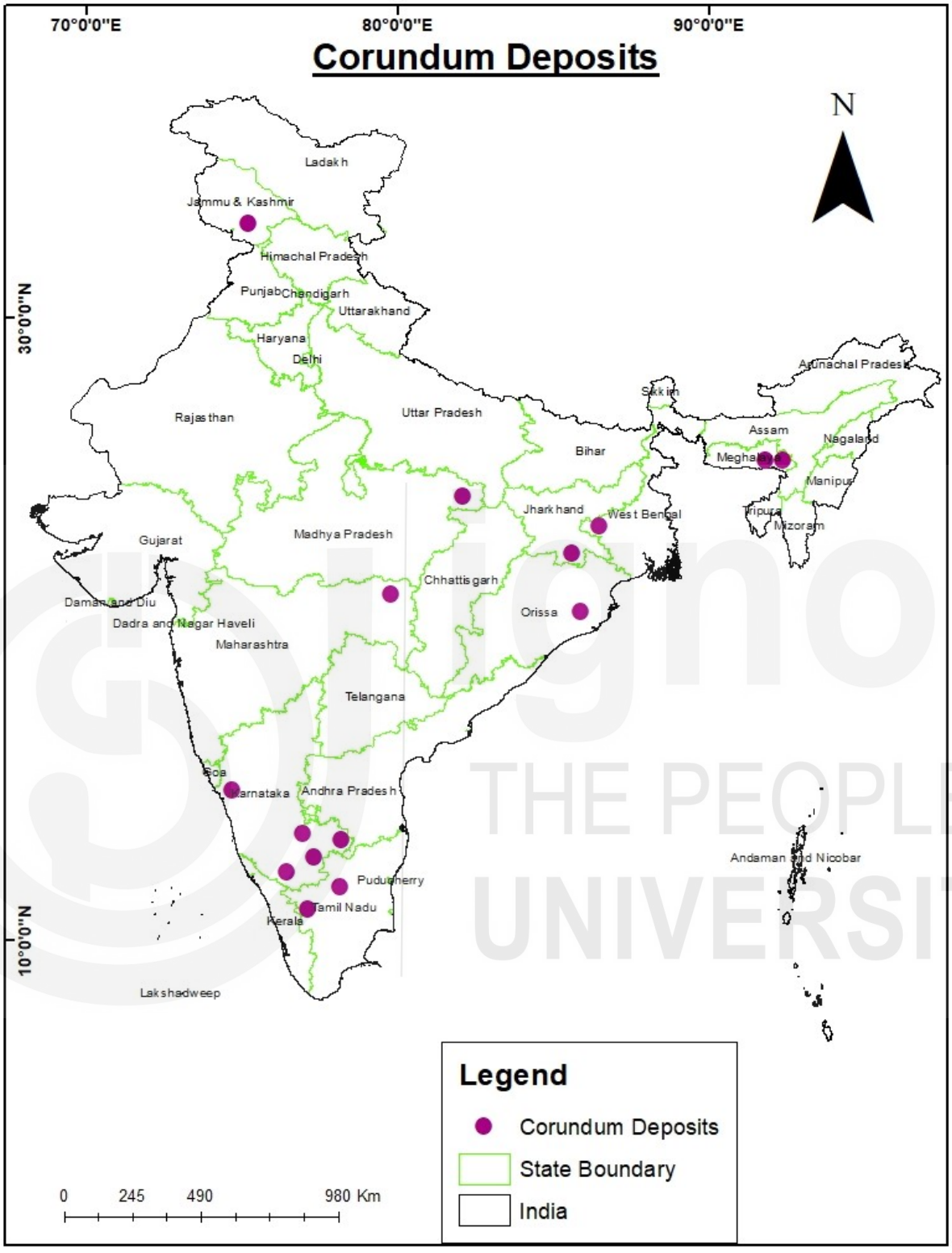


Fig. 6.12: Map showing spatial distribution of some of the corundum deposits of India.

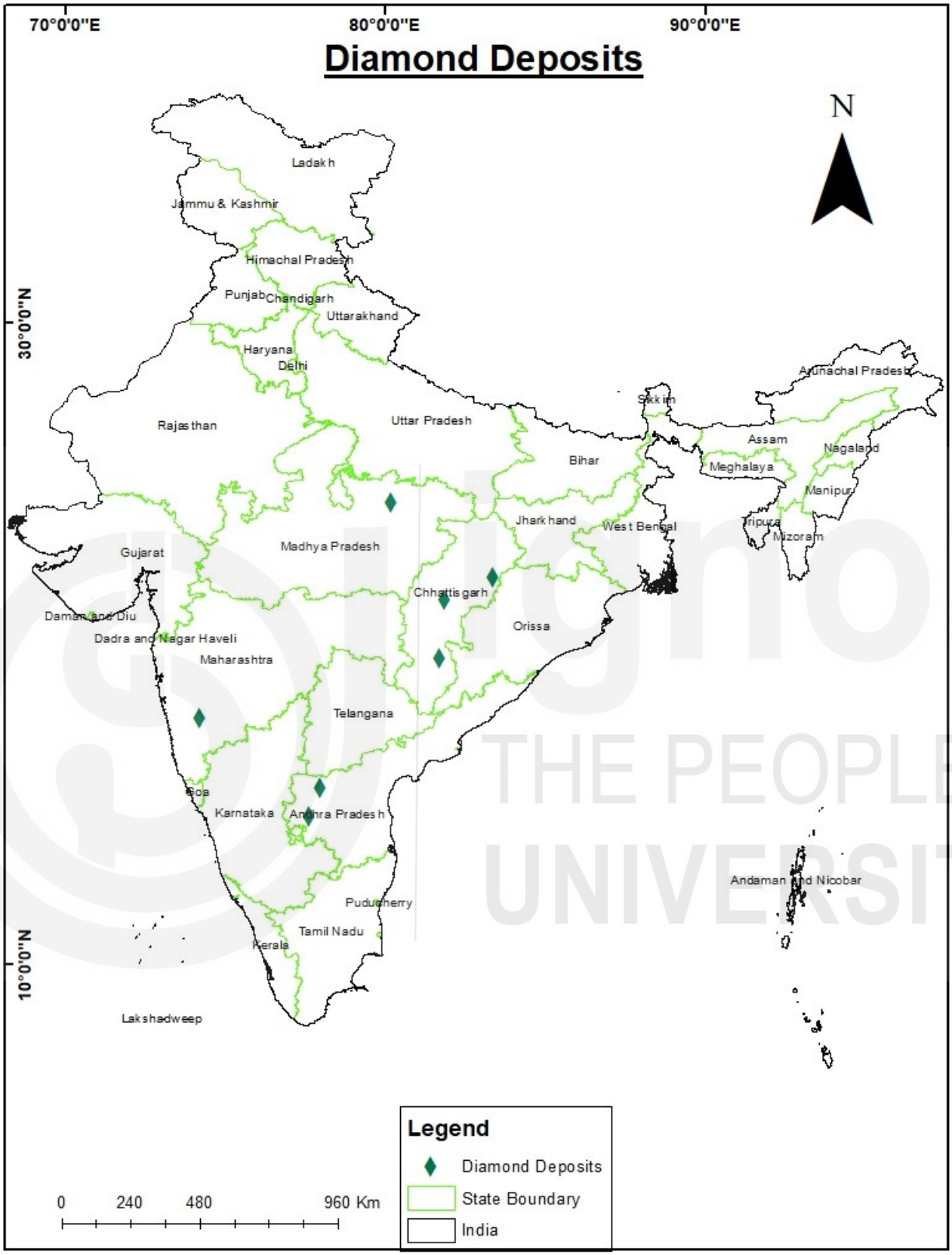


Fig. 6.13: Map showing spatial distribution of some of the diamond deposits of India.

6.16 LABORATORY EXERCISES

A blank map of India is given below (Fig. 6.14). You can make zerox copies of the India map and paste it on your laboratory file or draw neat outline map of India showing the political boundaries of the states. Plot the geographical distribution of various metallic mineral deposits on the map of India. You can use coloured pencil for marking the places. **Give answers of the following exercises in your laboratory file and submit it to your Academic Counsellor.**

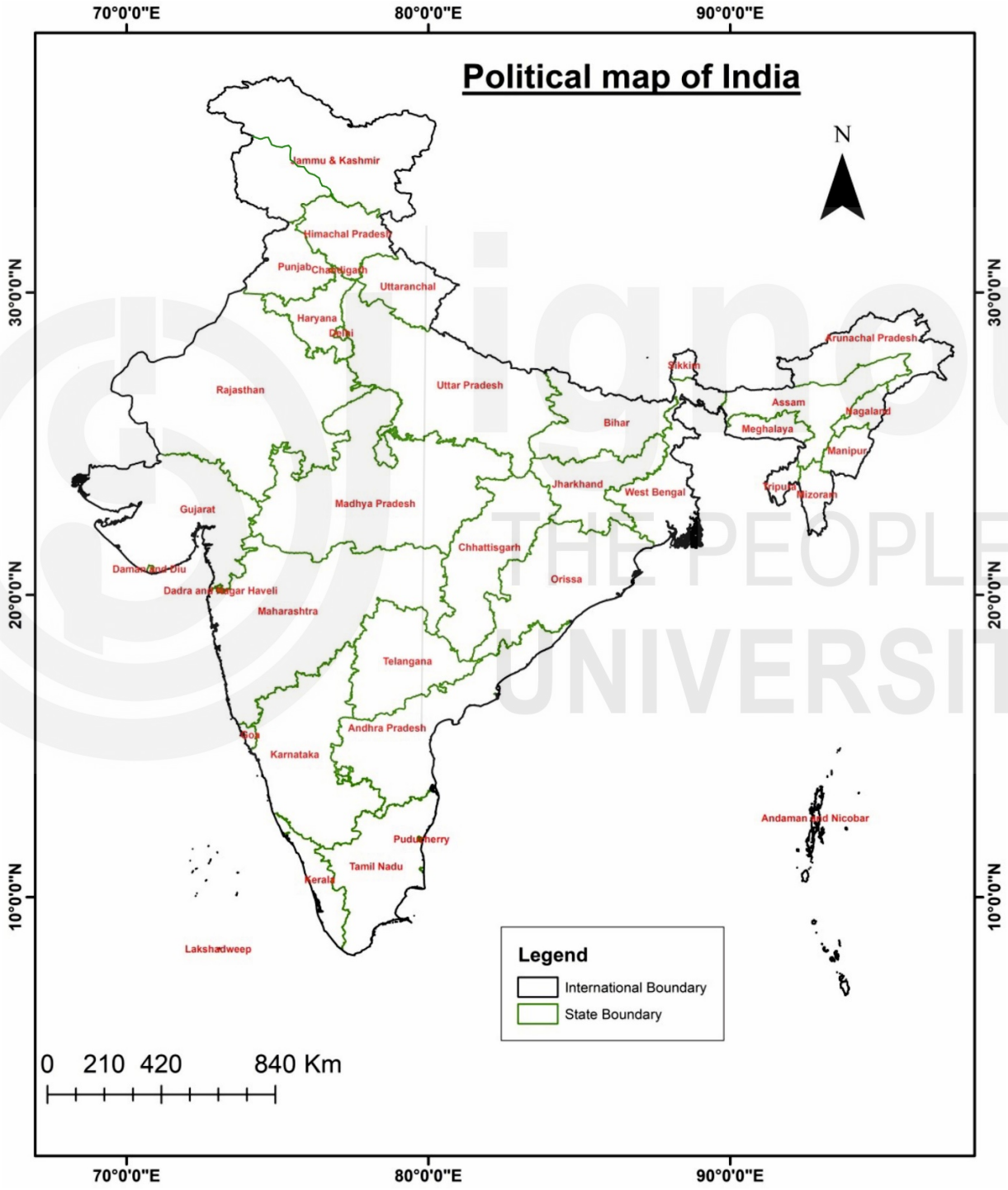


Fig. 6.14: Political map of India.

Exercise 1: List the localities or districts where limestone and dolomite deposits are found in India. Plot them in the blank outline map of India.

Exercise 2: List the localities or districts where sandstone deposits are found in India. Plot them in the blank outline map of India.

Exercise 3: List the localities or districts where quartz deposits are found in India. Plot them in the blank outline map of India.

Exercise 4: List the localities or districts where granite and marble deposits are found in India. Plot them in the blank outline map of India.

Exercise 5: List the localities or districts where magnesite and garnet deposits are found in India. Plot them in the blank outline map of India.

Exercise 6: List the localities or districts where fireclay, phosphate and gypsum deposits are found in India. Plot them in the blank outline map of India.

Exercise 7: List the localities or districts where corundum and diamond deposits are found in India. Plot them in the blank outline map of India.

6.17 REFERENCES

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- Indian Minerals Yearbook (2016) (Part- III: Mineral Reviews) 53rd Edition, Gypsum (Advance Release) Government of India, Ministry of Mines, Indian Bureau of Mines, Nagpur, 14 p.
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- Minerals and Metal Scenario. Ministry of Mines, Annual Report 2009-2010: https://mines.gov.in/writereaddata/UploadFile/chap3.pdf
- Roy, S., (1981) Manganese deposits. Academic Press, London. 458p.

6.18 LEARNING RESOURCES

- **Minerals in India**

  Link: https://www.youtube.com/watch?v=YoN06_j4EJE

- **Distribution of minerals in India**

  Link: https://www.youtube.com/watch?v=aJ45TdtKQck

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EXPERIMENT 7

PREPARATION OF MAP SHOWING DISTRIBUTION OF ATOMIC MINERALS OF INDIA

Outline of Experiment

7.1 Introduction
Expected Learning Skills
7.2 Requirements
7.3 Uranium Deposits
7.4 Thorium Deposits
7.5 Laboratory Exercises
7.6 References

7.1 INTRODUCTION

Atomic minerals are the most important among non-fossil energy resources which are the minerals of the radioactive elements like Uranium (U) and Thorium (Th). You have read about uranium and thorium in Unit 12 of BGYET-141 course. Uranium and thorium are members of the actinide (Ac) series. They are predominately found in the form of Achaean Schist or Pre-Cambrian rocks and placer deposits in a very low content in the world. In the magmatic rocks, they usually concentrate in acidic, plutonic rocks which include granitoids, pegmatite, rhyolite and acid tuffs. Sandstones, pyrite bearing quartz, pebble, conglomerates and phosphatic and carbonaceous rocks are good hosts for uranium minerals. They also occur in metamorphic rocks like phyllite and schist. Thorium minerals occur generally in acidic igneous rocks and high-grade metamorphic rocks.

In the previous experiment, you have prepared different maps showing the geographical or spatial distribution of some of the important non-metallic minerals such as limestone, sandstone, quartz/silica sand, granite, marble, dolomite, magnesite, fireclay, garnet, gypsum, phosphate, corundum and diamond deposits of India. In this experiment, you will prepare maps showing the spatial distribution of important atomic mineral deposits i.e., uranium and thorium deposits of India.

Expected Learning Skills

After completing this experiment, you would be able to:

- ❖ list and plot spatial distribution of uranium deposits of India;
- ❖ list and plot spatial distribution of thorium deposits of India; and
- ❖ identify the regions, with the maximum concentration of uranium and thorium deposits of India.

7.2 REQUIREMENTS

To perform this experiment successfully you require the following:

- Pen, pencil, eraser, scale, sharpener and coloured pencils
- Laboratory file
- Blank maps of India of A4 size (with demarcated states boundaries)
- Atlas of India (it will help you to plot the localities of atomic minerals in the blank map of India)

[Instructions: You are required to study Unit -12 Mineral Fuels of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling sessions.]

7.3 URANIUM DEPOSITS

Uranium is not found in its native state, but it also occurs in combination with other elements as compounds. Uranium minerals are radioactive and consist of three isotopes: ^{238}U, ^{235}U and ^{234}U. Some other isotopes of uranium are ^{232}U, ^{233}U, ^{236}U, ^{242}U etc. The chief minerals of uranium are: Pitchblende (Uraninite), Torbernite (Copper Uranite), Autunite (Lime Uranite), Carnotite and Uraconite (Zippeite).

In India uranium ores found in different geological basins are Singhbhum shear zone, Jharkhand; Cuddapah basin, Andhra Pradesh; Mahadek basin, Meghalaya; Bhima basin, Karnataka and Delhi Supergroup rocks of Rajasthan. Uranium bearing minerals also occur in the pegmatites in the Mica belt of Bihar, Durg district of Chhattisgarh, Bhandara district of Maharashtra and Kullu district of Himachal Pradesh. The important uranium deposits of India are given in Table 7.1 and are plotted in Fig.7.1.

Table: 7.1: Spatial distribution of uranium deposits of India.

State	Locality/District
Jharkhand	The Jaduguda in Singhbhum Thrust Belt (also known as Singhbhum Shear Zone or Singhbhum Copper Belt) is the first uranium deposit located in the country. Some of the other areas like Garadih, Kanyaluka, Nimdih and Nandup in this belt are also known to contain limited reserves.
Rajasthan	It occurs in Aravalli rocks at Umia and Udaisagar in Udaipur district, the Delhi formation at Kho-Dariba in Alwar district and

	at Khetri in Jhunjhunu district of Rajasthan. Delhi Supergroup rocks of Rajasthan.
Andhra Pradesh	Lambapur-Peddagattu, Chitrial, Kuppunuru, Tumallapalle, Rachakuntapalle, kanampalle of Cuddapah basin which have contributed towards the uranium reserve of India.
Meghalaya	Uranium deposits occur in Domiasiat, Wahkhyn, Mawsynram of Mahadek basin.
Karnataka	Ukinal, Dharshanapur, Gogi areas of Bhima basin.
Odisha	Sundergarh, Sambalpur, Bargarh, Jharsuguda, Deogarh, Kalahandi, Mayurbhanj and Jajpur districts.

7.4 THORIUM DEPOSITS

Thorium (Th) is a weakly radioactive unstable element. ^{232}Th is the most stable isotope of thorium and accounts for nearly all-natural thorium, with the other five natural isotopes (^{227}Th, ^{228}Th, ^{229}Th, ^{230}Th, ^{231}Th, ^{232}Th, and ^{234}Th), occurring in traces. Like uranium, it is not found in nature in a free state. The commercially important mineral of thorium is monazite. The chief minerals of thorium are Monazite, Thorite and Thorianite.

In India thorium along with uranium occurs in the cerium minerals. Monazite, which is a constituent of the heavy black sands occur on the sea coasts of India, from the Narmada estuary to Cape Camorin and to Odisha coast. Thorium is mainly obtained from monazite and ilmenite in the beach sands along the coast of Kerala and Tamil Nadu. World's richest monazite deposits occur in Palakkad and Kollam districts of Kerala, near Vishakhapatnam in Andhra Pradesh and the Mahanadi river delta in Odisha. The important thorium deposits of India are given in Table 7.2 and are plotted in Fig.7.2.

Table: 7.1: Spatial distribution of thorium deposits of India.

State	District/Locality
Tamil Nadu	Allanite and monazite have been reported from Thoothukudi, Kanyakumari, Tirunelveli, Ramanathapuram, Pudukkottai, Tiruchirapalli, Thanjavur, Nagapattinam, Thiruvarur, Cuddalore and Kanchipuram districts.
Andhra Pradesh	Coastal stretch between Kondadaand Donkuru: Kondada-Kandivalasa, Hukumpet and Bendicreek-Donkuru in Srikakulam district. Around Bhimunipatnam, Visakhapatnam and Vizianagaram districts.
Odisha	Monazite is found in the coastal tracts of Cuttack and Ganjam districts of Odisha.
Rajasthan	Uraninite has been reported along shear zones in Rohil-Ghateshwar-Khandel-Diara and Saladipura area in Sikar district.
Kerala	Monazite bearing sands are best developed along the beaches of the southwest coast of India in Kollam district and

	between Chavakkad, Thrissur districts and Ponnani, Malappuram districts.
Karnataka	Belgaum area and Gogi village of Yadgir district.

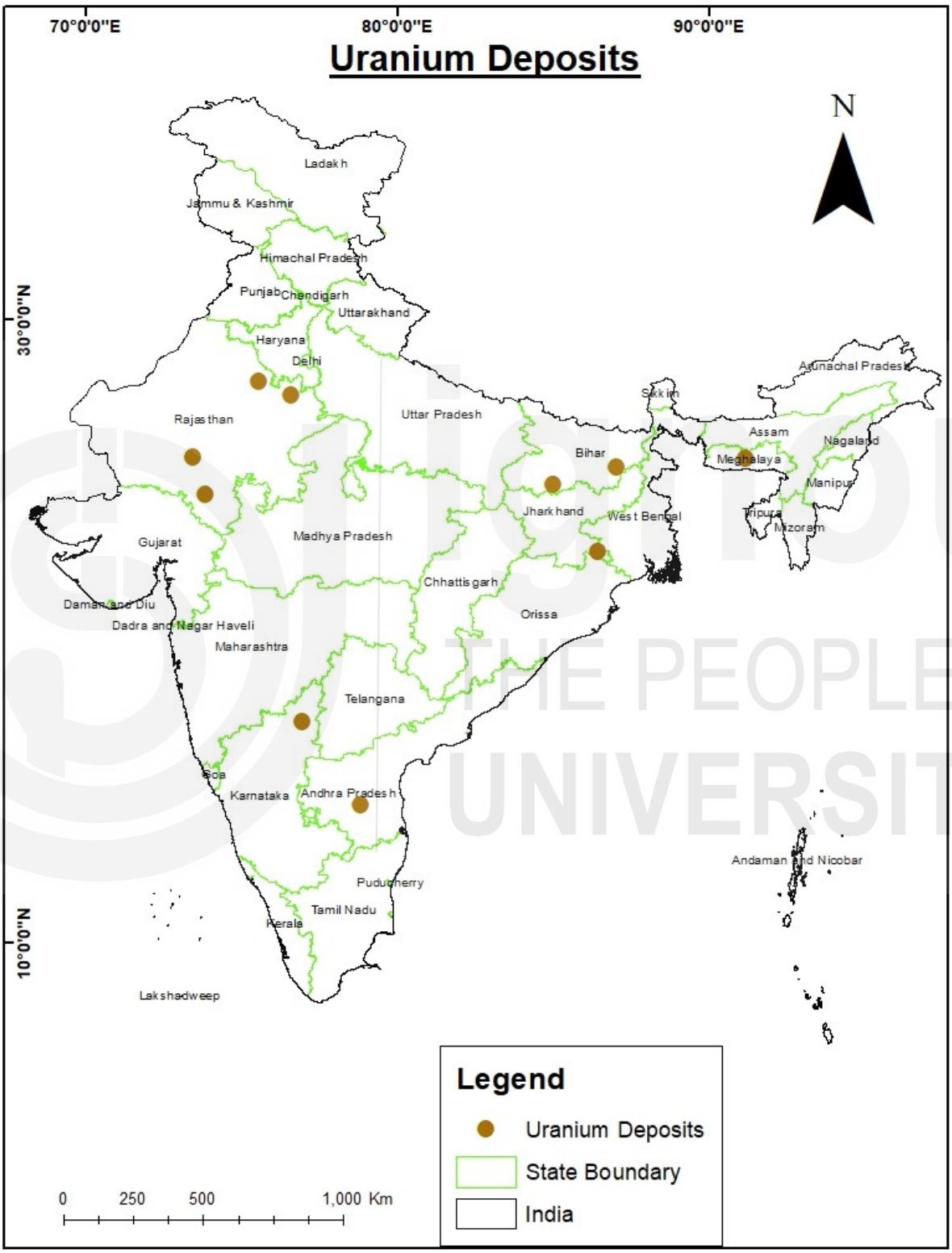


Fig. 7.1: Map showing spatial distribution of uranium deposits of India.

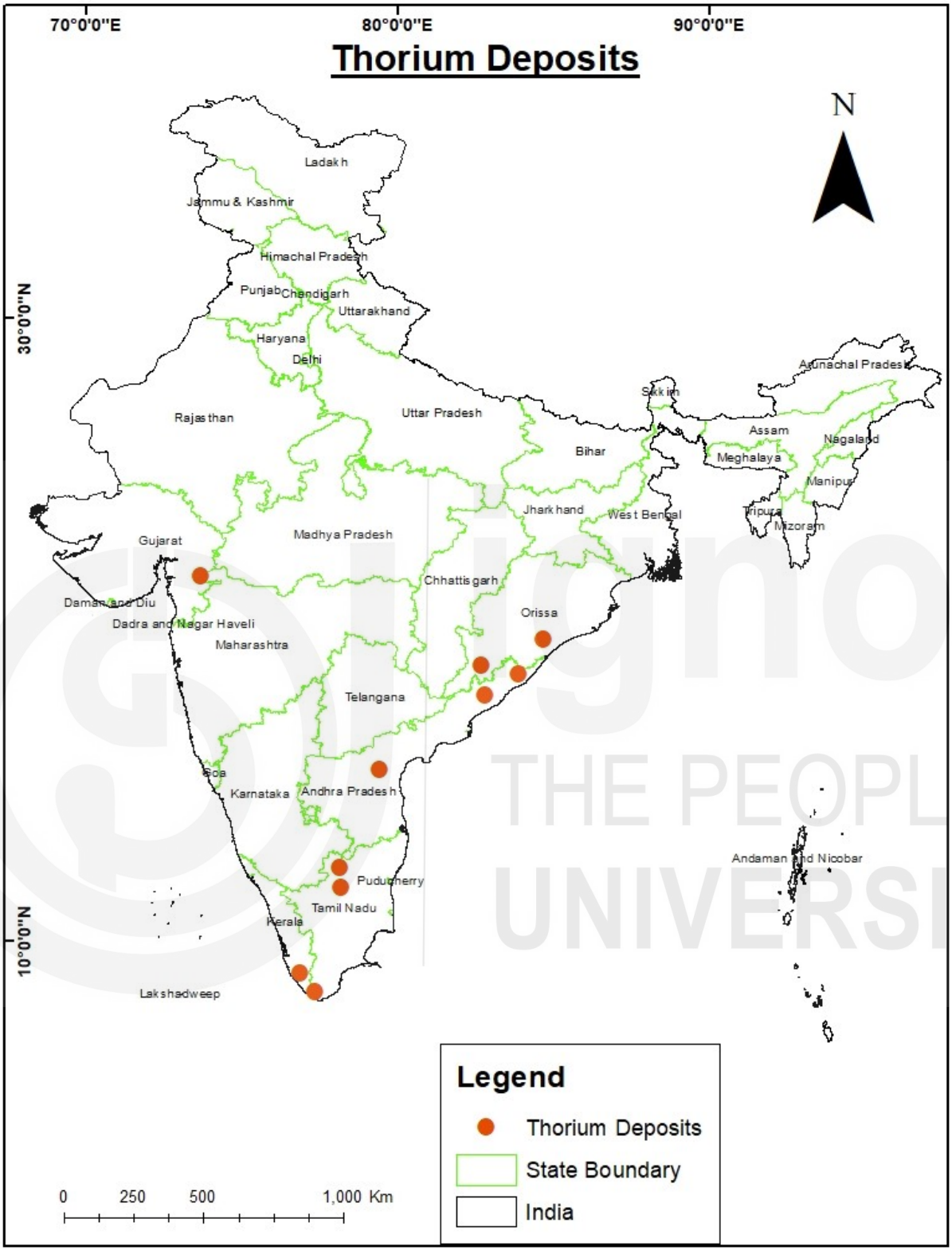


Fig. 7.2: Map showing the spatial distribution of thorium deposits of India.

7.5 LABORATORY EXERCISES

A blank map of India is given below (Fig. 7.3). You can make xerox copies of the India map and paste it on your laboratory file or draw a neat outline map of India showing the political boundaries of the states. Plot the geographical

distribution of various metallic mineral deposits on the map of India. You can use coloured pencil for marking the places.

Give answers of the following exercises in your laboratory file and submit it to your Academic Counsellor.

Exercise 1: List the localities or districts where Uranium deposits are found in India. Plot the same in the blank outline map of India.

Exercise 2: List the localities or districts where Thorium deposits are found in India. Plot the same in the blank outline map of India.

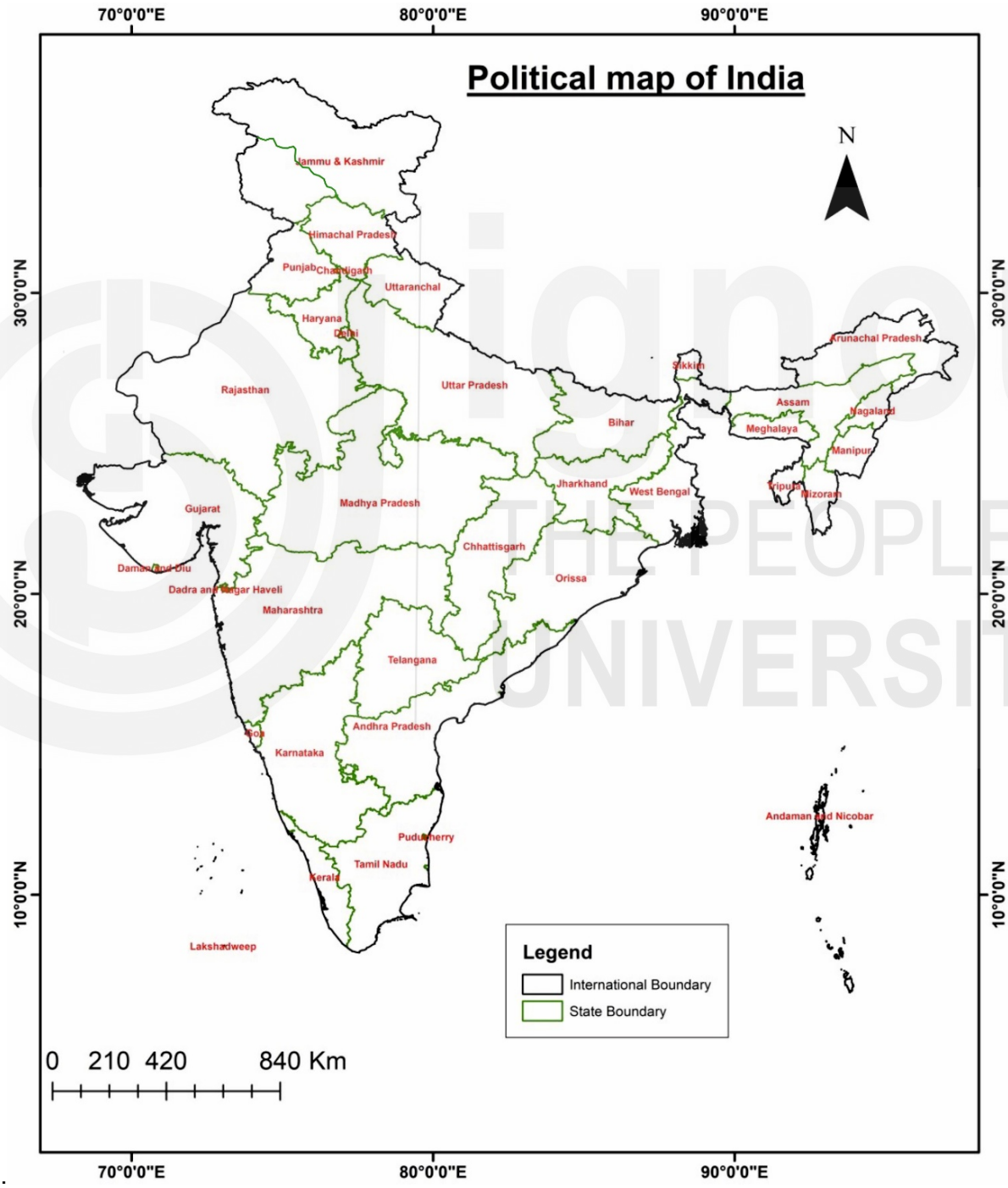


Fig. 7.3: Political map of India.

7.6 REFERENCES

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(Websites accessed between 1st April 2021 and 31st May 2021).

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EXPERIMENT 8

PREPARATION OF MAP SHOWING DISTRIBUTION OF COAL AND LIGNITE DEPOSITS OF INDIA

Outline of Experiment

8.1 Introduction
Expected Learning Skills
8.2 Requirements
8.3 Gondwana Coal Deposits
8.4 Tertiary Coal Deposits
8.5 Lignite Deposits
8.6 Laboratory Exercises
8.7 References

8.1 INTRODUCTION

Coal is one of the principal fossil fuels and is a primary source of energy as well as power. The coal originated as a result of the long burial of vegetable matter, formed by the decay of plant material under a thick cover of sediments, which have undergone a variety of physical and chemical transformations. The important period of coal formation were during the Carboniferous to Permian. The other period of coal formation was during the Cretaceous to Upper Pliocene times. India has the fourth-largest coal reserves in the world. Most of these are in the states of Jharkhand, West Bengal, Odisha, Bihar, Chhattisgarh, Telangana and Madhya Pradesh. Dhanbad city of Jharkhand is the largest coal-producing city and is called the Coal Capital of India.

Based on the occurrence of coal deposits relative to geological age, coal deposits of India are classified into two groups: Gondwana Coals and Tertiary Coals. Lower Gondwana coals of India are of Permian age. Most of the Tertiary coals of India are of Cretaceous to Upper Pliocene times.

The major coalfields of the country are situated in Damodar, Mahanadi, Godavari and Son-Narmada valleys.

In the previous experiment, you have prepared maps showing the distribution of important atomic mineral deposits of India. In this experiment, you will prepare maps of India showing the geographical or spatial distribution of some of the important Gondwana and Tertiary coalfields and lignite deposits of India.

Expected Learning Skills

After completing this experiment, you would be able to:

- ❖ list spatial distribution of Gondwana coalfields and tertiary coalfields of India;
- ❖ list spatial distribution of lignite deposits of India; and
- ❖ plot spatial distribution Gondwana coalfields, tertiary coalfields and lignite deposit on the map of India.

8.2 REQUIREMENTS

To perform this experiment successfully you require the following:

- Pen, pencil, eraser, scale, sharpener and coloured pencils
- Laboratory file
- Blank maps of India of A4 size (with demarcated states boundaries)
- Atlas of India (it will help you to plot the localities of coal and lignite deposits in the blank map of India)

[Instructions: You are required to study Unit -12 Mineral Fuels of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling sessions.]

8.3 GONDWANA COAL DEPOSITS

Gondwana Coals are exclusively found in the Peninsular region of India. About 98 per cent of coal annually produced in India comes from formations of the Lower Gondwana sequence (200 million years old) the Permian age. The Lower Gondwana coals are mainly of bituminous type. The important Gondwana coalfields are given in Table 8.1 and are plotted in Fig. 8.1.

Table: 8.1: Spatial distribution of Gondwana coals of India.

States	District/Locality
Jharkhand	The Jharia coalfield of Dhanbad District is regarded as the most important coalfield of India. The Bokaro Coalfield of Bokaro District contains some of the thickest coal seams. The Rajmahal coalfield is another important coalfield situated along the western side of the Rajmahal Hills in the north to

	the Birbhum District of West Bengal in the south. Other important coalfields are Girdih (Karharbari) coalfield; Karanpura and Ramgarh coalfields of Hazaribagh district; Auranga coalfield; Hutar coalfield; Deltenganj coalfield of Palamu district and Devgarh coalfields of Dumka district.
Chhattisgarh	Korba coalfield is one of the important coalfields located in Korba district. Some other important coalfields of Chhattisgarh are Birampur coalfield; Hasdeo-Arand coalfield; Sendurgarh coalfield (Bilaspur and Korba districts); Mand-Raigarh coalfields (Raigarh-Jashpur districts); Chirmiri coalfield and Lakhanpur coalfield of Surguja district; Jhilmili coalfield of Shandol district and Koriya district; Johilla coalfield of Johilla valley; Sonhat coalfield and Tatapani-Ramkota coalfields of Surguja district.
West Bengal	Raniganj coalfield is one of the largest coalfields in the country. Most of the coalfields are in the Raniganj area in the Bardhhaman, Bankura and Purulia districts in West Bengal. They extend to adjoining areas of Jharkhand. Darjeeling and Jalpaiguri are the chief producing districts.
Madhya Pradesh	Singrauli coalfield is one of the most important coalfields of the Madhya Pradesh. This coalfield lies partly in Sidhi district of Madhya Pradesh and partly in the Sonbhadra district of Uttar Pradesh mostly in the basin of the Son River. Other coalfields are Pench-Kanhan-Tawa in Betul-Chhindwara and Hoshangabad districts; Mohpani coalfield, Johilla coalfield, Umaria and Korar Coalfields of Narsinghpur district; Sohagpur coalfield of Shandol district.
Odisha	Talcher coalfield is the most important coalfield of Odisha and is located in Angul District of Odisha. Other important coalfields are Rampur-Himgir coalfields of Sambalpur and Sundargarh districts; Ib Valley coalfield of Sambalpur and Jharsuguda district.
Maharashtra	Wardha Valley Coalfield is located in Chandrapur district and Kamthi-Saoner coalfield (Nagpur district) of Maharashtra
Andhra Pradesh	Most of the Godavari valley coal reserves are located in the districts of Adilabad, Karimnagar, Warangal, Khammam. The workable collieries are situated at Singareni and Kothagudam.

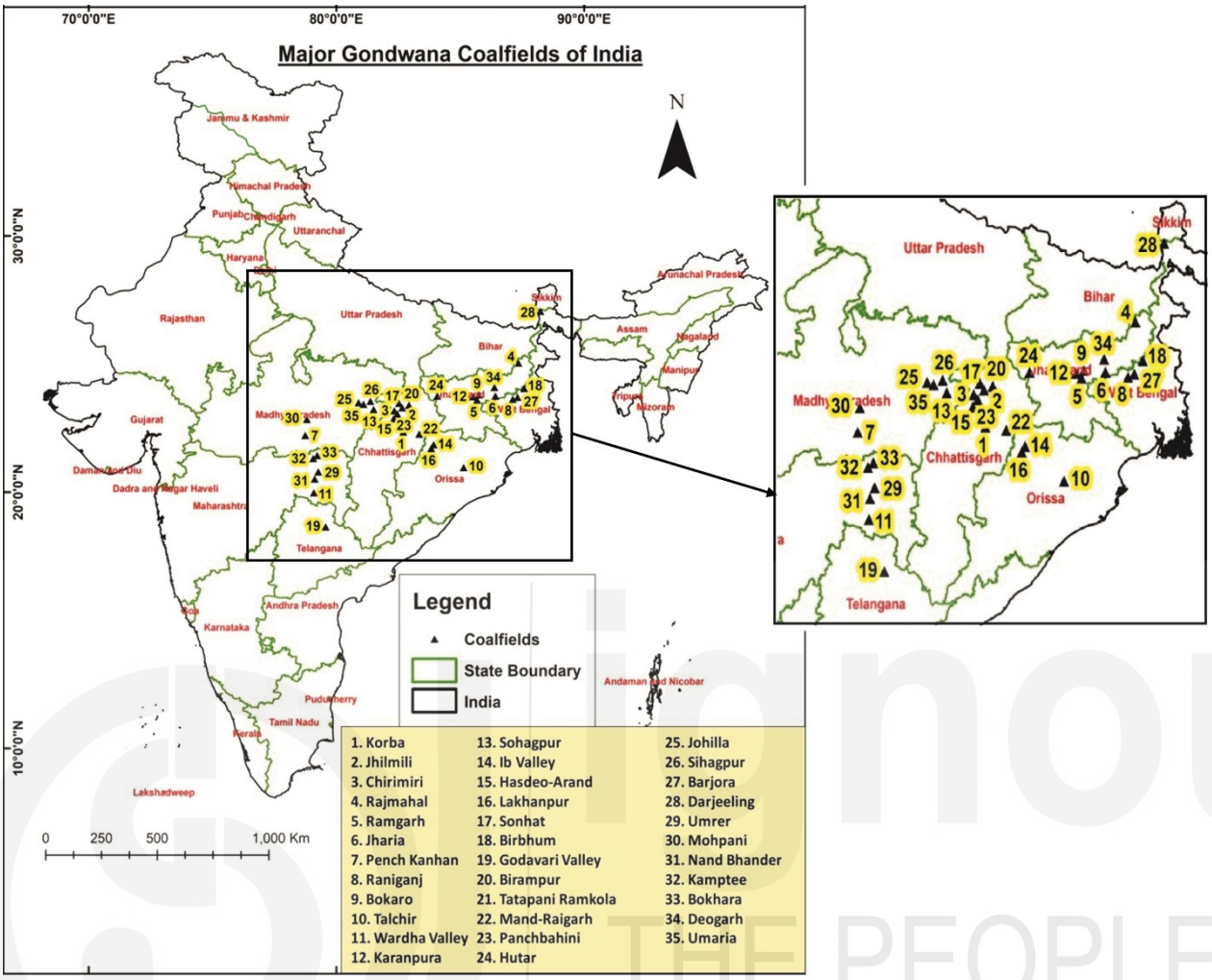


Fig. 8.1: Map showing the distribution of major Gondwana coalfields of India.
(Prepared by Rohit Kumar)

8.4 TERTIARY COAL DEPOSITS

Tertiary Coals are mainly confined to the extra-peninsular. Tertiary coals mostly occur in association with limestone and slates of either Eocene age or Oligocene-Miocene age. They are best developed in North-East region and a number of coal occurrences are reported. These coals are found in the states of Assam, Meghalaya, Nagaland, Arunachal Pradesh, Himachal Pradesh (Chamba district), West Bengal, Rajasthan, Kerala, Tamil Nadu, Puducherry and Jammu and Kashmir (Fig. 8.2). The important Tertiary coalfields are given in Table 8.2.

Table: 8.2: Spatial distribution of tertiary coals of India.

State	District/Locality
Assam	Tertiary coal of Assam are spread in Makum, Nazira, Mikir Hills, Dilli-Jeypore and Singrimari. Makum coalfield in Tinsukia district is the most developed field.

Meghalaya	In Meghalaya, coal deposits occupy in the areas of Khasi, Jaintia and Garo Hills. Some of the important coalfields of Khasi Hills are Langrin, Umrileng, Mawsynram, Cherrapunji-Mawkma-Laitryngew, Pynursla-Lyngkyrdem-Thanjinath, Maolong-Shella, Lumdidom, Mawbehlarkar. Coalfields of Jaintia Hills are Lakadong, Malwar-Musiang-Lamare, Sutnga, Loksi, Chyrmang, Bapung. East and West Darrangiri, Siju, Balphakram-Pendenguru, Karaibari and Rongrenggiri are some of the important coalfields in Garo Hills.
Arunachal Pradesh	Coal deposits occur at Namchik-Namphuk and Mio Bum of Arunachal Pradesh.
Nagaland	Coal deposits also occur at Borjan, Jhanzi-Disai, Tuensang and Tiru valley.
Jammu and Kashmir	Tertiary coal of Jammu and Kashmir are spread in Kalakot, Mohogala, Metka, Ladda, Saugar and surrounding regions in Jammu, and south of Pir panjal.

8.5 LIGNITE DEPOSITS

India has very rare occurrence of lignite deposits and occur in the Tertiary sediments in the southern and western parts of the peninsular shield. Tamil Nadu is the largest producer of lignite deposits. Important deposits reported so far are in Tamil Nadu, Puducherry, Kerala, West Bengal, Gujarat, Rajasthan, Jammu and Kashmir (Fig. 8.3). Of these, the Neyveli Lignite field in Cuddalore District of Tamil Nadu is the most important and are the largest deposit of lignite in southeast Asia. Neyveli Lignite field is spread over an area of > 480 sq. km. The important lignite deposits are given in Table 8.3.

Table: 8.3: Spatial distribution of lignite deposits of India.

States	Districts/Locality
Tamil Nadu	Lignite fields occur in Cuddalore. Ariyalur, Thanjavur, Thiruvarur, Nagapattinam, Ramnad, Sivaganga and Ramanthapuram districts.
West Bengal	Bagrakot and Tindharia in West Bengal are the notable lignite deposits. Other Lignite deposits are Rakshitpur, Mahalla and Dhobbanpur.
Gujarat	Panandhro Lignite Field (Kachchh), Jhagadia Lignite Field, are important lignite deposits of Gujarat. Other important lignite fields occur in Bharuch, Bhavnagar and Surat districts.
Rajasthan	Some important lignite fields of Rajasthan are Palana Lignite Field, Gurha Lignite Field, Barsinghsar Lignite Field,

	Khari Lignite Field (Bikaner). Other important lignite fields occur in Barmer, Jaisalmer, Nagaur, Pali and Jalore districts.
Kerala	In Kerala lignite/peaty lignite deposits occur in Varkala and Quilon. Important lignite fields are Madayi, Kadamkottumala, Kayyur and Nileswaram of Kannaur district.
Jammu and Kashmir	Lignite is found at Shaliganga and Chowkibal. Another important field is the Nichahom-Budhasung of Kupwara district.

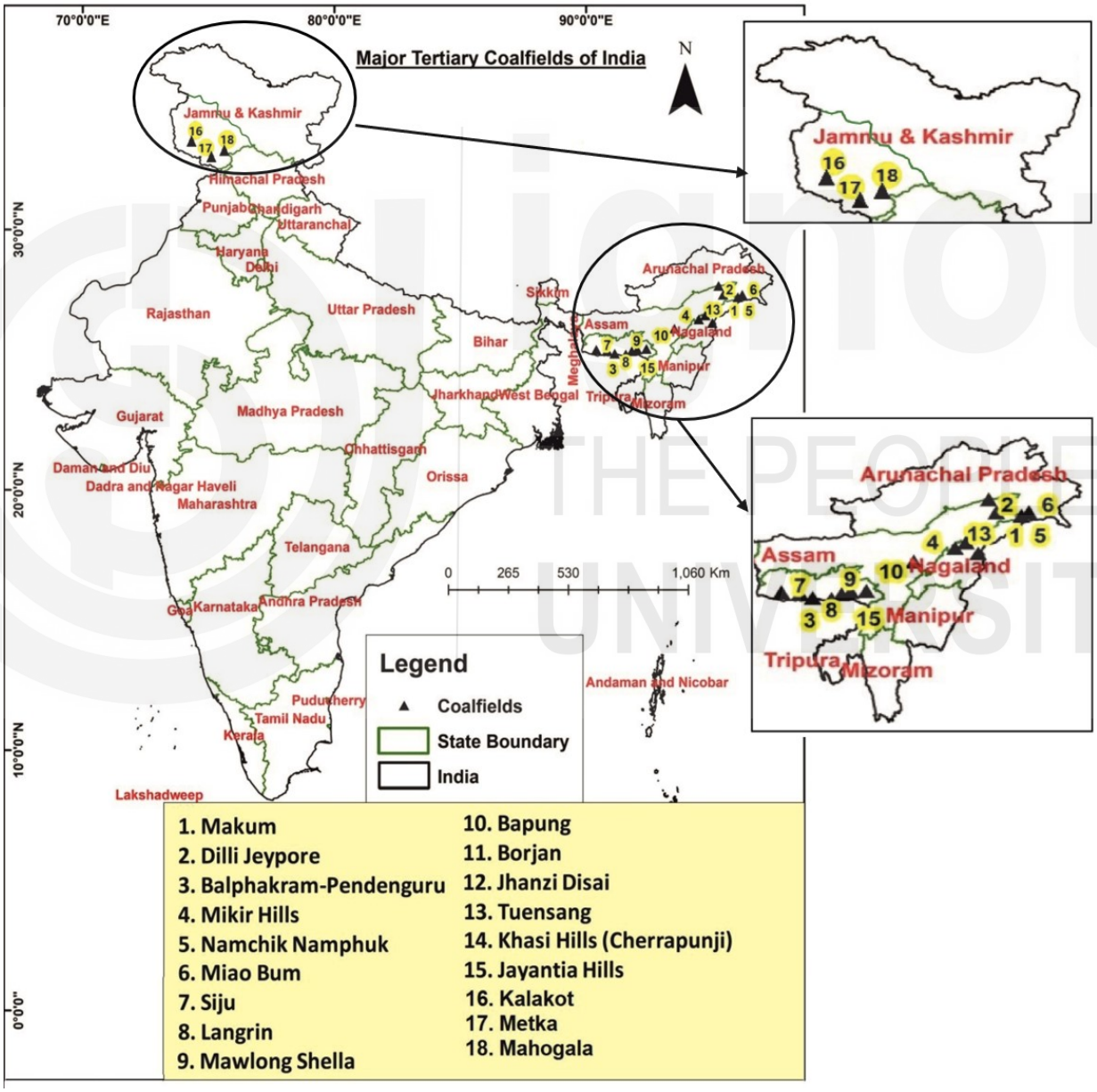


Fig. 8.2: Map showing distribution of major tertiary coalfields of India. (Prepared by Rohit Kumar)

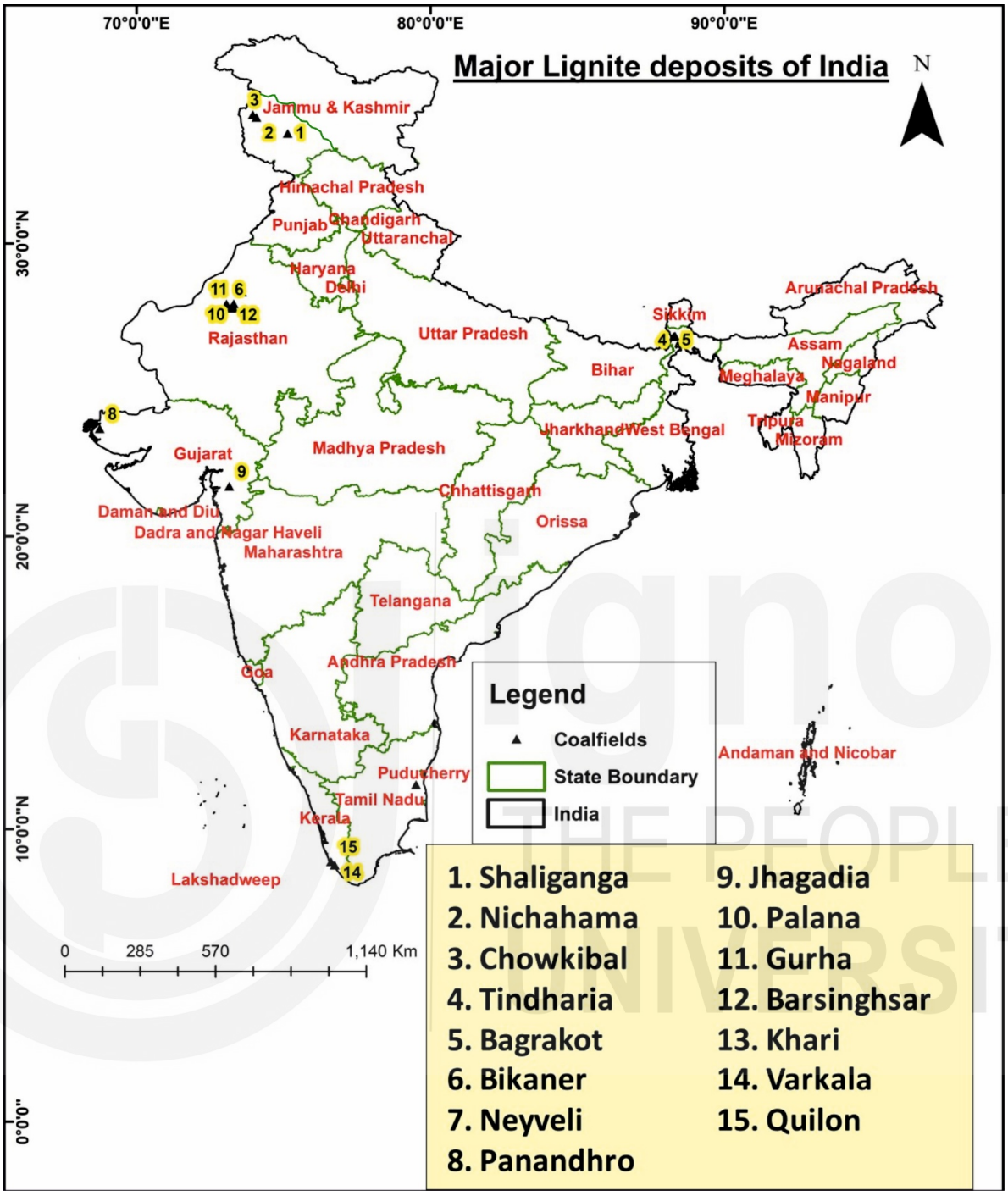


Fig.8.3: Map showing the distribution of major lignite deposits of India. (Prepared by Rohit Kumar)

8.5 LABORATORY EXERCISES

A blank map of India is given below (Fig. 8.4). You can make xerox copies of the India map and paste it on your laboratory file or draw a neat outline map of India showing the political boundaries of the states. You can use coloured pencils for marking the places. **Give answers to the following exercises in your laboratory file and submit it to your Academic Counsellor.**

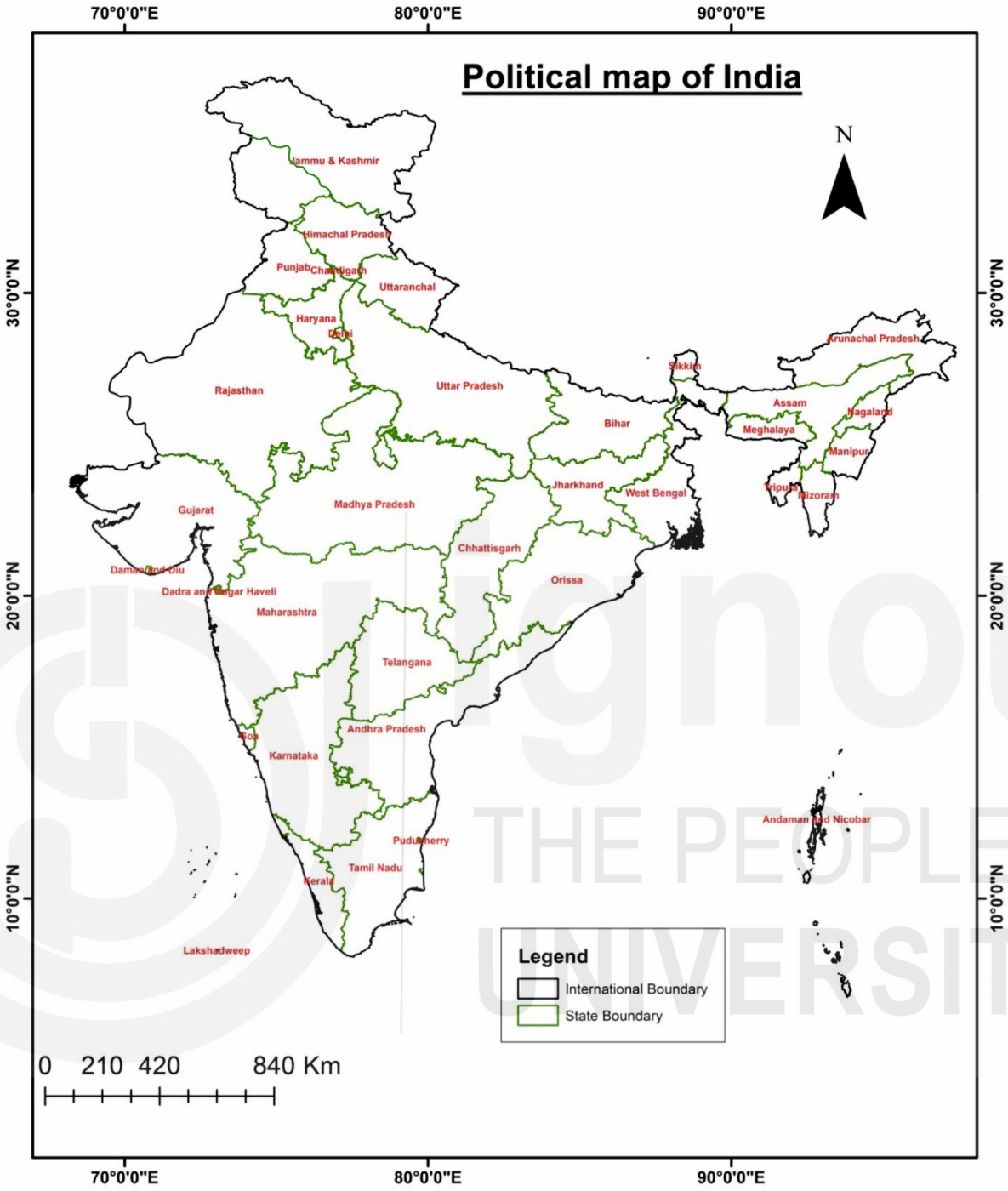


Fig. 8.4: Political map of India.

Exercise 1: Identify the Gondwana coalfields of India from Fig. 8.1 and prepare a list of the Gondwana coalfields.

Exercise 2: Identify the tertiary and lignite coalfields of India from Fig. 8.2 and Fig. 8.3 and prepare a list of the tertiary and lignite coalfields.

Exercise 3: Plot and label the Gondwana coalfields of India in the blank outline map of India.

Exercise 4: Plot and label the tertiary coalfields of India in the blank outline map of India.

Exercise 5: Plot and label the lignite deposits of India in the blank outline map of India.

8.6 REFERENCES

- Indian Minerals Yearbook 2013 (Part- III: Mineral Reviews) 52nd Edition Coal & Lignite (Final Release) Government of India Ministry of Mines Indian Bureau of Mines.
- National Mission on Himalayan Studies (NMHS) Progress Report (2016-18)
- Unit 12: Mineral Fuels of BGYET-141 course.
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EXPERIMENT 9

PREPARATION OF MAP SHOWING DISTRIBUTION OF HYDROCARBON BASINS OF INDIA

Outline of Experiment

9.1 Introduction

Expected Learning Skills

9.2 Requirements

9.3 Sedimentary Basins

9.4 Oilfields

9.5 Laboratory Exercises

9.6 References

9.1 INTRODUCTION

Petroleum, popularly known as liquid gold, also called rock oil and black gold, is the key fuel of modern times. Petroleum occurs widely in the Earth as gas, liquid, semisolid, or solid, or in more than one of these states at a single place. Hydrocarbon is a term often used interchangeably with petroleum for any of its forms. Petroleum is a complex mixture of hydrocarbons and some other compounds that occur in a liquid form, entrapped within the rocks of the surface of the earth.

In the previous experiment you have prepared maps of India showing geographical or spatial distribution of some of the important Gondwana and Tertiary coalfields and lignite deposits of India. In this experiment, you will prepare maps showing the spatial distribution of sedimentary basins of India. You will also prepare the spatial distribution of important oilfields of India.

Expected Learning Skills

After completing this experiment, you would be able to:

- ❖ list and plot spatial distribution of sedimentary basins of India; and
- ❖ list and plot spatial distribution of important oilfields of India.

9.2 REQUIREMENTS

To perform this experiment successfully you require the following:

- Pen, pencil, eraser, scale, sharpener and coloured pencils
- Laboratory file
- Blank maps of India of A4 size (with demarcated states boundaries)
- Atlas of India (it will help you to plot the sedimentary basins and oilfields of India in the blank map of India)

[Instructions: You are required to study Unit -12 Mineral Fuels of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with the Vol-2 of BGYET-141 course while attending the Practical Counselling sessions.]

9.3 SEDIMENTARY BASINS

Sedimentary basins occur in diverse geological settings and are usually associated with plate tectonic activity. Hydrocarbons commonly occur in sedimentary basins. In India, 26 sedimentary basins with an area of 3.36 million sq. km. have been found.. Out of which, 1.63 million sq. km. of the area is on-land, 0.41 million sq. km. of the area is shallow offshore up to 400m isobath and 1.32 million sq. km. area is deep-water beyond 400m isobaths. These 26 sedimentary basins have been divided into three categories (I, II and III) based on their degree of prospectivity as shown in Table 9.1 and are plotted in Fig.9.1.

Table 9.1: Major sedimentary basins in India. (Source: Directorate General of Hydrocarbons)

Category	Basin Name
Category I (Basins with 'Reserves' being produced and exploited)	1. Krishna-Godavari (KG) 2. Mumbai Offshore 3. Assam-Shelf 4. Rajasthan 5. Cauvery 6. Assam-Arakan Fold Belt 7. Cambay
Category II (Basins with 'Contingent	8. Saurashtra 9. Kutch 10. Vindhyan

Resources' to be developed and produced)	11. Mahanadi 12. Andaman	
Category III (Basins with only 'Prospective Resources' to be explored and discovered)	13. Kerala-Konkan (KK) 14. Bengal-Purnea 15. Ganga-Punjab 16. Pranhita-Godavari (PG) 17. Satpura- South Rewa – Damoda 18. Himalayan Foreland 19. Chhattishgarh	20. Narmada 21. Spiti-Zanskar 22. Deccan Syneclise 23. Cuddapah 24. Karewa 25. Bhima- Kaladgi 26. Bastar

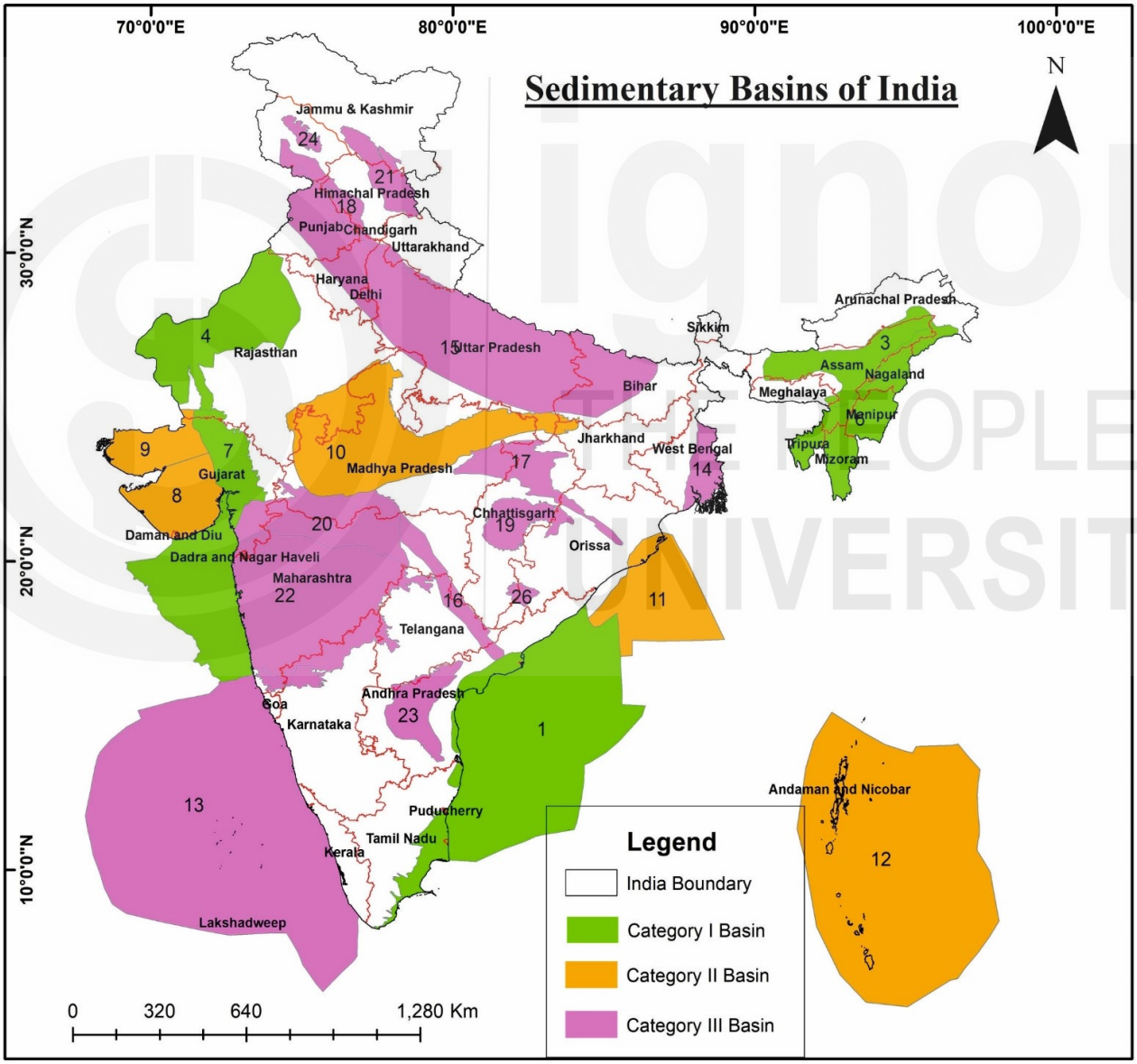


Fig. 9.1: Distribution of sedimentary basins of India. (Source: Modified from http://dghindia.gov.in/index.php/page?pageId=66)

9.4 OILFIELDS

You have already studied in Unit 12 of BGYET-141 that petroleum and natural gas originate from organic material buried in marine muds. It involves the reaction of carbides within the Earth to form acetylene and subsequently produces natural hydrocarbons. Organic material buried in marine sediments underwent chemical changes due to increased pressure and temperature generated by overlying sediments to produce natural hydrocarbon. Such hydrocarbons subsequently moved into porous sedimentary rocks known as **reservoir rocks** such as sandstone, coarse sands, porous limestones, conglomerates, dolomites and other argillaceous rocks.

Like many other countries, India is an oil deficient country and imports a huge amount of oil to meet its demand. Some of the important oil reserves are found in Assam, Gujarat, Maharashtra and Rajasthan. Some of the well-known oil fields of Western India are the Ankleshwar oilfield in Gujarat, Mumbai High (Arabian Sea offshore) in Maharashtra, the Cambay oilfield, the Kalol oilfield (Fig. 9.2 and 9.3). There are some good potential oilfields that are also found in Arunachal Pradesh, Tripura, Nagaland, Andhra Pradesh and West Bengal (Fig. 9.2 and 9.3).

Important oilfields of western India are the Cambay oil field, Ankleshwar oilfield, Kalol oilfield, Nawagam oilfield, the Bombay High oil and gas field. Coastal Oilfield are the oil-bearing marine sediments of the Cretaceous and Tertiary ages and are the source of oil found along the East Coast of the Peninsular India which includes Andhra Pradesh, Tamil Nadu and Orissa Coastal areas. The detailed distribution of important oilfields in India is given in Table 9.2.

Table: 9.2: Spatial distribution of important oilfields in India.

On-Shore Oil Fields of Northeast India	**Assam**: Digboi oilfield of Assam is the oldest oil field in India. It is located in the north-east of Tipam hills in Dibrugarh district of Upper Assam, The Naharkatiya field is located southwest of Digboi at the left bank of Burhi Dibing river. The Moran-Hugrijan field is located south-west of Naharkatiya. Other fields have been discovered at Rudrasagar, Sibsagar, Lakwa, Galeki, Badarpur, Barholla and Anguri.
	Arunachal Pradesh has oil reserves at Manabhum, Kharsang and Charali. Kumchai oil field and Ningru Oil & Gas Field in Districts Changlang and Namsai are the important oilfields
	In **Tripura**, oilfields have been discovered at Mamunbhanga,

	Baramura-Deotamura, Subhang, Manu, Ampi Bazar, Amarpur-Dambura areas.
	Nagaland has oil bearing rock strata in Champang and Tsori areas in the Wokha district. Borholla oilfield is on the border between Nagaland and Assam.
On-Shore Oil Fields of Western India	In **Gujarat** the main oil belt extends from Surat to Amreli. Kachchh, Mehsana, Vadodara, Surat, Bharuch, Ahmedabad, etc. are the main producing districts. Ankleshwar Oilfield is one of the important oilfield and is situated about 81 km. SSW of the Baroda town, South of the Narmada river. The oil producing sands are of the Eocene age. The oilfield is situated on an elongated doubly plunging anticline and dome. Lunej, Kalol, Nawgam, Kosamba, Kathana, Barkol, Indrora, Lahor, Mehsana, Dholka, Hirapur, Kadi, Wadu-Paliyad and Sanand are the important oil fields in this region. Sanand oil field.
	Rajasthan is one of the largest on shore oil producing state. The Mangala Area is a major oil field. Other important oilfields are Sarswati, Rajeshwari, and Aishwarya.
Off-Shore Oilfields of Western Coast	The **Cambay Oilfield** is situated in Gujarat and in the Cambay-Kalol area north of the Gulf of Cambay. The oil deposits found in the rocks of Oligocene age. The occurrence of oil is recorded in the off-shore region in the Arabian Sea. **Mumbai High** is located on the continental shelf off the coast of Maharashtra about 176 km north-west of Mumbai. The discovery of Mumbai High has revolutionised the oil production in India. Other important oilfields are Panna-Mukta, Ratna, Bassein, Aliabet Island in the Gulf of Khambhat, Hazira oil/gas field, Heera, Mid and South Tapti.
East Coast	The basin and delta regions of the Godavari, the Krishna and the Cauvery rivers hold great potential for oil and gas production. The Rawa field in Krishna- Godavari off-shore basin is one of the important oil-producing fields. The Narimanam and Kovilappal oilfields in the Cauvery on-shore basin are other important oilfields. Other on-shore hydrocarbon bearing basins are Rangapuram, Tatipaka, Pasarlapudi, Srikatapalli. Gopavaram, Mori, Kesavadasupalem, Adavipalem, Ponmanda, Mandapeta,

	Endamuru, and Bhimanapalli from East Godavari District, Andhra Pradesh. Ashoknagar Oilfield is an important oil field located at Ashoknagar in West Bengal.

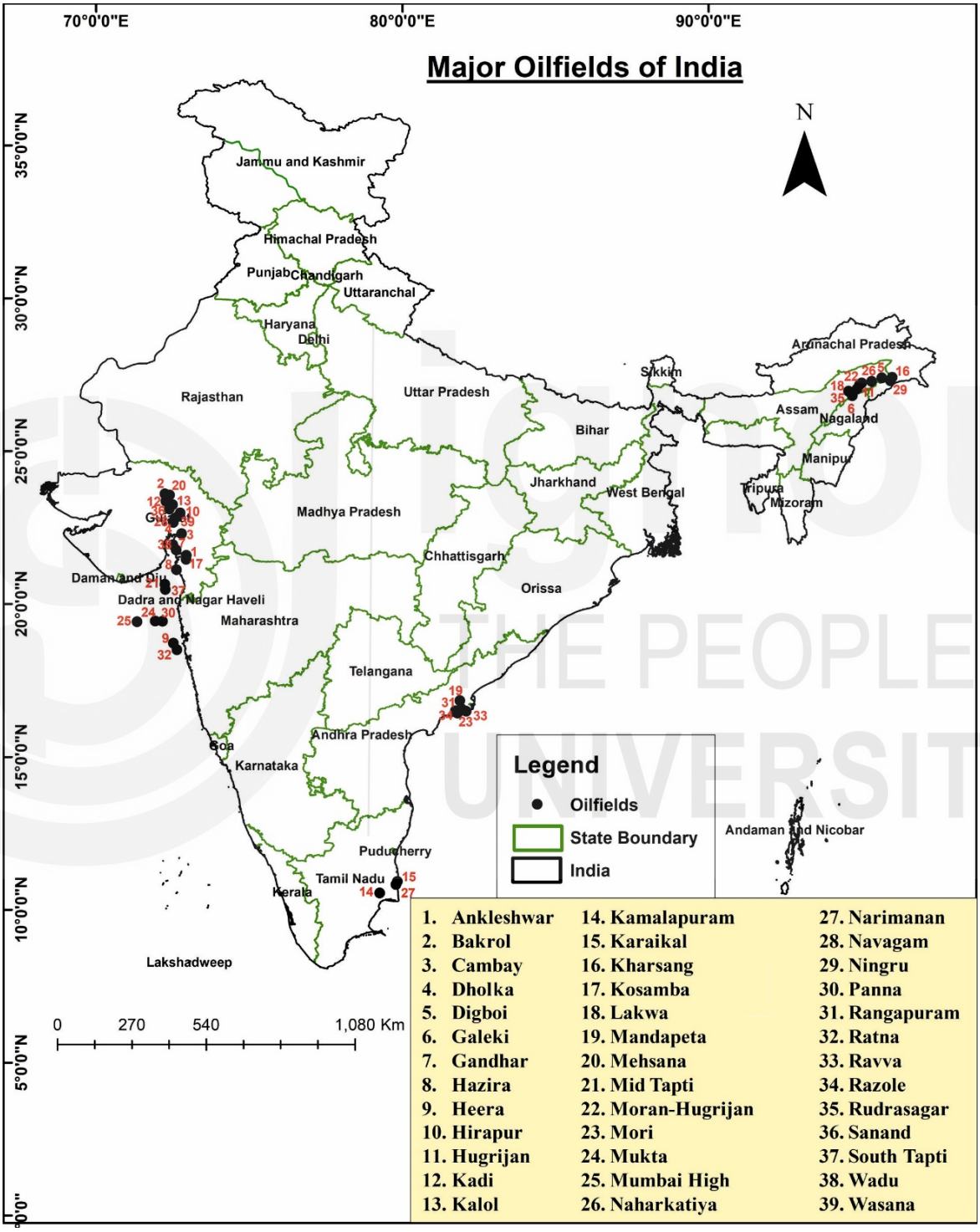


Fig. 9.2: Spatial distribution of major oilfields in India. (Prepared by Rohit Kumar)

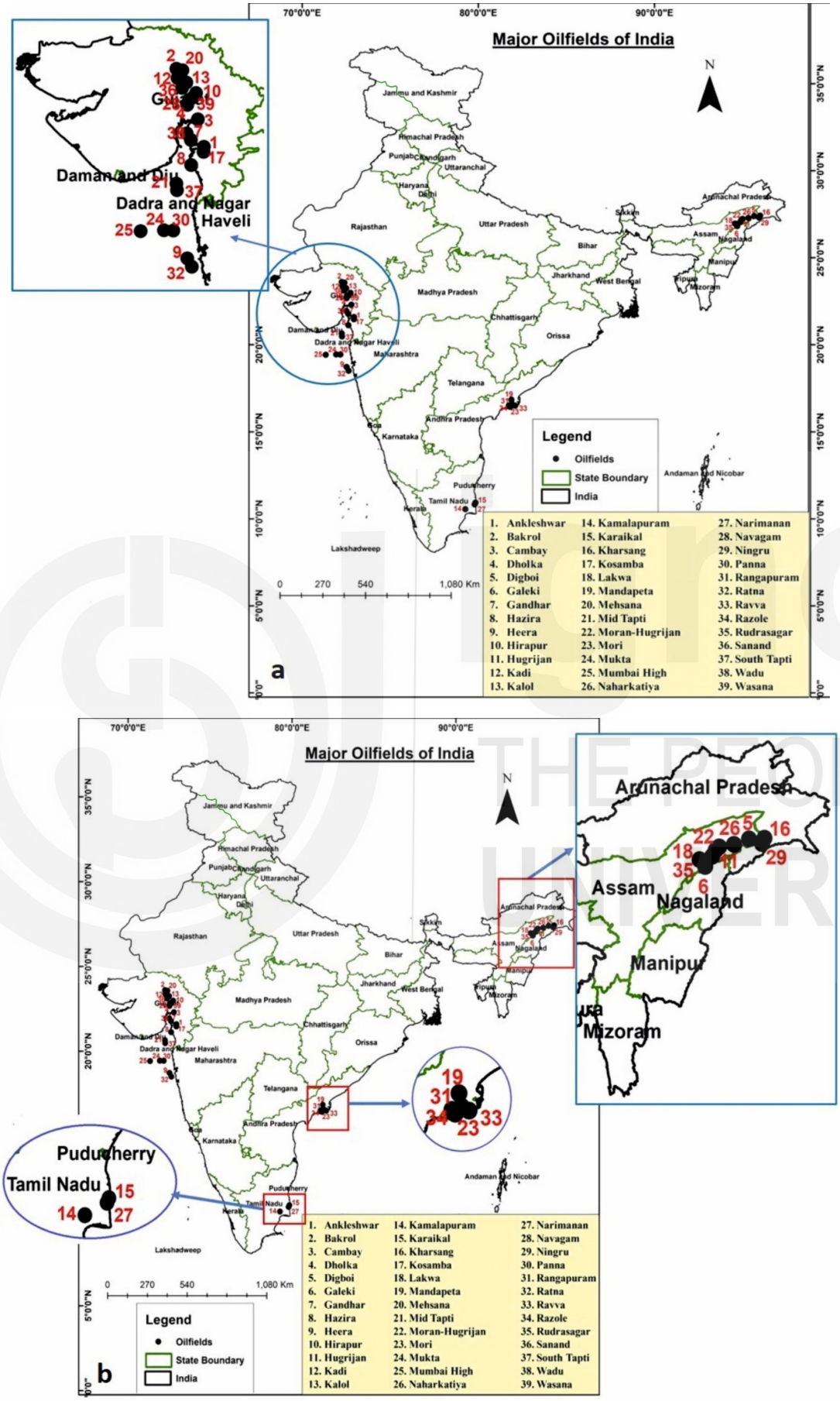


Fig. 9.3 a & b: Magnified view of distribution of major oilfields in India.

9.5 LABORATORY EXERCISES

A blank map of India is given below (Fig. 9.4). You can make xerox copies of the India map and paste it on your laboratory file or draw a neat outline map of India showing the political boundaries of the states. You can use coloured pencils for marking the places. **Give answers to the following exercises in your laboratory file and submit it to your Academic Counsellor.**

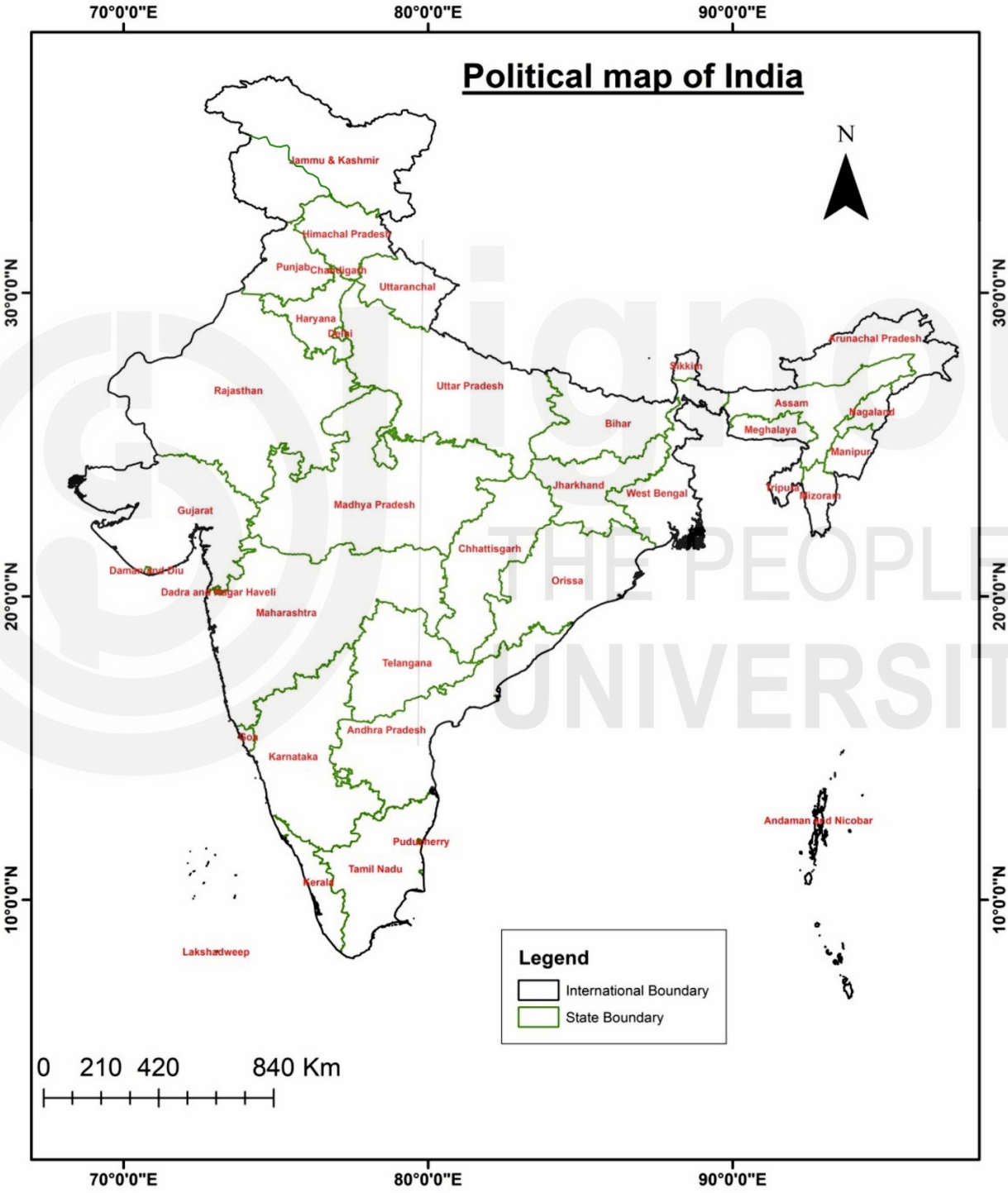


Fig. 9.4: Political map of India.

Exercise 1: List and mark the category I, category II and category III sedimentary basins of India in the blank outline map of India.

Exercise 2: Identify and label Gondwana Coalfields of India in the blank outline map of India.

Exercise 3: List and plot the on-shore oil fields of Northeast India in the blank outline map of India.

Exercise 4: List and plot the on-shore oil fields of Western India in the blank outline map of India.

Exercise 5: List and plot the off-shore oil fields of Western coast of India in the blank outline map of India.

Exercise 6: List and plot the East coast oil fields of India in the blank outline map of India.

Exercise 7: A blank map with sedimentary basins of India are shown in Fig. 9.5. Using three different colours mark the category I, category II and category III sedimentary basins of India.

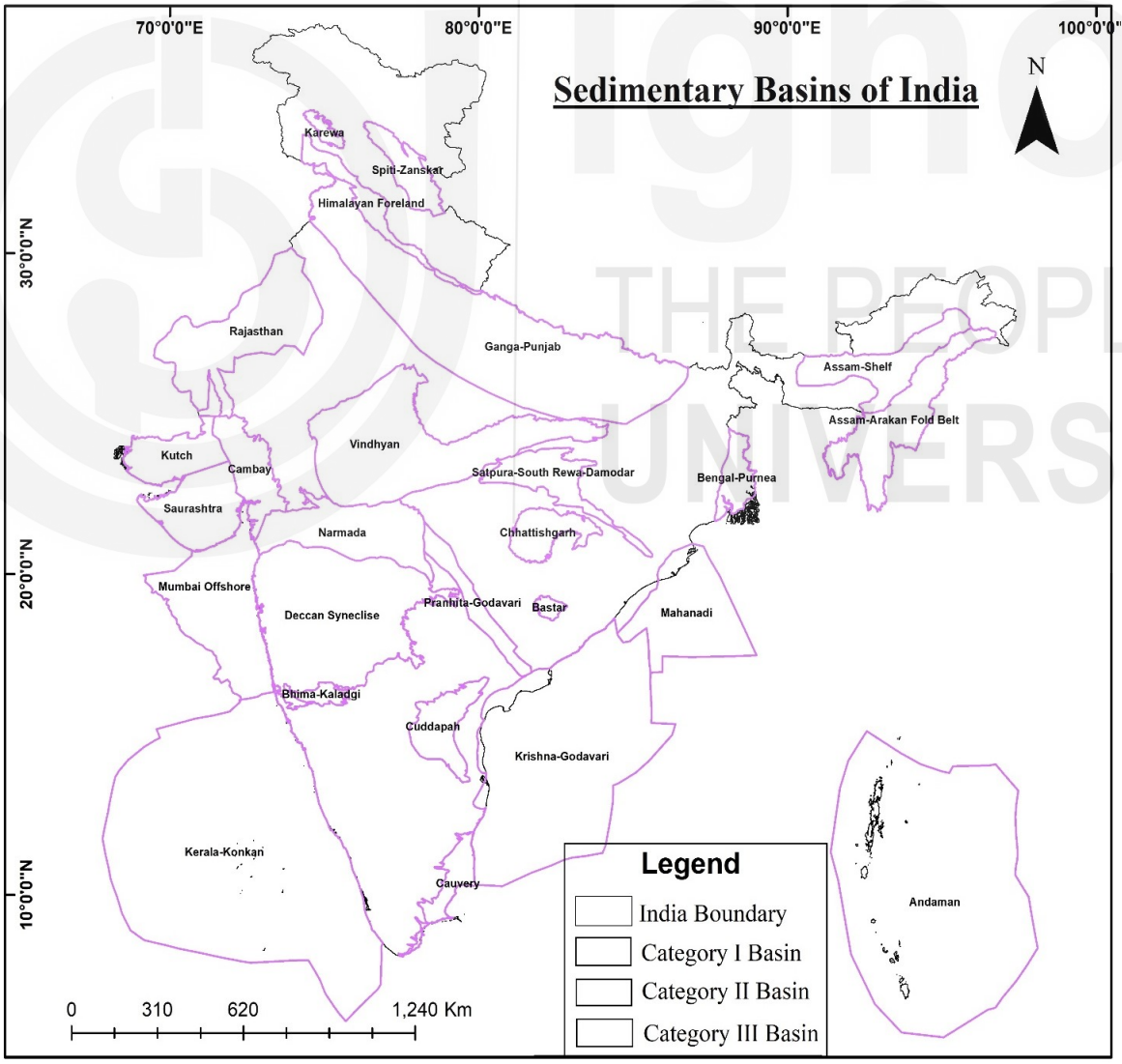


Fig. 9.5: Sedimentary basins of India.

9.6 REFERENCES

- Indian Minerals Yearbook 2013 (Part- III: Mineral Reviews) 52nd Edition Coal & Lignite (Final Release) Government of India Ministry of Mines Indian Bureau of Mines.
- National Mission on Himalayan Studies (NMHS) Progress Report (2016-18)
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- https://www.pmfias.com/coal-formation
- https://www.ndrdgh.gov.in/NDR/?page_id=603
- http://dghindia.gov.in/index.php/page?pageId=66

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EXPERIMENT 10

MICROSCOPIC STUDY OF COMMON SULPHIDE ORE MINERALS

Outline of Experiment

10.1 Introduction
Expected Learning Skills
10.2 Requirements
10.3 Basic Concepts
10.4 Optical Properties of Ores Under Plane Polarised Light Between Crossed Nicols
10.5 Pyrite
10.6 Chalcopyrite
10.7 Galena
10.8 Sphalerite
10.9 Laboratory Exercises
10.10 References
10.11 Learning Resources

10.1 INTRODUCTION

You have learnt to identify the ores of iron (Fe), manganese (Mn), copper (Cu), lead (Pb), zinc (Zn) and chromium (Cr) on the basis of physical properties in Experiment 1 Megascopic study of metallic minerals, of this course. Let us now in this experiment learn to identify common sulphide ore minerals such as pyrite (FeS_2), chalcopyrite ($CuFeS_2$), galena (PbS) and sphalerite (ZnS). While in the next Experiment 11, we will learn to identify common oxide ore minerals such as hematite (Fe_2O_3), magnetite (Fe_3O_4), chromite ($FeO.Cr_2O_3$), pyrolusite (MnO_2) psilomelane ($BaMn_3(OH)_6Mn_8O_{18}$). You have read in Unit 1 of this course that most of the ore minerals are opaque. They appear dark under the plane polarised light in a transmitted light microscope. Therefore, their optical characters are studied in reflected light with the help of an ore microscope.

You have also learnt about the difference between ore microscope and polarising microscope, steps for preparation of polished section, major components of ore microscope and their adjustments in BGYET-141 course. Let us recall that you had learnt to identify the optical properties of rock-forming minerals (non-opaque) with the help of polarising/petrological microscope in BGYCL-134 course. Now, in this experiment you will learn to identify the optical properties of ore minerals from the photographs of polished sections (given in laboratory manual) as observed under the ore microscope in reflected light.

Expected Learning Skills

After performing this experiment, you should be able to:

- ❖ learn about the common optical properties studied under the reflected light;
- ❖ identify the optical characters of common sulphide ores of iron and copper such as pyrite and chalcopyrite; and
- ❖ recognise the optical characters of common sulphide ores of lead and zinc such as galena and sphalerite.

10.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Photographs of polished sections of pyrite and chalcopyrite, galena and sphalerite
- Laboratory file, pen/ pencil, compass, colour pencil and eraser

Note:

- **You are advised to carefully study the photographs of polished section provided to you in the laboratory manual with the help of optical characters listed in the tables.**

***Instructions*: You are required to study Units 1, 9 and 10 of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with Block 3 in Volume 2 of BGYET-141 course while attending the Practical Counselling sessions.**

How to write Experiments 10 and 11 performed in your laboratory file?

You are instructed to follow the following steps:

1. Draw a circle using a drawing compass in your laboratory file to describe the optical characteristics of the ore minerals as visible in the polished section (given in photographs) that you would observe under the ore microscope.
2. The basic concepts of ore microscopy and physical properties of ore minerals which you have studied in Units 1, 9 and 10 of BGYET-141 course and also identified in Experiments 1 and 2 of BGYEL-142 course will help you in performing this experiment.

3. Make use of the colour pencils to represent colour(s) of the ore minerals as seen in the polished section. Describe the optical characters as listed in Table 10.1.

Table 10.1: Optical properties of ……			
Under Plane Polarised Light			
1.	**Colour**	:	
2.	**Cleavage**	:	
3.	**Bireflectance**	:	
4.	**Reflectivity**	:	
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	
6.	**Polarization Colours**	:	
7.	**Internal Reflectance**	:	
8.	**Associated Minerals**	:	
9.	**Name**	:	
10.	**Chemical Composition**		
11.	**Distinguishing Characters**	:	

10.3 BASIC CONCEPTS

You have to observe certain optical characters of the ore minerals are dependent upon reflected light in Experiments 10 and 11 of BGYEL-142 course. The important optical properties used in the study ore minerals include:

a) Colour
b) Cleavage
c) Bireflectance
d) Reflectivity
e) Anisotropy
f) Polarisation Colours
g) Internal Reflections

The former three properties such as colour, bireflectance and reflectivity, are observed under plane polarised light, i.e. without crossed nicols whereas the study of later three properties such as anisotropy, polarization colours and internal reflections require crossed nicols condition. Thus you will have to determine and document your observations regarding optical properties of ore minerals in your practical file into two categories:

- **Properties observed under plane polarised light** (without analyser): These include colour, cleavage, bireflectance and reflectivity.
- **Properties observed between crossed nicols**: These include isotropism vs. anisotropism, polarisation colours and internal reflections.

10.4 OPTICAL PROPERTIES OF ORES

The optical properties of ores are observed both under plane polarised light and between crossed nicols.

10.4.1 Under Plane Polarised Light

Properties observed under plane polarised light, i.e. without crossed nicols (analyser) include colour, reflectivity and bireflectance. You have read about colour in Unit 9 and 10 of BGYCT-133 course. You have also learnt to identify colour under plane polarised light in Experiments 7 and 8 of BGYCL-134 course. Similarly, while studying the optical properties of ore minerals colour is also observed.

a) **Colour**: Colour is a very important and useful property, nevertheless at the same time, it is very difficult for beginners to identify. However, gradual acquaintance with the colours of various minerals in association with other minerals provides a good experience. Many ore minerals range in colour from pure white to grey to yellow with various intermediate spectral tints. For understanding the helpfulness of colour, one should have considerable experience because eyes evaluate different colours more in contrast and comparison than in absolute values. The conditions required to observe colour of the ore minerals are: a) Colour of surrounding minerals, b) Type of illumination, c) Tarnishing and incorrect polishing, d) Index of refraction of the immersion medium, e) Two diaphragms should be open wide, and f) Use of low power objectives.

   The colour of a mineral is a function of the refractive index of the immersion medium. Therefore, the colour of the mineral in oil differs from their colour in the air. For example, covellite shows deep blue colour in the air, red violet colour in oil and blue-violet colour in water. The colour and brightness are the functions of transparency. Most of the transparent minerals appear dark in polished sections because they reflect little light, while the opaque minerals appear brighter as they reflect a greater percentage of light from the surface. The coated glass plate is preferred as a reflector. These conditions provide fairly good light of wider intensity. The colour difference varies from slight in certain minerals to striking in other minerals. Table 10.2 gives the list of diagnostic colour of minerals and their examples.

Table 10.2 : Diagnostic colour of minerals and their examples

Colour	Minerals
Cream colour (pinkish tint)	Pyrrhotite
White	Galena, Stibnite
White with blue tint	Chalcocite
Greyish white	Graphite, Wolframite
Dull to bright grey	Goethite
Grey	Sphalerite, Tetrahedrite
Brownish grey	Cassiterite

Pale brown	Magnetite
Bluish grey to greyish white	Psilomelane
Greyish yellow	Chromite
Pale yellow	Pyrite
Deep yellow	Chalcopyrite
Pinkish white	Pyrrhotite
Pale pink	Ilmenite

b) **Cleavage and Parting**: Though cleavage or parting is visible in the form of one or more sets of parallel, distinct or indistinct cracks. However, in polished surfaces the cleavages of minerals are not as well developed as in thin sections. Minerals may exhibit one to three sets of cleavages depending upon the number of sets present and the orientation of the polished surface with respect to these. The presence of cleavages may give rise to triangular pits usually arranged in rows parallel to one set. Such pits are characteristic of galena, and may also be present in magnetite, pentlandite, etc.

c) **Bireflectance**: You have read in Unit 1 of BGYET-141 course that bireflectance is an optical property similar to pleochroism where the mineral appears to change in intensity in different orientations when illuminated by plane polarized light on a rotation of the stage. The polarizers are not crossed to observe bireflectance. Minerals show distinct changes in colour or brightness when the stage is rotated. All sections of the cubic/isometric minerals and basal sections of the hexagonal and tetragonal crystals do not exhibit this property. This phenomenon of change in colour as seen under the ore microscope is termed **bireflectance**. This effect in ore microscopy is due to different causes such as the difference in two reflectivity values, i.e., (n_1 and n_2). Bireflectance varies from very weak, such as in sphalerite to very strong like in psilomelane. When you observe the bireflectance of a mineral, the number of grains of various orientations are required to be seen because bireflectance is the function of the reflective index of the immersion medium and crystallographic orientation. While observing the property of bireflectance it is usual to note the intensity with which these properties are exhibited. Intensity may vary from very weak, weak, moderate, strong, very strong. You can find out the difference in the intensity of bireflectance by closely observing adjacent grains. The following are some examples of bireflectance exhibited by ore minerals:

- **Weak** – chalcopyrite, sphalerite, ilmenite, arsenopyrite.
- **Moderate** - hematite, marcasite, pyrrhotite, chalcocite.
- **Strong** - covellite, molybdenite, psilomelane, stibnite.

d) **Reflectivity**: Reflectivity is a very important property and is defined as the ratio of the intensity of light reflected by the polished surface to the intensity of light incident upon it. It is expressed in percentage and is called reflectivity (R) and is expressed in per cent (R or R%). Reflectance of minerals varies as a function of the following:

- Crystallographic orientation of the polished surface relative to the vibration directions of linearly polarized incident light.
- Wavelength of light.
- Angle of incidence.
- Degree of polish.

Table 10.3: Seven reflectivity group of minerals and their ranges

S. N.	Reflectivity (in ranges)	Groups
1.	1-10	Very low reflectivity group of minerals
2.	10-20	Low reflectivity group of minerals
3.	20-30	Medium reflectivity group of minerals
4.	30-40	Medium to high reflectivity group of minerals
5.	40-50	High reflectivity groups of minerals
6.	50-70	Very high reflectivity group of minerals
7.	70-95	Very very high reflectivity group of minerals

Quantitative reflectance measurements are done with photometer, but you can make rough visual estimates and minerals in a section may be arranged in an order of increasing or decreasing reflectance, e.g. quartz (5%), magnetite (20%), galena (43%), pyrite (55%). Reflectance have been divided into seven groups representing various reflectivity ranges (Bowie, Simpson and Atkin,1975) as shown in Table 10.3.

10.4.2 Between Crossed Nicols

Properties observed under crossed nicols condition include anisotropism/ isotropism, polarization colours and internal reflection. You have read about anisotropism/isotropism and polarization colours in Unit 9 and 10 of BGYCT-133 course. You have also learnt to identify these two optical properties observed between crossed nicols in Experiments 7 and 8 of BGYCL-134 course. Similarly, while studying the optical properties of ore minerals they are also observed. Let us discuss them one by one:

a) **Isotropism/Anisotropism**: Anisotropism effects are observed in the mineral on rotating the stage between crossed nicols. When you rotate the ore minerals belonging to isometric/cubic systems through 360^o between crossed nicols you will observe either complete darkness or faint illumination with no change in intensity or colour of illumination. Such minerals are termed **isotropic minerals**. Whereas minerals crystallizing in other crystal systems (apart from cubic/ isometric) will show a change in the intensity of illumination or colour of illumination in white light. Such minerals are termed **anisotropic minerals**. However, the basal sections of hexagonal and tetragonal crystals sections are anisotropic. With the change in the intensity of illumination on the rotation of the stage by 360^o, you will find four positions of maximum illumination. These four positions alternate the four positions of

maximum darkness 90° apart. Isotropic ore minerals include pyrite (anomalous anisotropism), sphalerite, covellite, chromite, chalcocite and magnetite. Anisotropic ore minerals include stibnite, molybdenite, cassiterite, graphite, goethite and manganese group of minerals such as psilomelane, manganite, pyrolusite, etc.

b) **Polarization Colours**: The change in colour of a mineral during rotation between crossed nicols produces a beautiful effect know as polarization colours. Certain minerals have characteristic colours which are extremely useful in identification. The change in the colour of the illumination (when they are very distinct) is called polarization colours. Although, it is very difficult for beginners, with gradual experience, it is possible to detect these colours. In certain cases, such as molybdenite, pyrrhotite and covellite, changes in the colour is observed. In some cases, the cleavages seem to be more common than crystal outlines. If the mineral becomes dark when the cleavage becomes parallel to the vibration plane of analyser or polariser, then the minerals display parallel extinction.

c) **Internal Reflection**: The occurrence and colours of internal reflections are quite diagnostic. There are many ore minerals which are sufficiently transparent (sphalerite, cassiterite, rutile and others) such that the reflected light incident upon them penetrates deeply. When you observe the translucent minerals under reflected light, it allows light to penetrate beneath the surface and gets reflected back to the observer from cracks, crystal boundaries, cleavages and other flaws present within the crystal. This results in either diffused illumination coming from within the crystal or one or more glimpses of light like red, green, blue, etc. This is called internal reflection or reflection coming from within the minerals. They are very useful because only a few minerals exhibit these properties. Sometimes, the variation in the chemical composition of minerals is responsible for internal reflection. For example, the mineral sphalerite with low iron content shows abundant internal reflection and sphalerite rich in iron do not show internal reflection. Although internal reflections are visible in plane polarised light however it is best observed between crossed nicols and intense illumination using oil immersion and high power magnification. In order to observe this phenomenon, it is necessary to make an examination on number of grains. The following are some examples (Table 10.4):

Table 10.4: Examples of internal reflection

Sphalerite	Yellow to brown (sometimes red to green)
Azurite	Blue
Malachite	Green
Chromite	Very deep brown
Wolframite	Deep brown
Cassiterite	Yellow brown to yellow
Hematite	Blood red

d) **Associated Minerals**: You have to write the name of ore minerals commonly associated with ore being identified. For example, pyrite is commonly associated with chalcopyrite or sphalerite is commonly associated with galena.

e) **Name and Chemical Composition**: In this, you have to write the name of the ore mineral you have identified and its chemical composition.

f) **Distinguishing Characters**: This includes typical or diagnostic characters or ore you have identified. For example, colour, cleavage, bireflectance, etc.

10.5 PYRITE

Let us recall the megascopic characters/physical properties of pyrite that you have studied in Unit 9: Ferrous Ores of BGYET-141 course.

Pyrite has a high specific gravity (4.9 to 5.1). In hand specimen, it shows pale yellow to brass-yellow colour with greenish-black to brownish-black streak. It has a metallic lustre. Mostly pyrite occurs in crystalline form with hardness 6.0-6.5, conchoidal to uneven fracture and cleavage is absent. It crystallises in the cubic system.

You are advised to identify pyrite in the photographs of the polished section provided to you in this laboratory manual with the help of optical characters given in Table 10.5 and Figure 10.1a and b. After studying and identifying the optical characters of pyrite draw the sketch of the optical characters as shown in Figure 10.2 and write the optical properties as mentioned in Table 5, in your laboratory practical file.

In the polished section pyrite appears massive, fine-grained and sometimes subhedral forms are also seen. Zoning, cleavage and twinning are not visible. Gangue minerals such as chalcopyrite fill the veins.

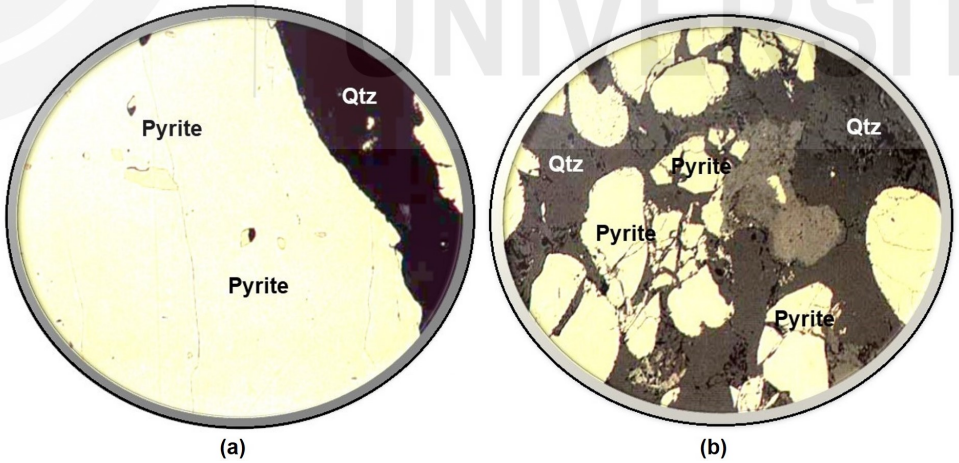


Fig. 10.1: Pyrite: a) Polished section; and b) Rounded pyrite grains (light yellowish white) are heavily fractured (centre) and contain small amount of chalcopyrite and quartz (Qtz) as seen in reflected light. (Source: http://www.atlas-of-ore-minerals.com/plate46c.htm)

Table 10.5: Optical properties of pyrite			
Under Plane Polarised Light			
1.	**Colour**	:	Pale yellow
2.	**Cleavage**	:	None
3.	**Bireflectance**	:	Absent
4.	**Reflectivity**	:	High
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Weakly anisotropic;
6.	**Polarization colours**	:	Nil
7.	**Internal reflectance**	:	Nil
8.	**Associated minerals**	:	Chalcopyrite, sphalerite, galena, arsenopyrite and pyrrhotite
9.	**Name**	:	Pyrite
10.	**Chemical Composition**	:	(FeS_2)
11.	**Distinguishing Characters**	:	Colour-yellowish white, high reflectance.

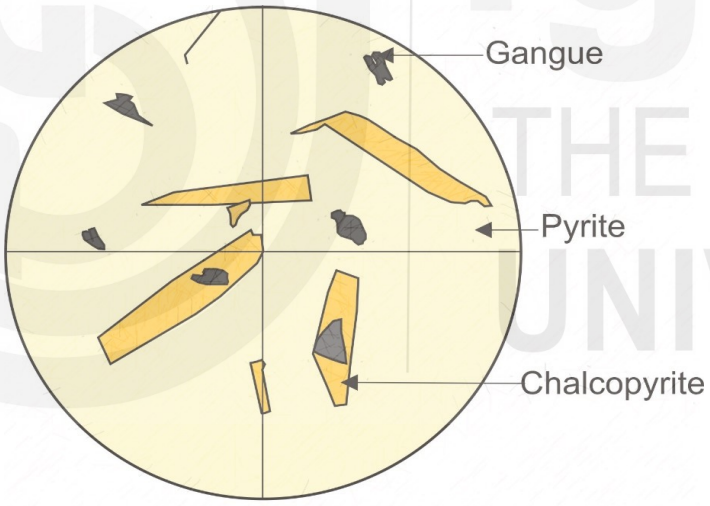


Fig. 10.2: Sketch of pyrite showing optical characters.

10.5 CHALCOPYRITE

Let us recall the megascopic characters/physical properties of chalcopyrite that you have studied in Experiment 1 of this course.

Chalcopyrite has a high specific gravity (4.1 to 4.3). In the hand specimen it shows brassy yellow colour with a characteristic greenish black streak. It has a metallic lustre. Mostly chalcopyrite occurs as massive compact, sometimes botryoidal forms with hardness 3.5-4, fracture and cleavage are uneven. It crystallizes in the tetragonal system.

You are advised to identify chalcopyrite in the photographs of the polished section provided to you in this laboratory manual with the help of optical

characters given in Table 10.6 and Figure 10.3a and b. After studying and identifying the optical characters of chalcopyrite draw the sketch of the optical characters as shown in Figure 10.4 and write the optical properties as mentioned in Table 10.6, in your laboratory practical file.

In the polished sections, chalcopyrite shows fine-grained and massive crystal forms and habits. Zoning and twinning are not present, cleavage is indistinct. Sphalerite may fill the spaces formed by fracture as gangue.

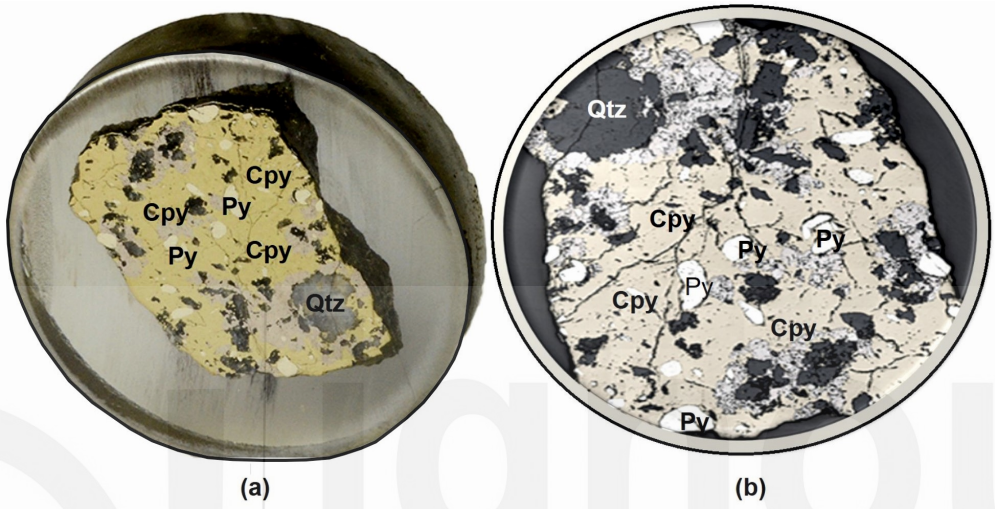


Fig. 10.3: Chalcopyrite: a) Polished section; b) In reflected light chalcopyrite shows golden yellow colour with dark grey quartz (Qtz). Pale yellow inclusions in the chalcopyrite are pyrite (Py). (Source: https://www.virtualmicroscope.org/content/chalcopyrite-0)

Table 10.6: Optical properties of chalcopyrite			
Under Plane Polarised Light			
1.	**Colour**	:	Yellow to brassy yellow
2.	**Cleavage**	:	Poor
3.	**Bireflectance**	:	Weak
4.	**Reflectivity**	:	High
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Weak to distinct
6.	**Polarization colours**	:	Could not be observed
7.	**Internal reflectance**	:	Nil
8.	**Associated minerals**	:	Sphalerite, pyrite, bornite, magnetite, pyrrhotite
9.	**Name**	:	**CHALCOPYRITE**
10.	**Chemical Composition**	:	($CuFeS_2$)
11.	**Distinguishing characters**	:	Color-bright yellow, commonly fractured

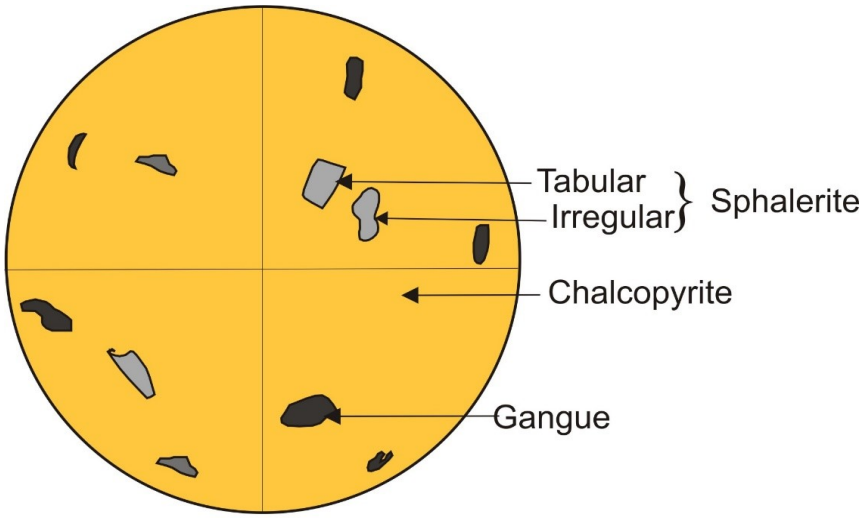


Fig. 10.4: Sketch of chalcopyrite showing optical properties. Sphalerite is present as gangue mineral.

10.6 GALENA

Let us recall the megascopic characters/physical properties of galena that you have studied in Unit 10: Non-Ferrous Ores of BGYET-141 course.

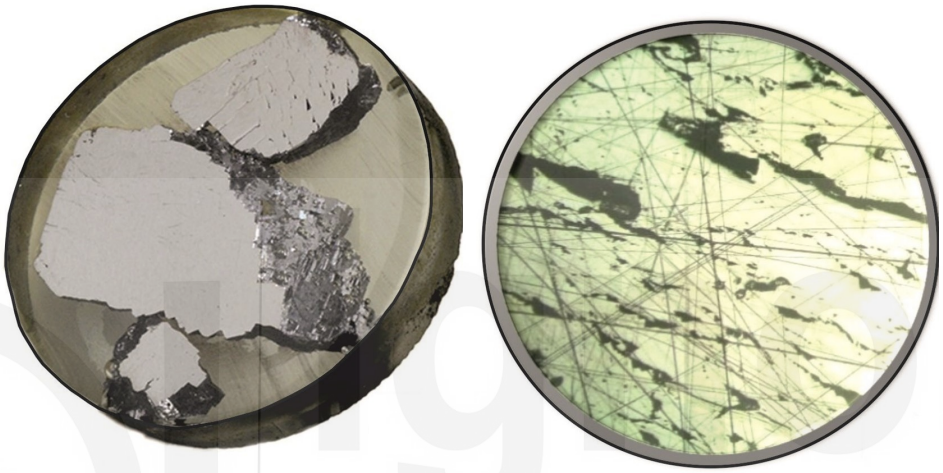
Galena has high specific gravity (7.4 to 7.6). In hand specimen it shows dull lead grey colour with characteristic lead grey to black streak. It has metallic lustre. Mostly galena occurs as cubes and octahedra, blocky crystals with hardness 2.5, subconchoidal fracture and cleavage perfect, cubic, three directions at right angles. It crystallizes in cubic/isometric system.

You are advised to identify galena in the photographs of the polished section provided to you in this laboratory manual with the help of optical characters given in the Table 10.7 and Figure 10.5a and b. After studying and identifying the optical characters of galena draw the sketch of the optical characters as shown in Figure 10.6 and write the optical properties as mentioned in Table 10.7, in your laboratory practical file.

In polished sections large and coarse-grained crystal of galena is seen in reflected light. Cleavage is perfect and triangular pits are arranged in parallel rows. Zoning, intergrowth and twinning are not visible.

Table 10.7: Optical properties of galena			
Under Plane Polarised Light			
1.	**Colour**	:	Creamy, white
2.	**Cleavage**	:	Perfect, triangular pits seen
3.	**Bireflectance**	:	Nil
4.	**Reflectivity**	:	High
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Isotropic
6.	**Polarization colours**	:	Nil

7.	**Internal reflectance**	:	Nil
8.	**Associated minerals**	:	Sphalerite, marcasite, pyrite, chalcopyrite, tetrahedrite
9.	**Name**	:	GALENA
10.	**Chemical composition**		(PbS)
11.	**Distinguishing characters**	:	White color, perfect cubic cleavage expressed by triangular pits, softness, and moderate reflectance.



(a) (b)

Fig. 10.5: Galena: a) Silvery grey of galena in polished section, and b) In reflected light galena shows characteristic triangular polishing pits where the material has fallen out during sample preparation. Note the abundance of scratches - also characteristic of this relatively soft mineral. [Source for a) https://www.virtualmicroscope.org/sites/default/files/html5Assets/galena_ref/index2.html?specimen=/node/407]

[Source for b) https://upload.wikimedia.org/wikipedia/commons/b/b0/Galena_%28Microscopic_image%29.jpg]

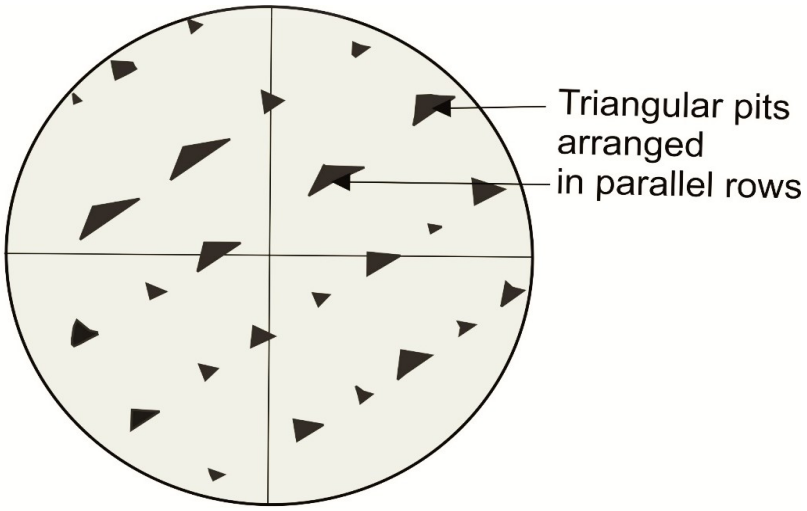


Fig. 10.6: Sketch of galena showing optical properties.

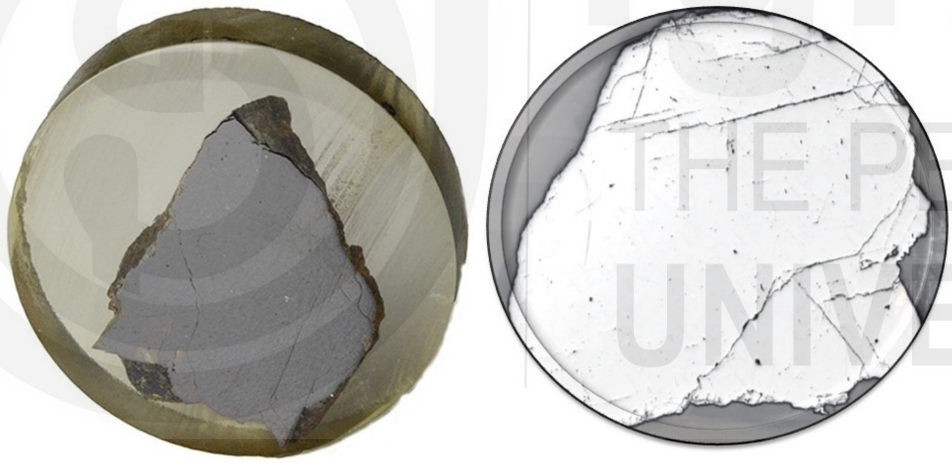
10.7 SPHALERITE

Let us recall the megascopic characters/physical properties of sphalerite that you have studied in Unit 10: Non-Ferrous Ores of BGYET-141 course.

Sphalerite has a high specific gravity (3.9-4.2). In hand specimen, it shows light grey to yellowish-grey, rarely red, green, white colour with characteristic brownish to light yellow and white streak. It has resinous to adamantine and also metallic lustre. Mostly sphalerite occurs as crystals commonly as granular, fibrous and botryoidal crystals with hardness 3.5-4, conchoidal fracture and cleavage perfect. Sphalerite crystallizes in cubic system.

You are advised to identify sphalerite in the photographs of the polished section provided to you in this laboratory manual with the help of optical characters given in the Table 10.8 and Figure 10.7a and b. After studying and identifying the optical characters of sphalerite draw the sketch of the optical characters as shown in Figure 10.8 and write the optical properties as mentioned in Table 10.7, in your laboratory practical file.

In the polished section the crystal form and habit of sphalerite is large, coarse-grained, anhedral, rounded or sub-rounded. Cleavage is present.



(a) (b)

Fig. 10.7: a) Polished section; and b) Massive brown sphalerite which in reflected light displays a silvery grey colour. (Source: https://www.virtualmicroscope.org/sites/default/files/html5Assets/sphalerite_ref/index2.html?specimen=/node/408)

Table 10.8: Optical properties of sphalerite			
Under Plane Polarised Light			
1.	**Colour**	:	Grey
2.	**Cleavage**	:	Not observed
3.	**Bireflectance**	:	Very very low
4.	**Reflectivity**	:	Low

Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Isotropic
6.	**Polarization colours**	:	Nil
7.	**Internal reflectance**	:	Nil
8.	**Associated minerals**	:	Chalcopyrite
9.	**Name**	:	**SPHALERITE**
10.	**Chemical composition**	:	(ZnS)
11.	**Distinguishing characters**	:	Gray color, isotropism, commonly with abundant yellow-brown to reddish-brown internal reflections.

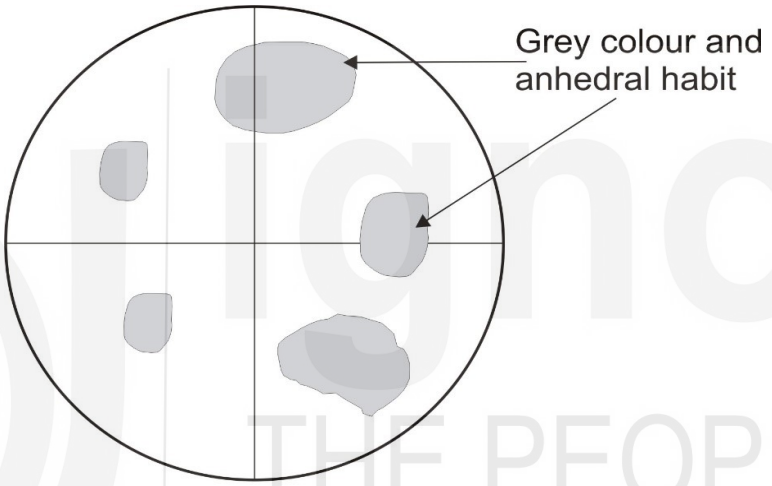


Fig. 10.8: Sketch of sphalerite showing optical properties.

10.8 LABORATORY EXERCISES

Instructions: **Carefully study the optical properties of the ores in the photographs of the polished sections given in your laboratory manual.** The proforma i.e., Table 10.9 should be used for recording the optical properties of all the ores. Give answers of the following exercises in your laboratory file and submit it to your Academic Counsellor.

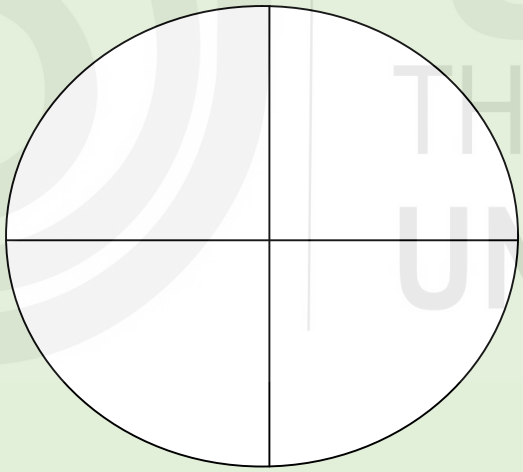
Exercise 1: Identify optical properties of pyrite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 2: Identify optical properties of chalcopyrite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 3: Identify optical properties of galena under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 4: Identify optical properties of sphalerite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Table 10.9: Proforma for recording the optical properties.

			Date: ……
Laboratory Exercise No.……:			
Under Plane Polarised Light			
1.	**Colour**	:	
2.	**Cleavage**	:	
3.	**Bireflectance**	:	
4.	**Reflectivity**	:	
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	
6.	**Polarization Colours**	:	
7.	**Internal Reflectance**	:	
8.	**Associated Minerals**	:	
9.	**Name**	:	
10.	**Chemical Composition**	:	
11.	**Distinguishing Characters**	:	
12.	**Sketch** 		

10.9 REFERENCES

- Bowie, S. H. U., Simpson, P. R. & Atkin, D. A. (I975) Reflectance measurements in monochromatic light on the Bowie-Taylor suite of 103 ore minerals. Fortschr Miner. 52, 567-582.
- Shrivastava, J. P. and Rani, N. (2012) Introduction to Ore Microscopy. PHI Learning Private Limited, New Delhi. 112p.
- http://www.atlas-of-ore-minerals.com/plate46c.htm
- https://www.virtualmicroscope.org/content/chalcopyrite-0

- https://www.virtualmicroscope.org/sites/default/files/html5Assets/galena_ref/index2.html?specimen=/node/407
- https://upload.wikimedia.org/wikipedia/commons/b/b0/Galena_%28Microscopic_image%29.jpg
- https://www.virtualmicroscope.org/sites/default/files/html5Assets/sphalerite_ref/index2.html?specimen=/node/408)

(Websites accessed between 20th May 2021 and 23rd June 2021)

10.10 LEARNING RESOURCES

- Geology Lab Skills: Microscope Components

  Link: https://www.youtube.com/watch?v=VpbAZpWSugw
- MS-91-COM Ore Microscope

  Link: https://www.youtube.com/watch?v=RQ4nOtucukM
- Interference colour

  Link: https://www.youtube.com/watch?v=2-W520RXf9Q<
- Chalcopyrite in ore microscope

  Link: https://www.virtualmicroscope.org/content/chalcopyrite-0
- Sphalerite in ore microscope

  Link:https://www.virtualmicroscope.org/sites/default/files/html5Assets/sphalerite_ref/index2.html?specimen=/node/408
- Galena in ore microscope

  Link: https://www.virtualmicroscope.org/sites/default/files/html5Assets/galena_ref/index2.html?specimen=/node/407

EXPERIMENT 11

MICROSCOPIC STUDY OF COMMON OXIDE ORE MINERALS

Outline of Experiment

11.1 Introduction
Expected Learning Skills
11.2 Requirements
11.3 Hematite
11.4 Goethite
11.5 Magnetite
11.6 Chromite
11.7 Pyrolusite
11.8 Psilomelane
11.9 Laboratory Exercises
11.10 References
11.11 Learning Resources

11.1 INTRODUCTION

In the previous experiment you have learnt to identify the sulphide ore minerals pyrite, chalcopyrite, galena and sphalerite in polished section. You have identified ores of iron (Fe), manganese (Mn), and chromium (Cr) in hand specimen in Experiment 1 Megascopic study of metallic minerals, of this course. In this experiment you will perform the identification of oxide ores of iron, chromium and magnesium such as hematite (Fe_2O_3), magnetite (Fe_3O_4), chromite ($FeO.Cr_2O_3$), pyrolusite (MnO_2) psilomelane ($BaMn_3(OH)_6Mn_8O_{18}$) from photographs of polished thin section.

Expected Learning Skills

After performing this experiment, you should be able to:

- identify the optical characters of common oxide ores of iron such as hematite, magnetite and goethite;
- learn to identify optical characters of chromite, oxide ore of chromium; and
- recognise the optical characters of common ores of manganese such as pyrolusite and psilomelane.

11.2 REQUIREMENTS

You will require the following to perform this experiment successfully:

- Photographs of polished sections of hematite, magnetite, chromite, pyrolusite and psilomelane.
- Laboratory file, pen/ pencil, compass, colour pencil and eraser

Note:

- **You are advised to carefully study the photographs of polished section provided to you in the laboratory manual with the help of optical characters listed in the tables.**
- **You have to perform and write the experiments in the same way as you have done in Experiment 10.**

***Instructions*: You are required to study Units 1, 9 and 10 of BGYET-141 course (Ore Geology and Industrial Minerals) before performing this experiment. Bring this practical manual along with Block 3 in Volume 2 of BGYET-141 course while attending the Practical Counselling sessions.**

11.3 HEMATITE

Let us recall the megascopic characters/physical properties of hematite that you have studied in Experiment 1 of this course.

Hematite has high specific gravity (5.26). In hand specimen it shows red, brownish red or greyish brown colour with a characteristic cherry red, red-brown streak. It has metallic to sub-metallic lustre. Mostly hematite has earthy to granular form with hardness 5-6, uneven to subconchoidal fracture and cleavage is absent. Hematite crystallises in hexagonal system.

You are advised to identify hematite in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.1 and Figure 11.1a and b. After studying and identifying the optical characters of hematite draw the sketch of the optical characters as shown in Figure 11.2 and write the optical properties as mentioned in Table 11.1, in your laboratory practical file.

In the polished section hematite exhibits typical tabular form however bladed form may be present. Zoning and inclusions are absent but micro-twinning may be present in hematite.

Table 11.1: Optical properties of Hematite

Without Crossed Nicols			
1.	**Colour**	:	White grey with bluish tint
2.	**Cleavage**	:	None
3.	**Bireflectance**	:	Weak
4.	**Reflectivity**	:	Medium
Between Crossed Nicols			

5.	**Isotropism/Anisotropism**	:	Anisotropic
6.	**Polarization Colours**	:	Nil
7.	**Internal Reflectance**	:	Nil
8.	**Associated Minerals**	:	Magnetite, pyrolusite, Ilmenite, magnetite, pyrite, chalcopyrite
9.	**Name**	:	**Hematite**
10.	**Chemical Composition**	:	(Fe_2O_3)
11.	**Distinguishing characters**	:	White to grayish-white, with moderate reflectance and distinct anisotropism. May contain internal reflections.

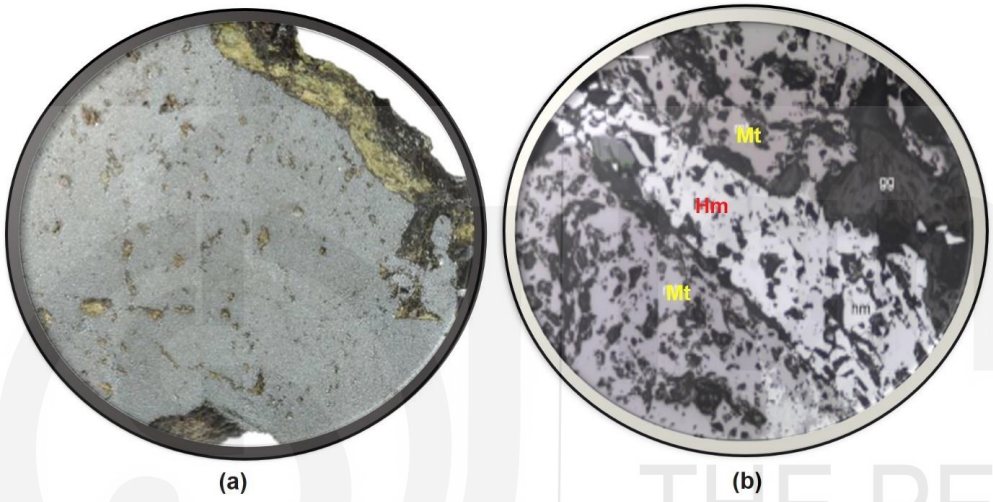


Fig. 11.1: Hematite: a) Polished section, and b) Hematite (Hm) vein (light grey) cutting magnetite (Mt). [Source for (a): http://www.atlas-of-ore-minerals.com/plate46d.htm and (b): John L. Lufkin, 2012]

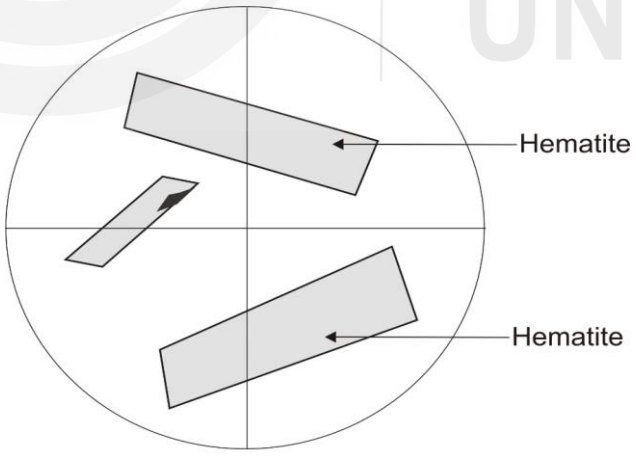


Fig. 11.2: Sketch of hematite showing optical characters.

11.4 GOETHITE

Let us recall the megascopic characters/physical properties of goethite that you have studied in Experiment 1 of this course.

Goethite has high specific gravity (3.3 to 4.3). In hand specimen it shows brownish black, yellowish and reddish brown colour with characteristic yellowish

brown, ochre yellow streak. It has adamantine, silky, metallic to dull lustre. Mostly goethite has radial, acicular, massive, crystalline form with hardness 5-5.5, uneven fracture and cleavage is perfect. Goethite crystallises in orthorhombic system.

You are advised to identify goethite in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.2 and Figure 11.3a and b. After studying and identifying the optical characters of goethite draw the sketch of the optical characters as shown in Figure 11.4 and write the optical properties as mentioned in Table 11.2, in your laboratory practical file.

In the polished section goethite exhibits botryoidal, fibrous and sometimes colloform crystal habit. Cleavage, zoning and twinning is absent. Gangue minerals can be present.

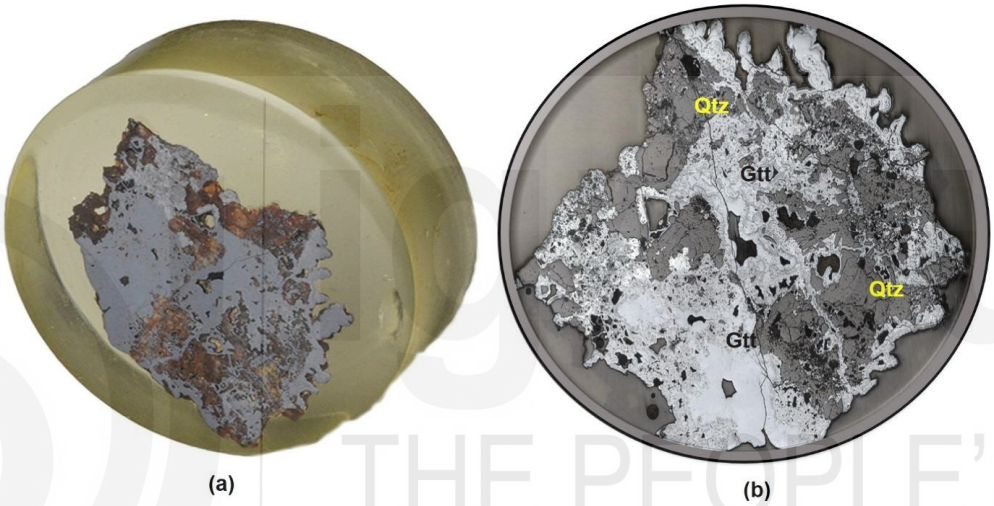


Fig. 11.3: Goethite: a) In polished section; and b) Botryoidal form seen in light grey goethite (Gtt) associated with quartz (Qtz). (Source: https://www.virtualmicroscope.org/sites/default/files/html5Assets/goethite_ref/index2.html?specimen=/node/406)

Table 11.2: Optical properties of Goethite			
Without Crossed Nicols			
1.	**Colour**	:	Dull grey to bright grey, often with bluish tint
2.	**Cleavage**	:	Perfect
3.	**Bireflectance**	:	Weak
4.	**Reflectivity**	:	Low
Between Crossed Nicols			
5.	**Isotropism/ Anisotropism**	:	Anisotropism
6.	**Polarization Colours**	:	Grey blue, grey yellow and brownish yellow
7.	**Internal Reflectance**	:	Commonly seen

8.	**Associated Minerals**	:	Magnetite, hematite, siderite, hematite, pyrite, pyrrhotite
9.	**Name**	:	**Goethite**
10.	**Chemical Composition**	:	[FeO(OH)]
11.	**Distinguishing characters**	:	Gray, low reflectance, distinct anisotropism, with abundant red, brownish, or yellow internal reflections.

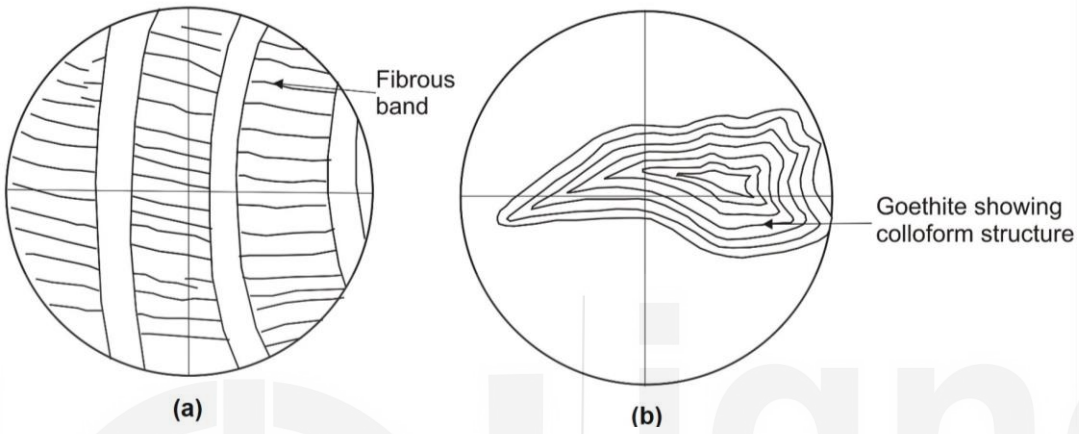


Fig. 11.4: Sketch of goethite showing optical characters: a) Fibrous bands; and b) colloform structure.

11.5 MAGNETITE

Let us recall the megascopic characters/physical properties of magnetite that you have studied in Experiment 1 of this course.

Magnetite has high specific gravity (5.5-6.5). In hand specimen it shows black to silver grey colour with characteristic black streak. It has metallic to sub-metallic lustre. Mostly magnetite has crystalline form with hardness 5.5-6.5, uneven fracture and cleavage is absent. Magnetite crystallises in cubic system.

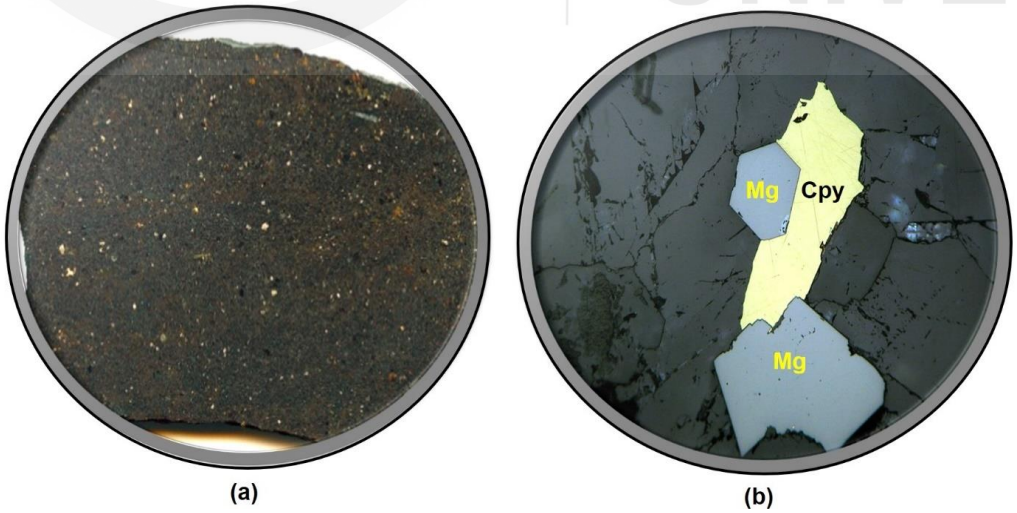


Fig. 11.5: Magnetite: a) Polished section; and b) Euhedral magnetite (Mg) crystals (light grey) overgrown by chalcopyrite-Cpy (yellow) in barite matrix (grey). [Source for (a): http://www.uranglasuren.com/ores/Index_CH/Example_CH04/index.html; and for (b): https://commons.wikimedia.org/wiki/File:Mt_Mulga-magnetite-chalcopyrite.jpg]

You are advised to identify magnetite in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.3 and Figure 11.5a and b. After studying and identifying the optical properties of magnetite draw the sketch of the optical characters as shown in Figure 11.6 and write the optical properties as mentioned in Table 11.3, in your laboratory practical file.

In the polished section subhedral grains of magnetite are seen in polished section. Cleavage, zoning and twinning are absent in magnetite. Ilmenite shows phenomenon of exsolution intergrowth and hematite can be present as gangue minerals.

Table 11.3: Optical properties of Magnetite

Without Crossed Nicols			
1.	**Colour**	:	Gray with brownish to violet tint.
2.	**Cleavage**	:	Imperfect, parting seen
3.	**Bireflectance**	:	None
4.	**Reflectivity**	:	Low
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Isotropic
6.	**Polarization Colours**	:	Nil
7.	**Internal Reflectance**	:	Nil
8.	**Associated Mineral**	:	Ilmenite, hematite, pyrrhotite, pyrite
9.	**Name**	:	**Magnetite**
10.	**Chemical Composition**	:	(Fe_3O_4)
11.	**Distinguishing characters**	:	Granular aggregates with good polish. Sometimes oxidized to hematite along fractures and parting planes.

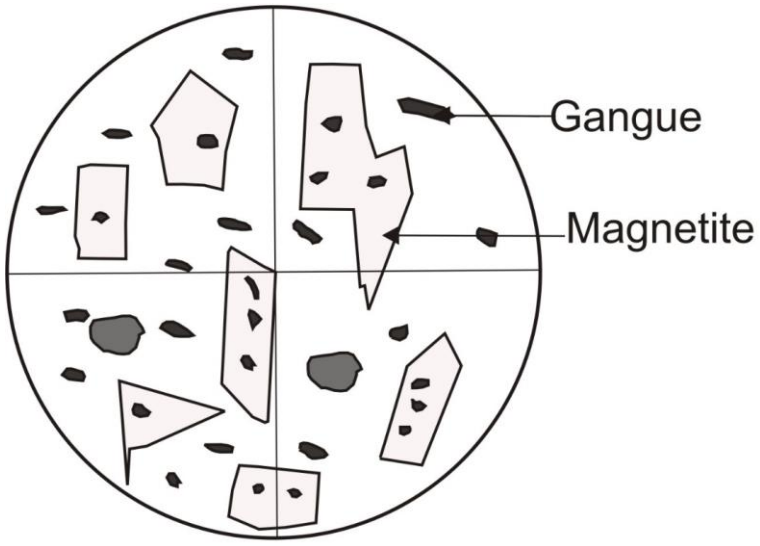


Fig. 11.6: Sketch of magnetite showing optical characters.

11.6 CHROMITE

Let us recall the megascopic characters/physical properties of chromite that you have studied in Experiment 1 of this course.

Chromite has high specific gravity (4.5-4.8). In hand specimen it shows brownish black, black, dark brown colour with characteristic brown streak. It has metallic lustre. Mostly chromite has rarely crystalline, typically massive, fine granular to compact form with hardness 5.5-6, uneven fracture and cleavage is absent. Chromite crystallises in cubic system.

You are advised to identify chromite in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.4 and Figure 11.7a and b. After studying and identifying the optical properties of chromite draw the sketch of the optical characters as shown in Figure 11.8 and write the optical properties as mentioned in Table 11.4, in your laboratory practical file.

In the polished section chromite shows granular texture with anhedral to subhedral crystals. Zoning, cleavage and twinning are absent in chromite. Inclusions are minute, tiny, white coloured ore inclusions.

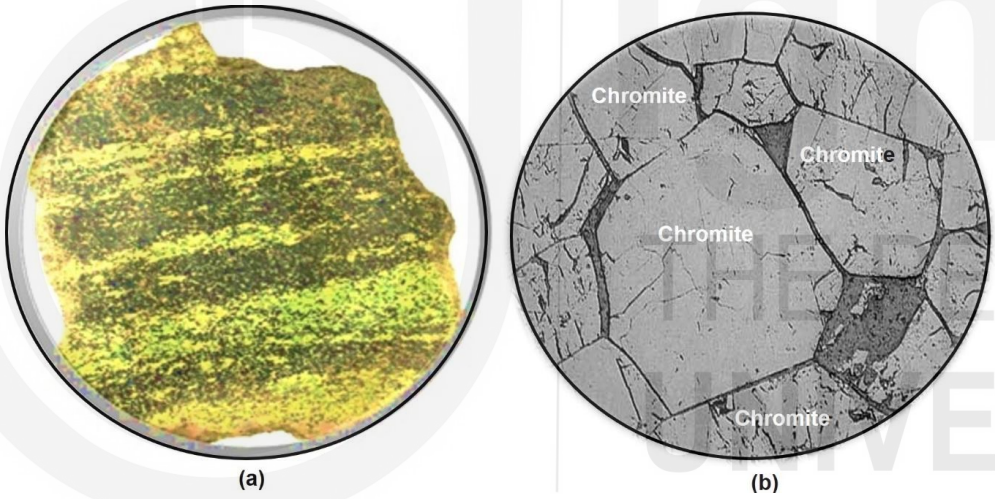


Fig. 11.7: a) Polished section showing bands of chromite (black in colour) and serpentine (green in colour). This is a cumulate rock associated with ultramafic rocks; and b) Euhedral chromite crystals (grey colour) are fractured. Some fractures are along a poorly defined cleavage (bottom centre) and are accompanied by incipient alteration (higher reflectance areas, centre right). Silicate (dark grey) forms the matrix to the chromite and replaces it (bottom right). [Source for (a): https://www.sandatlas.org/chromite/; and for (b) http://www.atlas-of-ore-minerals.com/plate07b.htm]

Table 11.4: Optical properties of Chromite			
Without Crossed Nicols			
1.	**Colour**	:	Dark-gray to brownish-gray
2.	**Cleavage**	:	None, parting may develop
3.	**Bireflectance**	:	Absent
4.	**Reflectivity**	:	Low

Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Isotropic
6.	**Polarization Colours**	:	Nil
7.	**Internal Reflectance**	:	Nil
8.	**Associated Minerals**	:	Olivine, magnetite
9.	**Name**	:	**Chromite**
10.	**Chemical Composition**	:	($FeO.Cr_2O_3$)
11.	**Distinguishing Characters**	:	Darker than magnetite, euhedral to rounded grains, good polish, low reflectance and isotropic

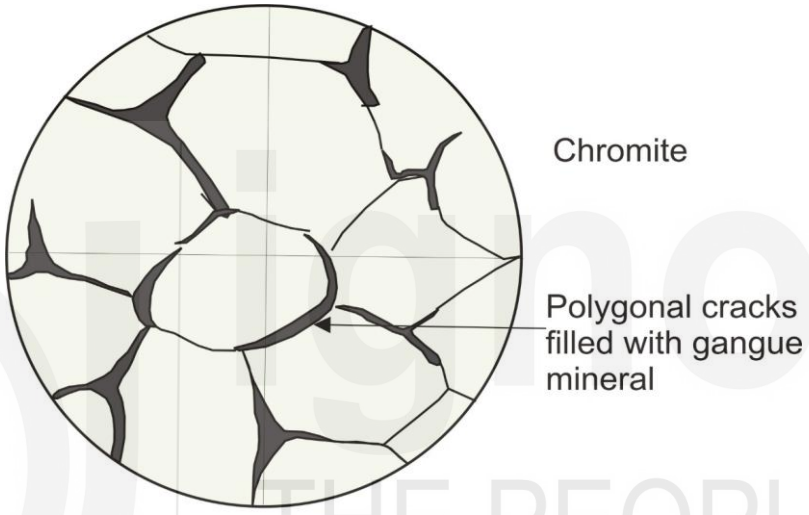


Fig. 11.8: Sketch of chromite showing optical characters.

11.7 PYROLUSITE

Let us recall the megascopic characters/physical properties of pyrolusite that you have studied in Experiment 1 of this course.

Pyrolusite has high specific gravity (4.5-5.06). In hand specimen it shows light to dark steel-grey colour with characteristic black or bluish-black streak. It has metallic lustre. Mostly pyrolusite has massive, columnar or fibrous form with hardness 2 to 6-6.5, uneven fracture and cleavage is perfect. Pyrolusite crystallises in tetragonal system.

You are advised to identify pyrolusite in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.5 and Figure 11.9a and b. After studying and identifying the optical properties of pyrolusite draw the sketch of the optical characters as shown in Figure 11.10 and write the optical properties as mentioned in Table 11.5, in your laboratory practical file.

In the polished section pyrolusite shows coarse grained crystal form and habit, with euhedral, tabular to prismatic crystals.

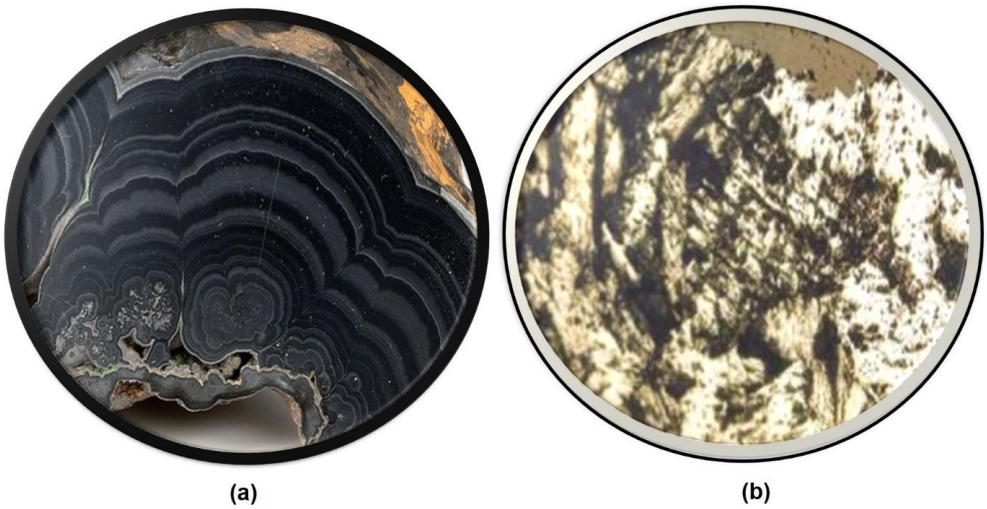


Fig. 11.9: Pyrolusite: a) Polished section showing colloform texture; and b) Interlocking of pyrolusite and gangue minerals in reflected light. (Source: Mehdilo Akbar, 2013)

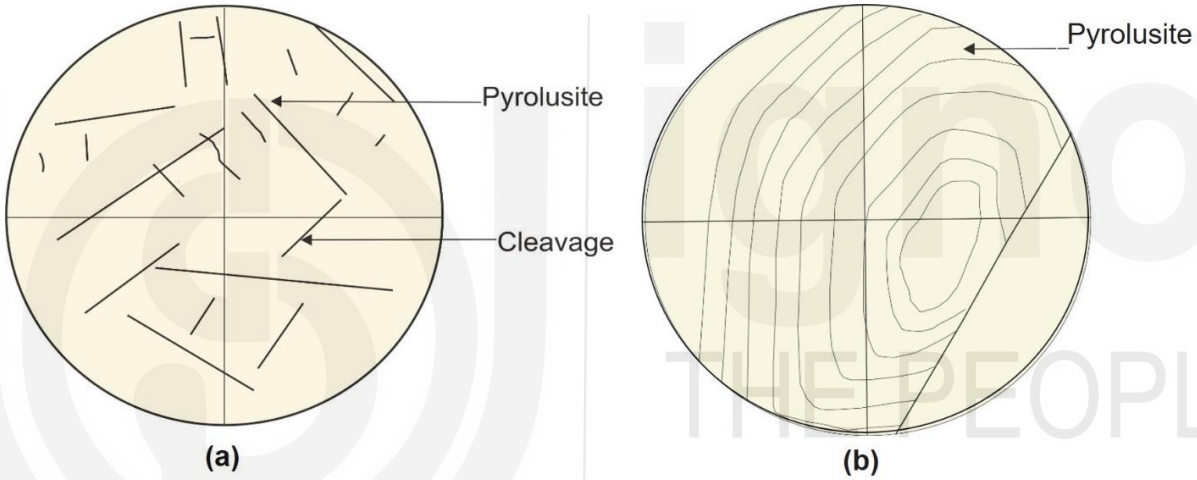


Fig. 11.10: Sketch of pyrolusite showing optical characters.

Table 11.5: Optical properties of Pyrolusite			
Without Crossed Nicols			
1.	**Colour**	:	White with distinct area of yellowish tint (which is brightest among all minerals)
2.	**Cleavage**	:	Perfect
3.	**Bireflectance**	:	Distinct in coarse grained variety, yellowish-white to grayish.
4.	**Reflectivity**	:	Medium
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Very strong, anisotropic
6.	**Polarization Colours**	:	Yellowish dark brown, greenish blue and slaty blue
7.	**Internal Reflectance**	:	Nil
8.	**Associated Minerals**	:	Goethite, psilomelane, hematite

9.	**Name**	:	**Pyrolusite**
10.	**Chemical Composition**		(MnO_2)
11.	**Distinguishing characters**	:	White colour with very strong anisotropism.

11.8 PSILOMELANE

Let us recall the megascopic characters/physical properties of psilomelane that you have studied in Experiment 1 of this course.

Psilomelane has high specific gravity (4.7). In hand specimen it shows light to dark grey to black colour or bluish gray with characteristic black streak. It has sub-metallic lustre. Mostly psilomelane shows massive and commonly botryoidal or colloform habit with hardness 5-6, conchoidal to uneven fracture and cleavage is absent. Psilomelane crystallises in monoclinic system.

You are advised to identify psilomelane in the photographs of the polished section provided to you in this laboratory manual with the help of optical properties given in the Table 11.5 and Figure 11.9a and b. After studying and identifying the optical properties of psilomelane draw the sketch of the optical characters as shown in Figure 11.10 and write the optical properties as mentioned in Table 11.5, in your laboratory practical file.

In the polished section psilomelane shows fine crystalline aggregates or colloform habit. Cleavage, zoning and twinning is not seen. Gangue minerals are present.

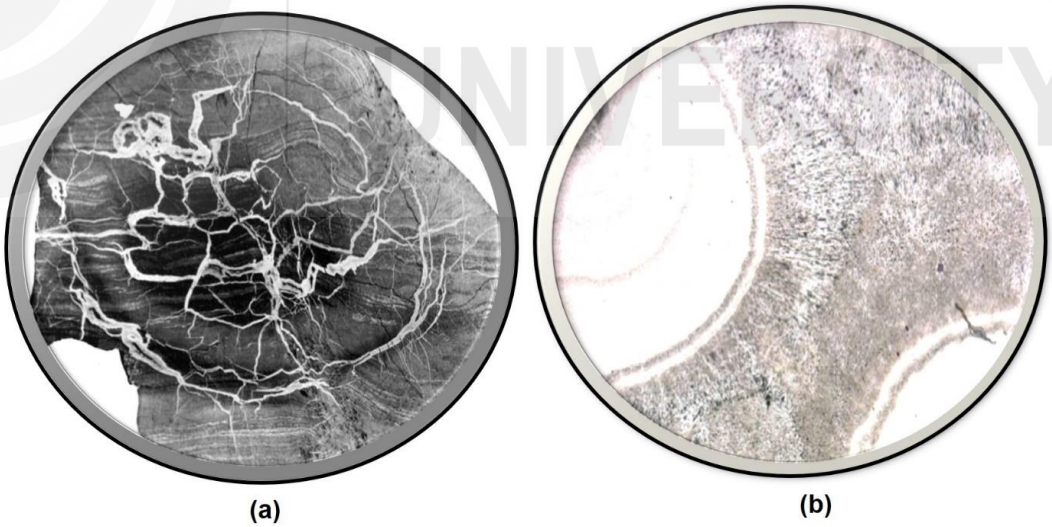


Fig. 11.11: a) Polished section of a nodule of psilomelane showing irregular radial and concentric shrinkage cracks that have been filled by the deposition of harder finer-grained psilomelane having a highly polished surface (white in photo). b) Colloform psilomelane. [Source for (a): http://luirig.altervista.org/pics/display.php?pos=267019**; and f**or (b) John L. Lufkin, 2012]

Table 11.6: Optical properties of Psilomelane			
Without Crossed Nicols			
1.	**Colour**	:	Bluish grey to greyish white
2.	**Cleavage**	:	None
3.	**Bireflectance**	:	Strong
4.	**Reflectivity**	:	Low reflectivity
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	Strongly anisotropic
6.	**Polarization Colours**	:	White to grey
7.	**Internal Reflectance**	:	May be visible
8.	**Associated Minerals**	:	Pyrolusite, goethite
9.	**Name and**	:	Psilomelane
10.	**Chemical Composition**	:	$(BaMn_3(OH)_6Mn_8O_{18})$
11.	**Distinguishing characters**	:	Colour, bireflectance, strong anisotropism and colloform texture are distinctive.

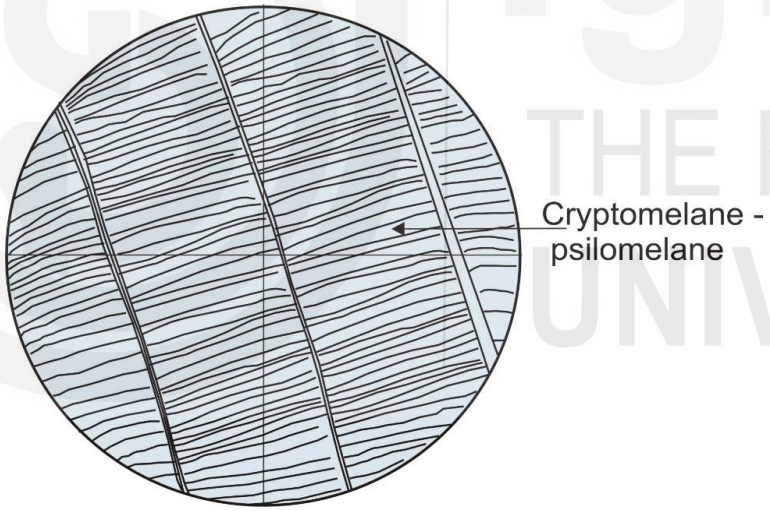


Fig. 11.12: Sketch of psilomelane showing optical characters.

11.9 LABORATORY EXERCISES

Instructions: Carefully study the optical properties of the ores in the photographs of the polished sections given in your lab manual. The proforma i.e., Table 11.7 should be used for recording the optical properties of all the ores. Give answers of the following exercises in your laboratory file and submit it to your Academic Counsellor.

Exercise 1: Identify optical properties of hematite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 2: Identify optical properties of goethite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

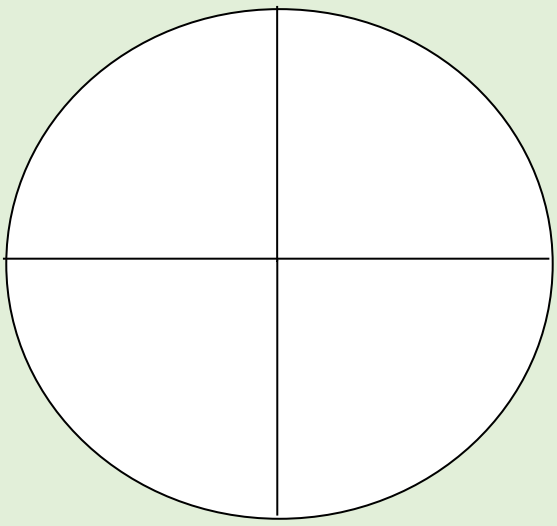
Exercise 3: Identify optical properties of magnetite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 4: Identify optical properties of chromite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 5: Identify optical properties of pyrolusite under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Exercise 6: Identify optical properties of psilomelane under plane polarised light and crossed nicols. List the optical properties and draw neat sketches.

Table 11.7: Proforma for recording the optical properties.

			Date: ……
Laboratory Exercise No.……:			
Under Plane Polarised Light			
1.	**Colour**	:	
2.	**Cleavage**	:	
3.	**Bireflectance**	:	
4.	**Reflectivity**	:	
Between Crossed Nicols			
5.	**Isotropism/Anisotropism**	:	
6.	**Polarization Colours**	:	
7.	**Internal Reflectance**	:	
8.	**Associated Minerals**	:	
9.	**Name**	:	
10.	**Chemical Composition**	:	
11.	**Distinguishing Characters**	:	
12.	**Sketch** 		

11.10 REFERENCES

- John L. Lufkin, 2012) Ore Mineralogy and Microscopy. Golden Publishers. Pages 191pp.
- Mehdilo Akbar (2013) Characterization and beneficiation of Iranian low-grade manganese ore. Physicochem. Probl. Miner. Process. 49(2), 725−741.
- Shrivastava, J. P. and Rani, N. (2012) Introduction to Ore Microscopy. PHI Learning Private Limited, New Delhi. 112p.
- http://luirig.altervista.org/pics/display.php?pos=267019
- http://www.atlas-of-ore-minerals.com/plate07b.htm
- http://www.atlas-of-ore-minerals.com/plate46d.htm
- http://www.uranglasuren.com/ores/Index_CH/Example_CH04/index.html
- https://commons.wikimedia.org/wiki/File:Mt_Mulga-magnetite-chalcopyrite.jpg
- https://www.sandatlas.org/chromite/
- https://www.virtualmicroscope.org/sites/default/files/html5Assets/goethite_ref/index2.html?specimen=/node/406

(Websites accessed between 20th May 2021 and 23rd June 2021)

11.11 LEARNING RESOURCES

- Geology Lab Skills: Microscope Components

  Link: https://www.youtube.com/watch?v=VpbAZpWSugw
- MS-91-COM Ore Microscope

  Link: https://www.youtube.com/watch?v=RQ4nOtucukM
- Goethite in ore microsope

  Link: https://www.virtualmicroscope.org/sites/default/files/html5Assets/goethite_ref/index2.html?specimen=/node/406
- How to identify magnetite in polish section

  Link: https://www.youtube.com/watch?v=wk2Yx1khrXs

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Dear Learner,

While studying the laboratory course BGYEL-142 (Ore Geology and Industrial Minerals: Laboratory), you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions, in order to improve the course. Therefore, we request you to please fill out and send us the following questionnaire, which pertains to this course (i.e., BGYEL-142). If you find the space provided is insufficient, kindly use a separate sheet.

Please mail to:
Course Coordinator BGYEL-142
Discipline of Geology
School of Sciences
IGNOU, Maidan Garhi
New Delhi – 110068 (India)

Questionnaire

1. Name: _____

2. Enrolment No.

3. Regional centre code and name: _____

4. Study centre code and name: _____

5. How many hours did you spend for performing the each experiment?

Course	BGYEL-142 (Ore Geology and Industrial Minerals: Laboratory)										
Experiment no.	1	2	3	4	5	6	7	8	9	10	11
No. of hours											

6. Please give your reactions (by '√' mark) to the following items based on your reading of the laboratorycourse:

Items	Excellent	Very Good	Good	Poor	Give specific examples, if poor
Presentation Quality					
Language and Style					
Illustrations used (Diagrams, Tables etc.)					
Conceptual Clarity					

7. Your specific comments on the course BGYEL-142

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