GEMS AND GEMMOLOGY IN PAKISTAN

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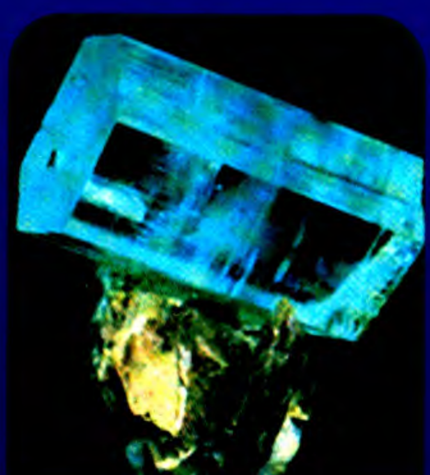

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Aquamarine specimen from Gilgit-Baltistan, Pakistan

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Gems and Gemmology in Pakistan

Tahseenullah Khan and Allah Bakhsh Kausar

GSP Special Publication

SPECIAL PUBLICATION
March 2010

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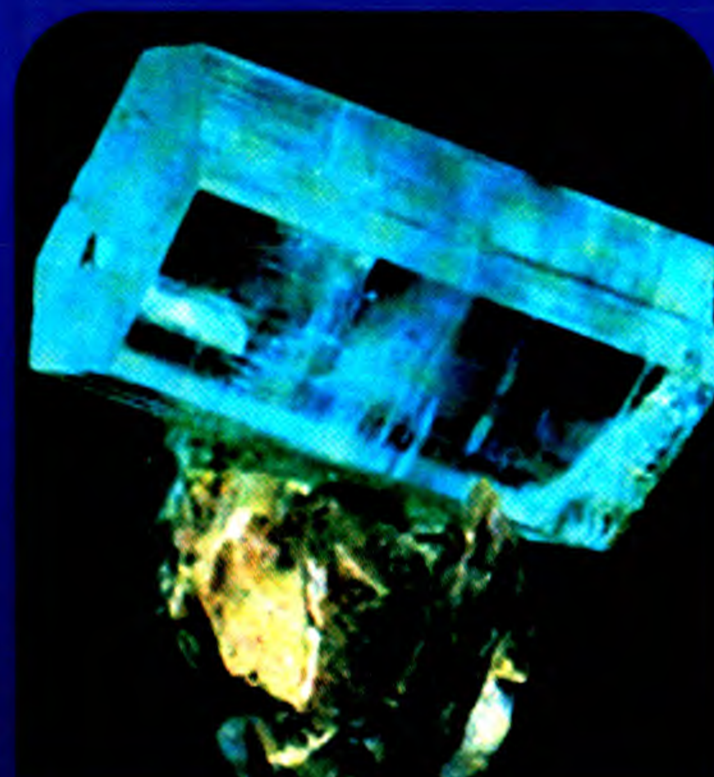

Issued by

Dr. Imran Khan
Director General
Geological Survey of Pakistan

Government of Pakistan
Ministry of Petroleum and Natural Resources
Geological Survey of Pakistan

SPECIAL PUBLICATION
OF
THE GEOLOGICAL SURVEY OF PAKISTAN

GEMS AND GEMMOLOGY IN PAKISTAN

by

Tahseenullah Khan and Allah Bakhsh Kausar

Issued by Dr. Imran Khan, Director General, Geological Survey of Pakistan
March 2010

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Government of Pakistan
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MINISTER

MESSAGE

It gives me immense pleasure to see the book on Gems and Gemmology in Pakistan. I congratulate the Geological Survey of Pakistan (GSP) and its scientists, particularly the authors of this special publication for having produced such a monumental work of research.

The present publication unfolds the history of the gemstones in terms of exploration, testing, mining, cutting and marketing in Pakistan. I further elaborate that this publication is the outcome of frequent and intensive geological work carried out by the authors for the last five years in the gem-bearing areas of Khyber-Pakhtoonkhwa, Gilgit-Baltistan and Azad Jammu & Kashmir.

Gemstone mining in Pakistan has always remained slow and steady. To this day, mining is crudely done and is usually limited to the surface extraction. Primitive tools, the remoteness of the mining sites, and intertribal strife have combined to make mining perpetually arduous and laborious as well as dangerous. Consequently, the private sector in Pakistan is facing problems in mining the precious stones and to extract significant quantities from the mines contrary to expectations. I am particularly glad that the book on Gems and Gemmology in Pakistan addresses all issues related to gemstones exploration and mining. This book also familiarizes the readers about the gem testing, gemstone cutting and the gemstone treatments. I hope the data provided in the book will definitely enhance the technical capabilities of the geologists, gemmologists, the gemstones lovers and may attract Foreign Direct Investment (FDI) in the Gemstone Sector of Pakistan.

(Syed Naveed Qamar)

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Government of Pakistan
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FOREWORD

Mineral deposits have supplied useful and valuable material for human consumption long before they became objects of scientific curiosity or commercial exploitation. In modern times, the study of mineral deposits has evolved into an applied science employing detailed field observations, sophisticated laboratory techniques for additional information, and computer modeling to build complex hypotheses. Understanding concepts that would someday help geologists to find new mineral deposits or exploit the known ones more effectively have always been and will continue to be, at the core of any research on mineral deposits, but it is a fascinating subject in its own right, even for few researchers who do not intend to be professional economic geologists.

Pakistan is a vast country with considerable wealth in natural resources and understanding Pakistan's geology is critical for efficient exploration and exploitation of these resources. Estimates for copper and iron ore resources were found to have the most potential for extraction in Pakistan. Researchers from the Geological Survey of Pakistan also found abundant deposits of gemstones, including emerald, ruby, aquamarine, topaz, tourmaline and peridot.

The natural resources of particularly gemstones have a quality comparable to the highest-class minerals of the entire region. Pakistan and gemstones have been inextricably linked for about 40 years and the country remains rich in precious and semi-precious gemstones deposits. There are four main gemstone producing areas: the Swat Valley producing emeralds; Hunza and Neelum Valleys producing the world-famous and most recognized of ruby gems; Naran Valley famous for peridot and Shighar Valley producing a wide range of semi-precious gems such as tourmaline, topaz, aquamarine, and beryl. Gemstones mining in Pakistan is typically an artsinal activity carried out by people living in villages surrounding the mines. Tunnels are excavated and gems are extracted by hand using drills and dynamite. These techniques lead to much waste and damage to gemstones and result in low yield.

Pakistan is also a source of good quality mineral specimens. Many specimens from Pakistan can be found at gems and mineral shows and for sale on the Internet. Pakistan has a great opportunity to increase its share of this market, particularly because of the proximity of India and Thailand, the world's largest coloured gemstone markets, and also because there is an increasing demand for higher quality gems in North America, Europe, East Asia and the Middle-East.

I hope that the present special publication of the Geological Survey of Pakistan on Gems and Gemmology in Pakistan will be useful in providing information to the geologists and non-geologists working in the gemstone sector with the aim of promoting sustainable economic development of Pakistan. Further, this assessment will be used in rebuilding Pakistan's natural resource sector, provide valuable new information to the national as well as to the global corporate business and mining communities, and serve as a foundation for future work on areas of gemstone resource potential.

(Kamran Lashari)

Government of Pakistan
Ministry of Petroleum and Natural Resources
GEOLOGICAL SURVEY OF PAKISTAN

Director General

PREFACE

Precious and semi-precious gemstones have been prized for centuries for their aesthetic qualities. Pakistan has been blessed with a great variety of precious and semi-precious stones with numerous records of mines, deposits, occurrences and showings. In fact, some of the earliest records of mining anywhere in the subcontinent are from Pakistan. Most operations today are small-scale, but the potential undoubtedly exists for the development of a significant precious stones mining industry in Pakistan. At a time when Pakistan seeks to enhance its domestic revenues and to create diverse but sustainable job opportunities, gem mining makes strong economic, social and political sense. Opportunities for gem mining are present in virtually northwest and western part of the country and initial support from government to facilitate a market-based sector is evident. Markets for the sector include domestic production and sales but more viably, export markets as close as China, Thailand and as far as Europe and the United States of America.

Geological Survey of Pakistan has successfully assessed these resources using modern methodologies and technologies. In the previous decades, many activities were undertaken by the GSP to study mineral resources, and to develop other geosciences expertise to support the natural resources sector. These activities produced many products including geological maps, reports, summaries, mineral locations that summarized the studies undertaken. The data and information in these reports and maps form the basis for providing a modern nationwide mineral resource assessment. This assessment will in turn provide impetus for planning and carrying out further data generation to make the assessments more credible and reliable, and thus to attract Foreign Direct Assessment (FDI) in mineral sector.

It is pleasing to note that the authors of book "Gems and Gemmology in Pakistan" worked effectively to compile existing information about the gemstones of Pakistan and evaluated the prospects of undiscovered deposits of gemstone resources. Such results may be used as a foundation for further work on areas of mineral resource potential particularly precious and semi-precious gemstones and in building Pakistan's natural resources sector.

Imran Khan

Islamabad, March 2010 **(Dr. Imran Khan)**

PROLOGUE

Gemstones are always fascinating due to their beauty, rarity and fashion. They are extracted from rugged mountains, plain areas and deep seas. Their ultimate use is in jewellery and electrical appliances. Beautiful gemstone specimens are also valued for decoration purposes. Pakistan is bestowed by Almighty Allah the treasures of variety of gemstones in her mountains. Pakistani emeralds, aquamarines, tourmalines, topazes, peridots and rubies are famous the world over for their colours, transparencies and weight, and consequently make Pakistan as paradise of gemstones not only for the native inhabitants but also for the gemstones lovers all over the world.

The book entitled as "Gems and Gemmology in Pakistan" is being published as GSP's Special Publication by the courtesy of Dr. Imran Khan, Director General of the Geological Survey of Pakistan. We are highly indebted to him for his guidance and encouragement to publish this book in the public interest. It was the idea of Syed Hasan Gauhar, former Director General of the Geological Survey of Pakistan to publish a book on the gemstones of Pakistan after incorporating up to date data regarding mining, cutting/polishing and marketing of the Pakistani gemstones. He kindly supported us morally and extended every help in executing the task. We are highly indebted to him for his invaluable help.

We are also thankful to Muhammad Sakhawat, former Superintending Geophysicist, Geological Survey of Pakistan for his cooperation and moral support to carry out surveys regarding gemstone mining, marketing and exploration. Tahir Karim, former Director of the Geoscience Advance Research Laboratories, Geological Survey of Pakistan Islamabad is thanked for providing all facilities while writing this book.

Thanks are extended to Prof. Dr. Mamoru Murata of the Department of Geosciences, Naruto University of Education, Tokushima Japan for his invaluable support and guidance while conducting analytical work on various gemstones of Pakistan, particularly, the bastnasite of Zaghi Ghar Warsak area of Peshawar in the Department of Geosciences, Naruto University of Education. Dr. Brendan M. Laurs, Senior Editor of the Journal "Gems & Gemology" provided literature regarding the gemstone deposits of Pakistan. Dr. Brendan himself carried out his research studies on Khaltaro emeralds and other pegmatite-bearing gemstone deposits of the Gilgit-Baltistan region. His contribution and moral support is superb. Dr. Gaston Giuliani of CRPG/CNRS, Nancy France has been in association with us while executing different projects on the gemstones of Pakistan. His contribution in this regard is invaluable. Dr. Fuzail Siddiqui, Senior Vice President and Chief Operating Officer of Global Mining Company (Pvt) Limited very critically reviewed this book. Dr. Syed Shahid Hussain, former Director of Natural History Museum and Member Science, Pakistan Science Foundation very generously spared his valuable time and reviewed the book thoroughly. Their guidance and suggestions to improve the manuscript are commendable. We acknowledge Prof. Dr. M. Q. Jan, Professor of Emirates, NCE in Geology, University of Peshawar and former Vice Chancellor, Quaid-e-Azam University Islamabad for reviewing the initial draft of this book and sharing very precious information on the gemstone deposits of Pakistan.

We collected data and got information from many government officials, gem traders and intellectuals nationally and internationally. Without their cooperation this book could not be completed. In this regard thanks are extended to numerous colleagues including Prof. Sahfiqullah Bangash, Department of Economics, University of Peshawar, Abdullah Baig, Manager of Hunza Inn Gilgit and Naik Alam of Hunza. Thanks are also extended to Abdul Rahman of Northern Gems collection, Gilgit who provided valuable information about the gemstones of Pakistan. We thank Sultan Tiwana, Bakhtiar Khan, M. Bilal and Kamran Masood Niazi of SMEDA for sharing information on the gemstones of Pakistan. Hamid Dawood of Pakistan Natural History Museum, Islamabad shared information on gemstones mining in Pakistan. We are thankful to him.

We also thank Khalid Aziz of Sagar Gems, Karachi for providing valuable information regarding the gemstones sector in Karachi. We are also indebted to Khawaja Hameed, Sajid Pervaiz Hashmi, Shaukat Ali Khan and Tahir Saleem Usmani of AKMIDC for fruitful discussion and information regarding gemstone mining and marketing in Azad Jammu and Kashmir.

A number of international and national institutions, organizations and individuals are thanked and acknowledged for providing up to-date knowledge regarding the nomenclatures and marketing of the gemstones in the form of projects, reports, research papers, books and

technical discussions. It will not be fair to ignore the name of A.H. Kazmi, former Director General of the Geological Survey of Pakistan and the author of many books and research papers on the gemstones of Pakistan, whose book entitled "Gemstones of Pakistan" with Michael O' Donoghue and the "Emeralds of Pakistan" with L.W. Snee as co-authors, provided immense input of the materials in this write up. We also acknowledge various reports published on websites, which are highlighted in Appendix-I. We may have not missed any reference in the manuscript, however, if some one finds such missing, we regret in this regard in advance.

Islamabad, March 31, 2010

Dr. Tahseenullah Khan
&
Dr. Allah Bakhsh Kausar

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INTRODUCTION

Gemstones have captured the imagination and desires of men and perhaps especially, women, for ages. The pursuit of gems has become the subject of legends, fairy tales, epics, and major motion pictures. Today, finer gemstone specimens are available to the average person than at any time in history.

Speaking generally, a gemstone is a stone that is beautiful, rare and durable (resistant to abrasion, fracturing and chemical reactions). The gemstones are naturally occurring inorganic crystalline elements or compounds with definite chemical compositions and physical properties. Out of more than 3,000 identified minerals, less than 100 are used as gemstones. This number also includes many gemstones, which do not conform to the strict definition of "minerals", e.g., pearl and coral, jade, agate etc. Gemmology is the science and study of these gemstones, including their source, description, origin, identification, grading, and appraisal that may be useful to mankind.

Cutting, polishing gemstones and their use in jewellery has long tradition in the Indo-Pakistan subcontinent since the Indus civilisation 5,000 years ago. Middlemiss is reported to have recognized aquamarine in Shigar of Skardu area as far back as 1915. In 1951, Geological Survey of Pakistan (GSP) first reported the presence of corundum, ruby, aquamarine and emerald in the Northern Areas of Pakistan. Since then a large number of new findings and discoveries of gemstones have been made, thus placing Pakistan on the gemstone map of the world. It is noteworthy that all gemstone deposits of Pakistan, in the rare exceptions, occur in Karakoram, Hindu Kush and the Himalayan regions of the country.

Whenever one begins to examine the history of these gemstones in Pakistan, particularly the early history, the inadequacy and scarcity of information soon becomes apparent. The study is based, in most cases, on relatively few of reliably dated examples and surviving literature. The literature itself is most often only in the form of copies, which compounds errors and makes interpretation of the texts difficult. From these direct sources of information one tries to piece together the early history of a gem material by integrating the present knowledge with probable sources of stones during early times.

Consequently, there are a number of reports, research papers and books published in different parts of the world, and of course, Pakistan is one of them. There are a few authors who worked on the gemstones of Pakistan, notably Kazmi and O' Donoghue (1990) and

Kazmi and Abbas (2001). Kazmi and Snee (1989) gave a detailed survey on the gemstone-related geology and the gemmological properties of the emerald found in Pakistan. Jan (1979), Jan et al. (1981c), Jan and Khan (1996), Kazmi et al. (1985), Kazmi and Jan (1997), Kazmi and Abbas (2001), Hussain et al. (1993), Kausar and Khan (1996), Gübelin (1982, 1989), Laurs et al. (1996, 1998), Dilles et al. (1994), Arif et al. (1996), Pecher et al (2002) and Khan and Kausar (2003) have also provided information on various aspects of the gemstones of NWFP and Northern Areas with main focus on their genesis.

In some of these publications, the known gemstone deposits of Pakistan are demonstrated as some of the biggest deposits of the world with the estimated reserves over millions of carats for each of the deposit. Previously, these deposits were explored and exploited by the Government enterprises, but at present, all the gemstone mining in NWFP and Northern Areas is done by private sector. In Azad Jammu and Kashmir (AJK) gemstone exploration and mining activity is still Government controlled.

This book is the outcome of frequent and intensive geological work carried out by the authors for the last five years in the gem-bearing areas of NWFP, Northern Areas of Pakistan and AJK. The first author of this manual worked in the then Gemstone Corporation of Pakistan on gemstone exploration and mining in NWFP from 1981 to 1984.

To get up to date information on the reserves of the gemstones, the authors visited emerald mines in Mohmand and Bajaur Agencies and Swat; topaz mine of Katlang; tourmaline mine of Stak Nala; ruby mines of Hunza and AJK and peridot mine of Sapat, Naran-Kohistan. During this survey, information was collected on the occurrence, mining operation and trade. In addition representative samples were collected for geochemical studies. Areas where showings of garnet, actinolite, epidote, rodingite etc., had been reported in the past were also visited and found that these mineral/rock showings were of limited extent.

The authors could not visit the aquamarine-topaz deposit of Balachi/Bulochi-Shengus, the aquamarine-topaz deposit of Dusso of Skardu area and the axinite deposit of Shigar Valley, Skardu area (?) because of inaccessibility. Gemstone mining in Pakistan has always remained slow and steady. To this day, mining is crudely done usually limited to the surface extraction. Primitive tools, the remoteness of the mining sites, and intertribal strife have combined to make mining perpetually arduous and laborious as well as dangerous. Consequently the private sector in Pakistan is facing problems in mining the precious stones and to extract significant quantities from the mines contrary to expectations. The authors believe that future production must depend on geo-structural analysis and with application of advanced mining techniques before the deposits are totally destroyed by primitive blasting methods. There is a need to change the thinking of the small-scale miners through education and training.

It is well known that Pakistan has not competed well in the international gemstone market in spite of its superior gemstone deposits. To see and study the gemstone trade and the cutting and polishing practices, several visits to the gemstone markets in Peshawar, Karachi, Islamabad and Rawalpindi were made. Besides, the following departments and the association offices/traders were visited:

1. Export Promotion Bureau (EPB), Peshawar and Karachi
2. Small and Medium Enterprises Development Authority (SMEDA), Peshawar
3. Directorate of Mines and Minerals, Peshawar
4. Directorate of Mineral Development (DMD), Swat
5. Azad Kashmir Mineral and Industrial Development Corporation (AKMIDC), Muzaffarabad
6. Gem and Gemmological Institute, Peshawar (GGIP)
7. All Pakistan Commercial Exporters Association (APCEA), Peshawar
8. Pakistan Gems and Jewellery Development Company (PGJDC), Karachi
9. Directorate of Industries and Mineral Development Northern Areas, Gilgit
10. Directorate of Mines and Minerals, NWFP, Peshawar

As a result much useful information regarding the gemstone sector was gathered, and incorporated in the book. In the present gemstone scenario, a significant quantity of cut and polished gems in the markets are synthetic and fake. In this book the authors have shed considerable light on this issue and have given guidelines for distinguishing synthetic materials from their natural counterparts. The book also deals with the current cutting and polishing (lapidary) facilities available in Pakistan and the trade of the Pakistani gemstones.

It is noteworthy that every naturally occurring gemstone has its own particular feature, which should be known before to explore it in the mountainous areas of the country. The last part of the book focuses on recommendations to improve the Gemstone Sector of Pakistan. Some of the materials related to recommendations are referred to a project report of SMEDA entitled "An overview of Gemstone Sector-Pakistan".

Appendix-I shows primarily the websites from where some of the materials related to the text of this book were downloaded and incorporated in their original forms. In appendices, tables showing comparison of Pakistani gemstones with other gemstones of the world, birthstones, glossaries, websites etc on gemstone and gemmological materials are incorporated.

The authors have written this book primarily for non-geologists and the gemstones lovers. However, it is hoped that the book will also prove useful to geologists and gemmologists working in the gemstone sector. The topic of gem-added is beyond the scope of this book and is excluded. Likewise the description on diamonds has been excluded, as the occurrence of diamonds in Pakistan has not been reported yet.

GEOGRAPHICAL PERSPECTIVE OF PAKISTAN

The Islamic Republic of Pakistan emerged as an independent sovereign country on August 14, 1947. It covers an area of 796,096 km^2, being equal to the combined areas of France, Belgium and Britain. Pakistan forms a bridge between the Middle East and the Orient, stretching in the extreme western tip of Balochistan from longitude 60°52′E to longitude 75° 22′E in the northeastern corner of the Punjab. Located in South Asia, Pakistan shares an eastern border with India and northeastern border with China. Iran makes up the country's southwest border, and Afghanistan runs along its western and northern edge. It stretches from 24° latitude on the arid cliffs of the Arabian Sea coast up to 37° latitude in the north, where the frontiers reach the permanent snowfields of the Pamir (Fig. 2.1). The Arabian Sea is Pakistan's southern boundary with 1,064 km of coastline. From Gawadar Bay in its southeastern corner, the country extends more than 1,800 km to the Khunjerab Pass on China's border.

Pakistan is a land of much splendour. The landscape changes northward from coastal beaches and mangrove swamps in the south to sandy deserts, desolate plateau, fertile plains, dissected upland in the middle and jumbled mass of mountains in northwest and north. The relief of the high Pakistan mountains is youthful: narrow valleys and steep, rugged peaks are their characteristic features. The great Indus River and its drainage basin form a dominant physiographic feature over a large part of the country. Some of the earliest civilizations on the sub-continent, one of the most brilliant in the chronicles of human history, flourished with its main centres at Moenjo Daro in Sindh, Harappa in the Punjab, Kej in the Baloch territory and Judeiro Daro in the Pathan region. It was here that Buddhist culture blossomed and reached its zenith under the Kushans in the form of Gandhara civilization at the twin cities of Peshawar and Taxila. It was on this very soil that the Graeco-Bactrian civilization had its best flowering and left the indelible marks of finest Greek art in the Potwar plateau around Rawalpindi. More recently excavations in Lasbela at Balakot have revealed even earlier evidence of human civilizations dating from 4,000 B.C and comparable with the earliest villages of Jericho in Palestine and Jarmo in Iraq.

Stretching in the north and from east to west, a series of high mountain ranges separate Pakistan from China, Russia and Afghanistan. These ranges include the Himalayas, the

Karakoram and the Hindu Kush, which also form the great continental divide between the Indian sub-continent and central Asia. The Himalaya, in Sanskirt, means the "home of snow". The people of central Asia call them the "Roof of the World". But the Hindus of India consider them as the "abode of gods" and worship them as such. The Himalayas stretch uninterruptedly for several hundred kilometres from west to east between Nanga Parbat in Pakistan and Namcha Barwa in Tibet.

Between these eastern and western extremities lie the three Himalayan Kingdoms of Sikkim, Bhutan and Nepal. The Himalayas are bordered to the northwest by the mountain ranges of the Hindu Kush and Karakoram and to the north by the high plateau of Tibet. The width of the Himalayas from south to north varies from 80 to 100 kilometer and can be grouped into four parallel, longitudinal mountain belts. They are designated as: (1) Outer, or Sub-Himalayas, (2) the Lesser or Lower Himalayas, (3) the Greater or Higher Himalayas and (4) the Tethys or Tibetan Himalayas. From west to east the Himalayas are divided broadly into three mountain regions: (1) Western, (2) Central and (3) Eastern. Viewed from the south, the Himalayas appear as a gigantic crescent with the main axis rising above the snowline, where snowfields feed the valley glaciers and constitute the sources of the most Himalayan Rivers, flowing southwest into Pakistan and southeast into India. The greater part of the Himalayas, however, lies below the snowline. The mountain building process that created the range is still active where river erosion and landslides accompany it.

One of the greatest splendours of Pakistan, rather of the world, is the Karakoram. The name means "small black rocks". Karakoram became the official spelling of the mountain range originally designated by the Survey of India. Protected on all sides by other mountain ranges, they form the greatest barriers on earth to the mass migration of people. In fact nobody knew about the Kararkoram mountains and their highest peaks, deep and steep gorges, and beautiful valleys before 1860. Godwin Austen launched the first significant attempt towards the exploration of this region in 1861 that was serving as the Surveyor General in the British Government of India. His attempt on the Muztagh Pass and his ascent of the Baltoro glacier led to the first close-up view of the massive ramparts of the Gasherbrum Range, Broad Peak and K2 itself. Each group of mountains within the Karakoram is called a Muztagh. From west to east there are seven Muztaghs; Batura, Hispar, Panmah, Baltoro, Siachen, Rimo and Saser. Each Muztagh derives its name from the major glacier/river system draining that group of peaks; together these seven Muztaghs form the greater Karakoram. Overall the Karakoram Mountain Range is more than 400 km long and over 100 km wide, running in an arcuate shape along the northern borders of northeastern Afghanistan, Pakistan and India, and the southern borders of the Tajikistan and the Xinjiang-Uygur (Autonomous Region of China). South of the Karakoram, the Trans-Himalayan Range runs parallel until the Shigar Valley area around Skardu, and includes the high Deosai Plateau. The Karakoram serves as a watershed for the basins of the Indus and Tarim rivers. The formation of river channels for the most part, occurs in the high altitude zone; the melted waters of seasonal and perpetual snows and glaciers being the principal feeders of these rivers. During winters, huge layers of ice are formed, which add to the beauty of the scenery. Exceptional severe natural conditions in the Karakoran Range make survival difficult for human beings. The Karakoram Highway, linking Pakistan with Xinjiang province of western China, is the only motorable road that crosses the Karakoram Range. Built over 20 years, it was completed in December 1979 at a cost of over 400 lives on Pakistani side. The highway follows the Indus River upstream from Thakot through Besham, Chilas, Bunji and Jaglot then turns west up the Gilgit Valley and finally northwards up the Hunza Valley.

The Hindu Kush range, 1600 km long and possibly 323 km wide, lies to the northwest of the Karakoram and runs parallel to the Oxus River in northwestern Pakistan and northeastern Afghanistan. The name "Hindu Kush" is generally interpreted as "killer of Hindus," but Commander James Rennel interpreted it as a corruption of "Indian Caucasus". The origin of this name is believed to date 450 years back when thousands of the lowland captives died while crossing these mountains due to extreme cold and pressure of the armies of Babur. Down the centuries, the passes across the Hindu Kush have been of immense historic and military significance, providing access to adventurers and invaders from or through central Asia access to the fertile northern Indo-Gangetic plains of south Asia. The centerpiece of the Hindu Kush range is Tirich Mir, towering more than 7,794 m. The mountains of the Hindu Kush diminish in height as they stretch westward and merge with the Koh-i-Baba, and other lesser mountain ranges.

Pakistan boasts of the largest share of the highest mountain peaks in the world and in its borders stand at least 40 giant peaks over 7,315 m. There are a total of 14 main peaks soaring above 8,000 m in the world. Out of these, 8 are located in Nepal, 5 in Pakistan and 1 in China. Pakistan's own highest peak famed and dreaded K2 (8,611 m), is the second highest in the world, being just some ropes short of the Everest in Nepal and is regarded as far more formidable to climb than its relatively facile superior. Nanga Parbat (8,125 m) is the second highest peak of Pakistan and no mountain in the world has a larger history of failures and disasters than Nanga Parbat. It has claimed more lives than any of the mountain peaks of the Himalayas and the Karakoram. So many mountaineers call it as the murderer mountain. It is also very well known that Pakistan has 7 of the 16 tallest peaks in Asia. Only in Baltistan over 45 peaks touch or cross the 6,000 m mark; in Gilgit within a radius of 110 km are over twenty four peaks ranging in height between 6,000 m to 8,000 m. The mountaineers generally consider these magnificent mountain peaks of Pakistan as the dreamland.

Northern Pakistan is also the most glaciated area than any other land outside the North and South Poles. Pakistan's glacial area covers some 13,680 square kilometres, which represents an average of 13 percent of mountain regions of the upper Indus Basin. Pakistan's glaciers can rightly claim to possess the greatest mass and collection of glaciated space on the face of the earth. In fact, in the lap of the Karakoram of Pakistan alone there are glaciers whose total length would add up to above 6,160 km^2. To put it more precisely, the southern flank of the Karakoram (east and west of the enormous Biafo glacier) has a concentration of glaciers, which works out to 59 per cent of its total area. Several glaciers are more than 65 km long and 1 km deep and fill the valleys. The Siachen glacier is 74 km long. There are several other large glaciers including Baltoro (62 km), Batura (58 km), Godwin Austen, Biafo, Chogolisa, Gondokhoro, Hispar (53 km) and Yazgil, etc. The Hispar joins the Biafo at the Hispar La (5,154 m) to form an ice corridor 116.87 km long. The Baltoro glacier fed by some 30 tributaries constitutes a surface of 1,291 km. It is, in fact, a treacherous and perpendicular wilderness where no one lives except the motionless mountains with all their mysteries, and mercurial moods.

South of these high mountains, the ranges lose their height gradually and settle down finally in the Margalla Range (600-700 m) in the vicinity of Islamabad. The western low mountains spread from Swat and Chitral hills in a north-south direction and cover a large portion of the North-West Frontier Province (NWFP). North of the River Kabul their altitude ranges from 1,800 m to 2,000 m in Mohmand and Malakand hills. South of the Kabul River spreads the Koh-e-Sofed Range with a general height of 3,000 m. Its highest peak, Skaram, being 5,200 m. South of Koh-e-Sofed are the Kohat and Waziristan hills (1,600 m) which are traversed by the Kurram and Tochi Rivers, and bounded on the south by Gomal River.

South of the Gomal River, the Sulaiman range runs for a distance of about 483 km in a north-south direction, Takht-e-Sulaiman (3,730 m) being its highest peak. At the southern end lie the low Marri and Bugti hills. The area shows an extraordinary landscape of innumerable scarps, small plateaus and steep craggy outcrops with terraced slopes and patches of alluvial basins, which afford little cultivation. South of the Sulaiman range is the Kirthar range, which forms a boundary between the Sindh plain and the Balochistan plateau. It consists of a series of ascending ridges running generally north to south with a broad flat valley in between. The highest peak named Kutte ji Kuber (dog's grave is 2,291 m). The valleys are green with grass and admit cultivation up to a highest of 1,000 m.

Although the country is in the monsoon region but on the whole, Pakistan is an arid land, except for the southern slopes of the Himalayas and the sub-mountainous tract, which has a rainfall from 76 cm to 127 cm. Balochistan, is the driest part of the country with an average rainfall of 21 cm. On the southern ranges of the Himalayas, 127 cm of precipitation takes place, whereas in Gilgit and Baltistan, rainfall is hardly 16 cm. It is to be noted that a large part of the precipitation in the northern mountain system is in the form of snow, which feeds the rivers continuously.

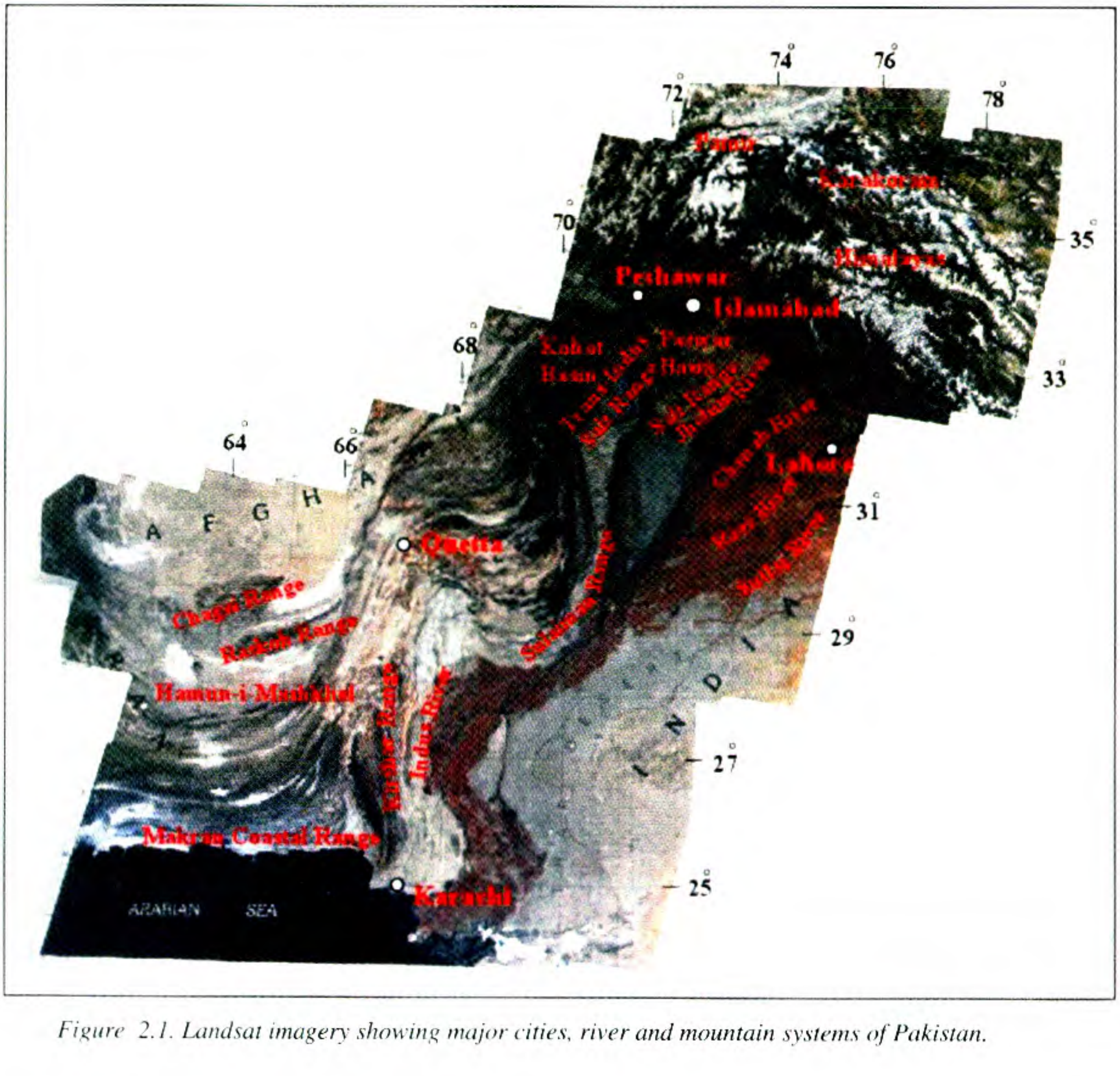


Figure 2.1. Landsat imagery showing major cities, river and mountain systems of Pakistan.

TECTONIC FRAMEWORK OF THE INDO-PAK SUBCONTINENT

The arcs, oroclines and syntaxes characterise Pakistan's geology, as there is no other country where mountain belts bend so often, and so severely. In the present plate tectonic setting, Pakistan lies on the northwestern corner of the Indian lithospheric plate representing part of the Tertiary convergence between the Indian and Asian plates. The deformation style and structure on the edges of these plates mimic their past and present inter-relationships. The tectonic setting of Indo-Pakistan subcontinent is an integral part of global tectonics. It is related to the formation and break-up of the super-continent Pangea, the rotation of the different continents relative to each other and opening and closing of major present day and paleo-oceans, such as the Tethys, Pacific, Atlantic, and Iapatus. These events led to rifting; shear movements, uplifts, and volcanic activities. During the late Paleozoic, most of the continental masses were joined to form one great super-continent called Pangea. During the Carboniferous to Early Permian, Pangea began to break up into Laurasia (Eurasia) continent in the north and Gondwana continent in the south (Fig. 3.1). A major new ocean called Tethys was created between these drifting continents. During the Jurassic and Early Cretaceous, the Gondwana continent also fragmented as further sea-floor spreading complicated the paleography of the Indian Ocean. During the Early Cretaceous, India, Madagascar and Seychelles were joined and they shared a common pre-120 million years stratigraphy. The tectonic history of the area becomes less clear due to lack of data and the overprinting of the older tectonics by younger ones.

Rifting of India from Africa and Madagascar probably started in the Cretaceous. By 65 million years at the Cretaceous-Tertiary boundary, a large, wide Tethyan ocean separated India from the South Asia margin. This margin comprises the Karakoram-Hindu Kush in the west and Lhasa block in the central and eastern segment. The initial northward drift of the Indian plate from Campanian to Middle Eocene was rapid at a rate of 130-150 mm/year. The counter clockwise rotation of the Indian plate relative to Asian around a close pole during Early Eocene was coincident with the reduction of its velocity to 40-60 mm/year, which finally settled down to 2 mm/year from Early Oligocene to the present (Patriat and Achache, 1984).

The continued under thrusting of the Indian plate since Cretaceous as it crowded northward into the Asian plate narrowed part of the Tethys Sea between the landmasses until it was destroyed. Sediments that had been laid down on the continental shelf extending south of Asia were bulldozed before India's relentless advance and produced the spectacular mountain ranges of the Himalaya-Karakoram and a chain of foreland fld-and-thrust belts (Valdiya 1984). The Himalayas show perfect continent-to-continent collision after having gone through the earlier stages of subduction, magmatism, and collision. The building of the highest mountain chain is also related to the opening up of the Indian Ocean as the Indian plate was displaced from north to northeast at different movement rates from post-Jurassic to recent times. In addition, crustal shortening, that is, compression of the cratons as they moved towards one another in the outer zone, appeared to exceed 2,000 km and has caused redeformation of major segments of this accreted collage of plates. Such a simplistic summation of the dynamic processes says little of the precise roles played by the kind of subduction process, the progression of the collision, or the buoyancy factors in the building of this unique and complex mountain range.

In the case of continental collisions, intensely compressed and metamorphosed ultramafic rocks and basalts commonly define a suture zone where two plates collided. Such zones are all that is left at the surface of a former oceanic zone that separated the two continents before collision. In the Indian Himalayas, northern collision zone has been identified as Indus-Tsangpo Suture (ITS), Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT). The collision zones in the northern Pakistan have been subdivided as the Main Karakoram Thrust (MKT), Main Mantle Thrust (MMT), Main Boundary Thrust (MBT) and the Salt Range Thrust (SRT).

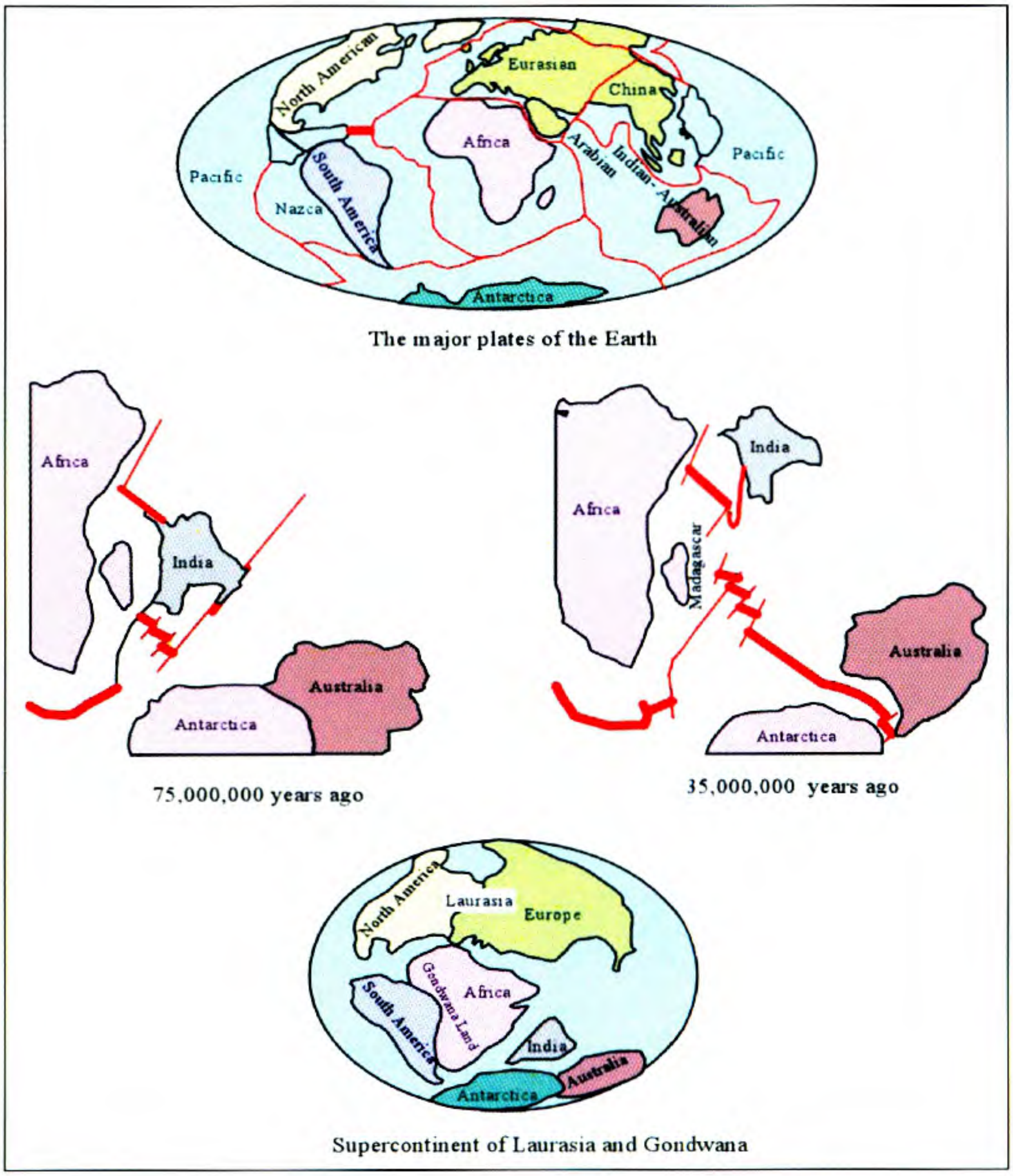


Figure 3.1. Tectonic history and the break up of Gondwana and Laurasia and the northward movement of the Indian (Indo-Pak) continental plate.

Indo-Pak continental plate is made up of Pre-Cambrian to Cambrian basement rocks and Palaeozoic to Mesozoic and Tertiary cover sediments. Pre-Cambrian basement rocks are exposed along the Sargodha High about 80 km south of the SRT. Its east-southeast trend parallel to the main Himalayas corresponds to the lithospheric flexural bulge developed due to northward under thrusting of the Indian plate and loading of south verging thrust sheets

(Duroy et al., 1989). Several episodes of plutonic activity ranging from Pre-Cambrian to Permo-Triassic and even Himalayan age have been recorded in the Indo-Pak continental margin. The Himalayas of northern Pakistan consist of three major tectonic provinces separated by the MBT and MMT (Fig. 3.2). South of the MBT, the Kohat and Potwar Plateaus expose unmetamorphosed Mesozoic and Tertiary sedimentary rocks and Neogene foredeep sediments deformed by folds and thrust faults. The rocks between the MBT and MCT record a transition from- the unmetamorphosed fold and thrust belt to the south -to high-grade metamorphic rocks in the footwall of the MMT. This region is referred herein as the Himalayan foothills; the topography between the MBT and MMT gradually rises in elevation northward toward the high Himalaya peaks. Further towards north lies the Nanga Parbat Haramosh Massif. The rocks in the Massif are mainly remobilised granitic augen gneiss, slate, quartzite, schist, paragneiss and amphibolite. The sequence of orogenic events that resulted in the formation of the Himalayan range also produced the gem pegmatite belt, which stretches through Afghanistan, Pakistan, India, Nepal and into Burma (Rossovsky 1975).

Karakoram lies along a critical juncture in the tectonics of central Asia. It is bounded to the south by the MKT; whereas to the north, less conspicuous, lies along the Tas Kupruk zone of Kafarskyi and Abdullah (1976) and its eastward prolongation, associated with alkaline femic volcanics (Zanchi et al., 1997) that may represent the Paleo-Tethyan suture, separating Karakoram from Hindu Kush-Pamir. Following Ganser (1964), the Karakoram unit is usually subdivided into three main parallel sub-units, from north to south: (1) Northern sedimentary belt is made up of a pile of thrust sheets (Zanchi and Gaetani, 1994). The most complete succession consists of a 5 to 7 km thick pile of sediments, discordant on a pre-Ordovician crystalline basement, and extending mostly under marine conditions up to the earliest Cretaceous. Isolated plutons intrude these sediments, (2) The Karakoram batholith covers about 30% of the range. Four intrusive episodes have so far been recognised in it, (3) Southern metamorphic belt is also predominantly made up of sedimentary series but the metamorphism accompanying the polyphased deformation usually reaches the amphibolite grade facies, and even, locally, the granulite facies (Rolland, 2000).

Geologically, MMT, Raikot Fault, and MKT bound the Kohistan terrane in south, east and north and northwest respectively. This terrane can be divided into six components. Southern Kohistan included the Jijal-Sapat and the Chilas complexes separated by the Kamila amphibolites. Northern Kohistan is dominated by numerous granitic plutons (Kohistan

batholith) and a sequence of arc-type volcanic rocks (Dir-Kalam group). The Chalt volcanics crop out along a linear belt approximately 300 km long immediately to the south of MKT.
The collision in the west is oblique along a transpressional fault zone. The discontinuous belt of ophiolites, which runs through the Bela and Zhob valleys represent the suture. Presently the Chaman/Ornach-Nal Transform Fault Zone (COTFZ) marks the western plate boundary. The triple junction located northwest of Karachi, is the eastern limit of the Makran Subduction Complex. The Indian Plate is separated from the African Plate along the Carlsberg Ridge. The Owen Fracture Zone is a transform fault which runs along the eastern boundary of the Arabian Plate, separating it from the Indo-Australian Plate for most of its length, and from the African Plate for a much shorter distance. It extends from the Carlsberg Ridge in the south, meets the Sheba Rift segment of the Aden Ridge, and then continues northeastward across the northwest Indian Ocean until it meets the convergence zone in the Iran-Pakistan border region where the continental crust of the Arabian Plate is colliding with the continental crust of the Eurasian Plate.

The mid Tertiary collision zone east of the COTFZ can be subdivided into stratigraphically and tectonically distinct regions: Collisional belt (Axial Belt) and Indus Basin. The Indus Basin is further subdivided into Upper, Middle and Lower Indus sub-basins and preserves sediments of Late Proterozoic to Cenozoic age. Commencing with Upper Proterozoic evaporitic and clastic units, which persist into the Cambrian, a widespread hiatus separates these sediments from the overlying Permian to Pleistocene strata, which record sedimentation spanning over 250 million years. Massive Cenozoic plate convergence with the Tethyan and Asian elements produced complex thrust and wrench geometries in the rocks of the northern and western parts of the Indus Basin.

The area west of collisional belt represents the Balochistan Basin, which include the Makran Subduction Complex and Kakar Khurasan Flysch Trough. The evolution of the Balochistan and Makran areas pursued a different fashion from that of the Indus Basin. The northward drift of the central Iran, Lut and Afghan microcontinents from the Gondwana, most probably started in Permian. The presence of arc associated volcanics in the Chagai and Raskoh magmatic belts of the campanian age suggest that a subduction complex has developed along the southern margin of these microplates, probably during the Cenomanian. The accreted Paleogene flysch gradually got younger from north to south. The pelagic condition, which prevailed during the Jurassic and Cretaceous were interpreted in the Late Cretaceous due to local uplift. The rapid erosion from the uplifted landmass to the north provided the sediments for the developments of thick turbidites in the south. In the coastal zone and offshore areas, the pro-grading shelf related sandstones with interbedded turbidites and mudstones of Panjgur and Parkini formations were deposited. The continuous subduction of the Arabian plate along Makran during the Middle Miocene uplifted large area in the north. The rapid erosion of Oligocene and Early Miocene rocks in the north accelerated the development of the accretionary prism to the south.

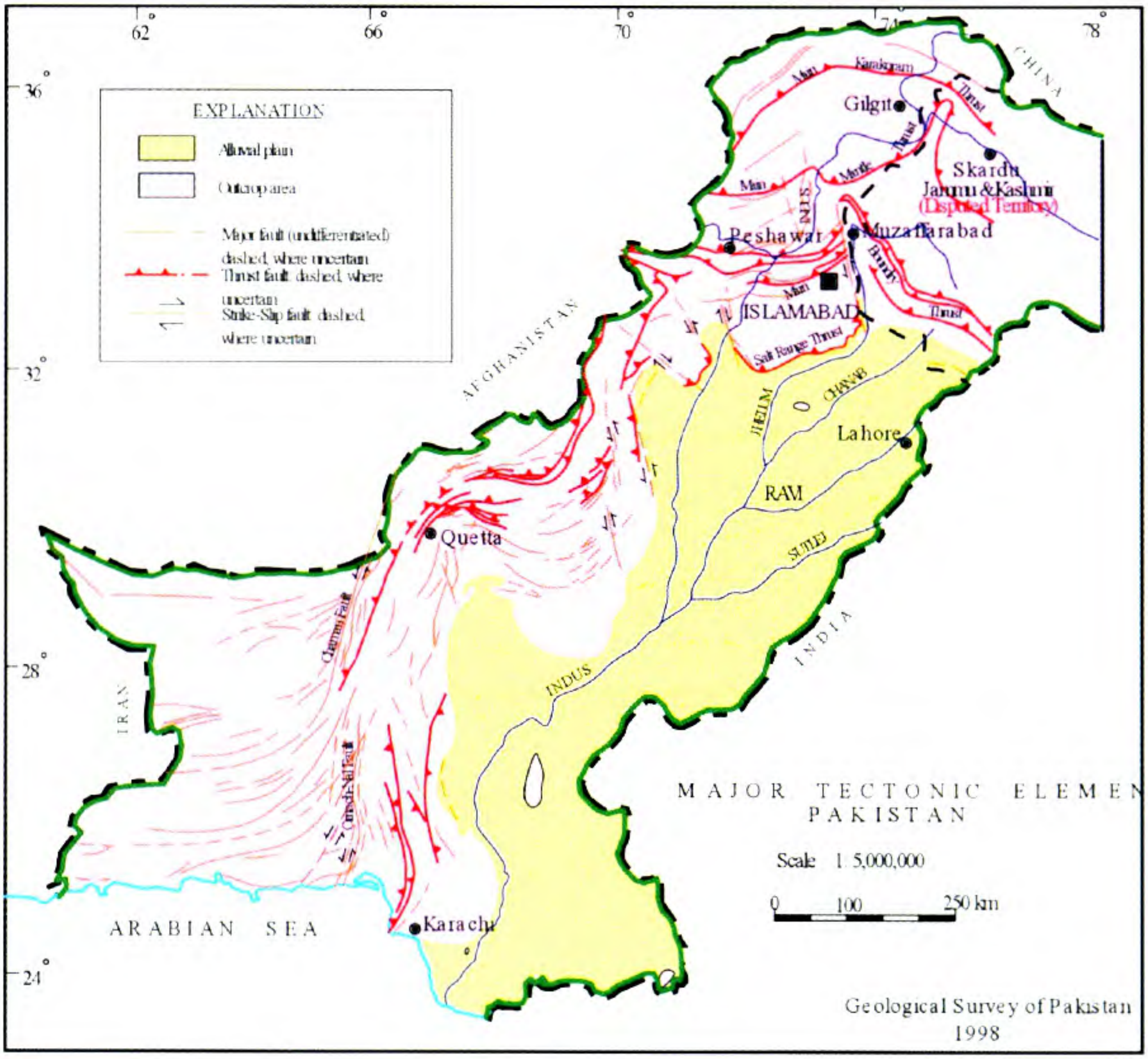


Figure 3.2. Tectonic Map of Pakistan showing different tectonic features of the country.

PHYSICAL, OPTICAL AND CHEMICAL PROPERTIES OF GEMSTONES

Most gemstones are rare minerals. They are naturally occurring inorganic crystalline elements or compounds with definite physical and optical properties, and chemical composition. In order to get clear idea about the nature and quality of a gemstone, various methods are applied. These methods range from physical to chemical including destructive ones such as crushing and classical wet analysis. The destructive methods are least desirable but only applied when broken and useless material is available for study.

Physical properties

Crystal structure

Gemstones may be formed in single or multiple discrete crystals (such as diamond), in massive collections of microscopic crystals such as chalcedony, or in amorphous or non-crystalline masses such as opal. In general, larger crystals were formed in areas of slow cooling of molten rock, and smaller crystals in areas of more rapid cooling. There are several classes of crystal structure based on symmetry of the resulting crystals, and there are also non-crystalline minerals used as gem materials. In addition, there are some organic materials (such as shell and bone) that have been used traditionally as gem materials.

Cubic crystals in the cubic or isometric system have three mutually perpendicular axes of equal length (Fig. 4.1). Common forms in the cubic system are the tetrahedron (4 faces), the cube (6 faces), the octahedron (8 faces), the dodecadehedron (12 faces), the trapezohedron (24 faces), and the hexoctahedron (48 faces). Gemstones occurring in cubic system include diamond, the garnets and spinel.

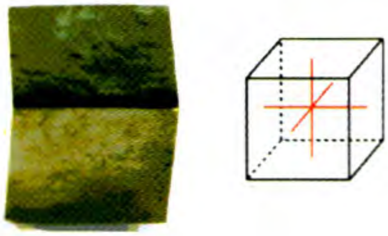


Figure 4.1. Cubic crystal system. Example: Pyrite.

Hexagonal crystals in the hexagonal system have four axes, three of which are of equal length and intersect at 60 degree angle within a plane, and the fourth, which is perpendicular to the plane of the other three (Fig. 4.2). Gemstones occurring in hexagonal crystals include beryl, corundum, apatite, quartz, and tourmaline. Some crystallographers further identify two subdivisions of hexagonal system: trigonal (corundum) and rhombohedral (quartz).

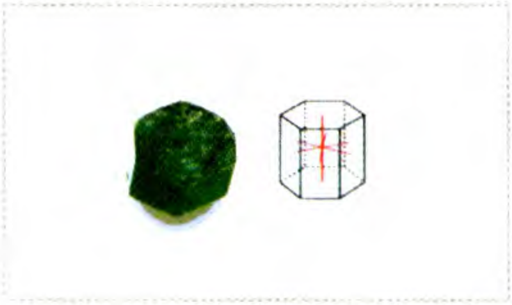


Figure 4.2. Hexagonal crystal system. Example: Beryl.

Tetragonal crystals have three axes intersecting at 90-degree angle, two of which are of equal length (Fig. 4.3). Examples include zircon, rutile and scapolite.

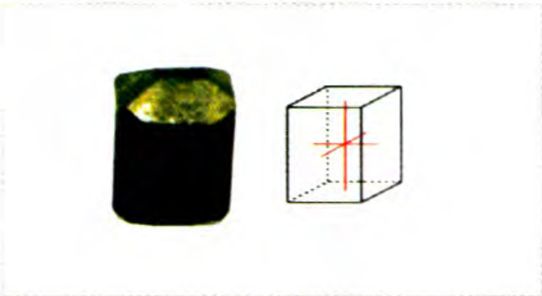


Figure 4.3. Tetragonal crystal system. Example: Idocrase.

Orthorhombic crystals have three axes at 90-degree angle, all of which have different lengths. Examples are topaz and barite (Fig. 4.4).

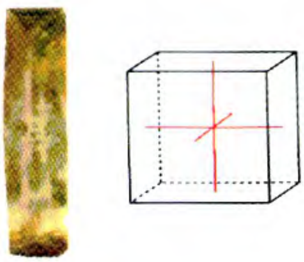


Figure 4.4. Orthorhombic crystal system. Example: Barite.

Monoclinic crystals have three axes of unequal length, two of which intersect at an angle other than 90 degree, and both perpendicular to the third (Fig. 4.5). Jadeite and nephrite are common examples.

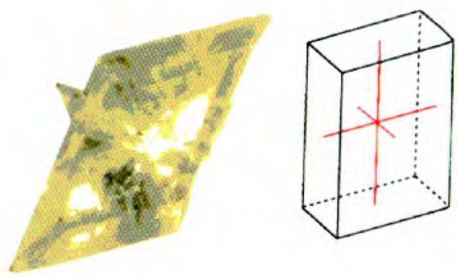


Fig. 4.5. Monoclinic crystal system. Example: Gypsum.

Triclinic crystals have three axes, all of unequal length and intersecting at angles other than 90 degree (Fig. 4.6). Examples include labradorite and microcline feldspars.

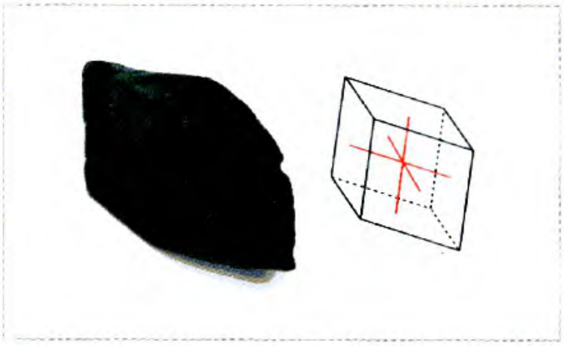


Figure 4.6. Triclinic crystal system. Example: Axinite.

Optical characteristics

Optical characteristics of gemstones are primarily derived from their chemical composition and crystal structure.

Colour: Colour is the apparent result of selective absorption or reflection of different frequencies of visible light. Colour can be described as the combination of three characteristics: hue, tone, and intensity. Hue is a function of the frequency of light and is described by familiar terms such as red, orange, yellow, green, blue, indigo, and violet. Tone is a variation from very light to very dark. Intensity is a measure of saturation or purity of a colour. The typical human eye can identify approximately 150 pure hues. The differences among colours may be immediately obvious or so subtle that direct comparison under controlled conditions is required to discern them. Colour acuity is also highly affected by fatigue, diet, and other factors, so it is unwise to attempt judging slight colour differences in gemstones such as diamond without attention to the physical and emotional condition of the observer, as well as properly graded comparison stones and careful control of lighting conditions.

Pleochroism: Pleochroism is the apparent change in colour of a doubly refractive gemstone when viewed through different directions of the crystal structure. In most cases, colour variations are not obvious to the unaided eye and must be viewed through a polariscope or dichroscope, but in some cases, pleochroic colours are strikingly obvious. For example, many green tourmalines appear black through C-axis of crystal. Dichroism refers to the display of two ("di") pleochroic colours in a gemstone. Alexandrite-like colour change, or photochroism, is the marked change in perceived colour of a gemstone under different lighting conditions. As the name implies, the most famous example appears in alexandrite, a form of chrysoberyl that typically appears blue or green in daylight and red or purplish in incandescent light, but similar colour changes may be observed in sapphire, garnet, and tourmaline. The phenomenon is due to selective absorption of different wavelengths of light, and predominance or absence of those wavelengths in the prevailing light (incandescent light has proportionately higher quantities of reddish wavelengths and less of blue or green).

Optic character: Gemstones may affect the passage of light differently through different directions in the crystal structure. If velocity of light is constant through all directions in the stone, the stone is said to be singly refractive, or isotropic, and has one refractive index. This is characteristic of isometric crystals. If velocity of light varies with direction, the stone is doubly refractive, or anisotropic, and has two refractive indices. In anisotropic materials, light is separated into two polarized components, ordinary ray and extraordinary ray. Anisotropic materials can be further characterised as uniaxial and biaxial positive, and uniaxial and biaxial negative. Amorphous (non-crystalline) materials, such as opal, amber and glass, may scatter light in unusual directions due to internal stress and display a phenomenon known as anomalous double refraction.

Refractive index: Refractive index or R.I. is the ratio of velocity of light in air to the velocity of light through a transparent material. If light passes from air into a transparent material at an angle of incidence other than 90 degree angle, it is deflected at different angle (coincident angle) according to the R.I. Gemstones with higher R.I. are generally more brilliant than those with low R.I., e.g. diamond has an R.I. of about 2.4 and quartz, 1.54-1.55. The R.I. of most gemstones is easily measured using a simple optical instrument known as refractometer.

Birefringence: Birefringence is the difference in value between the highest and lowest refractive indices in a doubly refractive (anisotropic) material. Depending on the orientation of a faceted stone, this can result in a "fuzzy" appearance and apparent doubling of facets viewed through the stone.

Dispersion: Dispersion is the ability of a gemstone to separate light into its component colours; that is, the quality of passing different wavelengths of light at different velocities. Dispersion is the quality in a diamond that produces sparkles of colour. Quartz (dispersion of 0.013) shows much less of this effect than diamond (dispersion of 0.044). Diamond, in turn, shows much less colour play than sphalerite (dispersion of 0.156).

Clarity: Gemstones can vary from complete opacity to lucid clarity and may contain few or many inclusions such as crystals of other minerals, gas- or liquid-filled cavities, or even insects. In some gemstones, such as emerald, certain inclusions are highly distinctive and can be used as reliable indicators of identity. A gemmological microscope (a binocular microscope with a typical magnification of 10X to 40X) is one of the most useful tools in identifying many gemstones, as well as grading them on relative clarity.

Specific gravity: Gem materials vary greatly in density-amber may float in salt water (density near that of water), while hematite is more than five times denser than water. That is why two different gemstones may have the same size but different weights and vice versa - one carat round brilliant diamond of typical proportions, will be approximately 6.5 mm in diameter, while a round brilliant ruby of the same size (6.5 mm in diameter) and proportions will weigh approximately 1.55 carats. Generally, gemmologists refer to specific gravity, or relative density -the ratio of the density of a gemstone relative to that of water.

Durability: The two most familiar qualities of durability -hardness and toughness-are often misunderstood. **Hardness** is resistance to scratching or piercing. It is often represented on the Mohs scale, a non-linear scale of scratch resistance varying from 1 (talc) to 10 (diamond). More precise, and less familiar, measurements of hardness are done using other systems, such as the Knoop scale of resistance to indentation. Because of the likelihood of physical damage, hardness tests are not recommended for gem identification. **Toughness** is resistance to breakage. The combination of the two largely defines the durability of a gemstone. Diamond is the hardest naturally occurring material and is also quite tough; however, it can be broken by a hard blow. Jadeite and nephrite (the jades) are much softer and relatively easy to scratch but are perhaps the toughest gem materials.

Cleavage: Cleavage refers to breaking of a gemstone along its crystallographic planes, which facilitates its identification. The interference colours developed within the stone or on its surface often reveal an indication that a stone possesses cleavage. Such rainbow-like colours can often be seen in fluorite, topaz and calcite crystals. Cleavage always ensues in certain directions, which can be properly observed. An example of a gemstone with octahedral cleavage is diamond. Spodumene has prismatic cleavage, topaz has basal cleavage, and calcite has rhombohedral cleavage. The quality of a gemstone cleavage is described as being perfect (as in case of diamond, fluorite and topaz), good (as with feldspar), distinct (andalusite, sphene), and poor (corundum, quartz).

Parting: Parting refers to the direction of weakness other than cleavage and is usually caused by a form of twinning. In other words, parting in a stone occurs at discrete intervals along the twinned crystals.

Thermal conductivity: Thermal conductivity (the ability to conduct heat) is very low in most gemstones but is extremely high in diamond (from 1.6 to 4.8 times as great as in pure silver!). This unusual property of diamond is the basis for several popular diagnostic probes that are used to distinguish diamond from its numerous imitations. Resistance to chemical degradation or to changes in temperature or humidity is important. Turquoise is often quite porous and can be discoloured by exposure to oils. Opals are heat-sensitive and have high water content; sudden temperature changes or extremely dry conditions can cause them to crack.

Fluorescence: Many materials are fluorescent, i.e. when exposed to ultraviolet (UV) light or X-rays, they transform some of the incoming energy into visible light. The colour and intensity of the fluorescence is often indicative, but not conclusive, of the identity of the material, e.g. natural yellow sapphires from Sri Lanka show a distinctive apricot-coloured fluorescence, while synthetic yellow sapphires generally show no fluorescence or a dull red when exposed to long-wave UV light. Most natural emeralds are inert (non-fluorescent) under long-wave UV, and most synthetic emeralds show a moderate to strong red fluorescence. Because of the prominent exceptions, this test alone is inconclusive.

Phosphorescence: If a fluorescent material continues to emit light after ultraviolet or X-ray light is removed, it is said to be phosphorescent. This phenomenon usually lasts only a few seconds but may occasionally persist for much longer period. This is a relatively rare characteristic in gemstones.

X-ray: X-ray source can be used to discriminate between natural and cultured pearls by means of a contact X-ray picture and to distinguish between diamond and its simulants. A technique called X-ray topography is used to distinguish crystal defects in diamonds. X-ray is used to scan the diamond, which is positioned so that the beam is diffracted by the atomic layers in the crystal lattice. The emerging X-rays fall on a photographic plate to produce a projection photograph of the stone. Gemstone identification can be achieved by means of X-ray diffraction (XRD) using a powder sample of the specimen (i.e. scrapping).

Chemical properties

Chemical composition

A gemstone may be a pure chemical element (diamond is essentially pure carbon), a relatively simple chemical compound (quartz is silicon dioxide, SiO_2), or a more complex mixture of various compounds and elements (the garnet family comprises a highly variable mixture of iron, magnesium, aluminium, and calcium silicates). The great majority of familiar gem materials are oxides or silicates (i.e., they contain oxygen and silicon). Out of 90 naturally occurring elements in the Earth's crust, only eight of these account for the bulk of the crust. Of these eight elements, oxygen and silicon is the dominant pair, and it is these two elements, which combine together with the remaining six elements of aluminium, iron, calcium, sodium, potassium and magnesium. Any remaining silicon combines with oxygen to form silica. Silica is found worldwide as quartz and makes up around 12 percent of the Earth's crust and upper mantle.

It is worth mentioning that some gemstones are very durable whereas others are not. The durability, one of the essential qualities that make a mineral suitable for use as a gem, depend mainly on the chemical properties, i.e. chemical composition, crystal structure and the atomic bonding of the gemstone materials. For gemmological the gemstones can be divided into four main groups of silicates, oxides, carbonates, and phosphates.

Silicates: These are hard and very durable, and represent the majority of gems. For example:

Beryl: (emerald, aquamarine) $Be_3Al_2(Si_3O_6)$

Tourmaline: a complex borosilicate of aluminium and iron

Pargasite: $(NaCa_2Mg_4Al_2lSi_6O_{22}(OH,F)_2$

Peridot: $(Mg, Fe)_2SiO_4$

Topaz: $Al(F,OH)_2SiO_4$

Garnet group: silicates of various combinations of magnesium, manganese, iron, calcium, aluminium and chromium

Feldspar group: aluminium silicates in combination with calcium, potassium or sodium

Jadeite: $NaAl(SiO_3)_2$

Nephrite: complex calcium, magnesium or iron silicates

Zircon: $ZrSiO_4$

Oxides: These are generally hard and resistant to chemical attack. For example:

Corundum: Al_2O_3

Spinel: $MgO.Al_2O_3$

Chrysoberyl: $BeAl_2O_4$

Carbonates: These are soft and easily attacked by acids. For example:

Bastnasite: $(Ce,La)CO_3F$

Parisite: $Ca(Ce,La)_2(CO_3)_3F_2$

Synchysite: $Ca(Ce,La)(CO_3)_3F$

Calcite: $CaCO_3$

Malachite: $Cu_2(OH)_2CO_3$

Rhodochrosite: $MnCO_3$

Phosphates: These are soft and not very resistant to acid attack. For example:

Apatite: $Ca_5(F,Cl)(PO_4)_3$

Turquoise: a complex hydrated phosphate of copper and aluminium

The gemstones found in Pakistan are described according to the chemical composition as adopted in this manual for convenience.

IDENTIFICATION TOOLS

Many gemstones are quite similar in appearance and cannot reliably be identified on visual appearance alone. The tools used by gemmologists for the identification and grading of different gemstones, range from the simple to the high-tech and exotic. Most gemstones can be identified by a few basic tools that every gemmologist should have at hand (e.g., microscope, refractometer, polariscope, spectroscope and hand loupe). Often, a single test is not conclusive, and a gemmologist needs to perform several different tests to achieve a positive identification.

Microscope

One of the most useful tools for gemmologists is the microscope (Fig. 5.1). Simple model may be obtained for a few thousand of rupees, but better microscopes with enhanced accessories, cost several hundred thousand rupees. These microscopes provide both light field (lighting from below) and dark field (lighting from the side) views and usually have a magnification range from 10x to perhaps 100-200x. Magnifications of 10x to 40x are most often used, but the higher range is sometimes needed for careful inspection of inclusions.

Refractometer

Another required tool for gemmologists is the refractometer (Fig. 5.2). A small drop of liquid with a high refractive index (RI) of around 1.81 for standard instrument is placed on a refractometer prism and illuminated from a separate light source (sometimes white light, but a monochromatic light source provides better accuracy). The RI is then read from a magnified gauge on the front of the refractometer.

As the refractometer prism is relatively delicate, care should be taken to avoid scratching the contact surface. The amount of contact fluid placed on the prism should be limited to a drop 2 to 3 mm in diameter. Too much fluid with a very small gem will cause it to "float", while a gem with a large table facet will require a little more to ensure overall contact with the prism. Refractometer is also used to identify the optic character in the gemstones.

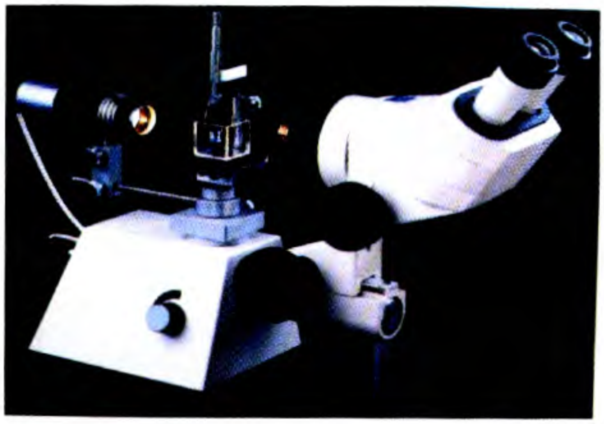


Figure 5.1. Photograph showing Immersion Stereo Zoom Microscope.

Figure 5.2. Photograph showing Refractometer.

Polariscope

The polariscope has two polarising filters and a light source below (Fig. 5.3). As the upper polarising filter is rotated, it allows a varying amount of light to pass through the system. A transparent gemstone held and turned between the crossed filters shows different patterns of light, depending on its optic character, and this can often be used to distinguish between different gemstones with similar appearance.

There are three basic tests that can be carried out using polariscope. One of these tests is employed to check the optical character of a gemstone; the second indicates the crystallinity of the stone, whereas the third reveals strain in the specimen (which may be indicative of a "paste", i.e. glass, gem).

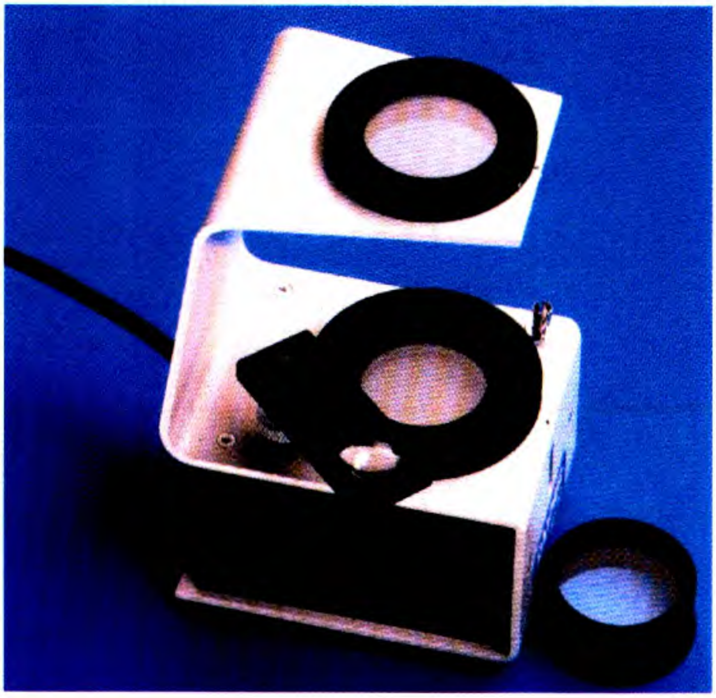


Figure 5.3. Photograph showing Polariscope.

UV light source

An ultraviolet (UV) light source, or black light, will reveal fluorescent activity in many gem materials, and this can help to identify many stones (Fig. 5.4). The majority of UV test units combine both Long Wave (LW) and Short Wave (SW) lamps, which can be operated either separately or together. Although UV lamps supplied for gemmological work have a relatively low UV emission, it is not advisable to look directly at them until special protective glasses are worn.

Figure 5.4. Photograph showing UV light source.

Chelsea filter

Chelsea filter is commonly known as the emerald colour filter (Fig. 5.5). It is one of the most helpful and productive of all colour filters and used primarily for recognising emeralds. It also identifies certain green, red and blue stones. The filter detects dyes in certain gems, like dyed green and blue chalcedony and must be used with intense light. Through Chelsea filter, many natural and synthetic emeralds appear red or pink; while most other green stones appear green. Synthetic blue spinel is seen as red in contrast with other blue gems which spinel imitates.

Figure 5.5. Photograph showing Chelsea filter.

Spectroscope

The spectroscope is sometimes used to separate natural from synthetic gem materials, as variations in chemical composition can be revealed in the absorption spectrum of light transmitted through the stone. These instruments can be quite simple, as shown here, or much more elaborate (Figs. 5.6, 5.7 and 5.8).

Figure 5.6. Photograph showing Spectroscope.

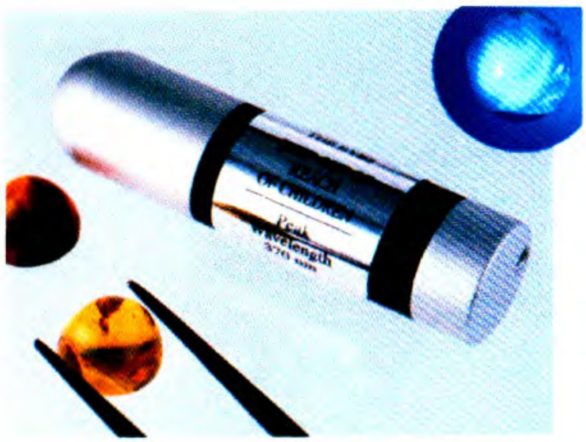
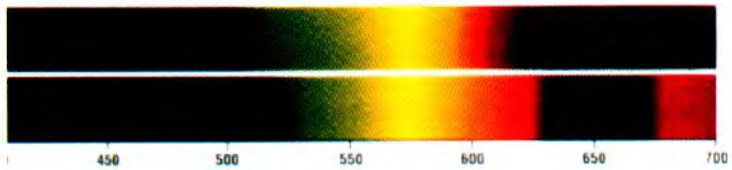


Figure 5.7. The lipstick-size (5.5x1.5 cm) long-wave portable ultraviolet lamp. Inset: Natural amber generally fluorescence blue under long-wave UV fluorescence (Boehm 2002).



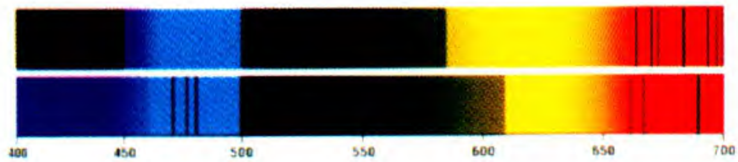


Figure 5.8. Spectroscopic figures show jadeite (natural colour and dyed; top and bottom of the first figure), and spinel (top) and ruby (bottom) of the second figure (Boehm 2002).

Hardness pencils are rarely used to test the hardness of a material, because they are by nature destructive. Occasionally, a gemmologist will attempt a very small scratch in an inconspicuous area of an object, such as a sculpture, but such tests should never be used until other tests are exhausted, and a faceted stone should never be subjected to a hardness test.

Diamond Tester is used for testing diamonds. The unit is switched on and a pointed tip of copper wire touches the diamond that is to be tested. A light will come on to indicate if the stone is a genuine diamond or not. When the tip is touched to the diamond, the meter will show green if it is a real diamond if not then it will remain in the red zone. This instrument can be used to test the diamond, as small as 0.02 carats. It can also separate coloured stones from one another. By merely touching the thermo electric probe to the gemstone, the relative heat conductivity of the material is exhibited on the dial.

Sets of several liquids of known specific gravity (Sp. Gr.) are sometimes used to distinguish between various materials that closely match in other characteristics. As the substrate of Sp. Gr. liquids evaporates, the Sp. Gr. changes, so such test sets must be recalibrated periodically. Specific gravity can also be tested on weight scales by comparing the weight of an object immersed in water with the weight of the same object in air. Another test often used to distinguish amber from its substitutes is simple immersion in a saturated salt solution; amber floats in salt water, but most of its imitations sink. Electron microprobe, Scanning Electron Microscope (SEM), X-Ray Fluorescence (XRF) (Fig. 5.9), X-Ray Diffractometer (XRD) and X-Ray Photographic techniques are used for the identification of inorganically formed gemstones and to differentiate between the naturals and synthetics and the imitations. A heated point can be used to separate some organic materials from their substitutes. For example, a hot point will elicit a sweet resinous smell from amber but an acrid odour from plastic.

Figure 5.9. X-Ray Fluorescence Element Analyser (XRF) [Horiba, Ltd., MESA-500].

GEMSTONE TREATMENTS

Many gemstones found, e.g., corundum, topaz, quartz, garnet, beryl, tourmaline, lazurite and agate are of low quality or represented by the varieties of the non-popular colours. The similar gems are often subjected to enhancement with the purpose of increasing their quality of transformation into more popular and precious varieties. Although the original material may have a natural origin, man's intervention has converted these materials into value-enhanced gemstones. As a result, the gemstone markets all over the world are flooded with artificially treated, synthetic and gemstone imitations.

Synthetic gemstones and imitations are produced in laboratories according to the desire and wishes of gemstone lovers. Keeping in view this desire, treatments are performed to improve the optical and other features, which can be termed treatment, enhancement or processing. The laboratory grown synthetic gemstones have the same appearance in optical, physical, and chemical properties as the natural material that they represent. The laboratory grown simulants and/or imitations have an appearance similar to that of a natural gemstone but have different optical, physical, and chemical properties.

Different properties can be affected or improved by treatment process, i.e., to change the depth of colour, to improve transparency and purity, and to increase mechanical stability and durability. It is not wise to sell any artificially enhanced gems without full disclosure of information about the treatment, and such treatments are properly documented and the treatment techniques are disclosed in gem markets when the stones are put for sale.

Treatment techniques

There are different techniques in use for the production of synthetic gemstones and imitations in different countries such as USA, Russia, Germany, France and Japan. These techniques are listed below (Hanni 2001):

Surface coating (e.g., vapour deposit, hydrothermal overgrowth)

Foil backing (painting, mirroring or back covering)

Impregnation with colourless organic substances (e.g., paraffin, epoxy)

Fissure filling with colourless organic substances (e.g. paraffin, epoxy)

Impregnation with dyes (using natural fissures or creating new ones)

Laser drilling (and subsequent dissolution of inclusion minerals)

Irradiation (electron-radiation)

Bombarding (neutron-radiation)

Heating (in controlled atmosphere)

Heating with protective or flux like substances (kryolite, borax)

Diffusion treatment (heating with adding chromophore trace elements)

Besides, **flame fusion method** (Verneuil,) and **flux-grown** (Ramura) are very common and popular methods for making the synthetic gems. In the flame-fused method, curved growth bands are the diagnostic feature (Fig. 6.1). Detailed description of some of the treatment techniques is given below:

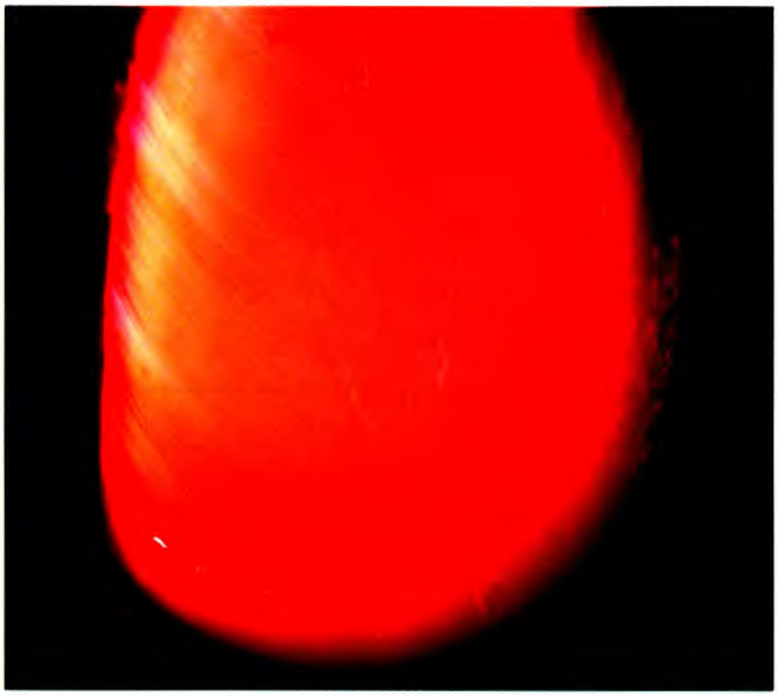


Figure 6.1. Curved growth lines in synthetic ruby (photo by Tahir Karim).

Gem enhancements

Many gemstones are treated to enhance their appearance (Fig. 6.2). This may be done to produce colours not usually found in nature, to improve colour, to improve clarity, to reduce porosity and stabilise colour (by preventing absorption of discolouring oils and other substances), or to enhance durability. Depending on the stone and the treatment, such alteration may be easy or impossible to detect. Here are a few examples of some of the methods frequently used: heat treatment, irradiation, impregnation, and assembled stones.

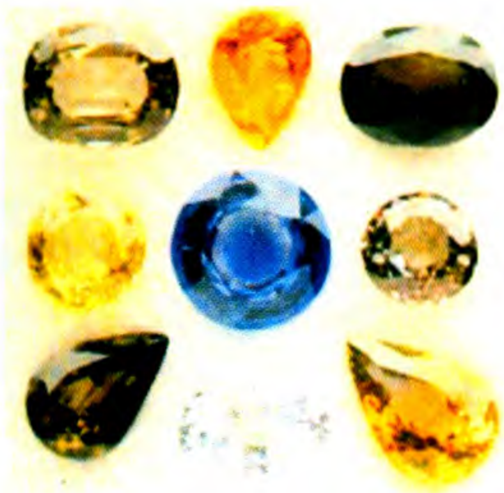


Figure 6.2. Some of the colours obtained by heat treatments of initially almost colourless sapphires by G.V.Rogers; note the yellow-blue bicolour at the lower right.

Heat treatment

Many gems are routinely heated under controlled conditions to improve colour (aquamarine, sapphire, ruby, tourmaline), alter colour (sapphire, amethyst to citrine, topaz, zircon), or improve clarity (sapphire, ruby). Since natural heating also occurs (e.g., in the volcanic areas), the artificial effects are sometimes indistinguishable from natural effects. In most cases, the results of heat treatment are permanent. The colour improvement is the annealing of diamonds done by applying high-pressure and high-temperature (HPHT) techniques (Gems and Gemology, 2002; Fig. 6.3).

Irradiation

Kunzite in the natural pink state after irradiation gives green colour that fades rapidly in light (Nassau 1994; Fig. 6.4). Colourless topaz is irradiated in large quantities and then heat treated to produce various shades of blue. Yellowish diamonds are often irradiated to produce a wide variety of colours. Other stones, such as tourmaline, are sometimes irradiated to enhance or produce new colours. In many cases, the effects of irradiation are somewhat unstable and can be reversed by heating.

Figure 6.3. Photograph showing heat treatment of diamond (1.07 ct) which changed from brown to green-yellow.

Impregnation and chemical treatment

Impregnation and chemical treatment alter the bulk of a material, or least penetrate the surface. This includes bleaches, colourless oil, wax, polymer, and glass impregnations; colourless fracture and cavity fillings, the analogous process with coloured materials; and various forms of dying.

Turquoise is often very porous and is sealed with wax or plastic resin to "stabilise" and improve the colour. "Black onyx" is almost always agate that has been impregnated with sugar, which is then washed by acid. Yellowish diamonds are sometimes coated on the girdle or pavilion with a thin bluish film to improve colour. Jadeite is sometimes chemically "bleached" and impregnated to improve colour, and this treatment can be difficult to detect.

In recent years, a new treatment for corundum has appeared, in which poorly coloured corundum is heated in chemicals to deposit a thin layer of enhanced colour on the surface of the stone. These stones can be quite impressive, but re-cutting removes the surface colouration and results in a very disappointing stone. Such treatment is easily detected by immersing the stone in a liquid with a high refractive index; the colour appears to concentrate along facet edges. Until mid nineties, only diffusion-treated blue sapphires were known, but the Journal of Gems and Gemmology Fall 1995 issue of Gemmological Institute of America (GIA), describes some diffusion-treated ruby, so other colours and perhaps other stones are likely to be entering the market.

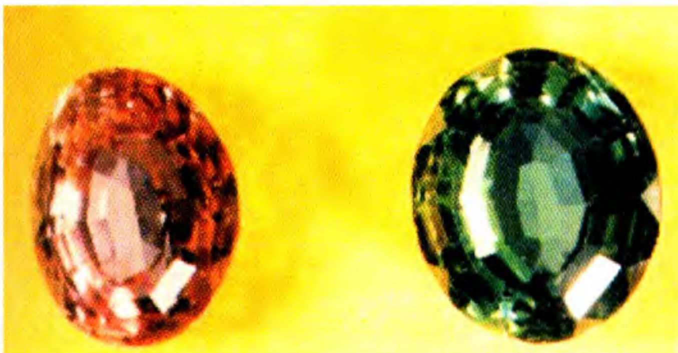


Figure 6.4. Kunzite in the natural pink state (left) and irradiated (right); the green colour fades rapidly in light (from Nassau 1994).

Assembled stones

Thin seams of opal are often assembled with backing of opal or black onyx to produce a doublet, and a clear quartz top is added to produce a triplet. In addition to making otherwise unusable material useful, the dark backing enhances the play of colour, and the quartz top adds to durability. Opal doublets and triplets must still be protected against heat and liquids.

After using these techniques, a huge number of synthetic gemstones and imitations are marketed. The most important synthetic gemstones are ruby (Fig. 6.5), emerald (Fig. 6.6), corundum, blue sapphire, orange sapphire, diamond yellow (high pressure and high temperature), diamond imitation-cubic zirconia of many colours, diamond-other imitations such as spinel, rutile, strontium titanate, yttrium garnet, gadolinium gallium garnet, moissanite, alexandrite, forsterite, peridot, opal (white, black and fire opal), phenakite, quartz including citrine, amethyst, smoky and rose quartz, spinel, jade and topaz. Since January 1999, Russian made gem-quality colourless to near colourless synthetic diamonds, which are available in the US market at prices more than double that of natural diamond. These diamonds have identifying metallic inclusions, which are magnetic and display Short-Wave Ultra Violet (SW UV) luminescence and phosphorescence, which differ from that of natural diamonds. Images from the De Beers Diamond View instruments are also diagnostic for these synthetic diamonds.

Figure 6.5. Photograph showing synthetic ruby and sapphire. Top: ruby and sapphire (Verneuil, flame fusion method). Bottom: Ramura (flux-grown).

It is believed that as the split sphere synthesis technology used in Russian factories or in factories under licensed to use the technology outside Russia become more productive and cost effective, the colourless synthetic diamond will eventually be in a position to compete against the natural diamond (Yuan 2000). The Gemmological Institute of Guangxi in the Peoples Republic of China has produced a new type of hydrothermally grown emerald

(Zhenqiang et al., 2001). Common diagnostic features of the new synthetic emerald included a strong reaction under the Chelsea colour filter, a moderate red Long-Wave Ultra Violet (LW UV) fluorescence and much lower chlorine and higher alkali element contents.

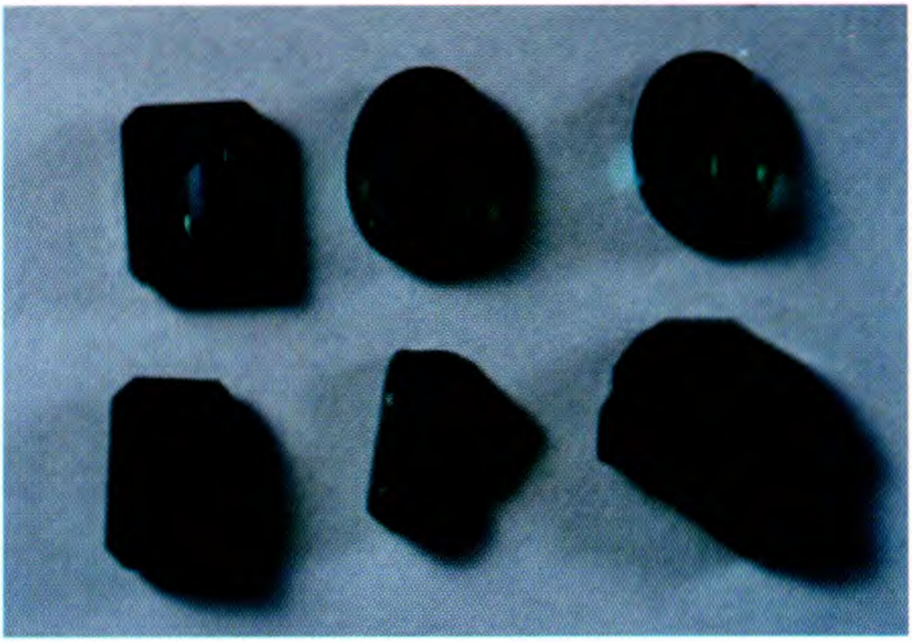


Fig. 6.6. Photograph showing synthetic emerald. Top: Baron Australia, hydrothermally grown. Bottom: Chatam, flux-grown.

GEMSTONE CUTTING AND POLISHING

There are many stones that people use and collect for all types of reasons. Some are very rare and expensive while others are found in great quantity at low prices. But each stone needs to be cut, shaped and polished for its greatest beauty (Fig. 7.1). The process of cutting and polishing gems is called gem cutting or lapidary, while a person who cuts and polishes gems is called a gem cutter or a lapidary (sometimes lapidarist). Gemstone material that has not been extensively cut and polished is referred to generally as "rough" (Fig. 7.2).

Figure 7.1. Photograph showing a citrine quartz and faceted stone.

Figure 7.2. Photograph showing rough corundum.

All gems are cut and polished by progressive abrasion using finer grits of harder substances. Diamond, the hardest naturally occurring substance, has hardness 10 on Mohs scale and is used to cut and polish a wide variety of materials, including diamond itself. Silicon carbide, a man made compound of silicon and carbon with a hardness of 9.5 on Mohs scale of hardness, is also widely used for cutting softer gemstones. Other compounds, such as cerium oxide, tin oxide, chromium oxide, and aluminium oxide, are frequently used in polishing gemstones.

Lapidary techniques

When a rough gemstone is brought to the factory for shaping and polishing, it is subjected to various processes. The following procedure is required to shape and polish a rough stone to a beautiful, well-shaped and polished stone. The material is cleaned first in acid, water or other fluid so that it can be examined very carefully and with ease. Hand lens or microscope is used to know about colour location, colour saturation, stone shape, clarity and inclusion location, degree of cutting angles, and identifying any present treatment of material and the preferred faceting style.

After the examination process, cutting is done by cutting wheel or with a slicing saw (Fig. 7.3). When the material has been given the basic desired shape, it is subjected to faceting and polishing. The faceting is done in four phases. First of all, the stone is properly attached to a cutting stick or a dop stick. When the faceting of the bottom of a stone is completed, the stone is detached from the dop stick and re-attached to cut the upper side. The last remaining part of the stone can be cut in many different ways depending upon the desired look and the best possible appearance. After faceting is completed, the stone goes to the polishing wheel where it transforms from a dull finish to a super shiny glowing gem.

Gem cutting is a skill of concentration, patience and knowledge. One can become a true master when he adds-in the two special ingredients in cutting: love and appreciation. Several common techniques are used in lapidary work such as sawing, grinding, sanding, lapping, polishing, drilling and tumbling. Using the techniques listed above, gemstones are typically fashioned into one of the several familiar forms, e.g., cabochons, faceted stones, beads and spheres, inlays and intarsia and mosaics, cameos and intaglios and sculptures.

Figure 7.3. Photograph showing sawing of a piece of smoky quartz.

Sawing

In most gems sawing, a thin circular blade usually composed of steel, copper, or a phosphor bronze alloy impregnated along the outer edge with diamond grit and rotating at several thousand surface feet per minute literally scratches its way through a gemstone. A liquid such as oil or water is used to wash away cutting waste and to keep the stone and the saw blade from overheating, which could cause damage to both the stone and the saw blade. Most gem cutters frequently use several sizes of circular rock saws.

There are also jigsaws that employ either a reciprocating wire or a continuous thin metal band. These are useful for cutting curved lines that are impossible with circular saws. They are also useful in minimizing waste on extremely valuable rough material.

Grinding

Grinding, usually with silicon carbide wheels or diamond-impregnated wheels, is used to shape gemstones to a desired rough form. As with sawing, a coolant/lubricant (water or oil) is used to remove debris and prevent overheating. Very coarse diamond or silicon carbide, such as 60 grit or mesh (400 micron) or 100 grit (150 micron) is used for rapid removal of stone, and finer abrasive (600 grit-30 micron, or 1200 grit-15 micron) is used for final shaping and sanding.

Sanding

Sanding is similar to grinding but uses finer abrasives. Its purpose is to remove deep scratches left by coarser abrasives during grinding. Since it removes material less rapidly, it also allows more delicate control over final shaping of the stone prior to polishing. For stones with rounded surfaces, a flexible surface such as a belt sander is often used to avoid creating flat areas and to promote smooth curves.

Lapping

Lapping is very similar to grinding and sanding, except that it is performed on one side of a rotating or vibrating flat disk known as a lap, and it is used especially to create flat surfaces on a stone (as in faceting). Laps are often made of cast iron, steel, or a copper-bronze alloy, but other materials can also be used.

Polishing

After a gemstone is sawed and ground to the desired shape and sanded to remove rough marks left by coarser grits, it is usually polished to a mirror-like finish to aid light reflection from the surface of the stone (or refraction through the stone, in case of transparent materials). Very fine grades of diamond (50,000 to 100,000 mesh) can be used to polish a wide variety of materials, but other polishing agents work well in many instances. Usually, these polishing agents are metal oxides such as aluminium oxide, cerium oxide, tin oxide, chromium oxide, ferric oxide and silicon dioxide. Different stones are often very inconsistent in their ease of polishing, particularly in the case of faceted stones, so gem cutters are often very inventive in trying new combinations of polishing agents and polishing surfaces- often tin, tin-lead, lead, leather, wood, or laps for flat surfaces such as facets. Rounded surfaces, e.g., cabochons, are often polished on leather, cloth or wood.

Drilling

When a gem cutter desires a hole in or through a gemstone (e.g., a bead), a small rotating rod or tube with a diamond tip, or slurry of silicon carbide and coolant, is used to drill through stone. Ultrasonic or vibrating drills are also very effective, but they tend to be costly and thus reserved for high-volume commercial drilling.

Tumbling

Large quantities of roughly shaped stones are often tumbled, i.e., turned at a slow speed in a rotating barrel with abrasives and water for extended periods (days or weeks). By tumbling with progressively finer grades of abrasive (usually silicon carbide) and washing carefully between grades, the stones are gradually smoothed and polished to very attractive shapes. Tumbling barrels are often hexagonal in outline in order to enhance the stirring action of barrel rotation. An alternative to rotator tumbler is a vibratory machine, often called a vibratory tumbler, in which the containing barrel vibrates rather than rotates. The more stationary arrangement of vibratory machines make it much easier to examine the progress of the stones inside, whereas standard tumblers must be halted in order to check progress. In addition to polishing gemstones, tumbling is often used to polish large quantities of metal jewellery.

Lapidary forms

Using the techniques listed above, gemstones are typically fashioned into one of several familiar forms

Cabochons

One of the simplest lapidary forms is the cabochon, a stone that is smoothly rounded and polished on top, relatively flattish, and either flat or slightly rounded on the bottom (which may be either polished or sanded; Fig. 7.4). This form of cutting is often used for opaque or translucent stones, but is also frequently used for transparent materials that contain too many inclusions to yield a good faceted stone. Colouration and patterning provide the major interest in such stones. Simply holding the stone in the fingers often performs cabochon cutting, but it is more commonly done by dopping (attaching the stone with adhesive wax or glue to a wooden or metal dop stick). This facilitates twirling the stone to form smooth curves and avoid flat areas during grinding, sanding, and polishing. A typical machine used for cabochon making holds several wheels of progressive series of diamond or silicon carbide grit, turned by a common motor, and a water supply that provides a coolant/lubricant to wash away debris and keep the stone from overheating as it is ground and sanded on progressively finer wheels.

Figure 7.4. Photograph showing a cabochon.

Faceted stones

Faceting is most often done on transparent stones. Flat facets are cut and polished over the entire surface of the stone, usually in a highly symmetrical pattern (Fig. 7.5). The stone is dopped (usually with adhesive wax, epoxy, or cyanoacrylate glue) on a metal dop stick, which is then inserted in a hand piece that allows precise control of positioning. The cutting angle is adjusted vertically via a protractor and rotationally via an index gear. The facets are then ground, sanded, and polished on a rotating lap, while water or another liquid acts as a coolant and lubricant. When one side (top or bottom) of the stone is finished, a jig is used to transfer the stone to a dop stick on the opposing side. In recent years, innovative faceters have employed techniques such as concave facets, grooves, and their combination to produce new forms in faceted stones.

Beads and spheres

Spheres are initially sawed into dodecahedrons (form of a cube) and then ground to shape between two pipes or rotating concave cutters and allowing the stone to rotate freely in any direction to form a perfect spherical shape. As with other lapidary processes, gradually finer grades of abrasive are used to grind, sand, and polish the gemstone. While beads may be faceted, they are more commonly cut and polished as small spheres and then drilled to allow stringing (Fig. 7.6). Bead mills are used to grind and sand large quantities of beads simultaneously. They typically employ a grooved lap and a flat lap between which the beads are rolled, and worn to shape. After shaping and sanding, tumbling usually polishes beads.

Figure 7.5. Photograph showing a faceted stone.

Figure 7.6. Photographs showing a string of beads (left) and a sphere (right).

Inlay

In an inlay, a gemstone is cut to fit and glued into a hollow recess in another material (metal, wood, or other stones) and then the top ground and polished flush with the surrounding material. Stones most commonly used for inlay are strongly coloured opaque stones such as black onyx, lapis lazuli, turquoise, tiger-eye etc (Fig. 7.7).

Figure 7.7. Photograph showing an inlay.

Intarsia and mosaic

In both intarsia and mosaic work, small bits of different coloured stones are fitted together and the top cut and polished to present a picture or other interesting pattern (Fig. 7.8). Strictly speaking, a mosaic is constructed on top of a flat base of another material (usually stone), while an intarsia (also known as Florentine mosaic) is set flush into the surface of the base material. The finest intarsia and mosaic were traditionally of Italian origin, but intarsia has enjoyed something of a renaissance in recent years with the fine work.

Figure 7.8. Photograph showing intarsia and mosaic work.

Cameos and intaglios

Cameos and intaglios are similar in that both usually are carved portraits in stones or seashells. They differ in that cameos are raised portraits, while intaglios are carved down into the surface of the material. Both typically take advantage of different coloured layers of material. The finest cameos and intaglios have traditionally come from Italy (usually shell) or Germany (usually agate).

Sculpture

Gemstones can be carved, like other materials, into almost any form. Carving is accomplished with a variety of diamond-impregnated steel bits, saws, and grindstones.

OCCURRENCE OF GEMSTONES

The crust of the earth has never been static. The Karakoram, Hindukush and Himalayas mountain ranges are the most active geological regions. Himalayas represent Indo-Pak continental plate whereas Karakoram, Hindukush represent Karakoram/Asian continental plate. In between the two continental plates lies an ancient Kohistan island arc, which represents mostly the north and northeastern parts of NWFP and Gilgit-Baltistan areas.

Geologically Indo-Pak continental plate is made up of Pre-Cambrian to Cambrian basement and Paleozoic to Mesozoic and Tertiary cover (Fig. 8.1). Several episodes of plutonic activity ranging from Pre-Cambrian to Permo-Triassic and even Himalayan age have been recorded. To the south lies the Himalayan fold belt: it comprises mostly sedimentary rocks of fore-deep and pre-cratonic shelf and consists of intensely deformed sediments of the outer Himalayan belt. To the north the Himalayan crystalline schuppen zone follows the belt: the precollisional crystalline rocks along the entire Himalayan belt represent this zone. Further towards north lies the Nanga Parbat Haramosh massif. The rocks in the massif are mainly remobilised granitic augen gneiss, slate, quartzite, schist, paragneiss and amphibolite.

Asian/Karakoram continental plate forms a part of the Karakoram-Himalayan Fold and Thrust Zone. Rocks exposed in this region are metamorphosed into phyllite, schist, gneiss, marble and amphibolite. These rocks follow the arcuate trend of major megashears in the area and show an increase in grade of metamorphism from south to north.

Kohistan island arc covers an area of about 40,000 km^2. It comprises igneous, sedimentary and metamorphic rocks. The three types of rocks are easily distinguishable. Igneous rocks, which are formed from magma or lava, are granular/glassy, hard and relatively fresh. They are coarse-grained (granites, gabbros etc), and fine-grained/glassy (rhyolite, basalt, obsidian etc). Igneous rocks are completely devoid of fossils. Sedimentary rocks are relatively soft and bedded (shale, sandstone, limestone etc). The process of erosion, transportation and deposition forms these rocks. Depositional features such as graded bedding, cross bedding are quite evident in them (sandstone). Some of the sedimentary rocks contain fossils (imprints of ancient dead animals and plants) such as in limestone. The metamorphic rocks are hard and granular. Minerals composing these rocks are aligned in certain directions thus making cleavages, laminations and layers (slate, schist and gneiss), which break with ease. At very low-grade, fossils may be present but at higher grades, they are completely absent.

Gemstone mineralisation in NWFP, Gilgit-Baltistan (formally known as Northern Areas of Pakistan) and Azad Jammu and Kashmir occurs in the Indo-Pak continental plate, Asian/Karakoram plate and in the suture zones. Gemstones like other mineral deposits are products of complex geological processes that have been operating on and inside the earth for millions of years (Keller 1990). Gemstones are originated from (i) surface water, e.g., the opals of Australia (ii) igneous hydrothermal/pneumatolytic activity (emerald deposits of Colombia, Pakistan, (iii) gem-pegmatites of Brazil and Pakistan (iv) metamorphism (ruby deposits of Pakistan, Myanmar (Burma), and peridot deposit of Pakistan and (v) gemstones formed at greater depths such as peridot deposits of Zabargad island of Egypt and diamond deposits of Argyl, Western Australia. Gemstones can be concentrated through action of water such as the gem gravels/placers of Sri Lanka and the African diamonds (Keller 1990).

Hydrothermal and pneumatolytic origin is related to the movement of hot fluids and gases that emanate when hot magma rises through the Earth's crust. Along the margins of the cooling magma, hot mineral rich solutions are given off and mix with cooling circulating groundwater that percolate downward from the surface. Gemstone deposits formed within the surrounding rocks by the process of igneous intrusions are called contact metamorphic or metasomatic deposits.

There are also some rare gemstones that mineralise in tectonically peculiar areas such as suture zones. The host rocks present in the suture zones (collisional plate boundaries), are very significant because they represent oceanic and upper mantle crusts and the present position of which is due to thrusting or obduction of one tectonic segment over the other. Here the process of mineralisation is also hydrothermal / pneumatolytic encompassing both igneous and metamorphic processes.

Of all the rock types encountered on earth, none is more gemmologically important for its variety and quantity of gemstones than the igneous bodies known as granitic pegmatites. Gem minerals are the result of the incorporation into the pegmatite of uncommon elements that are unable to fit in the crystal structure of quartz, feldspar, and mica, which make up the bulk of the pegmatites. These include elements of gemmological interest, such as beryllium, lithium, boron, manganese, phosphorous, and fluorine. Gemstones formed in this way are variable in size and much larger than their enclosing rock mineral composition.

Gilgit-Baltistan is world famous, amongst mineral collectors, for their granite pegmatites, which have produced vast quantities of gem-quality minerals (Fig. 8.2). Many of these pegmatites are well exposed and because of their resistance to erosion, standout as wall-like projections of light colour in a darker more weathered matrix.

Pegmatites, e.g., at Stak Nala contain cavities that were filled by colourful tourmaline. These pegmatites were known for their mineral pockets/large chambers reaching more than two metre in diameter. They were rounded or ovoid in shape, tightly packed with gem-crystals, and sometimes surrounded by yellowish or white clay. The general rule is that the larger the pocket, the larger the crystals. In some pockets, the crystals were packed tightly together, and it took considerable skill to extract them intact and unharmed. Similar to Stak Nala pegmatites, all gem-bearing pockets of the pegmatites were mined in Northern Areas for ruby, sapphire, spinel, garnet, aquamarine, tourmaline, topaz, quartz, fluorite and the combinations thereof.

Pakistan is world famous for its wonderful gemstones such as emerald of Swat, aquamarine of Somaiyar Nagir, tourmaline of Stak Nala, topaz of Katlang, peridot of Sapat Naran-Kohistan, ruby of Hunza and Azad Jammu and Kashmir, bastnasite of Zagi Ghar Warsak, garnet, pargasite, spinel etc.

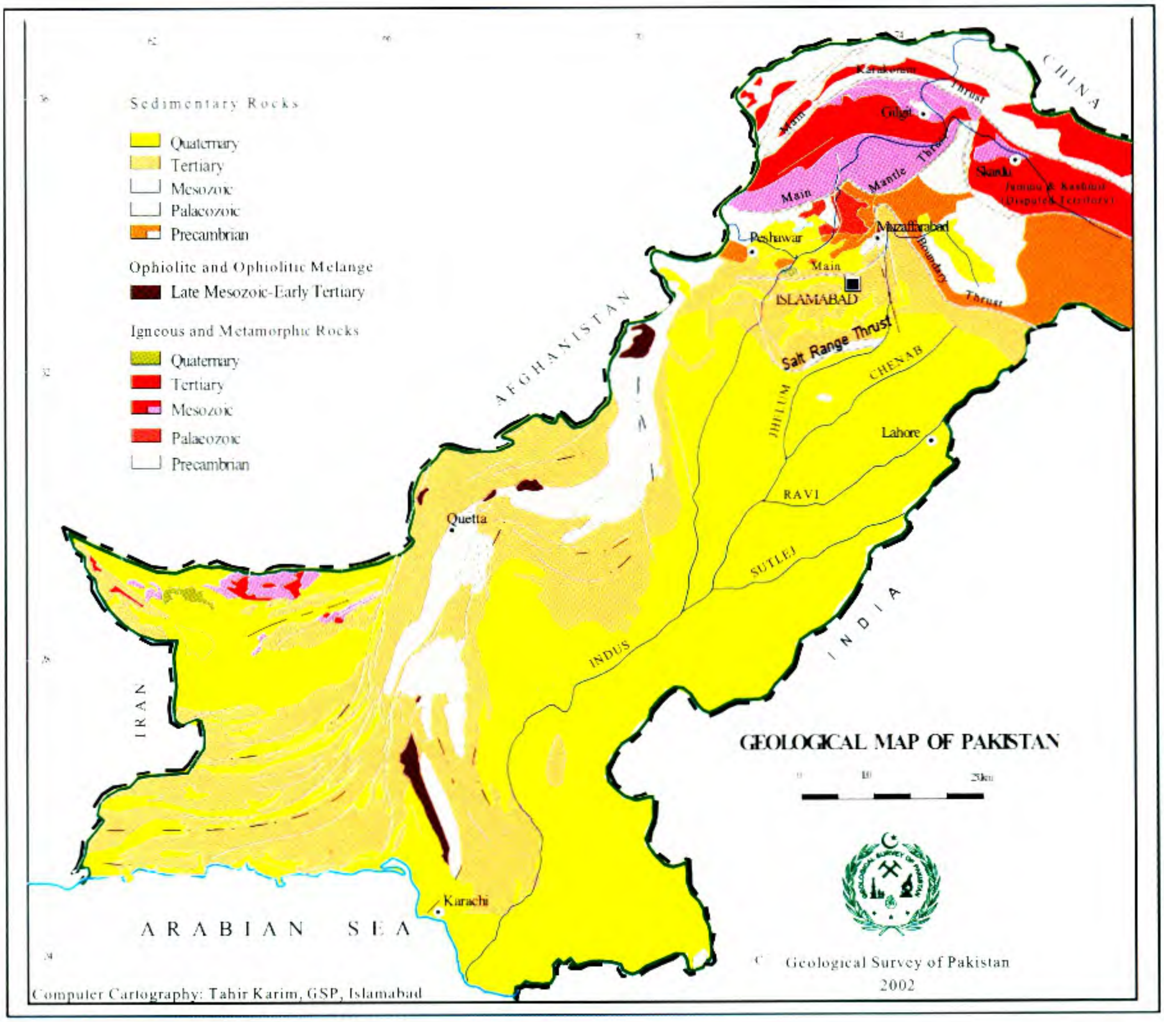


Figure 8.1. Geological Map of Pakistan.

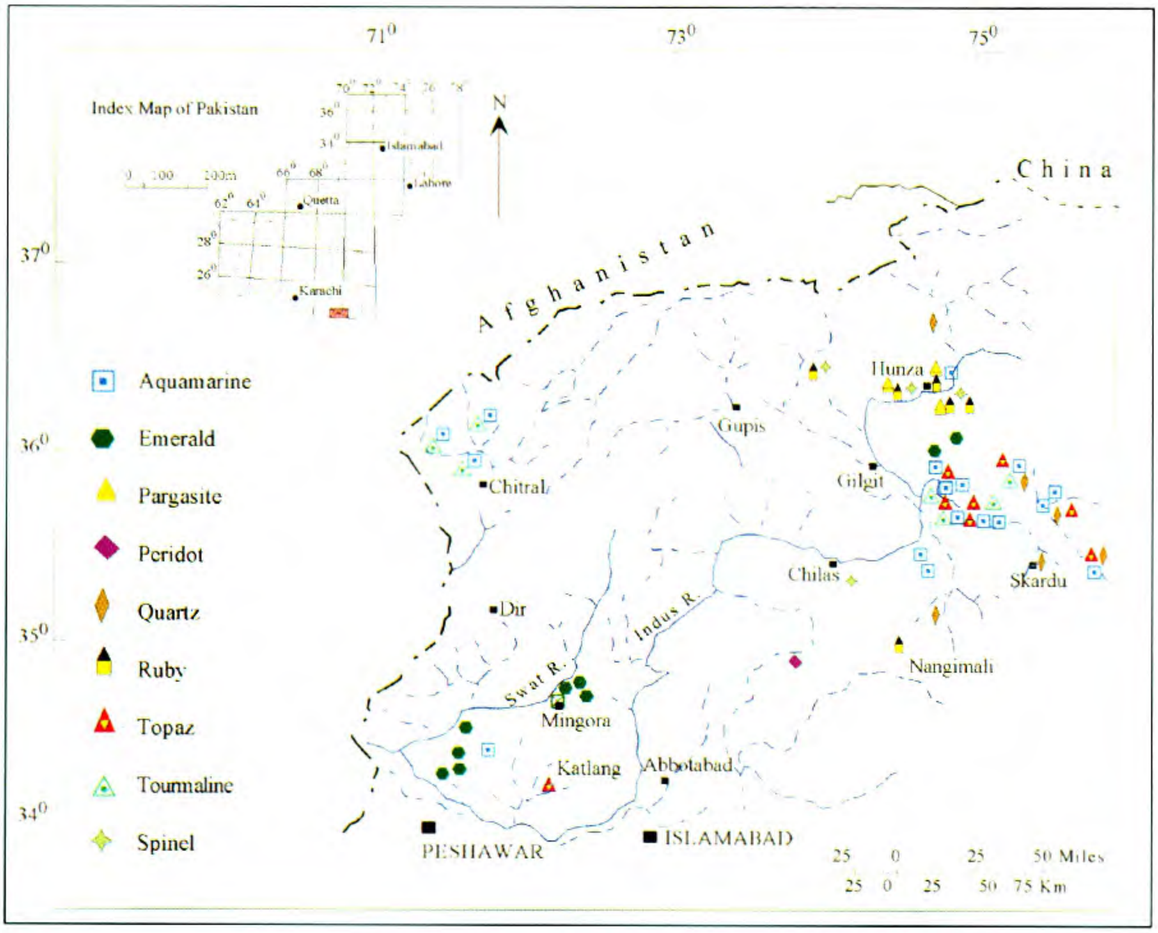


Figure 8.2. Map showing gemstone localities in Pakistan and Nangimali of Azad Jammu and Kashmir.

EMERALD

Emeralds are fascinating gemstones. They show the most beautiful, deepest and most brilliant green colours. Nevertheless, in top qualities, fine emeralds are even more valuable than diamonds. The name emerald was derived from French "esmeraude" which in turn goes back via Latin to the Greek root "smaragdos", meaning simply "green gemstone". There are uncountable adventure stories involving this splendid gemstone. Even the ancient Incas and Aztecs in South America, where the best emeralds are still being found today, worshipped it as a holy stone. Many centuries ago in the Veda, the ancient sacred writings of Hinduism, there were written down information on the valuable green gemstones and their healing power: "Emeralds promise good luck", or "The emerald enhances your well-being". It does not come as a surprise, then, that the treasure chests of Indian Maharajas and Maharanis contained most wonderful emeralds. One of the largest emeralds in the world is the "Mogul Emerald". It goes back to the year 1695, weighs 217.8 carats and is about 10 cm high. One side is inscribed with prayers: "He who possesses this charm shall enjoy the special protection of god". On the other side there are engraved opulent flower ornaments. The legendary emerald was auctioned off at Christie's of London for 2.2 million US dollars to an anonymous buyer.

Emeralds have been coveted ever since ancient times. Some of the most famous emeralds can therefore be admired in museums and collections. For example, The New York Museum of Natural History not only shows a cup from pure emerald, which was owned by Moghul Emperor Jahangir, but also a Colombian emerald crystal weighing 632 carats. The collection owned by the Bank of Bogota contains no less than five valuable emerald crystals weighing between 220 and 1796 carats. Also in the Irani State Treasure there are guarded some wonderful emeralds, among them the crown of ex-Empress Farah.

The good hardness may well protect emeralds from scratches to some extent, but its brittle structure and the many fissures can make cutting, setting and cleaning the stone somewhat problematic. Cutting emeralds always means a new challenge even for experienced cutters, on the one hand because of the high value of the rough crystal involved, on the othe hand because of the frequent inclusions. But this does not diminish their fascination with the unique gemstone. They have developed a special cut, especially for emeralds: the so-called emerald-cut. The clear design of the rectangular or square cut with its bevelled edges underlines the beauty of the valuable gemstone perfectly, while at the same time offering protection from mechanical strain. Emeralds, however, are also cut in many other, usually classical shapes.

The French chemist, N.L. Vauquelin (1763-1829) defined the correct chemical composition of emerald after he discovered chromium in crocoite and beryllium in "emerald from Peru two hundred years ago. He further discovered that the common difference between beryl $Be_3Al_2Si_6O_{18}$ and emerald was due to the presence of colouring agent "chromium". Other elements often present in small amount include traces of Fe, Na, K, Li, Cs and H. Emeralds are commonly characterised by their physical, optical and chemical properties as well as by nature of solid and fluid inclusions formed during their growth. The study of these inclusions can define the origin of emerald.

Occurrence

Beryl is not a common mineral in the continental crust, but it is significantly abundant in Al-rich granite and the associated pegmatite. Emerald has formed practically during all geological periods on the five continents of the world. The oldest emerald is formed in South Africa (Gravellote mines) during the Archean times (2.97 billion years ago). The Brazilian emerald from Carnaíba and Socota in Bahia state was formed during the Early Proterozoic (2.0 billion years ago). In Colombia, the Chivor deposits of the Cordillera Oriental (Eastern Belt) are about 65 million years old and those of the Muzo region about 40 million years old. The Muzo region is located in the Western Belt of Cordillera. Emerald of Rajhistan, India is formed 791 million years ago and Franqueira ones in Spain at 310-290 million years ago.

In Asia, Swat emerald has 23.5 million years age and that from Khaltaro, which is the youngest in the world, has 09 million years age. Emerald is also formed in different geological times in Afghanistan, Austria, Australia, Egypt, Madagascar, Mozambique, Norway, Russia, Tanzania, USA, Zambia and Zimbabwe. Most of the emerald deposits correspond to the episodes of continental collision tectonics, which generated the formation of mountain belts and huge area of deformation, uplift and erosion such as the great mountain chain of Himalayas. Some of the emerald deposits of the world are not related to the plate tectonic processes, and are resulted from the granite intrusions such as the emerald deposit of Australia.

In Pakistan, emeralds are found at Mingora, Gujar Killi, Shamozai, Charbagh, Makhad of Swat; Gandao (Tora Tigga of Mohmand Agency), Amankot of Barang in Bajaur Agency, Kot of Malakand Agency (?), and Khaltaro of the Gilgit-Baltistan areas (Fig. 9.1).

Typology

Emerald deposits can be typified geologically. The typology is based mainly on relationship between paragenesis of emerald and the geochemical processes responsible for its formation. Thus two types of deposits can be identified. Type I- the granitic pegmatite hydrothermal type including majority of the deposits of the world, located within mafic-ultramafic or metasedimentary rocks. For example the emerald deposits of Brazil, South Africa, Australia, India, Spain and Norway. Type-II- the tectonic-hydrothermal type, which includes the most productive and high-quality emerald deposits of the world, e.g., Colombia, Brazil, Pakistan, Afghanistan and Austria.

In Swat-Pakistan, emerald mineralisation is spatially connected with thrust and shears zone structures rather than the granitic pegmatites. The shear zone structures are depicted by the suture zone, which is composed of a number of fault bound rock mélange (blueschist, greenschist and ophiolitic mélange). Altered ultramafic rocks with volcanics and metasediments constitute the ophiolitic mélange that host emerald mineralisation.

The following paragraphs highlight a brief description of the emerald deposits found in Pakistan starting from the most productive deposits of Mingora and Gujar Killi, followed by Charbagh, Makhad, Shamozai of Swat (Fig. 9.1), Gandao of Mohamond Agency, Barang of Bajaur Agency and the Khaltaro emerald deposits of Northern Areas.

EMERALD DEPOSIT OF MINGORA

Location and access

Emerald mining area of Mingora, Swat Valley is located at the north western tip of the Himalayan mountain ranges. It lies 200 km to the northeast of Peshawar (34°47´14"N: 72°22´25"E and 34°47´18"N: 72°22´09"E; Fig. 9.1). The deposit is situated within the city and is accessible from all sides. From the roadside the deposit is only a few hundred metres away. A fence protects the mining area from free access.

Geology

Mingora emerald deposit occurs in the Mingora ophiolitic mélange of the Indus suture or MMT zone. This highly tectonised fault-bound block strikes north south and dips westward. Towards west, it is exposed near Kabal across the Swat River, and extends further west through Shamozai to Dir District. Towards east, its thickness varies from a few hundred metres between Mingora and Makhad to several thousand metres between Kishora and Alpurai. Generally the Mingora ophiolitic mélange is composed of talc-dolomite schist, greenstone/greenschist, metagabbro and the metasediments. All these rock formations occur in a matrix of talc-chlorite-dolomite schist and calcareous quartz-mica-chlorite schist. The Mingora ophiolitic mélange shows greenschist facies metamorphism similar to the underlying Saidu calc-graphitic schist of the Indo-Pak continental sequence.

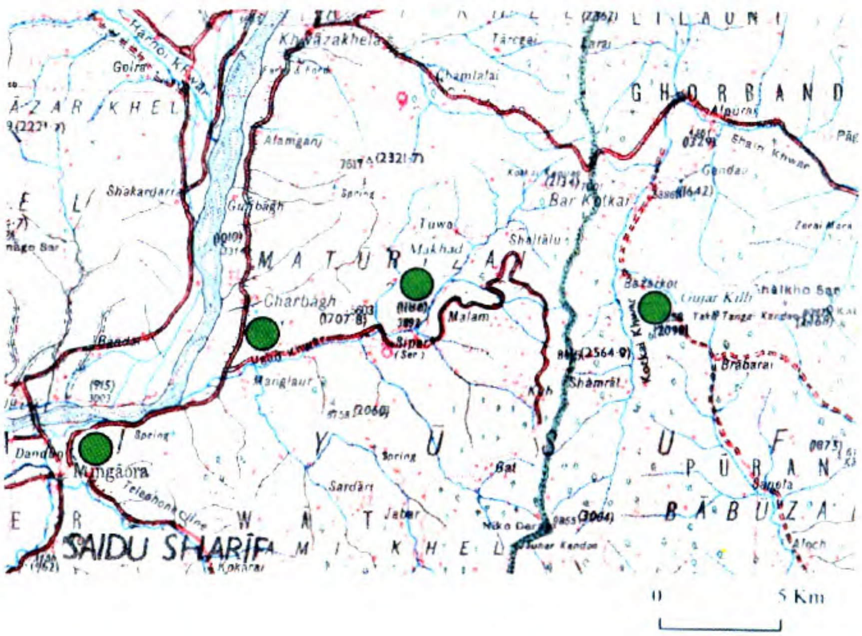


Figure 9. 1. Location map showing the Mingora, Gujar Killi, Charbagh and Makhad emerald deposits, Swat. Toposheet No. 43 B. Scale 1:250, 000.

The Mingora ophiolitic mélange, in the west has been thrust over by the Charbagh greenschist mélange along the Makhad thrust, and eastward, the Kishora thrust fault has pushed the Charbagh greenschist mélange over the Saidu calc-graphitic schist (Figs 9.2 and 9.3). The Charbagh greenschist mélange crops out between Charbagh and Shangla Pass, and forms a thick tectonic wedge between the Mingora ophiolitic mélange and the Shangla blueschist mélange.

A new occurrence of blueschist within the Indus suture (MMT) has been found at Tuwa northeast of Charbagh (34°51´30" N: 72°31´00" E on Survey of Pakistan Toposheet No. 43B/9 (Khan T. et al., 1994). Here the blueschist is intermixed with greenschist. The coexistence of glaucophane-crossite, actinolite-tremolite and epidote suggest high-pressure intermediate series metamorphism of the rocks. Thus blueschist mélange and greenschist mélange represent a coherent mélange group, which extends from Shangla towards Tuwa rather than two separate entities of mélange as envisaged earlier (Kazmi et al., 1984).

Physical and optical properties

Gübelin (1986) described the physical and optical properties of the Mingora emeralds, which are listed here.

Hardness: 7.50-8
Specific gravity: 2.75-2.78
Refractive index: n_e 1.588 to 1.593; n_o: 1.595-1.600
Birefringence: 0.007
Chelsea Filter: Reddish to pinkish red
Fluorescence: Orange-red to bright red
Inclusions: healing cracks, liquid tubes, liquid films, zoned banding, fine hexagonal liquid films, jaded growth defects, step-like growth edges, and two- and three phase inclusions and mineral inclusions. The mineral inclusions include calcite, dolomite, pyrite, actinolite, chromite, enstatite, feldspar, gersdorffite, magnesite, mica and pyrrhotite. Emerald is formed with less pressure and heat and, therefore, has more inclusions, which make it breakable. Toughness is rather poor.

Origin

The Mingora emerald deposit is spread over an area of about 180 acres. Emerald mineralisation is contained within talc-carbonates showing metasomatic zoning, i.e. an outer zone composed of talc-magnesite ± chlorite ± mica; an intermediate zone containing talc-magnesite with dolomite veins and an inner zone with dolomite-magnesite-talc schist and quartz-dolomite ± tourmaline ± fuchsite veins. Emerald is mineralised in the intermediate and inner zones within or spatially associated with veins. Isotopic study of magnesite from the outer zone shows that the paragenesis resulted from the effect of early metamorphic fluids whereas, the intermediate and inner zones resulted from the infiltration of hydrothermal fluids which carried Si, Be, B, K and Ca (Dilles et al., 1994; Arif et al., 1996). Chromium in the emerald emanated from the dissolution of chromite crystals from the serpentinite. The isotopic composition obtained on emerald, fuchsite, tourmaline and quartz are consistent with both magmatic and metamorphic origins of the fluids. However, the close similarity between these isotopic compositions and those found for muscovite and tourmaline from granites such as the Malakand granite, exposed 45 km to the southwest of Mingora, suggests that the mineralisation was caused by hydrothermal solutions derived from aluminous granitic magmas.

In addition, the presence of tourmaline in Barang emerald deposit and in talc-carbonate at Alpurai, favours magmatic model for the Swat and Barang emerald deposits (Hussain et al., 1993). The model is well constrained, especially when comparing the $^{40}Ar/^{39}Ar$ ages obtained for different rocks such as 83 ± 2 million years for the Shangla blueschist mélange, 22.8 ± 2.2 million years for the tourmaline-beryl fluorite bearing Malakand granite (Maluski and Matte, 1984) and 23.7 ± 0.1 million years for fuchsite from quartz vein in the Mingora emerald deposit.

Mining history

Emerald deposits in Pakistan were initially discovered in 1958 near the city of Mingora, Swat District, and the first report of the occurrence was published in 1962. Afterwards, a number of geologists described the geology of the area and gemmological characteristics of Swat emerald. In early 1960s, West Pakistan Industrial Development Corporation (WPIDC) started mining for emerald in Mingora, Swat. Subsequently, in late 1960s, the then Sarhad

Development Authority (SDA) took over the emerald mining responsibility. However, after the establishment of the Gemstone Corporation of Pakistan (GEMCP), a state enterprise, in February 1979, the emeralds from Swat were mined and sold internationally. Since 1979, gemstone business remained under the control of GEMCP, which was responsible for exploration, mining, regulating and managing business of gemstones including auction and direct export. But due to various reasons the mines were closed down bringing the trade to its lowest level, and ultimately, the GEMCP was disbanded in 1994.

In 1996, emerald mine at Mingora was auctioned for ten years at the rate of 90 million rupees to Mr. Azhar Wali Muhammad, owner of the Emerald Mining Company Private Limited, Mingora, Swat, NWFP. Owner of the mine failed to deposit the instalments, therefore, his mining lease was cancelled by the Directorate General, Mines and Minerals, NWFP.

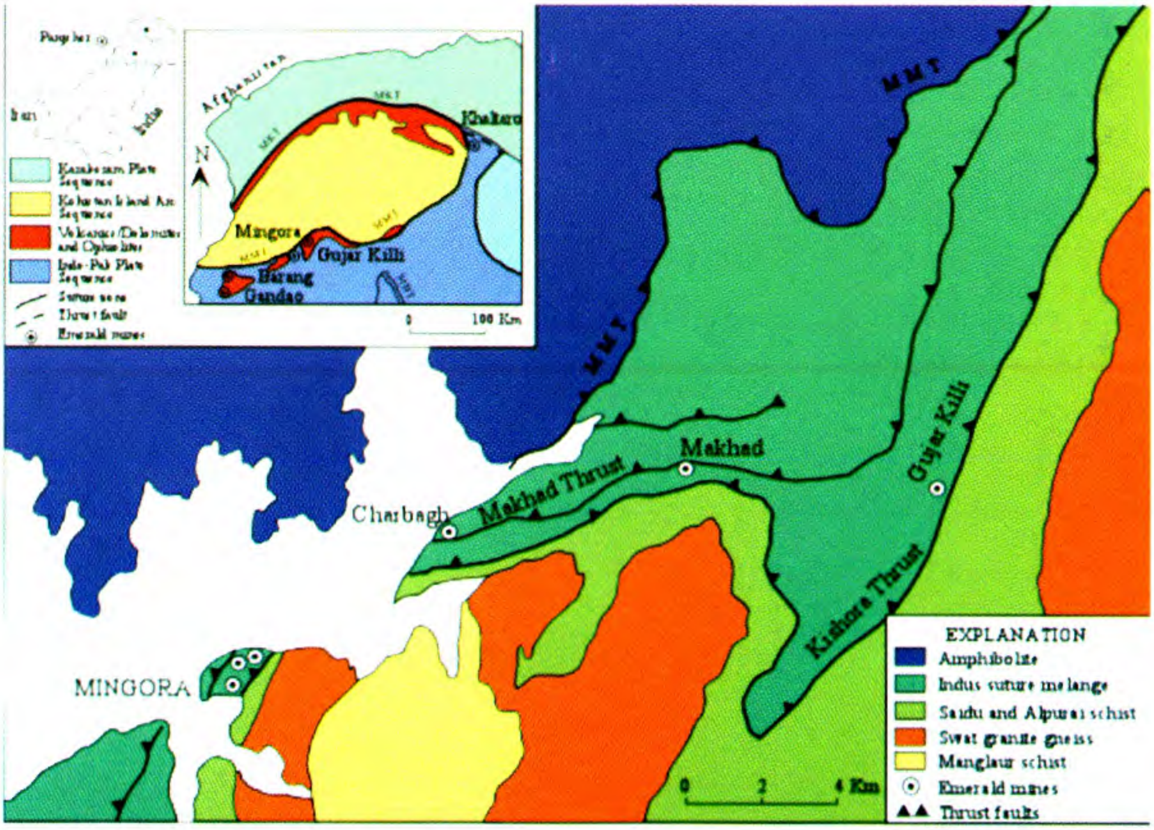


Figure 9.2. Geological map of part of Swat area showing the occurrence of emerald mines in Swat.

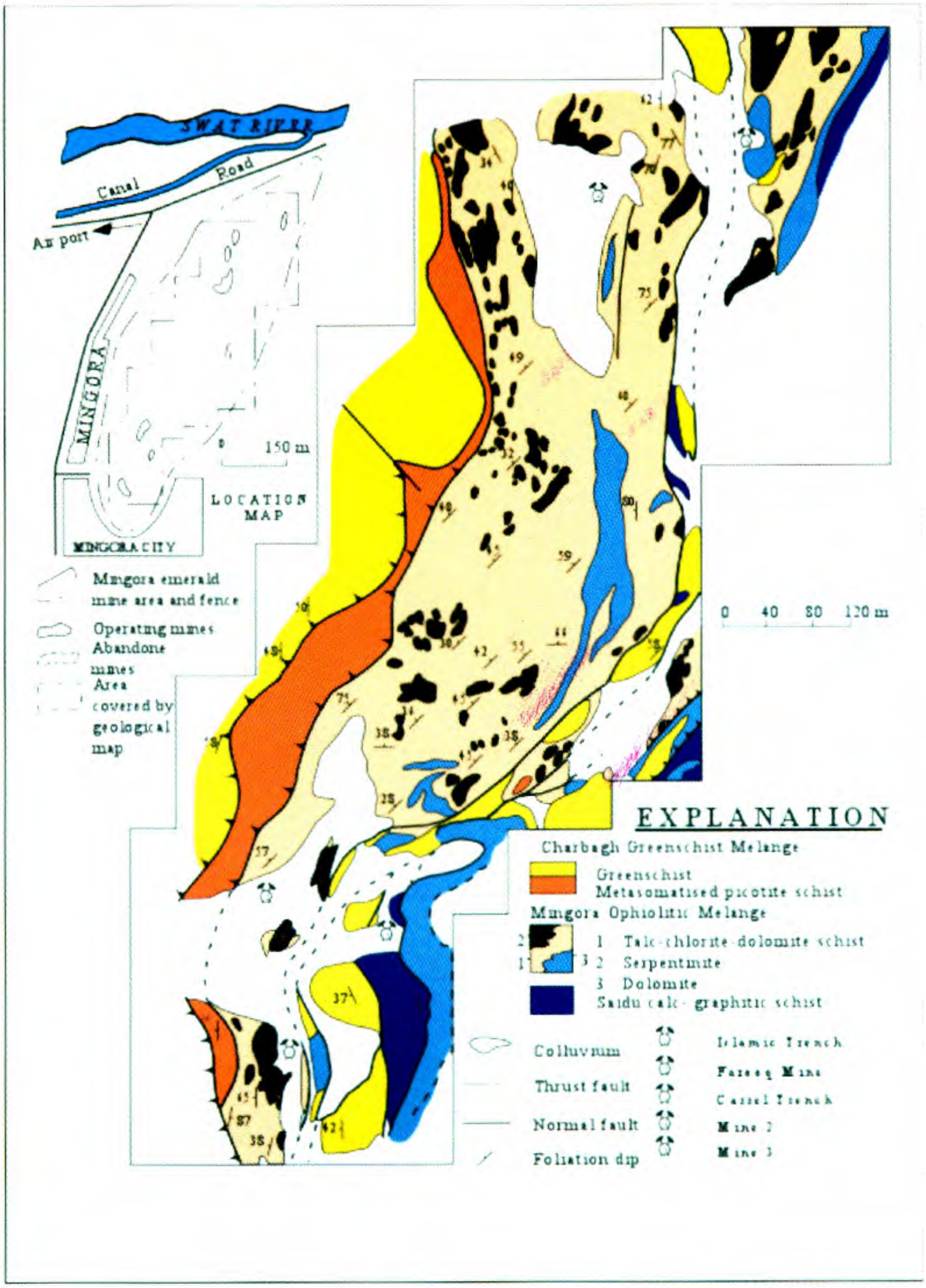


Figure 9.3. Geological map of the Mingora emerald mine, Swat. (After Kazmi et al., 1986).

Mingora emerald mine is closed at present. Previously the mining operation was open cut and underground (Fig. 9.4). In early 1960s, West Pakistan Industrial Development Corporation (WPIDC) started mining for emerald in Mingora, Swat. Subsequently, in late 1960s, the then Sarhad Development Authority (SDA) took over the emerald mining responsibility. However, after the establishment of the Gemstone Corporation of Pakistan (GEMCP), a state enterprise, in February 1979, the emeralds from Swat were mined and sold internationally. Since 1979, gemstone business remained under the control of GEMCP, which was responsible for exploration, mining, regulating and managing business of gemstones including auction and direct export. But due to various reasons the mines were closed down bringing the trade to its lowest level, and ultimately, the GEMCP was disbanded in 1994.

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Mining methods

Blasting is a common practice in mining through out the world. In the emerald mines of Mingora, emerald is found in a very soft rock. During mining operation, minimum use of the explosive was warranted, and the excavation of the mineralised zone was almost entirely done with pneumatic picks through out the mining operations in the past. The mining area at one site (Mine 2) was developed on modern lines where neatly terraces and benches were made. The mineralised zone was carefully excavated with pneumatic picks. At the quarry face, the excavated mineralised rock fragments were gently broken down with wooden mallets and searched for enclosed emerald. The emerald grains thus obtained were immediately dropped into a locked box through a slot. The mineralised debris discarded at this stage was then transferred to a mechanised washing plant where the debris was gently crushed, run through tommels, washed and passed through a centrifugal classifier which removed most of the talc and other fine material. The tailings were then spread over a white plastic sheet and emerald grains were removed by hand picking.

Production and quality

The available data shows that during initial 10 years operation by the GEMCP, the total production of emerald was about 0.3 million carats, and before that the annual production was about 5,000 carats. During the GEMCP tenure the average size distribution of emeralds had been of the following order:

Size (carats)	Percentage
a. Mellee (< 0.2 ct)	45
b. 0.5-1	33
c. 1-2	7
d. >2	15

Average grade wise distribution of rough gem-grade emerald produced from Mingora mines was approximately as follows:

Grade	Percentage
Excellent	5
Very good	12
Good	25
Fair	13
Mellee	45

During 1996-1999, private sector produced 0.4 million carats of emerald from approximately 800 cubic metre excavated material. About 15,000 cubic metre open pit excavation was done in two and a half years and later on this material was auctioned for rupees 500-800 per truck (three cubic metre materials per truck). About 30,000 cubic metre materials were dumped as debris in the mine area that might yield about 75,000 carats of emerald of various size and grades (Fig. 9.5). Total estimated reserve, as reported earlier, amounts to 20-30 million carats?

During 1996-1999, average size distribution of emerald had been approximately of the following order:

Size (carats)	Percentage
a. Mellee (< 0.2 ct)	70
b. 1-2	20
c. 2-10	10

During 1996-1999, average grade wise distribution of the rough gem-grade emeralds produced from Mingora mines had been approximately of the following order:

Grade	Percentage
Excellent	10-15
Very good	60-70
Good	10-20

Mingora emerald is well known for its brilliant, medium to deep green colours and unique transparency particularly in small size emerald. Up to two carats weight, these emerald grains are excellent but above two carats weight, the green colour becomes darker and consequently obscures the transparency, and hence reduces the quality.

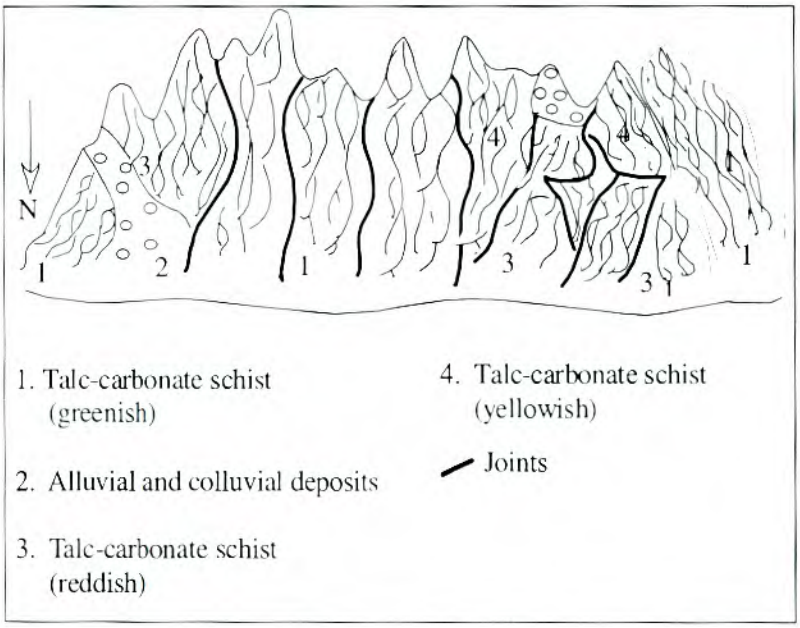

Fig. 9.4. Sketch showing open cut mining in Mingora emerald mines, Swat. Vertical and horizontal scale is exaggerated.

Figure 9.5. Photograph showing debris laying in the Mingora emerald mine, Swat.

EMERALD DEPOSIT OF GUJAR KILLI

Location and access

The deposit is located near Gujar Killi village 60 km to the east-northeast of Mingora and 12 km to southwest of Alpurai in Shangla District (34°50′40"N: 72°36′26"E; Fig. 9.1). A 12 km rough jeepable track from Shangla top and a 2 km long mule track join Gujar Killi with Shangla and Bazar Kot village respectively. Bazar Kot is 7 km away from Boat Chowk (junction of Pooran-Chakesar road with main Shangla-Alpurai road). The road is jeepable and all- weather. The deposit lies at 1,890 metres above sea level.

Geology

In Gujar Killi, emerald is mineralised in talc schist, sandwiched between graphitic schist (Figs. 9.6 and 9.7). The talc schist occurs as exotic rock of the ophiolitic mélange incorporated within the Indo-Pak continental plate margin. The talc schist shows variations and range almost from pure talc schist with minor carbonate to massive dolomite with minor talc. Talc-chlorite schist covers a large part of the mine area, which is brown to yellowish green and medium grained. Apart from talc and chlorite, the unit also contains a small amount of muscovite, fuchsite, siderite, magnesite and calcite. The unit is well jointed and traversed by several small faults and fractures. Quartz veins are common in it. Talc-chlorite schist contains parts of the carbonate-talc schist, massive carbonate and talc schist.

It is noteworthy that along the Indus suture zone, emerald mineralisation is confined only to talc-carbonate schist and/or talc-carbonate rock. The mineralisation is controlled by fault, joint, fracture filling, microfold, limonite zone, calcite nodule and veinlet and quartz vein and stockwork as in the case of Swat emerald deposits (Fig. 9.8).

Mining history

The Gujar Killi emerald mine was discovered and initially run by GEMCP. After the disbanding of GEMCP, the provincial government auctioned the mine in 1996 to M/S Balous Incorporated at 90.50 million rupees for 10 years. Since the party was defaulter regarding the payment of installments, the NWFP government cancelled the mining lease in 2001. At present, the mine is closed.

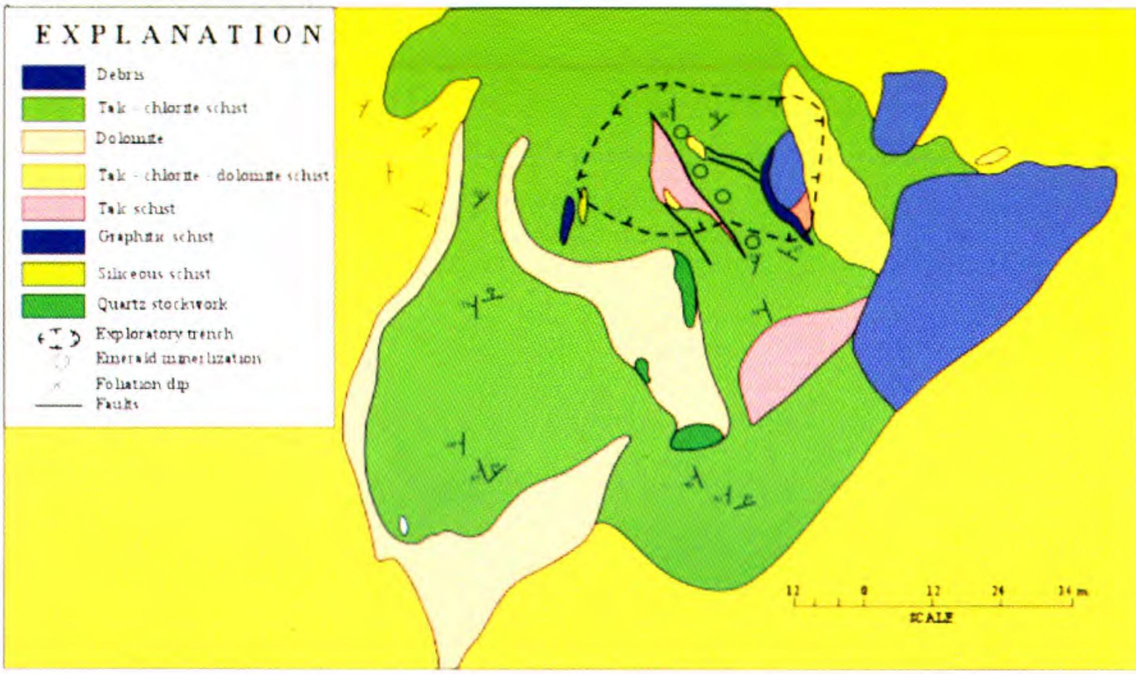

Figure 9.6. Geological map of Gojar Killi emerald mine, Shangla. (Modified after Kazmi et al., 1989).

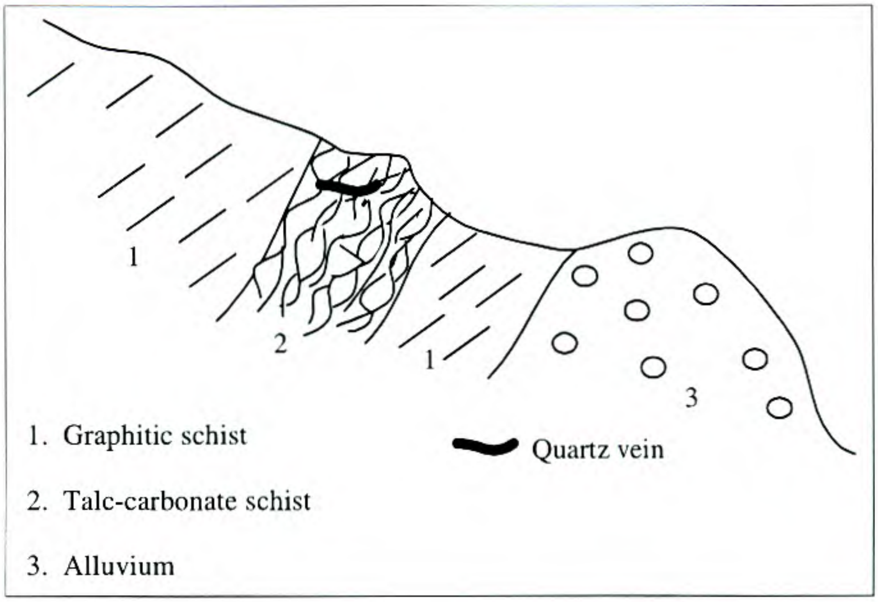

Figure 9.7. Sketch showing Gujar Killi emerald-mineralised talc-carbonate schist. Scale is exaggerated.

Mining methods

An area of 50 acres surrounding the Gujar Killi emerald mine was on lease but the deposit covers an area of about 13 acres. Open cut as well as underground mining has been done in the past but at present mining is underground only (Figs. 9.9 and 9.10). Dynamiting, compressor, pneumatic pick, crowbar, wheelbarrow, hammering of the rock and washing the debris by mechanical washer are the tools used for the extraction of emeralds. Two mining engineers and one geologist look after the mining operations. Besides, there are about forty labourers and thirty security personnel along with security inspector, mining supervisor and a compressor operator.

Currently two main adits "Abdullah Adit" and "Hamza Adit" each about 75 m long are dug along the mineralised zones using Stope and Pillar method, which are linked through branching adits. As the talc-carbonate rocks are very soft, timbering has been employed for safety. The ingress of spring water in the mine area creates problems in mining. Gujar Killi emerald mine remains remained closed due to heavy snowfall.

Figure 9.8. Sketch showing fracture-filling emerald mineralisation.

Production and quality

Production data of the past is scanty. However, the emerald production has increased from about 6,000 carats in 1986-1987 to about 80,000 carats by 1996-1997. The total estimated reserve of Gujar Killi emerald deposit, as reported earlier, is 20-30 million carats? Considering the limited aerial extent of this deposit and nature of mineralisation, this seems to be an exaggeration.

Gujar Killi emerald is as good as Mingora emerald. Emerald occurs as the well-formed crystals ranging in size from a few millimetres to large crystals weighing 100 to 200 carats. Smaller crystals are deep bluish green, transparent to translucent and contain few inclusions. Gujar Killi emerald is even deeper green than the Mingora emerald. Here also, small crystals are of good quality but contain carbonate inclusions creating much problem during cutting and faceting of the stone. Bigger crystals are of poor quality and depict cracks and inclusions.

Figure 9.9. Photograph showing open cut mining in the Gujar Killi emerald mine, Shangla.

Figure 9.10. Photograph showing underground mine entrance at the Gujar Killi emerald mine, Shangla.

EMERALD DEPOSIT OF CHARBAGH

Location and access

Charbagh emerald deposit occurs about two km south of Charbagh village, about 14.5 km northeast of Mingora and about 180 metres east of the Mingora-Charbagh road (34°49'20" N: 72°26'36" E; Fig. 9.1).

Geology

The area lying between Charbagh and Manglaur shows the following stratigraphy (Kazmi et al., 1984).

Charbagh greenschist mélange
-------- Makhad Thrust---------
Mingora ophiolitic mélange
-------- Kishora Thrust---------
Saidu calc-graphitic schist
Alpurai calc-mica-garnet schist
---------Unconformity-----------
Swat granitic gneiss

The Mingora ophiolitic mélange contains rocks in which emeralds are mineralised (Fig. 9.11). South of Charbagh village, this mélange comprises a 300 to 600 m wide east trending block of chlorite schist and talc-chlorite schist. The chlorite schist contains lenticular clasts of talc-chlorite dolomite schist (talc-carbonate), dolomite with minor talc, serpentinite and marble. These bodies are up to 30 m long and 0.5 to 8 m in thickness. Emeralds occur in the talc-chlorite dolomite schist and the localised faults (fault gouge) of the rock (Figs. 9.12 and 9.13).

Mining history

Charbagh emerald deposit is a very small deposit and has been intermittently worked first by the locals and later on by the GEMCP till 1994. At present, the mine is freely accessible as an outcrop where there is no mining activity.

Production and quality

Total emerald production so far recovered by the GEMCP from the Charbagh mine, amounts to not more than 15,000 carats. The Charbagh emeralds occur as relatively small crystals commonly in the 0.5 to 2 carat size range. These crystals are generally translucent and opaque and light green but generally contain dark coloured inclusions, which hamper its quality.

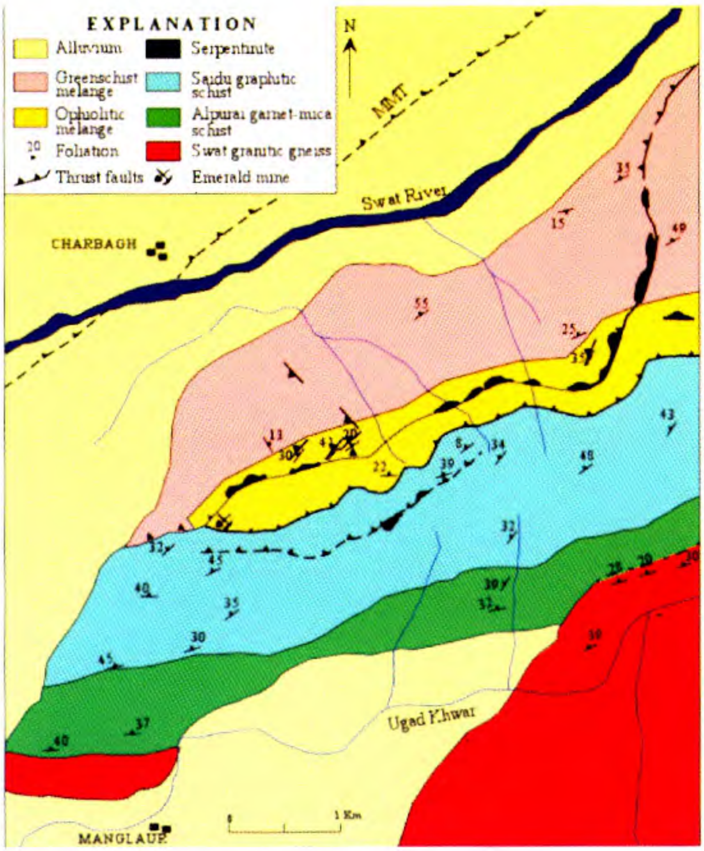

Figure 9.11. Geological map of the Charbagh area, Swat.

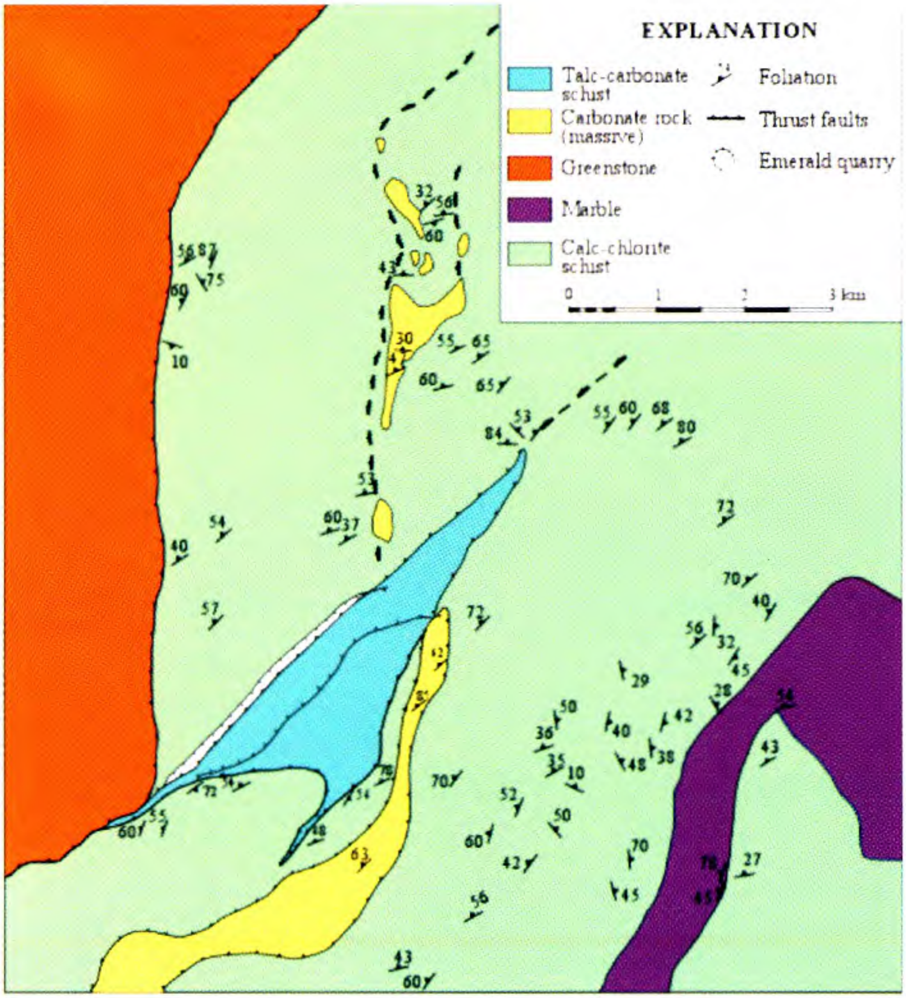

Figure 9.12. Geological map of the Charbagh emerald mine, Swat.

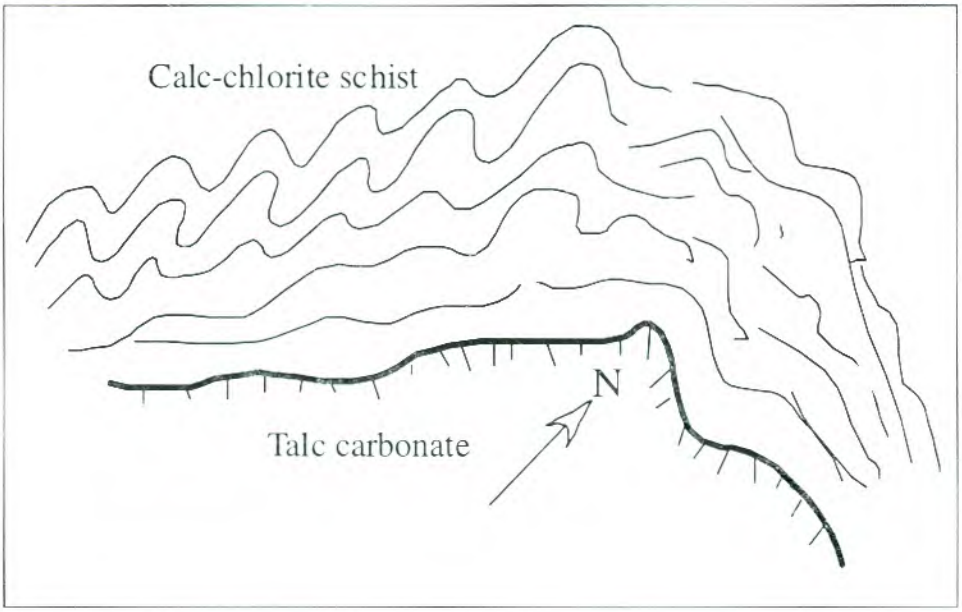

Figure 9.13. Sketch showing contact between calc-chlorite schist and talc-carbonate in Charbagh emerald mine, Swat. Vertical and horizontal scale is exaggerated.

EMERALD DEPOSIT OF MAKHAD

Location and access

Makhad emerald deposit occurs near the Makhad village at an altitude of about 1,230 m above sea level. Makhad is situated about 3.2 km north of Ser-Telegram village, which is on the Mingora-Malam Jabba road. From Mingora, Ser-Telegram is about 19 km in the east (34°51'25"N: 72°30'28"E; Fig. 9.1).

Geology

Geological setting of the Makhad emerald mine is similar to that of the Charbagh emerald mine. Both the deposits occur in the Mingora ophiolitic mélange (Figs. 9.12 and 9.14). Generally the rocks strike N20° W dipping 50° NE. Emerald occurs in talc-carbonate schist. The talc-carbonate schist lies in between calc-chlorite schist (above) and greenschist (below). Both the contacts are marked by fault gouge (Figs. 9.15 and 9.16).

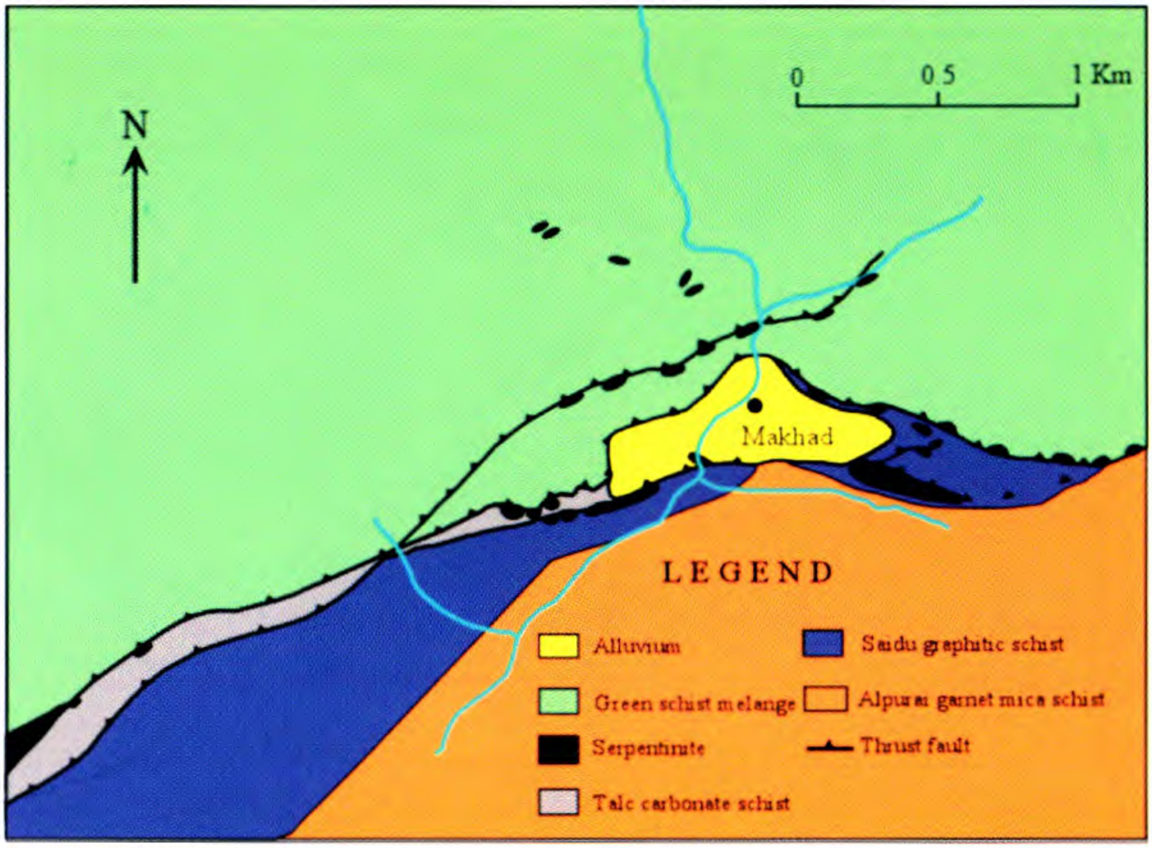

Figure 9.14. Geological map of Makhad area, Swat.

In talc-carbonate schist, emerald occurs largely as disseminated crystals whose shape/form is not ideally developed like typical hexagonal crystal. Some of the faces of the crystals are broken and corroded. The host rock has been highly weathered into a soft talcose limonitic powdery or clayey mass in which the emerald is embedded.

Mining history

Makhad emerald deposit spreads over a very small area and is confined to one talc-carbonate body only. Local people and the GEMCP excavated this deposit in the past as an open trench first and then 10 metre long adit along the dip direction of the body. During the GEMCP operation in 1981, the first author of this manual worked as in charge of mine for about six months.

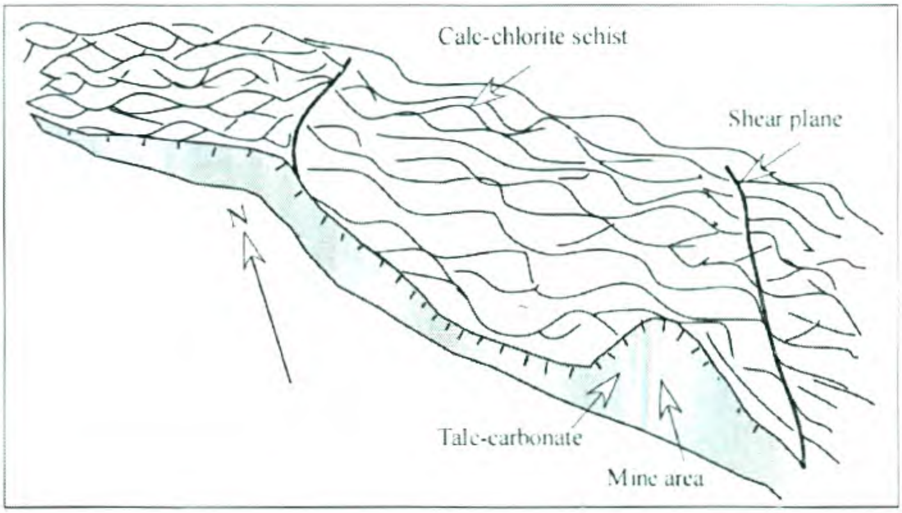

Figure 9.15. Generalized sketch showing the Makhad emerald mine, Swat.

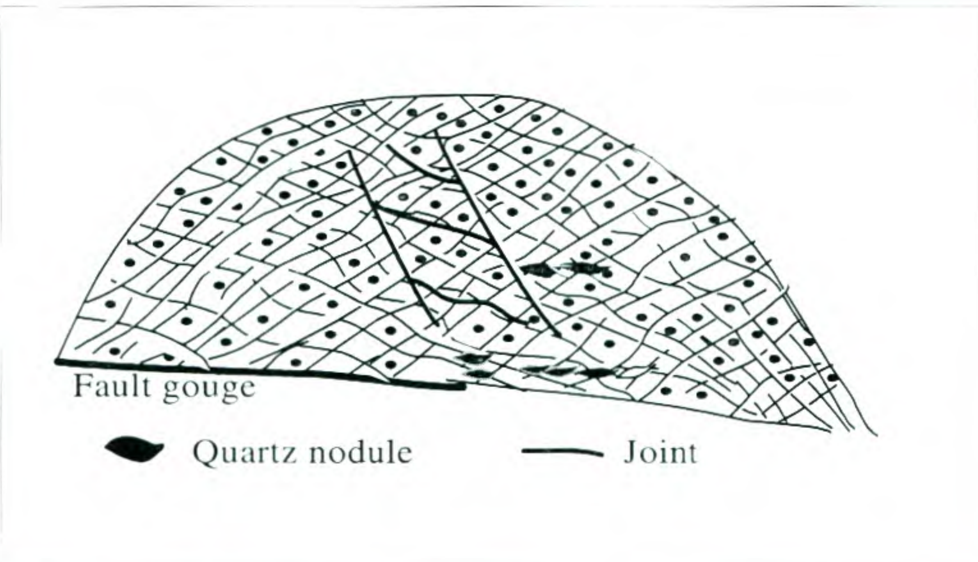

Figure 9.16. Generalized sketch showing emerald-bearing talc-carbonateschist inside the working area, Makhad emerald mined, Swat.

Production and quality

GEMCP extracted about 1,000 carats of emeralds in 6 months time. The production data pertaining to private mining is not available. Makhad emerald commonly occurs as fair size well developed crystals mostly in the size of 10 carats and above, however, they are very dark green. The crystals are largely opaque to translucent and are full of inclusions. Talc and siderite commonly occur as inclusions and give the crystals a pitted appearance. These stones are generally of low value as gems though some of the stones when cut and polished into thin slices provide beautiful, clear deep green hexagonal platy tabloids, which can be easily used in jewellery rather in an unconventional fashion. Due to the poor quality and limited reserves, Makhad emerald mine is not profitable.

EMERALD DEPOSIT OF SHAMOZAI

Location and access

Shamozai emerald deposit is located about 24 km to the west of Mingora (34°44´50"N: 72°11´59"E; Fig. 9.17). The deposit occurs at an altitude of about 2,000 m. The prospect area lies on a drainage divide line, separating the Shamozai village in the west from Kabal town in the east, on the right (west) bank of Swat River. The topography with respect to accessibility from the nearby villages is fair whereas a 6 km long non-metalled jeepable road connects Kabal with the prospect area. Apart from its accessibility from Mingora, the prospect area is also approachable from Chakdara town along the right bank of Swat River.

Geology

Emerald mineralisation in Shamozai area occurs in Mingora ophiolitic mélange under geological conditions very similar to those of Mingora and Gujar Killi emerald mineralisation. Altered ultramafics and associated greenschists are present within an area of about 0.8 square kilometre of the Shamozai emerald deposit.

According to Sarhad Development Authority (2001), major lens hosting emerald mineralisation is about 1,000 m long and 200 m wide with a structural attitude of N-E, dipping northwest. Other small elongated bodies, cropping out parallel to the south of the main altered ultramafic body, may represent northern limb of the anticline and may have folded along with the underlying metasediments at footwall. Spatial zoning of metasomatic alteration of the serpentinized ultramafic bodies exhibits an elongated pattern parallel to the length of the main body. In general, the linear zoning from contacts towards axial part of the body, range from dolomite, dolomite-magnesite schist and talc-carbonate- magnesite schist with limonite staining. Emerald mineralisation in association with genetically related quartz-fuchsite-chrome tourmaline appears to have been emplaced following strong deformation including shearing and post shearing intersecting faults (Fig. 9.18). The relics of serpentinite in the form of small patches and veins are uncommon in the prospect area.

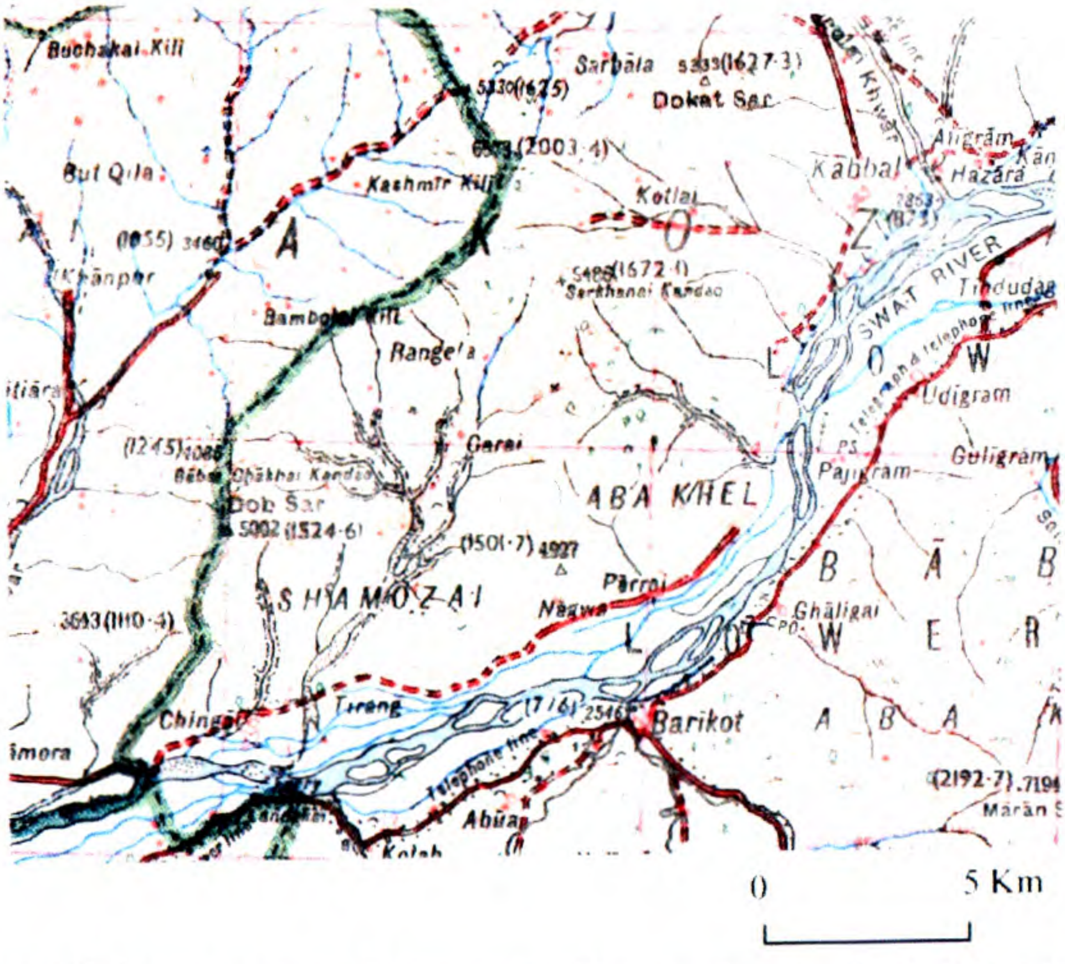

Figure 9.17. Location map showing the Shamozai emerald mine area, Swat. Toposheet No. 43 B. Scale 1:250, 000.

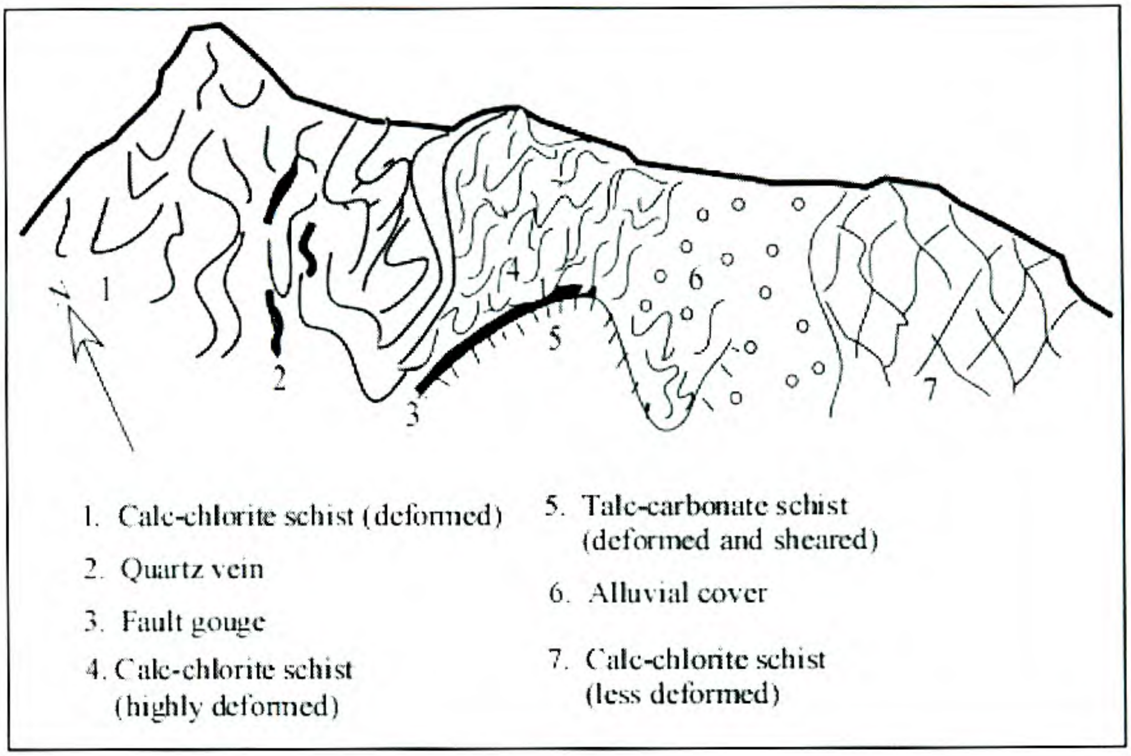

Figure 9.18. Generalized sketch showing geological section of the Shamozai emerald mine area. The emerald-host talc-carbonate schist is cut across in the form of an adit, which is 30 m long and 2 m wide. Vertical and horizontal scale is exaggerated.

Mining history

In 1989, the Shamozai emeralds were discovered and in 1990, the deposit was auctioned to a private party for three years. It is estimated that more than 50,000 carats of emerald have been recovered in a limited period through unsystematic mining (Sarhad Development Authority, 2001). Prior to this, informal production by local dwellers may be several times bigger as indicated by the size of excavation at the mine site. After the cancellation of lease to the previous party in the year 2002, the Shamozai emerald mine has been auctioned by the NWFP Government on 30.1 million rupees for 10 years to National Gem Mining Company, a private consortium, and consequently under the agreement, 76-acre area was leased out to the party.

Mining methods

Shamozai emerald mine, about 15-20 m deep, currently is an open pit mine (Fig. 9.19). One mining engineer, one geologist, twenty labourers, ten security personnel and one mining supervisor were the total working force of the mine.

Initially, a private party developed this mine as an open pit. Selective mining of the mineralised zone is evident from the underground workings in the form of foxholes (Fig. 9.20). The private party closed these narrow adits through re-filling of waste debris while abandoning the area. Other workings/open cut mining in the form of trenching are also observed across a linear zone extending towards east for a distance of 460 m exhibiting geological characteristics in consistence with emerald hosting altered ultramafic rocks. The main working areas are numbered as Mine1 at western end, Mine2 in the centre and Mine3 on the eastern end of said length of the linear zone of excavation. This alignment of open pit mining along a sheared talc-carbonate zone having an average of 40 m thickness, is a signifying resource potential of emerald mineralisation. Further continuation of the said mineralised zone with similar geological characteristics may be inferred for a linear extension of 500 m along the length of the altered ultramafic body towards northeast. Another parallel sheared zone 500 m x 20 m (average) along the southern contact of the body is also potentially significant for emerald.

During the current mining operation, the overburden, e.g., alluvium etc is being removed using bulldozer. Primitive techniques are being used for the recovery of the emerald. The techniques include blasting with dynamite, using shovels, handpicks, crowbars and wheelbarrows etc and hand washing of the debris.

Production and quality

There is very little data available about the emerald production from the Shamozai emerald mine. The data available with the Mineral Department of NWFP amounts to about 1,300 carats of six months (1993-1994) production. The total estimated reserves are about 16 million carats.

Shamozai emerald is transparent to translucent and pale green. Bicolour emerald has also been recovered from this mine. As Shamozai emerald is not commonly available in the gem market, therefore, detailed analysis of the stone may not be possible.

Figure 9.19. Photograph showing open pit mining in the Shamozai emerald deposit, Swat.

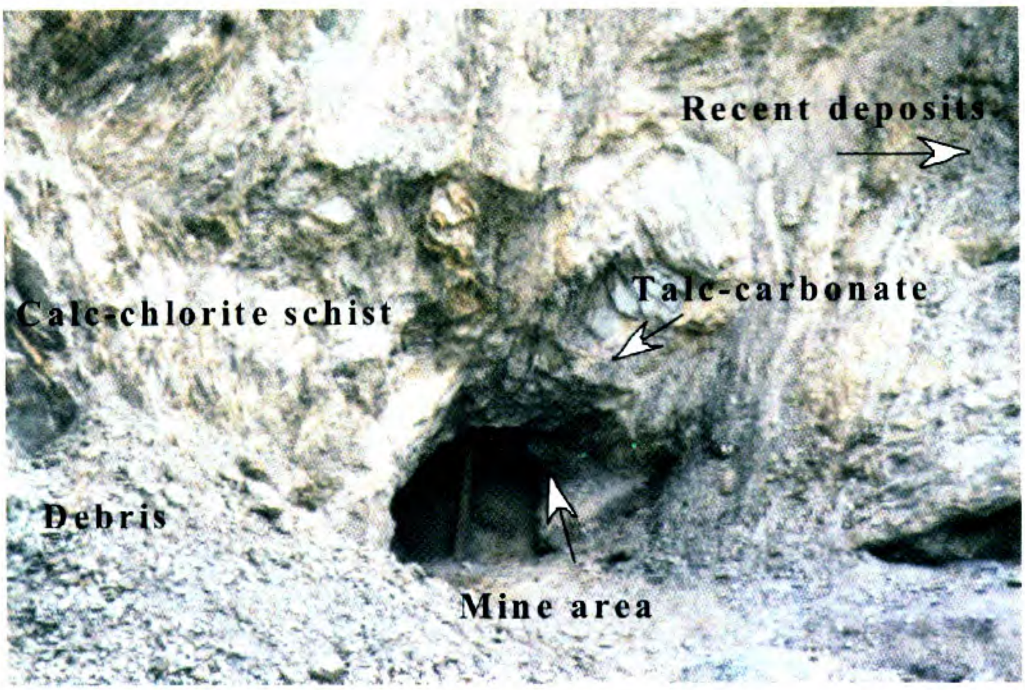

Figure 9.20. Photograph showing underground mining of Shamozai emerald deposit, Swat.

EMERALD DEPOSIT OF GANDAO

Location and access

Gandao emerald-bearing area lies in the Gandao region of Tora Tigga (Barokhel), Mohmand Agency within latitudes 34°21'30" and 34°24'30" N and longitudes 71°17' and 71°22'45" E, and at an altitude of 1,183 m above sea level (Fig. 9.21).

Emerald deposit is situated about one kilometre to the south of Tora Tigga village. The Tora Tigga village is about 68 km away from Peshawar and is approachable from the road that connects Shabqadar with Yusufkhel (Khattak and Aslam, 1974). Both the roads are metalled and all-weather.

Geology

Gandao area where emeralds are located comprises mainly of limestone, dolomite, and green, grey and black schists (Khattak and Aslam (1974). Dolerites are seen intruding the dolomite (Fig. 9.22). The rocks are metramorphosed up to greenschist metamorphic facies.

Dolomite containing emeralds crop out between Tora Tigga Sar and Ghare Kamar. It is dark grey on fresh surface. The weathered surface is pale brown as a 0.5 cm thick layer. It is massive, fine-grained and impure. The impurities are clearly indicated by mica and iron oxides. Emerald-bearing dolomite is partly re-crystallised and traversed with quartz veins. One of the dolomite beds containing emerald is about 100 m thick. Structurally, the dolomite is isoclinally folded with the fold axis trending east-west axis. At certain places, autoclastic breccia can be seen in the dolomite (Fig. 9.23).

Gandao emeralds occur mostly in quartz veins. Quartz veins are a few mm thick but some may range up to 30 cm. Emerald crystals occur in less than 2 cm thin quartz veins. The veins at places also contain pyrite and mica. Quartz veins containing beautiful emeralds are transparent. Besides, milky white quartz contains emerald showings (Fig. 9.24).

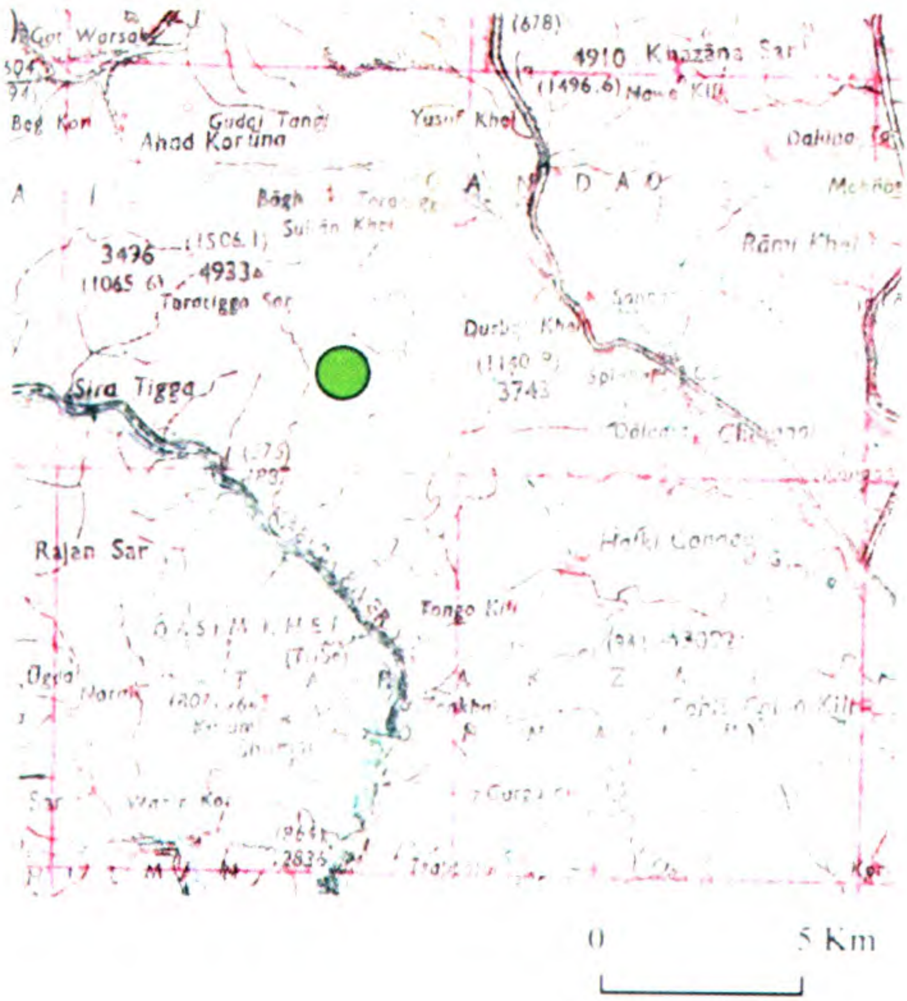

Figure 9.21. Location map showing Gandao emerald deposit, Mohmand Agency. Toposheet No. 38 N. Scale 1:250,000.

Origin

Gandao emerald, known as green beryl, is genetically different from the rest of the emeralds of the region. It is not possible to discuss the genetic model for the Gandao emeralds due to lack of adequate data. However, the presence of quartz veins, mica and pyrite, and breccia within the emerald-bearing dolomite support hydrothermal origin. It is noteworthy that dolerites intrude the dolomite at Gandao area. The colouring agent "vanadium" as determined in the Gandao emerald, can be assumed to have been derived from the dolerites. The occurrence of emerald in quartz veins is random. The emerald is green and transparent and of much value in the market.

Mining history

Gandao emerald deposit occurs in the Federally Administered Tribal Area (FATA). Private parties (e.g. Fancy group of Karachi) and the local influential, specifically Malik Haji Bahroz Khan of Barokhel extracted emeralds. According to the locals, there were about 75 working areas within a distance of about 1,000 m, engaging about 200 workers. It is further quoted that mining in the area was on a very small scale. Intermittent mining operation is still going on the southern slope of the Tora Tigga hills (Fig. 9.25). The mining operation is quite primitive and risky to life.

Production and quality

Production data of the Gandao emerald deposit is not available as the mining operation is not government controlled. However, yearly earning of the locals from this mine had been more than rupees 600,000 since the start of the mining in 1960s.

The Gandao emerald was known as green vanadium-bearing beryl, but due to deep green colour and of the beryl family, it was sold as Gandao emerald. It is transparent and translucent, and whitish green to deep green. At present good quality Gandao emerald can be sold in the market at about rupees 5,000 per carat and rupees 20,000 per specimen (Fig. 9.26).

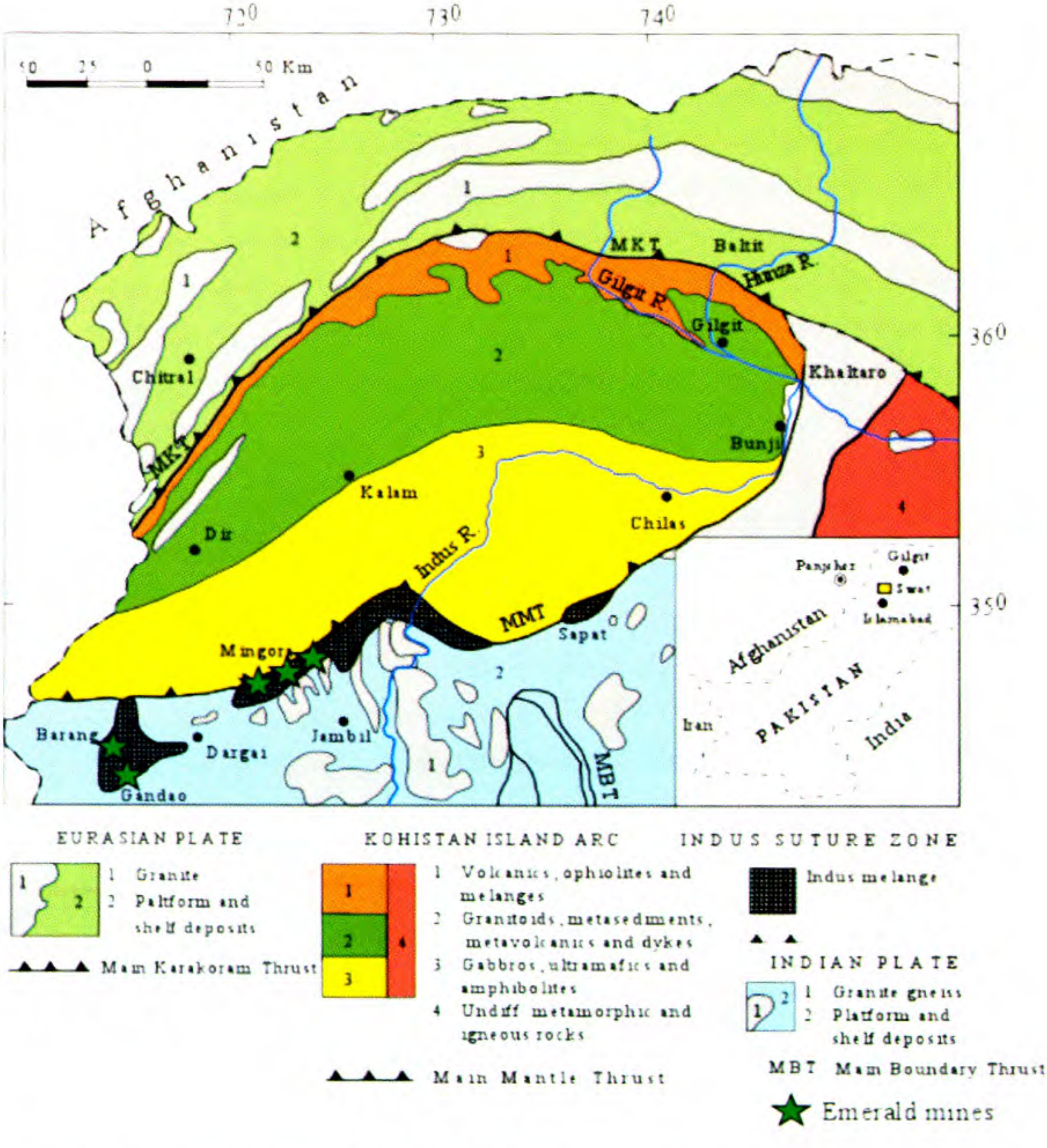

Figure 9.22. Regional geological map showing occurrences of Gandao and other emerald deposis in Indus suture zone melange (modified after Snee et al., 1989).

Figure 9.23. Photograpgh showing autoclastic breccia in the emerald-bearing dolomite, Gandao, Mohmand Agency.

Figure 9.24. Photograph showing two sets of quartz veins in N-S and N50°E directions in dolomite. Gandao, Mohmand Agency.

Figure 9.25. Photograph showing Gandao emerald mine area, Mohmand Agency.

Figure 9.26. Photograph showing emerald-bearing specimen from Gandao emerald mine, Mohmand Agency.

EMERALD DEPOSIT OF BARANG

Location and access

Barang emerald deposit is located in Amankot of Bajaur Agency that lies about 80 km north of Peshawar via Ghalanai, Mohmand Agency and about 200 km via Timurgara of Dir District (34°39'13" N:71°36'53" E; Fig. 9.27). Amankot is connected with Khar, the Agency Headquarter through a 15 km long all weather-metalled road. It is also connected with Dargai of Malakand Agency by a metalled all-weather road.

Geology

Barang emerald deposit, like other emerald deposits of the area, occurs within talc-carbonates of the Indus suture ophiolitic mélange (Hussain et al., 1993). The talc-carbonate bodies occur as thrust fault bound lenses extending to the south up to Dargai. Towards north the thrust faults seem to be imbricated from the Main Mantle Thrust (Fig. 9.28). Other lithologies in the mélange zone include ultramafic, gabbro, greenschist, amphibolite and metasediments.

In Amankot area of Barang, amphibolitic siliceous schist is associated with talc-carbonate where emerald mineralisation occurs in the silicified part (Fig. 9.29). Following types of mineralisation has been noticed: (i) with quartz veins present in joints and fractures. The emeralds found in such a pattern are the best; (ii) with quartz veins, cross cutting the siliceous rocks, overlying the talc-carbonate. The emeralds found in these veins are of poor quality; and (iii) silicified and shear zones within talc-carbonate containing emeralds.

Mining history

Local influential and private parties extracted emeralds since 1960s. In the past, three different mines were operative in the Barang area (Fig. 9.30). The first two were situated at one place and the third about 500 m further north. At present mining is closed for unknown reasons.

Production and quality

Formal records of emerald production or mining cost for the Barang emerald mine do not exist at all. As far as quality is concerned, Barang emeralds are the next best Pakistani emeralds after Mingora and Gujar Killi emeralds. Barang emeralds are bluish green, light blue with greenish edges, green, grassy green and deep green. They are opaque, translucent and transparent. Size of the emeralds varies from very small to 2.5 cm in longer dimension. The largest crystal recovered so far weighs about 150 carats. Clear and transparent high quality emeralds are usually bluish green. Crystals are generally well developed, and contain inclusions.

The authors believe that further production from Barang emerald mine depends on locating a major structure followed by organised mining before the deposit is totally destroyed by primitive blasting methods.

Figure 9.27. Location map showing Barang emerald deposit, Bajaur Agency. Toposheet No. 38 N. Scale 1:250,000.

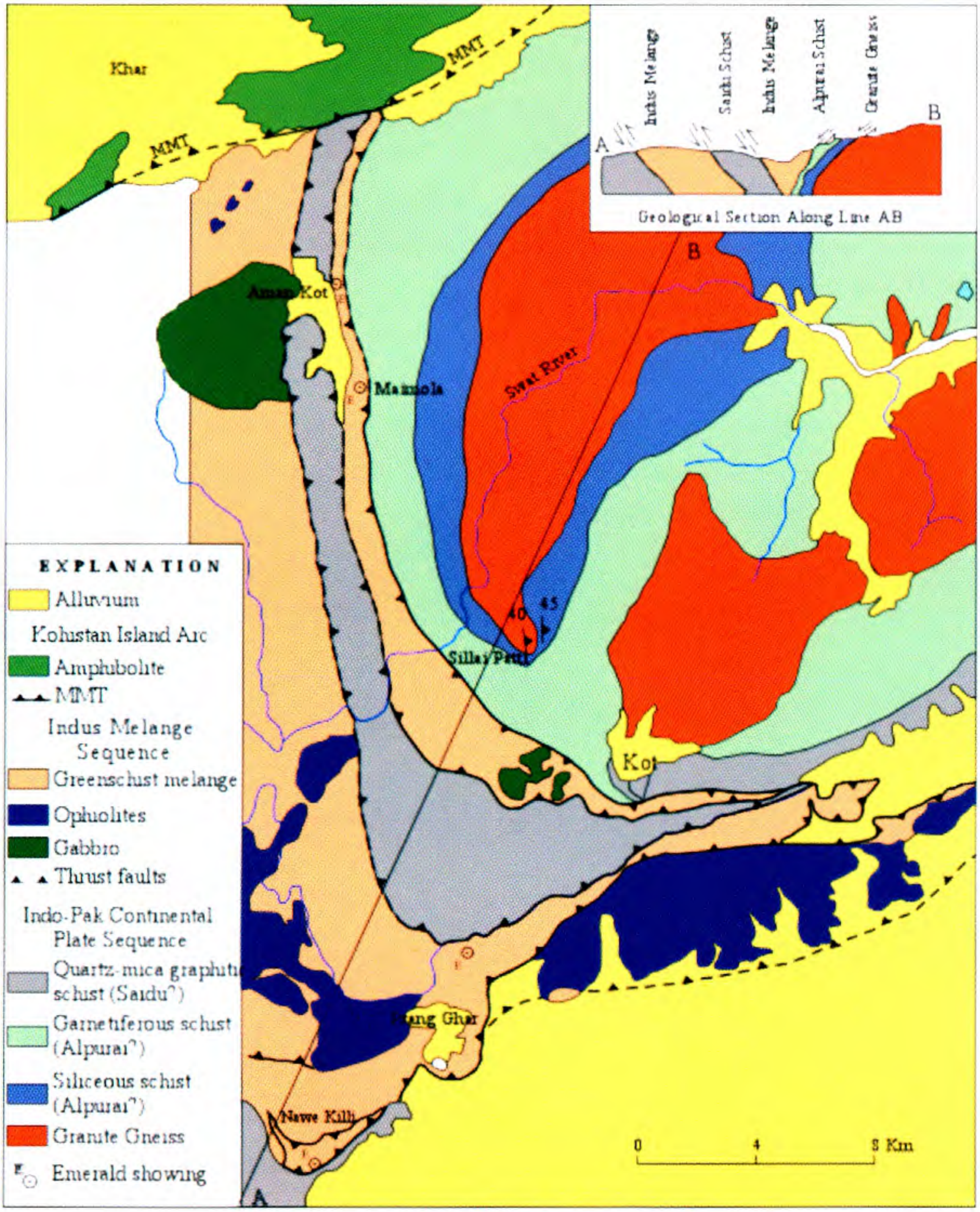

Figure 9.28. Geological map of Barang, Kot, Prang Ghar and Nawe Dand areas of Bajaur, Malakand and Mohmand Agencies (modified after Hussian et al., 1984).

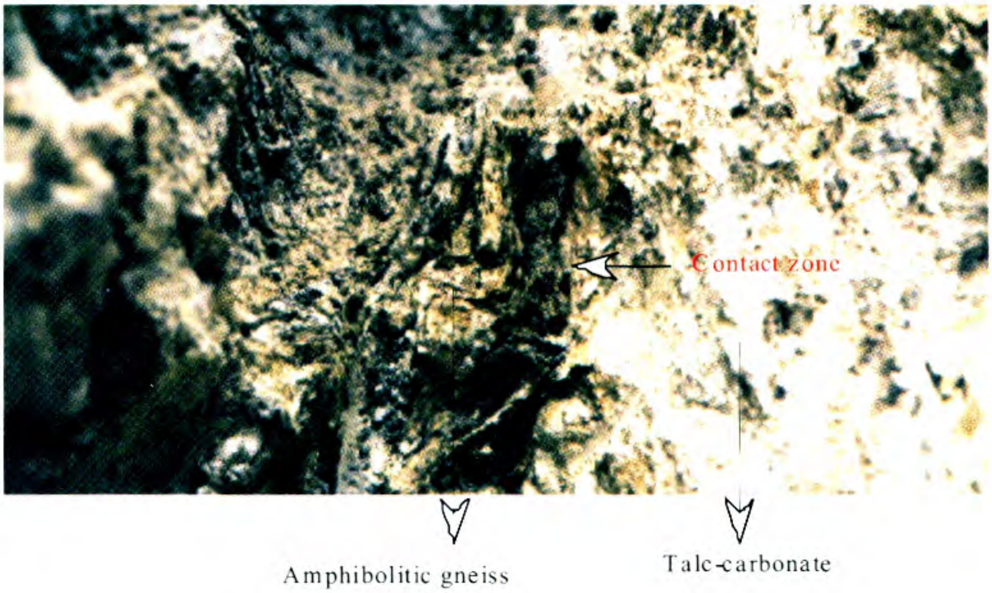

Figure 9.29. Photograph showing one of the emerald mine areas in Amankot, Barang, Bajaur Agency.

Figure 9.30. Photograph showing Amankot emerald mine of Barang, Bajaur, Agency. Emerald-bearing talc-carbonate and greenschist mélange are thrust fault bound (dashed lines).

EMERALD DEPOSIT OF KHALTARO

Location and access

Khaltaro emerald deposit occurs in the Khaltar valley of the Haramosh Mountain Range, which is about 70 km, east-southeast of Gilgit-Skardu road. In the Khaltar valley, emerald occurs at Rayjud of Khaltaro village (Fig. 9.31). Rayjud is about 32 km north of Sassi, a small village located on the Gilgit-Skardu road. The emerald deposit occurs further upstream to the Rayjud at an altitude of about 4,500 m above sea level. The emerald-bearing terrain is extremely rugged and remains covered with snow from the month of October till June.

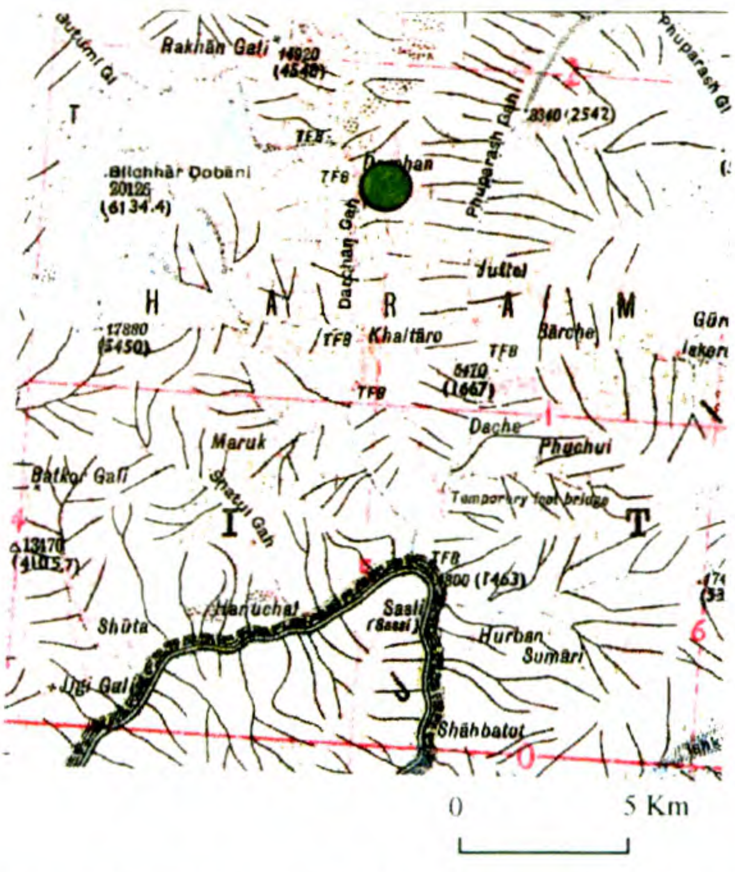

Figure 9.31. Location map showing Khaltaro emerald deposit, Gilgit-Baltistan. Toposheet No. 43 I. Scale 1:250,000 (after Kazmi et al., 1989; Laurs et al., 1996).

Geology

Khaltaro emerald deposit is the classic example of granite-pegmatite related deposit (Laurs et al., 1996). These deposits are associated with pegmatites but their geological and mineralogical features differ from those found in the 'classic granite-related' occurrences. Khaltaro emerald mineralisation occurs in the northwestern Haramosh massif near its contact with the Kohistan island arc (Fig. 9.32). The Haramosh massif comprises orthogneiss and paragneiss with locally developed biotite schist, calc-schist, amphibolite and marble. These rocks are named as the Nanga Parbat Group and are broadly subdivided into the Iskere orthogneiss and the Shengus paragneiss.

Khaltaro emerald mineralisation is apparently found within 0.1- to 1-m-thick veins and granitic pegmatites cutting amphibolite within the Nanga-Parbat Haramosh massif. The massif comprises paragneiss and orthogneiss of intermediate composition, with thick layers of amphibolite, marble, and deformed sills of granitic rocks, that overlies the Iskere orthogneiss (Figs. 9.33 and 9.34). The amphibolite forms a sill-like body within garnet-mica schist, and both are part of a regional layered gneiss unit of Proterozoic (?) age. The 40Ar/39Ar data for muscovite from a pegmatite yield a plateau age of 9 to 10 million years (Laurs et al. 1996).

According to Laurs et al. (1996), at Khaltaro, the emplacement and crystallisation of a small heterogeneous leucogranite sill and subsequent exsolution of the orthomagmatic fluid developed beryl-bearing pegmatite-vein system. Channelling of these fluids along cracks or the permeable zones in the host granite and Cr-bearing amphibolite formed pegmatites and veins, which are composed of quartz, albite, muscovite, and beryl-rich assemblage including emerald. Many of good quality emerald have come from quartz and tourmaline-albite veins.

Mining history

Khaltaro emerald deposit is a very small deposit, which was discovered by GEMCP geologists in early 1980s. The GEMCP worked for the extraction of emerald till it was disbanded. The mining operation had been of exploratory only. Due to remoteness and rugged and harsh topography of the area, the Khaltaro emerald mine is not in operation to date even by the locals.

Production and quality

Due to extremely rugged terrain and high altitude where mining is possible only for about three months in a year, the Khaltaro emerald deposit has not been fully exploited. A total of 600 carats of emerald of gem-grade had been recovered by the GEMCP during exploratory mining in eightees.

Khaltaro emerald is commonly of light to medium green colour (Fig. 9.35). It occurs as well-formed prismatic crystals. The crystals are largely 1- to 3 cm in diameter, though larger crystals are not uncommon. These stones generally contain inclusions and fine cracks, though some very fine clear stones also have been found.

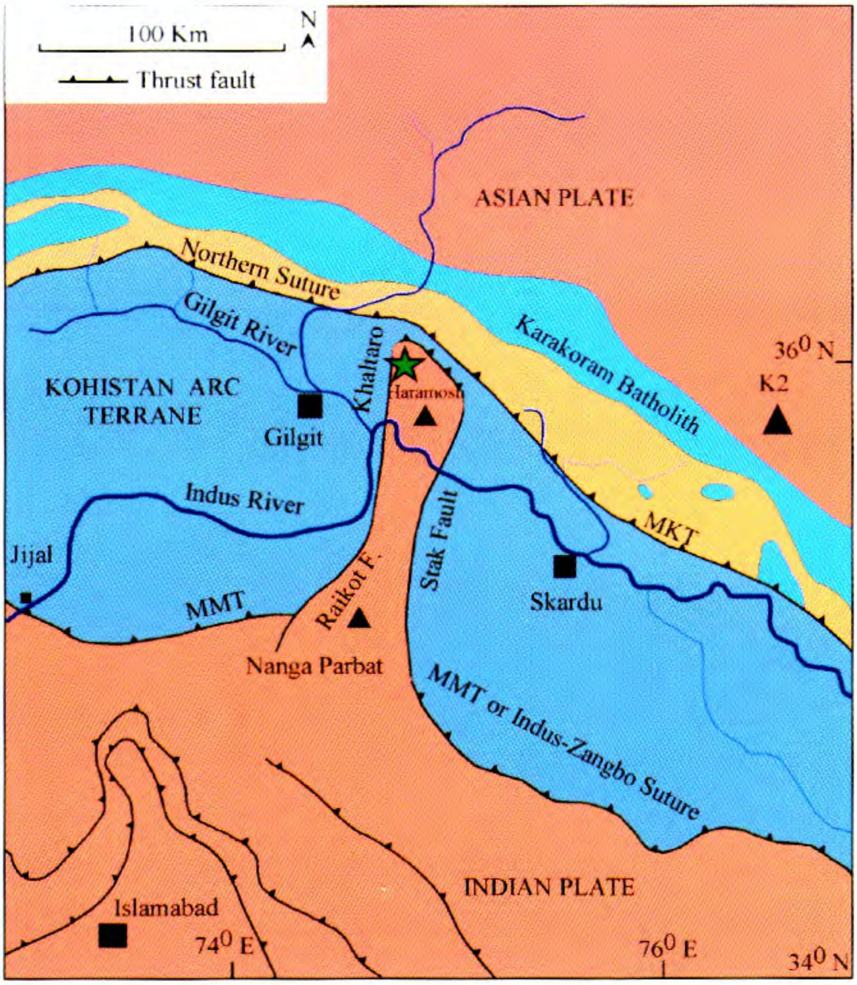

Figure 9.32. Geological and tectonic map showing Khaltaro emerald bearing area.

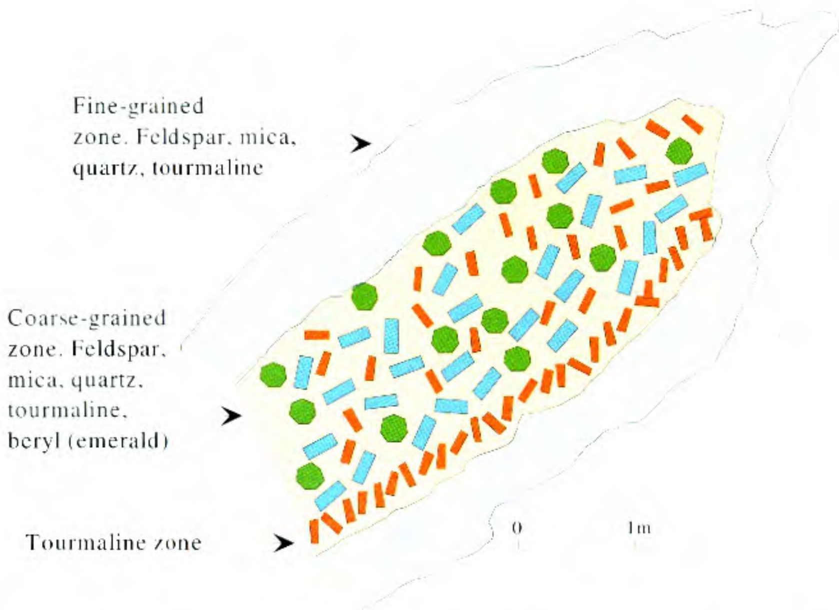

Figure 9.33. Sketch showing geological section of the emerald-bearing pegmatite at Khaltaro (from Khan and Aziz, 1985).

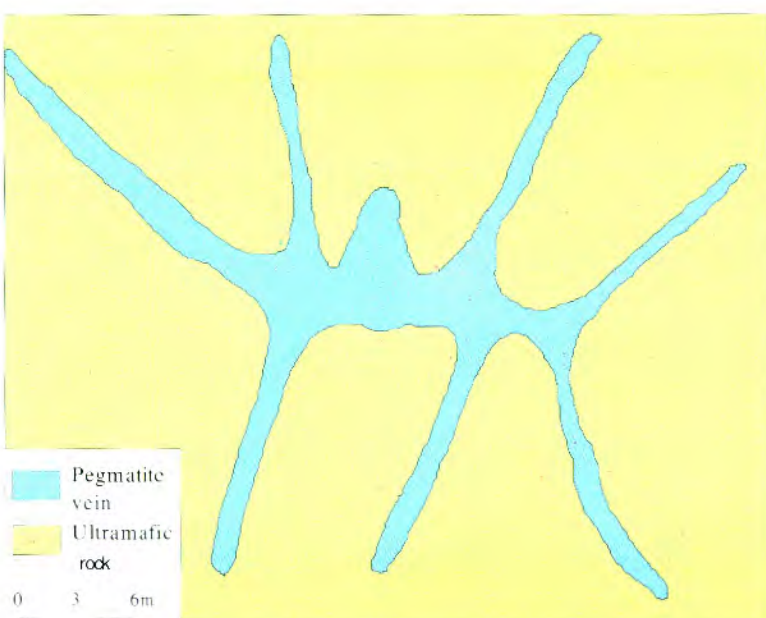

Figure 9.34. Sketch showing geological section of the emerald-bearing pegmatite at Khaltaro (from Khan and Aziz, 1985).

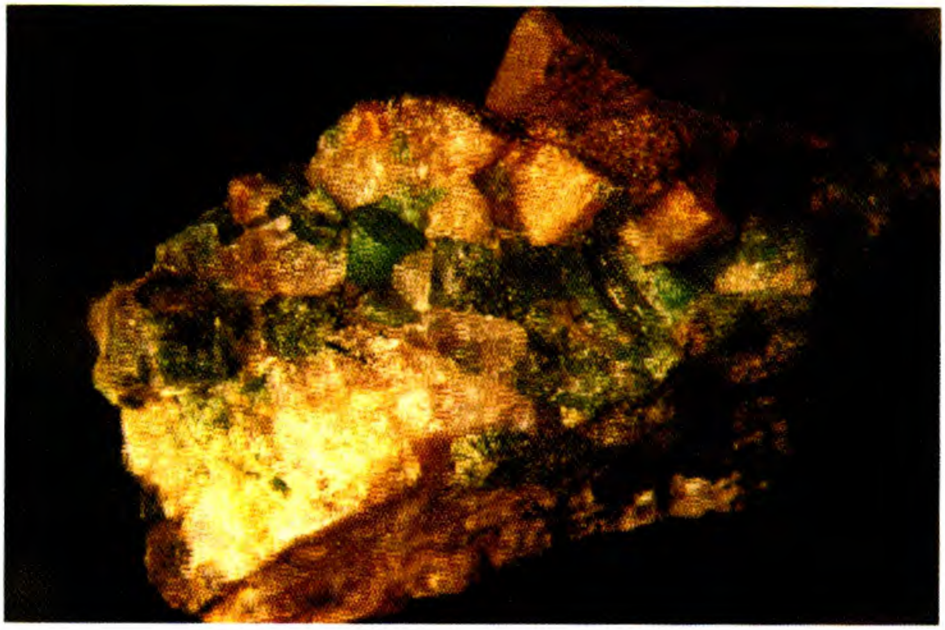

Figure 9.35. Photograph showing Khaltaro emeralds in pegmatite, Khaltaro (from Kazmi et al., 1989).

Guidelines for exploration

It is very difficult to find gemstones during exploration work without knowing proper techniques. The authors believe that by knowing such techniques, gemstones can be found. The guidelines for some of the gemstones in Pakistan are described in this manual starting from the emerald.

1. Talc-carbonate host: sheared zones, reddish brown (colouration due to leaching of iron oxide minerals) are conducive to emerald mineralisation. Emerald embedded in soft white lumps of talc, and quartz veins, is always present in association. Here the emerald is well shaped and possesses a magnificent colour, but rarely larger than one carat (Gübelin 1982).
2. Traversing veins/nodules of quartz/dolomite/calcite, with or without pale green talc, stilpnomelane, and fuchsite (green mica) contain emerald.
3. Contact zones between talc-carbonate and calc-chlorite schist and pale green talc-schist contain emerald. Quartz and ankerite are abundant in such zones.

4. Rigorously deformed talc-carbonate: joints, intersecting joints, fractures, faults, fault gouge and folds. These geological structures contain good quality emerald.
5. Dolomite host: re-crystallised dolomite, deformed, and intruded by dolerite: Tight isoclinal folding, faulting, jointing and the autoclastic breccia.
6. Traversing veins of quartz/calcite in re-crystallised dolomite: good quality emerald is found in thin quartz veins within the dolomite.
7. Re-crystallised dolomite containing calcite, quartz ± mica (± muscovite ± biotite ± phlogopite) ± argillaceous substance and pyrite.
8. Talc-carbonate rocks and stream sediments can be checked geochemically. High Cr, Be, Li, Sr and La may be taken as pathfinder elements for emerald mineralisation (Hussain et al., 1990).

AQUAMARINE

Aquamarine is one of the most popular and famous gemstones that are used for modern jewellery designs. Its name has been derived from the Latin terms "aqua", meaning water, and "mare" or sea. Aquamarine ($Be_3Al_2Si_6O_{18}$) crystallises in hexagonal system. It has specific gravity ranging from 2.69 to 2.73 and refractive index ranging from 1.574 to 1.580.

Aquamarine is characterised by many excellent features. It is almost as popular as emerald, ruby and sapphire. It is related to emerald because it also belongs to the gemstone family of beryl. However, the colour is more evenly distributed throughout aquamarine as compared to emerald. More frequent in occurrence than emerald, aquamarine is usually almost free of inclusions. It possesses a good hardness (7-to 7.5 on the Mohs's scale), and a tremendous brilliance. Its good hardness makes it quite vigorous and protects it generally from getting scratched. Iron is the substance responsible for the colour in aquamarine, and the shades of blue displayed range from almost colourless, pale blue through to bright sea blue. The higher value of aquamarine depends upon its intense colour. Some aquamarine crystals show a slightly greenish hue; that is also considered typical. But a really pure and clear blue is still cherished as typical aquamarine colour, as it best brings out the immaculate transparency and high brilliance of this gemstone.

Occurrence

The light blue of this fine beryl finds more and more friends. The different shades of aquamarine are distinguished by their own promising names: 'Santa Maria', is the name for the rare, intensely deep blue aquamarine found in the Santa Maria de Itabira mine in Brazil, and they are bound to cause excitement among gemstone lovers in general. Similar colours are found in some of the sparse aquamarine gemstone mines in Africa, especially in Mozambique. In order to better distinguish them, these aquamarine crystals are denoted as "Santa Maria Africana;. Not quite as deeply blue is "Espirito Santo", aquamarine from the Brazilian state of Espirito Santo. Another beautiful colour has in fact been named in honour of a Brazilian beauty queen from 1954, and has become famous as "Martha Rocha". The names of the colours already point out the importance of Brazil as the main country where aquamarine is found. Most of the rough crystals on the world market come from the gemstone mines of this huge South American country. From time to time, then, large aquamarine crystals of immaculate transparency and splendid colour are found here, a rare occurrence indeed where these gemstones are concerned. Now and then even sensationally large crystals are found, such as, e.g., in 1910 at Maraimba/Minas Gerais, where a 110.5 kg crystal was mined. Or there is the 'Dom Pedro', weighing 26 kg, which was cut in 1992 by Idar-Oberstein gemstone artist Bernd Munsteiner, thus achieving the title of largest ever cut aquamarine. Nevertheless, aquamarine is also found in other countries, for example Nigeria, Madagascar, Mozambique, Afghanistan and Pakistan (Fig. 10.1).

In Pakistan, crystals of blue, yellowish blue and greenish blue, transparent to translucent aquamarine and translucent to opaque beryl occur in the pegmatite at Gabor-o-Bakh, Monour (Garamchasma), Matak An (Rumboor) and west of the Brumburete Valley of Chitral District, Sumaiyar of Nagar area, Dache, Drot of Shengus, and Bulochi in the Gilgit-Baltistan areas of Pakistan (Figs. 10.2 and 10.3).

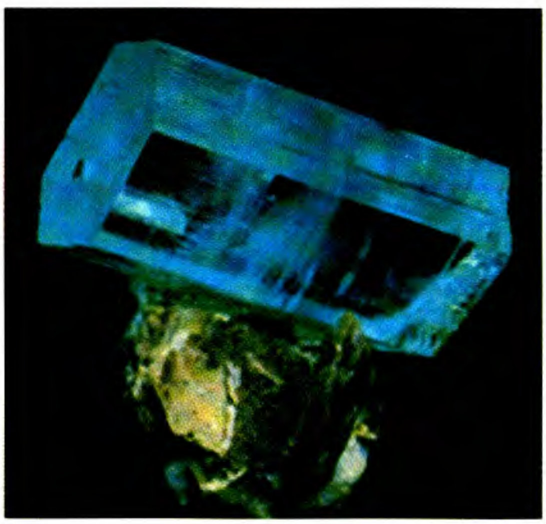

Figure 10.1. Photograph showing aquamarine specimen from Gilgit-Baltistan, Pakistan.

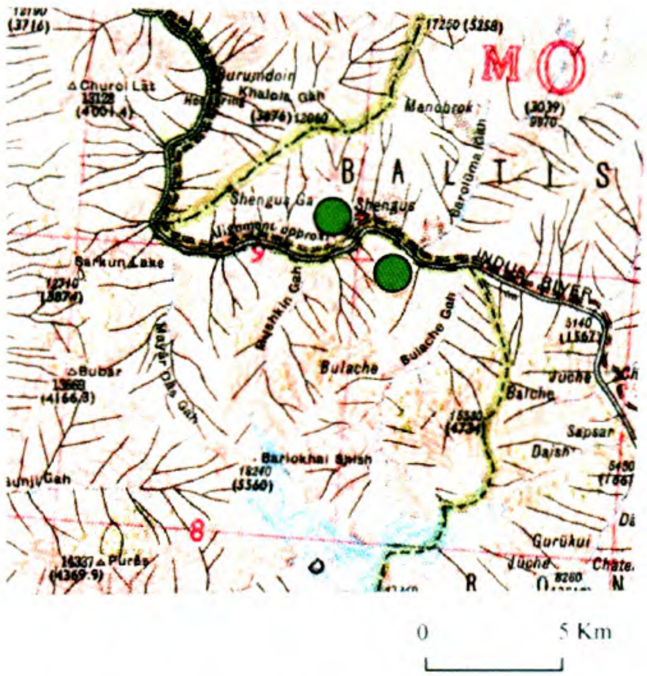

Figure 10.2. Location map of aquamarine-topaz deposits of Shengus and Bulochi areas (from Kazmi and O' Donoghue, 1990). Toposheet No. 43 I. Scale 1:250,000.

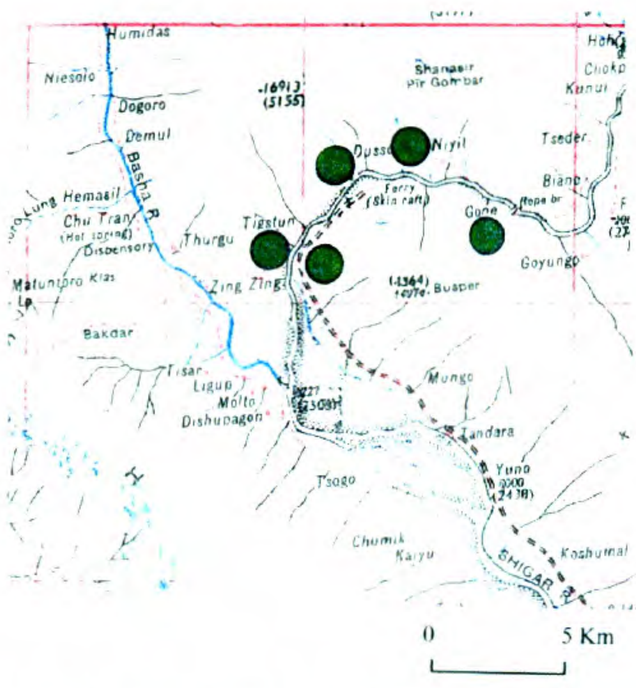

Figure 10.3. Location map of aquamarine and brown topaz deposits of Dusso area (from Kazmi and O' Donoghue, 1990). Toposheet No. 43 M. Scale 1:250,000.

The economic deposits of aquamarine only occur in Northern Areas, particularly in Sumaiyar of Nagar, Tisgtung (Dusso), Balachi/Bulochi, Shengus, Iskere, Shigar and Khaltaro areas. Except the Sumaiyar deposit, which occurs at 6,000 m above sea level, the other deposits occur in the areas lying between Gilgit and Skardu and north of Skardu. It is to be noted that Skardu is about 200 km away from Gilgit. In Chitral, at Monour, bluish aquamarine occurred in pegmatite that had been vanished during the exploratory mining work by the then GEMCP in 1983-1984.

Geology

In Northern Areas, amphibolite- to granulite facies schists and gneisses, and amphibolites occur in a region extending from Hunza River on the northwest to Shigar near Dassu on the southeast. This region is well known to host granitic pegmatites. The pegmatites are exposed in the Nanga Parbat Haramosh massif of the Indo-Pak continental plate at Dache, Drot, Khaltaro, and Stak Nala and in the Asian/Karakoram continental plate near Nagar and Dassu etc, but not within the Kohistan island arc.

The granitic pegmatites are invariably young with cooling ages of less than 10 million years, and are not deformed except the margins of the Haramosh massif. In general, they form swarms of sub-parallel, locally anastomosing dykes and lenses or nearly concordant sills. They attain thickness of several metres as such at Drot, the pegmatites are about 3,000 m long. They are important to contain aquamarine but tourmaline and topaz are also found.

Aquamarine occurs in the cavities of zoned and complex pegmatites of the Northern Areas. It is formed as individual mineral and/or clusters with other minerals, i.e., quartz, feldspar, mica, topaz, fluorite, tourmaline etc. The Nanga Parbat-Harmosh and Masherbrum Mountain Ranges host the aquamarine-bearing pegmatites. These mountain ranges are composed of schistose and gneissic rocks. For example, the rocks of the Nanga Parbat-Haramosh ranges, which belong to the Indo-Pakistan continental plate, comprise the Nanga Parbat gneiss and the Haramosh schist. The Nanga Parbat gneiss is further subdivided into layered gneiss, Iskere gneiss, Shengus gneiss and undifferentiated gneiss of Proterozoic age. They are best exposed at Shengus and the Bulochi areas. Other rock units exposed in the area include amphibole-biotite gneiss, biotite gneiss and quartzite. The Masherbrum mountain range, which belongs to the Asian/Karakoram continental plate, is composed mainly of Dusso gneiss and Karakoram metamorphics of Proterozoic to Mesozoic age. These rocks are best exposed at Dusso and on the left bank of the Shigar Valley. The MKT delineates the Karakoram metamorphics from the Ladakh island arc in the Shigar Valley (Agheem et al., 2004; Hassan 2007).

Mining history

The aquamarine mines of the Shigar Valley have been allotted recently on lease to Shahzad International, a multinational company but at present, local people using crude and primitive mining methods are mining aquamarine in Sumaiyar and Bulochi areas. Small quantities of aquamarine are currently being mined in Shigar Valley. The access to Sumaiyar region in Nagar is difficult and the mines are closed by heavy snow for seven to eight months of the year. But many mines in the Shigar Valley are operational year-round on a daily basis in spite of the sever weather conditions. All these mines are in the control of local people. Since the time of their discovery, the locals had been mining the gem-bearing pegmatite secretly and the crystals recovered were either sold to very select clients or kept by them. The mines were guarded carefully and the location was kept secrete. Numerous gem-bearing pegmatite mines in the region have tens of metres of underground workings mainly consisting of drifts and adits. Many of these mines were one or two man operations, which became exceedingly difficult to mine at depth. Most of these mines were subsequently abandoned and forgotten over the years.

The only official data available during GEMCP times, amounts to about 0.16 million carats of aquamarine from Shengus area in five working years, i.e., 1981- to 1984-1985, and 1987-1988.

Production and quality

The aquamarine from Pakistan is light bluish and aqua colour. The crystals are well developed and are being sold in the market mostly as aquamarine specimens (aquamarine with mother rocks) and individual crystals.

TOURMALINE

Tourmaline's name comes from the Sinhalese word "turmali," means "mixed." Bright rainbow collections of gemstone varieties were called "turmali" parcels. Tourmaline, occurring in more colours and combinations of colours than any other gemstone variety, lives up to its name. Tourmaline is also of interest to scientists because it changes its electrical charge when heated. It becomes a polarized crystalline magnet and can attract light objects. This property was noticed long ago before science could explain it: in the Netherlands, tourmalines were called "aschentrekkers" because they attracted ashes and could be used to clean pipes! Tourmaline is a hard and durable gemstone, which can withstand years of wear (http://www.jewellers.net/tourmaline.htm).

The tourmaline family is a group of closely related minerals with complex chemical formulae of alumino-borosilicates with varying quantities of sodium, magnesium, calcium, iron, chromium, manganese, potassium etc $(Na, Ca)_5 (Al, Fe, Mg, Mn, Ti)_{27} (Si, B)_{27} O_{86} (OH)_4$ (?) They vary widely in colours and physical properties but share a common crystal structure. They crystallise in trigonal system, and on Mohs's scale, they have hardness more than 7 and a mean specific gravity of 3.18 with refractive indices 1.62-1.64.

Found in many locations throughout the world, the tourmaline produces striking, relatively durable gems and show the widest colour variations of any gemstone, e.g., indicolite (blue or bluish-green), rubellite (red), bicolour or tricolour tourmaline, watermelon tourmaline (red central core surrounded by green), schorl (black), dravite (brown), chrome-tourmaline (vivid green) and achroite (colourless). Pink and green tourmaline is especially popular in designer jewellery. Blue tourmaline is also very much in demand but the supply is more limited. Tourmaline was used as a decorative stone at the time of Roman Empire (27 B.C.-A.D. 395).

Occurrence

Tourmaline crystals of an astonishing variety of forms and colours are widespread in the world, and notable deposits are found in Brazil, Tanzania, Kenya, Madagascar, Mozambique, Namibia, Afghanistan, Pakistan, Sri Lanka, and California and Maine in the United States. Maine produces beautiful sherbet colours of tourmaline and spectacular mint greens. California is known for perfect pinks, as well as beautiful bicolours.

One particularly beautiful variety is chrome tourmaline, a rare type of tourmaline from Tanzania, which occurs in a very rich green colour caused by chromium, the same element, which causes the green in emerald. In Pakistan, black, blue and greenish blue tourmaline crystals were found in simple and complex pegmatites at Gabor-o-Bakh, Chitral (no economic significance). The crystals are transparent and translucent and mostly fractured. However, tiny crystal is transparent and free from inclusions and fractures. Mineralisation is in small cavities as well as sparse dissemination. In the Northern Areas, at Stak Nala and Shigar Valley, colourful tourmaline was produced in the past (Fig. 11.1). The detailed description of Stak Nala tourmaline is given in the following paragraphs and the Shigar Valley tourmaline (see Hassan 2007).

Location and access

Tourmaline-bearing pegmatites are located in Stak Valley, which is about 15 km north of the Indus River and the Gilgit-Skardu Road. The junction of Stak Nala with the Indus River is about 180 km away from Gilgit. A rough dirt road leads from the main Gilgit-Skardu Road to Toghla village and a track provides an access to the pegmatites about 2 km to the north and 400 m above the valley floor (Fig. 11.2). The pegmatite north of the Toghla village lies at an elevation of approximately 2,800 m.

Geology

Stak Nala pegmatites are located in the Nanga Parbat Haramosh massif. In the Stak Valley both layered paragneiss and orthogneiss are exposed. And in the tourmaline-bearing pegmatite area, paragneiss and orthogneiss (banded orthogneiss and biotite granodiorite gneiss are exposed (Laurs et al., 1998). These rocks are metamorphosed up to amphibolite grade.

Pegmatites of Stak Nala are mineralogically zoned parallel to the contacts, miariolitic and consist of coarse-grained feldspar, quartz, schorl, muscovite and minor garnet (Fig 11.3). The pockets contain fluorite, coloured tourmaline, topaz, lepidolite, apatite, beryl etc (Fig. 11.4). Pockets are also present in other pegmatite sills but are barren. The pegmatite at Kaska, the same area, containing gemstones is about 120 m long and 1.2 m wide. It shows fairly even thickness along their length with a shallow dip southward. The other sill is about 110 m long and 4.6 m wide. Slivers of wall rock projecting into the pegmatites are common. Crystals of green pink tourmaline have been mined from the cavities in the core zone of pegmatitic sills. At the mine area the productive zone trends west-northwest along a broad open, antiformal structure. At both the mines, cavities are distributed intermittently through the core zone, but they are most common in the upper part near the contact with the wall rock zone. The cavities are oblate to highly irregular shaped. They are either isolated or inter-connected with one another (Fig. 11.5). The cavities range in size from small vugs (~1 cm) to large cavities, which are up to 0.5 m high and 3.0 m long. The cavities and associated "cleavelandite"-rich replacement zone contain the largest varieties of minerals (Laurs et al., 1998).

According to Laurs et al. (1998), mineral constituents of the cavities include albite, quartz, K-feldspar, elbaite, muscovite, lepidolite, topaz, goshenite and fluorite. These minerals project into the cavities. Roof of some of the cavities are characterised by a bunch of well-developed bigger and transparent quartz crystals (Fig. 11.6).

Figure 11.1. Photograph showing pegmatite-host colourful tourmaline specimen from Stak Nala, Gilgit-Batistan.

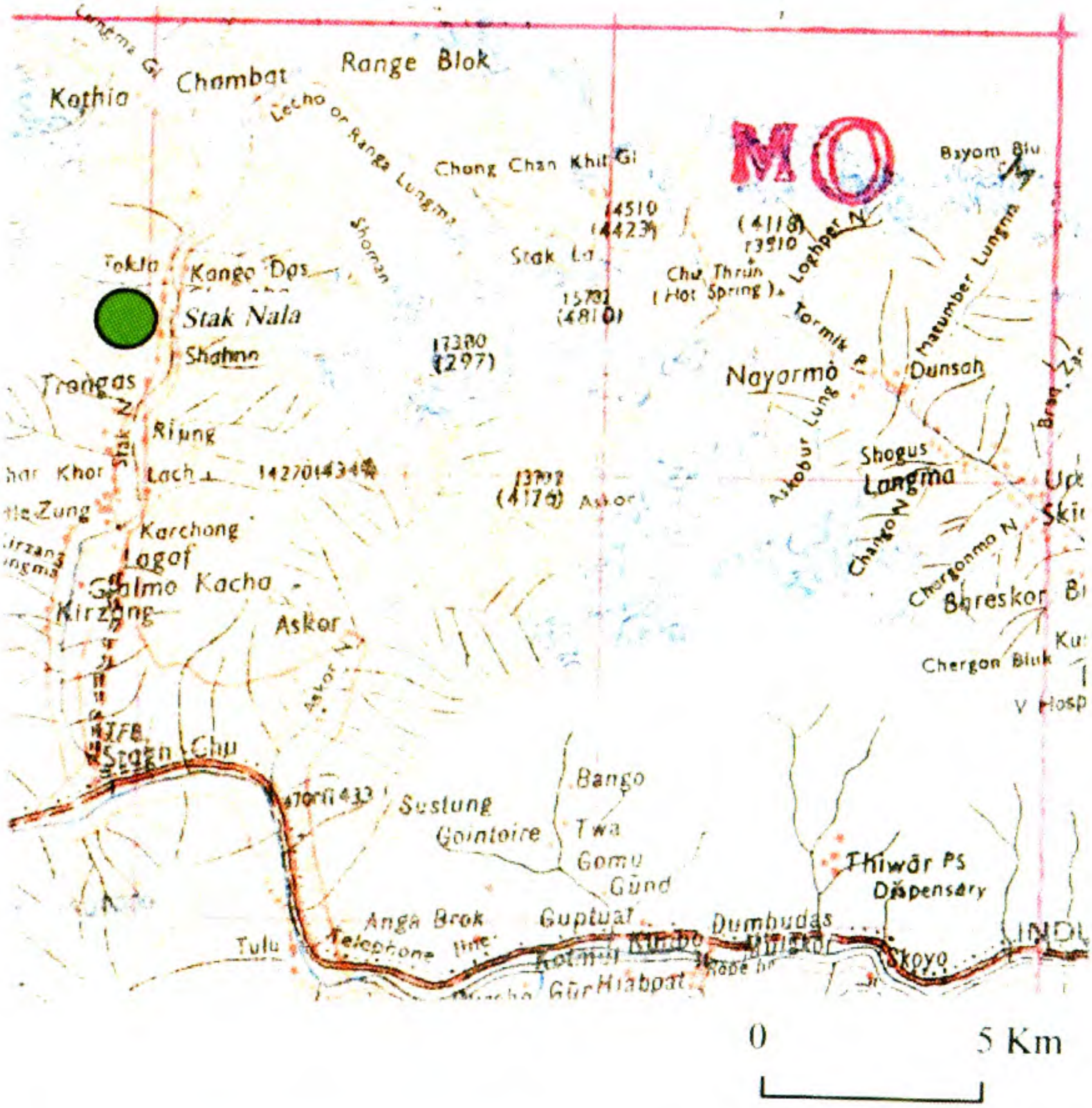

Figure 11.2. The location map showing tourmaline deposit of Stak Nala, Gilgit-Batistan. Toposheet No. 43 M. Scale 1:250,000.

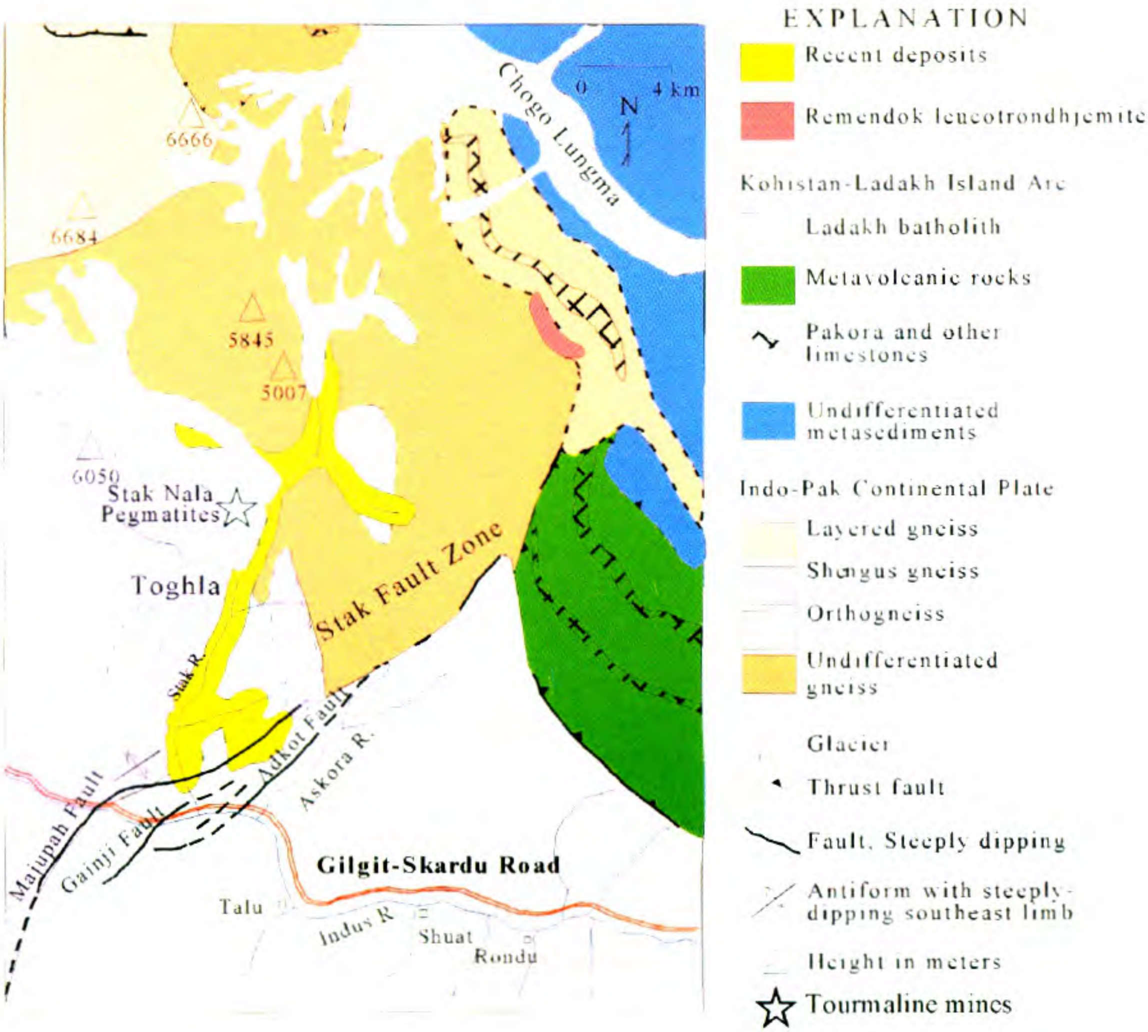

Figure 11.3. Geological map of northeastern portion of the Nanga Parbat Haramosh massif including the Stak Nala area, Gilgit-Baltistan. (Modified after Pognante 1993, Le Fort et al., 1995, Laurs et al., 1998).

Figure 11.4. Photograph showing contact of wall rock with core zone, which is depicted by radiating schorls (wall rock) and blocky K-feldspar (core zone), Kaska mine, Stak Nala, Gilgit-Baltistan.

Figure 11.5. Photograph showing white beryl, mineralised in the core zone of pegmatite, Kaska mine, Stak Nala, Gilgit-Baltistan.

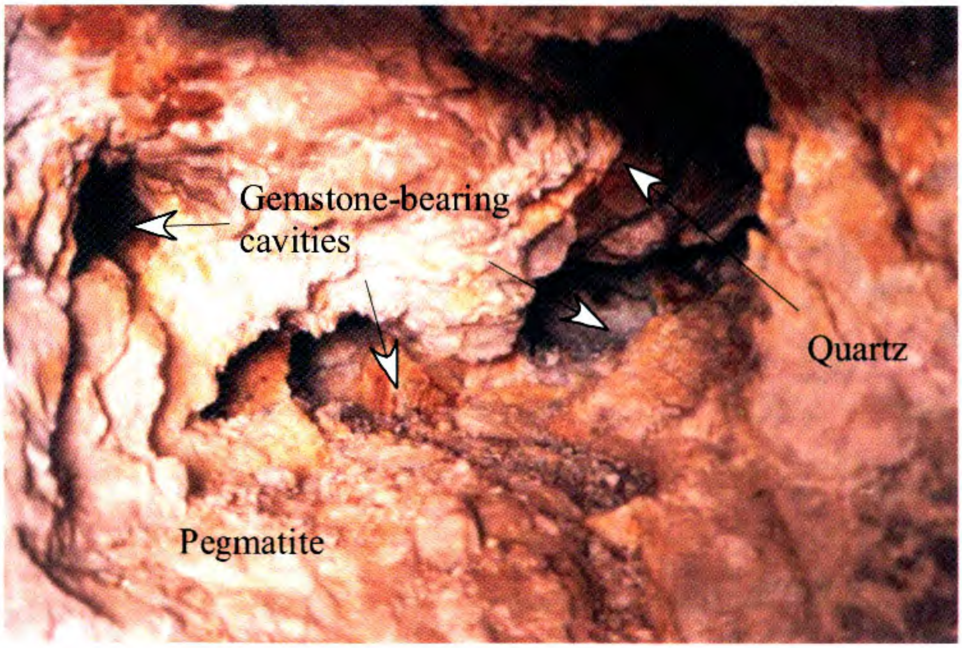

Figure 11.6. Photograph showing gemstone-bearing pockets developed in the Kaska tourmaline mine, Stak Nala, Gilgit-Baltistan.

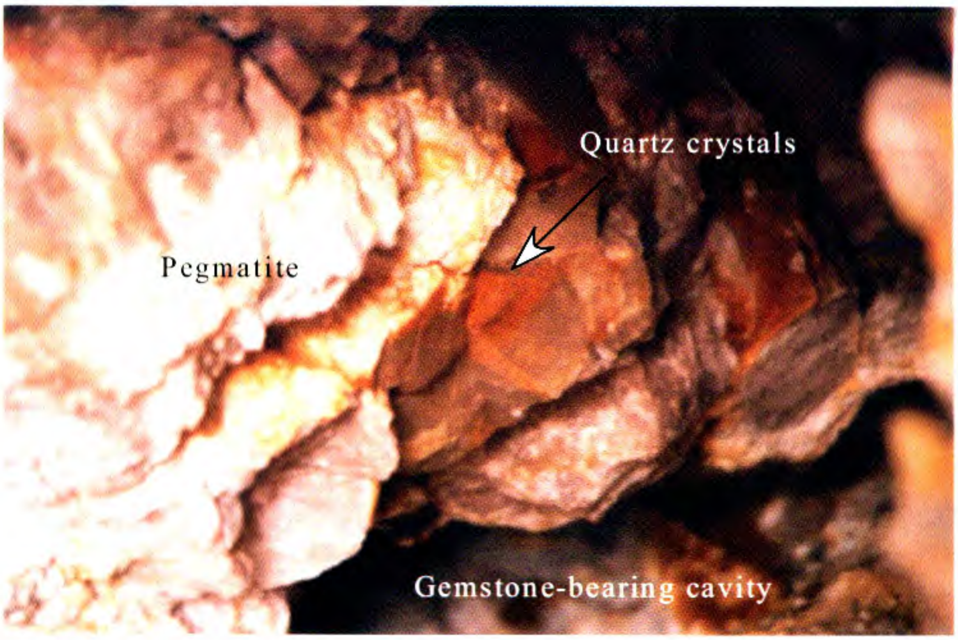

Figure 11.7. Photograph showing closer view of quartz crystals developed as cluster at the roof of a cavity that produced beautiful coloured tourmaline. Kaska mine, Stak Nala, Gilgit –Baltistan.

Mining history

Locals first discovered tourmaline in Stak Nala. After the establishment of GEMCP in 1979, mining for tourmaline was undertaken in 1980 in three pegmatite bodies situated at Baho, Zaloowa and Kaska. Besides, GEMCP, Mr. Mario, an Italian businessman started joint venture in mining with the GEMCP for one season in 1986-1987. After Mr. Mario, Mr. Edward Link, a German businessman carried out joint venture in mining with the GEMCP in 1988. In 1989, Mr. Wali Jan, a Pakistani businessman continued joint venturing with the GEMCP. In 1990, the GEMCP closed the mining operation.

Mining methods and production

Due to harsh winter and snowfall, mining operation in Stak Nala during GEMCP period, usually started in April and ended in September every year. Most of the tourmaline production was recovered from the Kaska mine, which is situated near Toghla village (35°44′31″ N: 75°02′33″ E; Figs. 70 and 76). Mining by GEMCP was underground and in this regard at Kaska mine, five adits were dug and as a result, abundant colourful tourmaline crystals and mineral specimens were recovered (Fig. 11.8). For the recovery of the gemstones, hammers, pneumatic picks and dynamiting, crowbars, chisels etc., were used. Geologists, Mining Engineers and other technical staff were employed in appropriate supervisory roles.

About 150 kg of tourmaline along with specimens during each season were extracted from the Kaska tourmaline mine. Once, Mr. Edward Link recovered 20 crystals of tricolour tourmaline, 12 cm long and 2 cm wide. The GEMCP data shows about 0.45 million carats of tourmaline production from Stak Nala in eight working years from 1981-1982 to 1988-1989.

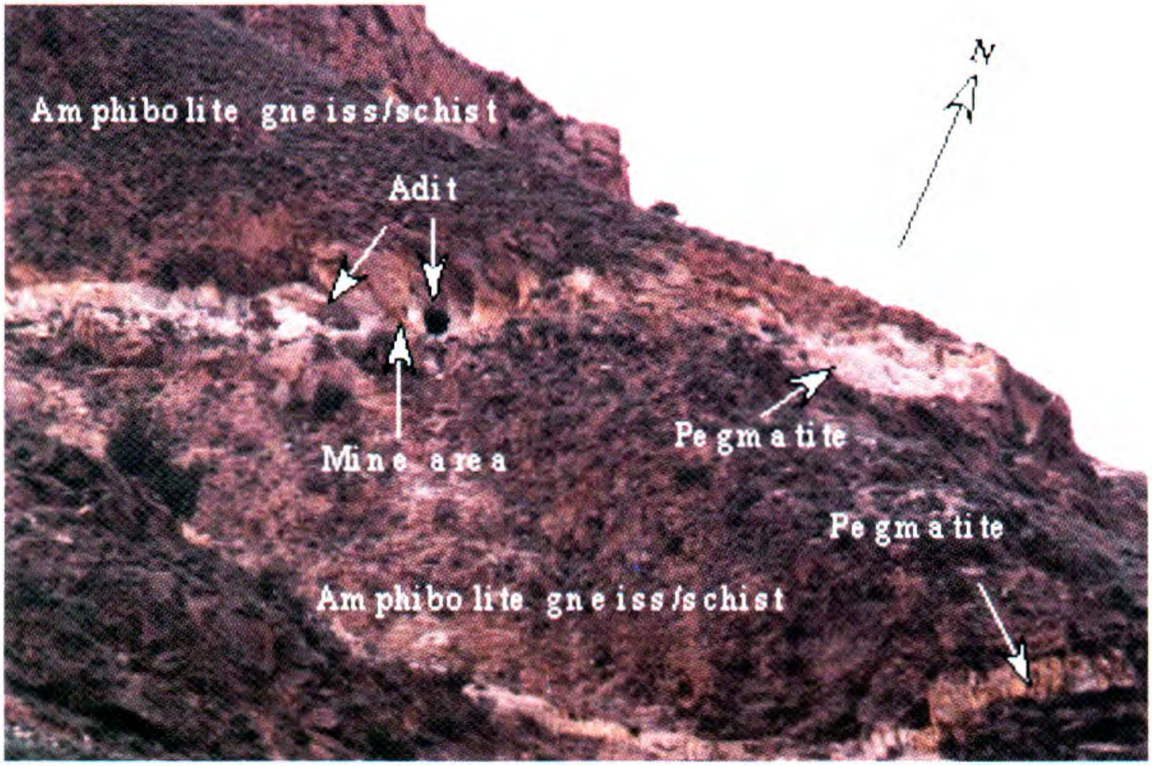

Figure 11.8. Photograph showing Kaska coloured-tourmaline mine area, Stak Nala, Gilgit-Baltistan.

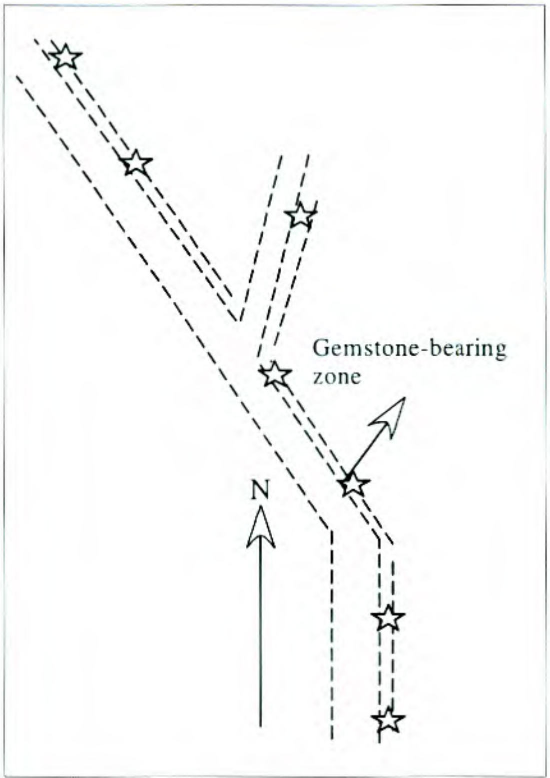

Figure 11.9. Sketch (plan view) showing underground mining in the Kaska tourmaline mine, Stak Nala, Gilgit-Baltistan. The main adit is about 40 m long, 2 to 2.5 m wide and 2 m high.

Guidelines for exploration in pegmatites

Pegmatites of North Pakistan have been a source of gem quality aquamarine, tourmaline and topaz etc. But all the pegmatites do not contain gemstones. For example in Stak Nala out of ten pegmatites only two yielded colourful tourmaline. Why this happens? The following questions need answers (after Einfalt et al., 1995).

What is the type of pegmatite in terms of classification? Do all pegmatites belong to the same generation and/or stage of evolution? Why is gem quality tourmaline, etc known only from a few pegmatites? Is there any exploration method to distinguish between barren and gem tourmaline pegmatite in these areas? Can this method possibly be applied to other pegmatite areas in Pakistan? In the following paragraphs an attempt has been made to target the gemstones in the pegmatites.

1. It is generally believed that complex pegmatites are the source for gemstones. Detailed geological mapping of the area and very careful observation of the pegmatite is required that could distinguish simple and complex pegmatites.
2. Trace and minor elements study of coarse-grained muscovite can be used as a rapid exploration tool in sorting out barren pegmatites from pegmatites with a potential for gem quality tourmaline and other such types of gemstones present. The most powerful distinguishing geochemical parameters are the concentration ranges of Rb, Ba, Nb, Ta, Sn, Li, Cs, MnO, MgO and the element ratios K/Rb and Li/Mg. The barren pegmatites contain high MgO contents and high K/Rb- and Mg/Li -ratios and with low Cs and MnO concentration in its muscovite whereas the gemstone-bearing pegmatites show the opposite characteristics (Einfalt et al., 1995).

TOPAZ

It is said that wearing topaz, dispels all enchantment and helps improve eye sight. The ancient Greeks believed that it had the power to increase strength and make its wearer invisible in times of emergency. Topaz was also said to change colour in the presence of poisoned food or drink. Its mystical curative powers waxed and waned with the phases of the moon: it was said to cure insomnia, asthma and haemorrhage. Today blue topaz, which has a pale to medium blue colour, is created by irradiation. In early 1998, a new type of enhanced topaz made its appearance, the surface-enhanced topaz, with colours described as blue to greenish-blue or emerald green.

Topaz is hydro-fluoro-alumino silicate gemstone $Al_2(F,OH)_2SiO_4$ and has orthorhombic crystal system Topaz is often found as large crystals. Natural pink and red topaz is rare. Fine orange-yellow material is relatively rare. Abundant colourless topaz is irradiated and heat-treated to produce the material resembling aquamarine. Topaz has hardness 8, and is fairly a hard gemstone but it can be split with a single blow due to the presence of perfect basal cleavage, a feature it shares with diamond. Therefore, it should be protected from hard knocks.

Occurrence

Topaz is found in different colours. For example, brown, yellow, orange, sherry, red and pink topaz is found in Brazil, Sri Lanka and Russia. In Pakistan, colourless and yellowish golden topaz is found in pegmatites of the Gilgit-Baltistan areas. On the other hand, pink topaz that occurs at Katlang of Mardan district, is very rare because it is the only known naturally deep red or deep pink topaz in the world with colours ranging from colourless, pale beige to light brown and from very deep pink to bright red and even to violet (Figs. 12.1 and 12.2). The properties of such gemstones are characterised not only by their colour, and the mineral inclusions in them, which can also lend colour to a stone, but also by their refractivity, hardness, specific gravity and fluorescence and other properties (Kazmi and O'Donoghue, 1990).

Figure 12.1. Photograph showing pinkish-red coloured Katlang topaz specimen.

Figure 12.2. Photograph showing pink and light golden colour Katlang topaz. The pink topaz represents the Ghundo deposit whereas the light golden topaz represents the Shamozai deposit.

Location and access

Katlang topaz is being mined at Katlang, Mardan (34°24′ N: 72°06′ E to 34°23′58" N: 72°06′11" E; Fig. 12.3) in the Peshawar basin of the Indo-Pak continental plate. The area lies in the Survey of Pakistan Toposheet No. 43B/3 (Arbab and Qurashi, 1972). Katlang topaz deposit is located at Ghundo hillock (Shaheed Ghundai) 2.5 km north of the town of Katlang and about 20 km north of the city of Mardan and about 60 km northeast of Peshawar. Another deposit occurs in the vicinity called Shamozai. Shamozai mine is 5 km away from the Shamozai Chowk. Near the government school at Shamozai, a 2 km unmetalled jeepable track leads to the mine area.

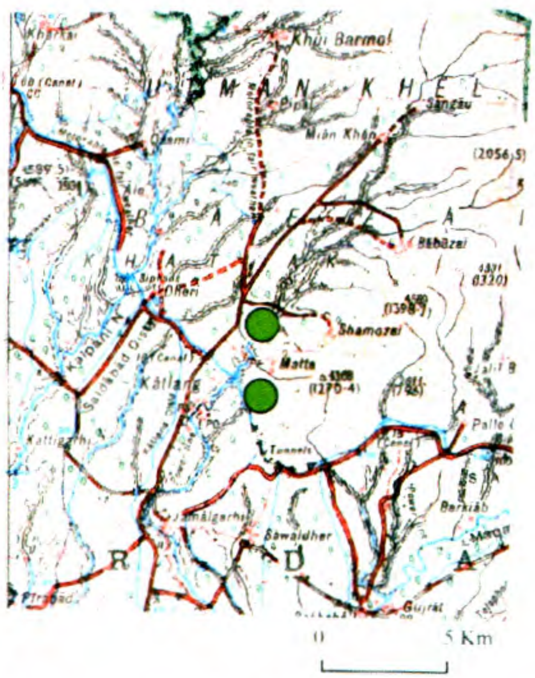

Figure 12.3. Location map showing topaz deposit of Katlang, NWFP, Pakistan. Toposheet No. 43 B. Scale 1:250,000.

Geology

North of Katlang, a few hillocks composed of metasedimentary rocks of Mesozoic age, rise above the level of the fertile alluvium of the Peshawar basin. These rocks belong to Kashala formation of Upper Triassic age. The Kashala formation comprises carbonates intercalated with phyllites and/or schists, and was deposited following thermal subsidence of the late

Paleozoic rift highlands of Swat (Pogue et al., 1992b). The overlying rock of the Kashala formation is the Saidu calc-graphitic schist, probably of Jurassic age and the underlying rocks belong to the Morghazar formation of Permo-Carboniferous age. Detalied studies show that the mother rocks of topaz are the carbonates of the Kashala formation (recrystallised limestones/dolomitic limestones with subordinate phyllites and autoclastic limestone breccia). The rocks are deformed due to folds and faults. In the Shamozai deposit, topaz mineralisation is confined to the limb of a large anticline? According to Arbab and Qurashi (1972), topaz is found in calcite-quartz veins penetrating carbonate rocks.

Limestones are medium to fine-grained and composed mainly of calcite with a little quartz, mica, carbonaceous dust and locally oxidised pyrite up to one centimetre across. Veins of calcite with little quartz are common but systematic relationship has not been found between the structure and the topaz-bearing veins. However, the topaz-bearing veins are mostly along the crests of the tightly folded anticlines (Fig. 12.4: Ghundo hillock). The calcite veins are of two types, (i) pure white calcite and (ii) those with white, grey or brown calcite accompanied by milky quartz, clayey material, and greenish talc and mica (Fig. 12.5). Topaz mineralisation is associated with the second type, especially in the cavities and vein breccia and particularly at the contact of calcite with grey limestone (Fig. 12.6). The country rocks do not contain topaz except a few crystals that extend from the veins. Colour in the topaz is due to trace elements rather than colour centres because sunlight cannot deteriorate the colour. Trace elements such as cobalt and chromium give pink colour to this topaz (Jan 1979).

Origin

Largest topaz crystal recovered so far is about 8.0 cm long with a deep pink colour; otherwise most of the crystals are less than 2.5 cm. Topaz and the associated transparent quartz lack crystalline outlines, many of them are broken and only two out of 50 crystals could be perfectly well developed. Katlang topaz has high water content (~15% F) suggesting hydrothermal/pneumatolytic origin (Jan 1979).

It is normally known that topaz mineralisation is always accompanied by fluorite. The absence of fluorite and the broken nature of topaz and quartz crystals would explain that the earlier hydrothermally formed topaz, fluorite and transparent quartz were subjected to tectonic movements, and the solutions thus produced, attacked topaz, fluorite and feldspar.

Topaz crystals were fractured and etched whereas fluorite was dissolved and the feldspars were destroyed later on by hydrothermal activity (Jan 1979).

Physical and optical properties

Katlang topaz is transparent to translucent, colourless, purple, pink and good crystals are free from impurities. The gemological properties of the topaz include (i) Refractive indices α = 1.630; β = 1.632; γ = 1.640), (ii) Birefringence (0.010), (iii) Axial angle (ZV=53°00), (iv) Pleochroism α = yellow; β = pale purple; γ = dense mauve to violet and (v) Density (3.51-3.53 g/cm^3).

Figure 12.4. Photograph showing Katlang topaz mine, Mardan. The recrystallised limestone is folded. Milky white calcite is wide spread as tension gash.

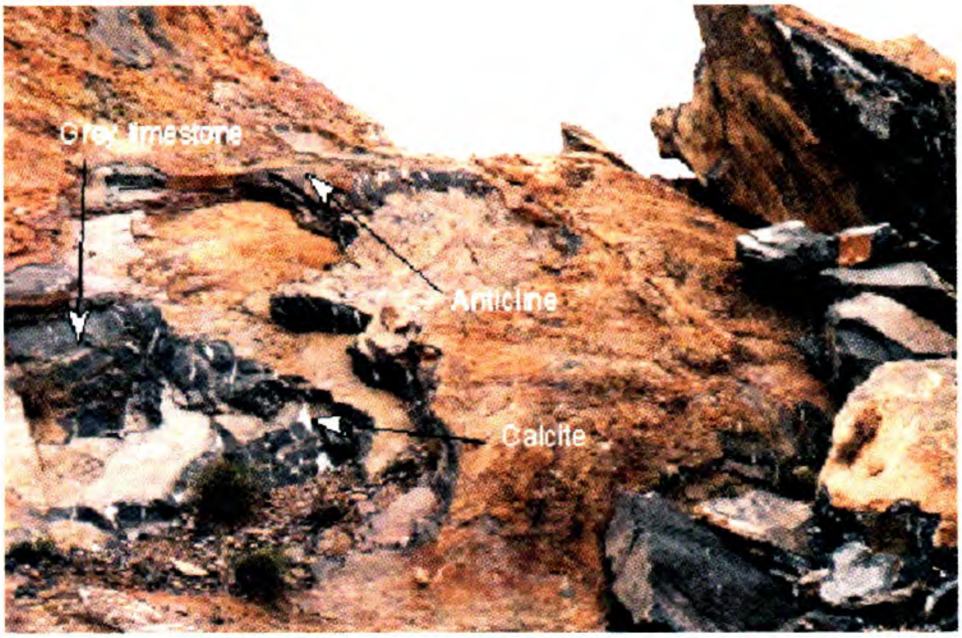

Figure 12.5. Photograph showing milky white calcite veins within gray limestone of Katlang topaz mine, Mardan.

Figure 12.6. Photograph showing cavities and hydrothermal breccia, Katlang pink topaz mine, Mardan.

Mining history

Katlang pink topaz mines have been run by GEMCP till it disbanded in 1994. At that time, there were two known deposits, the Ghundo and the Shamozai pink topaz deposits. The NWFP Government at the rate of rupees 0.95 million auctioned the Ghundo topaz deposit for ten years to Farmaullah of Peshawar. Since the party failed to deposit the auction money, the mining lease was cancelled.

Shamozai mine was subsequently auctioned through open bid at the rate of rupees 18 hundred thousand for ten years to Sardar Ateeq of Abottabad in 1998. The mine spreads over in a leased area of six acres.

The Shamozai topaz mine was later on made operational in 2002. Sardar Ateeq Khan, the owner of the mine had sublet this mine to a local Ali Zar Shah on lease for three years with terms and conditions that he had to pay him monthly instalments. There were about twenty labourers who worked in the mine as shareholders with Ali Zar Shah. At present mining is closed.

Mining methods

Mining methods used in the mine to extract the topaz were very primitive. Dynamites were used frequently to break the rock. Major mining tools included crowbars, hammers, and portable drilling machines. The drilling machine was used mainly for making holes for blasting in the rock.

Production and quality

Production data from the private sector is not available, however the GEMCP extracted 0.54 million carats rough pink topaz from Katlang from 1981-1992. Katlang pink topaz has a high price both in the national and international markets because of its unique colour.

Guidelines for exploration

1. Recrystallised limestone host: greyish, and at places brownish and deformed (folds, joints and breccia). The rock is hard, and impure due to argillaceous

substance and iron oxide leaching. Milky white (pure) and whitish grey (impure) calcite traverse the rock as veins and tension gashes. Topaz is found with impure calcite part of the rock. Other minerals in association with topaz-bearing impure calcite include talc, chlorite and quartz.

2. Topaz mineralisation is controlled both by the geological structures such as folds, faults and joints, and the specific mineral occurrence such as calcite, talc, chlorite and quartz. Topaz mineralisation is confined to the contact of impure calcite-bearing vein with the greyish recrystallised limestone.

PERIDOT

Peridot was mined in ancient Egypt on an island called Zabargat. Mining was used to be done at night according to the legend that peridot could not be easily seen during the day. The Romans called peridot "evening emerald" , since its green colour did not darken at night but was still visible by lamplight (http://www.jewelrycentral.com). It was also said that peridot had the power to drive away evil spirits and the power was considered to be even more intense when the stone was set in gold. The present fashion's passion for lime green has revived interest in peridot and increased the popularity of this gemstone worldwide.

Occurrence

In 1994, an exciting new deposit of peridot was discovered in Pakistan, and these stones were among the finest ever seen. The new mine is located 5.000 m above sea level in the Nanga Parbat region in the far west of the Himalayan mountains in Pakistan. Although peridot is treasured in Hawaii as the goddess Pele's tears, almost all of the peridot sold in Hawaii today is from Arizona, even though Hawaii's volcanoes produce peridot (http://shamballasoul.com). The island of Oahu even has beaches made out of olivine grains but unfortunately they are too small to cut into peridot (http://www.columbiagemhouse.com). Besides, the occurrence of peridots at Sapat, Pakistan, peridot has also been reported, e.g., at the Zabargat, Island or St. John Island, in the Red Sea where the host rock is serpentinitized dunite. In the Ross Island Antarctica, peridots occur in nodules in basalt. Other localities where peridot mineralisation is known include Upper Myanmar (Burma), Australia, Brazil, China, Mexico (light green peridot, and a more iron rich light greenish-brown variety), Norway and the USA.

Location and access

Peridot mines of Sapat occur to the northeast of Naran (34°54´17" N: 73°38´51" E) and north of Sohch village (34°56´29" N: 73° 42´40" E; Fig. 13.1) and fall in the Survey of Pakistan toposheet Nos. 43E and 43F. Naran is about 115 km away from Islamabad and takes seven hours by road. From Sohch village, which is lying on the bank of Kunhar River, a 20 km long mule track leads to the mine area.

Geology

Peridot is mineralised in the ultramafic part of the Sapat mafic-ultramafic complex. This complex occupies base of the Kohistan island arc, which is delineated from the Indo-Pak continental plate by a serpentinite body of the oceanic crust. The complex is about 600 m wide and 12 km long, and sheared. It is pinched in the northwest of Domel and southeast of Umer Di Baikh. The contact of the complex with graphitic schist of Indo-Pak continental plate is marked by a thrust fault. The contact of the complex with the layered gabbro is also marked by a thrust fault (Fig. 13.2). The mafic-ultramafic complex comprises layered gabbronorite, dunite-pyroxenite-gabbro- (anorthosite) layers, thinly layered dunite, pyroxenite, dunite with thin chromite layers and cumulate dunite at the base (Jan et al., 1993).

Peridot occurs in the cumulate dunite part of the complex to the southeast of west Sapat Gali, and to the north of Rah Wali Sapat (Parla Sapat, Kaghan-Naran area) and to the west of Ratti Gatti (Kohistan area). Here the dunite is brownish on the weathered surface, and grey with greenish tinge on the fresh surface. It is about 300 m wide and bounded towards the MMT by a 3 m wide intensely sheared zone (Fig. 13.3). A serpentinite exotic body delineates dunite from graphitic schist of the Indo-Pak continental plate.

The dunite shows intense jointing and veining. The joints and veins are cross cutting and contain clinochrysotile, antigorite, talc and magnetite as the associated minerals (Figs. 13.4, 13.5 and 13.6).

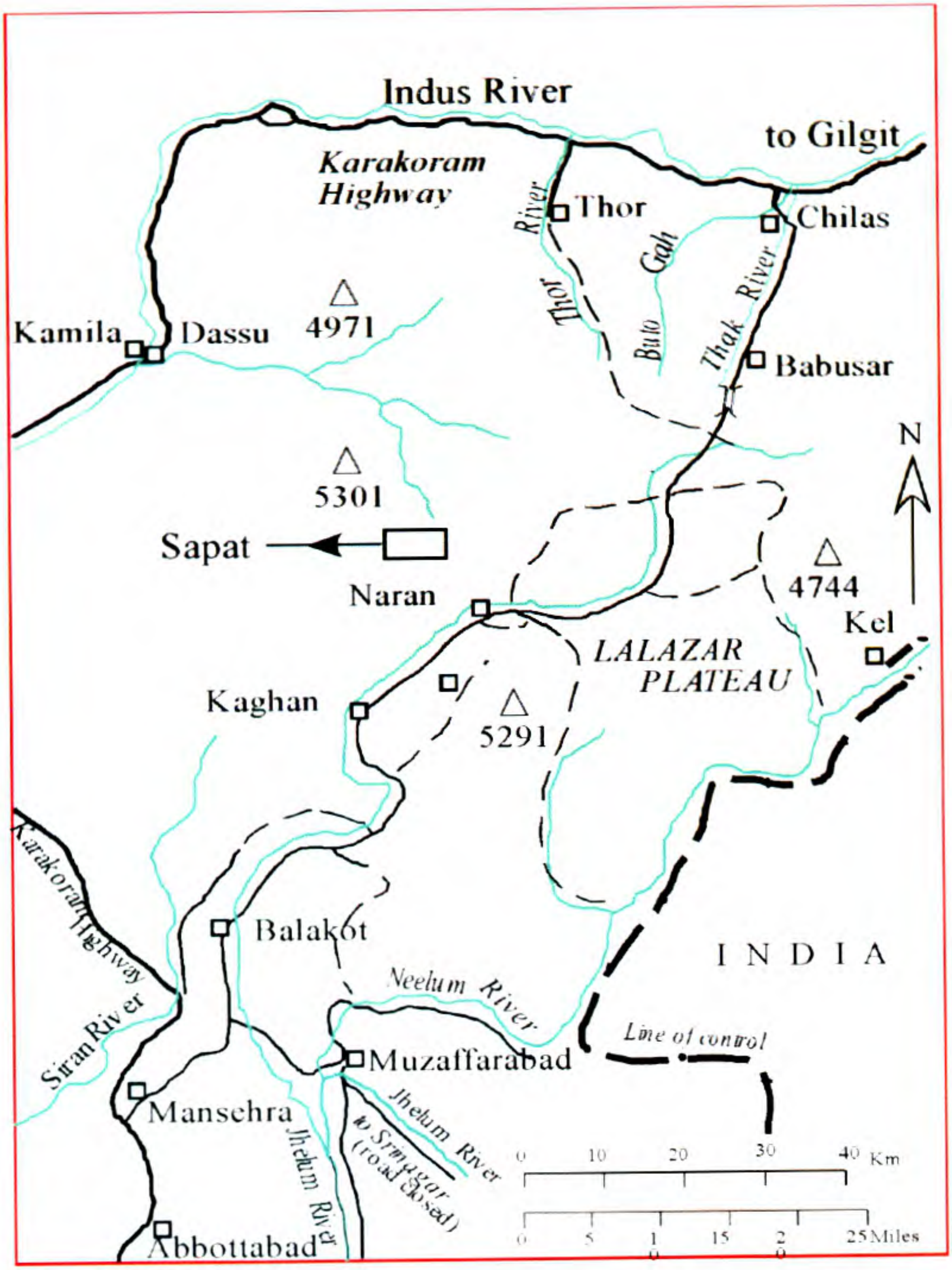

Figure 13.1. Location map of Sapat area, Naran-Kohistan.

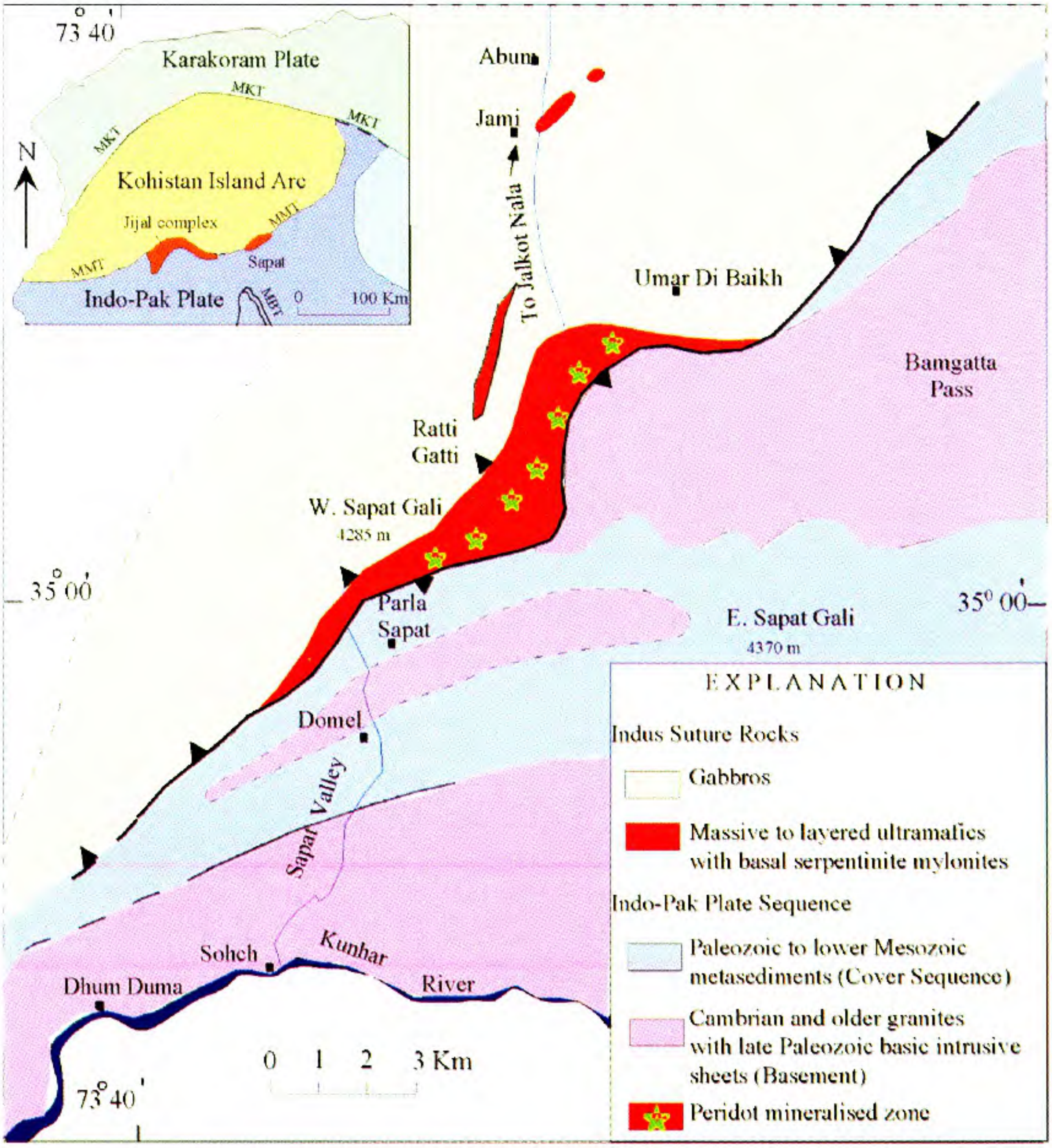

Figure 13.2. Geological map of Sapat and the surrounding areas, Naran-Kohistan, Pakistan (modified after Jan et al., 1993).

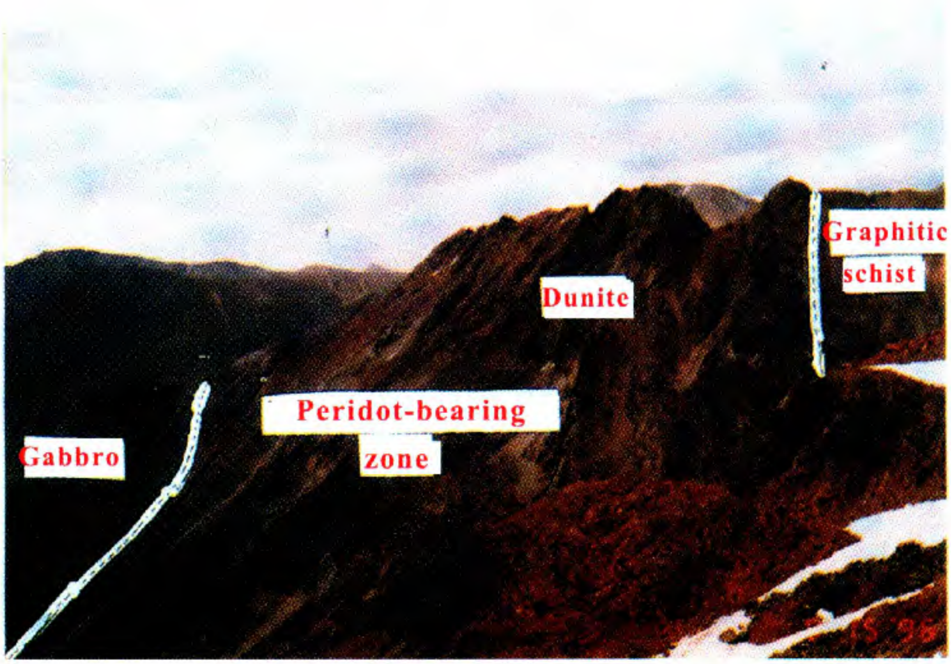

Figure 13.3. Photograph showing peridot mineralisation zone marked between graphitic schist of the Indo-Pak continental plate and gabbros of the Kohistan island arc, Sapat area,Naran-Kohistan.

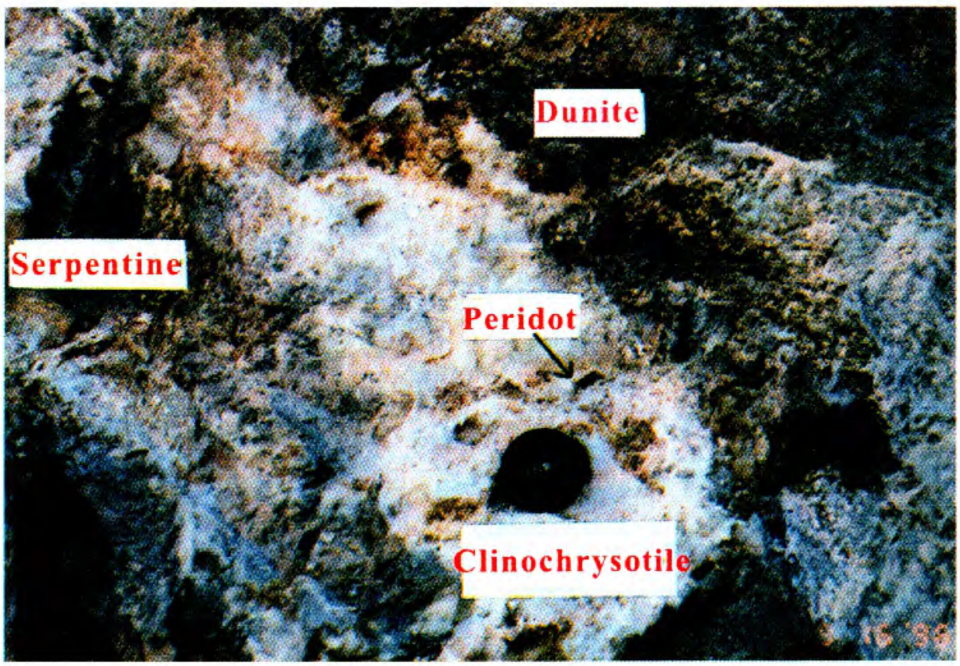

Figure 13.4. Photograph showing a peridot-bearing pocket along one of the joints within the dunite, Naran-Kohistan.

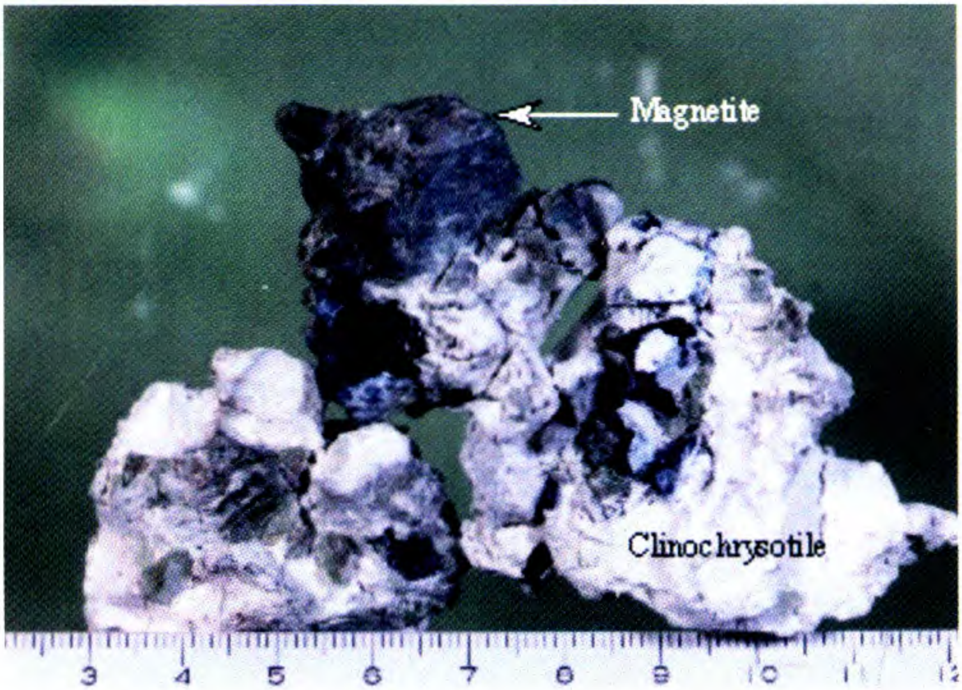

Figure 13.5. Photograph showing magnetite-host clinochrysotile, a path -finder mineral for Sapat peridot, Naran-Kohistan.

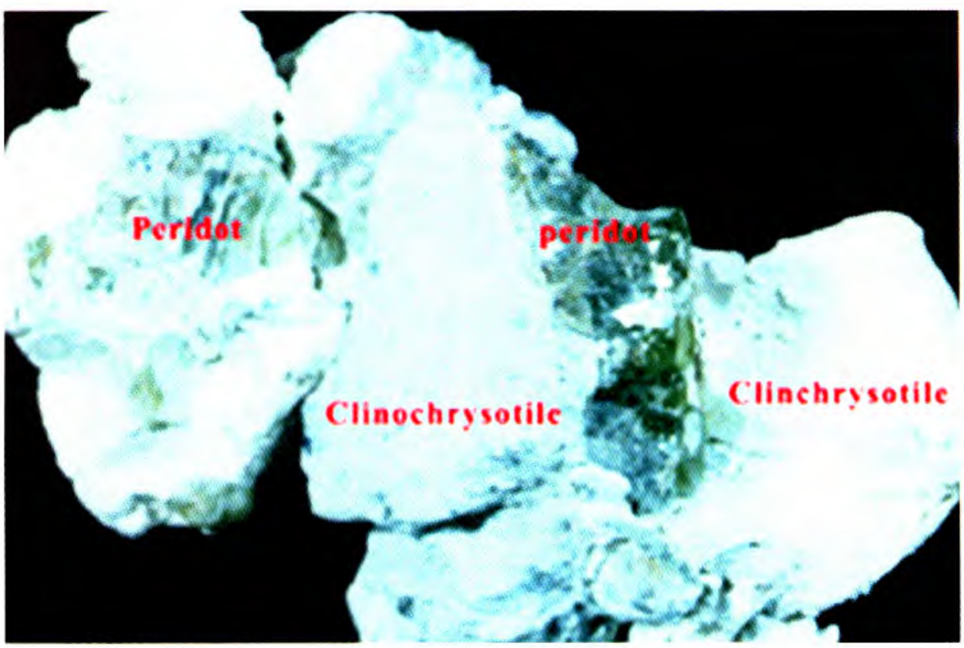

Figure 13.6. Photograph showing peridot crystals within clinochrysotile from the Sapat peridot mine area, Naran-Kohistan.

Physical and optical properties

Peridot crystals from Sapat are fairly-to well developed but most of the specimens are broken due to blasting during mining. Crystals are typically stubby orthorhombic, displaying prominent prisms (100) and (110), basal pinacoid (001), and pyramidal (021) and (111) faces. The faces lack overgrowths and are smooth, but in few cases the prismatic faces have striations and pits elongated to the c-axis. Some pyramidal faces are also pitted or rough. These pits are occupied by serpentine and a few show iron-oxide stains.

Peridot ranges in colour from light yellow to green to deep yellow green, but in few cases it is light green and in exceptional cases greenish yellow. It is transparent to translucent and mostly uniform in colour. The peridot does not possess any cleavage but displays usually glass-like fractures. It has hardness from 7.0 to 6.5. Refractive indices, birefringence and densities range (α) 1.644-1.653 and (γ) 1.682-1.689, 0.033 to 0.038 and 3.26-3.44 respectively. These values are similar to those of the two samples studied by Koivula et al. (1994) who also reported other optical determinations, such as, UV fluorescence: inert to both long and short wave; absorption spectrum: distinct but somewhat diffused absorption bands at about 453, 477, and 479 nm, as well as weaker band at about 529 nm.

Chemical characteristics

Peridot is the gem-quality dark green variety of olivine having a general composition of $R_2''SiO_4$ (where R" stands for Mg, Fe^{2+}, Mn and Ca). Common olivine is a solid solution of two end members, forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). The refractive indices, specific gravity, cell dimension and other physical properties vary systematically with variation in chemical composition, which is commonly expressed in mole percent forsterite ($Fo=100Mg/(Mg+Fe^{2+})$). It ranges in composition from about Fo_{87} to Fo_{97}, but most have the composition around Fo_{90}, irrespective of the individual paragenesis. The quantitative measurement of the element oxides of peridot is done by EPMA.

The depth of colour of peridot appears to depend on its iron content. Samples with high forsterite content (Fo_{95}) are greyish white to light yellowish green and those with low forsterite content (Fo_{90}) are deeply yellowish green. XRD and EPMA data revealed that the acicular inclusions in the peridot are the magnesian iron borate mineral ludwigite, which has chemical formula $(Ti_{0.011}Cr_{0.041}Fe^{3+}_{0.947})_{1.0}(Mg_{1.085}Fe^{2+}_{0.897}Mn_{0.004}\ Ni_{0.013})_{2.00}B_{1.00}O_5$ (Jan and Khan, 1996).

Origin

Peridot of the Sapat area is invariably associated with light greyish to whitish serpentine (clinocrysotile), magnetite, talc and chlrorite. This mineralogy, coarse-grain size and the presence of ludwigite inclusions in the peridot suggest that this mineralisation occurred in the presence of a fluid phase consisting of water with some carbon dioxide and boron (Jan and Khan, 1996).

Peridot ranges from Fo_{87} to Fo_{97} (Jan and Khan, 1996; Khan et al., 2000). The more magnesium composition than Fo_{93}, are unusual in igneous paragenesis, and found in some meteorites, metamorphic rocks, and adjacent to chromite grains due to Fe-Mg exchange. The consistent association of magnetite with the peridot and local inclusions of ludwigite suggest that some peridot may have been enriched in Mg during secondary processes (Jan and Khan, 1996).

From these observations the authors are of the opinion that the dunite was sheared during their emplacement onto the Indo-Pak continental plate. Consequently, cooling and hydration serpentinised it and the hydrothermal solutions thus produced, affected parts of this rock, leading to the growth of peridot and the associated minerals. The peridot-forming solutions may be related to the late phases of regional metamorphism of the underlying Indo-Pak continental plate (?) or the granites of Eocene time (Treloar 1995; Smith et al., 1994).

It is to be noted that the paragenesis of the Sapat peridot is similar to that of Eastern Sayan in Russia (Glazunov et al., 1973). That gem-crysolite Fo_{93} occurs in asbestos-like, chrysotile-sepiolite shells, and as crystalline inclusions in talc veins intersecting the serpentinised carbonaceous peridotites.

Mining, quality and marketing

In 1996, Geoscience Advance Research Laboratories, Geological Survey of Pakistan reported for the first time magnetite as a pathfinder mineral for peridot of the Sapat area, Naran-Kohistan in 1996. As this area lies in the remote and high altitude part of the region, therefore, due to heavy snowfall in the area, mining season is restricted from July to October.

Local people do mining. The government of NWFP could not auction the peridot mines till date due to the hostile nature of the local people. Peridots of Naran - Kohistan are green to yellowish green. The tiny peridot grains are generally transparent whereas bigger grains are translucent and occasionally opaque. Some of the peridots are typified with microfractures and metallic inclusions of chromite and magnetite. The green-coloured, transparent and fracture-free peridots are considered as good quality gemstones for jewellery.

Most of the peridots are broken and fractured due to uncontrolled blasting and crude methods of recovery. The stones are mostly less than 3 cm in length but up to 15 cm long crystals weighing 2 kg have been recovered so far. The largest faceted stone is reported to measure about 310 carats (Jan and Khan, 1996).

Local people earn their income by selling the Sapat peridot. The value of the rough peridot ranges from rupees 1,000 to 1,500 to rupees 1.0 to 1.5 millions per kg depending upon the quality and size of the material. Locally, cut and polished stones are sold from rupees 20 to 30 per carat (low quality) to rupees 3,000 or more per carat (excellent quality and lager size). The production data of the mine is not available as locals run these mines illegally. Annual production can be estimated as 25,000 to 30,000 carats? However, the resources can roughly be up to 100 million carats?

Guidelines for exploration

Peridot can easily be found in the Sapat and surrounding areas by knowing the following characteristics.

1. Finding of sheared dunite associated with ultramafic cumulate. The joints, cavities present in the dunite may contain peridots. Clinochrysotile (milky white platy serpentine, talc and magnetite are the associated minerals with peridot.
2. Magnetite is the pathfinder mineral for peridot in sheared dunite. Trails of magnetite found on the surface can indicate peridot mineralisation in the rock.

RUBY

Ruby has been the world's most valued gemstone for thousands of years. In the ancient language of Sanskrit, ruby is called ratnaraj, or "king of precious stones" and ratnanayaka, "leader of precious stones". Ruby is the gem quality of the mineral corundum, one of the most durable minerals, which exists in a crystalline form of aluminium oxide. Corundum has a hardness of 9 on the Moho's scale and is also extremely tough. In its common form, it is even used as an abrasive.

The most important factor in the value of a ruby is colour. The top qualities are as red as one can imagine: a saturated pure spectral hue without any overtones of brown or blue. The word red is derived from the Latin for ruby, which is derived from similar words in Persian, Hebrew, and Sanskrit. The intensity of colour of a fine ruby is like a glowing coal. It is no wonder to ascribe magical powers to these fires that burn continuously and never extinguish.

All colours of corundum except red are known as sapphires, which have created argument about where ruby ends and sapphire begins, particularly in pink shades of corundum. In 1991, the International Coloured Gemstone Association ruled that the lighter shades of the reddish hues of corundum should be included in the category of ruby.

After colour, other factors, which influence the value of a ruby, are clarity, cut, and size. Rubies that are perfectly transparent, with no tiny flaws, are more valuable than those with inclusions, which are visible to the eye. Cut can make a big difference in how attractive and lively a ruby appears to the eye. A well-cut stone should reflect backlight evenly across the surface without a dark or washed-out area in the centre that can result from a stone that is too deep or shallow. The shape should also be symmetrical and there should not be any nicks or scratches in the polish. Larger rubies, because they are rarer, will cost more per carat than smaller stones of the same quality.

Ruby sometimes displays a three-ray, six-point star. These star rubies are cut in a smooth domed cabochon cut to display the effect. The star is best visible when illuminated with a single light source: it moves across the stone as the light moves. This effect, called asterism, is caused by light reflecting off tiny rutile needles called "silk," which are oriented along the crystal faces.

The intensity and attractiveness of the body colour and the strength and sharpness of the star influence the value of star rubies and sapphires. All six legs should be straight and equally prominent. Star rubies rarely have the combination of a fine translucent or transparent colour and a sharp prominent star. These gems are valuable and expensive.

Occurrence

The most famous source of fine ruby is Burma, which is now called Myanmar but the ruby of Myanmar is commonly known as the Burmese ruby and here in this chapter, the authors retain the word Burma for convenience. The ruby mines of Burma are very old. Stone age and bronze- age mining tools have been found in the mining area of Mogok. Ruby from the legendary mines in Mogok often have a pure red colour, which is often described as "pigeon's-blood" although that term is more fanciful than an actual practical standard in the trade today. Burma also produces intense pinkish red ruby, which is also vivid and extremely beautiful. Many of the rubies from Burma have a strong fluorescence when exposed to ultraviolet rays like those in sunlight. Burmese ruby has a reputation of holding their vivid colour under all lighting conditions.

Since demand for fine rubies are really only limited by the tiny supply available, new sources are always treated as exciting news in the trade. An important mining area in Burma is called Mong Hsu. Mong Hsu ruby deposit is producing commercially the high quality Burmese ruby particularly in sizes up to a carat. Burmese ruby is now more readily available than Thai ruby, due to the new ruby rush in the area.

The new deposit has also affected the world capital of the ruby business. Many of the ruby traders and cutters from Chanthaburi and Bo Rai have moved to Mae Sai in Thailand. In Tachilek in Burma, across the border from Mae Sai, a flourishing trade in Mong Hsu ruby has transformed a village into a prosperous town. Most Mong Hsu ruby is cut and marketed in Thailand.

Thailand is the world's most important ruby trading centre. Perhaps 80 percent of the world's ruby goes through Thailand at some point in the trading cycle. The largest ruby cutting factories are in the Chanthaburi area of Thailand. Bangkok is, generally, where the world's buyers come to purchase ruby.

In 1992, a new ruby mine was discovered in Vietnam that produces ruby, which is very similar to rubies from Burma. In fact, the geology of the new mine may be a continuation of the same formation that produced the Burmese ruby deposits. Experts as being virtually indistinguishable from top quality, Burmese stones have praised some of the new Vietnamese ruby.

Fine ruby is also found in Thailand. Thai ruby tends to be darker red in tone: a real red, tending toward burgundy rather than pink, as Burma rubies do. This makes them very popular in the United States where consumers generally prefer their rubies to be a darker red rather than a darker pink. Some Thai rubies have black reflections, a phenomenon called extinction, which can make their colour look darker than it really is. But Thai rubies also can have a rich vivid red that rivals the Burmese in intensity. Sri Lankan rubies can also be very beautiful. Sri Lankan stones are often pinkish in hue and many are pastel in tone. Some, however, resemble the vivid pinkish red hues from Burma.

Ruby from Kenya and Tanzania were discovered in sixties. Unfortunately, most of the ruby production from these countries has many inclusions, tiny flaws, which diminish transparency. Rubies from the African mines are rarely transparent enough to facet. However, their fantastic colour is displayed to full advantage when cut cabochon style. A few rare clean stones have been seen which are of top quality.

Marble-host ruby deposits are the most important source of high quality ruby in the world. In Southeast Asia, marble–host ruby deposits are found in platform metamorphosed series (marbles) located within tectonic units resulting from the continental collisions between India and Asia. Besides, ruby deposits also occur in Australia and South Africa.

Ruby from the African mines are rarely transparent enough to facet. However, their fantastic colour is displayed to full advantage when cut cabochon style. A few rare clean stones have been seen which are top quality. Ruby from Jegdalek of Aghanistan also gives fantastic colour.

In Pakistan and Azad Jammu and Kashmir (AJK), the Hunza and Nangimali ruby deposits are the primary deposits, respectively. Ruby and pink sapphire are also reported from Battakundi and Basal areas of Naran in NWFP and Astore in Northern Areas of Pakistan. Non- gem grade corundum has also been reported from Timurgara area of Dir district in NWFP. In this text, the ruby deposits of Hunza and Nangimali are discussed, as these deposits are well studied and addressed for the last two decades.

RUBY OF THE HUNZA VALLEY

Location and access

Ruby and spinel crystals, many of gem quality, occur in marble, outcropping along the flanks of the Karakoram mountain range whose peaks tower above the Hunza Valley in a remote far-north corner of Pakistan (Fig. 14.1). The highest peak over the Hunza Valley is Rakaposhi at 7,885 m above sea level. The highest peak in the entire range is the famous K2, which is 8,600 m above sea level. Hunza is located on the Karakoram Highway or the KKH. It is about 180 km away from Gilgit and 220 km short of 4,800 m high Khunjrab Pass that connects China with Pakistan.

Geology

Ruby, pink sapphire, spinel and pargasite are developed in metamorphosed, recrystallised marble beds, which form part of thick sequence of metasedimentary and metavolcanic rocks of the Karakoram metamorphic complex (KMC) of Desio (1963a and 1964) that covers the entire zone between the central granitic belt to the north and the contact with the Kohistan-Ladakh formations to the south. The KMC can be schematically subdivided into two subunits: the gneissic domes representing the backbone of the structure and the metasedimentary formations lying north and south of them (Le Fort et al., 1995; Le Fort and Pecher, 2002).

In Hunza and the surrounding areas, metasedimentary formations are exposed which were originally named as the Dumordo group or the Baltit group (Tahirkheli 1982) of unknown age, and were described as a complex of metamorphic rocks dominated by crystalline limestones, rather in thick beds, interfoliated with calc-schists, schists and gneisses (Desio, 1963a, 1979; Desio et al., 1985). The bulk of the metsediments is made up of aluminous schists and rather monotonous terrigeneous formation of dominant sandy and pelitic alternation. Both the metasedimentary formations show metamorphism up to amphibolite grade. Rarely amphibolite horizons of basaltic composition are also present in them. The marble horizons exposed in the area can be grouped into four broad geographical groups from south to north: Chutrum limestone, west of Basha River in Shigar Valley, the

Chogo Lungma group, exposed in the area of the junction of the Bolocho and Chogo Lungma glaciers, the Baintha group exposed Berelter Valley and the Hispar Sar group (Fig. 14.2).

The Hispar Sar group runs along the right (north) bank of the Hispar glacier and across the snow lake for some 60 km. Tightly folded and very steeply dipping to the north, it is mainly associated with aluminous schists and quartzites. They are mainly in tectonic contact with the surrounding granodiorites of Hunza type. This last group of marbles has similar characteristics to the thick one running through the Toltar glacier and around the Sangemar Mar, cutting the Hunza Valley south of the Hunza pluton, and reaching the right bank of Hispar Valley-glacier (Fig. 14.2).

In the section of the Hunza Valley, the Ganesh marbles of Tahirkheli (1996) are associated with dark-coloured amphibolite layers. In the lower Hispar Valley, some marble beds form boudin of calc-silicates with amphibole, pyroxene and epidote within the pelitic schists and orthogneiss. It is in the 2 to 3 km thick marbles of the Hunza Valley crosscut by pegmatites that have the famous corundum deposits (ruby, sapphire, spinel and pargasite). In addition, marbles contain the following mineral associations: margarite, phlogopite, chlorite, pyrite, rutile, dolomite, sphene, apatite, tourmaline, plagioclase, quartz, calcite ± graphite ± goethite and ± pyrrhotite. The gem-bearing marbles extend over 100 km between the Hunza Valley in the east and the Ishkoman Valley to the west.

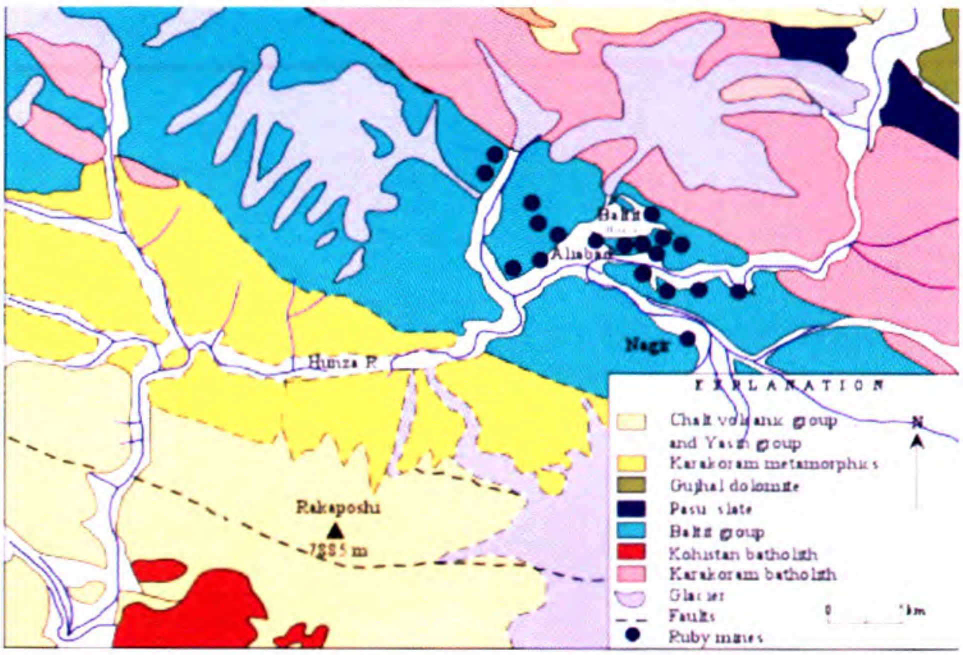

Figure 14.1. Geological and location map showing the ruby deposit of the Hunza Valley, Gilgit-Baltistan, Pakistan. Toposheet No. 42 L. Scale 1:250,000 (modified after Kazmi and O'Donoghue, 1989).

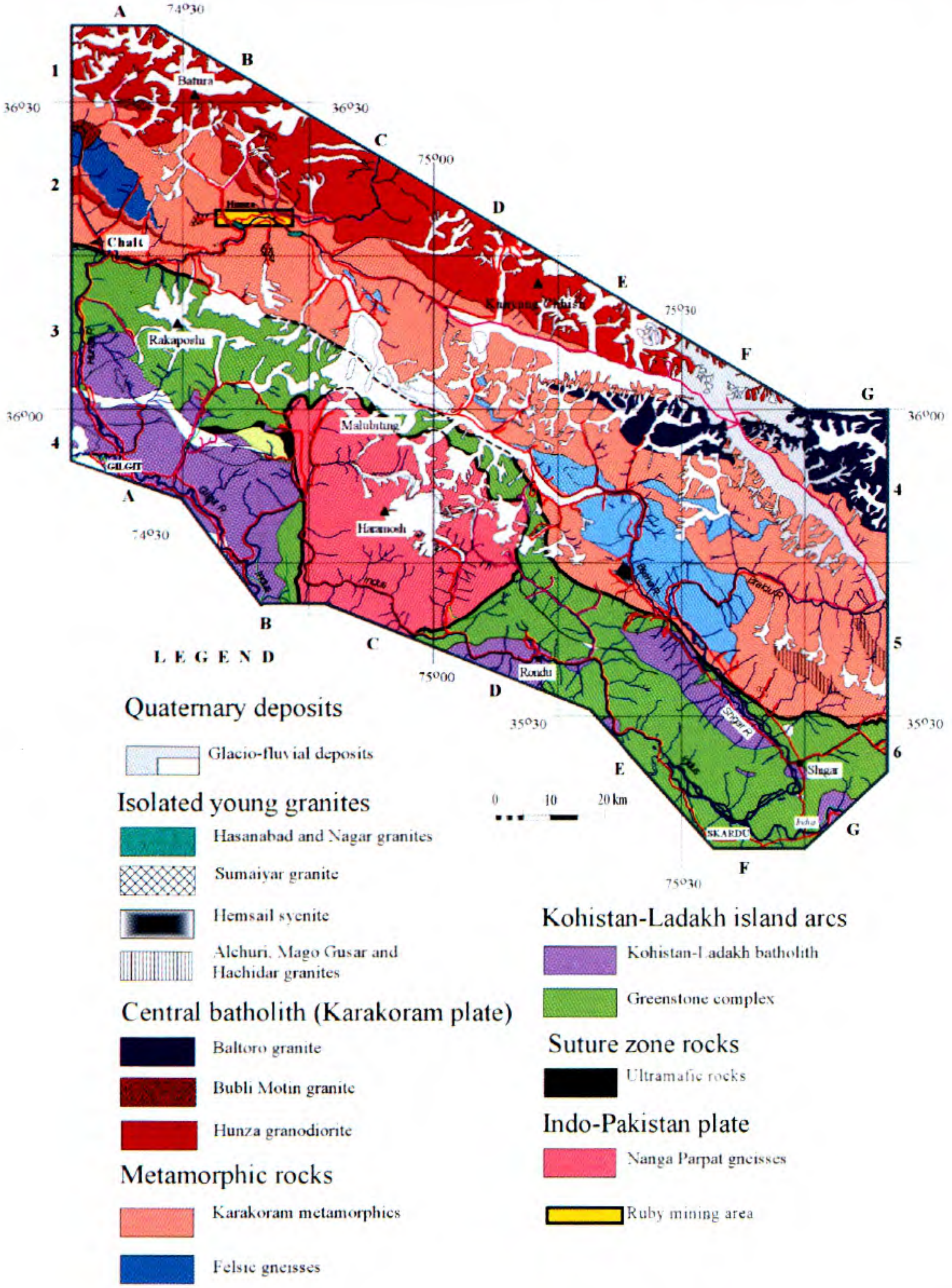

Figure 14.2. Geological map of Gilgit-Baltistan area, Pakistan showing ruby mine area at Hunza (modified afterLe Fort and Pecher, 2003).

Mining history

In Pakistan the main ruby deposit occurs in the marble beds close to the Main Karakoram Thrust. Little was known about the discovery of this deposit before the construction of the KKH. Tourists introduced Hunza rubies to the world. These were first examined and introduced to gemmologists by Okrusch et al. (1976). Access to the ruby deposits is difficult and sometimes, the mines are closed by heavy snow for 3-4 months of the year.

Local inhabitants and Mir of Hunza, who once governed the valleys might have mined ruby on an artisanal scale. Regular mining was started after 1972 when Pakistan Mineral Development Corporation (PMDC) took the responsibility to exploit the deposits. Gemstone Corporation of Pakistan (GEMCP) started mining the deposits in 1979. At present some of the mines are leased out to private companies.

Mining areas

At present mining operation on any large scale is not taking place. However, local people in small groups do carry out mining in some ruby -bearing areas using dynamite, hammers and hand picks. In the past, the gem-bearing marbles readily visible from the valley floor were mined in a primitive fashion; the rock was broken up with hammers, hand picks, pneumatic drills and dynamiting. In a few sites branching adits were driven into the rock. The marble was then broken up into smaller pieces and the gemmy crystals separated whereas those unfit for cutting were often left in matrix and sold as mineral specimens. The smaller ruby crystals tended to be sharper and multifaceted, whereas the larger displayed fewer faces and were generally less well formed.

Currently most of the mining is confined to about 20 mining centres spread over a length of 15 km in Hunza and Nagar Valleys. Some of the ruby deposits are located at Gafinis (36°20'14" N: 74°37'32" E), Dongat, Ganesh (36°18'37" N: 74°42'10" E), Dooikar, Altit (36°19'15" N: 74°41'19" E), Saitkutsbul, Hasanabad Nala (36°19'45" N: 74°34'23" E), Ahmadabad, Dorkahn, Bajouring, Fodandar, Fooliskahn, Datumbarsho, Moinbar, Hussainabad and spinel-pargasite mine at Aliabad (36°19'02" N: 74°39'12" E). All these ruby-bearing bodies show identical structural and petrographical characteristics.

Gafinis ruby-bearing marble covers an area of about 800 square metres (Fig. 14.3), and at present operated by local people.

Figure 14.3. Photograph showing the Gafinis ruby mine north of Aliabad, Hunza.

Dongat ruby mine, Ganesh area of Hunza is located on the roadside of the KKH. Here PMDC, GEMCP and the local people have recovered rubies through underground mining (Fig. 14.5). In this regard two main adits were driven across the strike of the marble following the ruby-mineralised sheared bands (Fig. 14.6). The marble strikes N20°W and dips 25° NE. Adit No. 1 is about 40 m long, the height and the width are 2 m each. There are three off shoots from the main adit, two in the south and one in the north direction. The offshoot adits are approximately 20 m, 10 m and 20 m long. The height and width of these subsidiary adits are same and equal to the main adit. Adit No. 2 is about 30 m to the south from adit No. 1. It is about 30 m long. The height and width are about 2 m each.

Ruby and spinel are developed in sugary white and grey marbles, which are highly sheared. Sheared bands of mm to cm scales are very much conspicuous containing mica, particularly phlogopite ± pyrite ± garnet ± spinel ± ruby (Fig. 14.7).

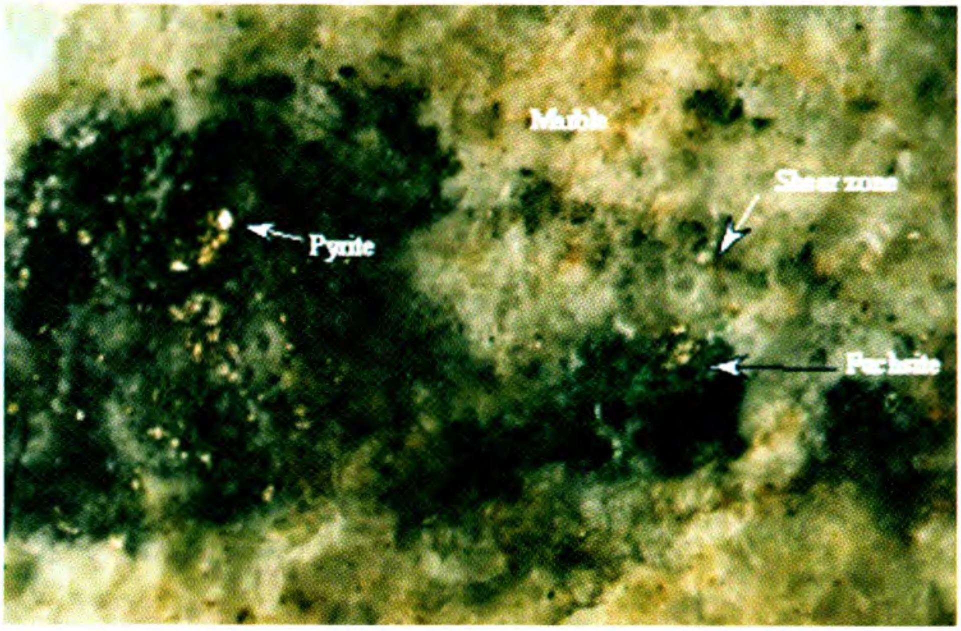

Figure 14.4. Photograph showing shear zone, fuchsite and pyrite within marble of the Gafinis ruby mine, Hunza.

Dooikar ruby mine is situated at 2,666 m above sea level. Here the ruby-host marble, strikes N70° W and dips 50° NE. Ruby has been recovered from this mine through open cut mining.

The signatures of ruby mineralisation in Dooikar ruby mine are similar to the rest of the ruby mines. Here one can see pods/lenses and veins of pegmatites intruding the marble. Besides, milky-white to yellowish and translucent to transparent quartz veins and pods/lenses can also be seen. The marble constituents include calcite ± dolomite, phlogopite, muscovite, biotite, fuchsite, pargasite, spinel, ruby and pyrite. Ruby mineralisation is confined between sheared zones marked by phlogopite, pyrite, fuchsite and pargasite. The rock units exposed in the Gafinis area include, the Karakoram batholith, Baltit group intruded by metadolerite, aplite and pegmatite. The Gafinis marble is comprised of calcite, dolomite, phlogopite, muscovite, fuchsite, biotite, spinel, pargasite, pyrite, limonite and ruby (Fig. 14.4). The ruby is recovered from marble through open cut and underground mining.

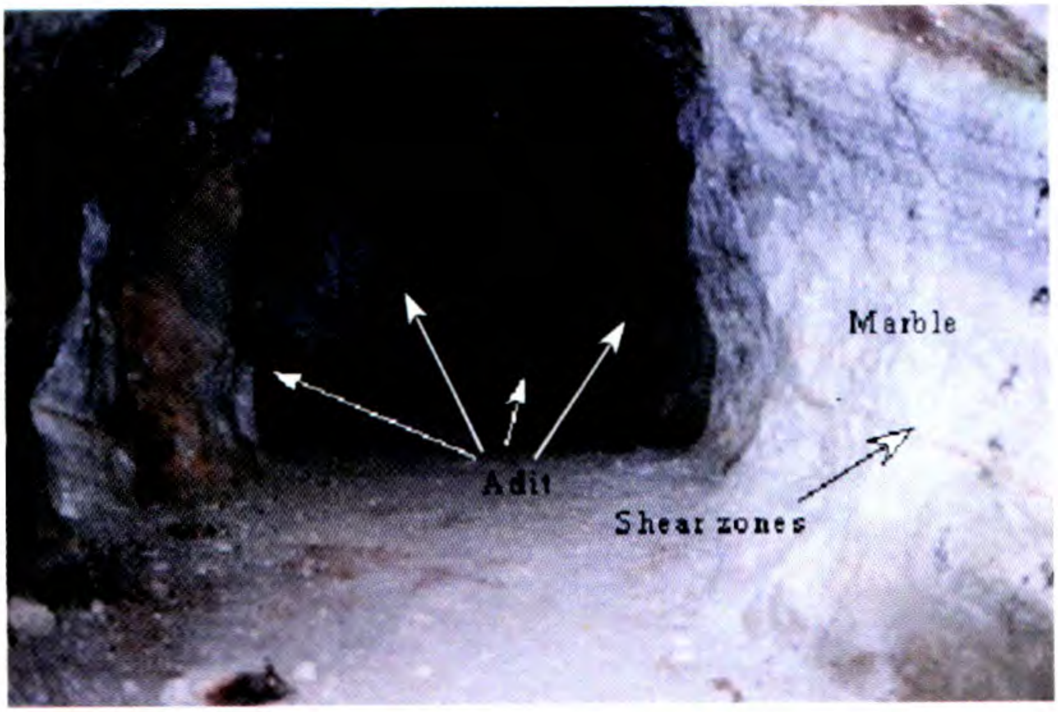

Figure 14.5. Photograph showing Dongat ruby mine of Ganesh area, Hunza.

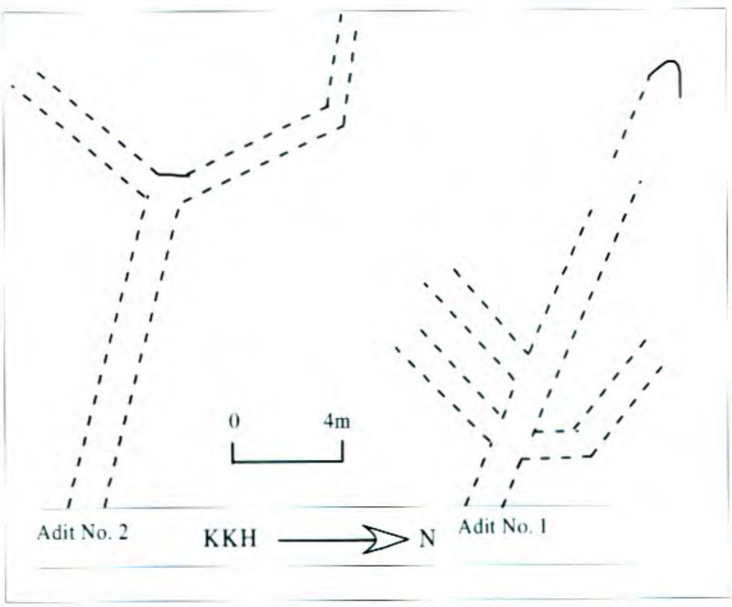

Figure 14.6. Sketch (plane view) showing underground mining at Dongat ruby mine of Ganesh area, Hunza.

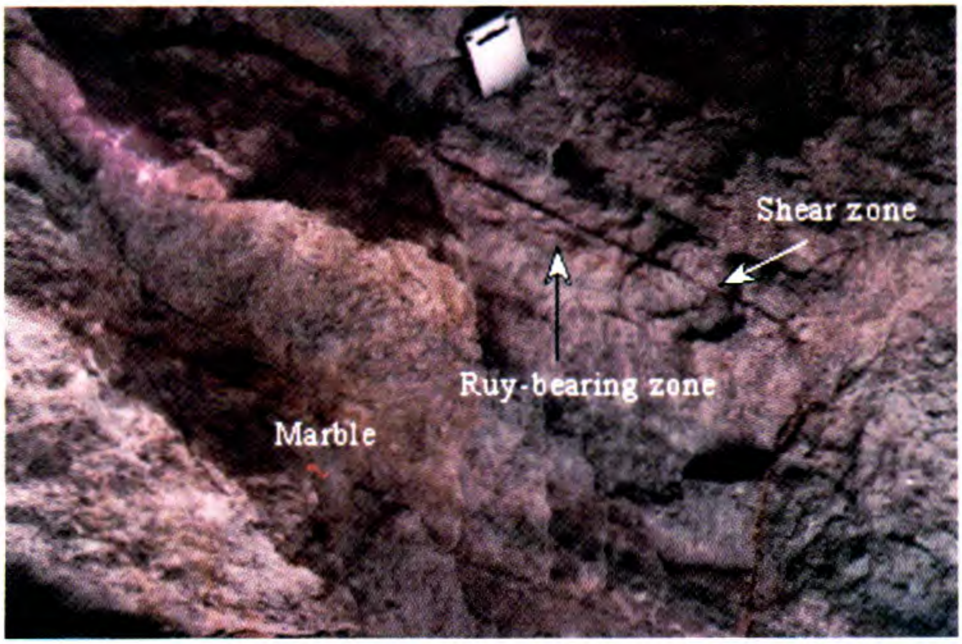

Figure 14.7. Photograph showing ruby-bearing zone in marble of the Dongat ruby mine of Ganesh area, Hunza.

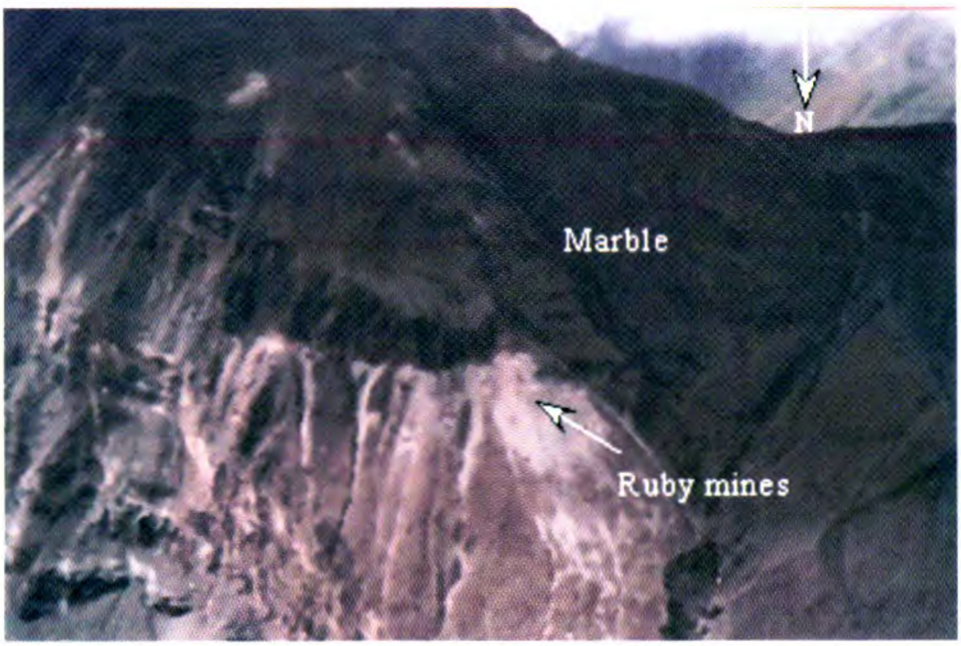

Figure 14.8. Photograph showing ruby mines in Halden Garetus above the Dongat ruby mine, Hunza.

In the **Saitkutsbul ruby mine** of Hasanabad Nala, ruby mineralisation is associated with dark grey and white marble along shear zones. Here the marble strikes N50° E and dips 30° NW. Ruby crystals have been recovered from this mine through open cut mining. Shear zone of about 6 cm long has been noticed. Here marble is soft and brittle, milky white, coarse-grained having trail of phlogopite, tiny grains of ruby, spinel, pyrite and a little fuchsite. To the north of Aliabad, spinel and pargasite-bearing marble has also been observed. Spinel is reddish in colour; however, blue spinel mineralisation along with ruby has been reported from Foolishkahn area near the junction of Hasanabad and Muchuhan glaciers.

Ruby has also been recovered from **Halden Garetus**. The ruby mines are visible from Altit. Here mining is underground and across the strike of marble (Fig. 14.8). The mines lie above the Dongat mine of the Ganesh area.

Production and quality

PMDC operated Hunza ruby mines for 7 years from 1972 to 1979. Later on GEMCP ran the mines operations from February 1979 to 1994. GEMCP data shows about 0.1 million carats rough ruby production from 1979 up to 1994.

Dorkahn ruby mine, which is one of the oldest ruby mines gave 110 kg or 0.55 million carats of ruby production from 18,000 cubic metre excavated material.

During the PMDC and GEMCP tenure, the average size distribution of ruby had been approximately of the following order:

Size (carats)	Percentage
a. 2.5 mm up to1 carat	95
b. 1-4	2-5
c. 4-10	2
d. 10-40	0.5-1.5

Average gradewise distribution of the rough gem-grade ruby produced from Hunza ruby mine was approximately as follows:

Grade	Percentage
Top grade	2-5
Medium grade	5-30
Low grade	65

According to local miners rubies of various sizes are recovered from the following ruby mines (in descending order from bigger to smaller size).

Ahmadabad

Dongat

Dorkahn

Bajouring

Fodandar

Saitkutsbul

Foolishkahn

The transparent and good colour rubies are recovered from the following ruby mines (in descending order from top to relatively poor quality).

Ahmadabad

Dorkahn

Dongat

Bajouring

Fadandar

Altit

Datombaresho

Some of the ruby crystals found in Hunza were of the classical 'pigeon's blood' colour, resembling the Myanmar (Burmese) ruby (Fig. 14.9).

Figure 14.9. Photograph showing Hunza ruby with host rock. (Source: Andreas Weerth 1998). Size of the ruby is 3 cm; photo by Rupert Hochleitner.

RUBY OF THE NANGIMALI, AZAD JAMMU AND KASHMIR (AJK)

Location and access

Good quality rubies are found at Nangimali in the Shontar-Kalejander (34°59' N: 74°23' E) region of the Neelam Valley in Azad Kashmir (Fig. 14.10). Nangimali is approachable both from Muzaffarabad, capital of Azad Kasmir and Naran side of NWFP. From Islamabad via Naran, the deposit lies about 388 km in the northeast direction. Nearby locality of the Nangimail ruby deposit is Utli Domel, which is 43 km away from Sharda of Azad Kashmir. From Sharda the dirt road follows the Neelum River. After Keil, this road goes along Shontar

Nar to Utli Domel. To reach the Nangimali ruby deposit one has to go by foot or to use horse/mule. The road from Naran to Utli Domel is umetalled and remains open only in summer. In winter this road, which leads through Nuri Pass remains closed due to snowfall.

Geology

The geology of Shontar Valley (Nangimali area) is characterised by part of Higher Himalayan Crystalline (HHC), which is separated into two main divisions; basement and cover rock sequence. The basement is consisted predominantly of gneisses (Fig. 14.10).

In Nangimali area, two main lithostratigraphic units, and a basement sequence of granitic rocks, migmatites and metasediments: Migmatite complex, Bhurjanwali formation and a cover sequence of Precambrian to Cambrian age (Nangimali formation of Malik 1995) characterise the area. The Nangimali formation largely comprised of quartzites, amphibolites, marbles and schists. A synclinal structure present in the marble dominates the geological structure of the mine area. The ruby deposit is hosted in the marbles and occurs in shear zones of the synclinal core (Figs. 14.11 and 14.12).

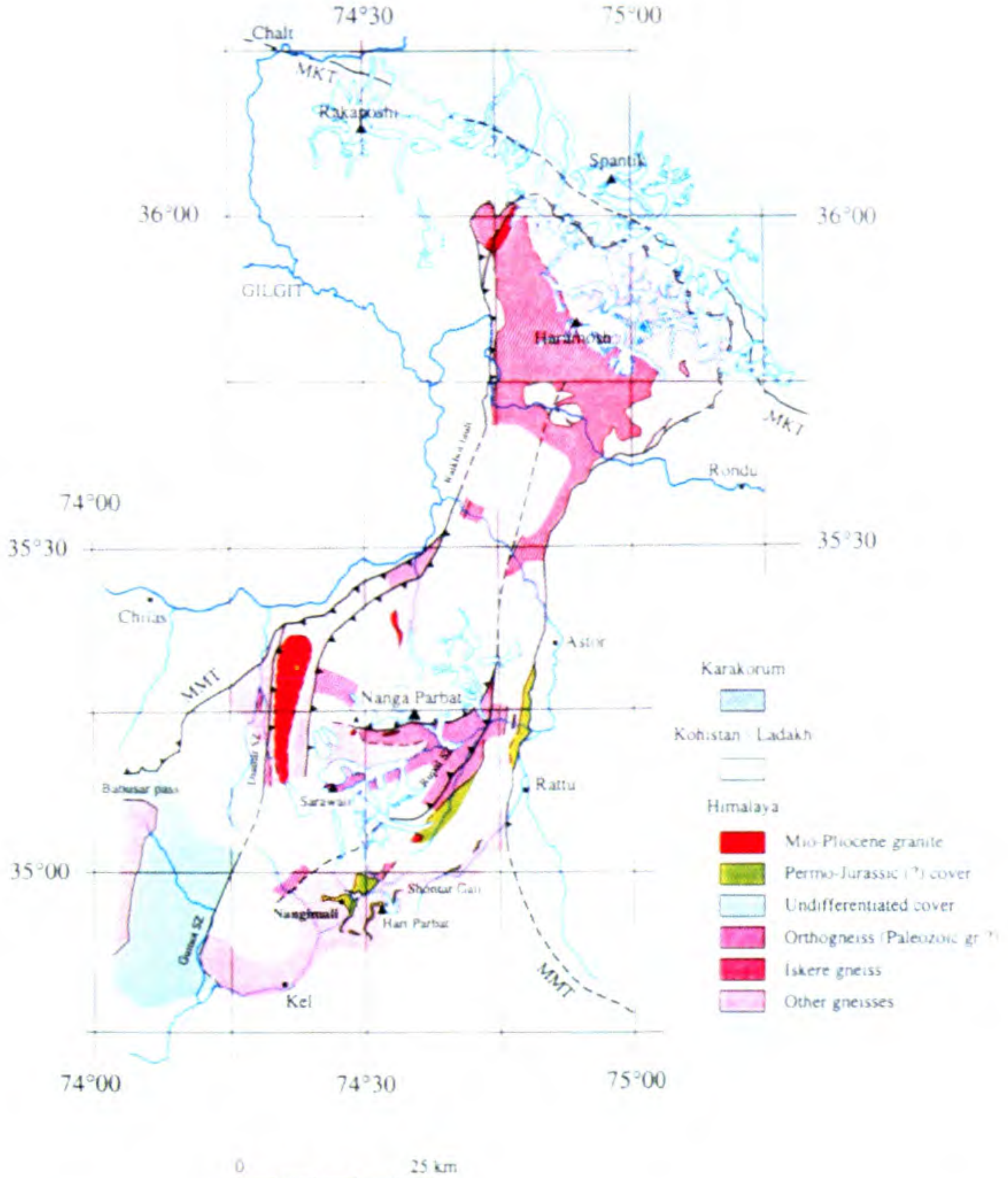

Figure 14.10. Map showing location of the Nangimali ruby deposit (AJK) and regional geology of the area (after Pecher et al., 2001).

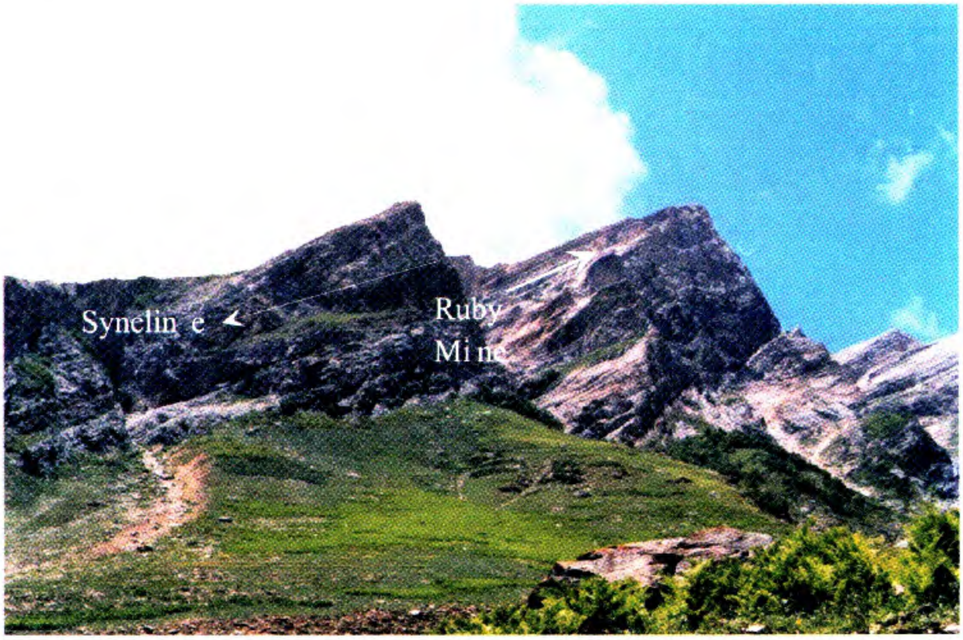

Figure 14.11. Photograph showing Nangimali ruby mine area and synclinal structure exposed in the ruby-bearing marble.

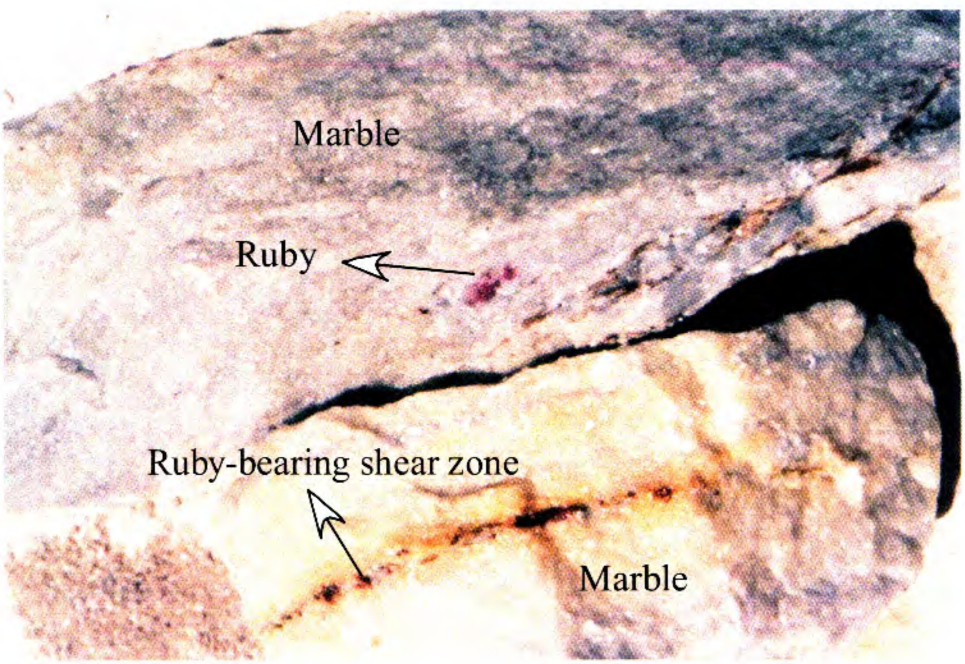

Figure 14.12. Photograph showing ruby mineralisation in marble from Nangimali ruby mine.

Mining history

The discovery of ruby mineralisation in Shontar Valley is recent and intriguing. The story began in 1979 when Mr. S. H. Farooqui, Geologist, discovered very fine crystals of ruby in the boulders of Shontar Nar. The geologists of AKMIDC, between 1988 and 1992, carried out detailed geological investigations in the Shontar Valley, and as a result rubies were discovered in the Nangimali area. Three years of pilot small-scale mining yielded an ore grade of 11 gram/ton and the production between 1990 and 1994 was 69 kg of rough ruby for four months of production per year (Malik 1995)

At present AKMIDC is operating the ruby mine in a leased area of 1,017 acres and the exploration activities remain confined to Khora area, which is 1.8 km southeast of Nangimali top.

Mining methods

The Nangimali ruby deposit lies at an altitude of 4,500 m above sea level. The mining activities are only for four months from June to September each year. The mine remains closed for the rest of the months due to heavy snowfall. Mining is done under the supervision of a mining engineer who is responsible for carrying out the excavation operations. A total number of twenty labourers and a few security guards make up total man power at the mine (Fig. 14.13).

Mining methods employed in the mine are mechanised. For example compressors, pneumatic picks, crushers, grading machines and washers are used. Other tools include crowbars, shovels, wheelbarrows and pans. Debris is washed sometimes manually to recover rubies. Melt-water is available where pipes are used to bring the melt-water to the mine area. For lightening in the mine area hurricane lamps and electrical bulbs are used. Electricity is produced through generator. As the ruby-bearing marbles are hard to excavate, blasting is used, which is carried out through the use of dynamite.

In the Nangimali ruby mine, there is one main adit, which is about 100 m long excavated to strike direction. This adit is connected through shafts to the upper level adits, which are two in numbers. These adits run along the ruby-mineralised zones horizontally and/or inclined manner. The main adit receives the debris dropped from the upper level working area through shafts. From here the debris is collected and brought outside using wheelbarrows for washing.

Production and quality

According to AKMIDC sources, the Nangimali ruby mine produces rubies on commercial scale whereas the nearby Borjanwali leased area is under assessment. The total estimated reserves as assessed by AKMIDC in the Nangimali ruby deposit is about 133 million carats. It includes 125 million carats of rubies in bed -rock and 8 million carats in colluvium. The total estimated value of the deposit is about US$ 200-400 million. At present, in Nangimali, the ore zone produces about 55 carats rubies in a cubic metre excavated material. Total production of the Nangimali ruby deposit is given in appendices.

It is worth mentioning that the ruby mineralisation is always very rare and that in marbles, this mineralisation has taken place along shear bands, which are quite irregular. To estimate the reserves accuracy in this situation is very difficult. As about ninety nine percent Nangimali rubies are pink sapphires and only one precent have red colour, the estimated value of the deposit by AKMIDC is on very high side.

Generally the AJK rubies are transparent to translucent and brownish pink to pinkish red or deep red (Fig. 14.14). According to the AKMIDC experts, the good quality red-coloured rubies of Nangimali show 'fire' effect. The most important characteristic of Nangimali rubies is that after cutting and polishing, red colour is enhanced many folds whereas in the Jegdalek rubies of Afghanistan, the red colour becomes paler after cutting. Good shape of uncut gemstone always gives about 20-25 percent recovery in cutting and polishing. Bigger rubies are considerably more expensive than smaller rubies. For example an excellent quality of Nangimali ruby of 2 carats can be sold for US$ 4,000-6,000 per carat and more than 5 carats top quality ruby costs about US$ 15,000-20,000 per carat. The one carat or less than one carat ruby costs about US$ 1,000-1,500 per carat.

Figure 14.13. Photograph showing people at work in the Nangimali ruby mine.

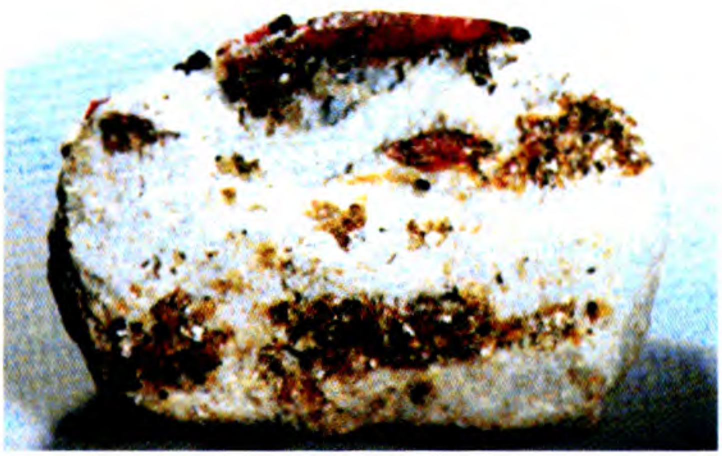

Figure 14.14. Photograph showing ruby (red; 2 cm long top crystal), phlogopite (yellowish) and pyrite (black) within marble from Nangimali ruby mine. (Source: Robert E. Kane 1998).

Guidelines for exploration

Marbles are the most important source of high-quality ruby in South-East Asia including Pakistan. Snow-white coarse-grained marble, commonly known as the lime-silicate marble, impart spectacular outlook in the greyish to blackish surrounding outcrops. Followings serve as guidelines for ruby exploration.

1. Recrystallised dolomitic limestones: banks of recrystallised dolomitic limestone lying in regional metamorphic terrain and at or near to the major structures on regional scale such as faults, shear zones and folds. The presence of such features may indicate ruby mineralisation.
2. Intrusions of dolerite (amphibolitised), aplite and pegmatite within or adjacent to marble may also indicate ruby minerlisation?
3. Phlogopite, fuchsite and pyrite are the pathfinding minerals for ruby. Pargasite and spinel of various colours may also be the associated gemstones with ruby. These minerals are developed in snow-white and grey coloured coarse-grained marble, in thin shear bands. There are also small pockets lying along the shear bands. The carbonate to host ruby is highly fragile and soft due to deformation. Normally marble gives fetid carbonate smell on hammering, but the ruby-bearing marble does not give such smell.
4. Good quality ruby is always mineralised in a zone lying between two thin shear bands, which can be carefully observed and located. These thin shear bands are marked with phlogopite and pyrite trails, an indication for ruby mineralisation.
5. The more abundant the phlogopite, fuchsite, biotite and the altered pyrite, the less chances to get ruby in the rock. It is note worthy that the barren marble always gives strong fetid smell on hammering as reported by local miners.

BASTNASITE

The rare-earth elements (REE) are the fifteen lanthanide elements with atomic numbers 57 through 71 which are included in Group IIIA of the Periodic Table: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Yttrium (atomic number 39), a Group IIIA transition metal, although not a lanthanide is generally included with REE as it occurs with them in natural minerals and has similar chemical properties. Scandium (atomic number 21) and thorium (atomic number 90) due to their similar chemical properties are also included with REE. The rare-earth elements are classified into two groups: the light or cerium subgroup, comprising the first seven elements (atomic numbers 57-63) and thorium; and the heavy or yttrium subgroup, comprising the elements with atomic numbers 64-71.

Geochemically, the rare-earth elements are relatively common in the rocks of the earth crust but their concentrations are rarer than other common ores. Generally soft, malleable and usually reactive especially at high temperatures, the rare-earth metals range in colour from iron-gray to silvery-white. World resources of rare-earths are contained primarily in bastnasite and monazite. The bastnasite, a rare-earth fluorocarbonate, is the second most important commercial source for cerium and the light rare-earths. Although it is quite high in cerium content, but not abundant enough to be a primary source of other light rare-earth elements. The bastnasite deposits in China and USA constitute the largest percentage of the world's rare-earth economic resources whereas monazite deposits in Australia, Brazil, China, India, Malaysia, South Africa, Sri Lanka, Thailand and USA constitute the second largest segment. The green fluorite from the Rogerley mine, England also contains the relatively large amounts of yttrium, cerium, lanthanum, samarium and neodymium (Falster et al., 2000; Fisher, 2002).

Bastnasite, sometimes spelled as bastnaesite, is one of a few rare-earth carbonate minerals $(Ce,La)CO_3F$. It has cerium and lanthanum in its generalised formula but the mineral is divided into three minerals based on the predominant rare-earth element. These are (i) bastnasite-(Ce) with more accurate formulas of $(Ce,La)CO_3F$, (ii) bastnasite-(La) with a formula of $(La,Ce)CO_3F$ and (iii) bastnasite-(Y) with a formula of $(Y,Ce)CO_3F$. There is a little difference in the three in terms of physical properties and most bastnasite is bastnasite-(Ce).

Structure of bastnasite is made up of stacks of carbonate ion and CeF layers. The CeF layers form flat hexagonal sheets with each cerium bonded to three fluorine atoms. The carbonate layers are more complex with angled carbonate triangular groups.

Colour of bastnasite is pale white, tan, grey, brown, yellow and pink and possesses the qualities of a gemstone. Here the bastnasite imparts yellowish brown-to-brown colour (Fig. 1). Luster is pearly, vitreous, and greasy to dull. It is transparent to translucent and opaque. Crystal system is hexagonal, and the cleavage is distinct in one direction (basal) and poor in three directions (prismatic). Fracture is uneven and the hardness is 4.0 to 4.5. Specific gravity is 4.7 to 5.0 (Table 15.1). Streak is white. Associated minerals are extensive and include albite, analcime, monazite, hematite, amphibole, aegirine-augite, rutile, rhodochrosite, calcite, apophyllite, fluorite, apatite, barite, quartz, parisite, dolomite, ankerite, ilmenite, zircon, etc. Best field indicators are crystal habit, colour, cleavage, density, luster and the locality.

Rare-earth elements are commonly used in metallurgy, glass polishing, hydraulic batteries, X-ray intensifying phosphores etc. The light rare-earths, e.g. lanthanum is used in ceramics, high quality optical glass, camera lenses, microwave crystals, glass polishing and petroleum cracking. Cerium is used in glass polishing, as petroleum cracking catalysts, alloys-with iron for sparking flints for lighters, with aluminium, magnesium and steel for improving heat and strength properties, radiation shielding and many others.

Location and access

Peshawar Plain extends to west and is characterised by network of roads. Zagai Ghar area lies further west to Kafir Dheri (local name Kafoor Dehri), and south of Warsak and to the northwest of Peshawar. One of the bastnasite localities in the Zagai Ghar is bounded by latitude 34^0 07′N and longitude $71^0$26′E, and lies in Survey of Pakistan Toposheet No. 38 N/8 (Fig.15. 1). The Zagai Ghar area is approachable from Peshawar by all weather-metalled road. From the main Warsak-Peshawar road, at Pir Bala Square (Chowk), which is at a distance of about 11 km from Peshawar, a road leads to Shahi and Burj village, where the Zagai Ghar is situated nearby. The Zagai Ghar is about 12 km from the Pir Bala Square (Chowk) and about 23 km from Peshawar. According to Obodda and Leavens (2004), Zagi

Mountain covers an area of approximately 3 x 5 km, with an elevation of approximately 175 m above its surroundings.

Geology

Previously, Coulson (1936) recognised Warsak granites as peralkaline granites in north Pakistan. Ahmad et al. (1969) mapped these granites and presented a comprehensive work on them. Arbab and Siddiqi (1972) reported alkaline granite from the Warsak area. Kempe (1973) described the petrography and whole-rock chemistry, mainly with major element descriptions. He also reported K/Ar age of 41 million years for the riebeckite from a coarse, undeformed facies of the main Warsak alkaline granite, regarding as the age of intrusions. Maluski and Matte (1984) determined $^{40}Ar/^{39}Ar$ ages on three Warsak granites ranging from 40 ± 5 to 43 ± 5 million years. Kempe and Jan (1970, 1980) correlated these granites with peralkaline granites of Shewa-Shahbazghari, Tarbela, and Ambela, and suggested that they formed an integral part of a Tertiary alkaline province located in and around the Peshawar Plain. Kempe (1986) reported ages of the alkaline rocks of the Peshawar Plain and described that the repeated magmatism in the area occurred between 315 and 31 million years. Tahirkheli T. et al. (1990) described the granites as A-type rift related granites of the Indian plate.

The Peshawar Plain is the alluvium plateau produced by Pleistocene glacial and fluvial action and runs irregularly from west to east, sub-parallel to the Karakoram Range, and south of the Main Mantle Thrust. Swat and Kabul Rivers to the west and the Indus River to the east occupy the Peshawar Plain, until their confluence at Attock (Fig. 15.3). The alluvial plain is bordered to north by greenschist facies metasedimentary rocks, mainly Silurian to Carboniferous in age. To the South lies a band of Mesozoic and Tertiary sedimentary rocks, which mark a thrust fault against the older metasediments (Jan and Kempe, 1970). The northern boundary of the plain contains a series of alkaline igneous intrusive complexes, mostly but not all lying on the plateau side of the metasediments, which form the only alkaline igneous rocks so far in Pakistan. The igneous rocks include alkaline granites and microgranites, albitites, syenites, and carbonatites and silicocarbonatites (Kempe 1983).

Kempe and Jan (1970) and Kempe (1973) suggested that these intrusions constituted an alkaline igneous province that covers areas up to Afghanistan border in the west and Tarbela or possibly Mansehra in the east. No alkaline rocks are found so far in the Mesozoic and

Tertiary rocks to the south, and the complexes appear frequently to occur along fault zones, into mainly Early Paleozoic metasediments. They are thought to be rift-related, which is caused partly by relief tension or compression release, perhaps during Late Cretaceous or Early Tertiary times, following contact between the Indo-Pak plate and the island arc or southern continental margin of the Eurasian plate (Kempe 1983). They are also often associated with doleritic and gabbroic rocks.

The Zagai Ghar granitic body hosting bastnasite may be part of the Warask Igneous Complex (WIC) of Tahirkheli T et al. (1990). The WIC contains three varieties of granites distinguished from each other on the basis of texture, mineralogy and geochemistry (Fig. 15.4). They include the Warsak main aegirine-riebeckite granite (WMARG0). The WMARG occurs at and around the Warsak Damsite and an isolated outcrop in the Kafir Dheri area. The granitic body seems to be apparently intruding the Paleozoic metasediments, but in the Zagai Ghar area, this granite extends east-west having contacts with the alluvial plain. Here the granite is massive and/or foliated. Pothole weathering structure and shearing at certain places are common. The brownish clayey material, and quartz veins characterise the weathered/foliated part of the granite (Fig. 15.5).

Under the microscope the granite at Zagai Ghar shows medium- to coarse-grained texture with deformed fabric. The granite includes dark minerals such as aegirine-augite and riebeckite (Figs. 15.6 and 15.7). The felsic minerals are quartz and feldspar. Feldspar is mostly microcline, perthite and albite. Quartz shows undulose extinction and kink bands. Accessory minerals include zircon, apatite, sphene and epidote. Biotite is developed after amphibole.

In the Zagai Ghar area, bastnasite mineralisation has been ensued in cavities of the alkali granite. Other minerals associated with bastnasite include rutile-bearing smoky and transparent quartz, tourmaline, fluorite, epidote, ilmenite and parisite. The host rock is weathered and altered. The altered product is rusty brownish clayey material. Pneumatolytic activity and/or greisening are the processes responsible for the mineralisation of bastnasite and other associated minerals.

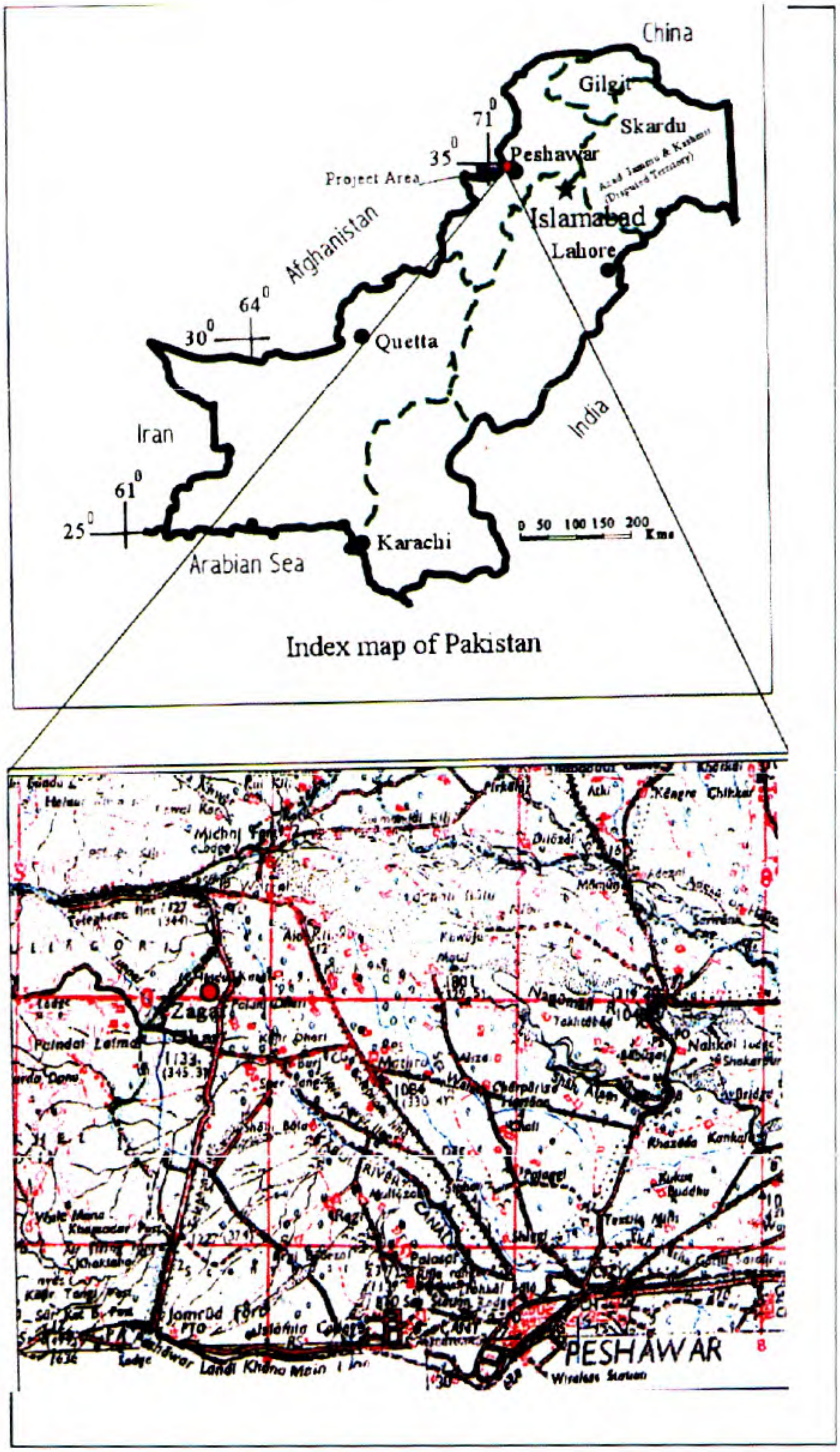

Figure15.1. Map showing location of the bastnasite-bearing Zagai Ghar area, Warsak, NWFP, Pakistan. Toposheet No. 38 N. Scale 1:250,000.

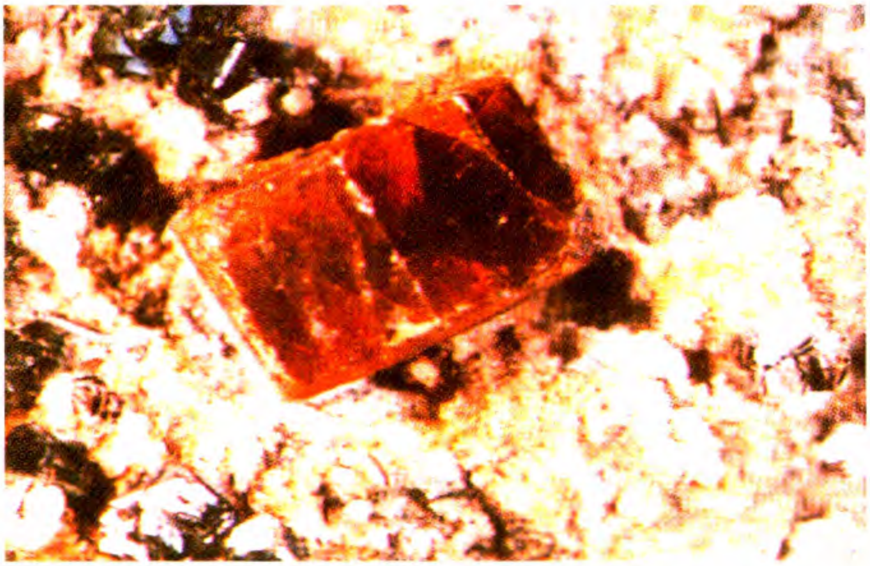

Figure 15.2. Photograph showing yellowish brown bastnasite crystal (1 cm x 1 cm) along with rutile-bearing smoky quartz and albite. The host rock is altered alkali granite, Zagai Ghar area.

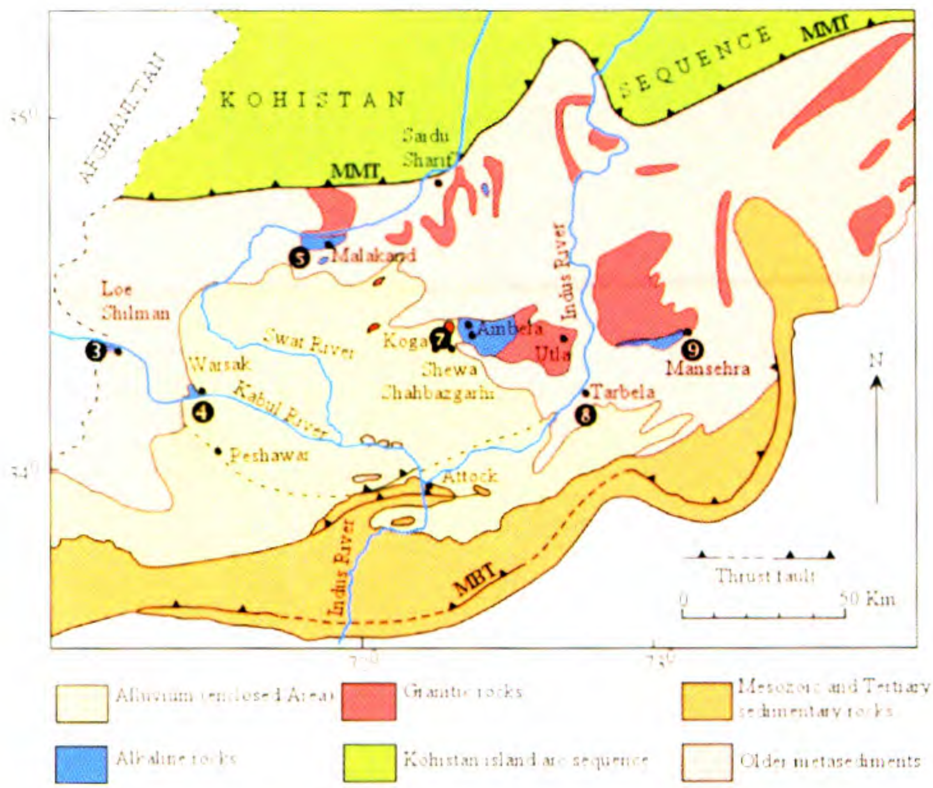

Figure 15.3. Regional geological map of North Pakistan (after Kempe 1983). The numbers plotted on the map relate to the radiometric dates for six of the granitic complexes. Serial number one, two and six are not plotted because their dates are not available (Kempe 1986).

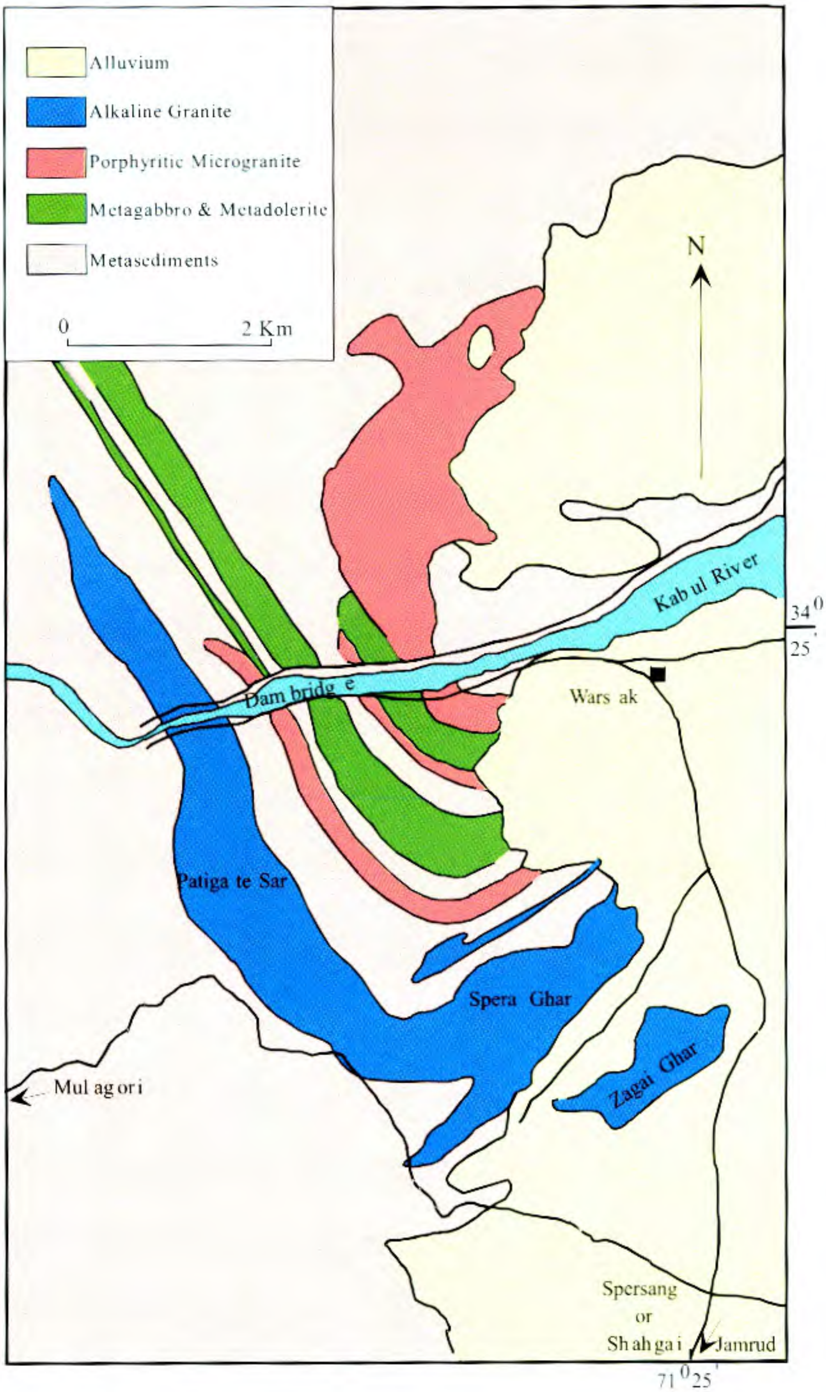

Figure 15.4. Geological map of Warsak and the surrounding areas showing the Zagai Ghar alkali granite (modified after Kempe 1983; Tahirkheli et al., 1990).

Figure 15.5. Photograph showing Zagai Ghar alkali granite. The yellowish brown clayey material is the possible host of bastnasite.

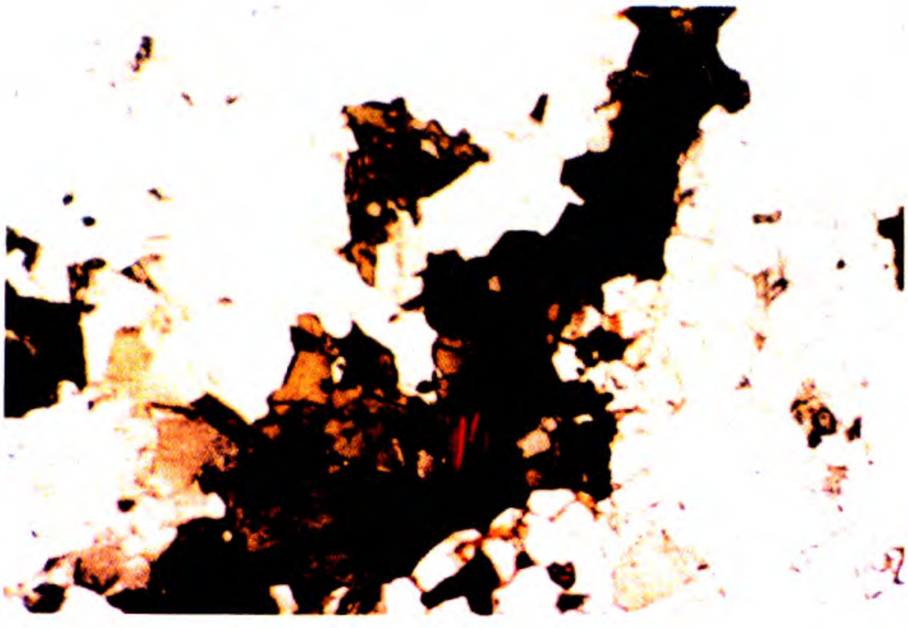

Figure 15.6. Photomicrograph showing aegirine-augite (light green), riebeckite (dark) and biotite (brown) in Zagai Ghar alkali granite. Plain Polarised Light (x2.5).

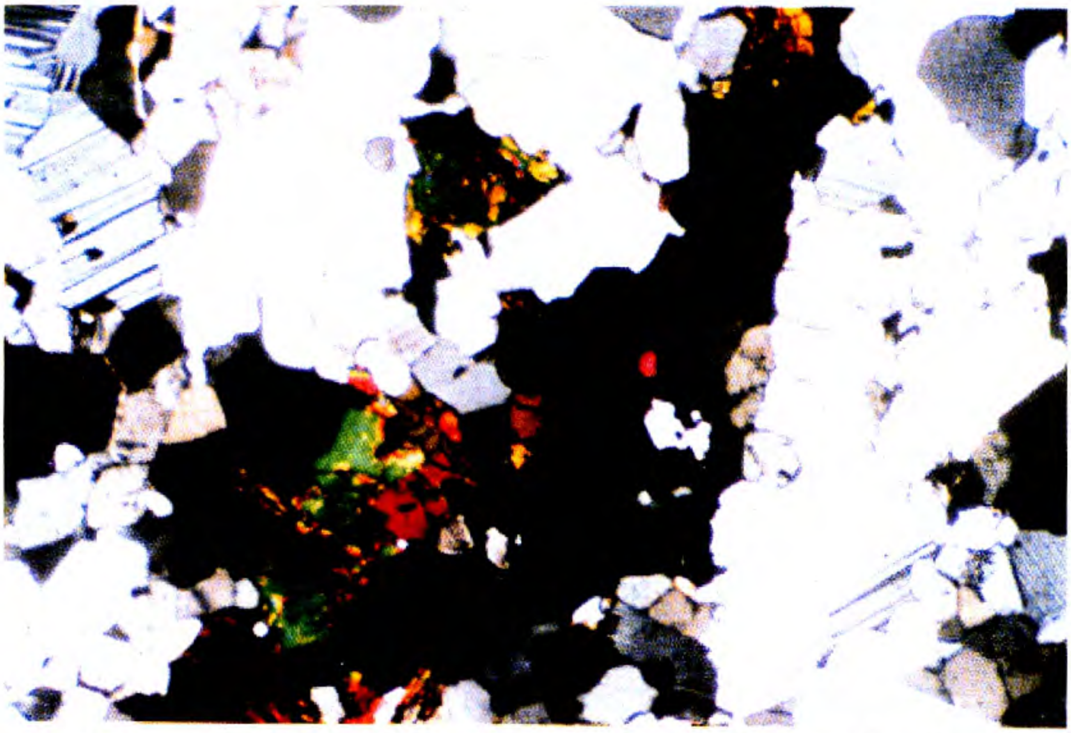

Figure 15.7. Photomicrograph showing mafic minerals as in figure 6 and felsic minerals such as quartz (deformed) and feldspar in Zagai Ghar alkali granite. Crossed Polarised Light (x2.5).

Table 15.1. Physical and optical properties of the bastnasite.

Colour	Pale white, tan, gray, brown, yellow and pink
Streak	White
Luster	Pearly, vitreous and greasy to dull
Transparency	Translucent to opaque
Fracture	Uneven
Cleavage	Distinct in one direction (basal) and poor in three directions (prismatic)
Hardness	4.0 to 4.5
Specific Gravity	4.7 to 5.0
Crystal System	Hexagonal
Crystal Habits	Small hexagonal rounded flakes and short prismatic crystals, also in rosettes and spheres as well as massive and granular. Bastnasite has been known to replace (pseudomorph) crystals of allanite.
Refractive Index	w = 1.717, e = 1.818
Birefringence	0.1010
Interference Figure	Uniaxial (+)

MISCELLANEOUS GEMSTONES

Garnet

Garnet group consists of complex silicates whose general formula is $A_3B_2(SiO_4)_3$. In this formula, A and B stand for Ca, Mg, Fe^{+2}, or Mn^{+2} and Al, Fe^{+3} or Cr and Ti, respectively. The Mn may be present in trace amounts. Garnet crystallises in cubic system. It is generally hard and tough. The varieties of garnet with gem-grade include (i) pyrope: a magnesium aluminum silicate, (ii) almandine: (an iron aluminum silicate), (iii) spessartine: a manganese aluminum silicate, (iii) grossular: (a calcium aluminum silicate) and (v) andradite (a calcium iron silicate). Most of the garnets have hardness up to 7 but the andradite has hardness up to 6.5. The specific gravity and refractive indices also vary in all members of the garnet group ranging from 3.65 to 4.31 and 1.73 to 1.89, respectively. Pyrope and almandine are red to orange red and grossular is reddish brown, dark green (green colour is due to chromium and vanadium). Green variety of andradite is known as demontoid.

According to Kazmi and O'Donoghue (1990), red garnets are found at several localities in NWFP. Crystals of pyrope/almandine are found in the pegmatites at Gabor-o-Bakh, Monour and Mogh area of Lutkho Tehsil and Matak An in Rumboor, Chitral District. These garnets are opaque, translucent and transparent. Crystals are dodecahedron with perfect cleavages. Transparent varieties are used as gemstones. Maximum dimension of the garnet is 3 cm x 4 cm.

Green garnet (tsavorite) mineralisation associated with metasediments and carbonatites of higher Himalayan crystalline slab of Bajaur and Malakand Agencies and Swat District (Hussain 2005).

Euhedral and anhedral tsavorite in Jambil, Swat is found in quartz veins within graphitic schist, which is part of Proterozoic basement pelitic-psamitic metasediments metamorphosed to upper amphibolite facies and intruded by granitic rocks of Tertiary and Precambrian ages. These rocks mark northern margin of the Indian plate, south of the Main Mantle Thrust.

In Miragai, Swat, Selai Patti of Malakand Agency and Bagh-Turghao of Bajaur Agency, green garnet-bearing pegmatites are exposed in a linear belt more than 100 kilometres. The pegmatites occur as sheets, sills and lensoidal bodies of variable extent. They are generally medium to coarse-grained, white, earthy white to brownish having sugary texture.

According to Hussain (2005), green garnets of Jambil are generally dark green and occur as dissemination and crystal aggregates in hydrothermal quartz veins and the graphitic schists adjacent to the quartz veins. Inclusions of graphite and mica are common in this garnet. They are high in Ca, typical of grossular garnet. High V and small quantity of Cr impart deep green colour.

Red spessartine garnets in the gem pegmatites of Dusso (35° 42´55" N: 75°29´5" E) and Shengus (35° 43´50" N: 74° 48´5" E) have also been found. Gem-grade spessartine garnet mineralisation has been noticed in a pegmatite in Jandaran area (AJK), 1.5 km northeast of Phullawii and some 200 km northeast of Muzaffarabad (34°48´30" N: 74°13´16" E) of the Neelam Valley (Jan et al., 1995). This pegmatite lies at an elevation of 2,590 m above sea level. Here the garnets form well-developed crystals reaching up to 30 gm in weight. Some 40 kg of gem-grade has been mined since 1994. Many of the stones to be used as gems are more than 10 carat in weight. The stones are transparent and range in colour from yellowish red to tangerine and crimson red. The good quality garnets are flawless (Jan et al., 1995).

Epidote

Epidote imparts yellow-green to deep olive green colour. The refractive index of epidote is 1.73-1.76. In Pakistan gem-grade epidote crystals are found in the mélange zone near Bunji in the Gilgit Division (35°39´55" N: 74°37´4" E), Kot (34°29´15" N: 71°43´2" E), Pranghar (34°26´55" N: 71°37´10" E), Usmankhel, Garhi, Manzari Baba Ziarat and Bucha (34°25´45" N: 71° 34´10" E) and Gandao in Malakand and Mohmand Agencies and at several places in Swat District (Kazmi and O'Donoghue, 1990).

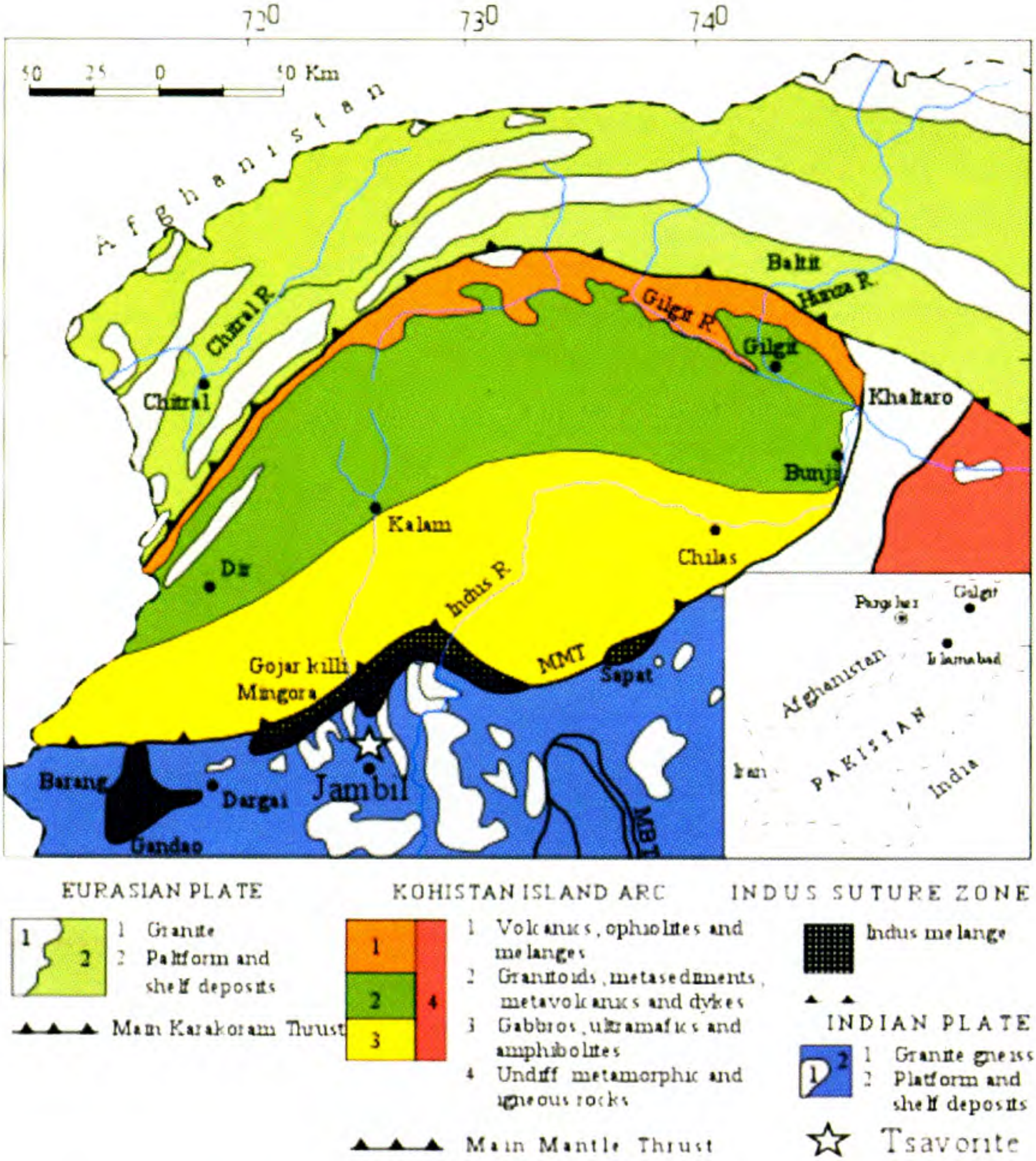

Fig. 16.1. Location of green garnet (tsavorite) in Jambil area of Swat (modified after Snee et al., 1986).

Pargasite

Pargasite $[Na][Ca_2][Mg_4Al][(OH_2)][Al_2Si_6O_{22}]$ is amphibole group mineral and crystallises in monoclinic system (Fig. 11.10). Exquisite deep pistachio-green pargasite crystals are found along with ruby and spinel in Hunza Valley and as showings with the ruby of Nangimali of AJK. The stones are translucent to opaque and are commonly fashioned into beautiful cabochons. Pargasite is a rare gemstone and locally sold as "Hunza emerald". The GEMCP from 1979-1994, produced about 0.15 million carats of pargasite. At that time pargasite was erroneously known as chrome-diopside.

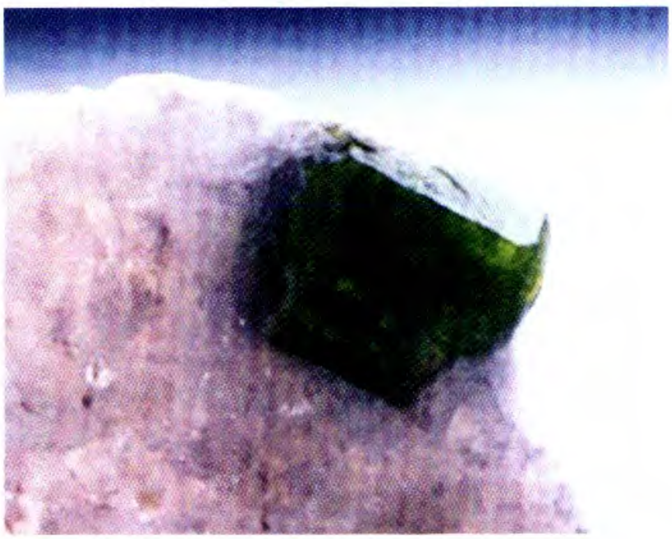

Figure 16.2. Photograph showing pargasite crystal in marble, Hunza, Pakistan. Size 1 cm (photo by Max Glas in Rubin, Saphir, Korund, No. 15, 1998).

Spinel

Spinel is the great imposter of gemstone history: many famous rubies in crown jewels around the world are actually spinel. The most famous is the Black Prince's Ruby, a magnificent 170-carat red spinel that currently adorns the Imperial State Crown in the British Crown Jewels after a long history: the Timur Ruby, a 352-carat red spinel now owned by Queen

Elizabeth, has the names of some of the Mughal emperors who previously owned it engraved on its face, an undeniable pedigree!

In Burma (Myanmar), where some of the most beautiful colors are mined, spinel was recognized as a separate gem species as early as 1587. In other countries, the masquerade lasted for hundreds of years after that. Spinels were most often referred to as "balas rubies" which may have referred to color or to country of origin.

Now treasured for its own sake, spinel is a favorite of gem dealers and gem collectors due to its brilliance, hardness and wide range of spectacular colors. In addition to beautiful rich reds, spinel can be found in a range of beautiful pastel shades of pink and purple. Of particular interest is a vivid hot pink with a tinge of orange being mined in Burma that is one of the most spectacular gemstone colors in any gem species. Spinel also comes in beautiful blues, which are sometimes called cobalt spinel, but these are very rare. Because spinels made in a laboratory are often used for imitation birthstone rings, many people think "synthetic" when they hear the name "spinel." They have often never even seen the real thing. In fact, the main thing holding back greater recognition for spinel is rarity. Fine spinels are now rarer than the rubies they used to imitate. Strangely, they are also more affordable: in the gem world, too rare can be a drawback because few people even get a chance to grow to love these gem varieties. In addition to Burma, spinel is mined in Sri Lanka, Tanzania and Tadjikstan.

Spinel is a durable gemstone that is perfect for all jewelry uses. It is most often faceted in oval, round, or cushions shapes and is not currently found in calibrated sizes due to its rarity. Chemically, spinel is a magnesium alumium oxide ($MgAl_2O_4$) with cubic crystal system. Found in Pakistan, Burma and Sri Lanka, spinel comes in a variety of colours, including oranges, pinks, blues, lavenders, mauves and vivid reds. While common in sizes up to 2 carats, larger gemstone can also be acquired. Spinel found along with rubies and sapphires, is durable and comes in all colours. Also found in Cambodia, Thailand, Nigeria, Africa and Afghanistan, the gemstone has no cleavage and hardness of 8.

In Pakistan, Hunza spinel occurs in a wide variety of colours ranging from brown, red and plume red, violet to blue. These colour variations are mainly a result of slight changes in chemical composition. The Hunza spinel is larger than those customarily found in Burma and are far attractive. They are commonly well formed crystals, showing recognizable crystal forms.

Vesuvianite (Idocrase)

Vesuvianite $Ca_{10}(Mg, Fe)_2 (OH)_2 Al_4 Si_9 O_{34} (OH)_2$ is a calcium-aluminum silicate. It crystallizes in tetragonal system and occurs as transparent green to brown crystals. The hardness of the vesuvianite is 6.5, specific gravity, 3.33-3.47 and the refractive index, 1.700-1.721. Vesuvianite is found in the serpentinites or rocks formed from contact metamorphism such as limestone and dolomite.

In NWFP, green to dark-coloured green vesuvianite occurs as 1 to 2 cm lenses within serpentinite of Spo-Darra, Dabar and Maizar in Mohamand Agency (Kazmi and O'Donoghue, 1990). At places yellowish brown to brown, 2 mm size hessonite garnet crystals are found in the vesuvianite rock.

Rodingite

Rodingite occurs in association with the ultramafic rocks at Hiru Shah in Malakand Agency (Qaisar et al., 1970; Kazmi and O'Donoghue, 1990). It is hydrous calcium-aluminum silicate and is the product of very low-grade metamorphism. It is light green-and/or light cream-coloured and mottled with green specks. It is used as beads, cabochons, artifacts, and for gem carving.

Quartz

Quartz is semi-precious gemstone having chemical formula (SiO_2) that crystallises in trigonal system. The crystals are prismatic and terminated by rhombohedra. It has many varieties such as amethyst (violet), citrine (yellow), agate (white and banded), chrysoprase (bright apple green), chalcedony (white and banded) and cornelian (brownish and opaque). Due to simple chemical composition, the physical and optical properties are unvarying, e.g., specific gravity of 2.651 and refractive indices of 1.544 to 1.553 with a birefringence of 0.009.

Quartz crystals occur in large quantities in the gem-pegmatites in the Chitral district and Northern Areas of Pakistan.

Zircon

Beautiful euhedral crystals of brownish-red zircon ($ZrSiO_4$) have been found in quartz calcite veins in schists and gneisses, about 20 km south of Chilas (Kazmi and O'Donoghue, 1990)..

Rutile

Showings of brown to reddish-brown rutile (TiO_2) have been observed in Silai Patti-Kolangi granite gneiss and talc chlorite schist south of Kot. At both these localities rutile is opaque and the mineralisation is associated with hydrothermal quartz veins (Hussain et al., 1984).

Azurite

Beautiful crystals of azurite $Cu_3\,(OH)_2(CO_3)_2$ have been found associated with chalcopyrite, malachite and bornite in metavolcanics near Henzel village, 21 km northwest of Gilgit (Kazmi and O'Donoghue, 1990).

LAPIDARY FACILITIES IN PAKISTAN

In Pakistan, gemstone cutting and polishing exist on a very limited scale, which is done mostly on individual basis or at a cottage scale (Figs. 17.1, 17.2). Presently, there are about 30,000 people involved directly or indirectly with gemstone trade in Pakistan, and most of them are exporters of rough gemstones. There are about 400 cutting and polishing units, on average employing one to three persons per unit. Out of these 400 units, 35 units are established in Namak Mandi, Peshawar. In Karachi alone there are about 100 gemstone cutting and polishing units. These units are established mainly in Raja Ghazanfar Ali Road Saddar: Jewellers Centre, New Jewellers Centre, Asif Centre, Sunar Centre, Gems Centre, Gold Centre and Anam Centre in Zaib-un-Nesa Street. Sara Jewellers Centre, Liaquatabad and Gulbahar are also known for this business. Besides, small cutting and polishisng units are also established in commercial buildings of the Karachi city. In Hyderabad about 150 cutting and polishing units are working in different parts of the city. Very low quality cutting and polishing is done in Suns Bazaar of Lahore.

Gemstone cutting and polishing is done manually using old and obsolete locally developed facetor named Angoora (Fig. 17.3). In Karachi Sadder, the standard of cutting and polishing is better as compared to other parts of the country. However, to get quality gemstone products, a complete lapidary is required along with the approximate cost of available material in local market as shown in the appendices.

It is to note that most of the skilled persons involved in the gemstone business belong to Jaipur, India who migrated to Pakistan after 1947 and set-up their shops/units. As observed, the transfer of technology in this field is in house so the expertise always remains within the family. The skill level of these craftsmen depends entirely on their experience.

These local craftsmen are unaware of latest technologies and internationally accepted quality-based calibrated standards. The younger generation, seeing no future in this trade, has started opting for other profitable professions. Those who are still associated with this trade are neither aware of international markets, nor have the capacity to produce quality products to compete in the international markets. This has resulted in low productivity and monotonous designs having no demand in the world market. Consequently ninety percent of Pakistani rough gemstones and gemstone-bearing rock specimen are exported at very low prices thereby causing significant loss to the exchequer.

Figure 17.1. Photograph showing cutting and polishing factory in Gulbahar (Gulimar), Karachi.

Figure 17.2 Photograph showing cutting and polishing factory in Namak Mandi, Peshawar.

Figure 17.3. Photograph showing different types of gemstone facetors used in Pakistan.

MAJOR GEMSTONE MARKETS

In the international markets, the availability of the data about the size and scope of gemstones is very limited, because most of the companies dealing with the gemstone business are family owned, and also due to the economic crisis. It is to be noted that there is constant shift in the global trade of gemstones due to rapid change in the demand for shapes, cuts, colours and type of gemstones. Asia still being the centre of gemstones has strong influence on the world trade. The world trade for coloured gemstones was US$ 1.56 billion in 1997, which was dominated by Thailand, Switzerland and India, having market shares of twenty-one, fourteen, and eleven percents, respectively. Out of total imports of US$ 2.2 billion up to 2001, Switzerland and Japan have the highest shares of twenty-eight and fifteen percent, respectively.

Leading countries like Thailand, India and China etc are dependent on imported raw material, which comes from countries like Myanmar (Burma), Russia, Brazil, Zambia, Zimbabwe, Australia and South Africa. The success of these countries in gemstone marketing is due to the government support and the active participation of their associations, and the availability of skilled but inexpensive labour. Moreover, extensive efforts are concentrated towards marketing by promoting local companies to participate in the international exhibitions with the financial support of their respective governments. Their emphasis is also towards value addition; hence most of these countries have banned the export of rough gemstones. Besides, these countries have the comparative advantage due to available resources of certain varieties of gemstones. Due to these factors leading gem related training institutions such as Gemmological Institute of America (GIA), International Gemmological Institute (IGI), Fellow of the Gemmological Association (FGA) and many other institutes at government and private levels have been established.

A conservative estimate of 1996 by a representative of International Coloured Gemstone Association (ICA) puts the total sales of coloured gemstones at US$ 10 billion per year. Many of the developing countries are playing an important role in the supply of gemstones to international markets. Thailand is the largest supplier of rough, cut and semi-cut gemstones followed by India, China and Hong Kong, which have become the centres for value addition. Besides, the main success of their export is investment friendly policies, marketing, and joint ventures and good relations of the associations with government organisations. Data regarding the gemstone marketing is highlighted in the following tables.

Table 18.1. Leading gem producing countries of the world. Source: Export Promotion Bureau, Peshawar.

S. No	Country	S. No	Country	S. No	Country
1	Pakistan	5	Angola	9	Zimbabwe
2	Australia	6	Sri Lanka	10	Botswana
3	Ghana	7	Zaire		
4	Venezuela	8	Brazil		

Table 18.2. Major import markets of the world. Source: SMEDA, Peshawar.

S. No	Country	S. No	Country	S. No	Country
1	Australia	5	Hong Kong	9	UK
2	India	6	Singapore	10	USA
3	Switzerland	7	Dubai	11	Germany
4	Belgium	8	Sri Lanka		

Table 18.3. Main buyers of Pakistani gems. Source: SMEDA, Peshawar.

S. No	Country	S. No	Country	S. No	Country
1	Australia	7	China	13	France
2	Holland	8	India	14	Japan
3	Saudi Arabia	9	Thailand	15	USA
4	Belgium	10	Gulf States	16	Germany
5	Hong Kong	11	Italy		
6	Singapore	12	UK		

Table 18.4. Precious/semi-precious gemstone exports from Pakistan (value in '000' US$). Source: Export Promotion Bureau, Peshawar.

S. No.	Name of the country	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-2001
1	Australia	-	-	-	-	1	17
2	Austria	-	-	-	18	9	4
3	Afghanistan	-	-	-	-	5	-
4	Canada	-	-	-	2	8	10
5	Dubai	34	126	1456	294	36	25
6	France	59	166	69	54	50	9
7	Finland	-	-	-	-	1	-
8	Germany	316	855	357	498	195	340
9	Hong Kong	1600	136	1280	942	1863	904
10	Italy	80	53	61	65	11	59
11	India	150	11	90	169	21	217
12	Japan	-	-	-	13	7	6
13	Iran	-	-	-	-	-	1
14	Netherlands	-	-	-	-	17	13
15	S. Arabia	-	-	-	3	4	1
16	Singapore	19	1	123	-	-	-
17	Thailand	59	91	105	67	89	186
18	USA	177	1504	1069	482	198	227
19	UK	20	220	744	41	13	39
20	China	-	-	-	-	-	5
21	Denmark	-	-	-	-	-	1
22	Irish Republic	-	-	-	-	1	-
23	Greece	-	-	-	-	-	3
24	Luxembourg	-	-	-	-	-	1
25	Malaysia	-	-	-	-	-	2
26	South Korea	-	-	-	-	-	3
27	Spain	-	-	-	-	2	-
28	Sri Lanka	-	-	-	-	1	22
29	Oman	-	-	-	-	-	1
30	Switzerland	-	-	-	-	14	49
31	Sweden	-	-	-	-	-	1
32	Others	130	149	534	85	5	27
	Total	2644	4412	5888	2733	2551	2173

Table 18.5. Unofficial figures of export performance of gems assessed by APCEA, Peshawar (value in millions of US$). Source: Export Promotion Bureau, Peshawar.

Year	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-2001	2001-2002
July	0.21	0.16	0.47	0.21	0.46	0.26	0.67
August	0.24	0.37	0.43	0.41	0.41	0.71	0.62
September	0.29	0.36	0.29	1.01	0.55	1.54	0.61
October	0.57	0.68	0.40	0.82	2.30	3.04	0.69
November	0.55	0.62	0.41	1.00	1.23	1.51	0.63
December	0.31	0.40	0.23	0.40	0.30	1.11	0.34
January	0.52	0.18	0.39	0.39	1.01	1.95	0.62
February	0.25	0.16	0.41	0.61	0.96	0.48	0.33
March	0.25	0.15	0.51	0.26	1.86	1.12	0.61
April	0.15	0.12	0.44	1.51	0.85	1.04	0.42

Table 18.6. Official figures of the export of gems (value in '000' US$). Source: Export Promotion Bureau, Peshawar.

Year	1996-97	1997-98	1998-99	1999-2000	2000-2001	2002-2003	2003-2004	2004-2005	2005-2006
Precious/Semi-precious stones	4412	5890	2733	2551	2173	2173	3693	3430	4612

Data for 2001-2002 is not available.

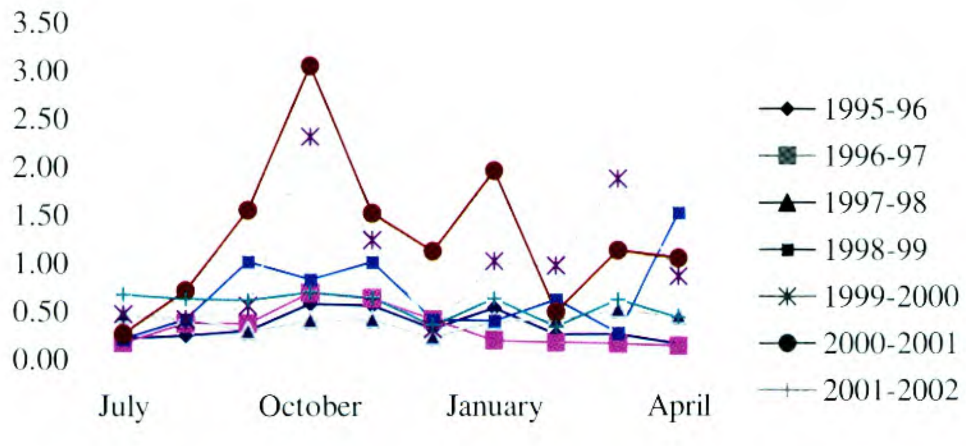

Figure 18.1. Chart showing month–wise export of the Pakistani gemstones.

RECOMMENDATIONS

Pakistan has not been able to contend the gemstone trade internationally because of low quality and below standard gemstone products. The overall problem for the slow growth exists in mining, cutting and polishing, marketing and skills. Other factors may include:

1. The non-recognition of the gemstone sector as an industry by the Government of Pakistan.
2. Lacking of proper infrastructure at the mining site and the use of obsolete and crude methods for the recovery of the gemstones.
3. The non-availability of the skilled labourers to exploit the deposits properly.
4. Lacking of effective regulatory and institutional framework.
5. Lacking of financial support from the government to the private sector.
6. Lacking of marketing skill.
7. Smuggling of the gemstones outside Pakistan.

In this regard an attempt has been made to put forward a few recommendations to revamp the gemstone sector and to bring it in good shape. It is recommended that the gemstone sector should be given the status of an industry and that to reinforce the infrastructure of the gem industry; the following institutions should be established under one umbrella.

1. Gemmological Institute: This will be a laboratory for the examination of the gemstones, their identification, authentication, definition and documentation. This laboratory should become the unaffected and independent institution that will determine the gemmological standards of the industry.
2. School of Gemmology: The School of Gemmology will offer courses and training programmes in fields tangential to the industry, such as evaluators and assessors, museum curators, jewellers and gold-silver-smiths, designers and people who will be having an academic interest in the subject.
3. Museums: Museums will display exhibitions related both to mineralogy and to the finished product of the industry that will be an advertising body presenting the

cultural aspect of the industry.

4. Research Departments: The research departments can include all entities who deal with improving the final product, whether by research and development of new production technologies or by developing processes to enhance gemstones or by improving methods to expose counterfeits, imitations or stones that have been altered. Research departments in their broad sense will be to teach marketing and advertising methods for gemstones as well as to promote the trade.

Due to the existing mining rules and leasing laws most of the mines in Pakistan are closed. The mining rules of 1995 and existing lease agreements for prospecting, exploration and mining need revision, which should protect and encourage private investors. After going through the laws, rules and regulations, related to gemstone trade of the world, a separate mining policy for gem industry needs to be formulated.

Due to lack of appropriate machinery and equipment, the cutting and polishing sectors have been unable to produce quality gems for exports. To make it affordable and to diffuse the modern technologies in the industry, institutional training and other facilities like cutting, and polishing should be provided to the gemstone sector.

Export Promotion Bureau (EPB) should strongly support and promote this sector through various promotional modes such as encouraging private companies to participate in the national and international exhibitions. EPB should share the cost with the participating private sector companies. Display centres for gems should also be established in various parts of the country.

Export of rough gemstone should be discouraged through various incentive measures such as provision of export refinance facility, tax holiday to cut and polished gem exporter. Capital financing should be provided to the investors for the gemstone mining and processing units.

Joint venture arrangements should be encouraged both in the mining, processing and research- based projects.

To bring the gemstone mines economically more viable and to increase the production, and to find out more gemstone deposits, gemstone exploration is necessary. The exploration work must include detailed geological mapping of the promising areas on 1:10,000 scale and the geochemical work for major, trace and rare-earth elements and fluid inclusions using XRF, EPMA, ICP-MS and Fluid Inclusion Equipment. The reserves of the deposits can be determined on proper scientific grounds. The gemstone reserves as reported earlier in different reports are overestimated and just personal views.

Gemstone and mineral mining in Pakistan is a labour-intensive business, which with appropriate technology can maximize the potential for employment and income generation. At present, the Pakistan gemstone wealth is mostly undiscovered, undetermined and unexploited. The authors believe that mineral potential of the country is so great as to promise an acceptable standard of living, to generate large amount of foreign exchange from mineral exports and improvements in the infrastructure. All these factors play important roles in the economic development of Pakistan.

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Table 1 showing gemstone/mineral localities of the Northern Areas of Pakistan (modified after Blauwet et al., 1997).

Locality	Alternate Spellings	Type	Latitude/ Longitude Kilometres	Higher Order	Minerals
Alchuri	Alchori	Population	35°32′ 75°39′	Baltistan: Shigar Valley, 15 km northwest of Shigar	Yellow apatite, aragonite, axinite, barite, bessolite, calcite, diopside, epidote, prehnite, orange and green titanite, zircon, zoisite
Aliabad		Population	36°18′ 74°37′	Gilgit District; central settlement in Hunza, on Hunza River. Note: there are other Aliabads in northern Pakistan	Ruby, spinel
Apaligun	Apligon	Population		Baltistan, on Braldu River, 9 km east of Dassu	Apatite, aquamarine, fluorite, blue phenakite, quartz, schorl, sherry topaz, etched topaz
Arondu	Arundu, Arandu	Population		Baltistan, Basha River at foot of Chogo Lungma Glacier	Quartz, adularia, calcite, titanite
Astor		Population, river	35°22′ 74°51′	Gilgit District, east of Nanga Parbat	Diopside, pink tourmaline
Baghicha	Bughicha, Byicha	Population	km 116	Baltistan, Indus River, near mouth of Tormiq River, 21 km east of Rondu. Not the Bagich on the Indus near the line of control.	-
Bagrot Gah	Bagrot	Stream, ravine		Gilgit District, 14 km downstream from Gilgit	Biotite, titanite
Baha		Population		Baltistan, Braldu Valley, 10 km southwest of Dassu	Aquamarine, biotite, fluorite, topaz
Baltistan		Administration		District of northern Areas	
Baltit		Population, Administration	36°20′ 74°40′	Hunza region, Gilgit District (not in Baltistan!) Sometimes called " Hunza", 5 km east of Aliabad	-
Basha	Basna	River	35°40′ 75°29′	Joins Braldu River to join Shigar River; from Chogo Lungma Glacier	Adularia, aquamarine, quartz, schorl, green apatite, titanite
Basho	Basha	Population, river	35°29′ 75°22′ km 132	Baltistan; southern tributary of Indus between Tormiq and Shigar Rivers; village is 42 km northwest of Skardu	-
Braldu		River	35°39′	Joins Basha River to	-

			75°28′	form Shigar River; from Baltaro Glacier and high Karakoram (There is a smaller Braldu River on the northeast side of the Karakorams)	
Bulbin	Bubind	Population		Gilgit District, due east of Nanga Parpat, 30 km southeast of Astor	Titanite, zircon
Bulochi	Balchi, Balochi, Balachi	Population		Gilgit District, 7 km south of Shengus, 4 km from Indus	Aquamarine, cassiterite, cleavelandite, hambergite (?), helvite, lepidolite, "mica", morganite, quartz, schorl, spodumene, topaz, tourmaline
Busper	Buspar	Peak		Baltistan, north of Haiderabad Bridge. Includes many localities described as Mungo, Yuno, Haiderabad (southside), Nyet, Bruke, Byansahpi and Gone (northside)	-
Byansahpi		Population		Baltistan, Braldu Valley; between Nyet and Apaligun	Topaz
Chamachhu	Changmachhu	Population		Gilgit District, Indus Valley, 10 km east of Shengus	Albite, aquamarine, garnet, microcline, muscovite, quartz, schorl
Chhappu		Population		Baltistan, junction of Hoh and Braldu Rivers, 7 km east of Apaligun	Aquamarine, yellow (cesium) rich beryl, herdenite, lepidolite, microlite, quartz, star muscovite, topaz, yellow and bi-coloured tourmaline
Chilas		Population, Administra tion	35°26′ 74°05′	Administrative centre for Diamir	Diopside, kyanite, vesuvianite, zircon
Chogo Lungma		Glacier		Baltistan, north of Haramosh Range	Quartz, titanite
Chumar Bakhoor		Pasture for Mir of Nagar's ares	4618 m elevation	Lower Nagar, 2200 metres above and south of Sumaiyar	Adularia, albite, apatite, aquamarine, axinite, calcite, pink and green fluorite, microcline, muscovite, twinned pericline, quartz, schorl
Chutran	Chu Tron (-"Hot Springs")	Population	35°43′ 75°24′	Baltistan, Basha River, 8 km from junction with Braldu River. (Not the Chutran in the Indus Valley near Chamachhu)	Adularia with rutile, siderite, schorl
Dache	Dacha, often	Population		Gilgit District, 10 km	Albite, aquamarine,

	pronounced "Dasu"			northeast of Hauchal. Not the Dache in the Astor Valley	garnet, topaz
Dambudas		Population	km 103	Baltistan: Indus Valley between Dasu and Shengus	Schorl
Dassu	Dasso, Dusso	Population	35°43′ 75°31′	Baltistan, on Braldu River; 11 km from Shigar River; 16 km north of Yuno	Classic locality; pre-1940. Albite, apatite, aquamarine, biotite, garnet, goshenite, manganotantalite, microcline, morganite, star muscovite, orthoclase, quartz, schorl, steirite, titanite, topaz, viitaniemiite on topaz
Dogoro		Population		Baltistan, lower Basha Valley, 4 km north of Chutran	Smoky quartz
Doko		Population	35°49′ 75°24′	Baltistan, on Basha River, 17 km from Shigar River	Albite, aquamarine, quartz, schorl
Drot		Population		Indus Valley, Gilgit District, that lies across the Indus from Shengus to Chamachhu, at 50 km to kilometer 65 of the Gilgit-Skardu Road	Apatite, aquamarine, cassiterite, cleavelandite, dravite, elbaite, garnet, goshenite, helvite, columbite, herderite, lepidolite, morganite, tantalite, quartz, schorl, spodumene, tapiolite, topaz. Specimens attributed to Shengus may come from here.
Fiqhar	Fighar	Population		Gilgit District, Lower Nagar, across Hunza River from Aliabad	Apatite, aquamarine, muscovite
Foljo	Folji, Pulji, Fuljo, Phuljo	Population		Baltistan, 200 metres above Apaligun, Braldu Valley	Aquamarine, topaz
Gilgit		Population, Administration District	35°55′ 74°98′	District of Northern Areas; Administrative centre	-
Gone		Population		Baltistan, 5 km east of Dassu	Aquamarine, muscovite, orthoclase, plagioclase, quartz, schorl, topaz
Gyaiungu		Population		Baltistan; on Braldu River between Gone and Apaligun; 7 km east of Dassu	Topaz
Haiderabad	Hyderabad; previously Bungla Bridge. Not the Hyderabad in Hunza.	Population	35°45′ 75°41′	Baltistan, 5 km north of Yuno, at the junction of the Braldu and Basha Rivers; recent (1994) name change from Bungla Bridge	Topaz (probably from Mungo or Yuno)

Hanuchal		Population	km 25	Gilgit District; on Indus, 28 km northwest of Shengus	Adularia, titanite
Haramosh		Range	35°40′ 75°22′	Baltistan, north of Indus River, west of Shigar River	Almandine, calcite, elbaite, epidote, fassaite, feldspar, mica, quartz, schorl, spessartine, titanite, topaz, uvite
Haramosh		Peak (7406 m) west end of Haramosh Range	35°50′ 74°54′	Gilgit District	(between peak and Shengus): apaptite, aquamarine, fluorite, topaz
Hasanabad	Hassanabad	Population, river		Hunza region, above and 2 km west of Aliabad	Ruby
Hashupa	Hashupi	Population		Baltistan, Shigar Valley, between Alchuri and Shigar	Barite, byssolite, diopside, epidote, orange and green titanite
Hispar		Population, river, glacier, pass	36°10′ 74°57′	Upper Nagar, village is 30 km north of Apaligun, 15 km east of Dassu	Aquamarine, green beryl, topaz
Hoh		Population, river		Baltistan; 5 km north of Apaligun, 15 km east of Dassu	Yellow and green tourmaline
Hopar	Hupar	Population		Upper Nagar, Gilgit District; 7 km south of Nagar Village	Green beryl
Hunza		Administra tion		Region of Northern Areas in Gilgit; on north bank of Hunza River	-
Hurchas	Hurchus	Population		Baltistan, 1 km east of Alchuri	Diopside, epidote, schorl, titanite
Hushe		Population, river	35°28′ 76°22′	River into Shyok River above Khapalu, Ghanche District: 36 km north of Khapalu	Topaz (sometimes pale green)
Ishkapul	Ishkapal	Valley, glacier	km 30	Gilgit District; joins Indus River at Shatot village	Aquamarine, cubic pink fluorite
Kachura Nala		Stream	km 145	Baltistan, 27 km northwest of Skardu	Scheelite (unreliable source)
Kaghan		Valley		Northwest Frontier Province; Valley for south-flowing Kunhar River	-
Khairbar		Population, gulch	36°37′ 74°48′	Gojal , on Hunza River, 19 km north of Pasu	Rock crystal
Khaltaro	Kaltoro	Population		Gilgit District, 6 km north of Sassi	Albite, allanite, emerald (some inside pale aquamarine), pink fluorite cubes, quartz, muscovite, oligoclase, prismatic

					schorl, titanite, dark brown and needle tourmaline, K-feldspar is rare. Chrome-rich amphibole contains zoisite.
Khapalu	Khaplu	Population, Administration	35°12′ 76°21′	Administrative centre for Ganche on Shyok River, 103 km from Skardu. Note: Travel east of Khapalu requires official permission.	Amethyst (pale)
Koshumal	Kashmal	Population		Baltistan, on Shigar River, 28 km northwest of Shigar	Aquamarine, green fluorite, bronze mica, microcline, schorl, yellow topaz
Morkhun		Population	36°37′ 74°52′	Gojal, on Hunza River, 24 km north of Pasu	Rock crystal
Muchara Nala	Muchu Har, Machara, Muciohul	Glacier, ravine		Hunza, northwest of Hasanabad, into the Hasanabad River	Apatite, tabular aquamarine, schorl
Mungo	Mango, Munyo	Population		Baltistan, 4 km northwest of Yuno, Shigar Valley	Apatite, aquamarine, cleavelandite, fluorite, manganotantalite, schorl, topaz
Nagar	Nagir	Administration		Gilgit District. Upper Nagar: Hispar Valley and further east. Lower Nagar: South bank of Hunza River below Hispar River, and north bank of Hunza around Chalt	Virtually all specimens ascribed to Nagar are from Chumar Bakhoor and Fiqhar
Nanga Parbat	Diamir	Mountain (8125 metres)	35°15′ 74°36′	Gilgit District; northwestern limit of Himalaya Range	-
Naran		Population	36°16′ 74°44′	North West Frontier Province, south of Diamir District; major centre in upper Kaghan Valley. Approx. 100 km south of Chilas	See Sapat, whose peridots are sometimes ascribed to Naran
Nieosla	Niesolo	Population		Baltistan, Basha Valley, between Chutran and Doko	Green apatite
Nyet Bruk				Across Braldu River from Nyet	Apatite, aquamarine, beryllonite, herderite, muscovite, plagioclase, quartz, schorl, topaz
Nyet	Niit, Niyit, Niyil	Population		Baltistan, on northside of Braldu River; 2 km east of Dassu	Albite, aquamarine, muscovite, quartz, schorl, topaz
Pasu	Passu	Population, glacier	36°28′ 74°54′	Gojal (Hunza), at the junction of the Hunza and Shimshal Rivers	Schorl

Phuldo				Baltistan, Basha Valley; near Ganto La	Topaz
Rondu	Ronda, Mendi	Population, region	35°35′ 75°15′ km 104	Gilgit District, on Indus, 70 km downstream from Skardu	Aquamarine, schorl
Sabsar	Supsar, Sapsir, Sabsir, Sabsan, Subsar	Population	km 67	Gilgit District, 14 km east of Shengus	Apatite, aquamarine, cleavelandite, dravite, orange garnet, goshenite, herdenite, schorl, tapiolite, topaz, bi-colour tourmaline. Specimens attributed to Shengus may come from here. Aquamarine with spiral growth are from near km 60.
Sapat, Sapat Gali	Sumpat, Suppatt	Locality, peak, stream		Locality is 24 km northeast of Naran, in the upper Jalkot Valley, in the Indus-Kohistan region of the Northwest Frontier Province	Magnetite, peridot. The peridots are often brought to market via the Jalkot Nala, through Indus-Kohistan to the KKH at Dassu (Kohistan). This route is not recommended to non-residents.
Sassi	Sasli	Population	35°52′ 74°45′ km 27	Gilgit District: at the great northern bend of the Indus	-
Shengus	Shingus; see also Sabsar	Population	35°49′ 74°49′	Gilgit District between Sassi and Stak River	Albite, almandine, apatite, aquamarine, columbite, elbaite, fluorite, manganotantalite, mica, microcline, pollucite, quartz, schorl, spessartine, stibiotantalite, titanite, water clear topaz
Shigar		River	34°39′ 75°51′	Union of Basha River and Braldu River; joins Indus at Skardu. Not the Shigar River of southern Baltistan	-
Shigar		Region		Includes Shigar, Braldu, and Basha valleys	-
Shigar	Shagar	Population	35°26′ 75°44′	Baltistan, 32 km north of Skardu	Often cited, probably as a generic locality for Shigar Valley localities
Shuut Nala	Shuta	Ravine		Gilgit District, 3 km above and east of Hanuchal	Diopside, epidote (some twinned)
Skardu		Population, Administration	35°18′ 75°37′ km 174	Administrative centre for Baltistan	-
Stak Nala		Gulch, ravine	km 79	Gilgit District, near Stak	Almandine-spessartine, aragonite twins, betrandite, cassiterite, cleavelandite, columbite-

					tantalite, bi- and tri-coloured elbaite, fluoroapatite, green fluorite, hambergite, lepidolite, löllingite, mica, microlite, monazite, montmorillonite, perthite, pyrochlore, plagioclase quartz, topaz, tourmaline, zircon. Beryl is very rare.
Stak		Population	35°42´ 75°04´	Gilgit District, Rondu region; 11 km above Indus, 28 km from Rondu	-
Sumayar	Sumariya, Sumaiyar, Sumair	Population		Lower Nagar, Gilgit District; 5 km east of and across the Hunza River from Aliabad	See Chumar Bakhoor
Teston	Tigston, Tisgtung, Tekston	Population		Baltistan on Braldu River 5 km west of Dassu	Aquamarine, biotite, garnet, quartz, muscovite, plagioclase, schorl
Tormiq	Tormic, Tormik, Torming	River		Baltistan: tributary to Indus between Shengus and Skardu, above Baghicha	Yellow apatite, axinite, byssolite, calcite, dolomite, epidote, hedenbergite, ilmenite, rutile, siderite, titanite, topaz
Tosho	Tosha	Population		Baltistan, 300 metres above and 2 km south of Chhappu	Approximately the same species list as Chhappu
Yuno	Ynau, Yunas	Population		Baltistan, on Shigar River, 8 km below Braldu and Basha River junction, and 45 km northwest of Shigar. Workings at 3,000 to 3,700 metres.	Cleavelandite, cassiterite with ixiolite/wodingite-like coating, green and phosphorescent fluorite, microcline, quartz, rutile, schorl, topaz (some with garnet inclusions)

Interpreting the table: "Population" designates a place name associated with the humane habitation such as a village, town, or even a single farm. "Administration" indicates a name associated with governmental administrative unit. The name Nala, Lungma, Gah, Gol, and Go denote a stream, gulch or ravine. Gali, La and Lah denote a mountain pass. Bruk and Brak mean "mountain" or "high pasture". "Kilometres" in the column is taken from markers along the Indus River (Gilgit-Skardu) Road, measuring southeasterly from the zero point: the Alam Bridge over the Gilgit River near its confluence with the Indus. The bridge is a little more than 1 km from the junction with the Karakoram Highway (KKH). Latitude and longitude are from the Times (London) Atlas, the Pakistan volume of the U.S. Board from Geographic Names. The distances provided under "Higher Order" are only approximations.

Table 2 showing comparison of physical and optical constants of Pakistani emeralds with emeralds from other countries (from Gueblin 1989).

Location	Refractive indices		Birefringence $\triangle n$	Density g/cm^3
	n_e	n_o		
Pakistan				
Swat Emerald Mine-1	1.578-1.586	1.584-1.594	0.006-0.008	2.72-2.77
Swat Emerald Mine-2	1.583-1.591	1.591-1.600	0.008-0.009	2.70-2.78
Swat Emerald Sarkan Mine	1.575-1.590	1.582-1.599	0.007-0.009	2.71
Charbagh Emerald	1.577-1.585	1.584-1.592	0.007-0.009	2.68-2.70
Gujar Killi Emerald	1.582-1.593	1.589-1.600	0.007-0.009	2.69-2.74
Makhad Emerald	1.579-1.587	1.586-1.595	0.007-0.008	2.74-2.76
Khaltaro Emerald	1.581-1.582	1.589-1.590	0.008	2.66-2.72
Australia				
Poona	1.572	1.578	0.005-0.007	2.693
Brazil				
Bahia				
Brumado	1.573	1.579	0.005-0.006	2.682
Carnaiba	1.583	1.588	0.006-0.007	2.72
Salininha	1.583	1.589	0.006	2.70
Socoto	1.577	1.583	0.006	2.71
Goias				
Santa Terezinha	1.585	1.592	0.006	2.752
	1.587	1.595	0.008	2.764
Minas Gerais				
Belmont (Itabira)	1.576	1.581	0.005	2.728
	1.582	1.590	0.008	2.742
India				
Ajmer	1.585	1.595	0.007	2.735
Colombia				
Burbar	1.569	1.576	0.007	2.704
Chivor	1.570	1.579	0.005-0.006	2.688
Muzo	1.570	1.580	0.005-0.006	2.698
Madagascar				
Ankadilalana	1.581	1.589	0.008	2.727
Mozambique				
Maria III	1.585	1.591	0.006	2.73
Melela (Morrua)	1.585	1.593	0.008	2.73
Norway				
Eidsvol (Minnesund)	1.583	1.590	0.007	2.759
Austria				
Habachtal	1.584	1.591	0.007	2.734
Zambia				
Kafubo	1.592	1.602	0.010	2.77
Kitwe	1.580	1.586	0.006	2.794
Miku	1.582	1.589	0.007-0.008	2.738
Zimbabwe				
Mayfield	1.584	1.590	0.006	2.72
Sandawana	1.584	1.590	0.006	2.75
Tanzania				
Lake Manyara	1.578	1.585	0.006	2.72
Republic of South Africa				
Cobra Mine (Transvaal)	1.583	1.594	0.006-0.007	2.74
Russia				
Tokowaya (Sverdlovsk)	1.580	1.588	0.006	2.74
USA				
Hddenite (N.C)	1.581	1.588	0.007	2.73

Table 3 showing physical and optical constants of the Pakistani gemstones compared with their standard value (modified after Kazmi and O' Donoghue 1990; Jan and Khan, 1996).

Gemstone	**RI**						**B** Δn	**D** g/cm3	**H**
	n	n_o	n_e	n_α	n_β	n_γ			
Spinel	1.718	-	-	-	-	-	-	3.60	8.00
Pakistan Hunza	1.715	-	-	-	-	-	-	3.558- 3.614	-
Pargasite	-	-	-	1.613	1.618	1.635	0.022	3.05	5.00-6.00
Pakistan Hunza	-	-		1.616	1.620	1.642	Strong	3.00- 3.45	5.5 -6.00
Topaz				1.606- 1.629	1.609- 1.631	1.616- 1.638	0.008- 0.011	3.49- 3.57	8.00
Pakistan Katlang				1.629- 1.631	1.631- 1.634	1.638- 1.642	0.009	3.52	8.00
Aquamarine		1.557	1.575				0.006	2.69	7.50
Tourmaline		1.62	1.64				0.018	3.18	7.00
Peridot				1.635- 1.827	1.651- 1.869	1.670- 1.879	0.035- 0.052	3.22- 4.39	6.50-7.00
Pakistan Sapat				1.644- 1.653	1.651- 1.869	1.682- 1.689	0.033- 0.038	3.26- 3.44	6.50

Key: RI, Refractive index; B, Birefringence; D, Density; H, Hardness

Table 4 showing characteristics of Hunza ruby as compared with rubies from other countries (Modified after Kazmi and O' Donoghue, 1990).

Location	**Colour**	**RI**		**B** Δn	**D** g/cm^3
		n_e	n_o		
Pakistan Hunza	Red	1.762	1.770	0.008	3.995
Myanmar Mogok Mong Hsu	 Fine Red Fine Red	 1.760 1.770-1.774	 1.768 1.762-1.765	 0.008 0.008-0.01	 3.996 3.990-4.01
Thailand	Red	1.760 1.764	1.768 1.722	0.008	4.006
Sri Lanka	Red	-	1.772	3.998	-
Malawi	Red	1.762	1.771	0.009	-
Afghanistan Jegdalek	Red	1.762	1.770	Strong	4.00

Key: RI, Refractive index; B, Birefringence; D, Density; H, Hardness

Table 5 showing excavation and production record of Nangimali top area, Nangimali ruby deposits. (Source: AKMIDC).

Year	Excavation (M^3)	Rough Ruby Production (Gms)	Specimen (Nos)
Pre-1989	-	5429	-
1989	400	5267	50
1990	800	7471	208
1991	1634	12809	426
1992	2010	17770	197
1993	1696	20000	165
1994	1358	24224	22
Total	7898	92970	1068

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers.

Table 6 showing excavation and production record of middle Khora area, Nangimali ruby deposits. (Source: AKMIDC).

Year	Excavation (M^3)	Ruby Production (Gms)	Specimen (Nos)
1989	150	851	02
1990	100	529	-
1991	-	-	-
1992	10	100	-
1993	454	235	-
1994	18	85	-
Total	732	1800	2

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers.

Table 7 showing excavation and production record of lower Khora area, Nangimali ruby deposits. (Source: AKMIDC).

Year	Excavation (M^3)	Rough Ruby (Gms)	Specimen (Nos)
1991	1510	18898	208
1992	1776	38360	248
1993	1354	47600	69
1994	1285	40111	24
1995	1826	28264	32
1996	1500	15270	6
1997	-	-	-
1998	280	1976	-
1999	820	7803	-
2000	825	8473	-
2001	246	8467	-
2002	-	-	-
Total	11422	215222	587

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers.

Table 8 showing excavation and production record of tourmaline and other minerals from Jandarwala Nar pegmatite. (Source: AKMID).

Year	Excavation (M^3)	Rough Spessartine garnet (Gms)	Rough Black Tourmaline (Gms)	Spessartine Specimen (Nos)	Tourmaline Specimen (Nos)
1993	55	51	10950		17
1994	235	3295	57100		88
1995	438	1775	25050	3	19
1996	419	10550		1	
1997	476	5320	3090		1
Total	1623	20991	96190	4	125

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers.

Table 9 showing excavation and production record of tourmaline and other minerals from Donga Nar pegmatite No. 2. (Source: AKMIDC).

Year	Excavation (M^3)	Green Tourmaline (Gms)	Topaz (Gms)	Tourmaline Specimen (Nos)
1989	40	-	-	-
1990	27	-	-	-
1991	34	-	-	-
1995	104	7615	290	14
1996	204	1670	-	6
1997	85	575	-	-
Total	494	9860	290	20

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers.

Table 10 showing excavation and production record of tourmaline and other minerals from Donga Nar pegmatite No. 1.(Source: AKMIDC).

Year	Excavation (M^3)	Green Tourmaline (Kgs)	Tourmaline Specimen (Nos)	Topaz (Gms)	Morganite (Kgs)	Topaz Specimens (Nos)
Pre-1989	-	9300	16	-	-	-
1989	360	60700	16	-	-	-
1990	463	10460	43	-	-	-
1991	389	41605	51	-	-	27
1992	310	23676	21	-	-	-
1993	520	43673	35	1937	1070	-
1994	110	5300	12	1325	-	-
1995	104	7615	14	290	-	-
1996	306	14686	-	-	-	-
1997	192	3750	-	-	-	-
Total	2754	220765	208	3552	1070	27

Key: M^3 = Cubic Metre; Gms = Grams; Nos = Numbers; Kgs = Kilograms.

Table 11 showing gemstone cutting and polishing machines, spares, tools and consumables. (Source: SMEDA)

S. No	Name of the Equipment	S .No	Name of the Equipment
1	Faceting machines for cutting facet gemstone	30	Gauges
2	Cabochon making machines	31	Gem microscope
3	Sawing machine for making slabs of gemstones	32	Gemolite super zoom portable microscope
4	Cabochon grinding machine	33	Chelsea colour filter
5	Performing machine	34	Gem metre
6	Beed grinding machine	35	Diamond colour metre
7	Beed making machine	36	Refrectometre
8	Bowl cutting machine for gemstones	37	Illuminator polariscope
9	Bowl polishing machine	38	Ultraviolet lamp
10	Tumbling machine	39	Fibrelite
11	Vibrator	40	Colour grader
12	Drilling machine	41	Spectroscope
13	Sawing machine	42	Overhead light source
14	Diamond powder/liquid of various mesh size	43	Gold tester
15	Amery powder	44	Karat acid
16	Sawing blades of various diametres	45	Gem tester
17	Diamond discs of various diametres	46	Diamond tester
18	Diamond blades of various diametres	47	Ultrasonic cleaners
19	Ultrasonic machinery	48	Sorting lamp with accessories
20	Diamond lap of various mesh size	49	Appraisal equipment
21	Tin lap	50	Camera systems
22	Dop sticks	51	Bench tools
23	Electronic scales	52	Carving machinery
24	Loupes	53	Engraving machinery
25	Magnifiers	54	Pliers and cutters
26	Tweezers	55	Power graver
27	Sorting equipment	56	Flex shafts
28	Gemstone testing mid grading equipment		
29	Gemstone sorting equipment		

Table 12 showing market price for the gem cutting and polishing material available in Pakistan. (Source: SMEDA).

S.No.	Name of the Equipment	Market Price in Pak. Rupees
1	Angoora (Gemstone facetor), local made	400
2.	Diamond discs of various diametres	1000-1500
3	Copper, Tin and Steel of various sizes	1500-2000
4	Leather and Rubber laps of various size	200-300
5	DopSticks (100 Nos.)	300
6.	Diamond powder (0-2) per 10 carats	250-1000
7.	Chromium oxide powder	500
8	Tin oxide	400-500

Table 13 showing examples of idiochromatic and allochromatic colouration by transition metal ions in minerals (from Nassau 1983).

Idiochromatic	Cr-uvarovite (a green Cr-rich garnet Cu-azurite, chrysocolla, turquoise, (blue); malachite (green); cuprite (red) Fe-lazulite (blue); olivine (green); almandine (red garnet); goethite (yellow) Mn-rhodochrosite, rhodonite (pink)
Allochromatic	Cr-emerald, Cr-jade, Cr-tourmaline (green); ruby, spinel, topaz (red) Fe-aquamarine, tourmaline (green); citrine, orthoclase (yellow); jade (green-yellow-brown) Mn-tourmaline (pink); andalusite (green, yellow)

Table 14 showing colouration in minerals due to colour centres (from Nassau 1983).

Amethyst, fluorite (purple)
Smoky quartz (brown to black)
Irradiated diamond (green, yellow, brown, black, pink)
Some natural and irradiated topaz (blue)
Halite (blue and yellow)

Table 15 showing important properties of major gem minerals (modified after Anderson and Jobbins, 1990).

Species Composition and Crystal system	Varieties and colours	H	SG	Mean RI and DR	Notes
Amber Hydrocarbon Amorphous	Baltic-yellow Sicilian-Reddish-yellow Romanian-Brown Burmese-Yellow to brown	2.50	1.08	1.54 Isotropic	A fossil resin. Often includes insects etc. Splinters under knife. Melts at 280ºC. Burns with characteristic flumes
Andalusite $Al_2O_3.SiO_2$ Rhombic	Green-greenish-brown, with reddish tints Chiastolite is impure variety showing greyish cross on black or pale ground	7.50	3.15	1.64 0.010	Striking pleochroism. Rare. Often confused with tourmaline, but has lower DR and higher SG
Apatite $Ca_4(CaF)(PO_4)_3$ Hexagonal	Yellow, blue, green, violet	5	3.21	1.638 0.003	Blue type from Burma, strongly dichroic. Yellow commonly shows rare-earth absorption bands (584 nm, etc.) Very low DR and higher SG distinguish it from danburite.
Axinite Complex borosilicate of Ca, Al, Mg. Triclinic	Clove brown, violet	7	3.28	1.685 0.011	Occurs in beautiful bladed crystals.
Beryl $3BeO.\ Al_2O_3\ 6\ SiO_2$ Hexagonal	Emerald-Green	7.5	2.71	1.575 0.006	Emerald usually flawed. **Pakistani** and South African emerald rather higher SG and RI; Brazilian emerald rather lower.
	Aquamarine-Pale blue to bluish green	7.50	2.69	1.75 0.006	Aquamarine usually flawless. Madagascar type shows strong dichroism.
	Golden beryl (Heliodor)-Yellow	7.5	2.68	1.57 0.005	
	Pink beryl (Morganite)-Rose pink, red. Also colourless	7.5	2.80	1.59 0.008	Constants of pink beryl usually high because of rare alkalies present.
Brazilianite $NaAl_3(OH)_4(PO_4)$ Monoclinic	Greenish-yellow Transparent or translucent	5.5	2.99	1.612 0.021	Discovered in 1944 in pegmatites in Minas Gerais, and (1947) in New Hampshire, USA.
Chrysoberyl $BeO.Al_2O_3$ Rhombic	Alexandrite-Green in day light, red in artificial light	8.5	3.71	1.75 0.009	Siberian and Brazilian Alexandrite show best colour change. So-called synthetic Alexandrites are usually synthetic corundum or spinel.

	Cat's-eye (cymophane)-Greenish or brownish-yellow, translucent and chatoyant Also yellow, greenish-yellow, colourless and brown	8.5	3.71	1.75 0.009	Several other species show chatoyancy, but 'Cat's-eye' without qualification signifies chatoyant chrysoberyl.
Corundum Al_2O_3 Trigonal	Ruby-Red Sapphire-Blue Also colourless, yellow pink, green and violet Star ruby, star sapphire-Translucent, showing asterism	9 9	3.99 3.99	1.765 0.008 1.765 0.008	Myanmar (Burma) ruby, bright red, strong dichroism. Contains 'silk'. Thai ruby, garnet red, less dichroism. **Pakistani** ruby, red and pink, clouded. Contains no 'silk'. Calcite is common inclusion. Sapphire shows strong dichroism. Green sapphire has slightly higher SG and RI than others. Synthetic corundum made in many colours.
Danburite $CaO.B_2O_3.2\ SiO_2$ Rhombic	Pale yellow, colourless	7	3.00	1.633 0.006	Lower SG and DR distinguish it from topaz. Didymium absorption spectrum frequently present. Myanmar (Burma) chief gem locality.
Diamond C Cubic	Colourless Shades of yellow and brown Rarely blue, red, green. (Boart and carbonado for industrial use only)	10	3.52	2.418 Isotropic	Hardest known substance. Perfect octahedral cleavage. Very constant properties. Green, brown, yellow induced by atomic bombardment.
Diopside $CaO.MgO.2\ SiO_2$ Monoclinic	Pale green to dark green Sometimes chatoyant Also star stones (four-rayed)	5	3.29	1.69 0.030	Distinguish from peridot by different shades of green and somewhat higher RI and lower DR. From enstatite by higher DR.
Enstatite $MgO.\ SiO_2$ Rhombic	Green, brown, colourless Sometimes chatoyant	5.50	3.27	1.67 0.009	Associated with diamond and pyrope in Kimberley district. Also found in large pieces but of less attractive green in Myanmar (Burma). Absrption line at 506 nm.
Epidote Silicate of Ca and Al Monoclinic	Dark brownish- green	6.5	3.45	1.75 0.035	Colour of crystals usually too dark to make attractive gems. Strongly dichroic. Distinctive 'pistachio' green.

Species Composition and Crystal system	**Varieties and colours**	**H**	**SG**	**Mean RI and DR**	**Notes**
Feldspar group	Yellow orthoclase	6	2.56	1.665 0.019	Important group of rock-forming minerals Yellow-orthoclase found in Madagascar, contains iron.
Orthoclase $K_2O.Al_2O_3.6\ SiO_2$ Monoclinic	Moonstone-Colourless with white or bluish sheen	6	2.57	1.53 0.005	Moonstone with star or cat's-eye rays.
Microcline Same composition	Amazonite-Bluish green, translucent to opaque	6	2.56	1.53 0.008	Amazonite, somewhat similar to poor-quality turquoise.
Albite Triclinic	Albite-Usually colourless; cat's-eyes	6	2.58	1.53 0.005	Only moonstone and labradorite are used at all widely in jewellery.
Plagioclase Na and Ca aluminosilicates Triclini	Oligoclase-Pale yellow	6	2.64	1.545 0.007	
	Labradorite-Grey with play of colour, pale yellowish	6	2.70	1.565 0.010	
	Sunstone-spangled reddish	6	2.64	1.54 0.009	
Fibrolite $Al_2O_3.\ SiO_2$ Rhombic	Pale blue, greenish	7.5	3.25	1.665 0.019	Same RIs as euclase, and also has very ready cleavage.
Fluorite CaF_2 Cubic	Purple, blue, yellow, pink, colourless Blue John or Derbyshire Spar-Massive banded	4	3.18	1.434	Perfect octahedral cleavage. Often bright fluorescence under ultraviolet light. Very constant SG and RI.
Garnet group Cubic Almandine $3FeO.Al_2O_3.3\ SiO_2$	Purplish-red	7.5	3.9-4.2	1.76-1.81	Almandine and pyrope form continuous isomorphous series of red garnets. Almandine coloured by iron. Finest pyrope coloured by chromium. Almandine characteristic absorption spectrum.
Pyrope $3MgO.Al_2O_3.3\ SiO_2$	Deep blood-red	7.25	3.7-3.9	1.73-1.76	
Grossular $3CaO.Al_2O_3.3\ SiO_2$	Hessonite-orange-brown. Also green, pink etc. massive grossular	7.25	3.65	1.74	Hessonite also contains almandine.

Species Composition and Crystal system	**Varieties and colours**	**H**	**SG**	**Mean RI and DR**	**Notes**
Andardite $3CaO.Al_2O_3.3\ SiO_2$	Demantoid-Green Topazolite-Yellow	6.5	3.85	1.89	Very high dispersion ('fire')
Spessartine $3MnO.Al_2O_3.3\ SiO_2$	Orange or yellow Flam red	7	3.16	1.80	Rather rare. Often resembles hessonite. Constants near those for almandine.
Idocrase (Vesuvianite) Ca and Fe silicate Tetragonal	Brown, yellow, green; transparent Californiate-green massive; transparent	6.5 5.5	3.38 3.3	1.70 0.005 1.70	Distinct dichroism Californiate variety resembles jade. Absorption band in blue at 461 nm.
Jadeite $Na_2O.Al_2O_3.4\ SiO_2$ Monoclinic	Green, white, brown, mauve; transparent	7	3.33	1.66 0.012	'Chinese jade'. Fibrous or granular structure. Often shows slightly dimpled surface. Colour often variegated. More highly esteemed than nephrite.
Kyanite $Al_2O_3.\ SiO_2$ Triclinic	Blue; sometimes green or colourless	4 to 7	3.69	1.72 0.019	Flaky structure. Sometimes fine sapphire blue. Strong pleochroism. Hardness varies greatly with direction.
Lapis lazuli	Blue; opaque	5.5	2.8	1.5	Brassy specks of pyrites frequent. Inferior pieces have white patches. Rock containing lazurite and other minerals.
Lazulite Fe, Mg, Al phosphate Monoclinic	Blue; transparent to opaque	5.5	3.1	1.62 0.031	Rare ornamental stone; sometimes resembles turquoise.
Malachite $Cu_2(OH)_2CO_3$ Monoclinic	Green, banded; opaque	4	3.8	1.78 0.025	Ornamental stone with typical concentric bands of dark and paler green, Effervesces with 10% diluted hydrochloric acid.
Nephrite Ca, Mg, silicate Monoclinic	Green, white; transparent to opaque	6.5	2.96	1.62	Classed with jadeite as true jade. Tough. Splintary (hackly) fracture. Colour less bright than jade.

Species Composition and Crystal system	Varieties and colours	H	SG	Mean RI and DR	Notes
Opal $SiO_2 + H_2O$ Amorphous	Fire-opal-Orange. Seldom shows play of colour	6	2	1.45 Isotropic	Contains a varying amount of water. Often porous; thus not advisable to test in heavy liquids. Fire opal usually faceted with domed table. Others cabochon cut.
	White opal-play of colour on pale, translucent background	6	2.1	1.45	
	Black opal-play of colour on dark background	6	2.1	1.45	
	Water opal-play of colour within almost colourless stone	6	2	1.45	
Pearl $CaCO_3$ with conchyolin and water	'Natural'- White or creamy	3.5	2.71	-	'Natural' pearls from Arabian Gulf and Coasts of Sri Lanka. Pearls also classified by shape-button, drop, baroque (irregular), etc. Pearls consist of about 90 percent $CaCO_3$ in form of aragonite. Pink conch pearl and back clam pearl have no pearly lustre and belong to different category. Pearls may be real, cultured and simulant.
	Australian-Silvery white	3.5	2.74	-	
	Venezuelan-Translucent white	3.5	2.7	-	
	Black-Bronze or gunmetal colours	3.5	2.65	-	
	Blue-Lead grey due to dark nucleus	3.5	2.6	-	
	Freshwater –Dull, iridescent	3.5	2.7	-	
	Conch-Pink; no pearly lustre	3.5	2.85	-	
	Clam-Black; no pearly lustre	3.5	2.65	-	
Quartz SiO_2 Trigonal	Rock-crystal-Colourless Amethyst-Purple Citrine-Yellow (Cairngorm)-Brown Morion-Smoky quartz Rose quartz-Pink, cloudy Aventurine- Green Spangled, also brown	7	2.65	1.548 0.009	Transparent varieties of quartz have very constant properties. Name 'topaz' should not be used for the yellow citrine or brown cairngorm. Japer is a very impure massive quartz , usually brown; stained with Berlin blue to make 'Swiss Lapis'.
	Quartz cat's-eye-Pale brown chatoyant Tiger's-eye or 'crocidolite'-Golden brown, chatoyant Rutilated quartz-Colourless with included rutile	7	2.65	1.548 0.009	

Species Composition and Crystal system	Varieties and colours	H	SG	Mean RI and DR	Notes
Quartz (Crytocrystalline) **Chalcedony group**	Chalcedony-Unbanded, grey Cornelian-Red Chrysoprase-apple green Agate-Concentric bands of various colours Onyx-Straight bands Sardonyx-Red and white bands	7	2.6	1.53 Small DR	The chalcedony minerals are translucent. They may be stained various colours, and are usually so treated.
Sinhalite Mg (AlFe) BO_4 hRombic	Pale yellow to dark brown or greenish brown; transparent	6.5	3.48	1.685 0.038	Cut stones formally thought to be 'brown peridot' were found in (1952) to be a new species. Named after Cylone (now Sri Lanka) where first found. Distinguished from peridot by SG, RI and spectrum.
Sphene (Titanite) $CaO.TiO_2$. SiO_2 Monoclinic	Yellow, green, brown	5.5	3.53	1.96 0.134	Rare. Highly valued in spite of softness for its magnificent appearance. Dispersion higher than diamond. Strong pleochroism and large DR.
Spinel $MgO.Al_2O_3$ Cubic	Red, pink, pale greyish-blue, shades of reddish-purple Ceylonite or Pleonaste-Black; opaque Gahnospinel-shades of blue, containing varying proportion of zinc	8 8 8	3.60 3.8 4.06	1.717 Isotropic 1.78 1.754	Pure spinel has SG 3.58, RI 1.715. Variety names such as 'Balas Ruby' are misleading and should be avoided. Ceylonite types contain much iron, raising SG and RI. Synthetic spinels made in colours to represent other species
Spodumene $Li_2O.Al_2O_3.4\ SiO_2$ Monoclinic	Kunzite-Lilac Hiddenite-Green. Also yellow	7	3.18	1.67 0.015	Easy cleavage in two directions. Pleochroism distinct or strong. True green hiddenite coloured by chromium, very rare.
Topaz Fluoro-hydroxy silicate of Al Rhombic	Colourless Blue Yellow Pink Orange Brown	8	3.56 3.56 3.53 3.53	1.62 0.010 1.63 0.008	True topaz not to be confused with yellow quartz. Perfect basal cleavage. Pink topaz is very rare and only found in Pakistan. Pink stones are also produced by heat treatment of brownish yellow Brazilian material. Much blue topaz toaz irradiated. Distinct pleochroism.

Species Composition and Crystal system	**Varieties and colours**	**H**	**SG**	**Mean RI and DR**	**Notes**
Tourmaline Complex boro silicate of Al, Mg, Fe, alkalis, etc. Trigonal	Achroite-Colourless Rubellite-red, deep pink Indicolite-Deep inky blue Also green, pink yellow, brown, black and particoloured	7	3.05	1.63 0.018	Strongly dichroic. Pyroelectric. Colour often in segments or concentric zones. Red types have lowest SG. Yellow, blue, higher; black highest. Distinguished from topaz and andalusite by larger DR.
Turquoise Hydrous phosphate of Al and Cu Triclinic	Dark to pale sky blue, pale greenish –blue; translucent to opaque	6	2.6 to 2.8	1.61	Egyption (strong blue, translucent) and Iranian (fine blue) are least porous and have SG near 2.8. American types softer, more porous and have lower SG. Veins of dark limonite matrix frequent.
Zircon ZrO_2. SiO_2 Tetragonal	Colourless, blue, orange red, yellow, golden brown Green and shades of green	7.5 6.5	4.69 4 to 4.5	1.95 0.059 1.79	Heat-treated types from Indo-China and Thailand have properties of normal zircon as given. Strong DR a distinguishing feature. Green types from Sri Lanka are metamict and have lower and variable properties. Blue zircon the only type to show dichroism.
Zoisite (Tanzanite) Silcate of Ca and Al Rhombic	Blue, purple, brown, Massive green Thulite-massive pink	6.5	3.35 3.38 3.10	1.695	Transparent blue zoisite, an important gemstone. Massive types seldom-used in jewellery. Thulite (pink zoisite) was found in Pakistan (Khan T et al., 1987).

Key: H, Hardness; SG, Specific gravity; RI, Refractive index; DR, Double refraction.

Table 16 showing Glossary (modified from Bates and Jackson (1990).

aegirine-augite	A green variety of strongly pleochroic monoclinic pyroxene mineral. Aegirine-Augite: $(Na,Ca)(Fe^{+3},Fe^{+2}, Mg)(Si_2O_6)$.
agate	Rock composed of layers of quartz, sometimes of different colours. Agate usually occurs as rounded nodules or veins. The layers of quartz are often concentric. The composition of agate varies greatly, but silica is always predominant, usually with alumina and oxide of iron. Other types of silica - chalcedony, carnelian, amethyst, jasper, opal, and flint -often occur as layers in agate.
albitite	A porphyritic igneous rock, defined by Turner in 1896, containing phenocrysts of albite in a groundmass chiefly consisting of albite. Muscovite, garnet, apatite, quartz and opaque oxides are common accessory minerals.
alluvium	Silt, sand, clay, gravel, or similar loose material deposited by flowing water. Alluvium usually occurs at any point where the velocity of fast-running water is abruptly slowed and the carrying capacity of the flow is reduced to a point where transport of the sediment is no longer possible.
amorphous	Laterally, without shape. An amorphous substance is one in which the internal arrangement of the atoms or molecules is irregular and which in consequence has no characteristic form.
amphibolite	A metamorphic rock composed mainly of hornblende and plagioclase, generally with or without oriented fabric.
apatite	Apatite (Greek apate, "deception"), mineral so named because it resembles various other minerals for which it might be mistaken. It consists chiefly of phosphate of lime. Apatite is a distinct mineral of composition $Ca_5(PO_4)_3F$ in which some or all of the fluorine may be replaced by chlorine (chlorapatite). The mineral crystallises in the hexagonal system and has a hardness of 5 and a specific gravity of 3.2. When pure, apatite is colourless and transparent, but it may exhibit various degrees of colour and opacity. These mineral phosphates of lime were often used in the preparation of fertilizers, but they have been replaced by phosphate rock.
aquamarine	(Latin aqua, "water"; marina, "sea"), gemstone, a variety of the mineral beryl that is blue, blue-green, or green.
axinite	A mineral of the cyclosilicate group $Ca_2(Mn,Fe^{+2})Al_2BO_3(Si_4O_{12})(OH)$ formed by the contact metamorphism of limestone or by pneumatolysis.
bastnasite (bastnaesite)	A greasy, wax-yellow to reddish-brown mineral: $(Ce,La)CO_3(F,OH)$. It occurs in alkaline igneous rocks, especially carbonatite as in Zagai Ghar granite of Warsak, Peshawar, Pakistan and at Mountain Pass, California. Bastnasite is the chief U.S. source of rare-earth elements.
bead	While beads may be faceted, they are more commonly cut and polished as small spheres and then drilled to allow stringing. Bead mills are used to grind and sand large quantities of beads simultaneously. They typically employ a grooved lap and a flat lap between which the beads are rolled and worn to

	shape. After shaping and sanding, tumbling usually polishes beads.
beryl	Mineral and, in certain varieties, a valuable gem material. Chemically it consists of aluminium beryllium silicate, $Be_3Al_2(SiO_3)_6$, and it is the chief commercial ore of beryllium. Pure beryl is colourless and transparent.
biotite	A widely distributed and important rock-forming mineral of the mica group. It is generally black or dark brown and occurs in metamorphic and igneous rocks.
birefringence	A ray of light entering any crystal other than cubic in directions other than that of an optic axis is at once split into two polarised rays, each vibrating at right angles to each other. These rays travel at different speeds through the crystals, and are in consequence refracted by different amounts, the effect being known as birefringence or double refraction.
breccia	Coarse-grained rock, typically made up of angular rock fragments larger than 2 mm (0.08 in) in diameter, cemented in a finer-grained matrix. A breccia reveals its origin by the size and shape of its parts.
carbonatite	A carbonate rock of apparent magmatic origin, generally associated with kimberlites and alkalic rocks.
cabochon	A style of cutting in which the top of the stone form a curved convex surface. The base may be convex, concave or flat.
cameos and intaglios	Cameos and intaglios are similar in that both usually are carved portraits in stone or seashells. They differ in that cameos are raised portraits, while intaglios are carved down into the surface of the material.
carat	The metric carat, equivalent to one -fifth of a gram, is internationally accepted as the standard weight for precious stones.
chelsea colour filtre	An effective di-chromatic colour filter transmitting light of only two wave-length regions; one in the deep red, the other in the yellow-green. Useful for discriminating between emerald and its imitations and for detecting synthetic spinels and pastes coloured blue with cobalt.
chemical element	Matters composed of atoms of only one chemical type and which thus cannot be decomposed into simpler substances by chemical means.
chlorite	A group platy, monoclinic, usually greenish minerals of the general formula $(Mg,Fe^{+2},Fe^{+3})_6AlSi_3O_{10}(OH)_8$.
chromite	Chromite, only ore mineral of chromium, consisting of ferrous chromite, $FeCr_2O_4$, and belonging to the spinel group. It crystallises in the isometric system (*see* crystal) and has a hardness of 5.5 and a specific gravity, or relative density of 4.1 to 4.8. It is found in irregular brownish-black or black grains or octahedral crystals. Chromite is one of the first minerals to crystallise from magma. It occurs principally in rocks containing various amounts of ferromagnetic minerals.
clarity	Gemstones can vary from complete opacity to lucid clarity and may contain few or many inclusions such as crystals of other minerals, gas- or liquid-filled cavities, or even insects! (Large, perfectly preserved insect specimens in amber are highly prized).

cleavage	The tendency shown by certain stones to split along one or more definite directions. Cleavage planes are always parallel to a possible crystal face of the mineral in question.
colour	An effect produced in a normal human eye by light of certain wave-lengths.
continental crust	That type of the Earth's crust, which underlies the continents and the continental shelves. It is equivalent to the sial and ranges in thickness from 35 km as much as 60 km under the mountain ranges.
corundum	Corundum, mineral consisting of aluminum oxide, Al_2O_3. Next to the diamond, corundum is the hardest natural substance with a relative hardness of 9 and a specific gravity of about 4. Corundum crystallises in the hexagonal system (*see* crystal). Gem-quality transparent crystals of the mineral form sapphires and rubies. Common corundum, which occurs either in a crystallised or granular form, is usually gray, grayish-blue, or brown; the black granular variety, which contains varying amounts of hematite and magnetite, is called emery. Common corundum and emery are both used as abrasives. Synthetic corundum, sold under various trade names, is also used as an abrasive.
crust of the Earth	That portion of the Earth lying above the Mohorovicic Discontinuity. It is divided into two shells, a lower, continuous one- the sima (silca and magnesia) and an upper, discontinuous layer -the sial (silica and alumina).
crystal	A substance in which the constituent atoms, ions or molecules are arranged in accordance with a definite regular structure through out.
crystal axes	Imaginary lines passing through a crystal in important symmetry directions, intersecting in the 'origin' at a centre of a crystal.
crystal systems	The seven main symmetry groups into which all crystals, whether natural or artificial, can be classified.
crystalline	Irregular crystals in which the atomic arrangement has fully developed internally but not displaying crystal faces, i.e., the internal atomic arrangement is not reflected outward.
density	The weight of a substance per unit volume, measured in grams per cubic centimetre. Since 1 cm^3 of water weighs 1 gm, the density of a substance is numerically equal to its specific gravity.
deposit	Deposit, in geology, natural accumulation of mineral or rock material formed through deposition by waters, glaciers, or the wind and by igneous and/or metamorphic activity.
diamond	Diamond, mineral form of carbon, valued as a precious stone, and also used for various industrial purposes. It has hardness 10 on Mohs's scale. Diamonds occur in various forms, including the diamond proper (a crystalline gemstone), bort, ballas, and carbonado. Bort is an imperfectly crystallised diamond, extremely hard, and dark in colour. The term bort sometimes is applied also to minute fragments of gem diamonds. Ballas is a compact, spherical mass of tiny diamond crystals of great hardness and toughness. Carbonado, sometimes called black diamond or carbon, is an opaque grayish or black form of diamond with no cleavage, the property of a crystal to split along a definite plane. Carbonado, ballas, and bort are all

used industrially, in lapidary work, and for the cutting edges of drills and other cutting tools.

Two important characteristics of the diamond when used as a gem are its brilliancy and fire. Both the index of refraction and the dispersion (the physical properties that determine luster and fire) are higher for diamond than for any other natural, transparent, colourless stone. Uncut diamonds have a greasy luster and are not brilliant, but when cut the same stones exhibit a high luster, characterised technically as adamantine. The effect of the high dispersion is to separate the coloured components of white light so that the stone sparkles when properly cut. Some diamonds exhibit fluorescence when exposed to sunlight or other ultraviolet-light sources. The colour usually is light blue, but yellow, orange, milky white, and red fluorescence may occur in some stones.

Other characteristics of the diamond add nothing to its appearance but are frequently useful in identifying the stone and in differentiating between true diamonds and imitations. Because diamonds are excellent conductors of heat, they are cold to the touch. Most diamonds are not good electrical conductors and become charged with positive electricity when rubbed. Another important physical characteristic of the diamond is its resistance to attack by acids or bases. Transparent diamond crystals heated in oxygen burn at about 800° C (about 1470° F), forming carbon dioxide.

diopside — A mineral of clinopyroxene group -$CaMg(SiO_3)_2$.

dispersion — Dispersion is the ability of a gemstone to separate light into its component colours; that is, the quality of passing different wavelengths of light at different velocities.

drilling — When a gem cutter desires a hole in or through a gemstone (e.g., a bead), a small rotating rod or tube with a diamond tip, or slurry of silicon carbide and coolant, is used to drill through the stone.

durability — Toughness and hardness define durability.

dyke — A sheet like body of igneous rock, which cut across the bedding or structural planes of the host rock.

emerald — Green gem variety of the mineral beryl having a hardness of 8 and a Specific gravity of 2.7 to 2.9. The emerald was known in ancient times, not only for its beauty but also for its alleged power of healing diseases of the eye. It is essentially identical to other types of beryl in composition and properties, but contains sufficient chromium to impart a bright green colour.

epidote — (a) A yellowish-green, pistachio-green, or blackish-green mineral: $Ca_2(Al,Fe)_3Si_3O_{12}(OH)$. It commonly occurs associated with albite and chlorite as formless grains or masses or as monoclinic crystals in low-grade metamorphic rocks (derived from limestones), or as a rare-accessory constituent in igneous rocks, where it represents alteration products of ferromagnesian minerals. (b) A mineral group, including minerals such as epidote, zoisite, cinozoisite, piemontite, and hancockite.

euhedral — A term applied to grains displaying fully developed crystal form.

extraordinary ray — That ray for which, in minerals belonging to the hexagonal, trigonal, and

	tetragonal systems, the refractive index varies according to its direction through the crystals.
faceting	Faceting is most often done on transparent stones. Flat facets are cut and polished over the entire surface of the stone, usually in a highly symmetrical pattern.
facies	Rocks of any origin formed within certain pressure-temperature conditions, such as mineral facies; metamorphic facies.
fault	In geology, a line of fracture along which one body of rock or section of the earth's crust has been displaced relative to another. The movement responsible for this dislocation may be in the vertical direction or the horizontal, or a combination of the two
feldspar	Feldspar, large group of minerals composed of aluminosilicates of potassium, sodium, calcium, or occasionally barium. They occur as single crystals or as masses of crystals and form an important constituent of many igneous and metamorphic rocks, including granite, gneiss, basalt, and other crystalline rocks. Feldspars are the most abundant of all minerals and account for nearly half of the volume of the earth's crust. Although the feldspar minerals may belong to either the monoclinic or triclinic systems, they nevertheless resemble each other in crystal habit, methods of twining, and especially by having cleavage surfaces inclined to each other at an angle of nearly 90°. They have a hardness of 6 to 6.5 and a specific gravity ranging from 2.5 to 2.8. Feldspars have vitreous luster and vary in colour from white or colourless to various shades of pink, yellow, green, and red. All the feldspars weather readily to form a type of clay known as kaolin.
	The plagioclase feldspars comprise an isomorphous series of triclinic mineral ranging from pure sodium aluminosilicate to pure calcium aluminosilicate. Pure sodium aluminosilicate is called albite, and oligoclase, andesine, labradorite, bytownite, and anorthite are minerals with increasing percentages of calcium. Anorthite is pure calcium aluminosilicate with the formula $CaAl_2Si_2O_8$. The plagioclase feldspars are of lesser commercial importance than orthoclase and microcline. They sometimes show an attractive play of colours and are polished as semiprecious stones. Opalescent albite and iridescent labradorite are called moonstones. Oligoclase with included impurities that cause a sparkling effect is called sunstone.
fire	Flashes of spectrum colours from a facet of a cut stone due to dispersion.
fluorescence	The emission of visible light by certain minerals when exposed to radiation of shorter wavelength such as ultraviolet light of X-rays.
fluorite	Fluorite or Fluorspar, mineral composed of calcium fluoride (CaF_2), the principal fluorine-bearing mineral. It occurs as cubic, isometric crystals and cleavable masses with a hardness of 4 and Sp. g. of 3-3.3. When pure, fluorite is colourless and transparent, or translucent with a glassy luster. It often occurs with impurities that make it yellow, blue, purple, green, rose, or brown. Several varieties exhibit fluorescence.
fluvial	(a) Of or pertaining to a river or rivers. (b) Produced by the action of a stream or river.

fold	A flexure in rocks; that is, a change in the amount of dip of a bed and also often a change in the direction of dip.
fracture	In the broadest possible sense the word fracture may be applied to any break in a material. However in geology, the term usually implies breakage along a direction or directions, which are not cleavage; this implies to both rock and minerals.
fuchsite	A bright –green, chromium rich variety of muscovite.
garnet	Garnet, group of related minerals, often used as gemstones or abrasives. Large quantities of garnets are ground up and made into a variety of sandpaper. Garnets crystallise in the isometric system, usually as rhombic dodecahedrons. The different varieties of garnet exhibit almost all colours except blue. Brown, red, green, yellow, black, and colourless stones are common. Darker stones are usually opaque, and light ones may be transparent or translucent. The hardness of garnet varies from 6 to 7.5, and the specific gravities, or relative densities, of specimens range from 3.6 to 4.3. Garnets have a vitreous or resinous luster, and some varieties exhibit considerable brilliance. Chemically, garnets are compound silicates. However, the composition of individual specimens varies widely, and the formulas given below are only approximate.
gem	A cut –and-polished stone that has intrinsic value and possesses the necessary beauty, durability, rarity, and size for use in jewellery as an ornament or for personal adornment
gemmologist	One who has successfully completed recognized courses in gemmology and has demonstrated his competence in identification and evaluation of gem materials.
gemmology	The science and study of gemstones, including their source, description, origin, identification, grading, and appraisal.
gemstones	Minerals that are treasured for their beauty and durability. A large number of minerals have been used as gems. Their value generally depends on four elements: the beauty of the stone itself; its rarity; its hardness and toughness; and the skill with which it has been cut and polished. Stones such as diamonds, rubies, and emeralds represent one of the greatest concentrations of money value.
glacial action	All processes due to the agency of glacier ice, such as erosion, transportation and deposition. The term sometimes includes the action of meltwater streams derived from the ice.
gneiss	Metamorphic rock in which the minerals have been segregated into parallel layers, creating a banded or laminated structure. The metamorphosis of many igneous and sedimentary rocks has resulted in a banded structure in which the quartz and feldspar are segregated into layers that alternate with layers of dark minerals. The different varieties of gneiss are named after the type of rock from which they have been formed (as granite gneiss and diorite gneiss) or after a mineral in which the rock is unusually rich (as biotite gneiss and hornblende gneiss).
goethite	Common ore of iron, and one of the most commonly occurring minerals in nature. An iron hydroxide mineral, FeO(OH), goethite generally contains about 63 percent iron.

greenschist	Schistose metamorphic rock whose green colour is due to the presence of chlorite, epidote or actinolite.
greisening	A process of hydrothermal alteration in which feldspar and muscovite are converted to an aggregate of quartz, topaz, tourmaline and lepidolite (i.e., greisen) by the action of water vapour containing fluorine.
grinding	Usually silicon carbide wheels or diamond-impregnated wheels, is used to shape gemstones to a desired rough form, called a preform.
gypsum	Gypsum, common mineral consisting of hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$). It is a widely distributed form of sedimentary rock, formed by the precipitation of calcium sulfate from seawater, and is frequently associated with other saline deposits, such as halite and anhydrite, as well as with limestone and shale.
hardness	Hardness is the ability of a solid substance to resist surface deformation or abrasion. Various interpretations, depending on the usage, are applied to the term. In mineralogy, hardness is defined as the resistance of the smooth surface of a mineral to scratching.
hornblende	Group of translucent to opaque silicate minerals, typically of general formula $Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)_3Si_8O_{22}(O,OH)_2$, found in metamorphic, igneous, and volcanic rocks. Hornblendes contain considerable iron and aluminium and some sodium; they crystallise in the monoclinic system (*see* Crystal) and have a hardness of 5 to 6 and a specific gravity of 2.9 to 3.4.
hydrothermal process	The name given to any process associated with igneous activity, which involves heated or super heated water. Water at very high temperature is an exceedingly active substance, capable of breaking down silicates and dissolving many substances normally thought of as insoluble.
idocrase (vesuvianite)	A mineral: $Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$. It is usually brown, yellow or green, sometimes contain iron and fluorine, and is commonly found in contact metamorphosed limestones and serpentinites.
igneous rock	In geology, rock that has been formed by the cooling and subsequent solidification of a molten mass of rock material, known as magma. Depending upon the conditions under which the magma cooled, the resulting rocks may be coarse-grained or fine-grained
ilmenite	An iron-black, opaque, rhombohedral mineral: $FeTiO_3$. It is the principal ore of titanium. Ilmenite occurs as a common accessory mineral in igneous rocks and is also concentrated in mineral sands.
imitation stones	Materials such as glass or the plastics, which may resemble genuine stones in colour and appearance but differ from them in composition and physical properties.
inlay	In an inlay, a gemstone is cut to fit and glued into a hollow recess in another material (metal, wood, or other stones) and then the top ground and polished flush with the surrounding material.
intarsia and mosaic	In both intarsia and mosaic work, small bits of different coloured stones are fit

	together and the top cut and polished to present a picture or other interesting pattern
island arc	An arcuate chains of islands formed due to intra-oceanic subduction and/or subduction of oceanic plate beneath the continental plate. They are associated with strong seismic activity and deep-focus earthquakes. For example Japan arc, Kohistan arc etc.
jade	A hard, extremely tough, compact gemstone consisting of either pyroxene mineral jadeite or the amphibole mineral nephrite and having an unevenly distributed colour ranging from dark or deep green to dull or greenish white.
jadeite	A high-pressure mineral of the clinopyroxene group, essentially: Na(Al, Fe)Si_2O_6. It occurs in various colours, especially green.
joint	A fracture in a rock between the sides of which there is no observable relative movement. In general joints intersect primary surfaces, such as bedding, cleavage, schistosity etc. They develop preferentially in the competent members of the series rather than incompetent ones.
lapidary	(a) A cutter, grinder, and polisher of coloured stones, or of precious stones other than diamonds, (b) The art of cutting gems.
lapping	Lapping is very similar to grinding and sanding, except that it is performed on one side of a rotating or vibrating flat disk known as a lap, and it is used especially to create flat surfaces on a stone (as in faceting). Laps are often made of cast iron, steel, or a copper-bronze alloy, but other materials can also be used.
lepidolite	Trioctahedral Li-rich mica. It commonly occurs in rose or lilac-coloured masses made up of small scales, as in pegmatites.
leucogranite	A term applied to granite containing light-coloured minerals such as quartz, feldspar and white mica etc.
limestone	Common type of sedimentary rock composed principally of calcite (calcium carbonate, $CaCO_3$). When "burned" or calcined (raised to a high temperature), it yields lime. Crystalline metamorphosed limestone is known as marble.
mafic rock	Igneous rock composed chiefly of one or more ferromagnesian dark-coloured minerals in its mode.
magma	A molten fluid formed within the crust or upper mantle of the Earth, which may consolidate to form an igneous rock
magnetite	Magnetite, mineral and common ore of iron having the composition Fe_3O_4. It occurs as a strong natural magnet known as lodestone and crystallises in the isometric system (*see* Crystal), usually in granular masses but frequently in octahedral crystals. Iron black and opaque, with a metallic luster, it has a hardness of 5.5 to 6.5 and a specific gravity of 5.18.
mantle	The portion of the Earth's interior lying between the Mohorovicic and Guttenburg Discontinuities that is from a depth of 35 km to 2,900 km. Mantle is homogeneous and composed mainly of silicates.

marble	Crystalline, compact variety of metamorphosed limestone, consisting primarily of calcite ($CaCO_3$), dolomite CaMg $(CO_3)_2$ or a combination of both minerals.
mélange	A body of rock mappable at a scale of 1:24000 or smaller, characterised by lack of internal continuity of contacts or strata and by the inclusions of fragments and blocks of all sizes both exotic and native, embedded in a fragmental matrix of finer-grained material
metamorphic rock	The original composition and texture of which has been altered by heat and pressure deep within the earth's crust. Metamorphism that is a result of both heat and pressure is referred to as dynamothermal, or regional; metamorphism produced by the heat of an intrusion of igneous rock is termed thermal, or contact.
mica	Term applied to a group of rock-forming minerals, crystallizing in the monoclinic system, and characterised by a perfect basal cleavage that causes them to separate into very thin, somewhat elastic leaves. The micas are complex aluminium silicates, the colour varying with the composition. They range in hardness from 2 to 4 and in specific gravity from 2.7 to 3.2. The most important micas are muscovite, phlogopite, lepidolite, and biotite.
microscope	Instrument used to obtain a magnified image of minute objects or minute details of objects. It consists of the lens (or lenses) of the objective and of the eyepiece set into a tube, and held by an adjustable arm over a stage on which the object is placed. Types of microscopes vary according to intended use and type of energy used, e.g. natural light, polarized light, transmitted light, electrons, or x-rays.
mineral	Mineral is naturally occurring object with definite chemical composition and a member of a crystal system, which has a characteristic shape.
mohs's scale	A scale of hardness suggested by Friedrich Mohs over 100 years ago, and still used by mineralogists. The figures in this scale merely denote an order of hardness (resistance to scratching) and have no quantitative significance whatever. The minerals chosen by Moh's as standard for his scale are as follow: 1. talc, 2 gypsum, 3 calcite, 4 fluorite, 5 apatite, 6 feldspar, 7 quartz, 8 topaz, 9 corundum, 10 diamond.
monazite	A yellow, brown or reddish-brown monoclinic mineral: $(Ce,La,Nd,Th)PO_4SiO_4$). It is a rare-earth phosphate with appreciable substitution of thorium for rare-earths and silicon for phosphorous; thorium free monazite is rare. . It is widely disseminated as an accessory mineral in granites, gneisses, and pegmatites, and it is often naturally concentrated in detrital sand, gravel and alluvial tin deposits. Monazite is a principal ore of the rare-earths and the main source of thorium.
nephrite	An exceptionally tough, compact, fine-grained, greenish or bluish amphibole constituting the less rare or valuable kind of jade and formerly worn as a remedy for kidney diseases.
obduction	The overriding or over thrusting of oceanic crust onto the leading edges of continental lithospheric plates.
oceanic crust	The type of the Earth's crust, which underlies the ocean basins; it is equivalent to the sima. The oceanic crust is about 5-10 km thick

olivine	Olivine, mineral, magnesium and iron silicate, $(Mg,Fe)_2SiO_4$. It crystallises in the orthorhombic system and usually occurs in the form of granular masses. The colour ranges from olive-green or grayish-green to brown. Olivine has a hardness of 6.5 and a specific gravity (relative density) from 3 to 4. It exhibits conchoidal fracture, has a glassy luster, and is transparent or translucent.
opal	Opal, mineral consisting of hydrated silica ($SiO_2 \cdot NH_2O$), in the gel state. Opal has a hardness of between 5.5 and 6.5 and a specific gravity of 1.9 to 2.3. The fracture of the mineral is conchoidal, and its luster varies from glassy to dull. It also shows variations in colour from white to black and in transparency from transparent to opaque. One of the chief characteristics of the opal is the brilliant play of colours that may be seen in superior stones. These colours result from the formation of minute fissures in the stone as it hardens and the deposition of additional opal in the fissures. The indices of refraction of the original stone and the additional deposits are frequently different and result in light interference causing a play of colours. Opal has been used as a gemstone for many centuries in spite of a superstition that the gem brings bad luck to its owners.
ophiolite	Any of the mixed metamorphic rocks produced along the line of collision between an oceanic plate and a continental plate of the earth's crust. Ophiolites form in subduction zones—convergent plate boundaries where the basaltic seafloor plunges (is subducted) beneath the continent and is melted and consumed—such as, for example, Muslimbagh ophiolite, Zhobe ophiolite and Waziristan ophiolite etc. The ophiolites created in these zones consist of detached slices of seafloor basalts altered to greenstone schists and serpentine, inter-layered with other metamorphosed rocks. Many of today's high mountain ranges, including the South American Andes, consist partly of ophiolitic rocks and thus mark former junctures of seafloor and continent.
ordinary ray	In uniaxial stones, that ray which travels with constant velocity in any direction within the crystal.
pargasite	Pargasite $(NaCa_2Mg_4AlAlSi_6O_{22}$ $(OH,F)_2$ is sodium-bearing amphibole that crystallises in monoclinic system.
parisite	A brownish yellow secondary mineral: $(Ce,La)_2Ca(CO_3)F_2$. It is related to synchysite.
pegmatite	A variety of extremely coarse-grained igneous rock chemically similar to and closely associated with granite. The mineral constituents of pegmatite are largely those typical of acidic intrusive rocks: orthoclase feldspar, quartz, and mica. Individual mineral crystals may be up to several meters (tens of feet) in length. The growth of crystals this large indicates that the parent magma, from which the rock solidified, was able to cool very slowly, after injection into fissures extending outward from a central magma chamber. Pegmatite is widely distributed in the crust of the earth but is found especially in older mountain chains, where it is restricted essentially to those surface areas in which igneous and metamorphic rocks are prevalent. Minerals containing the elements boron, beryllium, and lithium are abundant in some pegmatites. Other pegmatites contain commercial quantities of the

	feldspar, mica, and gem-grade tourmaline.
peralkaline	Said of an igneous rock in which the molecular proportion of aluminium oxide is less than that of combined sodium and potassium oxides.
peridot	A transparent to translucent green gem variety of olivine.
phlogopite	Phlogopite–$K_2(Mg,Fe^{+2})_6(Si_6Al_2)O_{20}(OH,F)_4$ is trioctahedral mica that crystallises in monoclinic system. It is common in igneous and metamorphic rocks. It is noticed that calc-silicate metamorphic rocks and basic- to ultrabasic rocks tend to contain Mg-phlogopites.
phosphorescence	If a fluorescent material continues to emit light after the exciting UV or X-ray light is removed, it is said to be phosphorescent. This phenomenon usually lasts only a few seconds but may occasionally persist for much longer periods. This is a relatively rare characteristic in gemstones.
phyllite	The term phyllite is used for metamprphic rocks, which are coarse-grained and less perfectly cleaved than slates, but which are fine-grained and better cleaved than schists. Phyllitic rocks are formed by low-temperature regional metamorphism.
plate tectonics	Theory of global tectonics (geologic structural deformation) that has served as a general framework for understanding the structure, history, and dynamics of the earth's crust. The theory is based on the observation that 13 semi rigid plates form the earth's crust. The boundaries of these plates are zones of tectonic activity, where earthquakes and volcanic eruptions tend to occur.
pleochroism	It is the apparent change in colour of a doubly refractive gemstone when viewed through different directions of the crystal structure.
pneumatolysis	Those changes brought about by the action of hot gaseous substances (other than water) associated with igneous activity. The commonest volatiles involved in pneumatolysis are fluorine, hydrofluoric acid and boron fluorides.
polariscope	An instrument using plane-polarised light to determine the pleochroism in the gemstone.
polishing	After a gemstone is sawed and ground to the desired shape and sanded to remove rough marks left by coarser grits, it is usually polished to a mirror-like finish to aid light reflection from the surface of the stone (or refraction through the stone, in the case of transparent materials).
quartz	Most common of all minerals, composed of silicon dioxide, or silica, SiO_2. It is distributed all over the world as a constituent of rocks and in the form of pure deposits.
refractive index	Refractive index, or R.I., is the ratio of the velocity of light in air to the velocity of light through a transparent material.
refractometre	An instrument designed for measuring the refractive indices of various substances.
riebeckite	A blue or black monoclinic mineral of the amphibole group: $Na_2(Fe,Mg)_5Si_8O_{22}(OH)_2$. It occurs as a primary constituent in some acid or sodium rich igneous rocks.

rock	Any naturally formed mineral aggregate. The term is applied to objects of various sizes from the solid rock of the Earth's mantle to sand and clay. Rocks are divided according to their origin into sedimentary rock, metamorphic rock, and igneous rock.
ruby	Precious stone that occurs as a red, transparent variety of the mineral corundum. The colour varies in different specimens from rose red through so-called ruby red and carmine to a deep purplish red, called pigeon blood. Clear stones of the deeper shades are the most highly prized
rutile	(Latin rutilus, "golden red"), brilliant red or black mineral, with diamond like lustre, composed of titanium oxide, TiO_2. It crystallises in the tetragonal system, usually in prismatic crystals ranging from opaque to transparent and less often in compact massive formations.
sanding	Sanding is similar to grinding but uses finer abrasives. Its purpose is to remove deep scratches left by coarser abrasives during grinding. Since it removes material less rapidly, it also allows more delicate control over final shaping of the stone prior to polishing
sapphire	sapphire, precious gemstone that occurs as a transparent, blue variety of the mineral corundum. The ruby is a red variety of gem-quality corundum. Although the term sapphire is often applied to gem-quality varieties of corundum of all other colours, the true sapphire is deep blue, the best tint being a cornflower blue called Kashmir blue. Colourless, precious corundum is called white sapphire; yellow corundum is called yellow or golden sapphire, or Oriental topaz; and pale pink stones are called pink sapphire. The various colours in corundum are caused by small amounts of impurities, such as chromium, iron, or titanium, in the aluminum oxide (Al_2O_3) of which the mineral is essentially composed.
sawing	In most gem sawing, a thin circular blade usually composed of steel, copper, or a phosphor bronze alloy impregnated along the outer edge with diamond grit and rotating at several thousand surface feet per minute literally scratches its way through a gemstone.
schist	The term applied to any of several metamorphic rocks in which the crystals of the predominating mineral are aligned in parallel layers, forming a large number of close, well-developed foliations. Schistose rocks are easily broken along a lamination, or schistosity, into thin flaky plates. The various schistose rocks are named and characterised according to the predominating mineral that produces the foliation.
sculpture	Gemstones can be carved, like other materials, into almost any form, limited only by the talents of the sculptor. Carving is accomplished with a variety of diamond-impregnated steel bits, saws, and grindstones.
sedimentary rock	In geology, rock composed of geologically reworked materials, formed by the accumulation and consolidation of mineral and particulate matter deposited by the action of water or, less frequently, wind or glacial ice. Most sedimentary rocks are characterised by parallel or discordant bedding that reflects variations in either the rate of deposition of the material or the nature of the matter that is deposited.
serpentine	Serpentine, common, widely distributed mineral, composed of hydrated

magnesium silicate, $Mg_3Si_2O_5(OH)_4$, so called because of serpent like bands of green colour occurring in massive varieties. It crystallises in the monoclinic system and occurs in two distinct forms: antigorite, a massive variety, and chrysotile, a fibrous variety. The massive variety has a greasy, waxy luster, and the fibrous variety is silky. Both varieties are coloured light and dark green, which in massive formations of antigorite produce a beautiful, variegated colouring. The term serpentine is also applied to a rock composed principally of antigorite. The hardness of the mineral ranges from 2 to 5, and the specific gravity ranges from 2.2 for chrysotile to 2.65 for antigorite. Chrysotile is the mineral from which asbestos is made. Antigorite, often used as an ornamental stone, sometimes occurs as a collateral mineral in verd antique marble.

Serpentine always occurs as an alteration product of olivine.

serpentinite — A rock consisting almost wholly serpentine group minerals.

silicates — Silicates are the most important group of compounds occurring in the crust of the Earth, and probably make up 95% of the crust. They are classified according to their atomic structure. The various silicate structures may be regarded as being derived from a tetrahedral unit, SiO_4, by linking them together with the elimination of oxygen at each linkage.

spectroscope — An instrument, which resolves light into its component wavelengths by refraction through prisms or diffraction by a grating.

sphene — A usually yellow or brown mineral: CaTiSiO5. It often contains other elements such as niobium, chromium, fluorine, sodium, iron, manganese and yttrium. Sphene occurs in wedge–shaped or lozenge-shaped monoclinic crystals as an accessory mineral in granitic rocks and in calcium-rich metamorphic rocks.

sphere — Spheres are initially sawed into cubes or dodecahedrons and then ground to shape between two pipes or rotating concave cutters, allowing the stone to rotate freely in any direction to form a perfect spherical shape. As with other lapidary processes, gradually finer grades of abrasive are used to grind, sand, and polish the stone.

spinel — Mineral composed of magnesium aluminates $MgAl_2O_4$. It crystallises in the isometric system with a vitreous lustre. Various amounts of impurities, such as iron, manganese, and chromium, impart different colours to the mineral, including red, lavender, blue, green, brown, or black.

suture zone — Region on the surface marking the area of contact between the adjacent plates (plate tectonics).

syenite — A group of plutonic rocks containing alkali feldspar (usually orthoclase, microcline, or perthite), a small amount of plagioclase (less than in monzonite), one or more mafic minerals (esp. hornblende) and quartz, if present, only as an accessory.

symmetry — There are three elements of symmetry recognised in crystallography: planes of symmetry, axes of symmetry and a centre of symmetry. On this basis crystals can be divided into 32 classes. These in turn are grouped into seven crystal systems.

synchysite	A mineral: $(Ce,La)Ca(CO_3)_2F$
synthetic stones	Manufactured stone, which have essentially the same composition, crystal structure, and properties as the natural mineral they represent.
talc	Talc, soft, greasy, granular or fibrous mineral composed of an acid metasilicate of magnesium, $H_2Mg_3(SiO_3)_4$, and crystallising in the monoclinic and orthorhombic systems. It has a hardness of 1 to 1.5 and a specific gravity of 2.7 to 2.8 and exhibits perfect basal cleavage. The mineral ranges in colour from apple-green, gray, or white to silver-white and shines with a pearly to greasy luster.
thermal conductivity	Thermal conductivity (the ability to conduct heat) is very low in most gemstones but is extremely high in diamond (from 1.6 to 4.8 times as great as in pure silver). This unusual property of diamond is the basis for several popular diagnostic probes that are used to distinguish diamond from its numerous imitations.
thrust	An overriding movement of one crustal unit over another, as in thrust faulting.
thrust fault	A fault with a dip of 45° or less over much of its extent, on which the hanging wall appears to have moved upward relative to the footwall. Horizontal compression rather than vertical displacement is its characteristic feature.
topaz	Variety of mineral aluminium fluorosilicate, crystallises in the orthorhombic system and valued as a gem. It has a vitreous lustre and may be colourless, yellow, green, blue, or red. It has a hardness of 8 and a specific gravity of 3.4 to 3.6.
toughness	Toughness is resistance to breakage.
tourmaline	Mineral that has a complex and somewhat variable chemical composition and is valued as a gemstone when transparent and cut. The chief constituents are silica and alumina in nearly equal proportions, forming about three-fourths of the whole.
tumbling	Large quantities of roughly shaped stones are often tumbled, i.e., turned at a slow speed in a rotating barrel with abrasives and water for extended periods (days or weeks). By tumbling with progressively finer grades of abrasive (usually silicon carbide) and washing carefully between grades, the stones are gradually smoothed and polished to serendipitous but often very attractive shapes.
ultramafic rock	Igneous rocks consisting essentially of ferromagnesian minerals. For example dunite, peridotite, pyroxenite etc.
ultra-violet light	Invisible rays of wavelengths, somewhat shorter than those of visible white light. Conveniently classified as long-wave ultra-violet light, e.g. from the 365 nm line of mercury, and short-wave ultra-violet, e.g., the 253.7 nm mercury line.
x-rays	Electromagnetic radiations having the same nature as visible light but of much shorter wavelength (usually less than 0.2nm). Some times termed Rotëngen rays, after their discovery.

zircon	Transparent, translucent, or opaque mineral, composed chiefly of zirconium silicate, $ZrSiO_4$, and crystallising in the tetragonal system. It has a hardness of 7.5 and a specific gravity of 4.2 to 4.86; it shines with an adamantine lustre.

Table 17 showing Glossary of unusual names (Webster 1994).

This list includes alternative or disused gem names, misnomers and trade names. Misnomers are printed within inverted commas and trade names italics.

'Adelaide ruby'	red South African garnet
'Afghan turquoise'	dyed magnesite
'African emerald'	green fluorite
'African jade'	massive green grossular garnet
'Alexandrite' or 'Alexandrine'	synthetic colour change sapphire or spinel
'Almandine spinel'	natural violet spinel
'Alpine diamond'	pyrite
'Amazone jade'	green micocline feldspar
'American ruby'	(1) pyrope garnet (2) rose quartz
'Arabian diamond'	rock crystals
'Arizona ruby'	pyrope garnet
'Arizona spinel'	garnet
'Australian ruby'	garnet
'Balas ruby'	red spinel
'Black amber'	jet
'Blue alexandrite'	change colour sapphire
'Blue zircon'	synthetic gree-blue spinel
'Bohemian ruby'	(1) pyrope garnet (2) rose quartz
'Bohemian topaz'	citrine
'Brazilian aquamarine'	blue topaz
'Brazilian emerald'	synthetic yellowish-green spinel
'Brazilian peridot'	light-green tourmaline
'Brazilian ruby'	red or pink topaz
'Brazilian sapphire'	blue tourmaline
'Brzilian diamond'	rock crystal
'Burma sapphire'	synthetic blue sapphire
'California moonstone'	chalcedony
'California ruby'	garnet
'Cat's -eye'	operculum
'Cat's-eye jade'	chatoyant tremolite or actinolite
'Chinese jade'	jadeite
'Colorado diamond'	transparent smoky quartz
'Colorado ruby'	pyrope garnet
'Colorado topaz'	yellow quartz
'Congo emerald'	dioptase
'Cylone peridot'	yellow-green tourmaline
'Danburite'	synthetic yellow sapphire
'Envening emerald'	peridot
'False emerald'	green fluorite
'False topaz'	citrine or yellow fluorite
'German diamond'	rock crystals
'Gold topaz'	golden quartz
'Green ganet'	enstatite
'Green quartz'	fluorite
'Hawaiian diamonds'	rock crystals
'Indian emerald'	green-dyed quartz
'Indian jade'	green aventurine quartz
'Indian topaz'	yellow sapphire
'Kidney stone'	nephrite

'King Topaz'	natural yellow sapphire
'Lithia amethyst'	kunzite
'Lithia emerald'	hiddenite
'Mari diamond'	rock crystals
'Medina emerald'	green glass
'Mexican agate'	banded calcite or aragonite
'Mexican diamond'	rock crystals
'Mogkok diamond'	white topaz
'Montana ruby'	red garnet
'Mt. Saint Helens emerald'	green glass
'Neveda diamond'	obsidian
'Neveda topaz'	obsidian
'Night emerald'	peridot
'Orange topaz'	brownish-yellow quartz
'Ruby spinel'	red spinel
'Scientific emerald'	green beryl glass
'Scientific emerald'	synthetic stone or paste
'Smoky quartz'	smoky quartz
'South African jade'	massive gren grossular garnet
'Spanish emerald'	green glass
'Spinel ruby'	red spinel
'Swiss jade'	green-dyed jasper
'Swiss lapis'	blue-dyed jasper
'Topaz'	yellow-brown quartz
'Uralian emerald'	green garnet
'Verdellite'	green tourmaline
'White garnet'	leucite
'Zerfass emerald'	synthetic emerald
Axe stone	nephrite
Azurlite	pale-blue chalcedony
Black moonstone	labradorite feldspar
Brazilian emerald'	green tourmaline
Canadian jade	nephrite from British Colombia
Chrysoprase	green-dyed chalcedony
Cylone sapphire	synthetic sapphire
Dnburite	synthetic light-red corundum
Emeralda	synthetic yellow-green spinel
Epidosite	epidote
French colour rubies	light red rubies
Frost agate (Frost stone)	agate with white markings
Geneva ruby	reconstructed ruby
Glass stone	Axinite
Greenstone	(1) Nephrite (2) chlorastrolite)
Hakik	agate
Hawaiite	peridot (Hawaii)
Imperial jade	fine green Chinese jade
Imperial topaz	sherry-colour topaz
Inca emerald	emerald from Ecuador
Indian agte	moss agate
Jasperine	banded jasper
Jet stone	black tourmaline (schorl)
Kimberlite Gem	synthetic rutile
Labrador moonstone	Labradorite feldspar
Love stone	aventurine quartz
Macot Emerald	Soude emerald
Opalite	plastic imitation of opal

Peacock stone	malachite
Pigeon –blood agate	cornelian
Royal topaz	blue topaz
Synthetic Alexandrite	synthetic corundum or spinel
Synthetic Aquamarine	synthetic corundum or spinel
Synthetic Turquoise	an imitation turquoise
Tanzanite	purple-blue zoisite
Topazolite	greenish-yellow to yellow andradite garnet
Volcanic glass	obsidian
Wood stone	fossil stone
Zircolite	synthetic white sapphire

Selected References on Rocks, Minerals and Gemstones.

Items on this list have been selected for scientific accuracy, general interest, and availability. They emphasize geology, location, and identification of rocks, minerals, and gemstones. They can be ordered from the publisher or from book dealers. Further information on availability and price can be obtained from the publisher listed or from book dealers.

Guidebooks and Reference Books for Collectors

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Audiovisual on Gems and Minerals

The Earth Explored-103 - Rocks And Minerals, 1985, 29 minutes, in colour, VHS video: Public Television Videocassette Service, 1320 Braddock Place, Alexandria, Virginia 22314. (High school and up). Shows basic methods of identifying rocks and minerals. Discusses the uses and importance of minerals in everyday life.

Gemstones Of America, 1991, 60 minutes, in colour, VHS video: STS Productions, P.O. Box 27477, Salt Lake City, Utah 84127. (High school and up). Contains footage of currently productive, important gemstone mines in the United States. Discusses geological origins of a number of gemstone deposits in the U.S. and their production.

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Emerald Themed Books

Actual Gem-Related Books:

Emerald and Tanzanite Buying Guide -by Renee Newman Practical Hints on buying Emerald

Emerald (Fred Ward (1cm Series) -by Fred Ward. Charlotte Ward How to buy Emeralds.

Emeralds of Pakistan: (Geology, Gemmology and Genesis - by Ali H. Kazmi, Lawrence W. Snee
Details on Emerald mined in Pakistan

Standard Catalog of Gun Values -by Anna M. Miller, John Sinkankas (Contributor)
General book on gemstones.

Fun Books with have an Emerald in the Title:

The Wizard of Oz / With Emerald Tinted Glasstrn - by L. Frank Baum, Lisbeth Zwerger (Illustrator)
Classic Fun book about Emerald City (nice illustrations)

Emerald Enchantment - by Marylyle Rogers (Contributor), Raine Cantrell
Romance book about Celtic love and Irish luck (title alludes to Emerald Isle)

Emerald House Rising - by Peg Kerr
A fun fantasy book I enjoyed reading.
Cat With an Emeraki Eye; A Midnight Louie Mystery (The Midnight Lode Series) -by Carole Nelson Douglas
Mystery series starring a woman and her cat
Emerald - by Phyllis A. Whitney Romantic mystery

Emerald Garden - by Andrea Kane Romantic mystery

An Emerald Ballad-by B. J. Hoff
Book of 5 well wriuen literature books based on Irish history.

Cut and Assemble the Emerald City of Oz -by Dick Martin For those who are young at heart
Castafiore Emerald (Adventures of Tintip) -by Merge A funny children's book

Travel Books to Places with Emerald in their Name:

Ireland: The Emerald Isle and Its People - by Mark Morris, Anthony Cassidy About Emerald Isle, Ireland

The Emerald Sea: Exploring the Underwater Wilderness of the Pacific Northwest and Alaska -by Diane Swanson (Designer), Dale Sanders (Photographer)
Great book for people interested in scuba diving
Nice pictures above and below water in and near the Puget Sound and up into British Columbia

Timeless Ireland: Faces and Places of the, Emerald Isle -by Michael Rutherford (photographer) and Aubrey Watson
About Emerald Isle, Ireland; Great Pictures

Emerald Fairways and Foam-Flecked Seas: A Golfer's Pilgrimage to the Courses of Ireland -by James W. Finegan

Journals

Gemological Newsletter. Michael O' Donoghue. 7 Hillington Avenue, Sevenoaks, Kent, TN13 3RB, UK.

Gems & Gemology, Gemological Institute of America, 5345 Armada Drive, Carlsbad, CA 92008-9526 USA. Phone (800) 421-7250. Fax (310) 453-7674. Quarterly journal for gemologists.

ICA Gazette, Internatioal Coloured Gemstone Association, ICA, 609 Fifth Avenue, New York, NY 10017, USA.

JCK Group offers Jewellers Circular-Keystone, a monthly jewellery trade magazine. Write to JCK, P.O. Box 2085, Radnor, Pennsylvania 19080-9585 USA. Phone (610) 964-4464.

Jewelers Circular –Keystone, Cilton Way, Rendo, Pennsylvania 1908, USA.

Jewellers' Book Club-Catalog (annual). Catalog of more than 550 jewellery-related publications from more than 250 publishers. Includes video- and audio-cassettes and book reviews. Jewellers' Book Club - News (quarterly) informs members of new titles and provides book reviews. Published by the

Jewellers Book Club, Chilton Way, Radnor, PA 19089.
Lapidary Journal (monthly). Articles on gemstones, locality information, expeditions to find sources of gemstones, gemcraft, club news, show news, product news, and book reviews. Published by the

Lapidary Journal, Devon Office Center, Suite 201, 60 Chestnut Avenue, Devon, PA 19333-1312.

Lapidary Journal, P.O. Box 124, Devon, Pennsylvania 19333-9933 USA. Phone (610) 293-1112.

Monthly magazine for jewellers, gemcutters, and collectors. An annual issue (May) contains an extensive directory of dealers and clubs.

Lapidary Journal, P.O. Box 80937, San Diago, California, USA.

Mineralogical Abstracts. Mineralogical Society, 41 Queen's Gate London. SW7, UK.

Mineralogical Record, bimonthly: Mineralogical Record, Inc., 7413 N. Mowry Place, Tucson, Arizona 85740, USA.

Modern Jewellers, P.O. Box 1416, Lincolnshire, IL 60069-9924 USA. Phone (913) 451-2200. Monthly trade magazine for the jewellery industry.

National Jeweler, 1 Penn Plaza, New York, NY 10019. Monthly trade magazine for the jewellery industry.

Rock and Gem, 4880 Market Street, Ventura, CA 93003-7783. Monthly magazine for gem and mineral collectors, gemcutters, and jewellers.

Rocks & Minerals (bimonthly). Features articles of interest to students of mineralogy, geology, and paleontology. Includes articles about gemstone localities. Regularly lists announcements of hundreds of mineral, rock, and gem shows (local, State, national, Canadian, and European). Includes media reviews, museum notes and announcements, and classified ads. Published by Heldref Publications, 4000 Albermarle Street, NW., Washington, DC 20016.

Rocks and Minerals, bimonthly: Heldref Publications, 1319 Eighteenth Street, N. W., Washington, D. C. 20036-1802.

Synthetic Crystals Newsletter. Michael O' Donoghue.. 7 Hillington Avenue, Sevenoaks, Kent, TN13 3RB, UK.

The Journal of Gemmology. Gemmological Association and Gem Testing Laboratory of Great Britain. 27 Greville Street, London, ECIN 8TN, UK.

Videocassettes

Gemstones of America (60 minutes), Smithsonian Institution, 1991, can be ordered for US$ 29.95 from the Museum Shop, Attention: Mail Order Clerk, National Museum of Natural History, 10th Street and Constitution Avenue, NW, Washington, DC 20560; (202) 357-1535.

Splendid Stones. This National Geographic Society special details the evolution from raw material to cut and polished gem, outlines many of the steps involved in marketing gemstones, and examines some of the world's most famous jewellery collections. It can be ordered for US$ 95 from the National Geographic Society, 17th and M Streets NW. Washington, DC 20036.

Book Dealers

Gemmological Instruments Limited, a division of the Gemmological Association of Great Britain, 27 Greville Street, 1st Floor, London EC1N 8SU, United Kingdom. Phone (171) 404-3334. Fax (171) 404-8843. Email gagtl@btinternet.com.

GIA Bookstore, 5345 Armada Drive, Carlsbad, CA 92008-9526 USA, phone (800) 421-7250 ext 701, fax (310) 449-1161.

JCK Jewellers' Book Club, One Chilton Way, Radnor, PA 19089, phone (215) 964-4490.

Lapidary Journal Book & Video Sellers, 60 Chestnut Ave., Suite 201, Devon, PA 19333-1312, phone (800) 676-4367, fax (610) 293-1717.

Where to Get More Information on Gemmology and Gemcutting

Schools and Organizations

American Gem Trade Association (AGTA), P.O. Box 581043, Dallas, TX 75258-1043 USA, phone (214) 742-4367. Gem dealers trade organization.

Gemological Institute of America (GIA). Correspondence and in-residence classes in gemology, jewellery making, jewellery design, and lapidary. Diplomas offered include Graduate Gemologist (G.G.). Also books and instruments.

Gemmological Association of Great Britain, 27 Greville Street, 1st Floor, London EC1N 8SU, United Kingdom. Phone (171) 404-3334. Fax (171) 404-8843. Email gagtl@btinternet.com. Correspondence and in-residence classes in gemmology. Diplomas offered include Fellow of the Gemmological Association (F.G.A.). Publish the "Journal of Gemmology" quarterly, along with "Gem and Jewellery News" (in conjunction with the society of Jewellery Historians). Gemmological Instruments Limited sells equipment and books, and the Gem Testing Laboratory of Great Britain tests and certifies gemstones.

Scottish branch of the Gemmological Assocation of Great Britain.

Nederlandsch Genootschap voor Edelsteenkunde (Dutch Association for Gemmology) provides a course (Dutch language) leading to Registered Gemmologist. Contact address: Drs. J. Vis (email: janvis@ngve.org). Telephone: 078-6761386 Fax: 078-6763795.

Federation for European Education in Gemmology has links to several European organizations involved in gemology.

Hoge Raad voor Diamanten, Hoveniersstraat, 22 2018 Antwerpen, Belgium. Phone +32 3 222 05 11 (central), +32 3 222 07 50 (diamond office).

Asian Institute of Gemmological Sciences, 484 Rachadapisek Road, Samsennok, Huay-Kwang, Bangkok 10310, Thailand, phone 513-2112.
International Gemmological Institute, Inc., 579 Fifth avenue 10017 New York, NY, USA. tel:1-212-753.71.00 fax:1-212-753.77.59 email:igi@interport.net. Diamond and coloured stone appraisals and courses, diamond repairs.

International Gemmological Institute bvba Schupstraat 1/7,2018 Antwerp,Belgium. tel:32-3-231.68.45 fax:32-3-232.07.58 email:igi@glo.be (IGI-Belgium site:soon on www). Diamond and coloured stone appraisals and courses, diamond repairs.

Wildacres Retreat offers workshops in gemcutting and jewellerymaking as well as other interests.. For more information write to Wildacres Retreat, P.O. Box 280, Little Switzerland, NC 28749.

William Holland School of Lapidary Arts, P.O. Box 980, Young Harris, Georgia 30582 USA. Phone (706) 379-2126. Classes in the lapidary arts, Jewellery making and other crafts.

The Canadian Gemmological Association, 1767 Avenue Road, North York, Ontario, M5M 3Y8 Canada. Phone: (416) 785-0962. The Canadian Professional Gemmology Program is offered in Toronto, Vancouver and Montreal, and graduates are admitted to the CGA as fellows with the designation of FCGMA.

Canadian Institute of Gemmology . Classes in gemmology. Books and instruments.

Gemmological Association of Australia, PO Box 102, Sydney NSW 2000, phone 61 2 267 5063.

Centre for Gem Studies, Kalabhavan Road, Cochin-682018, Kerala, India, Phone- 0091-484 -365044, E-mail- gemsfair@satyam.net.in
International Coloured Gemstone Association.

Other Resources on the Internet

The Mineral and Gemstone Kingdom (excellent extensive info site)--http://www.minerals.net/rec.crafts.jewellery is a lively Usenet newsgroup devoted to jewellery and related topics.

The Eclectic Lapidary is a new monthly E-zine on the web, covering all aspects of gems, jewellery, minerals, and the like.

http:/www.yourgemologist.com/ a free gemology reference site. info on building lapidary, equipment-http://tomaszewski.net/Kreigh/Minerals/Homemade.shtml.The Mineralogical Record (bimonthly publication about minerals)- http://www.minrec.org/

The Canadian Rockhound is another new online 'zine for gem and mineral collectors.
The Amber Homepage provides detailed information about amber.
Bob's Rock Shop, is an online 'zine for rockhounds and gem lovers. Lots of great info here!

Rapaport Corporation. Martin Rapaport's RapNet, a pricing and news resource for diamond dealers and jewellers. It now includes a growing forum on many different aspects of the gem and jewellery industry.

Smithsonian Gem & Mineral Collection . Many fabulous images from the world famous collection of the Smithsonian Institution.

The Oregon Rockhounds' Home Page . Images and info on collecting sites in Oregon for agate, jasper, petrified wood, opal, etc.

Berne Museum of Natural History-Earth Sciences-Mineralogy and Petrography Images and information on minerals.

Rockhounds Information Page. Links to items of interest to gem and mineral collectors.

The Gemstone Gallery, a nice collection of gemstone photographs.

The Lapidary Club of Tasmania has an interesting site down under.

Midland Center for the Arts is presenting The Nature of Diamonds on display July 11 Bluechart is a new and up-to-date gem identification chart. It contains the distinctive features of some 200 gemstones. Well worth a look!

Birthstones (Webster 1994).

Month	Colour	Official stone
January	Dark red	Garnet
February	Purple	Amethyst
March	Pale blue	Aquamarine
April	White (transparent)	Diamond
May	Bright green	Emerald
June	Cream	Pearl
July	Red	Ruby
August	Pale green	Peridot
September	Deep blue	Sapphire
October	Variegated	Opal
November	Yellow	Topaz
December	Sky-blue	Turquoise

Gemstones for the days of the week (Webster 1994).

Day	Stone
Sunday	Topaz or diamond
Monday	Pearl or crystal
Tuesday	Emerald or ruby
Wednesday	Amethyst or loadstone
Thursday	Comelian or sapphire
Friday	Emerald or cat's-eye
Saturday	Diamond or turquoise

Local names for the gemstones.

Gemstone	Local name
Agate	Aaqiq
Emerald	Zamorud
Epidot	Zabargad
Garnet	Thumra Yaquoth
Lapis Lazuli	Lajawardh
Peridot	Peridot
Quartz	Baqar
Ruby	Yaquoth (ruby)
Spinel	Lal
Aquamarine	Neelum
Tourmaline	Bairooj

List of some famous gemstone and jewellery shops in Pakistan.

Name of Firm	Telephone No.
Badar Gems, Lahore	042-6301756
Ghalib Gems and Jewellery, Lahore	042-7661118
Focks and Minerals Co., Peshawar	091-214287
Saleem Enterprises Peshawar	091-213591
Ruby Corporation, Peshawar	091-219402
Qureshi and Company, Peshawar	091-251449
NMI Pak International, Peshawar	091-2566806
Hammad Gems, Peshawar	091-2568874
Sana Traders, Peshawar	091-2573492
Real Gems Traders, Peshawar	091-212517
Northern Minerals and Gems, Peshawar	091-215219
Mufti Gem Traders, Peshawar	091-240941
Panyala Jewellers, Peshawar	091-284663
Himalaya International, Peshawar	091-813374
Karakoram Gems Corporation, Peshawar	-
Hindukush Marble Gems and Minerals, Peshawar	-
Kihkashan Jewellers, Peshawar	-
New Arusa Minerals, Peshawar	030-7861265
Asia Gems and Lapidary Centre, Peshawar	091-2569506
Royal Gemstone Centre, Mingora, Swat	0936-711851
Northern Gems Collection, Gilgit	0572-53399
Pakistan Mining and Exploration Inc., Chitral	-
Beauty Jewellers, Quetta	-
Haji Muhammad Anwar Jewellers, Quetta	-
Rock International, Quetta	-
Crystal Trading International, Rawalpindi	-
Real and Rear, Rawalpindi	-
Zaheer Qadeer Jewellers, main Sarafa Bazar, Rawalpindi	03335155493
Gems and Mineral Collection (Pvt.) Ltd, Islamabad	051-2820453
Menika Mines, Islamabad	0512650491
Shinghai Gemstone (Pakistan Branch) Trade Centre, Islamabad	051-2253790
Arts and Gems, Karachi	021-5678781-5213357
Almas Gems and Jewellers, Karachi	021-5673838-5678383
Saba Gems, Karachi	021-5675436
New Evershine Gem Corporation, Karachi	021-2639801-2
Sattar Gem and Jewellers, Karachi	021-5650408-9
Ruby Star Traders, Karachi	021-5216731
Sagar Gems, Karachi	021-5678917
Ebrahim Sony Gems, Karachi	021-5676786-5216982
Faizan Gems, Karachi	021-5673961
Fashion Gem and Jewellers, Karachi	021-4552233-4552666
Arfi Gems, Karachi	021-5219247
Karachi Gem International, Karachi	021-5671973-5214243
Jewel Treasure Exports, Karachi	021-5651144
Anwar's Mahnoor Collection, Karachi	021-5216128

Leasing Policy of the Government of Pakistan.

As far as the matter regarding other discoveries of emeralds in talc-carbonate schists in Swat and other gemstones, the government of NWFP has formulated and announced Small Gem Mining Policy under the concept of National Mining Policy of 1995 where any firm or individual will be granted a 5 acre mining lease for any gem discovered by that party for five year lease under normal fee. The royalty under this small policy is as under:

(i). Precious gemstones: ten percent of the market value.
(ii). Semi-precious gemstones: three percent of the market value.

The dead rent under concession rule 1976 is as under:

(i). For the prospecting license: rupees five per acre and per year.
(ii). In case of mining lease, which is unproductive the dead rent is rupees six per year with six months advance payment.

Lucky Stone Traders, Karachi	021-5653108
Noorani Gems, Karachi	021-5660492
Jewel's Decor, Karachi	021-5678781
Tessori Trading Co Private (Ltd), Karachi	021-5654288-5657777
ASY Gems, Karachi	021-5673203
Crystal Enterprises, Karachi	021-5676085
Kunzit Lapidary Works, Karachi	021-6682722
Precious Collection, Karachi	021-5223298-5212486
Al Faisal Gems, Karachi	021-5676482
Al Bilal Gem and Jewellers, Karachi	021-5215831
Gems and Gold Jewellers, Karachi	021-5214289-5680370
Abdul Aziz Gems, Karachi	021-5218961-5650679
Royal Gems Stones, Karachi	021-5215840
Bombay Gems, Karachi	021-5212111
Euro Gems and Jewellers, Karachi	021-5653914
Gems and Gold Jewellery, Karachi	021-5214289