METALLOGENY AND MINERAL DEPOSITS OF PAKISTAN

By

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Syed Ghazanfar Abbas

OPI

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Cover photo: Emerald crystals in Pegmatite, near Khaltaro, Gilgit (Pakistan).
Photo A. H. Kazmi

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FOREWORD

A. H. Kazmi and Ghazanfar Abbas need no introduction to geoscientists interested in the geology and mineral potential of Pakistan. They have asked me to write a foreward to their book on Metallogeny and Mineral Deposits of Pakistan. They are far too well known internationally to need a foreward to their book. I feel that this is their way of honouring an old colleague for which I am grateful.

I have read the book in parts and feel that it fills a critical gap in our knowledge of the economic geology of Pakistan. This will be an invaluable source of information not only for teachers and students of economic geology but also for the local and foreign investors in the mineral sector of Pakistan.

Even though the title of the book is Metallogeny and Mineral Deposits of Pakistan, extensive coverage is given to host rocks, ore forming processes, types of mineral deposits and metallogeny and plate tectonics. It is thus a book on Economic Geology with special reference to minerals and ore deposits of Pakistan.

Mineral deposits have been described under various heads such as those related to plate tectonics (gold, silver, platinum, iron, lead, zinc, manganese, radioactive minerals etc.), mineral fuels (coal, petroleum and natural gas), precious and semi-precious stones, ceramic and industrial minerals with particular reference to their usage like fertilizers, ceramics, cement etc.

Thus a reader can refer to the particular chapter of his interest. The extensive data on the mineral deposits has been summarized in tables spread over more than 40 pages enabling the reader to get information he requires quickly. These references will also enable the reader to consult the original papers on the mineral deposits of his interest. Such summarized information is not available at present. It must have been a very arduous task for the authors to collect, compile and present so much information from widely scattered literature in an easily readable form.

The book is an invaluable addition to the geological literature on Pakistan and I am sure will be welcomed by the geoscience community at large.

I heartily congratulate the authors on this monumental work and hope that they will turn their attention to other so far neglected aspects of geology of Pakistan e.g. groundwater resources and environmental geology. I also thank them on behalf of the geoscience community of Pakistan.

I am sure that the book will be well received by a wide range of readers and if their comments are made available to the authors it can be further improved.

March 2001.

Dr. S. A. Bilgrami

PREFACE

Over the years, on being introduced to people as geologists, we were frequently asked whether Pakistan had gold, silver, uranium, oil and gas and other mineral deposits, why we did not find them, what was being done to exploit our mineral wealth, etc. Their lack of information was nor surprising because we had done so little to disseminate the available information. Persons in key positions also were not adequately informed. Most people appeared to be eager to have short, summarised and digested accounts which could provide them a bird's eye-view of our mineral resources.

Accordingly we prepared a very short booklet entitled " A brief review of the mineral wealth of Pakistan", which was published by the Geological Survey of Pakistan in 1991. It had all the short-comings that a hurriedly prepared, extremely condensed summary on a vast subject is likely to have. Yet within a short period it was out of print and unavailable. We were greatly astonished when many professional persons, including some in various aid giving agencies, appreciated this booklet and confided that they frequently consulted it.

During the past several years, we had the opportunity to interview hundreds of geologists for various jobs and found that their knowledge of our economic minerals was most inadequate. Discussions with teachers at various institutions brought home the fact that they had no access to uptodate literature on Pakistan's mineral resources and that whatever was available was scattered and not easily available to them. There was thus a growing demand for an uptodate, condensed volume that would highlight the salient features of our mineral deposits, their geological framework, their quality, quantity, development potential and the present state of their utilisation.

Considering these factors we have been motivated to produce this volume. To make it more meaningful to the uninitiated and students, we have added introductory material to briefly explain the nature of rocks and minerals, and the processes that form these deposits. The structure of the earth has been outlined. It has been explained that complex physico-chemical changes constantly occur in the interior of the earth and provide the energy and the motive force for the movement of the crustal plates and they are also responsible for various magmatic and minerallogenic processes.

Geological mapping has demarcated many highly prospective metallogenic zones and reconnaissance surveys have revealed numerous mineral showings. However, only a few selectd minerals have yet been proved and vast areas are yet to be evaluated in detail. A brief account of all these is included. For those who may seek a wider perspective of our mineral resources, we have tabulated data on more than 200 metallic and 146 nonmetallic mineral showings and deposits, each with references so that the original source of information may be gleaned if so required.

We are grateful to many persons whose encouragement, help and assistance made this work possible. We are particularly indebted to Dr. S.A.Bilgrami for his valuable suggestions and a critical review of the manuscript. Mr. S. Hasan Gauhar gave his unflinching support to this venture. Messers Anwar Hussain Syed and Nazrul Islam helped with the compilation of mineral production data and Saleem Awan with the typing work. Our thanks are also due to Messers Abbas Ali Shah, M.Talib Hussain, K.Sabir Ali Khan and M Saeeduzzafar Khan for their valuable suggestions, kind assistance and help in the preparation of this book. And finally we are most grateful to our sponsors, **Orient Petroleum Incorporation,** for their help and financial assistance, without which this book would not have seen the light of the day.

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March
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1

INTRODUCTION

In the chequered history of mankind minerals have remained in the forefront in all the human endeavours for progress and advancement. Indeed the evolution and progress of mankind is intimately linked with his efforts to utilise minerals. Undoubtedly the mineral industry is the oldest in the world. Numerous Paleolithic sites in the Potwar Plateau, which are more than 400,000 years old, highlight this fact. These sites are littered with thousands of fragments of chipped quartzite cobbles and are the remnants of the factories where our stone-age ancestors fashioned their stone implements. Similar sites are scattered all over India, south of the Vindhyans and they exist in several other parts of the world as well.

According to some authors, the Paleolithic stone-industry not only created the earliest and the longest lasting civilisation (duration over 500,000 years) but it also contributed to the evolution of the modern man. There is apparently a close inter-relationship between cultural achievement and biological endowment. Thus adoption of an erect posture by our ancestors and freeing of hands from locomotion made their hands available for tool-using and tool-making. There is some evidence to suggest that these activities facilitated modifications of the architecture of the brain and stimulated the development of the brain. Thus the most advanced homonids evolved as an outcome of the developments in the stone age cultures (Clark 1965). Field evidence supports this theory. One of the earliest Homonids, *Australopithecus*, lived during Early Pleistocene (more than 1.2 to 1.4 million years ago). Their brains had a mere capacity of about 685 cc (about half of modern man) and some of them were probably tool-makers because their skeletal remains have been found with flaked stone-tools in Tanganyika. There is, however, no evidence yet that these people had acquired even a rudimentary culture.

It was a few thousands of years later, during the Middle Pleistocene (800,000 to 100,000 years B. P. ?) that the more highly evolved homonids, *Pithecanthropus pekinensis,* appeared with a larger brain and cranial capacity of 1,000 cc. They made chopping tools by alternate flaking from chert pebbles, giving a sinuous working-edge. They could make fire and possessed a rudimentary culture (Clark 1965). With the passage of time we find more advanced forms of homonids and eventually see the appearance of the genus *Homo* in Late Pleistocene, beginning with early species such as *H. rhodesiensis,* and *H. neanderthalensis* and culminating in *Homo sapiens* (cranial capacity 13,500 cc) during very Late Pleistocene or Early Holocene. We also notice a similar advancement in the shape, style and refinement of the stone implements through the ages.

About 8,000 to 5,000 years ago people in this country learned to make extensive use of another mineral resource – the clay. A new culture was born that made extensive use of clay pottery and baked bricks (Wheeler 1960). With this application the great Indus Valley Civilization (2,500-1,500 B.C.) came into being which soon learned the use of metals (bronze and iron). During this period a variety of minerals were being used. Belonging to this age we find steatite vases, statues and seals; jewellery made of steatite, agate, chalcedony, and carnelian; antimony powder used by ladies as eye-shadow; copper implements such as knives, arrow-heads, utensils, head-pins, gold fillets with perforations at both ends, and decoration pieces made of marble (Khan 1964). Heaps of slags in Balochistan and northern areas suggest limited and sporadic mining, smelting and use of metallic ores since the Chalcolithic period (5,000-3,000 years B. P.) and particularly during the Medieval period.

Regular, large scale mining of minerals in the territory now comprising Pakistan, however, began only in the latter half of the nineteenth century when salt mines were established at Khewra, Warcha and Sardi in the Salt Range in 1878 and coal mining started in the Chittidand, Dandot and Ara areas of the Salt Range around 1880. Mining of chromite in the Hindubagh (now renamed Muslimbagh) area began in 1903.

Practically no information was available about the mineral resources of the Pakistan region until the establishment of the Geological Survey of India (GSI) in 1851, about 150 years ago. The present Geological Survey of Pakistan (GSP) is the post-partition off-shoot of that organisation. Several reconnaissance surveys of some of the more accessible areas of the region now comprising Pakistan were carried out by GSI during the latter half of the nineteenth century and a large number of mineral showings were examined and recorded (La Touche 1918). More detailed reports on several mineral occurrences and deposits were also published from time to time in the records and memoirs of the GSI (Heron 1950). On the eve of the creation of Pakistan, Gee (1949) prepared a paper giving a summary of the known mineral resources of Northwestern India (the region that eventually became Pakistan) and suggested ways and means for their development and utilisation. This was followed by Heron (1950) with a more comprehensive account of the mineral deposits in his Directory of Economic Minerals of Pakistan.

Both these publications are bench-mark papers on mineral resources of Pakistan inasmuch as they record the status and thinking concerning Pakistan's mineral deposits and their development potential at the time of Independence. These papers mention occurrences of a large number of minerals, namely alum, antimony, asbestos, barite, bauxite, bentonite, beryl, bismuth, borax, building stones, chromite, cinnabar, clays, coal, copper, fluorite, glass sand, gold, gypsum, iron ore, lead, limestone, magnesite, manganese, mica, nitrates, ochres, petroleum, gemstones, salt and sulphur. However, they also report that the only minerals that were being mined and utilised in appreciable quantities at that time were only building stones (including limestones), bentonite, chromite, clays, coal, gypsum, petroleum and salt. Since then there has been an appreciable increase in mineral production and utilisation (Tables 1 and 2).

At the time of Independence, based on their limited experiences in various parts of the world, the general consensus amongst the earth scientists was that valuable mineral deposits were largely to be found in the Precambrian rocks of the ancient shield areas like Africa, South India and Australia and that the relatively younger mountain chains of the world such as the Rockies, Alps and Himalayas were not likely to host significant mineral deposits. Because Pakistan was largely comprised of such younger formations, most geologists were not optimistic about the occurrence of any major mineral deposit in this region, except oil and gas. Dr. E R. Gee was one of the more optimistic geologists, but he also expressed fairly cautious views about mineral development prospects in Pakistan. He wrote (1949):-

"---the fact that the more easily accessible areas are composed of almost unaltered sedimentary rocks free from igneous intrusions, rules out over wide tracts the possibility of the occurrence of many of the more valuable metalliferous and other mineral deposits. Where igneous and metamorphic rocks do occur in the Himalayan region, in the southern Punjab and Balochistan, there appears to be in most cases, an absence of pegmatite veins bearing minerals of industrial value. One might expect metalliferous and other mineral deposits in the Archaean rocks that form the basement of southern Punjab and which continue into Rajputana. Unfortunately, however, from the evidence available, the covering of Recent alluvium is in most cases atleast several hundred feet thick; therefore, except as a possible source of mineral oil in hidden Tertiary strata overlying the Archaeans in the alluvial plains of the southern Punjab and of the lower Indus region, these areas must, for the present, be discounted as likely sites of valuable mineral deposits.

"Fortunately, however, the sedimentary suite includes important nonmetalliferous minerals, whilst the igneous and metamorphic rocks of certain areas afford a useful, if not considerable quota of metalliferous ores, many of which require further investigation.---"

Immediately after Independence despite its extremely limited resources of trained manpower, equipment and funds, the GSP mounted a crash programme of mineral investigations and within a few years a vast array of new information was gathered and published in the revised edition of the Directory of Economic Minerals of Pakistan by Heron and Crookshank (1954). This publication was instrumental in the development of several small to medium-size mineral deposits. As the GSP's activities gathered further

Table 1. Reserves and production of minerals being mined in substantial quantities.

Minerals	Reserves (million tonnes)	Production (1997-98) (tonnes)
Abrasives	Large	3,045
Antimony	0.026	3
Asbestos	Large	*50.000 ?
Barite	30	30,239
Ball clay	Small	905
Bauxite	74	5,015
Bentonite	2.0+	15,156
Brine	Large	60,123
Building stones	Very large	17,249
Celestite	0.33	961
Chalk	Not estimated	6,758
Chromite	Large	37,472
China clay	6.4	67,910
Coal	194,028	3,168,434
Copper ore	500	—
Dolomite	Very large	105,836
Feldspar	Large	26,365
Fire clay	100	94,395
Fluorite	Not estimated	135
Fuller's earth	Very large	214,889
Granite	Inexhaustible	6,013
Gypsum & Anhydrite	Very large	347,000
Iron ore	897	5,500
Lake salt	Small	15,304
Laterite	Very large	24,995
Limestone	Inexhaustible	10,353,538
Magnesite	12	3,427
Manganese	Small	N. A.
Marble	Very large	372,000
Mill-stone	Not estimated	1,174
Nepheline syenite	Very large	40
Ochres	100	9,718
Phosphate rock	27	55
Pumice	Not estimated	2,011
Quartz/quartzite	Very large	216
Red oxide (ochre? or laterite)	Not estimated	6,830
Rock salt	100	960,518
Soapstone	Not estimated	51,738
Shale (clay)	Very large	1,090,881
Silica sand	Very large	166,678
Slate	Very large	100,005
Sulphur	796,000	450
Talc	Not estimated	260

*These figures are from Jehan et al., 1997. Figures from Dept. of Mineral Development are much less.

Table 2. Yearwise mineral production 1994-95 to 1998 . Production for 1982-83 is also given for comparison (in tonnes) to indicate long-term increase in production.*

Minerals	1982-83	1994-95	1995-96	199-97	1997-98
Antimony	—	—	50	2	3
Asbestos	—	130	120	6	60 **
Barite	20,088	21,374	14,014	30,464	30,239
Ball clay	—	940	1,090	1.120	905
Bauxite	2,772	4,456	2,284	4,934	5,015
Bentonite	—	12,152	11,790	15.342	15,156
Brine	—	35,228	46,945	49,232	60,123
Building stones	—	4,913	13,443	18,625	17,249
Celestite	406	1,323	761	812	961
Chalk	—	11,930	7,221	8,140	6,758
Chromite	4,487	15,035	27,806	35,282	37,472
China clay	23,583	36,293	41,821	64,429	67,910
Coal	1,854,514	1,595,861	3,562,941	3,646,604	3,168,434
Dolomite	—	215,571	185,792	202,660	105,836
Feldspar	—	20,799	32,552	28,397	26,365
Fire clay	69,443	151,652	11,635	108,803	94,395
Fluorite	2,938	1,359	909	869	135
Fuller's earth	20,781	21,628	21,191	15,941	214,889
Granite	—	7,681	5,287	6,859	6,013
Gypsum & Anhydrite	340,747	500,119	419,501	520,563	347,000
Iron ore	—	8,103	6,076	4,575	5,500
Lake salt	—	11,862	17,062	20,777	15,304
Laterite	—	27,900	21,196	35,317	24,995
Limestone	4,231,624	9,685,738	13,355,925	9,533,915	10,353,538
Magnesite	1,687	6,000	7,387	6,679	3,427
Manganese	—	664	1,175	429	N. A.
Marble	120,597	488,322	509,689	462,308	372,000
Mill-stone	—	392	335	1,508	1,174
Nepheline syenite	—	200	—	100	40
Ochres	558	8,208	25,378	8.331	9,718
Phosphate rock	—	12,708	—	—	55
Pumice	—	720	1,401	1,839	2,011
Quartz/quartzite	—	144	48	232	216
Red oxide (ochre? or laterite)	—	15,919	25,593	16,180	6,830
Rock salt	5,47,546	934,778	996,754	1,066,429	960,518
Soapstone	19,081	35,939	45,816	45.425	51,738
Shale (clay)	—	711,119	757,605	806,380	1,090,881
Silica sand	140,701	175,320	222,076	106,957	166,678
Slate	—	87,216	134,360	91,214	100,005
Sulphur	—	600	570	640	450

* Source- GSP publications, Provincial Depts. of Mineral Development, Pakistan Statistical Year Book 1998-99 (No. 1999)-Federal Bureau of Statistics.

** Jehan et al. (1997) have reported the asbestos production at 50,000 tonnes.

momentum with technical assistance from USAID and the US Geological Survey, a greater wealth of data on mineral deposits was collected and made available to the public (Ahmad 1969, Gauhar 1969, and Kazmi and Abbas 1991). From time to time several papers on various mineral deposits of Pakistan have been published by various geologists and organisations like Pakistan Mineral Development Corporation, the Punjab Mineral Development Corporation, the Sarhad Development Authority, the Azad Kashmir Mineral and Industrial Development Corporation, the universities and various other organisations. Most of these papers have been mentioned in the list of references at the end of the book. It is unfortunate that since Ahmad (1969) there is a long gap in time before any other mineral inventory could be published. A brief account of the mineral deposits of Pakistan, however, appeared in Bender and Raza 1995 and in Kazmi and Jan in 1997.

Since Independence, during the past 50 years, three significant developments have taken place in the mineral sector of Pakistan. Firstly a very large number of mineral showings and deposits of various sizes have been discovered. Several of these are now being mined and utilised (Table 1). However, most of the deposits are being mined through crude and unscientific methods. Presently the mining industry is largely sustained by the non-metallic industrial minerals, which have made a very substantial contribution to the establishment and growth of some of our industries such as cement, paper, ceramics, steel, fertiliser, glass wares, paints and pigments, gem and jewellery, pesticides, chemicals, agriculture etc. Nevertheless, the contribution of the mineral sector to the GNP is still only about 0.50% and it is not surprising considering the pathetic industrial development of this country.

The second notable event has been the identification of a number of metallogenic provinces in the country by the GSP in the late sixties while formulating the national fourth five year plan. This included the Chagai District (Chagai-Raskoh magmatic arc), the Bela-Khuzdar districts (Bela ophiolitic thrust belt), the Zhob-Waziristan area (Zhob ophiolitic thrust belt), the Gilgit-Chitral region (Kohistan magmatic arc) and the Kirana Hills and the Thar Parkar and Nagar Parkar region (portions of the Indian peninsular shield). GSP made plans for intensive and extensive exploration of these regions and was rewarded with excellent results. During this same period as a result of geological, geophysical, and oceanographic research, the old concept of a 'rigid' earth was discarded, the plate tectonic theory was enunciated (Dewey and Bird 1970) and it found world-wide acceptance. It proved the voracity of Alfred Wegener's hypothesis of continental drift which he propounded in 1912 (Hallam 1976).

We have discussed plate tectonics in Chapter 3 and need not elaborate it here other than the fact that this theory has revolutionised geological thoughts and concepts and has provided greater insight and explanation for various geological phenomena such as mountain building, volcanicity, earthquakes, magmatism and metamorphism, sedimentation and metallogenesis. The plate tectonic concepts revealed that the mountain ranges of Pakistan were the result of the collision of the Eurasian and Indian continental plates, that the plate margins were subduction–related in the north, and of the transform type in the west, and that there were two magmatic island arcs wedged in between the two continental plates. On a world wide basis this theory also proved that the plate margins were the main mineral generating sites and even in the ancient Precambrian shield areas most minerals occurred at sites which may have been ancient plate margins (Windley 1984). Thus the old notion that the young geological terrain of Pakistan was likely to be bereft of significant mineral resources was totally discredited. Owing to its unique geodynamic situation, overnight Pakistan became world famous and attracted a vast array of earth scientists from all over the world for geoscientific investigation of this fascinating region (Farah and Dejong 1979, Kazmi and Jan 1997).

And lastly the earlier demarcation of metallogenic zones by GSP has proved to be valid even in the light of the plate tectonic theory. In the preceding paragraphs, while mentioning these zones we have given in parenthesis their present tectonic names. A number of authors, mainly Sillitoe 1975, 1979. Gauhar et al. 1979, Jankovic 1984c and Gauhar 1992, have reviewed the metallogeny of Pakistan in the context of plate tectonics. A discussion of this vast topic is beyond the scope of this book, though we have briefly dealt with it in Chapters 3 and 4.

The most significant result of the work in Pakistan and the most notable development in the mineral sector during this period is the discovery of large deposits of natural gas and proving of large economic reserves of some important metallic and non-metallic mineral deposits. These include the copper-gold-molybdenum deposits of Saindak (Balochistan), the iron ores of Kalabagh, Dilband and Chagai (Balochistan), the lead-zinc and barite deposits of Bela–Khuzdar (Balochistan), the coal deposits of Lakhra, Sonda–Thatta and Thar (Sindh), the phosphate deposits of Kakul (NWFP), the gold, silver and tungsten deposits of Chitral (NWFP). gem peridot deposits of Kohistan-Kaghan (NWFP), ruby deposits of Nangimali area (Azad Kashmir), emerald deposits of Swat, and the excellent orange-red spessartine garnets in the Neelam Valley (Azad Kashmir). These buried resources are, however, of little value and consequence unless they are mined and utilised. Unfortunately uptil now we have given the least priority to the development and utilisation of our mineral resources, ignoring the fact that no nation can progress or prosper without an industrial base which can only be established securely on the utilisation of its indigenous mineral resources.

In this volume we have given a brief account of the occurrences and mineral deposits of Pakistan. For the benefit of the non-professionals, in the second chapter we have tried to explain what is metallogeny, what are ores, minerals and rocks, how they are formed, what are different types of rocks and what kinds of minerals are associated with them and what are the geological processes which form different kinds of mineral deposits. The third chapter briefly explains the plate tectonic theory, that is, the structure of the earth and how it provides a mechanism for plate movement, different kinds of plate margins and how and why they form habitats for mineral deposits. It ends with a summary of continental drift through the ages. It is hoped that these two chapters would be valuable for the students also and provide them a good base for their studies in economic geology.

The fourth chapter presents an outline of the tectono-metallogenic zones of Pakistan and the minerals which characterise them.

Chapters five to nine contain an account of the metallic minerals, mineral fuels, precious stones, ceramic minerals, and fertiliser and industrial minerals. However, in the text we have confined ourselves to a brief discussion of only those mineral deposits that have some potential for economic development. It is obviously beyond the scope of this book to discuss all the mineral showings and occurrences. However, for the professionals and those who may want to have an in depth view of the metallogeny (or mineralogeny), we have summarised the available data about almost all the known mineral occurrences, showings and deposits in Tables 9 and 10. For each mineral occurrence, these tables provide information concerning the name and location of the deposit, tectono-metallogenic setting, minerals present, geological setting and type of deposit, quality, grade, size and references.

The last and final chapter deals with the possibilities and prospects of exploration and development or minerals in Pakistan. It is followed by a comprehensive bibliography and index.

We sincerely hope that this book will provide the much needed concise and up-to-date information on mineral deposits of Pakistan, to all those who are interested in minerals– students, researchers, economists, planners, prospectors, entrepreneurs as well as the laymen.

2

METALLOGENIC PROCESSES: A BRIEF REVIEW

ORES AND MINERALS

Metallogeny is the subject dealing with the origin of ore deposits. *Ores* are comprised of minerals, which may be used to obtain one or more metals. Most ores consist of metallic minerals, for example magnetite comprises iron oxide and galena contains lead sulphide. However, some ores are composed of nonmetallic minerals such as malachite (hydrated carbonate of copper), bauxite (hydrated aluminium oxide) or cerussite (lead carbonate). Some ores occur as native metals, for example gold, silver and platinum. Others are found in combination with other substances such as sulphur, arsenic, oxygen, silicon etc.

Ores commonly occur in a matrix of nonmetallic minerals of little or no commercial value. They are known as *gangue minerals*. Some of the common ores and gangue minerals are listed in Tables 3 and 4. The term ore-deposit is commonly used synonymously with the term *mineral deposit*. The latter connotes a rock or mineral that is of economic value and repays working. It therefore includes the nonmetallic minerals also. Inasmuch as ores are comprised of minerals it may be helpful to mention some of the main characteristics of minerals.

Minerals are the basic components of the earth's crust. Almost all minerals are crystalline and have definite chemical compositions that vary within specified limits. They have well defined physical properties and each of them has a unique atomic structure that gives it a characteristic crystal shape (Fig. 2.1). About 2,000 minerals are known and between them they contain almost all the chemical elements of which the earth is made. Although a wide variety of rocks make up the earth, most of these are composed of not more than a few dozen out of these 2,000 minerals that are known. Most of these *rock-forming minerals* are made up of complex silicates (Table 5). It may be, therefore, seen that in general minerals comprise two broad groups, the rock-forming minerals and the economic minerals. The latter include the ore minerals.

ROCKS THAT HOST THE ORE DEPOSITS

Rocks are physical mixtures of minerals, usually in the form of interlocking crystals or grains bound together by natural cement. A rock may comprise of one mineral only such as the limestone or it may be a mixture of various minerals such as the granite or the sandstone.

Table 3. List of common ore minerals (from Jensen and Bateman 1981).

Metal	Ore Mineral	Composition	Percent Metal	Primary	Supergene
Gold	Native gold	Au	100	X	X
	Calaverite	$AuTe_2$	39	X	
	Sylvanite	(Au, Ag) Te2	..	X	X
Silver	Native silver	Ag	100	X	X
	Argentite	Ag_2S	87	X	X
	Cerargyrite	AgCl	75		X
Iron	Magnetite	$FeO.Fe_2O_3$	72	X	
	Hematite	Fe_2O_3	70	X	X
	"Limonite"	$Fe_2O_3.H_2O$	60		X
	Siderite	$FeCO_3$	48	X	X
Copper	Native copper	Cu	100	X	X
	Bornite	Cu_5FeS_4	63	X	X
	Brochantite	$CuSO_4.3Cu(OH)_2$	62		X
	Chalcocite	Cu_2S	80	X	X
	Chalcopyrite	$CuFeS_2$	34	X	X
	Covellite	CuS	66	X	X
	Cuprite	Cu_2O	89		X
	Enargite	$3Cu_2S.As_2S_5$	48	X	
	Malachite	$CuSO_3.Cu(OH)_2$	57		X
	Azurite	$2CuCO_3.Cu(OH)_2$	55		X
	Chrysocolla	$CuSiO_3.2H_2O$	36		X
Lead	Galena	PbS	86	X	
	Cerussite	$PbCO_3$	77		X
	Anglesite	$PbSO_4$	68		X
Zinc	Sphalerite	ZnS	67	X	
	Smithsonite	$ZnCO_3$	52		X
	Hemimorphite	H_2ZnSiO_3	54		X
	Zincite	ZnO	80	X	
Tin	Cassiterite	SnO_2	78	X	?
	Stannite	$Cu_2S.FeS.SnS_2$	27	X	?
Nickel	Pentlandite	(Fe,Ni)S	22	X	
	Garnierite	$H_2(Ni.Mg)SiO_3.H_2O$	..		X
Chromium	Chromite	$FeO.Cr_2O_3$	68	X	
Manganese	Pyrolusite	MnO_2	63		X
	Psilomelane	$Mn_2O_3.xH_2O$	45		X
	Braunite	$3Mn_2O_3.Mn_SiO_3$	69	?	X
	Manganite	$Mn_2O_3.H_2O$	62		X
Aluminum	Bauxite	$Al_2O_3.2H_2O$	39		X
Antimony	Stibnite	Sb_2S_3	71	X	
Bismuth	Bismuthinite	Bi_2S_3	81	X	X
Cobalt	Smaltite	$CoAs_2$	28	X	
	Cobaltite	CoAsS	35	X	
Mercury	Cinnabar	HgS	86	X	
Molybdenum	Molybdenite	MoS_2	60	X	
	Wulfenite	$PbMoO_4$	39		X
Tungsten	Wolframite	(Fe, Mn) WO4	76	X	
	Huebnerite	$MnWO_4$	76	X	
	Scheelite	$CaWO_4$	80	X	

Table 4. List of Common Gangue Minerals (from Jensen and Bateman 1981).

Class	Name	Composition	Primary	Supergene
Oxides	Quartz	SiO_2	X	X
	Other silica	SiO_2	X	X
	Bauxite, etc.	$Al_2O_3.2H_2O$		X
	Limonite	$Fe_2O_3.H_2O$		X
Carbonates	Calcite	$CaCO_3$	X	X
	Dolomite	$(Ca, Mg) CO_3$	X	X
	Siderite	$FeCO_3$	X	X
	Rhodochrosite	$MnCO_3$	X	
Sulphates	Barite	$BaSO_4$	X	
	Gypsum	$CaSO_4+2H_2O$		X
Silicates	Feldspar	...	X	
	Garnet	...	X	
	Rhodonite	$MnSiO_3$	X	
	Chlorite	...	X	
	Clay minerals	...	X	X
Miscellaneous rock matter	Fluorite	CaF_2	X	
	Apatite	$(CaF)Ca(PO_4)_3$	X	
	Pyrite	FeS_2	X	X
	Marcasite	FeS_2	X	X
	Pyrrhotite	$Fe_1\text{-}xS$	X	
	Arsenopyrite	FeAsS	X	

the granite or the sandstone. Rocks constitute the outer solid shell of the earth known as the *crust*. A relatively small number of elements and minerals constitute the bulk of the crust (Table 6) and most of these do not fall within the category of ore minerals. It therefore follows that the substances which form the ore deposits are present in the crust in extremely small amounts, despite the fact that the deposits comprise a wide range of elements and minerals (Table 3). Various geological processes operating in the earth concentrate these thinly and widely distributed elements at one place to form mineable ore deposits. These deposits are hosted in different types of rocks which are usually divided into three main groups (I) igneous, (2) sedimentary and (3) metamorphic.

Igneous Rocks

The igneous rocks form by the consolidation of a hot, mobile and molten mass of earth material known as *magma*. The composition of magmas varies widely. They are high temperature solutions of silica, silicates, metallic oxides, hot liquids and gases in all possible proportions and combinations. Their temperature ranges from about 600°C (rhyolite magma) to about 1,250°C (basaltic magma). Magmas form in the earth's crust in pockets or reservoirs and are forced upward due to tectonic forces. As they move upward, they cool and solidify to form igneous rocks. These rocks are known as *plutonic* if formed in depth. In case the magma comes out on the earth's surface in the form of volcanic eruptions, it forms the *volcanic rocks.*

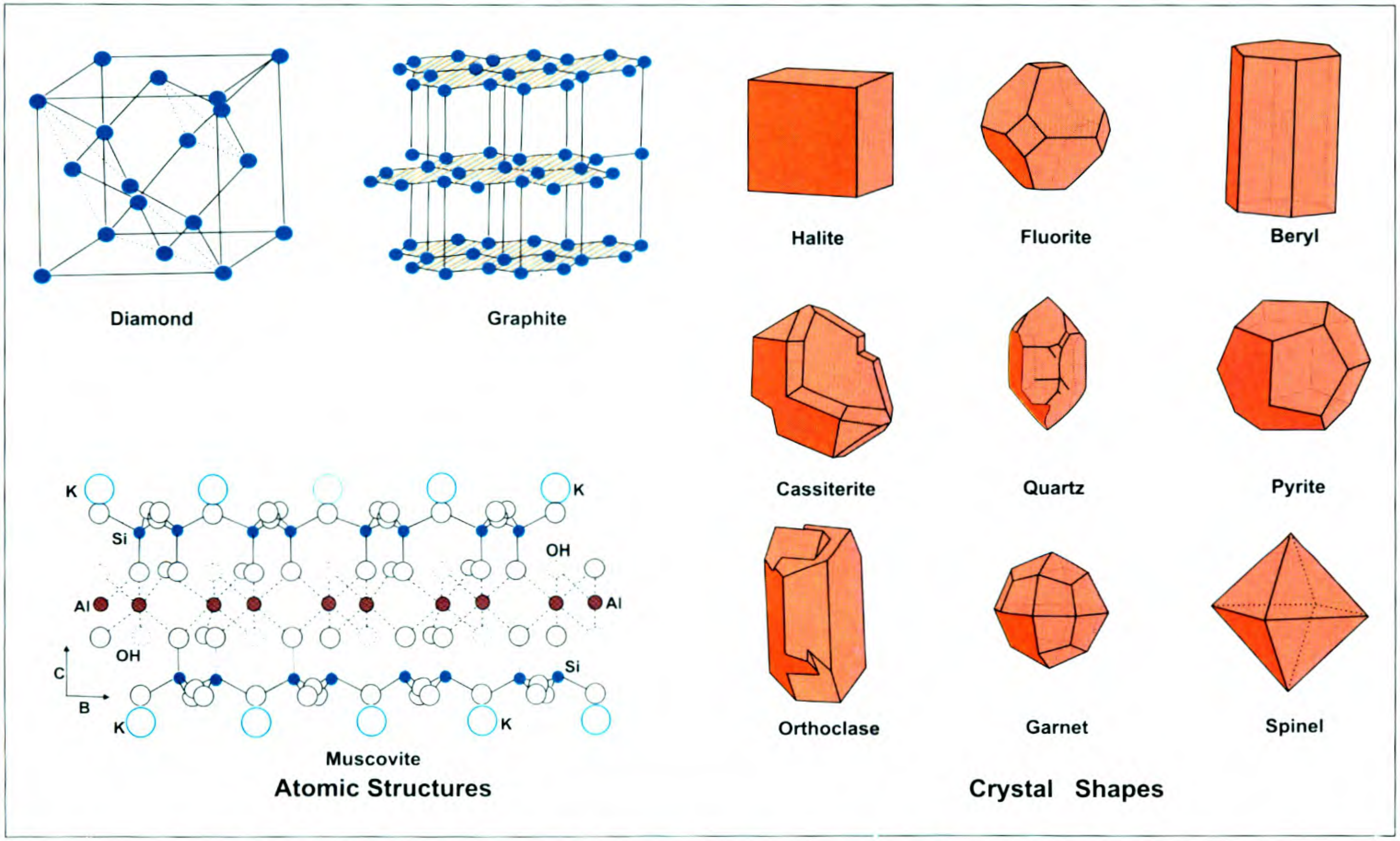


Figure 2.1. Crystal structures and shapes of a few common minerals (from Read 1953).

Table 5. Some common rock-forming minerals as constituents of various rocks (%).

Mineral	Mineral Composition	Igneous rocks		Metamorphic rocks		Sedimentary rocks		
		Granite	Basalt	Amphibolite	Schist	Shale	Sandstone	Limestone
		1	2	3	4	5	6	7
Quartz	Silicon dioxide	30	–	–	32	17	97	3
Alkali feldspar	K-aluminium silicate	60	5	–	–	–	1	1
Plagioclase	Na-Ca aluminium silicate	5	45	42	18	–	–	–
Pyroxene	Silicate of Ca, Mg, Fe or Al	–	40	–	–	–	–	–
Amphibole	Complex hydrated silicates of Ca, Na, Mg, Fe, Al	–	–	50	–	–	–	–
Olivine	Mg, Fe, silicate		5					
Biotite	Silicate of Al and K	4	–	5	7	–	–	–
Muscovite	Silicate of Mg, Fe, Al, K, with hydroxyl and fluorine	–	–	–	38	1	1	–
Magnetite	Iron oxide	1	5	3	3	1	1	1
Staurolite	Hydrated silicate of Fe and Al	–	–	–	–	2	–	–
Clay minerals	Hydrous Al silicates	–	–	–	–	80	–	1
Calcite	Calcium carbonate	–	–	–	–	1	–	94
		100	100	100	100	100	100	100

(from Wright 1984)

Table 6. Average composition of the crustal rocks.

In Terms of Elements			In terms of Oxides				
Name		Percent	Name		Formula		Percent
Oxygen	–	46.60	Silica	–	SiO_2	–	59.26
Silicon	–	27.72	Alumina	–	Al_2O_3	–	15.35
Aluminium	–	8.13	Iron oxides	–	Fe_2O_3	–	3.14
Iron	–	5.00		–	FeO	–	3.74
Calcium	–	3.63	Lime	–	CaO	–	5.08
Sodium	–	2.83	Soda	–	Na_2O	–	3.81
Potasium	–	2.59	Potash	–	K_2O	–	3.12
Magnesium	–	2.09	Magnesia	–	MgO	–	3.46
Titanium	–	0.44	Titania	–	TiO_2	–	0.73
Hydrogen	–	0.14	Water	–	H_2O	–	1.26
Phosphorous	–	0.12	Phosphorous pentoxide	–	P_2O_5	–	0.28
		99.29					99.23

(From Holmes 1966)

Magmas

Depending upon the relative abundance of silica (Fig. 2.2), the igneous rocks and their parent magmas are classified as acidic or granitic (70-75% silica), intermediate or andesitic (52-64% silica) and basic or basaltic (45-50% silica). The granitic magma ranges in temperature from 800-600°C. It often forms vast, narrow, plutonic masses tens to hundreds of kilometre long, known as *batholiths*. These are commonly generated above subduction zones and are a characteristic feature of orogenic belts.

Andesitic magma is less viscous than the granitic one, but more viscous than the basaltic magma. It is also generated above subduction zones. The andesitic and rhyolitic magmas form new continental crust, which grows by progressive accumulation of rhyolitic and andesitic volcanism. The only true primary magma, however, is of basaltic composition. It is generated by direct partial melting of mantle peridotite, beneath active volcanic ridges, which are the sites of formation of lithospheric plates. The oceanic crust is basaltic in composition. It has a very uniform character over vast areas. It consists of an upper layer of volcanic rocks (pillow lavas), underlain by a zone of basaltic sheeted dykes which are in turn underlain by gabbros, with cumulate layers, representing the magma chambers in their lower parts.

Gradual cooling of the magma leads to a serial crystallisation of various minerals. The most insoluble crystals, that is those with the highest melting points crystallise first. Amongst the rock-forming minerals the sequence is olivine and orthorhombic pyroxene,

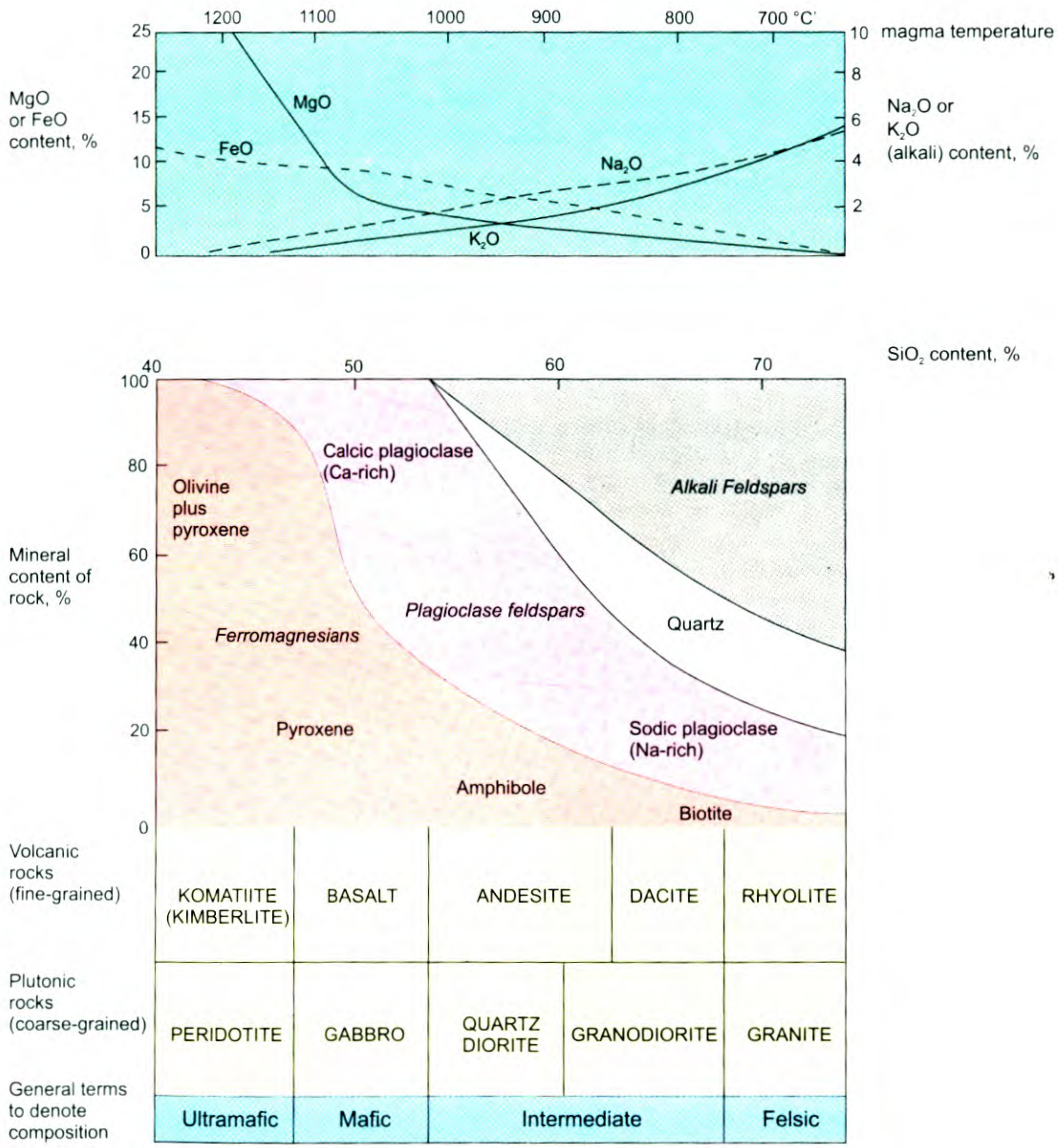


Figure 2.2. Common igneous rock types and their mineralogical and chemical composition. The diagram also gives the temperature of magmas from which the rocks crystallise. However, it does not include some important rocks like syenite (plutonic) and trachyte (volcanic). Both of these are mainly characterised by high content of alkali feldspars (66% or more) and minor amounts of quartz and feldspathoids which may be absent (modified from Sawkins et al. 1974).

followed by clinopyroxene, hornblende, feldspar, mica and quartz. Amongst the *accessory minerals* (minerals which occur in extremely minute quantities and are not relevant to rock classification), some of the early-formed ones are pyrrhotite, argentite, apatite, zircon, titanite, rutile, ilmenite, magnetite and chromite.

It would be thus seen that some minerals form early and at high temperatures while others at intermediate or low temperatures. A few examples of such temperature-indicator minerals is given in Table 7.

Table 7. Selected temperature indicator minerals.

High Temperature	Intermediate Temperature	Low Temperature
Olivine	Chalcopyrite	Stibnite
Magnetite	Arsenopyrite	Realgar
Specularite	Galena	Cinnabar
Pyrrhotite	Sphalerite	Marcasite
Tourmaline	Tetrahedrite	Chalcedony
Cassiterite	Leucite	Rhodochrosite
Garnet	Pyrite	Adularia
Pyroxene		Siderite
Amphibole		Gold
Topaz		

(From Jensen and Bateman 1981).

Magmatic differentiation

From the foregoing account it may be seen that most metalliferous deposits and many nonmetallic deposits result from igneous activity and are associated with various stages of the consolidation of the magma. There is thus a close kinship or genetic association between mineral deposits and the magma. As the magma cools, most of the ore minerals are left in the magma-residue. Thus the magmatic differentiation gives rise to a magmatic fluid (hydrothermal solution) in which there is a rich concentration of metals and other ore forming constituents. These solutions rise upwards and sideways and lodge in the fractures, cavities and other favourable sites in the country rock.

The cooling of magma and its differentiation also creates a series of different rock types, each formed at different temperature and pressure. Cooling causes a progressive increase in the concentration of silica and other low temperature minerals in the residual magma. Thus rocks of different composition are formed, their relative silica content ranging from low to high. Based on their relative silica content the igneous rocks are categorised as ultrabasic or ultramafic, basic or mafic, and intermediate to acid.

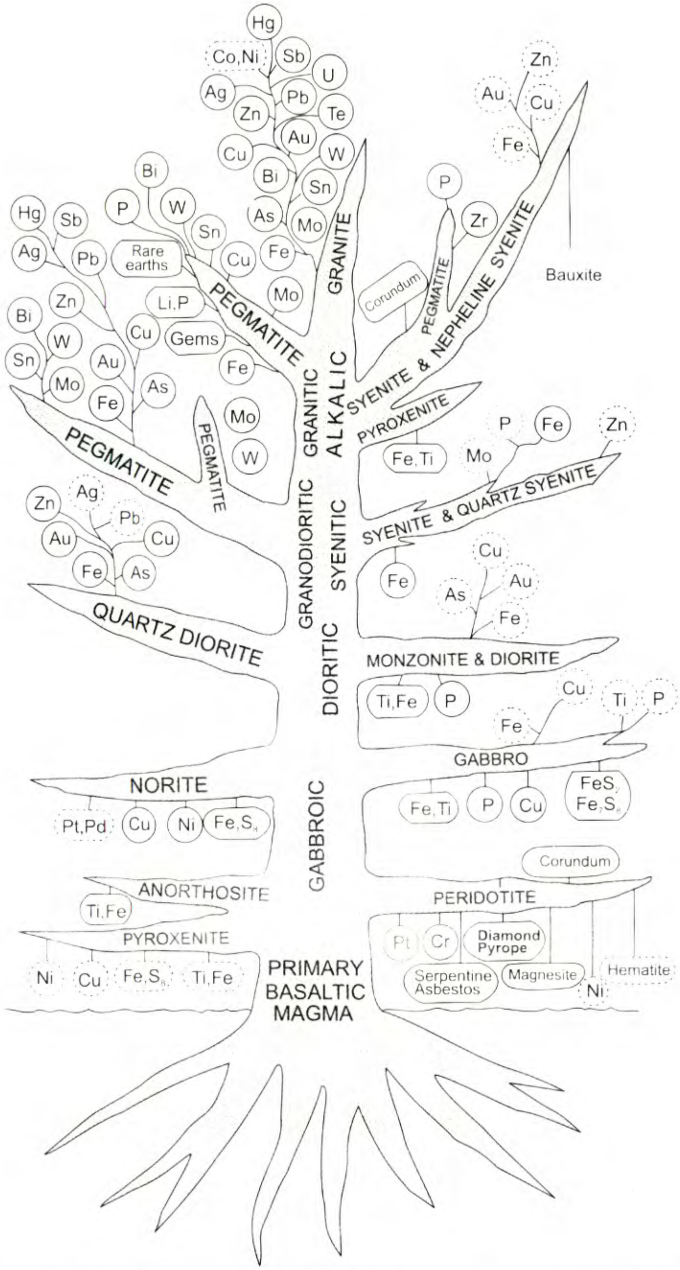


Figure 2.3. Relation of igneous rocks to mineral deposits. The elements that branch upward occur in deposits formed from magmatic emanations; those hanging down are magmatic concentration; fallen ones are weathered products. Full circles indicate major associations (from Bateman 1951)

Era	Period	Epoch	Millions of years ago (approximate)	Significant developments
CENOZOIC	QUATERNARY	Recent Pleistocene		
			2	Man as a user of fire and tools
	TERTIARY	Pliocene Miocene Oligocene Eocene Paleocene	— 25	First man-like primates
			65 —	
MESOZOIC	CRETACEOUS		— 135	First flowering plants First birds
	JURASSIC		— 190	
	TRIASSIC			First mammals
			225 —	
PALEOZOIC	PERMIAN		— 280	First reptiles
	CARBONIFEROUS		— 325	
			— 350	
	DEVONIAN		— 400	First land animals (amphibians)
	SILURIAN		— 430	First land plants
	ORDOVICIAN		— 500	First vertebrates (fish)
	CAMBRIAN			
			600 —	Invertebrate fossils common
PRECAMBRIAN	PROTEROZOIC			Rare invertebrate fossils (670) Well-preserved unicellular organisms (2000)
	ARCHEAN		— 4600	Probable unicellular organisms (3000)

Duration of Eras

Cenozoic:	65 million years	Paleozoic:	375 million years
Mesozoic:	160 million years	Precambrian:	4,000 million years

Total.....................4,600,000,000 years-approx.

Figure 2.4. Geological time-scale

These are further subdivided into a number of groups, largely based on the relative abundance of quartz, types of feldspars and the dark ferrumagnesian minerals (Fig. 2.2).

Association of ores with specific rock-types

It has been observed that several mineral deposits are preferentially hosted in a particular rock type. For example chromite, serpentine, nickel and platinum commonly occur in ultramafic rocks, while ores of mercury, wolfram, zirconium, tin, and tungsten are more abundant in acidic rocks. This is well illustrated in Figure 2.3. It therefore follows that if the occurrence and distribution of various rock types is known in a given area, it may be possible to make an educated guess about the type of mineral deposits that may be expected to be found in that region.

Sedimentary rocks.

Sedimentary rocks form in oceans or on land surface. They are deposited in layers, one above the other, and they are progressively younger upwards. Such stratified layers are called *beds* and a group of beds is called a *formation*. More precisely, a formation may be defined as a set of strata which are comprised of similar rock types and lithologic characteristics and well marked upper and lower contacts. A formation may be easily distinguished from the overlying and underlying strata and is traceable over a wide region. A geologic formation commonly represents a specific time interval in the earth's history. A formation may also contain remains of ancient plants and animals, known as *fossils*. A formation often has a suit of fossils peculiar to itself. Thus the relative age, or its position in time may be ascertained from its distinctive fossils. The fossils have been instrumental in revealing the evolution of life on earth. Coupled with the superposition of fossiliferous strata and various structural features, the main time intervals of earth's history e g. Archaeozoic (primaeval life), Proterozoic (earlier life), Paleozoic (ancient life), Mesozoic (middle life) and Cenozoic (recent life) were established and a relative geological time scale was prepared. With the advent of radiometric dating methods it has now been possible to assign dates of real time to the previous scale of relative time (Fig. 2.4).

Mechanically formed sedimentary rocks

On the earth's surface the igneous and metamorphic rocks disintegrate due to the processes of weathering and erosion. The loose particles are carried away by wind and water and deposited in surface depressions, flood plains, lakes and the seas. Over a period of time, largely due to overloading-pressure and cementation, these sediments get consolidated to form the detrital sedimentary rocks. The more common types are the sandstones, mudstones and claystones which are composed largely of quartz, feldspar, mica and clay minerals.

Chemically formed sedimentary rocks

Another type of sedimentary rock is of chemical origin. It consists not of terrigenous material but is comprised of minerals that form by precipitation within the depositional area. Precipitation may be due to purely chemical process or caused by organisms. Evaporites, limestones and dolomites are good examples.

Organically formed sedimentary rocks

A third type of sedimentary rock is biogenic which is largely comprised of fossil corals and algal reefs, fossil shells and diatomite.

Mineral deposits associated with sedimentary rocks

Mineral deposits commonly associated with sedimentary rocks are evaporites (salt and gypsum), rock phosphate, iron and manganese ores; various types of clays, radioactive minerals, lead, zinc, barite, fluorite; placer deposits of gold, silver, platinum, tin, gemstones and coal, oil and gas.

Metamorphic rocks

Substances formed on the earth's surface, such as clays, when subjected to increased pressure and temperature, change to more stable forms such as mica or other silicates. Similarly various pre-existing rocks also transform into a different variety under changing conditions of temperature and pressure. This process is known as *metamorphism* and may be defined as the process which transforms pre-existing rocks into new types by the action of heat, pressure, stress and hot, chemically active, migrating fluids. Rocks thus produced are the metamorphic rocks. A few examples of metamorphic alteration of rocks is given in Table 8.

Table 8. Metamorphic alteration of selected pre-existing rocks

Pre-existing rock	Metamorphosed rocks
Sandstone	Quartzite® feldspathised quartzite® granite
Clay	Shale® slate® mica schist® migmatite® granite
Limestone	Marble
Granite	Granite gneiss
Dolerite	Hornblende-schist
Peridotite	Talc-schist
Basalt	Amphibolite® hornblendic migmatite® granodiorite® granite

Mineral deposits in metamorphic rocks

Minerals are largely stable under the conditions in which they were formed. They become unstable with changes in the environment, particularly changes in temperature and pressure. They alter into other substances which are more stable under the new conditions. Thus most of the *hypogene minerals* (those formed early during mineralisation) are altered to native metals, oxides, carbonates, sulphides, sulphates, chlorides, silicates and other forms. The solutions carrying these substances are squirted out, as it were, by metamorphic processes and they deposit the ores at favourable sites in the metamorphosed rocks. Such ore minerals are classified as *supergene*.

Mineral deposits more commonly associated with metamorphic rocks are asbestos, graphite, talc, garnet, sillimanite and a host of minor metallic ores, largely in the form of hydrothermal veins.

ORE FORMING PROCESSES AND TYPES OF MINERAL DEPOSITS

A variety of geological processes are involved in the formation of various mineral deposits. Mineral deposits are commonly classified on the basis of the dominant geological process which formed them. Some of the more common types are magmatic segregations, pegmatitic ore deposits, pneumatolytic, hydrothermal, metasomatic, metamorphic, sedimentary and placer deposits, and deposits formed due to secondary enrichment.

Magmatic segregations

We have earlier discussed in some detail the cooling and differentiation of magma and formation of igneous rocks and associated minerals. This process concentrates by gravity settling, the least soluble minerals during the early stages of the cooling of magma. Important deposits of platinum, magnetite, ilmenite, chromite, and some sulphides e.g. pyrrhotite and chalcopyrite have formed in this manner.

Pegmatitic ore deposits

These deposits are formed by the residual portion of the magma during the later stage of magma cooling. At this stage valuable minerals are concentrated in the residual magma fluid and the presence of rich fluxes leads to growth of large crystals. The pegmatitic fluids are very mobile and intrude as dykes, stringers and veins in the vicinity of granite masses. This process has formed deposits of exquisite gemstones besides ore deposits of a great variety of other minerals such as mica, lithium, beryl, rubidium, cesium, tin, titanium, niobium, tantalum, and the rare lanthanides (Y, Tn, U, Zr and Hf).

Pneumatolytic ore deposits

After the pegmatitic stage, there is further concentration of the relatively more soluble material in the residual magma. There is considerable accumulation of heated gases with potential for great chemical activity. The gases and liquids are initially in solution in the magma but with cooling and changes in temperature and pressure, they separate and rise to the highest part of the magma chamber. As they move upward, they collect metals and other minor constituents. As the gases cool and condense, the metallic load is transferred from the gaseous to the aqueous environment. Finally, under pressure they are expelled on to the surface and form fumaroles associated with volcanism or react with the country rock and form various alteration products due to metamorphism or metasomatism. Amongst others, some deposits of sulphur, tourmaline, topaz, lepidolite, axianite, apatite and tinstone have formed in this manner.

Hydrothermal ore deposits

These are formed from aqueous solutions during the final stages in the consolidation of magma. These hydrothermal solutions are believed to represent a stage beyond the pegmatitic liquids and have been greatly modified by crystallization of the last rock minerals. Some economic geologists, however, suggest that the hydrothermal solutions are often a mixture of solids, residual magmatic melt, water and gases. The gases eventually condense and mix with the hydrothermal solutions which are further enriched in their metallic content. The solutions deposit their load in cavities or fissures or between grains of sediments (impregnation). Several deposits of iron, copper, nickel, lead, gold, silver and other metals have formed due to this process.

Metasomatic ore deposits

These are characterised by complete or partial replacement of a pre-existing rock by the ore body, largely due to the passage of heated water from igneous sources. For example some of the deposits of iron, lead-zinc, chalcopyrite, pyrite, zincblende, sericite, albite and serpentine have formed in this manner. Such deposits commonly occur in the vicinity of igneous rocks and the limestones are the most favourable host rocks.

Metamorphic ore deposits

Due to metamorphism pre-existing minerals in a rock formation may be subjected to high temperature or pressure or both. This process often increases the concentration of the ore minerals and forms workable deposits. Some of the deposits of hematite, magnetite, graphite, talc, garnet, sillimanite group etc. have formed in this manner.

Secondary enrichment type deposits.

At the surface, low grade ores often decompose due to weathering and get concentrated at the top due to removal of some of the lighter and less stable material. In some instances the valuable substances are dissolved and carried down by descending waters. Chemical action takes place between descending waters bearing oxy-salts and the unaltered sulphides and other materials, with the result that a new series of ore minerals is formed and gets concentrated at some depth beneath the zone of weathering. Several deposits of copper, lead, zinc, and other metals have formed in this manner.

Sedimentary mineral deposits

These are formed by the processes of sedimentation and are largely inter-bedded with sedimentary rocks. Sedimentary mineral deposits form due to mechanical transportation, sedimentation, evaporation in open bodies of water, and by precipitation or bacterial action. Amongst others, some of the valuable mineral deposits of this type include iron, manganese, copper, phosphate, coal, oil shale, carbonates, magnesite, potash, salt, gypsum, sulphur, uranium, vanadium, bentonite, Fuller's earth, and other industrial clays.

Placer deposits

These are largely formed by stream or wave action. Valuable mineral particles are eroded from pre-existing rocks which contain sparsely disseminated ore minerals or commercial ores and are transported by moving water or wind. In the process they are separated from the lighter non-economic minerals by gravitational separation and mechanical concentration and are finally deposited along river beds, flood plains or seashores. The placer minerals are characterised by high specific gravity, resistance to chemical weathering and durability. Minerals that commonly occur as placer deposits include gold, platinum, tinstone, magnetite, chromite, ilmenite, rutile, native copper, gemstones, zircon, monazite etc.

Residual deposits

Under warm and humid climate, pre-existing rocks are often subjected to deep and long continued weathering. This process produces mechanical disintegration of the rock and subjects it to the action and effects of water, oxygen, carbon dioxide, heat, acids, alkalies and the plants and animals. Most of the gangue minerals are thus removed mechanically or in solution, leaving behind a concentration of ore minerals. Some of the important residual ore deposits include iron, bauxite, manganese, kaoline, nickel and to a lesser extent kyanite, barite, zinc, tin, cobalt and gold.

3

METALLOGENY: A PRODUCT OF PLATE TECTONICS

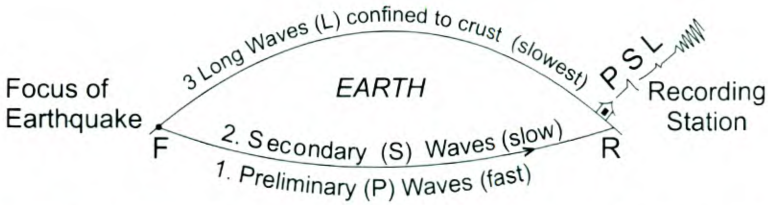
THE EARTH : ITS COMPOSITION AND STRUCTURE

In the previous chapter we have discussed that the primary source of all ore forming substances is the magma. As we shall see in this chapter, magma is one of the products of the complicated dynamic and chemical processes that operate deep inside the earth. These processes also result in the drifting of continents, a concept, which is now commonly known as plate tectonics and involves mass deformation on a global scale. The unique structure of the earth makes possible the operation of these processes.

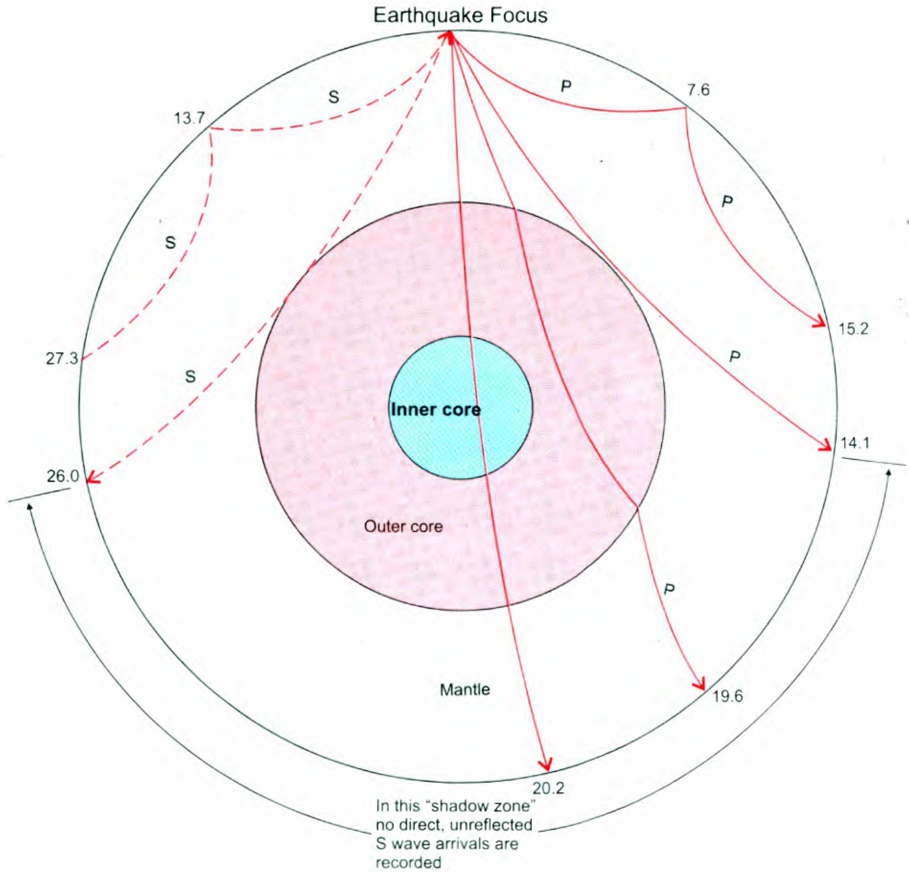
The internal structure of the earth has been revealed in considerable detail by the seismic waves generated by the earthquakes. There are three main types of waves: the L waves, which are the slowest and travel along the surface, the S waves which are slower and travel through the earth, and the P waves which are the fastest and they also move through the earth (Fig. 3.1). These waves penetrate the earth and X-Ray it as it were, revealing its internal structure. The seismological record shows that as the seismic waves traverse the earth, they undergo changes in velocities which have been interpreted to indicate variations in density, pressure, temperature, phase changes and the physical state of the various layers of the earth. The internal structure of the earth is thus comprised of a series of concentric shells (Fig. 3.1), each distinguished by changes in S and P wave velocities and by its characteristic density, pressure and temperature condition and its composition (Fig. 3.2).

The Core

The innermost zone of the earth, the core is its densest part and forms a 3,670 kilometres wide spherical body. The inner part of the core, known as the inner core is about 1,370 kilometres in radius and consists of a solid mass in which the P wave velocity is high. It has the highest density (13-16 g/km^3), highest temperature (about 3,500°C), and highest pressure (more than 3 megabars). The inner core is surrounded by the 2,300 kilometres thick molten mass of the outer core which has a relatively lower density (10-13 g/km^3), lower temperature (3,000-3,500°C) lower pressure (about 1.2 to 3 megabars) and lower P wave velocity. The liquid nature of the outer core is demonstrated by the fact that it blocks the S wave (Figs. 3.1 and 3.2). The core is largely comprised of iron and nickel with some sulphur and silica.



A. Section through a segment of the earth, showing the paths followed by the P, S, and L waves of an earthquake originating at the focus F and recorded at a station R (from Holmes 1966).



B. Seismic wave travel-paths through the earth. The time (in minutes) it took each wave to travel from the earthquake is shown where the paths surface. Over a little less than half the earth, directly opposite the earthquake focus, there are no direct, unreflected S wave arrivals. Note the reflected P wave (15.2 min) and S wave (27.3min), in which the seismic energy bounced from the surface back into the interior. The paths are curved because of the increase of seismic velocity with depth within the earth. (From Sawkins et al. 1974)

Figure 3.1. Earhquake waves and their characteristics.

(**A**) Variation of seismic velocity with depth within the earth; v_p is compressional (P wave) velocity and v_s is the shear (S) wave velocity. Note that the S wave velocity drops to zero in the outer core. The velocities for the inner core are somewhat speculative. The region of low velocities, near 100-km depth, is called the seismic low velocity zone (indicated by arrow)

(B) Approximate variation of density with depth within the earth. The density of the inner core is not well known. Note the inversion of density (heavier material on top of lighter) at about 100-km depth seismic low velocity zone.

(**C**) One model of the variation of temperature (C) and pressure (D) with depth within the earth. In its deeper portions, the curve could be in error by as much as 1000° C. Because the calculated pressure is not very sensitive to errors in assumptions and observations used to deduce it, the curve (D) is not likely to be seriously wrong. The pressure at the center of the earth is more than 3 million times as great as that of the atmosphere; 1 million atmospheres.

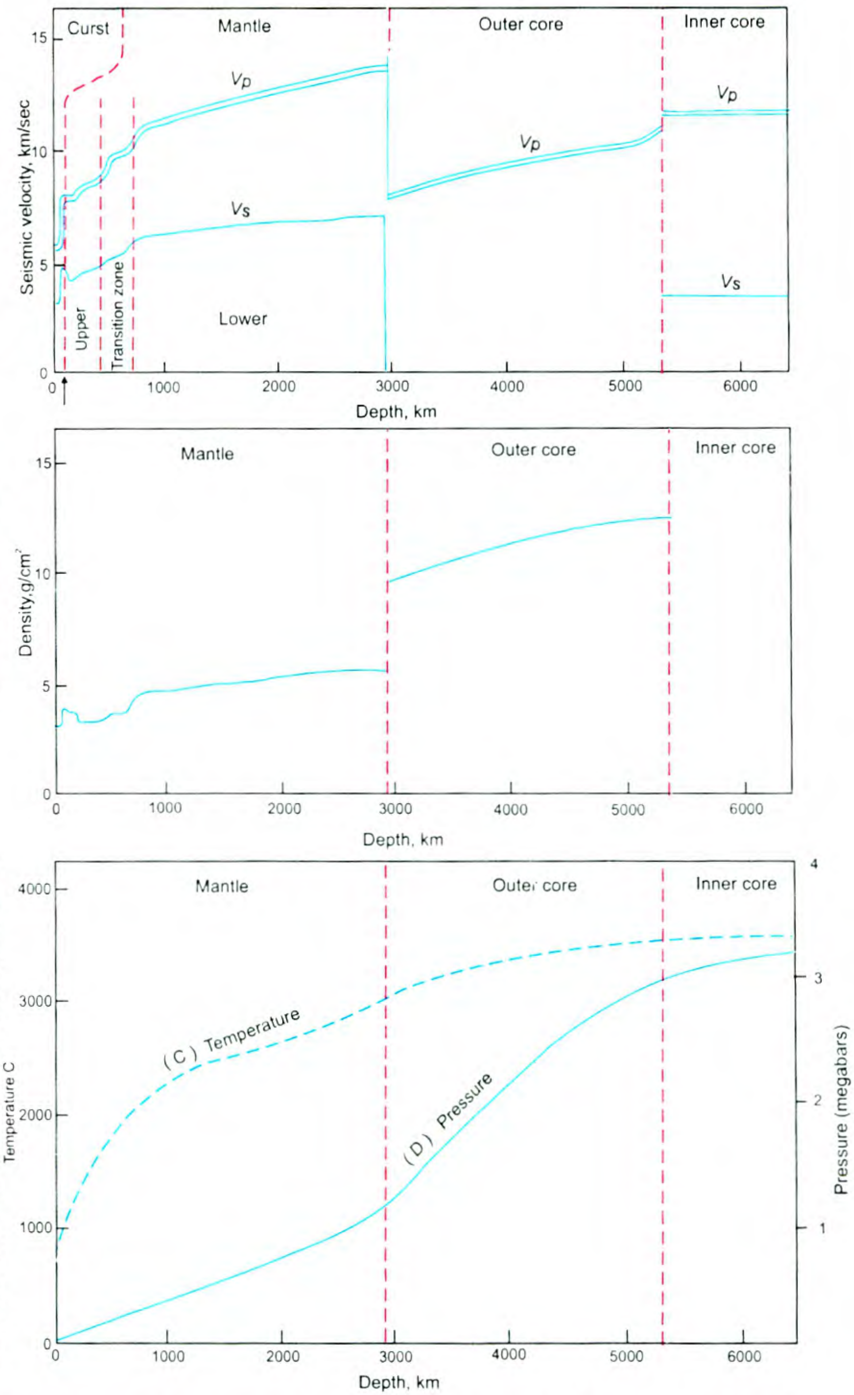


Figure 3.2 . Variations in the seismic velocity, density, temperature and pressure with depth, within the earth (from Sawkins et al. 1974).

The Mantle

The core is surrounded by the mantle. It is a 2,900 kilometres thick shell that transmits both the S and P waves, has an average density of 4.5 g/cm^3 and is largely comprised of hot rock material containing oxygen, silica, magnesium and iron. These elements are grouped to form minerals adjusted to different conditions of temperature, pressure and depth. Olivine, pyroxene and garnet appear to form early, as indicated by the kimberlites which originate at depths of 150-300 kilometres. The mantle, particularly its upper portion, is of great interest to earth scientists, because it has a profound influence on the earth's crust. Not only that the crust, the oceans and the atmosphere are distillates of the mantle, but it also provides the driving force that slowly moves the continents on the earth's surface.

Changes in the seismic wave velocities define three major zones within the mantle. The *lower mantle,* which is the inner most, is the thickest (about 2,200 kilometres) and extends from a depth of about 700 to 2,900 kilometres. Its density and velocity of the seismic waves is fairly steady and higher than in other zones. Its temperature increases steadily from nearly 2,000°C in its upper part to about 3,000° C near its contact with the core. Similarly the pressure gradient varies from about 0.2 to 1.2 megabars (Fig. 3.2). The lower mantle is surrounded by a *transition zone* which lies at a depth of 400 to 700 kilometres, followed upwards by the *upper mantle.* The latter extends from the base of the earth's crust down to a depth of 400 kilometres.

The Crust

Above the mantle lies the upper-most layer of the earth, the crust. It is hard, solid and 12 to over 50 kilometres thick. The crust comprising the landmasses is known as the *continental crust.* It is 25 to more than 50 kilometres thick. Its upper part consists of an intricate assemblage of igneous, metamorphic and sedimentary rocks. Its lower part is characterised by higher seismic velocity, which reflects changes in composition or phase changes. The crust beneath the oceans is known as the *oceanic crust.* Its thickness is commonly less than 12 kilometres. Its upper part is covered with deep sea sediments which are underlain by basaltic pillow lavas, a zone of sheeted basaltic dyke complex and a bottom layer of gabbroic rocks.

At the base of the crust, its contact with the upper mantle is characterised by a sudden increase in the P wave velocity. This boundary is known as *Mohorovicic discontinuity* or Moho for short (Fig. 3.2).

The Lithosphere and the Asthenosphere

The upper 70 kilometres thick zone of the earth is characterised by high shear (S) wave velocity and acts as a rigid body. This zone is known as *lithosphere* and it comprises the crust and the upper part of the mantle. Beneath the continents, the lithosphere is much thicker and may extend to a depth of 150-200 kilometres (Fig. 3.3). It is underlain by the

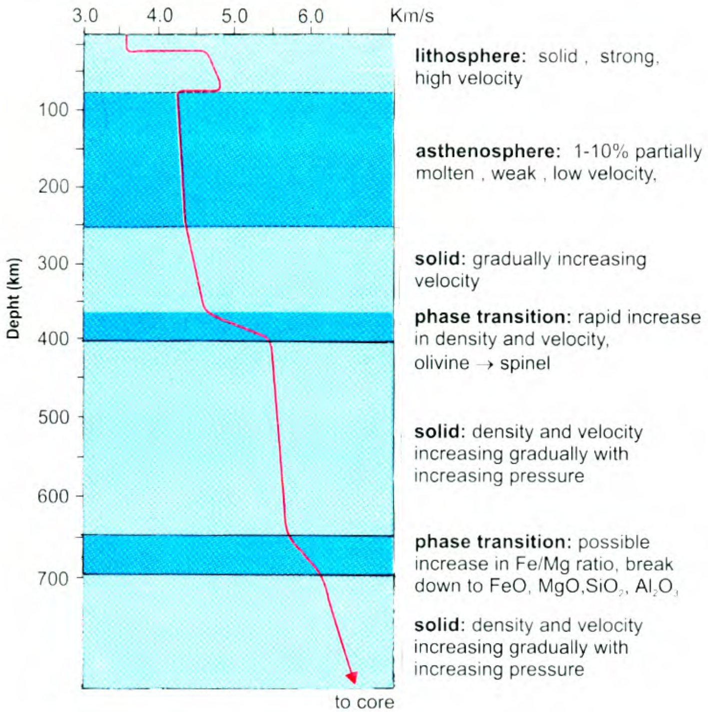


Figure 3.3. Structure of the outer most 700 kilometres of the Earth illustrated by a plot of S-wave velocity (red line) against depth (from Smith 1984).

asthenosphere, which extends down to about 250 kilometres. The asthenosphere is a low velocity, weak and molten layer, which can flow easily. The asthenosphere is largely peridotic in composition.

The boundary between the two represents a phase change, separating the solid lithosphere from the weaker asthenosphere. It may be mentioned here that a change of phase is due to readjustment of the atomic structure of the silicate minerals. At lower pressure each silicon atom is surrounded by four oxygen atoms to form a tetrahedron. At higher pressure and temperature they are squeezed and densely packed with silicon atoms in six-fold coordination, thus causing a phase transition.

Upper Mantle and Transition Zone:
the melting pots for the lithospheric plates.

The upper 700 kilometre thick zone of the earth, comprising the upper mantle and the transition zone, is of particular interest to the earth-scientists owing to frequent variations in its physico-chemical properties, as reflected by abrupt changes in the seismic wave velocities (Fig. 3.3). The layers in which the seismic wave velocity increases rather at a slow rate, reflect zones in which there is a gradual increase in density and pressure.

However, the layers in which the seismic wave velocity rises sharply are believed to be the phase transition zones in which mineralogical changes take place (Smith 1984).

These features provide mobility to the upper mantle and its underlying layers. The low velocity zone in the upper mantle, at 80-120 kilometre depth is the one in which considerable flow and motion takes place (Sawkins et al. 1974). Further evidence of mobility of the material in the upper mantle is provided by diamond bearing *kimberlite pipes*. These pipes are mainly composed of olivine, pyroxene and garnet and form in the upper mantle at about 50-kilobar pressure and 150-300 kilometres depth (Sawkins et al. 1974). They have been ejected on the earth's surface in the form of volcanoes, the tops of which have been eroded and their root zones are seen today in the form of pipes. It is interesting to note that the deepest known earthquakes occur at depths of about 700 kilometres. The subducted lithospheric plates are totally consumed by the time they reach this depth. It coincides with the presumed phase change at the top of the lower mantle.

PLATE TECTONICS AND MINERALISATION

Laboratory experiments show that the minerals olivine and pyroxene, which comprise the bulk of the upper mantle, deform under high pressure and temperature and thus facilitate plastic flow. The physico-chemical characteristics of the mantle provide a dynamic picture of a mobile mantle, wherein the lithospheric plates are moving laterally over the asthenosphere. A number of models have been proposed for convection in the mantle as the driving mechanism for the movement of the plates. However, before we consider some of these models, here it would be pertinent to take a look at the lithospheric plates.

Earth's lithospheric plates and their motion

The earth is shaken by thousands of earthquakes each year. These earthquakes largely originate along linear belts that girdle the earth. These seismic belts are also associated with active volcanoes (Fig. 3.4). They delineate zones of weakness and instability in the earth's crust and define the margins of the lithospheric plates (Fig. 3.5). These plates are and have been in motion in the geological past as well. It has been proposed that the production of radiogenic heat within the mantle causes convection currents which move the lithospheric plates (Holmes 1928). According to this concept convection cells extend through the entire mantle (Fig. 3.6a). Another view is that the main driving force is provided by the sinking of the lithospheric plates along plate margins in the subduction zones. This force pulls the lithosphere over the asthenosphere (Smith 1984). In this situation (Fig. 3.6b) the mantle convection cells are confined to depths above the phase transition from olivine to spinal (400 to 500 kilometre depth). Yet another model (Wyllie 1976) suggests that the convection cells are confined to the asthenosphere (Fig. 3.6c).

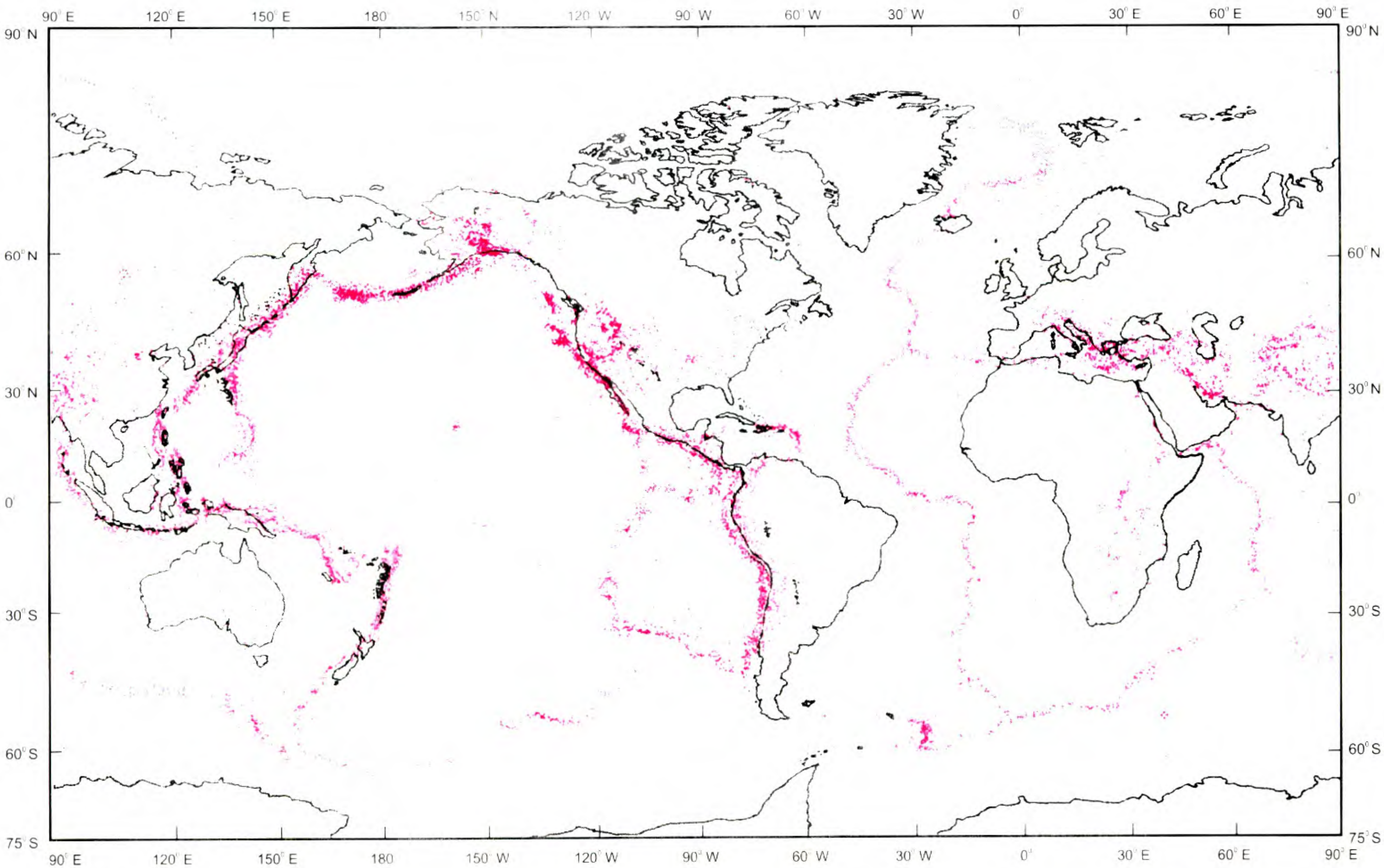


Figure 3.4. World map of earthquake epicenters. The red dots represent epicenters down to a depth of 700 kilometres.

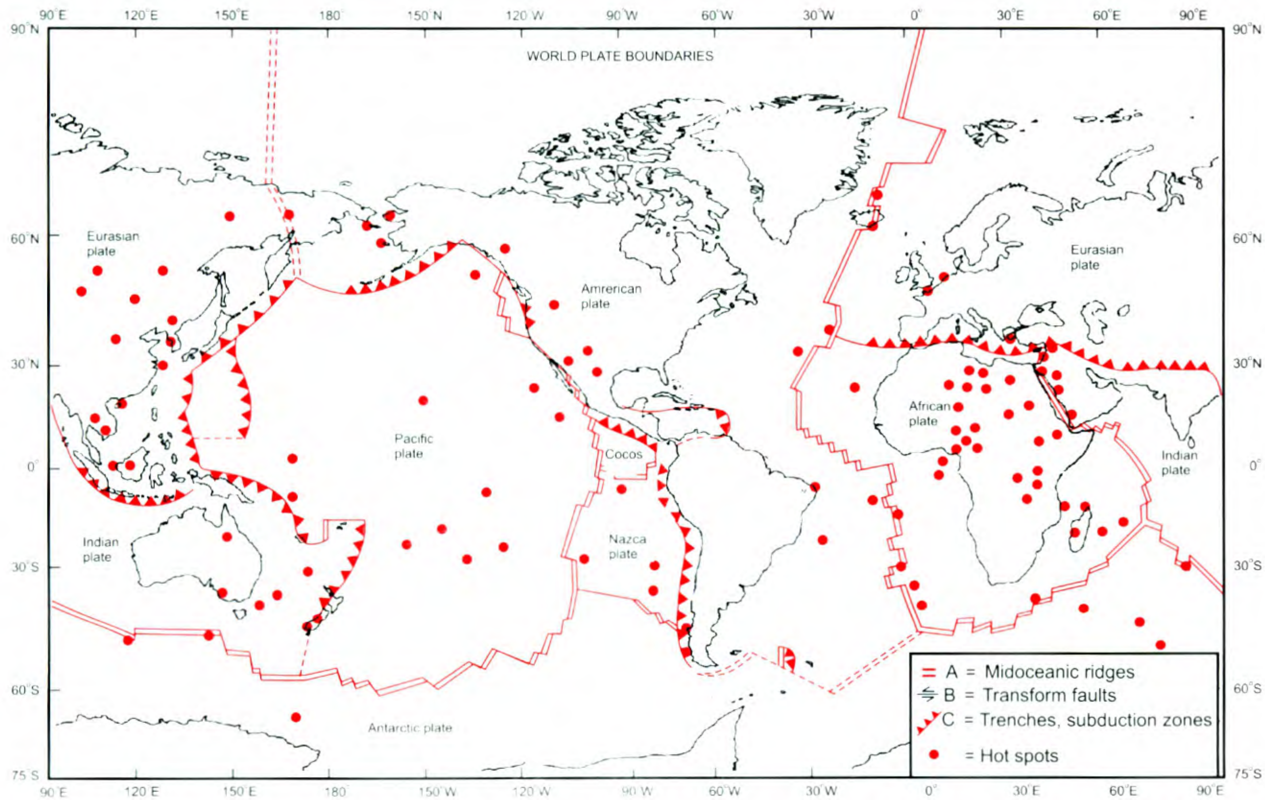


Figure 3.5. Major plates of the world. **A**= Midoceanic ridges at which the plates move apart, are represented by double lines. **B**=Transform fault boundries are shown by single lines. **C**=Trenches and other subduction zones are marked by lines with teeth on side. The teeth point down the descending slab. Dotted lines are used where the exact location or nature of the boundary is uncertain. Large dots show some of the hot spots. They are found on all the major plates and on both oceanic and continental crust, but their distribution is decidedly not uniform. There is a concentration along midocean ridges, and in particular along the Mid-Atlantic Ridge. What is even more conspicuous, of the 122 hot spots, 43 are on the African plate. Together with other evidence, this abundance of hot spots suggests that the African plate is stationary over the mantle. If the Africa is adopted as a frame of reference, other areas that have many hot-spot volcanoes, such as Antarctica and Southeast Asia, are found to be moving only slowly. On fast-moving plates hot-spot volcanism is rare (from Wilson 1976, Smith et al. 1984).

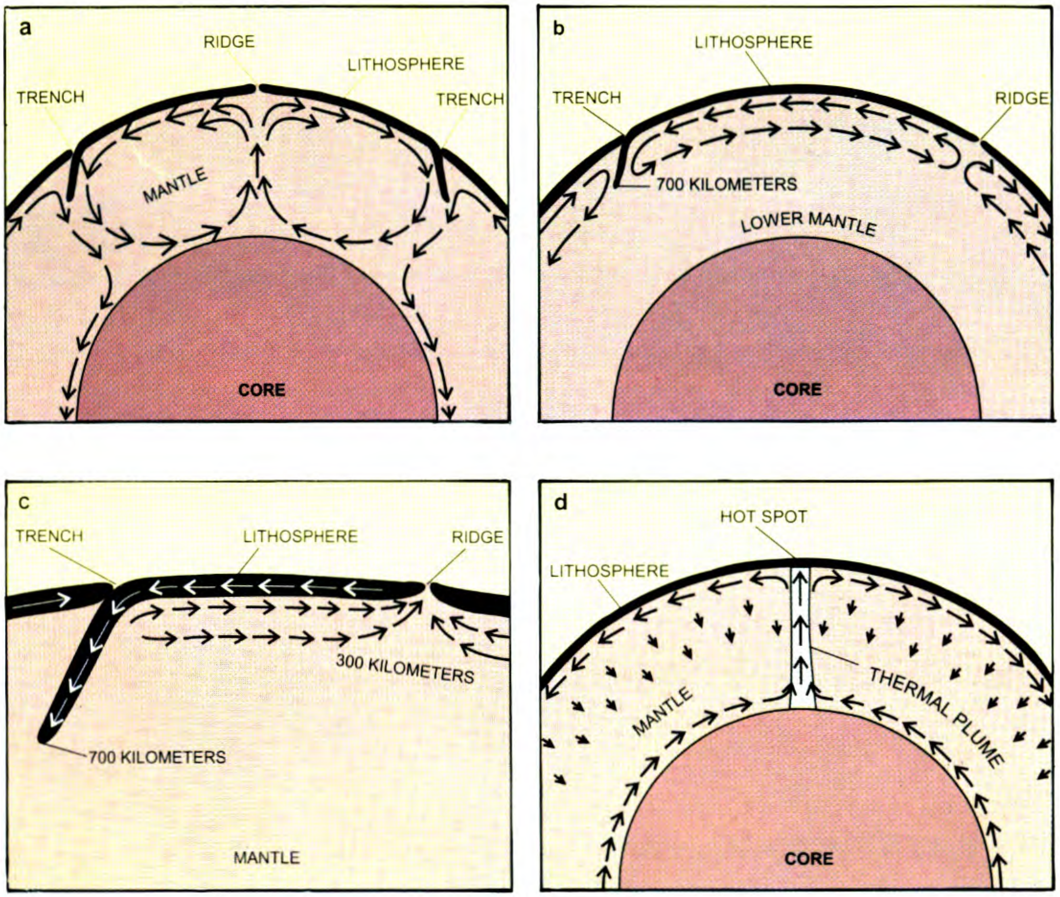


Figure 3.6: Models for crustal plate movement. Convection models have been proposed to explain how activity in the mantle drives the lithospheric plates. In convection warmer material moves upward and colder material moves downward. One model (a) holds that convection cells extend through the entire mantle. According to a second model (b), they are confined to depths above the phase transition from spinel to olivine. A third model (c) confines movements of the mantle to the asthenosphere. In the thermal-plume model (d) all upward movement is confined to a few thermal plumes, and the downward flow is accomplish by slow movements of the remainder of the mantle (from Wilson 1976).

Mantle plume, hot spots and rifts

According to a widely held view, the plate driving mechanism involves vertical upward movement of hot mantle material from near the core–mantle boundary. These upward mantle currents are a few hundred kilometres in diameter and are known as *thermal plumes*. As a plume reaches the lithosphere, the flow becomes horizontal and spreads radically in all directions (Fig. 3.6d). It causes an upward doming of the lithosphere. The dome and the consequent volcanism characterise a *hotspot*.

Whereas most of the active volcanoes are confined to the plate margins, the hotspots are largely located in the intraplate region. World wide there are at least 122 hotspots that have been active in the past 10 million years (Burke and Wilson 1976). They form elevated domes 200 kilometres across and are centres of volcanic activity (Fig. 3.7). They are characterised by alkali-rich basalts. Besides providing a mechanism for translating the relative motion of lithospheric plates with respect to the mantle, the hotspots may also initiate plate tectonic activity.

The dome that swells up over a hotspot is subject to fracturing and rifting. Commonly these rifts have three (or more arms) and they are often the prime location from which an ocean grows. Two arms of the rift open to form an ocean, while the third arm fails and hangs on to the continental land mass in the form of a rift valley. This failed rift is often referred to as an *aulacogen*. Such rifts may be seen extending from folded mountain belts into the continental platforms (Fig. 3.7).

The rifts that open up to form an ocean become the focus of extensive extrusion of basaltic lava flows. These flows eventually form *mid-oceanic ridges*, where new crust is added regularly. The lithospheric plates on either side of the spreading centre move laterally and collide with the adjacent lithospheric plates (Fig. 3.8). It is interesting to note that while new crust is being regularly formed along the mid-oceanic ridges and spreading centres, the older lithospheric crust along plate margins is being lost to the asthenosphere through subduction. The growth of new lithosphere is thus balanced by the destruction of lithosphere elsewhere.

Mineralisation associated with hotspots, aulacogens and rifts

Hotspots, aulacogens and rifts (Fig. 3.7) are venues of different types of mineralisation. Intra-continental hotspots often bear tin, niobium and fluorite deposits. Minerals associated with aulacogens and rift zones include lead, zinc, silver, niobium and REE in carbonatites, copper in volcanics, deposits o^f uranium, thorium, niobium, beryllium and zirconium, barium and rare earths, Mississippi-type lead, zinc and barium (Windley 1984).

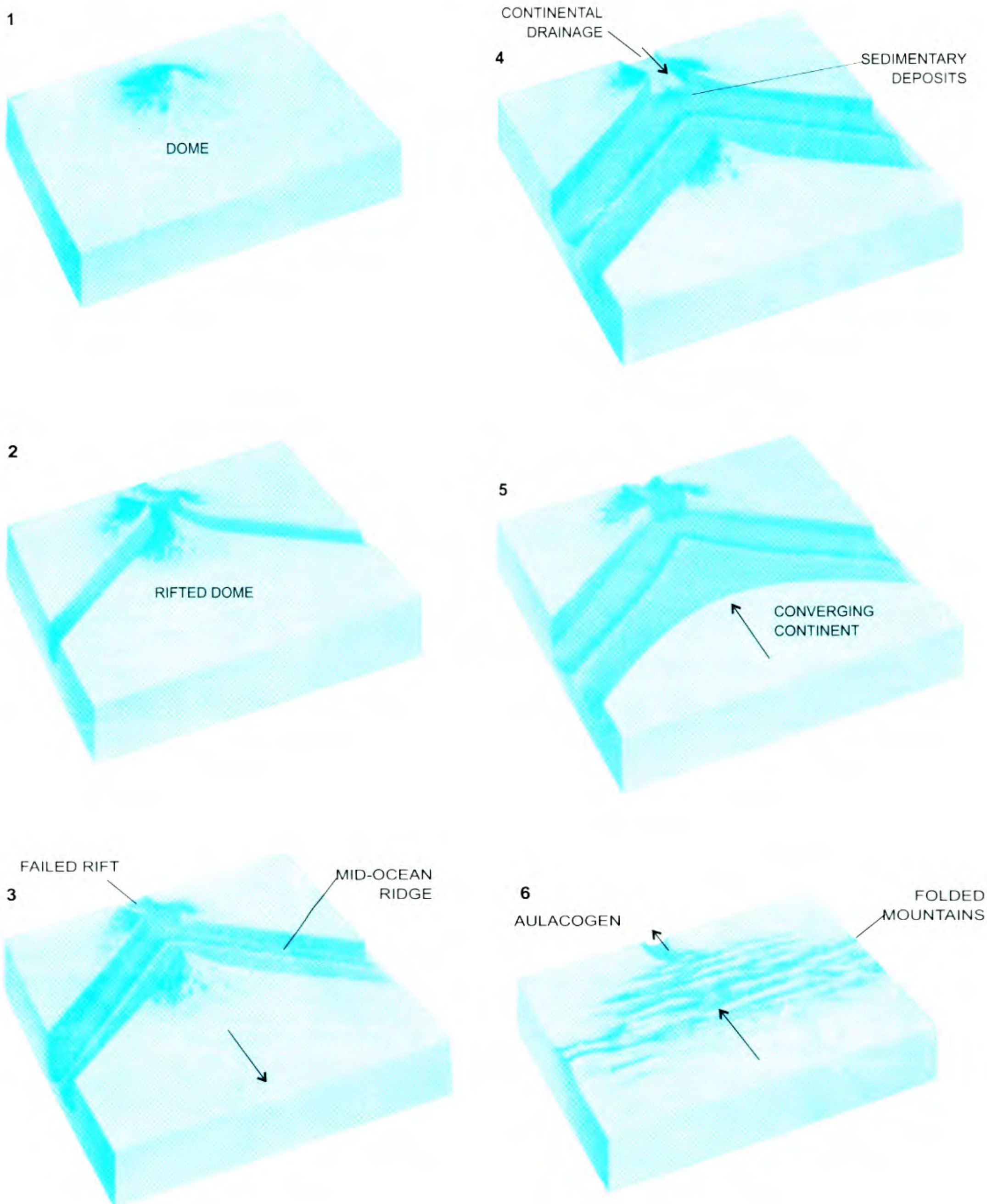


Figure 3.7. Diagram showing role of hot spots in rifting and continental drift (from Burke & Wilson 1976).

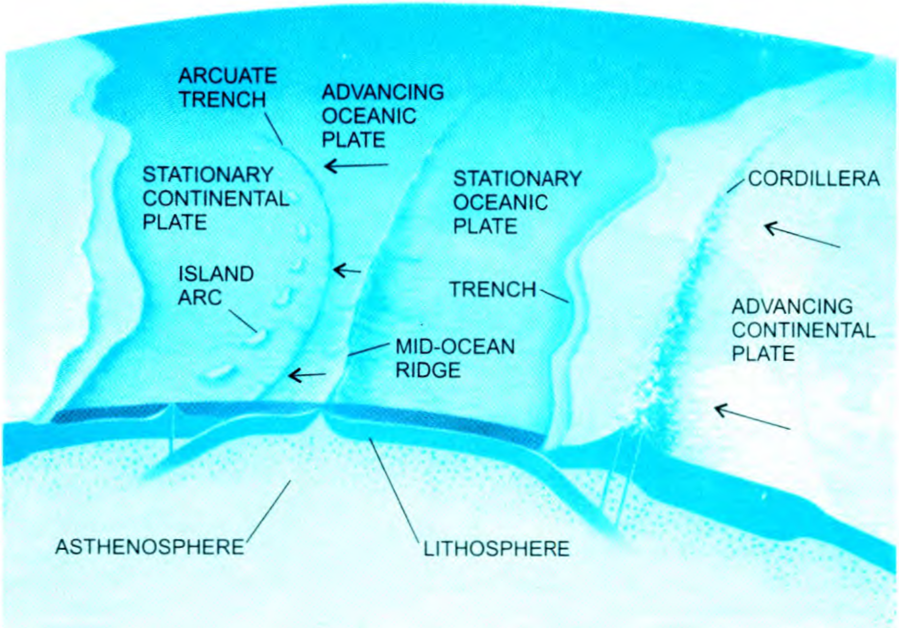


Figure 3.8. Convergent plate margin. These can assume two different forms. Where an oceanic plate is advancing on a stationary continent, the thin and flexible sea floor buckles offshore in a characteristic arcuate pattern. The volcanoes rising above the subduction zone create an island are like the areas of Japan and Indonesia. When a moving continent overrides a stationary oceanic plate, the descending slab of lithosphere is forced to bend the coastline; as a result the volcanoes rise through the continent, forming a mountain system such as the Andes (from Burke & Wilson 1976).

PLATE MARGINS AND MINERALISATION

The foregoing discussion provides an over-simplified view of the processes and mechanisms that are responsible for plate tectonics. This activity is most vigorous along plate margins, which are also the sites where most ore deposits form. The plate boundaries are of three main types: divergent, collisional and transform.

Divergent plate-margins and associated minerals

The divergent boundaries are characterised by mid-oceanic ridges, rifting, widespread volcanism, formation of new oceanic crust and shallow earthquakes (<70 km) which show focal mechanism solutions typical of normal faulting. The ore deposits that form at the oceanic ridges (Figs. 3.7 and 3.8) comprise iron and manganese ore in the oceanic sediments and massive sulphides (Cu, Ni, Cd, Zn, Hg, As, and U) in the volcanics, and chromite and platinum group elements (PGE) in ultramafics.

Convergent plate-margins

The convergent plate boundaries are rather complex and comprise two colliding plates (Fig. 3.8). Collision may be between two oceanic plates, an oceanic and a continental plate or two continental lithospheric plates. One of the colliding plates is deflected down into the asthenosphere, a process known as *subduction*. In case the convergence is between a continental and an oceanic plate, it is the oceanic plate that is subducted owing to its greater density and being cooler. Depending upon the prevailing physico-chemical conditions, it may retain its identity down to a depth of up to 700 kilometres and then it is eventually resorbed. The continental plates comprise lighter material and are not easily forced down or consumed by subduction.

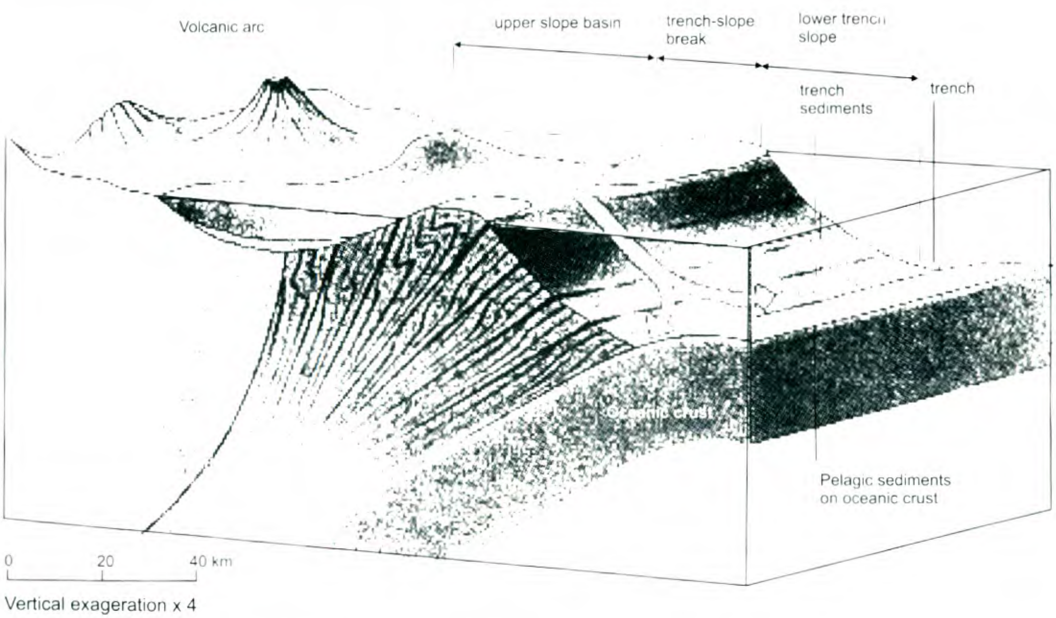


Figure 3.9. Block diagram of a subduction zone, showing the trench, trench sediment (accretionary prism) and the formation of an arc terrain (from Smith 1984)

Convergent margins comprising two approaching oceanic plates are characterised by an *oceanic trench* which forms between the descending and overlying plates. The trench gets filled up with the oceanic sediments scraped off the descending lithospheric plate. It also contains disrupted and broken blocks of crust and mantle material (melange). This material forms a sedimentary wedge or *accretionary prism* beneath and behind the trench. It is strongly deformed and metamorphosed to the blueschist facies. Prolonged accretion often gives rise to a ridge which forms the outer arc terrain, with an upper-slope basin behind it (Fig. 3.9). When the descending plate carrying hydrated oceanic crust and oceanic sediments reaches a depth of about 100 kilometres, dehydration releases hydrous fluids into the overlying mantle. It causes melting, rise and intrusion of magma into the over- riding plate and produces surface volcanism (Fig. 3.11). This leads to thickening of the over-riding plate and forms extensive island arc orogenesis along subduction zones (Fig. 3.8).

Convergent zones comprising continent to continent collision are characterised by complex structures and formation of large mountain chains. When the two converging blocks approach, the intervening oceaning crust is consumed through subduction and a trench is formed in between. As in other instances, this trench is filled up by oceanic sediments and fragments of *ophiolites* which comprise rock fragments from the oceanic crust. The trench material is deformed and metamorphosed. It is often intruded by late magmatic rocks and thrust over the earlier continental rocks (Fig. 3.10). The trench zone now forms a narrow suture zone, containing oceanic sediments, flysch type rocks and melanges with ophiolites.

The *island arcs* occur as arcuate or linear belts, often several thousand kilometres long (Fig. 3.8) and are characterised by a positive gravity anomaly and relatively high heat flow. They are comprised of rocks of basic and intermediate composition (gabbro and diorite) emplaced into the crust. A volcanic pile of basalt and basaltic andesite accumulates at the surface. The island arcs are often split by back-arc spreading and form a back-arc and a fore arc. This creates a shallow marginal basin on the continental side. On the oceanic side the arcs are followed by the accretionary wedge and the oceanic trench of the subduction complex.

Collision of a continental and an oceanic plate results in a sequence of events not very different from those occurring at collision of two oceanic plates as discussed earlier. The presence of continental crust, however, provides additional complexities and leads to the formation of a cordillera-type orogenic belt along continental margins, rather than an island arc (Fig. 3.12). Magma generated in the subduction zone migrates upwards and leads to under plating and thickening of the continental crust. Uplift causes subsequent sub-aerial volcanism. The intrusive rocks comprise diorite-granodiorite-granite association and the erupted rocks are rhyolite, andesite, dacite and pyroclastics.

Mineralisation associated with convergent plate margins

The convergent plate margins, also referred to as destructive plate margins, are the most highly mineralised ones (Figs. 3.13 and 3.14). The mineralisation characteristic of various tectonic zones of such margins is briefly summarized below.

Mineralisation along colliding oceanic plates

Island arc: In this environment porphyry copper ores containing 0.4 to 1.0% disseminated

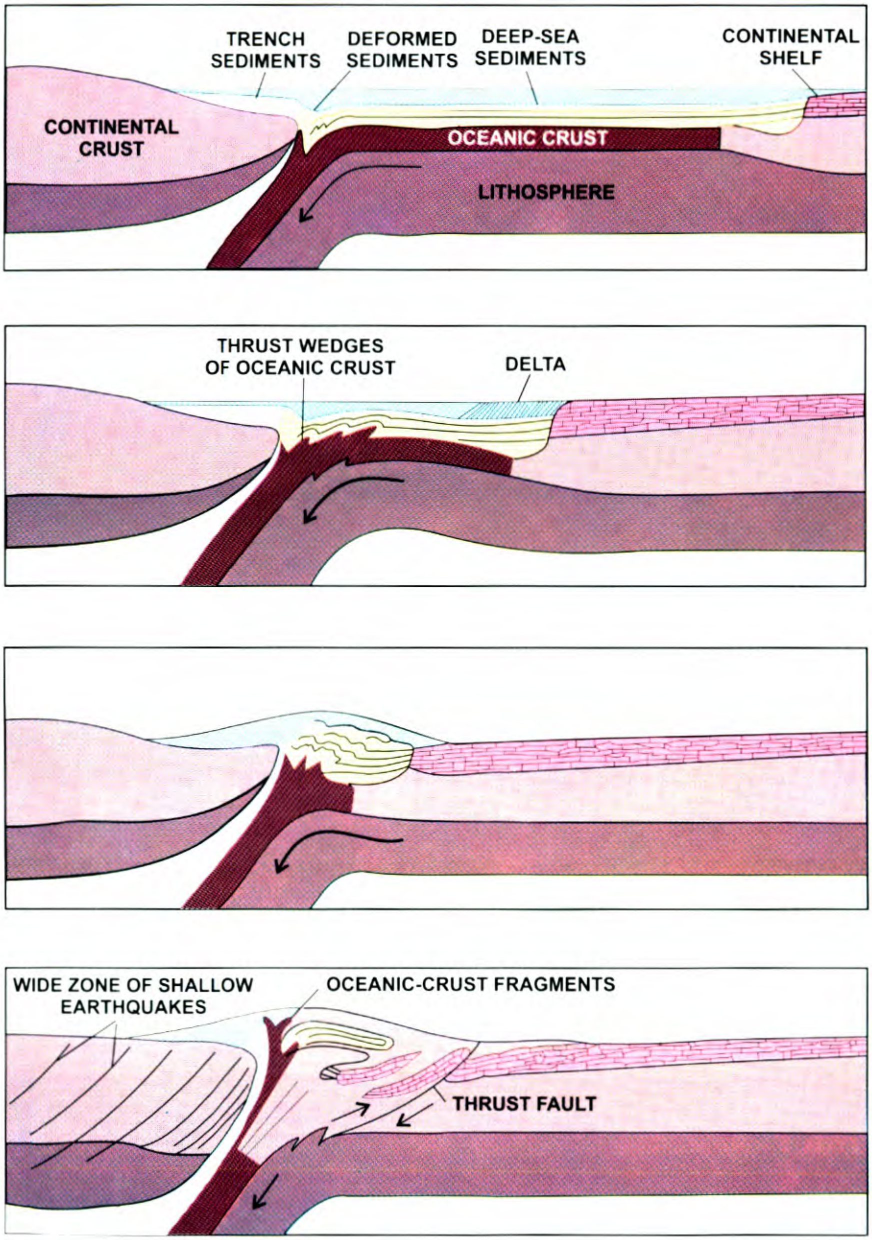


Figure 3.10. Sketches showing continent to continent collision. This occurs when an oceanic slab that is subducting at the edge of one continent (left) is itself part of a lithospheric plate bearing a second continent (right). Such a collision took place when the Indian lithospheric plate, traveling generally northward for 200 million years, was subducted under Eurasian plate. This kind of subduction eventually ends, but not before crust of subducting plate has been detached and deformed and has pushed up a mountain range, (in the case of the Indian plate the Himalayas) (From Toksoz 1976).

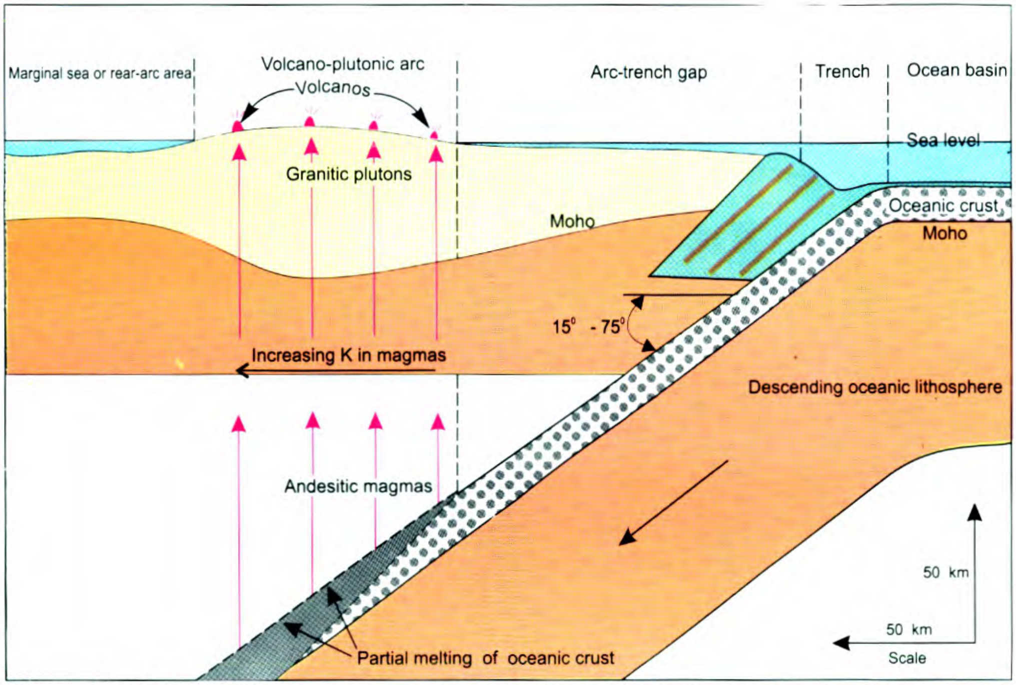


Figure 3.11. Generalized cross section of an arc trench system to illustrate the concept of generation of arc magmas by partial melting of oceanic crust subducted at a convergent plate boundary. Note that for clarity the basaltic magas generated from the mantle overlying the Benioff zone have been omitted from the diagram. (From Sawkins 1974).

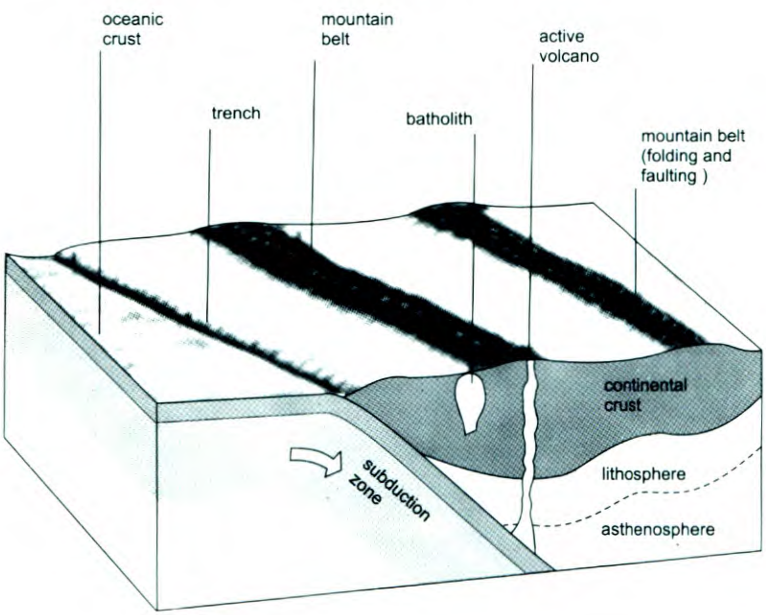


Figure 3.12. Destructive plate margin of cordilleran type. Subduction of oceanic crust along a trench gives rise to mountain-building and intrusive and extrusive igneous activity within the continent (from Smith 1984).

copper are associated with porphyritic intrusions (diorite, granodiorite and granite). The primary ore minerals comprise chalcopyrite, bornite and pyrite with some molybdenite. Kuroko-type lenticular deposits of massive sulphides interstratified with submarine volcanic rocks containing iron, zinc, lead, copper and minor amounts of silver and gold also occur in the island arc terrain (Fig. 3.13A). These deposits are believed to have formed from submarine hot springs related to explosions on flanks of the submarine dacite or rhyolite domes (Smith 1984).

Arc-trench gap: Besshi type stratiform sulphide deposits (chalcopyrite, sphalerite, pyrite) are associated with volcanic rocks and deep-water sediments in arc-trench gap. They have higher contents of lead, zinc, silver and barium (Windley, 1984).

Back-arc: This region contains tin ore disseminated in dacite, rhyolite, and sedimentary rocks (e.g. Bolivia). Besides tin (cassiterite) some deposits contain tungsten (wolframite and scheelite) as in Burma and Thailand.

Outer-arc: It is commonly associated with tin, copper and arsenic deposits containing lead and zinc also. They occur in S-type granites intruding flyschoid rocks (e.g. in Japan). Disseminated sulphide deposits also occur in this zone and contain pyrite, chalcopyrite, sphalerite and smaller amounts of galena and pyrrhotite. The ophiolitic masses which often occur in the outer arc contain pods of chromite and nickel sulphide segregations (Smith 1984).

Mineralisation along cordilleran-type margins

We have discussed earlier that new magmas are generated at successive pressure/ temperature levels along a collision zone when an oceanic lithospheric plate is carried down a subduction zone. These magmas form plutonic and volcanic rocks, as well as mineral deposits, which change in composition and type with increasing distance from the trench. The mineral deposits formed across island arc and cordilleran margins are substantially similar. The prime examples are the mineral deposits formed along the continental margin of eastern Pacific, commonly referred to as the Andean-type (Fig. 3.14). They include contact-metasomatic iron deposits, copper-gold and silver veins, Manto-type copper deposits, stratiform manganese deposits, copper-bearing breccia pipes, porphyry copper, molybdenum deposits, copper-lead-zinc-silver deposits of vein-type and contact- metasomatic type copper-lead-zinc-silver deposits, volcanogenic iron deposits, tin-wolfram and tin silver veins, porphyry type tin deposits and magmatogenic copper-gold-molybdenum, copper-lead-zinc-silver and tin-wolfram-silver-bismuth deposits (Windley 1984).

Mineralisation along continent to continent collisional margins

These contain tin deposits mainly in S-type granites which formed within the continental crust during or following collision. A host of pegmatite ore minerals such as beryllium, rubidium, cesium, tin, titanium, niobium, tantalum, lithium, radio-active minerals, besides mica and gemstones are also found in the continental fold belts. The sedimentary basins along continental margins often contain reworked deposits of gold and uranium in conglomerates, manganese and lead-zinc in sediments, banded iron ores, copper, uranium and vanadium in clastics.

Transform plate-boundaries

Along these boundaries, adjacent lithospheric plates are in contact and slide past each other without addition or destruction of any crustal material. The contact zone comprises the strike-slip type transform faults. The shear motion across the fault produces ridges and troughs that run roughly parallel to the motion. The San Andreas, Anatolian and Chaman faults are some of the famous transform boundary faults.

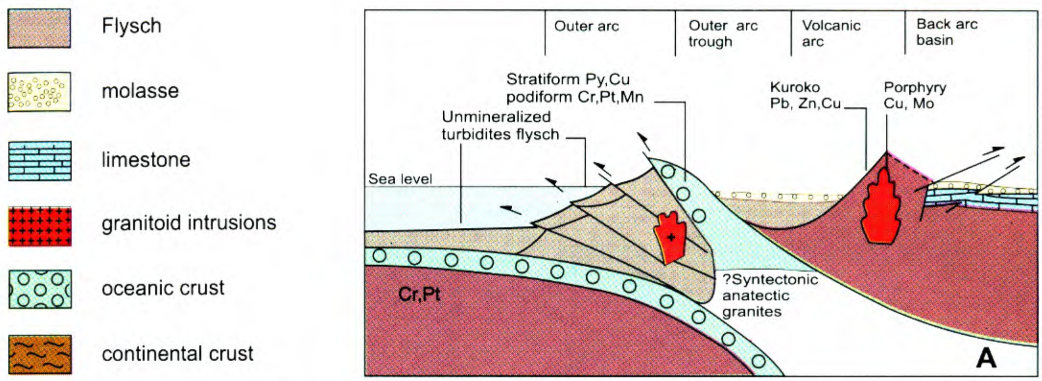
Mineralisation along transform fault

Metalliferous exhalations from the deeper parts of the crust apparently emanate along the transform faults and form ore bodies. The lead, copper and manganese deposits in the Red Sea region, porphyry copper deposits in Philippines, barium deposits along San Clements Fault zone and manganese deposits along Romanche Fracture zone are but a few example of mineralisation along transform faults (Windley 1984).

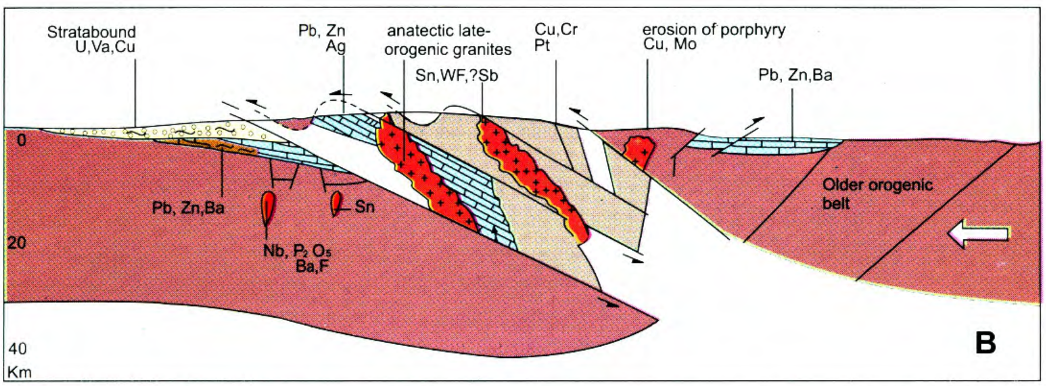
FORMATION OF MINERAL-BEARING SEDIMENTARY BASINS

Movement of lithospheric plates control locations, formation and preservation of sedimentary basins in intraplate environments due to plate margin processes. These include lateral flow of material in the ductile lower crust leading to stretching, thinning, faulting and thermal as well as isostatic subsidence of the lithosphere. Far from plate margin a sedimentary basin may form due to the processes initiated by a hot spot. In the mantle it creates a vast amount of low density material and a basin takes shape. According to Kearey and Vine (1990) the various types of sedimentary basins, which contain mineral and hydrocarbon deposits, include:-

1. Basins associated with continental rifting, e.g., Gulf of Suez and the Red Sea.
2. Passive continental margin basins, e.g., the Gabon Basin.
3. Ensialic back-arc basins, e.g., the Oriente Basin of Ecuador and Peru.
4. Forearc basins, e.g., the Cook Inlet of southern Alaska.
5. Pull-apart basin, associated with wrench faults, e.g., the Los Angeles Basin.
6. Himalayan-type foreland basins.



A. Location of different types of mineralisation in an island arc orogenic belt.



B. Location of different types of mineralisation in the late stages of continent to continent collisional zone

Figure 3.13 . Mineralisation in island arc and continent - continent collision environments (from Smith 1984).

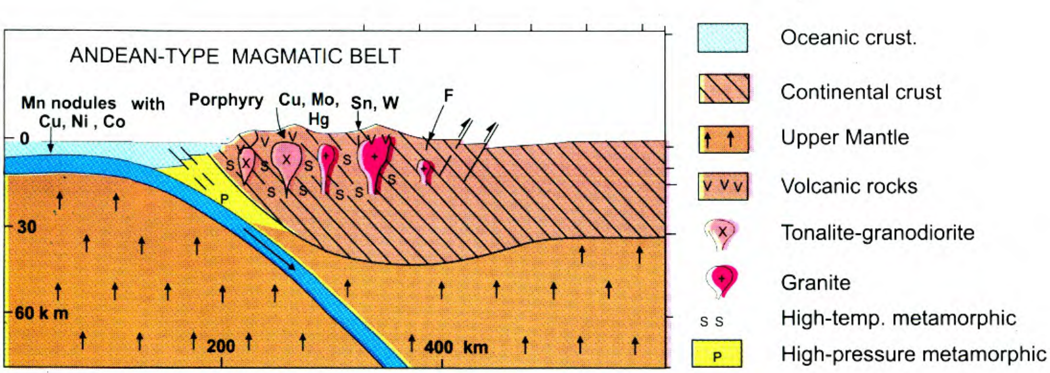


Figure 3.14 . Location of different type of mineralisation in an Andean-type magmatic belt (from Windley 1984).

7. Tensional basins associated with indentation tectonics, e.g., the Rhine Graben.

8. Marginal seas, e.g., the Andaman Sea.

9. Accretionary prisms, e.g., the coastal oil-fields of Ecuadur and Peru.

10. Intracratonic basins formed by hotspot activity, e.g., Paris and Michigan basins.

Valuable deposits of evaporites, limestone, dolomite, diatomite, rock phosphate, iron ore, manganese, clays, coal, oil and gas, Mississippi and Sedex-type lead, zinc, barite, celestite and other minerals are formed in these sedimentary basins.

PLATE TECTONICS AND DRIFTING OF CONTINENTS THROUGH THE AGES

In the previous pages we have given a very elementary outline of the earth's plates and the mechanism that keeps them adrift and in motion. We have briefly discussed the processes that form new oceans through rifting, create oceanic ridges, form new oceanic crust, make the continents to collide and destroy the ancient oceans through subduction of their lithospheric plates, give rise to some of the earth's most pronounced physical features, such as the oceanic ridges, the oceanic trenches, the chain of volcanic islands, island arcs and their associated basins and the large mountain chains of the world. And most significantly we have pointed out how these plate tectonic processes lead to the concentration of valuable elements and formation of major ore deposits in various geological environments. It would now be pertinent to briefly review the drifting of the continents through the ages, particularly with reference to the Indo-Pakistan subcontinent.

Some of the plate tectonic processes have been in operation probably since the Archaean times. Geomagnetic data (polar wandering curves) suggest that as early as over 3,000 million years ago, continental areas were moving re'ative to the poles (Smith 1984). The thick greenstone belts which largely formed 2,700-2,600 million years ago are believed to have formed due to a sag-subduction or rift-and-sag process (Goodwin 1981). Earlier a subduction-controlled, island arc model was proposed by Anhaeusser (1973). According to Windley (1984), a modified type of plate tectonics, which he calls the proto-plate tectonic model, was in operation during the Late Archaeans. It was, however, during the Early Proterozoic Era (2,500-1,600 m.y. ago) that the modern-type plate tectonic process came into full play. It was during this period that the first aulacogens, Andean-type orogenic belts and asymmetrical mobile belts were formed (Windley 1984). Large-scale continental drift and frequent global rearrangement of the continental land masses was also initiated from this period onward. Palaeomagnetic data suggests that during the Proterozoic there was one supercontinent surrounded by the ocean (Fig. 3.15). Subsequently, by the Cambrian period (535 m.y.), it was split into several small continents that drifted away. By the Permian period (about 280 m.y.), these land masses regrouped to form once again another supercontinent, the Pangaea (Fig. 3.15). This supercontinent lasted for about 100 million

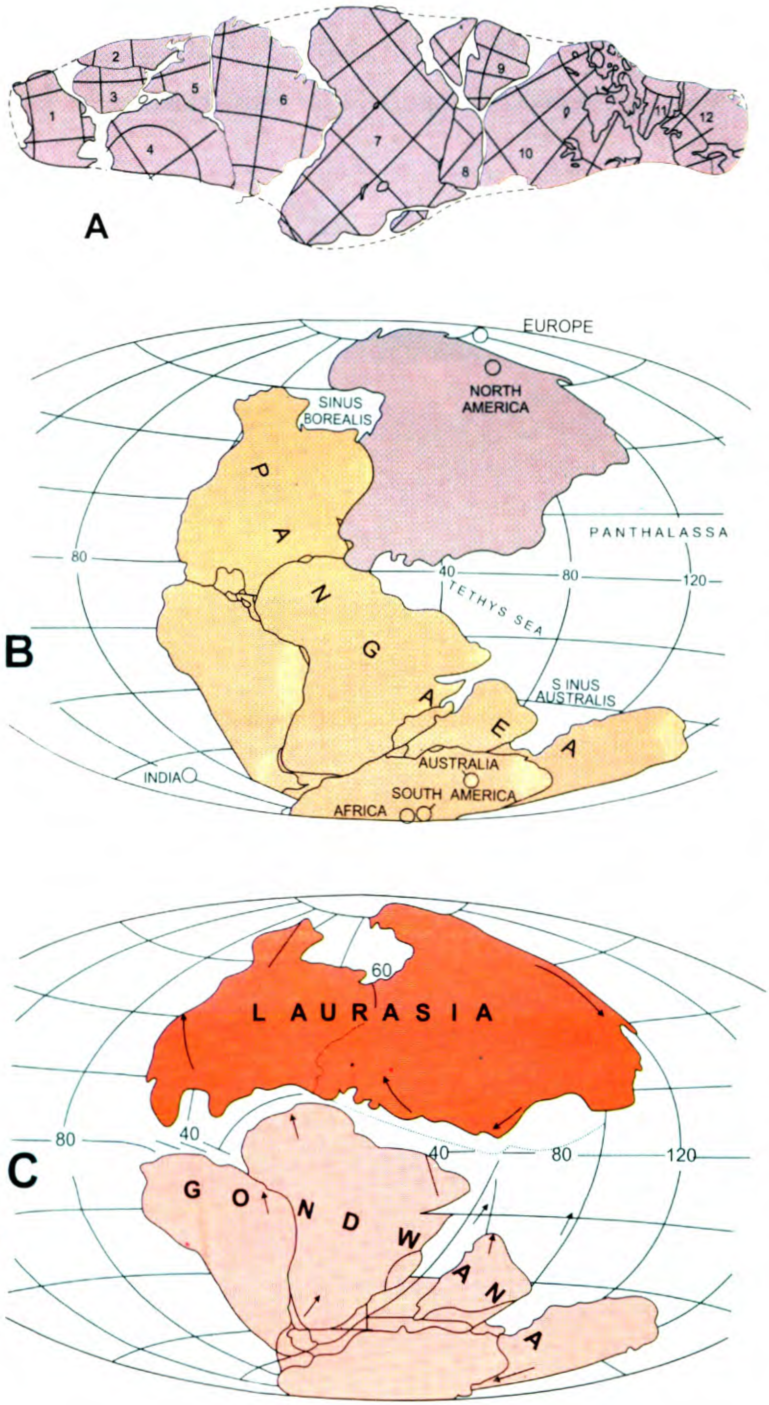


Figure 3.15. Assembly and break up of ancient continents.

A The Late Proterozoic (750 million years) super continent 1= Australia, 2= N. China, 3 = S. China, 4 = Antartica 5 = India, 6 = S. America, 7 = Africa, 8 = Arabia, 9 = Siberia, 10= N. America, 11= Greenland, 12 = Fennoscandia-Ukrain.

(From Piper 1987) **B** Pangaea, the Late Paleozoic (350 million years) supercontinent.

C. Break up of Pangaea into Laurasia and Gondwanaland supercontinents (180 million years ago.) (from Dietz and Holden 1976, Smith 1984).

years and then began to break up. A large ocean, the Palaeo-Tethys divided Pangaea into a northern block–the Laurasian super continent, and a southern block–the Gondwanian super continent (Fig. 3.15).

Beginning with Late Permian (around 250 million years ago) and until the Miocene (about 20 million years ago) several continental blocks were broken loose from the northern margin of the Gondwanaland. They drifted across the Tethys ocean, and successively collided with and were accreted to the southern margin of Eurasia (a fragment of the ancient Laurasia). This process was accompanied by the replacement of the Palaeo-Tethys by several minor oceanic spaces (e.g. the Meso-Tethys and Neo-Tethys), which opened and closed with the northward drifting of each major Gondwanian fragment (Kazmi and Jan 1997).

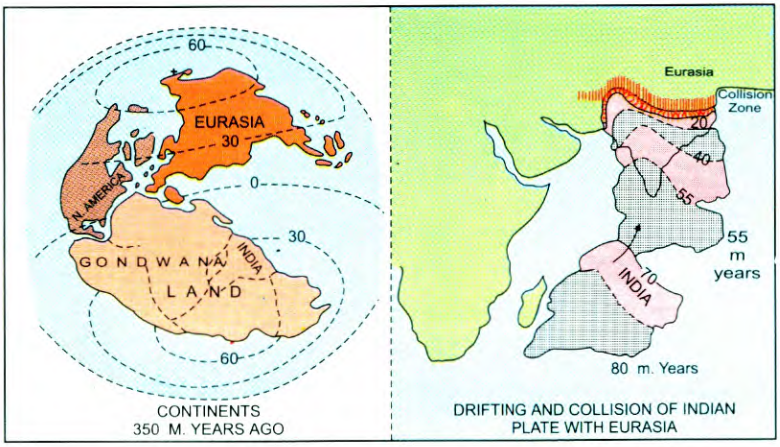


Figure 3.16. Breaking of Gondwanaland and northward drift of Indian subcontinent (Seyfert and Sirkin 1973; Powell, 1979).

The Indo-Pakistan subcontinent, which was earlier a part of Gondwanaland, separated from the motherland about 130 million years ago and drifted northward (Fig. 3.16). While India was drifting, ahead of it intra-oceanic subduction generated a series of volcanic arcs (Chagai, Kohistan-Ladakh, Nuristan and Kandhar). As the back-arc basin closed, the Kohistan-Ladakh arc collided with Eurasia some time between 102-85 million years ago. After accretion to Eurasia, the Kohistan arc formed an Andean-type passive margin. The northward moving Indian plate eventually collided with the Kohistan-Ladakh margin of Eurasia about 65 to 60 million years ago. These events formed the Karakoram and the Himalayan Ranges and controlled the sedimentation and evolution of the sedimentary basins. They produced the various magmatic sequences, formed the significant tectonic features and above all created the associated mineral deposits.

4

METALLOGENIC PROVINCES

REGIONAL GEOLOGICAL SETTING

Pakistan and its surrounding regions consist of three main geotectonic domains. From north to south these comprise (a) the Laurasian, (b) the Tethyan and (c) the Gondwanian domains (Fig. 4.1). In the previous chapter we have briefly discussed the origin of these domains and have shown how the Paleozoic supercontinent-Pangaea was eventually dismembered into two main components, Laurasia in the north and Gondwanaland in the south and that the two were separated by a vast ocean the Paleo-Tethys. The eastern part of Pakistan is a continuation of the Indian peninsular shield which in itself is one of the dismembered fragments of Gondwanaland. North of Pakistan lies the southern portion of the Laurasian Domain. This region it is characterised by a continental crust but also includes remnants of cratonised Paleozoic (Paleotethyan) oceanic crust. It consists of Hercynian (Late Paleozoic) realm of Central Asia, which has been overlapped, deformed and largely consolidated by strong Early Cimmerian orogeny (Stöcklin 1977).

Between the Indo-Pakistan Gondwanian Domain and the Laurasian Domain there is an extensive belt of island arcs and dismembered fragments of the Gondwanaland which have been stitched together, as it were, by a ramifying network of sutures and this enormous collage has been accreted to Laurasia from the Permian up to the Miocene time. We refer to this composite belt of continental blocks and island arcs as the Tethyan Domain (Fig. 4.2). Situated between the Himalayas and the Tien Shan Mountains, this domain is comprised of Central southern-Pamir, Nuristan and Southwest Pamir, Karakoram, Ladakh, the Chagai-Ras Koh magmatic arcs, and the Makran accretionary zone.

The Tethyan Domain is characterised by a Precambrian crystalline basement of Gondwanic affinity. This basement is covered by deformed Platform type Infracambrian to Paleozoic sequence. Mesozoic volcanics and shallow-water carbonates and clastics with coal and evaporite beds unconformably overlie the earlier rocks. The suture zones, along the margins of these blocks, contain relics of the subducted oceanic realms in the form of pelagic sediments, ophiolites and melanges, continental-margin sediments and well developed magmatic arcs, with subduction related as well as convergent margin magmatism. The sutures commonly exhibit greenschist to amphibolite-grade metamor-

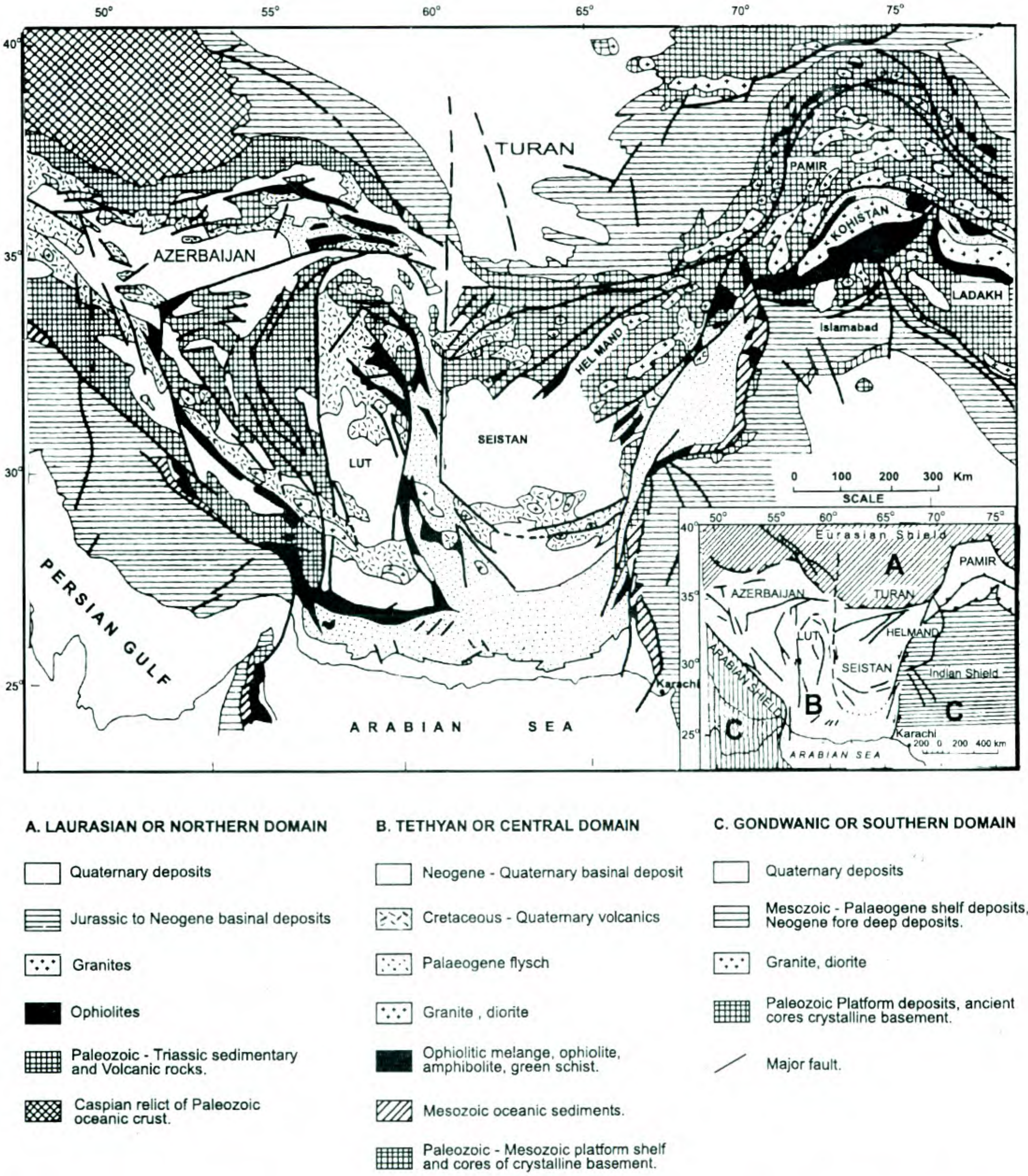


Figure 4.1. Generalised geological map of Pakistan and adjacent areas showing major plate tectonic features (Stöcklin 1977).

phism and local occurrence of eclogites and blueschist. Collision events have led to orogenic movements, syntectonic granites as well as post-tectonic shallow-water limestones and clastics deposited in intracratonic or pericratonic geosynclines (Stöcklin 1981, Boulin 1988).

In Pakistan the Indus suture zone, the Chaman-Nal-Ornach transform faults and the Makran trench form the southern margin of the Tethyan Domain and its contact with the Gondwanian Domain.

The Gondwanian Domain

South of the Laurasian Domain, the greater part of the Indo-Pakistan subcontinent is comprised of the Gondwanian Domain. Traditionally it has been divided into three principal geologic divisions, namely (I) the Peninsular Region, (2) the Himalayan Foredeep and (3) the Himalayas (Wadia 1957). In Pakistan, the Peninsular Region extends up to the eastern part of the Indus Plain and the Cholistan and Thar Deserts. Parts of the Indus Plain and the Kirthar-Sulaiman foot-hills form the foredeep, whereas the Himalayas include the Pir Panjal, the mountain ranges from Hazara to the Afghan border, the Potwar Plateau, the Salt Range and the Sulaiman-Kirthar Ranges.

The Peninsular Region is composed of a series of metamorphosed plutonic, volcanic and sedimentary rocks ranging in age from Archean to Late Proterozoic. These rocks crop out as cratons associated with supracrustal enclaves and surrounded by various Proterozoic mobile belts. The northern margin of the Peninsular shield is covered by Mesozoic to Cenozoic sedimentary cover. Farther northwards, the Himalayas and its subsidiary ranges have formed in the collision zone, on the subducted margin of the Indo-Pakistan crustal plate. Structurally they largely consist of fold belts and crystalline thrust sheets, intruded by syntectonic granites.

The Gondwanian and Tethyan domains of Pakistan are comprised of a number of smaller geological divisions, each characterised by distinctive physiographic, structural and lithostratigraphic set up and having its own typical metallogenic characteristics. We refer to these domains as tectono-metallogenic zones. Pakistan may be conveniently divided into the following broad tectono-metallogenic zones:

GONDWANIAN DOMAIN

Indus basement
Indus platform and foredeep
Foreland sedimentary fold-belt
Ophiolitic thrust belt *and Margalla–Kalachitta thrust belt*
Las Bela
Zhob-Waziristan
Margalla–Kalachitta

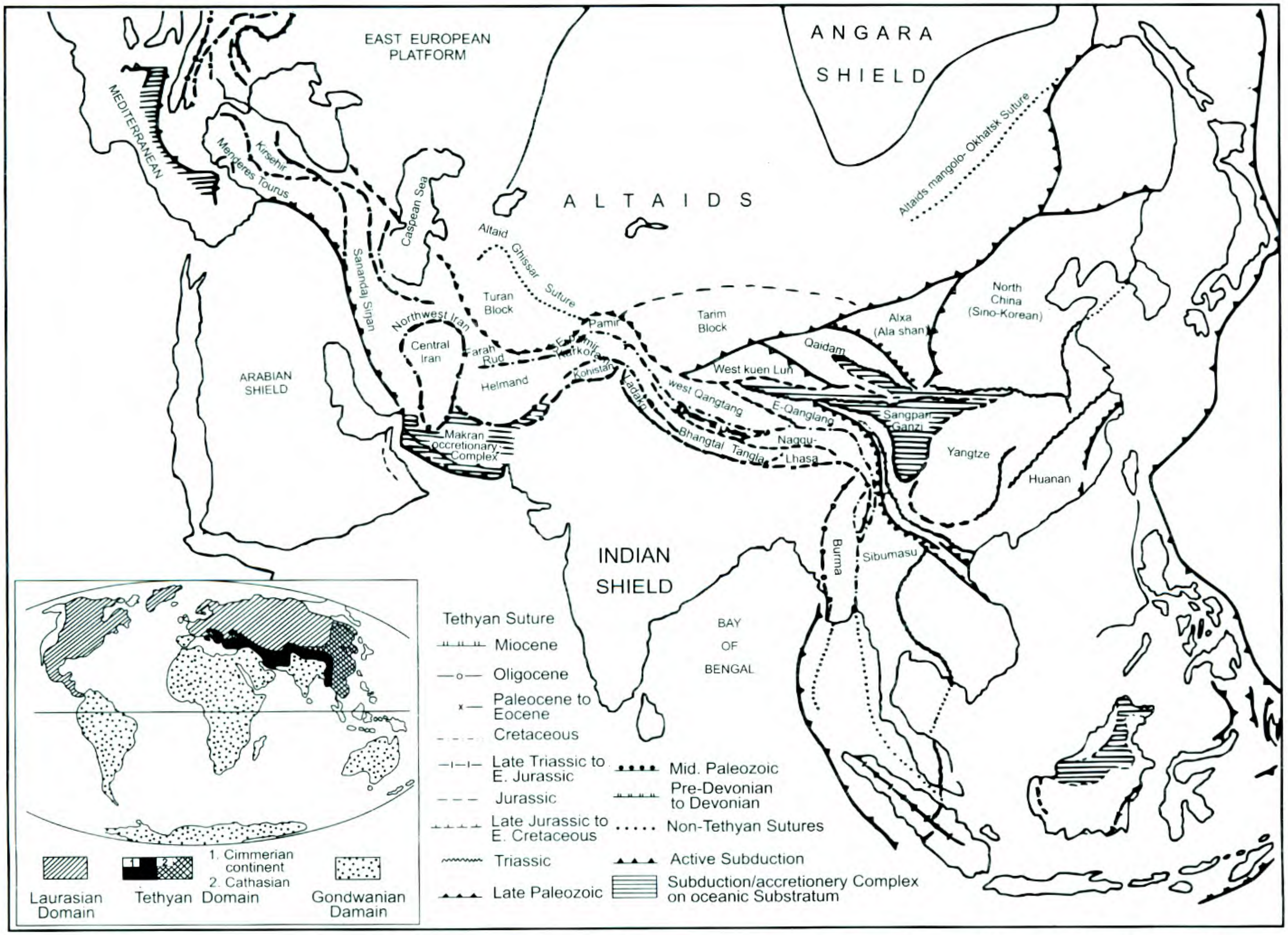


Figure 4.2. Map showing broad tectonic zones of Eurasia and the major suture and accretionary blocks of the Tethyan Domain (madified from Sengor et al. 1988).

TETHYAN DOMAIN

Indus suture zone
Kohistan magmatic arc
Karakoram Block
Chagai-Ras Koh magmatic arc
Balochistan flysch basins

These tectono-metallogenic zones and some of their characteristics have been shown in Figure 4.3 and they are briefly discussed below.

GONDWANIC DOMAIN AND ASSOCIATED MINERALS

Indus Basement

About 870 million years old Precambrian basement rocks crop out in the Sargodha-Shahkot region in the form of small monadnocks. These are the exposed summits of the buried Sargodha-Shahkot ridge, which is the northwest extension of the Indian Peninsular Shield. It is largely comprised of metasediments (phyllites and quartzites) and metavolcanics of the Kirana Group, which may be correlated with the orogenies and mobile belts that formed in several parts of the world at this time, e.g. the Grenville belt in North America, the Pan African belt in Africa, and the Delhi and post-Delhi events in India (Davies and Crawford 1971, Windley 1984, Kazmi and Jan 1997). The Kirana Group sequence contains beds of *magnetite-hematite* with traces of *gold* (Table 9). These may eventually turn out to be similar to the banded iron ore formation of the Late Proterozoic Grenville belt in North America.

Basement rocks also crop out in the Nagar Parkar region, in the southeast corner of Pakistan. These are largely in the form of small scattered hillocks. In this region Late Proterozoic granites intrude a basement comprised of mafic rocks. This sequence is known as the Nagar Parkar Igneous Complex and it is the source of valuable *pink granite* and *kaolinite* deposits.

Indus platform and foredeep

This zone covers the foot-hill regions of the Kirthar and Sulaiman ranges, the Indus Plain and the Cholistan and Thar Deserts. It is underlain by the continental crust and the crystalline rocks of the Peninsular shield overlain by a thick sequence of platform-type, shallow water Mesozoic and Cenozoic sedimentary rocks, capped by Quaternary alluvium. Oil exploration wells drilled in the northern part of the platform show that the Precambrian to Cambrian sediments overlie the crystalline sequence. In the platform zone the sedimentary sequence slopes gently westward and in the foredeep region it forms broad, gentle folds with N-S axes. The folds are

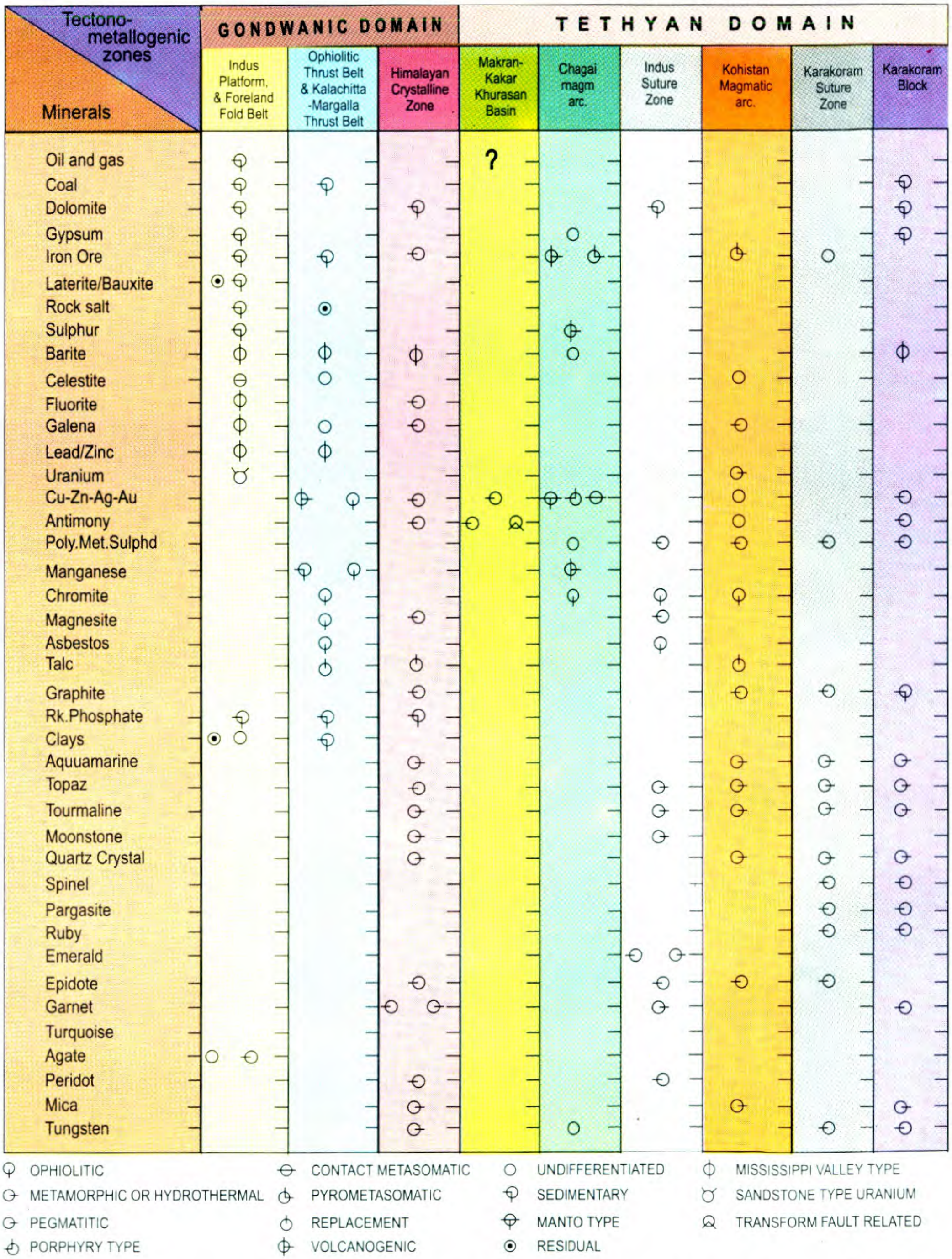


Figure 4.3. Map showing tectono-metallogenic zones of Pakistan (right), and some of the more common and significant mineral occurrences (left) which characterize there zones (from Kazmi and Snee 1989).

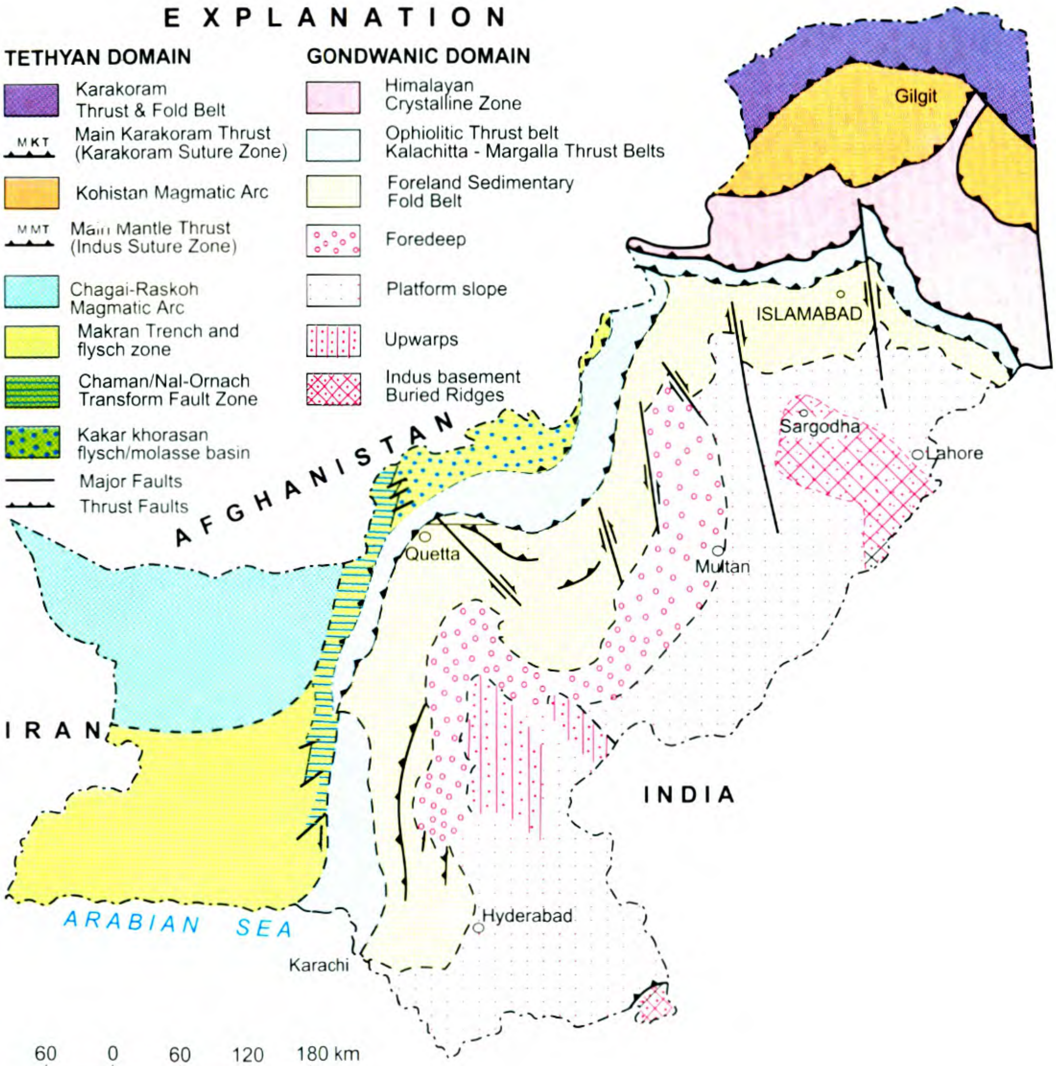


Figure 4.3. (Continued) Map showing tectonic-metallogenic zones of Pakistan and some of the more common and significant mineral occurrences which characterise these zones.

commonly affected by strike faults. The basement is also extensively traversed by faults, contains horst and graben structures and ancient rift valleys (Kazmi and Jan 1997). The sedimentary sequence in this zone contains valuable deposits of *oil*, *gas* and *coal*. The upwarp zones contain deposits of *Fuller's earth, dolomite, limestone* and other building stones.

Foreland sedimentary fold-belt

This belt forms the hill-ranges west and north of the Indus Plain (Potwar Plateau, Salt Range, Trans-Indus Ranges, Sulaiman Range, Kirthar Range). It is characterised by a thick shallow-water sequence of Mesozoic to Cenozoic pericratonic shelf carbonates, neritic shales and volcanics, interlayered marine and continental deposits and Neogene molasse. In the Salt Range, however, Precambrian to Cambrian and Permian sedimentary rocks also crop out. The entire sedimentary sequence of this fold-belt is interrupted by several unconformities. The rocks form simple, large anticlines and synclines, traversed by high-angle gravity faults.

This zone is truely a sediment-hosted minerallogenic province and contains strata-bound deposits of *barite, bauxite/laterite, bentonite, clays, celestite, coal, dolomite, fluorite, Fuller's earth, fire clay, glass-sand, gypsum, anhydrite, iron ore, lead-zinc ores, limestone, oil* and *gas, ochre, oil shale, potash salts, radioactive minerals, rock salt* and *sulphur* (see Tables 9 and 10).

Ophiolitic thrust-belt

This tectonic belt stretches from near Karachi, through Las Bela, Zhob and up to Waziristan and Kurram Agency. It forms the western margin of the Indo-Pakistan crustal plate. It comprises an imbricated sequence of Mesozoic to Paleogene sedimentary rocks, melanges and ophiolites. This belt is comprised of a northern and a southern part.

The southern part, known as the **Bela ophiolitic thrust-belt**, extends northward for about 320 kilometres from the sea coast and terminates abruptly near Khuzdar (Fig. 4.3). To the west this belt is truncated by the left-lateral Ornach-Nal fault which also forms the transform western margin of the Indian plate. The Bela ophiolitic thrust-belt is largely comprised of a thick, broken and imbricated sequence of Early Mesozoic to Neogene rocks. The Mesozoic sedimentary sequence is unconformably overlain by lava flows, volcanic boulder conglomerates and also tectonically overlain by Paleocene Kanar Melange (Sarwar 1992) and Bela Ophiolites (Dejong and Subhani 1979). The Kanar Melange is composed of clasts derived both from the oceanic crust as well as from the continental rocks (Kazmi and Jan 1997). Structurally this zone is characterised by nappes and thrust slices of ophiolites and melanges, reverse, normal and tear faults and short, tight, steeply-dipping or isoclinal, complex folds. The Bela ophiolitic thrust-belt contains showings and deposits of *asbestos, barite, chromite, copper, iron ore, lead-zinc, magnesite, manganese, mercury, soapstone* and *talc* (Tables 9 and 10).

The northern part of the ophiolitic belt, known as the, **Zhob ophiolitic thrust-belt**, lies to the north of the Bela ophiolitic thrust-belt and there is only a short gap of about 20–40 kilometres between the two. Neogene to Recent deposits cover the connection between the two belts. In its western part, between Mashkai and Quetta, the Zhob ophiolitic thrust-belt largely consists of thrust blocks and slices of the Jurassic Shirinab Formation, faulted against the Cretaceous sequence. Eastward the Mesozoic sequence is unconformably overlain by Paleogene lava flows, conglomerates and limestones. Between Quetta and Zhob this belt finds its best expression. Here thick imbricates of Mesozoic rocks tectonically overlain by enormous slabs of obducted melanges and ophiolites are exposed (Ahmad and Abbas 1979, Kazmi and Jan 1997). This sequence continues into the Waziristan-Kurram region (Beck et al., 1996). The Zhob and Bhalla Dhor faults form the northern and western margins of this thrust belt, whereas its southern extent is defined by a series of smaller thrust faults (Kazmi and Jan 1997). The Zhob ophiolitic thrust-belt contains showings and deposits of *chromite, copper, fluorite, graphite, iron ore, magnesite, manganese, nickel, platinum, serpentine* and *talc* (Table 9 and 10).

Kalachitta-Margalla thrust-belt

This arcuate and narrow thrust-belt lies to the northwest of the Foreland sedimentary fold-belt. It extends south-westward from near Balakot, through Margalla Hills, Attock-Chert and Kalachitta ranges to the Sufaid Koh Range on Afghan border, a distance of about 350 kilometres (Fig. 4.3). Southward it has been thrust over the Kohat-Potwar plateau region of the Foreland fold-belt. To the north the Khairabad-Panjal thrust forms its boundary with the Himalayan crystalline zone. It is an intensely deformed and tectonised belt with isoclinal folds and several south-verging thrust sheets.

The stratigraphic sequence in various thrust sheets ranges from Proterozoic to Neogene, though the Ordovician to Permian sequence is missing. The Proterozoic rocks comprise dark grey slate, phyllite, quartzite and subordinate limestone, intruded by basic dykes and sills. The Mesozoic and Cenozoic rocks consist of a marine to non-marine sequence of shales, limestones and sand-stones. This thrust belt contains showings and deposits of *bauxite, chalcopyrite, coal, galena, iron ore, rock phosphate* and *manganese* (Tables 9 and 10).

Himalayan crystalline zone

This intensely tectonised zone forms the northwestern margin of the Indo-Pakistan crustal plate, and lies between the Khairabad-Panjal thrust and the Indus suture zone (MMT). It includes the Nanga Parbat-Haramosh Massif and extends westward up to the Sarobi fault in Afghanistan, a distance of about 450 kilometres. Its southern part is comprised of Precambrian metasediments and fossiliferous Paleozoic to early Mesozoic rocks. This sequence is affected by low-grade metamorphism. However, northwards the tectonometamorphic setting changes from an essentially sedimentary fold-and-thrust belt to a higher grade metamorphic and magmatic terrain, characterised by thick stacks of nappes, thrust sheets and mylonitised shear zones, intruded by Mesozoic to Cenozoic granitoids (Di Pietro et al. 1999, Treloar 1995).

The Himalayan crystalline zone contains showings and deposits of *beryl, feldspar, fluorite, galena, garnet, graphite, magnetite, magnesite, marble, mica, quartz, scheelite, talc* and *gemstones*. The latter include *aquamarine, moonstone, pink topaz, peridot, ruby, spessartine garnet,* and *tourmaline* (Tables 9 and 10).

TETHYAN DOMAIN AND ASSOCIATED MINERALS

Indus suture zone

This suture zone marks the boundary between the Indian crustal plate (Gondwanian Domain) and the Kohistan magmatic arc (Tethyan Domain). It is largely comprised of a complex sequence of melanges which are composed of tectonic blocks of ophiolites, blueschists, greenschists, metavolcanics and metasediments in a matrix of sheared metasediments and/or serpentinite (Jan 1980, Kazmi et al. 1984).

The Indus suture zone is characterised by showings and deposits of *asbestos, chromite, peridot, emerald, magnesite, talc, soapstone* and *platinum-group* of minerals associated with *gold* (Tables 9 and 10).

Kohistan magmatic arc

This E-W oriented 104 million year old island arc is wedged between the Indo-Pakistan crustal plate to the south and the Karakoram block to the north (Fig. 4.3). It is an intraoceanic island arc welded to the Indian plate along the Indus suture zone and accreted to the Karakoram block along the Shyok suture zone or Main Karakoram Thrust (MKT). A sequence of Late Cretaceous to Paleocene volcanic and sedimentary rocks crops out along the MKT in its northern and western part and forms the upper part of the arc sequence. The central part of the arc terrain is mainly composed of Kohistan batholith which comprises extensive intrusions of gabbro, diorite and granodiorite. The southern part of Kohistan contains the lower part of the sequence which consists of a thick pile of thrust slices of mafic and ultramafic rocks. These comprise norites, gabbros, amphibolites, garnet-pyroxene-granulites, peridotites, and orthogneisses (Tahirkheli and Jan 1979, Khan et al. 1993).

The Kohistan terrain contains extensive gossan and alteration zones associated with the volcanic rocks all along the MKT. They contain anomalous traces of *copper, lead, zinc, antimony,* and *gold*. There are large vein-type deposits of *pyrite*, stockwarks of quartz veins containing disseminated grains of *galena, sphalerite, chalcopyrite,* *arsenopyrite, azurite, bornite, chrysocolla, malachite, pyrrhotite,* etc. There are several showings of massive *magnetite* or magnetite disseminated in amphibolite, deposits of *chromite,* showings of *platinum,* small deposits of *fluorite, realgar* and *orpiment* (antimony), showings of *graphite, mica* and *talc* (Tables 9 and 10).

Karakoram block

This is a 1,400 kilometres long, 70 to 120 kilometres wide structural zone. It is one of the fragments of the Gondwanaland, accreted to Eurasia. To the north, the South Pamir fault separates it from the South Pamir Block, to the east and west it is bounded by the Karakoram and Sarobi faults, while to the south the Shyok Suture Zone (Main Karakoram Thrust) separates it from the Kohistan terrain (Kazmi and Jan 1997). Along this suture zone the Kohistan arc has been subducted beneath the Karakoram block. This block is comprised of four main tectonostratigraphic zones.

(1) The Tirich Mir Zone forms its western end and is largely comprised of the highly deformed and imbricated metasediments, consisting of dark grey phyllites, quartzites and marbles, intruded by leucogranites, granodiorite and augen gneiss which range in age from about 117 to 9 million years (Searle 1991).

(2) The northern part of the block is covered by the Northern sedimentary belt which extends westward from Shaksgam through upper Hunza and Chapursan Valley, up to Baroghil Pass and the Yarkhun Valley. Fossiliferous strata comprising interbedded limestones, shales and sandstones ranging in age from Permian to Cretaceous crop out in this belt.

(3) Southward the Karakoram Axial Batholith underlies the Northern sedimentary belt. This complex batholith consists of a number of large parallel or en echelon plutons which range in age from Jurassic to Miocene (Searle 1991).

(4) Southward the plutons of the Karakoram Batholith intrude the sedimentary belt, which forms the southern margin of the Karakorams. This belt consists of a Late Paleozoic to Cenozoic sequence of slates, schists, quartzites and crystalline limestones.

The Karakoram block contains showings and minor deposits of *antimony, polymetallic sulphides, gold, scheelite, dolomite, gypsum, barite, coal, graphite* and *gemstones (aquamarine, topaz, tourmaline, ruby, spinel, pargasite, epidote* and *garnet* (see Tables 9 and 10).

Balochistan flysch basins:
Makran and Kakar Khorasan

Presently these two tectonostratigraphic zones constitute separate and distinct structural units, northwest and west of the Ophiolitic thrust belt of the Gondwanian Domain. The Chaman left-lateral strike-slip fault separates these two zones. However, both share a common depositional history and are filled with a thick sequence of Cenozoic flysch type deposits.

The Kakar Khorasan Basin contains outcrops of Eocene limestone and Oligocene to Miocene flysch and deltaic sediments. These are covered by Pliocene or younger molasse. This sequence forms broad synclines and tight anticlines cut by reverse faults.

The Makran region is an active subduction zone. Eastward the Ornach-Nal transform fault separates it from the Bela ophiolitic thrust belt of the Gondwanian Domain. Westward it extends up to the Lut Block in Iran. Northward it extends up to the Chagai-Ras Koh volcanic arc terrain. A large part of the Makran accretionary prism is subaerially exposed and comprises an east-west trending fold-and-thrust belt, with tight asymmetrical, recumbent or isoclinal folds and well developed cleavage. Reverse and wrench faults are common. The earliest rocks in this region comprise Paleocene conglomerates overlain by Oligocene to Miocene flysch type sediments which are up to 15,000 metres thick. These are overlain by Pliocene shelf-sandstones and neritic mudstones.

The Kakar Khorasan flysch basin and the Makran accretionary zone contain small traces and showings of *antimony, gold,* and *mercury* (Tables 9 and 10).

Chagai-Ras Koh magmatic arcs

These magmatic arcs are a part of the Makran trench arc system, located on the southern and eastern margins of the Afghan and Lut blocks respectively and lie to the west of the Indo-Pakistan Gondwanian Domain (Fig. 4.3). These arcs have developed in response to northward subduction of the Neo-Tethys and the Arabian oceanic plate under the southern margin of the Afghan block. They comprise four main tectonostratigraphic components. From north to south these are (1) the Chagai arc, (2) the Mirjawa-Dalbandin trough, (3) the Ras Koh block and (4) the Kharan fore-arc basin (Kazmi and Rana 1982).

Recent work by Siddiqui (1996) has shown that the Ras Koh is a fore-arc which is older and was initiated during Middle Jurassic? to Late Cretaceous due to an intra-oceanic convergence in the Neo-Tethys. This was followed to the north by the Chagai rear arc. Both these arcs are characterised by Late Cretaceous to Paleocene, tholeiitic lava flows followed by Eocene and later flows which are calc-alkaline.

The Chagai-Ras Koh terrain is largely covered by a thick sequence of Cretaceous basaltic to andesitic lava flows and volcaniclastics with minor shale, sandstone, limestone and radiolarian chert and a dominantly sedimentary Cenozoic sequence comprising interbedded shale, sandstone and limestone with minor intercalations of volcanic rocks. However, the Chagai arc contains thick Late Miocene and Pleistocene andesitic-basaltic lava flows and volcaniclastics, whereas the Ras Koh arc contains Paleocene to Eocene ophiolitic melange in its northwestern part. According to Siddiqui (1996), the Ras Koh ophiolitic melange occurs between the Chagai and Ras Koh arcs and was emplaced due to collision of the Chagai-Ras Koh terrain with the Afghan block.

As may be expected from its tectonic setting, the Chagai-Ras Koh region is one of the most richly mineralised areas of Pakistan. Discoveries made uptil now include several *copper-gold-molybdenum* prospects, *massive sulphide* occurrences, vein-type deposits or showing of *base metals,* volcanogenic *iron ore,* contact metasomatic *iron-copper* showings, *chromite* deposits, showings of *manganese* and *tungsten,* deposits of *barite, gypsum, pumice, onyx marble, sulphur,* and *vermiculite* (Tables 9 and 10).

5

METALLIC MINERALS

A very large number of showings of metallic minerals have been observed in Pakistan (Fig. 5.1). However only a few of these may be classified as deposits and fewer still may be considered as economically exploitable. A discussion of all the showings is beyond the scope of this book. We have however summarised the relevant information in Tables 9 and 10. In this chapter we have discussed only the more significant deposits.

ANTIMONY

Antimony is an element and an important metal. It occurs as native metal in nature but more frequently the ore is in the form of either sulphide or oxide. Important oxide minerals are valentinite (Sb_2S_3), senarmontite (Sb_2S_3), stibiconite ($Sb_2O_4.H_2O$), bindheimite ($Pb_2Sb_2O_7.nH_2O$) and kermesite ($2Sb_2S_3.Sb_2O_3$). However, the most common antimony ore mineral is stibnite (Sb_2S_3). Antimony ores are usually associated with igneous activity and intrusive rocks, such as granite, diorite and monzonite. Complex antimony deposits also contain lead, gold, silver, zinc or tungsten. Antimony deposits tend to be small and the reserves are usually in a few to several thousand tonnes.

Antimony is used for making alloys in which antimony imparts hardness to the final product. It is also used in the manufacture of antimony compounds and other chemicals having varied commercial uses. An important antimony salt is its trisulphide which is used in the production of safety matches, in percussion caps of cartridges, in tracer bullets and similar light signals. It is used in storage batteries, power transmission equipment, flame-retardants, rubber, plastic products, and glass products.

An antimony deposit, which has been sporadically mined in the past, is near Qila Abdullah in Pishin district of Balochistan. In this area, stibnite is associated with quartz veins which fill fractures and joints in Khojak Shales of Oligocene age. More showings of antimony in similar geological setting have been recently discovered by Geological Survey of Pakistan in Kharan district.

In Pakistan several showings of antimony occur in the Salt Range, Kurram valley, near Khuzdar, and in Kharan District (Table 9) but the main deposits are located near Qila Abdullah (Pishin District) and Krinj (Chitral District).

Qila Abdullah antimony deposits

Antimony deposits occur in the Chaman fault zone of the Kakar Khorasan flysch basin of Balochistan, near Qila Abdullah, about 70 kilometres NW of Quetta. The main deposit is 24 kilometres NE of Qila Abdullah, whereas a few smaller deposits are scattered in the vicinity of Qila Viala, 40 kilometres east of Qila Abdullah. The mineralisation occurs in oxidised zones which are 15 to 70 metres wide and up to 700 metres long. These zones are spread over a 6.4 x 0.8 kilometres wide area. Antimony ore occurs along a fault zone and forms discontinuous lenses in a matrix of friable and oxidised slates of the Oligocene Khojak shales. Antimony is also associated with quartz veins and occurs as fracture fillings. The ore consists of stibnite, quartz and small amounts of limonite, hematite, calcite and secondary oxides of antimony.

The better grade ore from Qila Abdullah contains 54.29% antimony, 10.73% barium, 3.36% iron, 0.3% lead and 0.22% arsenic, with traces of mercury, copper and zinc (Ahmad 1975). Antimony has been sporadically mined from this deposit. Reserves have not yet been estimated, but the wide extent of the ore-bearing oxidised zone suggests that it may prove to be a valuable deposit.

Krinj antimony deposits

These deposits are located in the western part of the Karakoram block, in the vicinity of the Reshun and Pasti faults, near the Krinj village, which is about 18 kilometres north of Chitral town (Fig. 5.2). In the vicinity of Krinj there are two antimony localities. One of these is referred to as Krinj, which is 2 miles NE of Krinj village. At this locality there are three antimony mines, the Angarum, Kamal Gol and Bakht Gol mines. The other locality is Partsan which is 6.4 kilometres NE of Krinj village. There is an antimony showing and two copper-antimony showings at this locality.

The Krinj antimony deposits occur in quartz-stibnite veins along the faulted contact between Chitral Slates and the overlying limestone and marble of the Reshun Formation (Calkins et al. 1981). These deposits are believed to be of metamorphic origin and presumed to have been derived from connnate fluids expelled from the sedimentary sequences along structural pathways (Sillitoe 1979).

The stibnite veins are a few centimetres to more than 1.5 metres thick. The stibnite content ranges from 30 to 60 percent. Chemical analyses of random mine samples indicate that the antimony content varies from 29 to 37.6 percent. In addition to antimony, the ore also contains small amounts of silver, gold, copper, lead, vanadium and zinc (Calkins et al. 1981).

The Partsan antimony deposit is within Sarikol shale and parentally unconnected with the Krinj deposits. Some intermittent mining has been carried out at this locality.

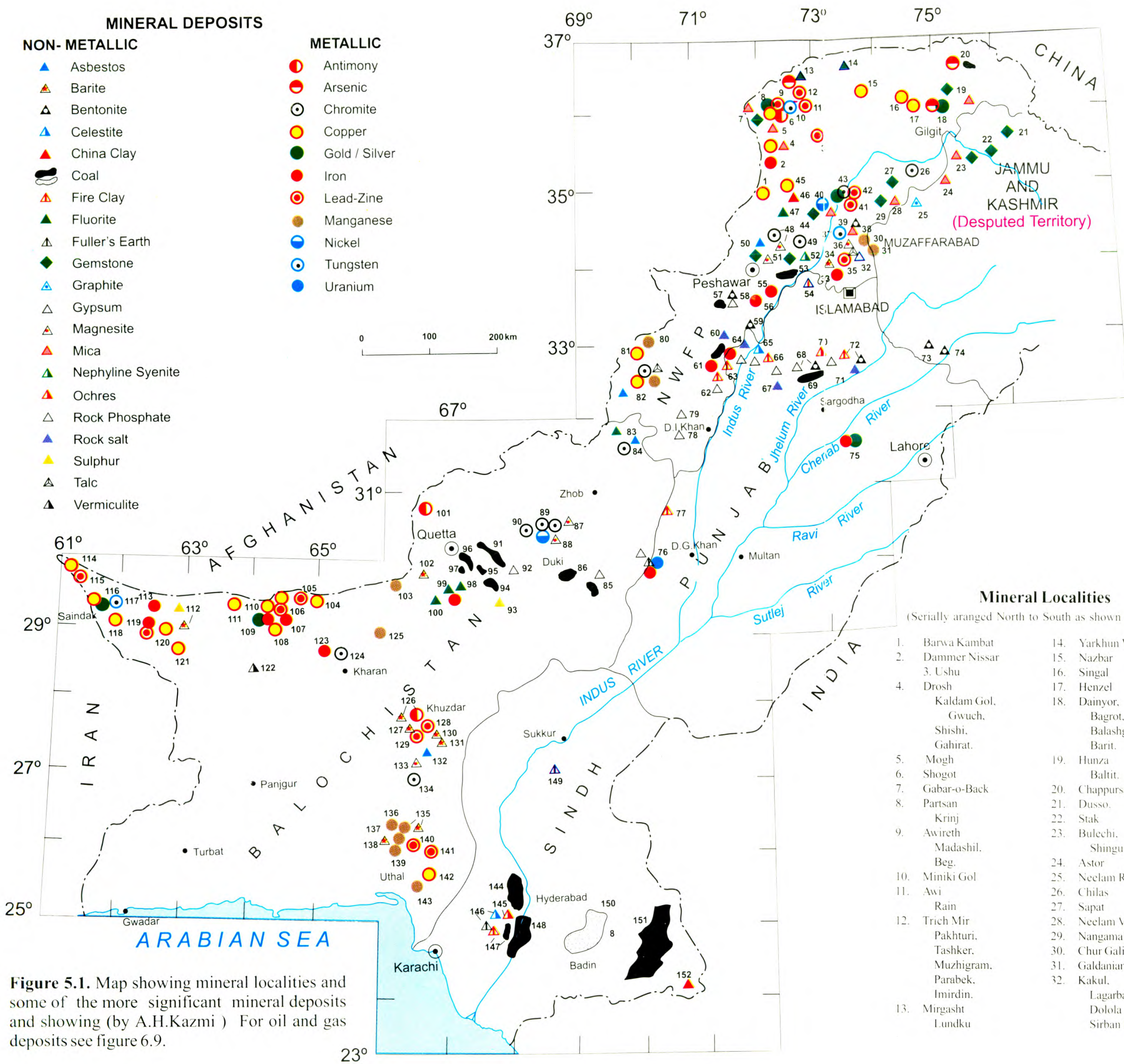


Figure 5.1. Map showing mineral localities and some of the more significant mineral deposits and showing (by A.H.Kazmi) For oil and gas deposits see figure 6.9.

Mineral Localities

(Serially aranged North to South as shown in the map)

1. Barwa Kambat
2. Dammer Nissar
   3. Ushu
4. Drosh
   Kaldam Gol,
   Gwuch,
   Shishi,
   Gahirat.
5. Mogh
6. Shogot
7. Gabar-o-Back
8. Partsan
   Krinj
9. Awireth
   Madashil,
   Beg.
10. Miniki Gol
11. Awi
    Rain
12. Trich Mir
    Pakhturi,
    Tashker,
    Muzhigram,
    Parabek,
    Imirdin.
13. Mirgasht
    Lundku
14. Yarkhun Valley.
15. Nazbar
16. Singal
17. Henzel
18. Dainyor,
    Bagrot,
    Balashgah,
    Barit.
19. Hunza
    Baltit.
20. Chappursan
21. Dusso.
22. Stak
23. Bulechi,
    Shingus.
24. Astor
25. Neelam River
26. Chilas
27. Sapat
28. Neelam Valley.
29. Nangamali
30. Chur Gali
31. Galdanian
32. Kakul,
    Lagarban
    Dolola
    Sirban Hill.
33. Langrial
34. Haripur
    Kag
    Aluli
    Darwaza
    Kachhi
    Faqir Mohd.
    Tipra
35. Hal
    Minhal
    Paswal.
36. Kumhar.
    Sherwan
37. Oghi
38. Bagarian
39. Kohala
40. Rajdhawari
41. Pazang
42. Lahor
43. Jijal
44. Swat,
    Mingora
    Derai.
45. Usheri
46. Shah Dheri
47. Chakdarra
48. Sakhakot.
    Qila
49. Harichand
50. Pranghar
    Bucha
51. Katlong
52. Koga
53. Cherat
54. Kalachitta
    Bagh,
    Chhoi,
    Surg.
55. Nizampur
56. Mazari Tang
57. Hangu
58. Karak
    Jatta.
59. Jabli.
    Shakardarra.
60. Makarwal.
61. Pezu.
62. Paniala.
63. Chapri,
    Isa Khel.
64. Kalabagh.
65. Daudkhel.
66. Western Salt Range
    Dhak Pass
    Manza Bazar
    Chabil
    Dama
    Gole Wali
67. Warcha
68. Dandot
69. Salt Range
    Pail
    Choa Saidan Shah
70. Uchhali
71. Khewra
72. Eastern Salt Range
    Manhiala
    Wehali
    Dalwal
73. Chitti Dheri
74. Bhimbar
75. Chiniot
    Kirana Hills
76. Rakhi Munh
    D. G. Khan
77. Kot Kasarain
78. Domanda
79. Drazinda
80. Datta Khel
81. Mami Rogha
82. Shinkai
    Boya
    Kaniguram
83. Khojakzai Kalai
84. Naweoba
    Zizha
85. Chamalang
86. Duki
87. Nisai
88. Sra Salawat
89. Muslimbagh
    Jang Tor
    Saplai Tor
90. Khanozai
91. Sharigh-Harnai
92. Spintangi
93. Khattan
94. Mach
95. Pir Ismail Ziarat
96. Sor Range
97. Deghari
98. Isplinji
99. Dilband
100. Pad Maran
101. Qila Abdullah
102. Sheikh Wasil
103. Nushki
104. Dasht-i-Kain
105. Ziarat Balanosh
     Dirang Kalat
106. Koh-i-Marani
107. Kundi Baluchap
108. Dalbandin
109. Chilghazi
110. Ziarat Pir Sultan
111. Darban Chah
112. Koh-i-Sultan
113. Pachin Koh
114. Talaruk
115. Makki Chah
116. Saindak
117. Amalaf
118. Koh-i-Dalil
     (Rekodiq)
119. Chigendik
120. Amir Chah
121. Mashki Chah
122. Doki
123. Bandegan
124. Nag
     Rayo Nai.
125. Sotkinoh Hill
     (Ras Koh)
126. Shekran
127. Monar Talar
128. Gunga
129. Surmai
130. Khuzdar
131. Naka Pabni
132. Wad
133. Baran Lak
134. Sonaro
135. Siro Dhoro
136. Haji Khan Bent
137. Sanjro
138. Bankhari
139. Khan Kheo
140. Mithi
141. Duddar
142. Sap Dhoro
143. Kharrari
144. Lakhra
145. Jhol Dhand
146. Thano Bula Khan
147. Jhimpir-Meting
148. Sonda
149. Khairpur
150. Badin
151. Thar
152. Nagar Parkar

Alphabetical list of localities (shown on Mineral Map).

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Bagrot	18
Baltit	58
Bandegan	123
Bankhari	138
Baran Lak	133
Barit	19
Barwa Kambat	1
Beg	9
Bhimbar	74
Boya	82
Bucha	50
Bunap	124
Bulechi	23
Chabil	66
Chakdarra	47
Chamalang	85
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Chapri	63
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Chhoi	54
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Dandot	68
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Manhial	72
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Minhal	35
Miniki Gol	10
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Nag	124
Nagar Parkar	152
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Naweoba	84
Nazbar	15
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Nisai	87
Nizampur	55
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Pachin Koh	113
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Table 9. Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Antimony ore.	Foreland sedimentary fold belt.	-Karangali Hill 32°45':70°05' Salt Range	Galena with small amount of stibnite	Not known	—	Trivial	Was mined sporadically	Heron and Crookshank 1954.
		-Zaimukht Hills 32°22':70°35' Kurram Valley		Not known	Not known	Trivial	Ancient mine reported.	Heron and Crookshank 1954.
	Ophiolitic thrust belt.	-Shekran 27°85':66°38' 12KmNW of Khuzdar.	—	Mineralisation in Jurassic limestone of Shirinab Formation.	—	Minor	As minor constituent in iron, lead barite ore.	Heron and Crookshank 1954.
	Karokaram block	-Krinj-Partsan area 36°00':71°50' 18 km Nof Chitral Town		Mineralisation in the vicinity of Pasti Fault and Reshun Thrust.	—	—	Promising prospect.	Sillitoe 1979.
		-a) Awireth Gol.	Very fine grained Pb-Sb sulphides with chalcopyrite pyrite & boulan-gerite: quartz dolomite gangue.	Mineralisation at contact of Cre-taceous Reshun Formation and Paleozoic (?) phyllites.	Sb 12.8-17%, Pb 45.2-56.6%, Ag(av) 980 ppm, Au 77 ppm.	Minor	—	Calkins et al., 1981.
		-(b) Krinj	Stibnite, Quartz.	In Chitral Slate, at the faulted contact between the slate and overlying limestone.	Sb 29-37.6%, Ag<2-22 ppm, Au 0.6-4.3 ppm, V 15-35 ppm	Medium (60,000 tonnes)	Annual production 50-120 t	Calkins et al., 1981. Austromineral 1978.
		-(c) Partsan	Stibnite, Quartz.	Mineralised quartz veins adjacent to altered, faulted contact between dolerite and Lun Shale.	Sb 4.8-50.5%, Cu 0.24-2.8%, Ag <2-750 ppm, V 25-38 ppm.	Minor	At one locality 1,000 ppm Ag, 16 ppm Au, 0.1% Zn, 7% Pb.	Calkins et al., 1981.
	Chaman Fault zone.	Qila Abdullah 30°44':66°40'	Stibnite & valentinite in gangue of quartz calcite, limonite, & hematite.	Mineralised quartz vein in slate and sandstone of Khojak Fm. Fissure fillings in oxidised zones.	Sb 5-30%, Ba 10.73%, Fe 3.36%, Pb 0.3 % As 0.22 %.	Minor	Traces of Hg, Cu, Zn. Sporadic small scale mining.	Ahmad 1975. HSC 1960. Sillitoe 1975. Klinger et al., (undated).

(Modified from Kazmi and Jan 1997)

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Arsenic	Kohistan magmatic arc.	-Dainyor Nala 15 km NE of Gilgit. Bagrot Nala 20 km E of Gilgit.	Arsenopyrite, chalcopyrite, malachite, pyrite.	Sulphide mineralisation at contact of meta-volcanics and Eocene diorite.	—	—	Promising prospect .for massive sulphide.	Kazmi 1951b.
		-Chitral: -a) Mirgasht Gol -b) Yar Khun Valley.	Realgar, orpiment, fluorite.	Staratabound replacement deposit, associated with fluorite mineralisation related to dolorite dykes in Permian limestone and shales.	—	—	—	Tipper 1921, Ahmad 1969, Nagell 1969, Searle 1991.
	Karakoram block.	-Lundku-Mirghasht 36°26':72°17' (Tirich Gol Valley).		Mineralisation related to dolerite dykes cutting limestone and calc. shales.	—	Un-explored	Deposits at altitudes of 11,000 to 15,000 ft. Small scale sporadic mining in the past.	Tipper 1921. Searle 1991.
Bauxite	See page 108-112.							
	Karakoram block.	-Chapursan (Hunza)	Orpiment.	—	—	—	—	Searle 1991.
Bismuth, Cadmium, Cobalt	Himalayan crystalline zone (Besham nappe)	-Lahor and Pazang (3 & 4 km N & SE of Besham 34°56':72°52').	—	In altered pegmatite and granite complex enclosing Proterozoic metasediments.	Bi-0.2-0.8%, Cd-0.1-0.2%, Co-0.005%, Sn-0.12%, W-400 ppm.	Un-explored.	—	Chaudhry et al., 1983, Ashraf et al., 1980a.
Chromite	Ophiolitic thrust belts and suture zone-(Dargai klippe).	-Harichand-Sakhakot-Qila, west of -Dargai (34°28':71°54')	Chromite.	In the pyroxenite and dunites of the Ultramafic Complex.	Cr_2O_3-24.3-64.1%, Al_2O_3-6.5-42.7%, Cr/Fe-1.4-4.5:1 Refractory grade.	Several small deposits (more than 50,000 t. estimated).	Intermittent mining	Ahmad 1969, Ahmed 1983, Rossman and Abbas 1970.
	Ophiolitic thrust belt and suture zone	-Boya 32°57':69°50' (North Waziristan).	Chromite.	In dunite of the Waziristan ophiolitic complex.	Apparently low grade.	Minor showings.	—	Khan et al., 1982.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Chromite (contd.)	Ophiolitic thrust belt.	-Naweoba, E of Zhob town 31°20':69°27' -Zizha 24 km NE of Zhob.	Chromite.	In dunite bodies of ultramafic tectonite and cumulates. In dunite bodies of ultramafic tectonite and cumulites.	Cr_2O_3-36.7 -46.5%, Al_2O_3-20%, Cr/Fe-2.9:1, Refractory grade.	Several minor deposits	Intermittent mining	WPIDC 1970c, Bilgrami 1964a, Bilgrami 1964b.
		-Khanozai 30°36':67°20' 47 km WSW of Muslimbagh.	Chromite.	In dunite of ultramafic tectonites and cumulates.	Cr_2O_3-49.3 -52.6%, (Av-45%), Cr/Fe-2.7:1 to 3.5:1.	Small	Mined sporadically.	Ahmad 1975, Bilgrami 1964a,b, Ahmad 1969, Ahmad and Abbas 1979.
		-Jang Tor 9 km S of Muslimbagh 30°50':67°44'	Chromite.	In dunite of the ultramafic complex.	Metallurgical grade ore. Cr_2O_3-4.8+, Cr/Fe-3:1.	Several small deposits.	Being mined since 1903.	Ahmad 1975, Bilgrami 1964a,b, Rossman et al., 1971a. Ahmad and Abbas 1979, Ahmad and Bilgrami 1987.
		-Saplai Tor 8 km SE of Muslimbagh.	Chromite.	Occurs in dunites of ultramafic cumulates.	Med. grade ore Cr_2O_3-44.0% -52.5%, Cr/Fe-3:1.	Several small deposits.	Being mined since 1903.	Ahmad 1975, Bilgrami 1964a,b, Ahmad 1969, Ahmad and Bilgrami 1987.
		-Nisai 35 km SE of Muslimbagh.	Chromite.	Pods and layered disseminations in dunites of the Zhob Ophiolites.	Cr_2O_3-39-49%, Cr/Fe-2.1 to 2.6:1, Low grade ore.	Small	Mined on small scale.	Ahmad 1975, Bilgrami 1964a,b, Ahmad 1969, Ahmad and Abbas 1979.
		-Sonaro 26°21':62°28' (Pat Nadi & Dirya deposits) near Wad.	Chromite.	Associated with ultramafic tectonites of Las Bela ophiolites.	—	Medium, probable reserves 1.3 m.t.	Being mined, production up to 10,000 tonnes p.a.	Islam et al., 1993, Ahmad and Abbas 1979, Abbas 1989.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Chromite (contd.)	Indus suture zone.	-Jijal 35°01':72°52' N of Besham.	Chromite.	Associated with a repetitive dunite-wehrlite-websterite sequence.	Cr_2O_3-22-55%, Cr/Fe-2.8:1 to Metallurgical grade.	Several dozen pods and lenses reported. Identified reserves over 0.6 m.t.	Large reserves may be expected. Mining in progress.	Ashraf and Hussain 1982, Miller et al. 1991.
	Kohistan magmatic arc.	-Chilas 35°26':74°04'	Chromite.	In the ultramafic rocks of the stratiform? Chilas Complex.	Low grade, Cr_2O_3-26%, Al_2O_3-26% FeO-37%, MgO-9%.	Not known.	Un-explored.	Jan et al., 1984, Khan and Jan 1992, Ahmad and Abbas 1979.
	Chagai magmatic arc.	-Ras Koh a) Nag-Bunap 29°50':65°18' b) Rayo Nai, 28°55':64°43' (S of Nok Chah).	Chromite.	In the ultramafic rocks of Ras Koh Range.	Cr_2O_3-47-57%, Cr/Fe-2.6-3.1:1.	Small, over 30,000+ tonnes.	Mined sporadically.	HSC 1960, Ahmad 1975.
Copper ore.	Hamalayan crystalline zone.	-Babusar 34°08':74°02'	Chalcopyrite, pyrrhotite, fluorite.	Mineralisation associated with Late Mesozoic to Early Tertiary granites and diorites.	Not known.	Trivial.	Un-explored.	Ahmad 1969.
		-Phalkot 34°09':73°02'	Malachite, chalcopyrite.	In veins cutting Hazara Fm.	Not known.	Trivial.	Un-explored.	Ahmad 1969.
		-Galdanian 34°15':73°19'	Malachite, chalcopyrite.	In sandstone associated with hematite deposits.	Not known.	Trivial.	Un-explored.	Ahmad 1969.
	Foreland sedimentary fold-belt. (Salt Range).	-Katha 32°39':72°26' -Musa Khel 32°38':71°45' -Nilawahan Gorge. 32°39':72°26' -Warcha 32°29':71°59'.	Malachite, cuprite, native copper	Occurs as nodules, specs and stains disseminated in Sardhai Shale and Warcha Sandstone (Late Paleozoic).	Low grade, in traces to 110-1,800ppm, Cu; some samples contain 0.2-0.7% copper.	Not known	Un-explored.	Memon 1965, Qureshi 1980, WPIDC 1970b, Ahmad 1969.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.).	Ophiolitic thrust belt. and suture zone.	-Gujarghuna 33°59':69°56' (2 km NNW of this village) Parachinar District.	Chalcopyrite, (altered to goethite, hematite, & malachite).	Mineralisation along major fault. In quartzites, underlain by shale and limestone.	Not known.	Not known.	Unexplored (also refered to as Neela-tota Cu-Pb mineralisation of Piewar).	Meissener et al., 1975, Beck et al., 1995, Badshah 1983b.
	Ophilitic thrust-belt and suture zone.	-Shinkai (Boya) 32°55':69°52' (Waziristan).	Chalcopyrite, bornite, pyrite, malachite, azurite, cuprite, tenorite, brochantite, covellite, native Cu.	Several copper deposits occur in the Shinkai region and in the Khost suture zone, associated with the ophiolites and volcanics of the Waziristan igneous complex and melanges.	Average Cu content in 6 bore holes: 0.37%, 0.89%, 0.11%, 0.43%, 0.52%, 0.79%.	Inferred reserves down to 150 m are 120 m.t. of 0.3 to 0.5% Cu.	Promising deposit. Breccia pipe-type minerali-sation.	Badshah 1983b, Beck et al., 1995, Khan et al., 1982.
		-Mami Rogha 32°50':69°51' -Zhob 31°21':69°26'	Malachite.	Disseminations in serpentinised ultramafics and volcanics.		—	Unexplored	Ahmad 1969.
		-Sange Gar 19 Km N of Zhob. -Zhiza, 24 km NE of Zhob. -Shin Ghar, 14 Km SE of Zhob. -Otman, near Jalat Killi.	Copper sulphides & carbonates with manganese & Pyrrhotite.	Disseminations and veinlets associated with chromite bearing ultramafic rocks in the Zhob Melange.	Not known	Trivial.	—	Ahmad 1969, Heron and Crookshank 1954.
	Ophilitic thrust belt and suture zone.	-Nasai 30°50':68°02'	Copper sulphide.	Mineralisation in the contact zone, between Dungan Limestone (Paleocene) and ultramafic rocks.	Not known.	Trivial.	—	Ahmad 1969, Heron and Crookshank 1954.
		-Tor Tangi 30°33':67°47'	Copper mineral with magnetite.	Occurs as lenses in serpentinised ultramafic, mafic rocks.	Not known.	Trivial.	—	Ahmad 1969.
		-Ann Dhoro (Las Bela)	Malachite.	Malachite, azurite and chrysocolla encrustations on pillow lava and pelagic sediments.	—	—	—	Abbas 1980b.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality/Grade	Size	Remarks	References
Copper ore. (contd.)	Ophiolitic thrust belt and suture zone.	-Paha Dhoro (Las Bela).	Native Cu, Malachite, azurite, replacing belemnite & chalcocite nodules.	In SemberFm.	—	Trivial	—	Abbas and Ahmad 1974.
	Kohistan magmatic arc	-Dainyor Nala NW of Gilgit 35°55':74°17'		Along fault zones and contact of metavolcanics and diorites and granodiorites.	—	—	Unexplored. May reveal massive sulphides.	Bughio and Khan 1970. Kazmi 1951b.
		(a) Barit	Chalcopyrite, pyrite.	In quartz veins, fissure fillings in diorite.	0.4-0.6% Cu	Spread over 60 acres.	Not explored	Bughio and Khan 1970, Kazmi 1951b.
		(b) Bulashgah 2 km E of Barit	Malachite, azurite, chalcopyrite, bornite, chrysocolla, pyrite.	At contact of metavolcanics with diorite.	0.2-2.5% Cu (average 0.7% Cu).	Probable reserves 0.5 m.t. mineralised zone 700 m wide, 25 m thick.	Promising prospect.	Bughio and Khan 1970, Kazmi 1951b.
		(c) Majadar 3 km E of Bulashgah. magnetite.	Malachite, azurite, chrysocolla,	In ultramafic pod in metavolcanics along a steeply dipping fracture zone.	0.4% Cu, 8.4% Fe, (only one surface sample tested).	Small.	Unexplored.	Bughio and Khan 1970, Kazmi 1951b.
	35°-58' 74°-31'	(d) Bora Nala 3 km NE of Barit.	Pyrite, malachite azurite.	In metavolcanics with quartz stockwork.	Traces to 1.3% Cu.	Not estimated.	Unexplored. Promising prospect.	Bughio and Khan 1970. Kazmi 1951b.
		-Bagrot Nala (18 km E of Gilgit).	Malachite Pyrite, pyrrhotite,	Similar to Balushgah mineralisation in metavolcanics.	Not known	—	Unexplored. Promising prospect. Massive sulphide type.	Kazmi (verbal communication).

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Kohistan magmatic arc.	-Henzel 10 km NW of Gilgit.	chlcopyrite, bornite, magnetite, garnet, epidote, actinolite.	Along faulted contact of marble and biotite schist, close to granitic intrusion.	Random samples contain 2.5 to 7% Cu.	Small.	—	Kazmi 1977, Sillitoe 1979.
		-Sher Qila 33kmNW of Gilgit	Malachite, azurite.	Gossan zone in metavolcanics, close to their contact with granitic intrusion.	Not known	Not known	Not explored.	Kazmi 1977.
		-Singal 45 km NW of Gilgit.	Oxidised Cu minerals	Quartz veins in granite, along minor fault.	Not known	Trivial	—	Sillitoe 1979.
		-Nazbar Valley 22 km W. of Yasin 36°22':73°20'	Pyrite, pyrrhotite.	In metasediments of the Darkot Group, close to the Main Karakoram Thrust and an intrusion of granodiorite.	Analysis of random samples Fe-30-56%, Cu-0.2-1.3%, Zn-0.1-1.2%, Co-0.03-1.5%.	Not known	Unexplored	Kazmi 1977.
		-Drosh 35°33':71°45' several showings in the vicinity, noteably:			Based on random samples:			Pudsey et al., 1985.
		(a) Gawuch Gol.	Malachite, azurite,	In the volcanics and sedimantary rocks close to the MKT (Shyok suture zone) which runs along the the Shishi River, near Drosh town, and contains melanges and ophiolites.	(a) Cu-3.0%, Ag-150 ppm.	Trivial	With small amount of Sb, Zn, V.	Calkins et al., 1981.
		(b)Kaldam Gol. 5km E of Drosh	Chalcopyrite, malachite, galena, pyrite, malachite.		(b)Cu-8.9%, Pb-39.5%, Sb-5.6%, Ag-0.17%, Au-4.3 ppm.	Not known	Promising prospect.	" "
		(c) Shishi, near Shishi village	Sulphides,	Disseminations in greenstone.	(c) Cu-7.0%, Ag-15 ppm.	—	—	" "

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Kohistan magmatic arc.	(d)Drosh Gol 1 km E of Drosh.	Malachite, quartz, calcite.					
		-Dir (a)Ashnamal 35°13':72°14' (b)Lal Qila 34°55':71°45' (c)Barwa Kambat 34°59':71°40' (d) Dommel Nissar 35°22':71°39' (c)Mirkhani 35°27':71°45'	Chalcoyrite, azurite, malachite, bornite, pyrite.	Mineralised quartz veins in diorites and amphibolites.	Not	Not known	—	Hussain 1974, Ahmad 1969.
		(f) Pana Kot	Malachite, azurite and chalcopyrite.	Mineralisation in skarn; dissemination and secondary stainings along fractures.	Not known	Not known	Reportedly a large showing.	WPIDC 1970a.
		(g) Usheri Region	Bornite, chalcopyrite, malachite.	Mineralised veins in granite. Veins small but widespread (9x0.8 km area).	Average Cu content 2%.	—	Showings near Nashnamal, Tarpatar & Shadia village, promising prospects.	WPIDC 1970a
		(h) Bekarai -Rokhan	-see page 122					Khan and Ahmad undated.
	Karakoram block	-Yarkhun Valley 36°35':72°53' (near Kanhur)	Chalcocite, azurite.	Mineralisation near contact of limestone and granite gneiss.	Not known	Not known	—	Ahmad 1969.
		-Mastuj (a) Chapali 36°20':72°36' (b)Chapchirag 36°20':72°40'	Azurite	Disseminations in white quartzite.	Not known	Not known	—	Ahrnad 1969.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Karakoram block.	(c)Pakhturi 36°22':71°72' 22 kmW of Mustuj.	Copper sulphides & galena.	Numerous mineralised quartz veins cut quartzite, phyllite and limestone.	Not known	Not known.	—	Ali 1950. Ahmad 1969.
		(d) Rain 36°24':72°23'	Copper sulphide minerals & galena.	Mineralised quartz veins cutting shale, quartzite, phyllite and limestone.	—	—	—	Ali 1950.
		-Imirdin 36°03':71°23' 3 km SW of the village.	Chalcopyrite, galena.	Mineralisation in quartz vein and as stringers in quartzite and slate.	—	—	—	Ali 1950. Ahmad 1969.
		-Madashil 36°04':71°50'	Malachite, azurite, galena, pyrite.	Mineralisation along fault zone, quartz-veins in phyllite and phyllitic dolomite.	Cu-0.5%, Pb-0.72%, Sb-1.0%, Au-0.6 ppm.	—	—	Calkins et al., 1981.
		-Shoghot 36°10':71°46' Chitral.	Chalcopyrite, galena, malachite.	Showings bound by two parallel faults-the Pasti and Reshun Faults. The fault zones are mineralised and comprised of brown, weathered gossan-like, (14-15 m thick) breccia zone.	2 sp. of gossan like breccia contained 0.05% Cu, 0.78% As, 2 ppm gold. Sp. from Reshun Fault zone shows 3.6 ppm Ag.	—	Promising prospect.	Calkins et al., 1981.
		-Prince Burhanuddin locality. 35°58':71°48' Chitral.	Chalcopyrite, malachite.	Mineralised quartz veins along fractures in Chitral Slate.	One sp. shows Cu-3%, Ag-4.7 ppm, & smaller amounts of Pb, Zn & Au.	—	—	Calkins et al., 1981.
		-Koghozi 35°50':71°50' Chitral.	Chalcopyrite, malachite.	Disseminations in metavolcanics, showing alteration zones with malachite stains and calcite veinlets.	Random sp. analysis Cu-0.01-1.0%, Au-up to 0.2 ppm	Not known.	—	Calkins et al., 1981.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Karakoram block.	-Mogh 36°01':71°40'	Malachite chalcopyrite.	Disseminations in garnet-biotite quartz schist.	Random sp. analysis Cu-2%, Ag-15 ppm, Au-0.2 ppm.	Not known	—	Calkins et al., 1981.
		-Kukil Gahirat 6.4 km E of Chitral.	Chalcopyrite, galena. pyrite.	Mineralised quartz vein in Chitral Slate.	Cu-0.33%,	Trivial.	—	Calkins et al., 1981.
	Chagai magmatic arc.	-Saindak 29°18':61°33'	Chalcopyrite, chalcocite, covellite, digenite, bornite, molybdenite.	The porphyry type sulphide ore body is in hydrothermally altered and mineralised sequence known as Saindak alteration zone, developed in siltstone, sandstone and tuff of Amlaf Fm.	Cu-0.33-0.44%, (Average -0.38%) with recoverable quantities of Mo, Ag & Au.	Large 412 m.t. (proved).	An open-pit mine has been developed.	Sillitoe and Khan 1977, Ahmad et al., 1972. Bizanjo 1994.
		-Dasht-e-Kain	Malachite, goethitic, limonite, chalcocite, covellite, chalcopyrite, magnetite. molybdenite.	The porphyry type copper mineralisation is associated with two tonalite porphyry stocks which intrude a monzonite and diorite batholith.	Cu-0.09 -1.2%, Mo-21 ppm.	Large 400 m.t probable.	Estimates based on 8 test holes.	Ahmad 1980.
		-Darband Chah 29°27':63°44'		Porphyry type deposit similar to Dasht-e-Kain.	—	—	—	Siddiqui 1984.
		-Ziarat Pir Sultan 29°22':64°10'		Porphyry type deposit similar to Dasht-e-Kain.	—	Rough estimate 200 m.t.	—	Islam et al., 1993. Kazmi and Abbas 1991.
		-Kabul Koh	sulphide minerals.	Porphyry type mineralisation, good K alteration in granodiorite.	—	Rough estimate 50 m.t.	—	Islam et al., 1993.
		-Missi	sulphide minerals.	Potassic and sericitic alteration zones well developed.	—	Rough estimate 100 m.t.	—	Islam et al., 1993.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Chagai magmatic arc.	-Humai -Max G. White -Kangord -Karkam -Zjarat Malik -Bazgawanan	Sulphide minerals.	Porphyry type deposits.	—	Not known	—	Islam et al., 1993.
		-Talaruk 29°45':61°02'	chalcocite, pyrite.	Hypogene chalcocite disseminated in dacite pyroclastics (Sinjrani Volcanics).	—	Small.	—	Sillitoe 1975.
		-Amuri 29°15':63°35'	Crysocolla, malachite. chalcocite, chalcopyrite, native copper.	Mineralisation along fissures and as disseminations in andesitic volcanics (Sinjrani Volcanics).	Random samples contain up to 6.0% Cu.	Small.	—	Ahmad 1975. Sillitoe 1975.
		-Kundi Baluchap. 29°12':64°28' -Mashki Chah 29°01':62°26'	chalcopyrite, magnetite.	Skarn type small deposits in Cretaceous limestone at the contact with diorite and granodioritic intrusives.	Not known.	Small	—	Sillitoe 1975.
		-Bandegan 23°49':65°03'	Chalcoprite, magnetite.	Small deposit in andesitic tuffs in conact with syenodiorite intrusion.	Cu-0.5-1.0%, Fe-40-45%.	Small (32,000 tonnes).	Electro-magnetic survey & 9 shallow holes drilled.	Ahmed 1964. Ahmad 1975.
		-Robat 29°27':65°56'	Copper carbonate, sulphide & silicate	Mineralised veinlets in basic dykes.	—	Trivial	—	Ahmad 1975.
		-Amir Chah 29°01':62°38'	Malachite galena, pyrite.	Mineralised shear zones in granite and granodiorite.	—	Trivial	—	Ahmad 1975.
		-Dalbandin 28°21':64°24'	Copper sulphide, & carbonate.	Mineralised quartz vein filling shear zone in syenite.	—		—	Ahmad 1975.
		-Koh-e-Dalil (and others) see Table 15 and p. 119-128. (Rekodiq)						

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality/Grade	Size	Remarks	References
Copper ore. (contd.)	Ophiolitic thrust belt and suture zone.	-Paha Dhoro (Las Bela).	Native Cu, Malachite, azurite, replacing belemnite & chalcocite nodules.	In SemberFm.	—	Trivial	—	Abbas and Ahmad 1974.
	Kohistan magmatic arc	-Dainyor Nala NW of Gilgit 35°55':74°17'		Along fault zones and contact of metavolcanics and diorites and granodiorites.	—	—	Unexplored. May reveal massive sulphides.	Bughio and Khan 1970. Kazmi 1951b.
		(a) Barit	Chalcopyrite, pyrite.	In quartz veins, fissure fillings in diorite.	0.4-0.6% Cu	Spread over 60 acres.	Not explored	Bughio and Khan 1970, Kazmi 1951b.
		(b) Bulashgah 2 km E of Barit	Malachite, azurite, chalcopyrite, bornite, chrysocolla, pyrite.	At contact of metavolcanics with diorite.	0.2-2.5% Cu (average 0.7% Cu).	Probable reserves 0.5 m.t. mineralised zone 700 m wide, 25 m thick.	Promising prospect.	Bughio and Khan 1970, Kazmi 1951b.
		(c) Majadar 3 km E of Bulashgah. magnetite.	Malachite, azurite, chrysocolla,	In ultramafic pod in metavolcanics along a steeply dipping fracture zone.	0.4% Cu, 8.4% Fe, (only one surface sample tested).	Small.	Unexplored.	Bughio and Khan 1970, Kazmi 1951b.
	35°-58' 74°-31'	(d) Bora Nala 3 km NE of Barit.	Pyrite, malachite azurite.	In metavolcanics with quartz stockwork.	Traces to 1.3% Cu.	Not estimated.	Unexplored. Promising prospect.	Bughio and Khan 1970. Kazmi 1951b.
		-Bagrot Nala (18 km E of Gilgit).	Malachite Pyrite, pyrrhotite,	Similar to Balushgah mineralisation in metavolcanics.	Not known	—	Unexplored. Promising prospect. Massive sulphide type.	Kazmi (verbal communication).

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Copper ore. (contd.)	Chagai magmatic arc.	-NokChah 28°57':64°45'	Copper sulphide, Cu carbonate. Cu silicate magnetite, hematite.	Mineralised shear zone at contact of volc. tuff and syenite, monzonite, diorite.	—	—	—	Ahmad 1975.
		-Pakus Nala 23°51':65°06'	Chalcopyrite, sphalerite, pyrite.	Quartz veins in diorite and shear zones at contact of metavolcanics and diorite.	—	—	—	Ahmad 1975.
		-Koh Marani 29°28':64°25'	Chalcopyrite, galena, hematite.	Quartz veins in andesite porphyry, granodiorite and tuff.				
Gold	See Tables-16 & 17.							
Iron ore	Indus Platform (Shahpur buried ridge)	-Kirana Hills (Sargodha) 31°58':72°34'	Hematite, magnetite,	Massive beds of hematite interlayered with metavolcanics (Precambrian Kirana Gr.) and sills of dacite.	$Fe_2O_3$75-95% Si_2O-0.5-3.8%, with traces of gold.	Not known.	Likely to contain large reserves.	Kazmi and Abbas 1991. Hasan et al. 1997
	Himalayan crystalline belt.	-Besham	Magnetite.	Skarn-hosted magnetite concentrations in Precambrian metasediments (Karora Gr.).	Fe-up to 40%, Zn-2.0%, Sn-0.2%, W-0.05%, Mo-0.01%.	Small (6.8 m.t.)	—	Ashraf et al. 1980b.
		-Abbottabad (E of the town, along hill crest).	Hematite.	Sedimentary ore in the Paleozoic sequence (Abbottabad Group).	Fe-14-46%,	2.6 m.t.	—	Ahmad 1969.
		-Galdanian 34°1':73°19' 16 km NW of Abbottabad	Hematitic claystone.	Sedimentary ore, between a sequence of dolomite and limestone (Jurassic).	Average Fe-20%, SiO_2 -9%, P-0.3%.	60 m.t.	20 m.t. ore with about 40% Fe.	Klinger et al., 1963.
		-Langrial 33°55':73°07' 32 km S of Abbottabad.	Chamosite-limonite,	Lateritic and oolitic hematite occurs along the unconformity between Paleocene Lockhart Limestone and Cretaceous Kawagarh (?) sandstone.	Fe-9-50%, (Av=30%), SiO_2-0.0-60.3%, Al_2O_3-5.7-31.05%,. CaO-1.0-12.0%	30 m.t.	—	Khan and Ahmad 1966. Asrarullah 1978. Kazmi and Abbas 1991.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality/Grade	Size	Remarks	References
Iron ore. (contd.)	Foreland sedimentary fold belt.	-Mazar Tang 33°45':71°55' 64 km NE of Kohat	Oolitic hematite.	Lenticular beds of masssive, oolitic hematite in Jurassic limestone.	Fe_2O_3-50.4 57.6%, SiO_2-5.6-5.8%, Al_2O_3-3.6-14.6%,	0.5 m.t.	Chem. analysis based on 2 random samples only.	Asrarullah 1978, and 1979.
		-Kalabagh 32°55':71°32'	chamosite, siderite, glauconite, siderite.	Occurs in sandstones in upper part of the Chichali Fm. Late Jurassic to Early Cretaceous.	Fe-32-36%, SiO_2-20-26%, Al_2O_3-5-13% P-0.2-0.3%, S-0.1-0.5%.	350 m.t.	Proved reserves.	Ahmad 1969, Asrarullah 1978. WPIDC 1970b.
		-Pezu (SE of the town) 32°20':70°44'	Limonite, siderite, glaucophane, chamosite.	Sedimentary oolitic ore in Cretaceous Lumshiwal Formation.	Fe-31.3%, SiO_2-19.8%, Al_2O_3-5.5%, Ca/MgO-8.4%, TiO_2-0.4%.	66 m.t.	Sulphur & Phosphorous below 0.62%.	WPIDC 1970b, Hussain and Karim 1993.
		-Samana Range. (16 km from Hangu)	Hematite, limonite.	Sedimentary oolitic ore in Cretaceous Lumshiwal Formation.	Fe_2O_3-55.85%, Al_2O_3-9.4% TiO_2-0.35%, SiO_2-20.64%.	Small	—	Ahmad 1969.
		-Rakhimunh 52 km W of D.G. Khan	Limonite siderite.	Sedimentary lateritic ore at the base of Oligocene Nari Fm.	Fe-37.5%, Al_2O_3-7.1%, Ca/MgO-6.6%,	Small (14.5 m.t.)	Medium grade	Asrarullah 1979.
		-Nizampur Peshawar Division).	Hematite, limonite	Beded sedimentary deposit at the base of Jurassic sediments.	Fe-25-35%.	100 m.t.		Hussain and Karim 1993.
		-Dilband Kalat Dist.	Hematite.	Sedimentary iron-stone bed at the unconformity between Jurassic Chiltan Limestone and Sembar Shale.	Fe-35.45%.	200 m.t.	—	Abbas et al., 1998.
	Ophiolitic thrust belt (Zhob).	-Naweoba 31°35':69°22' -Inzarkai 31°35':69°25'	Magnetite.	Minor occurrences associated with Zhob ophiolites.	—	Small	—	HSC 1960.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality/Grade	Size	Remarks	References
Iron ore. (contd)	Ophiolitic thust belt, (Bela Khuzdar).	-Shekran 27°51':66°23' (A) 21 km NW of Khuzdar. (B) 24 km NW of Khuzdar (C) 1.6 km NE of B ahove.	Siderite, limonite, hematite, calcite, quartz.	Veins and stock works in impure siliceous limestone (Jurassic Zidi Lst.).	Fe-35-40%.	Small (10 m.t. down to 16 m depth).	—	HSC 1960, Ahmad 1975.
		-Monar Talar 27°44':66°35' 9.5 km SW of Khuzdar.	Hematite, siderite.	Irregular network of ferrugenous veins in Jurassic limestone occurs below the barite deposits. The exposure is essentially a Pb-Zn gossan.	Not known	Not known.	—	Ahmad 1975.
	Indus suture zone.	-Sherkot Kolai. 34°57':73°02'	Magnetite.	Associated with amphibolites of the Jijal Complex of the Kohistan magmatic arc.	Fe-38%.	Small.	—	Miller et al., 1991. Ashraf et al. 1980b.
		-Jijal 27°51':66°23'	Magnetite.	" "	Fe-38%.	Small.	—	Ashraf et al. 1980b.
	Kohisan magmatic arc.	-Ghazanosar 24kmNWof Shah Dheri (34°53':72°54')	Magnetite.	Associated with amphibolites of Kohistan magmatic arc.	Fe-30%.	Small.	—	Asrarullah 1979.
		-Manarai 25.5kmW of Saidu (34'78':72'37)	Magnetite, ilmenite, spinel, hematite, pyrite.	Disseminated magnetite in amphibolite, with small lenses of massive magnetite.	Av. comp. of crushed ferro-magnetic con-centrates (%) Fe_2O_3-80, SiO_2-8, Al_2O_3-4, MgO-4, CaO-2.5, TiO_2-2.8. (Iron 14-46).	Not known.	There are vast reserves of magnetite bearing amphi-bolite in the region.	WPIDC 1970a.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Iron ore. (contd.)	Kohistan magmatic arc.	-Munda (Dir District)	As above	As above	Percent Fe-10, TiO_2-0.8, MgO-16, Mn-1.2, Ni-0.25, Co-0.15.	Not known	—	WPIDC1970a.
		-Dammer Nissar (35°22':71°39') Chitral Dist.	Magnetite, specularite, pyrite, chalcopytite.	Deposit in garnet-epidote meta-volcanosedimentary rocks intruded by granodiorite and quartz diorite, close to the northern suture (MKT).	Fe-50-65%, (Av=48.6%) SiO_2-4-15%, CaO-1-5%, Al_2O_3-0.5-4%, Mn>0.5%.	Small (6.5 m.t.)	—	WPIDC 1970a. Austromineral 1978. Hussain and Karim 1993.
	Chagai magmatic arc.	-Saindak 29°17':61°32'						
		(a) 3.5 km SE of Saindak.	Hematite.	Volcanogenic deposit in Amalaf Formation.	Not known	Small	—	Ahmad 1975.
		(b) 5.6 km NE of Saindak.	Hematite.	Massive bodies in volcanics of Juzzak Fm. or as low-grade hematite with galena in quartz veins cutting sedimentary rocks.	Not known	Small	—	Ahmad 1975.
		-Mashki Chah 29°02':62°24'	Hematite, magnetite	There are several small contact-metasomatic deposits within andesitic Sinjrani volcanics and intercalated sediments, close to quartz porphyry intrusions.	Fe-30-50%, Al_2O_3-2.8%, TiO_2-0.13%, Cu-0.01%.	Small. (0.43 m.t.)	—	HSC 1960. Asrarullah 1978, 1979.
		-Durban Chah 15 km N of Mashki Chah.	Magnetite, hematite.	Veins in Sinjrani Volcanics.	Not known.	Small (1.125 m.t.)	—	Asrarullah 1978.
		-Amir Chah 29°13':62°27'	Hematite, magnetite.	Deposit in Sinjrani Volcanics-intruded by small granitic intrusions.	Not known.	Small (1.125 m.t.)	—	HSC 1960. Ahmad 1975.

(continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Iron ore. (contd.)	Chagai magmatic arc.	-Chilgazhi 29°08':64°14'	Magnetite.	Massive to disseminated, layered deposit in Sinjrani Volcanics which contain several small intrusions of diorite and granodiorite.	Fe-32-55%, Cu-0.39%, Au-tr-2.8g/t.	Small 23 m.t.	—	Farooq and Rehman 1970, Shcheglov 1969, Ahmad 1975, Kazmi and Abbas 1991.
		-Gorband Kasanen Chapar 29°06':64°18'	Hematite, magnetite.	In Cretaceous limestone at intrusive contact of syenite and Sinjrani Volcanics.	Not known	Very small (50,000 t.)	Two deposits NNW of Dalbandin.	HSC 1960. Ahmad 1969.
		-Kundi-Baluchap 29°08':64°30' 30kmNEof Dalbandin	Hematite, magnetite,	Two deposits in Sinjrani Volcanics. (a) Siderite-calcite vein in basalts intruded by dorite and granodiorite. (b) Hematite-magnetite concentration in garnet epidote rock.	Fe-43-64%.	Small. (0.13 m.t.)	—	Ahmad 1969, Asrarullah 1978.
		-Pachin Koh (88 km NW of Nokkundi) (40 km NW -Chigendik (40 NW of Nokkundi).	Magnetite, hematite.	Magnetite intercalated with andesite (Sinjrani Volcanics). Magnetite-actinolite plugs accompany two principal magnetite flows.	Fe_2O_3-67-82%, SiO_2-9-22%, Al_2O_3-1.4-4.4%, CaO-1.2-2.2%, (Av. of 11 channel sps.)	Medium 45 m.t. (30 m.t. proved).	27 small magnetite-hematite bodies at the locality. 78 test holes (19,700 m) drilled.	Asrarullah 1978, Ahmad 1978, Kazmi and Abbas 1991.
		-Bandegan 28°51':64°03' (Ras Koh)	Magnetite, hematite.	Contact-metasomatic to pyrometasomatic deposits in Kuchakki Volc. Gr. intruded by diorite and syenite.	Fe-24-54%.	Small (0.18 m.t.)	—	Ahmad 1975. Asrarullah 1978.
		-Nok Chah (Ras Koh)	Hematite, magnetite.	Mineralisation in Kuchakki Volcs. intruded by syenite stock. Deposits in limestone with epidote garnet, diopside.	Not known	Small	Mined sporadically.	Ahmad 1975.
Laterite	-see pages 108-112.							
Lead-Zinc ore.	Foreland sedimentary fold belt.	-Faqir Mohd. 33°57':73°09' -Hazara Dist.	Galena.	Galena in quartz-barite veins, in Eocene limestone.	Uneconomic	Trivial	—	Ahmad 1969.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Lead-Zinc (contd.)	Himalayan crystalline belt.	-Hal 34°11':73°03' -Kokal 34°27':73°26'	Galena.	These showings are in Hazara Dist. Galena bearing quartz veins (fracture filling) occur in Pre-Cambrian meta-sediments of Hazara Fm.	Uneconomic	Trivial.	—	Ahmad 1969.
		-Mihal 34°09':73°08' -Paswal 34°12':73°07'	Galena.	As above.	—	Trivial.	—	Ahmad 1969.
		-Lahor 6 km N of Besham (34°56':72°52')	Galena, sphalerite, melnikovite, chalcopyrite, pyrite, pyrrhotite.	Zoned polymetallic sulphide mineralisation occurs in Pre-Cambrian metavolcanics and metasediments of the Pazang Fm. Mineralisation is in veins or is disseminated. It is volcanogenic exhalative type affected by subsequent metamorphism.	-Pb-3.1%, Zn-4.2%, (average).	Small 0.5 m.t.	—	Ashraf et al., 1979.
		-Pazang 3 km E of (34°56':72°52')			Pb-3.45%,	—	—	Khan 1983,
	Ophiolitic thrust belt. (Bela)	-Shekran 27°88':66°35' (NW of Khuzdar)	Galena, siderite, limonite, calcite.	Staratabound mineralisation occurs in Jurassic Loralai Lst.	Pb-0.02%, Zn-3.15%, (from gossan zone).	Not known.	—	Ahsan and Khan 1994, Ahmad 1969.
		-Malkhor Ranj Laki 20 km NW of Khuzdar (27°49':66°35')	Galena, siderite, limonite.	Mineralisation characterised by E-W gossan zone comprising 7-8 bedded ore bodies in Jurassic Loralai Lst.	Malkhore- 2.3%Pb+Zn, (Pb dominant) Ranj Laki- 0.3% Pb, 2.61% Zn, 7g/t. Ag.	Not known.	—	Ahsan and Khan 1994, Ahmad 1969.
		-Gunga 27°44':66°33' 11 km SW of Khuzdar	Sphalerite, galena, pyrite, barite, siderite.	Pb-Zn-Ba mineralisation occurs as strata-bound-hydrothermal deposit (Sedex type) in Anjira Member of Shirinab Formation.	Zn-5.36%, Pb-1.43%, Ag-up to 2,500 ppm.	3.0 m.t. (in addition the Zn-Pb-Ba ore reserves are estimated at 9.9 m.t.)	—	Jankovic 1984a,b, Ahsan and Khan 1994, UNDTCD 1990.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Lead-Zinc ore. (contd.)	Ophiolitic thrust belt (Bela)	-Surmai (1 km S of Gunga)	Sphalerite, galena, pyrite, siderite, marcasite, chalcopyrite.	Mississippi type mineralisation occures in Loralai Lst. (lower stratigraphic position than Gunga), along bedding plane and also in fissure filling. Out-crop characterised by reddish to yellowish brown gossan.	Zn+Pb<5%, Ag-15g/t.	0.76 m.t.	—	Ahsan and Khan 1994, Subhani and Durrazai 1989.
		-Duddar 26°35':66°50' (135 km NNW of Karachi).	Pytite, marcasite, sphalerite, galena, barite.	Sedex type mineralisation occurs in Anjira Member of Shirinab Formation and is constrained between 2 major faults. It is stratiform and conformable to bedding.	Zn-11.43%, Pb-2.1%, Fe-3.89%, Ag-2.7 ppm.	10.29 m.t.	—	Jones and Shah 1994. Azam et al., 1989.
		-Mithi (15 km E of Bela).	Galena, barite.	Mineralisation is hosted in Jurassic Loralai Lst and is marked by extensive jasperoid gossan. Mineralisation is epigenetic, with veins along bedding planes, joints and cross-cutting fractures.	Zn-up to 2.7%, Pb-up to 2.6%, (Random chip samples).	Not estimated.	—	Ahsan and Khan 1994.
	Kohistan magmatic arc.	-Ushu 35°44':72°40' (Swat)	Galena, sphalerite pyrite, Chalcopyrite.	Fracture filling, mineralised quartz vein in diorite.	Zn-12%, Pb-14-57%, Sb-tr.	Not estimated.	—	Tahirkheli 1959.
	Karakoram block.	-Tirich Mir Zone i) Parabeck 35°59':71°24' ii) Imirdin 36°03':71°23' iii) Muzhigram 36°06':71°40' iv) Tashker 36°06':71°48' v) Pakhturi 36°22':72°18'	Galena, sphalerite, pyrite, chalcopyrite.	Scattered small showings in the form of quartz veins in quartzite and slate (Arkari Fm.). The deposits are within short distanse of Hot Spring and Tirich Mir plutons.	Not known.	Not estimated	—	Calkins et al., 1981.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Lead-Zinc ore. (contd.)	Karakoram block.	-Baig 36°09':72°01'	Galena.	Galena in quartz veins cutting slate and phyllites (Lurn shale).	Not known	Not estimated	—	Ahmad 1969, Calkins et al., 1981.
		-Madashil 36°03':71°49'	Galena, malachite, azurite.	Mineralised breccia and quartz veins in Lun Shale, close to Pasti Fault.				
		-Awireth 35°58':71°44'	Fine-grained Pb-Sb sulphides.	Mineralised vein in breccia zone along fault separating Cretaceous Reshun Formation and Paleozoic Lun Shales.	Pb-45-51%, Sb-12-17%, Ag-980 ppm, Au-77 ppm.	Small.	Old mine working.	Ahmad 1969, Calkins et al., 1981.
	Kohistan magmatic arc.	-Rain 36°24':72°23'	Galena.	Mineralised vein in shale, limestone and quartzite of Lun Shale.	Not known.	Not estimated.	—	Ahmad 1969.
		-Awi 36°16':72°20'	Jamsonite.	In quartzite and dolomite of Darkot Group, close to Buni Zom pluton and MKT.	Not known.	Not estimated.	Limited mining.	Ahmad 1969.
		Gahirat 35°41':71°46'	Galena, stibnite.	Mineralised quartz vein in Gahirat Lst. near contact with Buni Zom Pluton.	Not known.	Not estimated.	—	Ahmad 1969.
		-Drosh (35°57':71°80') 5 km to the E.	Galena, chalcopyrite, pyrite.	Mineralised breccia zone between marble and siltstone near contact of Purite and Gawuch Fms. close to MKT and Kohistan Batholith.	Pb-39.5%, Cu-8.9%, Sb-5.6%, Ag-0.17%, Au-4.3 ppm.	Not estimated	—	Calkins et al., 1981. Pudsey et al., 1985.
	Chagai magmatic arc.	-Saindak 29°17':61°34'	Galena.	Mineralised calcite veins in basaltic dykes that intrude Paleocene volcanics.	Pb-12-22%.	Trivial.	—	Ahmad 1975.
		-Koh Marani 29°28':64°25'	Galena.	Small quartz veins in andesite porphyry.	Pb-29-59%, Zn-4.24%, (one sample).	Trivial.	—	Ahmad 1975.
		-Dirang Kalat 29°28':64°33'	Galena, sphalerite, limonite, siderite.	Mineralised veins along fault in andesite.	Pb-42-51%, Zn-2.4%, Ag-0.8-1.44oz/t. Au-0.1-0.02 oz/t.	V. small.	Worked	Ahmad 1975.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Lead-Zinc ore. (contd.)	Chagai magmatic arc.	-Makki Chah 4km SE of Talaruk 29°45':61°02'	Sphalerite, pyrite.	Massive sulphide mineralisation occurs along the upper part of a sequence of dacite and tuffs. Three massive lenticular ore bodies are enclosed in gypsum bed overlying the dacite. Mineralisation is volcanogenic and of syngenetic sub-marine exhalative origin (Kuroko type).	Zn-3.8%, Ag-15g/t.	Small	—	Saigusa 1977.
		-Ziarat Balanosh 100 km NE of Dalbandin.	Galena.	Galena pods in agglomerates and along fault planes.	—	—	Old mines containing high grade ore.	Bilgrami, personal com.
Lithium	Himalayan crystalline zone. (Nanga Parbat Massive).	-Shengus 35°43':43°1948'	Lepidolite.	The Nanga Parbat region comprises a major pegmatite field with thousands of pegmatites cutting the Proterozoic Nanga Parbat Gneisses. Several of these contain various gemstones with lepidolite.	Up to 4.24%, Li_2O.	—	—	Butt and Qadir 1987. Kazmi et al., 1985.
Manganese ore.	NW Himalayan fold-and thrust belt	-Galdanian 34°16':73°19' 16kmNE of Abbottabad.	Pyrolusite, psilomelane.	Manganese and iron bearing red bed formation occurs within a Cambrian sequence of limestone, shale sand-stone, quartz and dolomite (Abbottabad Fm.). Mn ore occurs in thin, discontinuous lenses (2-7m long). There are several lenses in the region.	Mn-6.7%, Fe-20.4%, (Av. of 19 channel sp.).	Small	—	Quraishi and Imam 1960, WPIDC 1970a.
		-Chur Gali 34°18':73°38' 20 km NE of of Abbottabad.	Pyrolusite, psilomelane.		Mn-7-22%, Fe-28.6%, (Av. of several channel sp.).	Small. 180,000 tonnes	—	WPIDC 1970a, Quraishi and Abdullah 1960.
		-Shangla 30kmNEof Mingora (Swat)		Veins and lenses of manganese ore have been reported in metavolcanics of the Indus suture melange.	MnO_2-32.46%.	Not known.	—	Hussain et al., 1990.
		-Kassai (Mohmand Agency).		Veins and lenses of manganese ore have been reported in tectonic blocks of quartzite in the Kot-Prangharr Melange.	MnO_2-60%.	Not known.	—	Hussain et al., 1990.
	Hangu Distt.	-Thal 33°22':70°32' (2.5 km SW of Town).	Pyrolusite, hematite, magnetite, barite.	Manganese ore occurs in a cherty hematite shale of a Cretceous volcanosedimentary sequence (Kahi Melange).The ore body is lenticular and fairly extensive.	Not known	Not known.	—	Ahmad 1969, WPIDC 1970. Beck et al., 1995.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Manganese ore. (contd).	Ophiolitic thrust belt and suture zone.	-Shinkai area 32°55':69°52' Waziristan.		Widespread occurrence of lenses and stringers of Mn ore has been reported from Waziristan. Mn occurs at the contact of volcanic flows and cherty shale and limestone (Kahi Melange).	Not know	Not known	Main localities: Garang, Dala algad, Barazai, Ser Kour, Ghundai, Algad & Saidgi.	Khan et al., 1982. Badshah 1985, 1994.
		-Naweoba 31°33':69°22' N of Zhob. -Waltoi Rud 30°40':68°1' S of Nasai.		Managnese ore occurs in Zhob Melange. Veins and layers of Mn are found in Parh Limestone which is intercalated with tectonic blocks of volcanics and ophiolites.	Not known	Not known.	—	Ahmad 1975.
		Las Bela region: (a) Kohan Jhal 26°37':66°19' (64 km N of Bela).	Psilomelane, pyrolusite.		MnO, 36.85%.	Small 11,000 t.	—	HSC 1960, Ahmad 1975, Sarwar 1992.
		(b) Haji Khan Bent. 26°31':66°24'		Mn ore occcrs in Kanar Melange in a sequence of pillowed basalt, dolerite, shale and limestone. The mineralised zone comprises irregular layers and lenses of Mn ore in a jasperoid layer, underlain by pillow basalts and commonly overlain by red shales. These are largely stratabound volcanogenic deposits. However a few (e.g., Siro Dhoro) are replacements and veinlets in basalt and dolerite dykes probably represent feeders to the syngenetic accumulations.				
		(c) Sanjro 26°28':66°27'	Oxysilicate of manganese, brunite, psilomelane, pyrolusite.		Mn-1.10-30.02%,	21,000 t.	—	
		(d) Khabri Dhora 26°25':66°25'			Mn-17.99-23.99%.	65,000 t	—	HSC 1960. Ahmad 1969,1975. Sarwar and DeJong 1984. Sarwar 1992. Sillitoe 1975.
		(e) Siro 26°17':66°33'			Mn-2.88-31.72%,	45,000 t.	—	
		(f) Khan Kheo Nai. 26°11':66°34'			MnO_2-40%.	5,800 t		
		(g) Kharrari Nai. 25°54':66°45'			MnO_2-42%.	40,000 t.	see Table 29 also.	

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Manganese ore. (contd.)	Chagai magmatic arc	-Nushki 29°43':66°01' (9 km N of town).		Mn ore occurs as nodules in the Cretaceous Humai Formation.	Mn-40.78%.	Trivial.	—	Ahmad 1969.
		-Sotkinoh Hill 29°14':65°51' (Ras Koh).		Mn ore occurs as fissure fillings in quartz veins which cut the volcano-sedimentary sequence of the Paleocene Rakhshani Fm.	MnO_2 40-50%.	Small 3,200 t. down to 7m depth.	Large reserves possible.	Ahmad 1975.
Mercury	Bela ophiolitic thrust belt.	-Gunga, Duddar		Mercury occurs in very small quantities in the Pb-Zn ore.	0.017-89.6 ppm.	—	—	Azam et al., 1989. Jankovic 1984a,b.
Nickle	Indus suture zone.	-Souch 34°55':73°40' (Kaghan)	Heazle-woodite, pentlandite.	In ophiolites along the suture zone.	Ni-0.28-0.32%.	Not estimated.	—	Ahmad 1981.
		-Swat, Malam-Jabba, Shangla-Alpurai area.	Pentlandite, milerite, polydymite.	Anomalous values of Ni have been reported from the serpentinites and talc-carbonate rocks of the Mingora ophiolitic melange.	Ni-0.4-0.8%.	Not estimted	—	Chaudhry et al., 1980.
	Zhob ophiolitic thrust belt.	-Muslimbagh 30°51':67°40'		In ultramafic rocks of Zhob ophiolites.	Ni up to 0.85%.	Not estimated.	—	Shams 1995.
Niobium and Platinum	Himalayan crystalline zone.	-Loe Shilman (Khyber Agency)	Pyrochlor, betafite.	Carbonatites in alkaline complex.	0.01-0.03% Nb.	Small showing	—	Butt 1981b.
	Kohistan magmatic arc.	Chilas 35°26':74°04'	Moncheite, michinerite merenskyite, platinum arsenide, palladium telluride.	In dunites of the Chilas ultramafic complex.	PGE+Au 800 to 2,800 ppb.	—	—	Ashraf and Hussain 1994.

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Niobium and **Platinum** (contd.)	Kohistan magmatic arc.	-Jijal 34°97':72°00'	Sperrylite, melonite, atheneite, tetraauri-cupride, electrum, hessite.	PGE and gold mineralisation occurs in association with disseminated accessory sulphides in the Jijal ultramafic complex. Five precious metal zones have been identified and in the layered complex stratigraphically they lie one above the other (Table 19).	Pt-56-723 ppb. Pd-40-2,276 ppb.	Not estimated.	—	Miller et al., 1991.
	Indus suture zone (Dargai Klippe)	-Sakhakot-Qila (West of Dargai 34°47':71°90'	Awaruite, irridian.	Pt, Pd and Rh have been reported in dunite, harzburgite and chromitite samples from the Dargai Complex Ir-Ru-Os-Ni-Fe reported from one sample.	Pt+Pd+Rh-5-23 ppb.	Not estimated.	—	Page et al., 1979, Ahmad and Bevan 1981.
	Zhob ophiolitic thrust belt.	Muslimbagh 30°51':67°40'	Chromitites.	Associated with chromite deposits, in the Zhob ultramafic complex.	Pt+Pd+Rh up to 375 ppb.	Not estimated.	—	Page et al., 1979, Ahmad and Bevan 1981.
Rare Earths	Himalayan crystalline zone.	-Koga (Swat Dist)		In nepheline syenite and alkaline granites of Koga alkaline complex. Also in Koga carbonatites.	(Random samples) La-0.01-0.02%, Y-0.005%, Ce-0.079%.	Not estimated.	—	Ashraf et al., 1987.
		-Sillai Patti 30 km W of Dargai.		Associated with carbonatites in alkaline complex.	La-0.04%, Y-0.01-0.02%.	Not estimated.	—	Ashraf et al., 1987.
		-Loe-Shilman (Khyber Agency).		In carbonatites associated with the alkaline complex.	La-0.005-0.055%, Y-0.004-0.006%, Nb-0.007-0.02%, Ta-0.006-0.01%.	Not estimated.	—	Ashraf et al., 1987.
		-Sakhakot-Qila (Malakand)		In monozite-bearing chlorite schists.	Very small amount of Ce.	Not estimated.	—	Ahmad 1986.
Silver	-see Table 17.							

(Continued)

Table 9. (contd.) Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals	Geological setting	Quality	Size	Remarks	References
Tungsten	Himalayan crystalline belt.	-Oghi 34°10':74°19'	Scheelite, powellite.	In pegmatites and aplites traversing the Precambrian Susagali granite.	3.2%W.	Trivial	Analysis based on random sample.	Shams 1995.
	Karakoram block.	-Miniki Gol 35 km NW of Chitral 35°50':71°48')	Scheelite.	Stratabound skarn- type scheelite occurs in the Arkari Fm. at several locations in a 7 km long mineralised zone. W is concentrated only in parts of the horizon. The mineralised zone (host rock) comprises calc-silicate quartzites, tourmaline-quartz gneiss, quartz-calcite schist, albite quartzite and graphitic schist. The Lutkho River, Miniki Gol and Arkari River sediments contain significant amounts of W (180-2,500 ppm), suggesting much wider mineralisation than known presently.	0.08 to 0.85% W.	Not known.	—	Leake et al., 1989.
	Chagai magmatic arc.	-Amalaf 29°18':61°37'	Scheelite, tungstite.	Xenothermal alterations in Saindak Fm. which comprises pyroclatics intruded by quartz porphyry.	Not known	Not known	—	Shams 1995.
Uranium	-see Table 26.							

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Table 10. Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Anhydrite	Foreland sedimentary fold belt.	-Kalabagh 32°55´:71°32´	-Gypsum, anhydrite, salt.	Anhydrite occurs a minor constituent in association with gypsum in the Kalabagh salt mines (drift No. 6).	—	—	—	Alam and Khan 1982.
		-Daud Khel	-Gypsum, anhydrite.	Anhydrite occurs in association with gypsum in the shales and limestone of the Sakesar Limestone.	—	16.3 m.t.	—	Alam and Khan 1982.
		-Buri Khel (32°43´:71°45´) 33 km from Mianwali.	-Gypsum, anhydrite.	1.6 to 6 m thick beds of anhydrite are associated with gypsum and dolomite and occur in the Salt Range Formation.	—	0.038 m.t.	—	Alam and Khan 1982.
		-Bangla and Chuna Pahari	Anhydrite, gypsum.	Anhydrite is interbedded with gypsum and their contact is apprently gradational. The deposits occur in the Salt Range Formation.	H_2O-1.21%, CaO-38.8%, SO_3-56%.	—	—	Alam and Khan 1982.
		-Dhariala (NW of Khewra).	-Anhydrite.	Drilling at Dhariala revealed several feet of pure anhydrite in the Salt near the top of the Salt Range Formation.	—	—	—	Heron and Crookshank 1954.
Asbestos	Ophiolitic thrust belt	-Wad (Las Bela)	Chrysotile	In ultramafic rocks associated with ophiolite complexes.	—	Small	—	
		-Taleri Mohd Jan (near Muslimbagh)	-Tremolite	As above	—	Small	—	Ahmad 1969.
		-Naweoba 22 km N and NE of Zhob.		As above	—	Small		
		-Boya (32°59´:69°55´) (Waziristan)		As above	—	Small	—	
		-Kaniguram (32°31´:69°51´)		As above	—	Small	—	
		-Sakhakot-Qila (Malakand)	Chrysotile and tremolite.	As above	Good	Large	Annual production 50,000 t.	Jehan et al. 1997.

(continued)

Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Barite	Ophiolitic thrust belt.	-Naka Pabni (26°46′:66°31′) (Las Bela)	Barite, pyrite.	Nodules and stockworks in Cretaceous shale.	—	Small 12,000 t.	—	Ahmad 1969.
		-Gacheri Dhoro (Las Bela)	Barite, galena.	Bedded replacement (?) in Jurassic limestone blocks of mineralised limestone found in Kanar melange.		Small		Mohsin et al. 1981.
		-Siro Dhoro (Las Bela)	Barite, galena, quartz, pyrite.	Lenticular bodies and veins in Windar Limestone (Jurassic).		Small		Mohsin et al., 1981.
		(Las Bela) -Bankhari 26°15′:66°35′	Barite, galena.	In fissure veins along shear zones in Jurassic limestone.		Small 2,000 t.		Klinger and Ahmad 1967.
		(Las Bela) -Kundi 26°25′:66°35′	Barite.	In Windar Limestone, replacement bodies folded with host rock.		Small 14,000 t.		Ahsan 1989.
		-Gunga 26°46′:66°31′ (Khuzdar).	Barite, galena. sphalerite.	Replacement bodies in Jurassic Ziddi Limestone.	Good	Large, 1.4 mt.		Mohsin et al., 1983. Ahmad 1969
		-Shekran (Khuzdar)	Barite, fluorite, galena, siderite.	Bedded replacement and fracture fillings in Jurassic Ziddi Limestone.		Small	Ancient Pb mines.	Ahmad 1969
		-Monar Talar 27°44′:66°32′ (6.5 m SW of Khuzdar).	Barite, calcite, quartz, hematite, goethite, galena, cerussite, cinnabar, rhodochrosite	Discontinuous tabular lenses in altered limestone and shale (Jurassic), restricted to a narrow stratigraphic zone 200-270 m below the J-K boundary. Layered barite cut by irregular veins of course barite. Secondary epigenetic deposit formed by hydrothermal alteration of sedimentary rocks (Klinger et al. 1967). According to Sillitoe (1975) it is a Mississippi Valley type mineralisation, generated south of the ophiolite province, within a miogeocline bordering Gondwanaland. Incipient rifting of the miogeocline during initiation of the Indian Ocean South of Indian Plate may have promoted mineralisation.	Good	12.28 m.t.		Klinger and Ahmad 1967. Ahmad 1969. Sillitoe 1975

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Barite (contd.)	Chagai magmatic arc.	-Koh-i-Sultan 29°10′:62°45′ 5m NW of Miri Camp.		As irregular lenses in a siliceous, vesicular dyke. Contact of barite with igneous rocks gradational. Replacement type deposit.	BaO-61.22 to 63.18%, SO_3-34.13 to 34.59%, SrO-0.18-0.63%.	500 t.	—	Klinger and Ahmad 1967.
	Himalayan crystalline belt	-Kag. -Aluli, -Darwaza, -Kacchi, -Faqir Mohd, -Tipra. (near Haripur)	Barite, quartz, calcite, dolomite, iron oxide.	Veins in dolomite and quartzite of Tanawal Formation.	$BaSO_4$ 82-92%, $CaCo_3$-6-14%, Fe_2O_3-0.12-0.20%, SiO_2-0.5-32%.	Small	—	Hussain et al. 1990. Klinger and Richards 1967.
Bentonite	Foreland sedimentary fold belt	-Kohala 34°06′:44°27′		Veins and lenses in Hazara Slates.	Good	25,000 to 30,000 t	—	Ahmad 1964. Klinger and Richards 1967
		-Bhimbar 32°58′:74°05′. -Jammu 32°42′:44°72'		Sedimentary deposit, in upper part of Siwalik Gr.	Good	Large.	—	
		-Chitta Dheri 33°01′:74°03′		In Siwalik Gr	—	90,000 t.	—	
		-Salt Range (a) Qadirpur Bhilmor (b) Bhadrar (c) Rohtas Dhariala. (32°:73°35')		In Siwalik Gr. (largely in Dhok Pathan Formation).	SiO_2 45.35%, Al_2O_3-23.4%, Fe_2O_3-0.81-1.23%, CaO-1.75-1.78%, Loi-22.98-29%.	—	—	Heron et al., 1954. Ahmad 1969.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tctono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Bentonite (contd.)	Foreland sedimentary fold belt.	(d) Ganda 33°51′:73°31′ (e) Padhrar 32°40′:72°30′		As above.	Good	—	—	Shah 1980. Ahmad and Siddiqi 1992.
		-Jabli 33°13':71°36′		In Chinji Formation				Ahmad 1969.
		-Karak (56 km NW of Bannu)		In Eocene beds overlying the slates.	silica-52.27%, alumina-18.71%, ironoxide-5.98%, titania-0.59%, lime-3.22%, magnesia-4.68%, soda-0.79%, potash-1.33%.	Large 36 m.t.	—	Ahmad & Siddiqi 1992.
Celestite		-Thano Bula Khan 25°2':67°50'		Veins along major fault in Laki Formation. Nodules and lenses along bedding plane in Tyon. Formation.	Good $SrSO_4$ 98.5%.	Small 320,000t.	Being mined	Ahmad 1969. Moosvi 1973. Shcheglov 1969.
		-Daud Khel 32°35′:71°35′		Veins in brecciated limestone.	$SrSO_4$ 82.7 %.	V. small, 10,000t.	Mined, depeleted.	Ahmad 1969.
Fluorite		-Pad Maran 29°25′66°50′	Fluorite, galena, sphalerite, calcite.	Veins and stratabound type, concordant replacement bodies in Chiltan Limestone, along sheared or unconformable Jurassic -Cretaceous contact. Also along faults and fissures.	Good	Large, 100,000t.	Being mined.	Abbas et al., 1980. Ahmad 1975.
		-Chah Bali (North of Koh-i-Maran)	Fluorite, calcite, barite.	Veins and replacements along bedding planes in Chiltan Limestone.	—	Small	—	Mohsin and Sarwar 1980.

(continued)

Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-Metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Fluorite (contd.)	Foreland sedimentary fold belt.	-Dilband 29°32′:66°55′ (Kalat).	Fluorite.	Replacement bodies in Chiltan Limestone.	—	Medium	—	Kazmi and Jan 1997.
		-Dobranzel 29°28′:67°02′ (Isplinji).	Fluorite. crystals.	Purple, zoned crystals in the soil overlying Jurassic limestone. Calcite-fluorite veins in limestone.	—	—	—	Nagell 1969.
		-Khojakzai Kalai 31°33′:69°31′ (Zhob).	F;uorite, calcite.	Fluorit-bearing calcite veins in in Alozai Gr.	15% flurite.	—	—	Heron and Crookshank 1954.
	Himalayan crystalline belt.	-Bicheha Kurd 34°11′:73°03′ (4.5 km SW of Sherwan)		Disseminations in silicic dykes cutting Precambrian schists (Hazara Fm?).	—	Trivial showing.	—	Ahmad 1954. Nagell 1969.
		-Chakdara	Fluorite.	Veins in granite-gneiss and schist.	Good	Small	Mined sporadically.	Ahmad 1969.
	Kohistan magmatic arc	-Chitral: (a) Mirgasht Gol (b) Yarkhun Valley	Fluorite, realgar, orpiment.	Found in association with realgar and orpiment. Stratabound replacement deposit. Mineralisation related to dolerite dykes cutting Permian lst. and calc. shale.	—	—	—	Tipper 1921. Ahmad 1969. Searl 1991.
Gemstone	-See Text.							
Graphite	Karakoram block	-In Chitral at Shah Salim, Momi and Muzhigram villages and Burzin valley.	—	—	—	Trivial	—	Heron et al., Crookshank 1954. Ahmad 1969.
		-Nagar (Hunza River gorge).	Graphite, ruby, spinel, pargasite, calcite etc.	Crystals of graphite up to 1cm across occur in the ruby bearing Paleozoic Dumordo crystalline limestone E of Baltit in the Hunza River Gorge.				Kazmi & O'Donaghue 1990.

(continued)

Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-Metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Graphite (contd.)	Karakoram block	-Chalt 36°18':74°20'						Ahmad 1969.
		-Chhelish 36°36':73°17'						Ahmad 1969.
	Kohistan magmatic are	-Moriwal Baikh 35°01':7°25'						Ahmad 1969
	Himalayan crystalline belt	-Neelam River 34°56':74°13'				Small (1.4 mt)		Ghaznavi 1981.
		- Norang 34°53':73°38'						Ahmad 1969
		-Sherwan 34°12':73°04'			—	Trivial.	—	Ahmad 1969.
		-Garhi Habibullah			—	Trivial.	—	Ahmad 1969.
		-Shahid Mina 34°09':71°17'			—	Trivial.	—	Ahmad 1969.
		-Sper Tor (Landi Kotal)		Earthy amorphous graphite in graphitic schist.	—	Trivial.	—	Ahmad 1969.
		-Lowara Mena			—	—	—	Ahmad 1969.
		-Loe Agra (Malakand)		Thin layers in carbonaceous schist.	C:20-24%.	Trivial.	—	Ahmad 1969.
	Ophiolitic thrust belt.	-Sheikh Wasil 29°55' :66°36'		Stringers and lenses of graphite in Shirinab Fm.	—	—	Sporadic mining.	Ahmad 1969.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-Metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Gypsum	Indus Platform	-Bahawalpur (Cholistan).	Gypsum.	Small deposits in interdunal depression.	Low grade.	Small.	—	Heron and Crookshank 1954.
	Himalayan crystalline belt.	-Kalabagh (Abbottabad)	Gypsum.	—	—	—	—	Hussain and Karim 1993.
		-Dowatta (34°17′:73°30′) (Hazara).	Gypsum.	Beds and veins in slates. Gypsum is up to 100' thick at some points.	—	—	—	Heron and Crookshank 1954.
		-Macol (Abbottabad).	Gypsum.	—	—	—	—	Hussain and Karim 1993.
	Foreland sedimentary fold belt.	-Murree and (33°54′:73°27′) Dunga Gali (34°4′:73°30′)	Gypsum.	In Kuldana beds, between Nummulitic limestone and Murree sandstone.	—	—	—	Heron and Crookshank 1954.
		-Lachi (Karak)	Gypsum.	In Jatta Gypsum Formation, associated with rock salt.	Good.	29.59 m.t.	—	Hussain and Karim 1993.
		-Mami Khel (Karak)	Gypsum.		—	894.55 m.t.	—	Hussain and Karim 1993.
		-Jatta (Karak).	Gypsum.		—	694.96 m.t.	—	Hussain and Karim 1993. Alam et al., undated.
		-Bahadur Khel 33°11′:71°01	Gypsum.	Associated with limestone and oil shale.	—	71.28 m.t.	—	Heron and Crookshank 1954.
		-Karak (Karak Dist.).	Gypsum.	In Jatta Gypsum Fm.	Good.	237.89 m.t.	—	Hussain and Karim 1993.
		-Panoba (33°37′:71°54′)	Gypsum.	Massive bed in Nummulitic limestone.	—	—	— —	Heron and Crookshank 1954.
		-Saidu Wali (32°12′:71°06′) (D. I. Khan)	Gypsum.		Good.	Medium.	—	Heron and Crookshank 1954. Hussain and Karim 1993.
		-Paniala (32°15′:70°56′) (D. I. Khan).	Gypsum.	In Jurassic clays	—	—	—	Heron and Crookshank 1954.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Gypsum (contd.)	Foreland sedimentary fold belt.	-Drazinda-Moghal kot (D. I. Khan).	Gypsum.		—	—	Inexhaustible.	Heron and Crookshank 1954.
		-Domanda (D. I. Khan).	Gypsum.		—	13.7 m.t.	—	Hussain and Karim 1993.
		-W of Daraban in Tribal area, -D. I. Khan, at Zor Shehr, Zam Burj, Girdghund and Parwar.	Gypsum.		—	—	—	Hussain and Karim 1993.
		-Kalabagh (32°97´:71°57´) Salt Range	Gypsum. and Anhydrite	Gypsum and anhydrite occur in associated with the salt deposits in Salt Range Fm. of Cambrian age.	—	—	Of no commercial vale.	Alam and Khan 1975.
		-Mari Indus Kalabagh.	Gypsum		Good	18 m.t.	—	Gauhar 1966. Ahmad 1969.
		-Daud Khel (32°53´:71°43´) Salt Range.	Gypsum and Anhydrite.	Associated with the limestone and shale of the Sakesar Limestone (Eocene).	CaO-31-39%, MgO-1-4.6%, SO_3-41-56%, N_2O-1-20%, Co_2-1.2-4.9%.	52.27 m.t.	Mining in progress	Alam and Khan 1982. Gauhar 1966, Ahmad 1969.
		-Buri Khel (32°43´:71°45´)	Gypsum and Anhydrite.	Gypsum occurs in the upper part of the Salt Range Fm. (Cambrian) and is interbedded with marl and dolomite.	CaO-29-35%, SO_3-43-51%.	2.86 m.t.	Due to dolomite interbeds mining will be difficult.	Alam and Khan 1982.
		-Chhidru (26 km NE of Mianwali).	Gypsum. and Anhydrite.	(as above).	CaO-32-38%, SO_3-38-54%.	0.515 m.t.	—	Alam and Khan 1982.
		-Warcha (13 km NE of Qaidabad).	Gypsum.		Good.	0.54 m.t.	—	Alam and Khan 1982.
		-Choha (32°24´:72°05´) NW of Khushab.	Gypsum.	Occurs in a faulted block of Salt Range Fm. It is interbedded with dolomite and marl.	Good.	0.178 m.t.	—	Alam and Khan 1982.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-Metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Gypsum (contd.)	Foreland sedimentary fold belt.	-Dhokri. (32°24′:72°05′) near Jabbi NW of Khushab.	Gypsum	Occurs in the Salt Range Fm.	—	0.199 m.t.	—	Alam and Khan 1982.
		-Sardhai (32°40′:72°43′) near Bhuchal Kalan.	gypsum.		—	Small.	—	Alam and Khan 1982.
		-Sodhi (32°24′:72°05′) near Khewra.	Gypsum.	Gypsum mixed with red marl occurs in the Salt Range Fm.	Not of good quality.	2.5 m.t.	—	Heron and Crookshank 1954.
		-Channuwala (near Khewra).	Gypsum.	Occurs in the Salt Range Fm.	—	10 m.t.	—	Ahmad 1969. Heron and Crookshank 1954.
		-Mokrach (32°49′:73°55′) near Khewra.	Gypsum.	Occurs in the Bhandar Kas Gypsum Member of Salt Range Fm. and is interbedded with dolomite and marl.	CaO-32.48%, SO_3-44.17%.	0.6 m.t.	—	Ahmad 1969. Alam and Khan 1982.
		-Dandot (3 km W of Khewra)	Gypsum.		Good. CaO-33.04%, SO_3-46.25%, (average).	0.85 m.t.	—	Alam and Khan 1982.
		-Jutana (NW of Khewra).	Gypsum.	Associated with red marl beds of Salt Range Fm.	Good to pure CaO-32.2-33.04%, SO_3-43.1-45.1%.	2.0 m.t.	—	Alam and Khan 1982.
		-Khewra	Gypsum. anhydrite.	Associated with marl, dolomite and anhydrite beds in the Salt Range Fm.,	Good. CaO-30-39%, SO_3-42-56%.	78 m.t.	—	Alam and Khan 1982.
		-Zor Shahr (34°4′:73°30′) (D. I. Khan).	Gypsum.	12 beds of gypsum varying from 1-11 feet.	—	—	—	Heron and Crookshank 1954.
		-D. G. Khan 30°08′:70°32′ Alipiri, Sorika Kot Bagge Ka Dot etc.		In Eocene Ghazij Shales.	High grade.	In exhau-tible.	—	Heron and Crookshank 1954. Ahmed 1981.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Gypsum (contd.)	Foreland sedimentary fold belt.	-Dadhao 30°42´:70°26´ D. G. Khan.	Gypsum	In Eocene Ghazij Shale.	Good.	Medium.	—	Heron and Crookshank 1954.
		-Chamalang 30°12´:69°25´ (Duki)	Gypsum.	15 m thick gypsum interbedded with shale and limestone (Ghazij ?).	—	7 m.t.	—	Bender 1995. Ahmad 1975.
		-Momand 29°39´:68°43´ Marri Hills	Gypsum.		—	—	—	Heron and Crookshank 1954.
		-Vitakri 29°42´:69°21´ Sibi District.	Gypsum.		—	—	—	Heron and Crookshank 1954.
		-Barkahn (Loralai Dist.).	Gypsum.		—	—	—	Heron and Crookshank 1954.
		-Spin Tangi 29°55´:68°10´	Gypsum	Interbedded with green shales and Nummulitic lst. at contact of Spin Tangi lst. and Ghazij shale.	Small.	Small.	Being mined.	Ahmad 1969.
		-Khattan and Mawand (Mari-Bugti)	Gypsum	In lower part of Spin Tangi limestone (Eocene).	—	—	—	Ahmad 1975
		-Mach	Gypsum.		—	—	—	Ahmad 1975.
		-Sanni (10 miles S. of Sanni).		In narrow veins associated with sulphur in sandstone of Siwalik Gr. Above the veins there is a 34 ft thick gypsum bed.	—	—	—	Ahmad 1975.
		-Puleji 29°1´:68°22´ Kalat.	Gypsum.	Irregular masses up to one ft. at the base of the Siwalik Gr.	—	—	—	Heron and Crookshank 1954.
		-Jiand-Laghani 29°1´:68°46´ Bugti area.	Gypsum.		—	—	—	Heron and Crookshank 1954.
		-Juhi Dadu District.	Gypsum	Three beds of gypsum (0.33-0.93m) occur interbedded with reddish clays in the Miocene Gaj Fm.	Good	10.4 m.t.	—	Alizai et al. 2000.
	Chagai magmatic arc	Gawalishtap (30 miles S. of Nokkundi	Gypsum	There is a 3.3 m thick bed of gypsum in red shales of the Eocene Washap Fm.	—	Small	—	HSC 1961. Ahmad 1975.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Kyanite	Himalayan crystalline belt.	-Oghi 34°30´:73°41´ (Mansehra).		In schists containing about 30% kyanite.	—	—	—	Heron and Crookshank 1954.
		-Jabba 34°36´:73°01´ (Hazara).		Kyanite-quartz vein in mica schist.	—	Trivial	—	Heron and Crookshank 1954.
		-Kuz Banda 34°39´ :73°00'		Kyanite schist.	—	—	—	Ahmad 1969.
		-Landokai 34°39´:72°08´ (Swat).		Kyanite bearing quartz veins.	—	—	—	Ahmad 1969.
Magnesite	Ophiolitic thrust belt (Dargai Klippe)	-Sakhakot 37°24´:71°56´ (Malakand).	Magnesite	Magnesite veins in serpentinised ultramafic rocks.	Good. MgO-45-47.7%, CaO_2- 2% Los-52%.	Small	—	Ahmad 1969.
		-Pran Ghar (Mohmand).	Magnesite.		—	—	—	Hussain and Karim 1983.
	Himalayan crystalline belt	-Kumhar (29 km NW of Abbottabad)	Magnesite.	Irregular lenses of crystalline magnesite in dolomite and dolomitic lime-stone of Abbottabad Fm.	MgO-46-48%, SiO_2-0.7-1.20%, Al_2O_3-0.2-1.28%, Fe_2O_3-0.3-0.55%, CaO-0.22-1.4%.	Medium, 11 m.t.	5 m.t. proved	Chem. Consultants Ltd. 1970.
	Ophiolitic thrust belt	-Nisai (Zhob) 32 km E of Muslimbagh	Magnesite	Magnesite veins in serpentinised dunite.	MgO-45.4%.	Very small 60,000 t.	—	Ahmed 1981.
		-Spin Tangi 30°47´:68°06´	Magnesite	Massive, crypto-crystalline magne-site layer in serpentinised dunite.	MgO-43-45%.	Very small 6,000 t.	—	Vloten 1963. Nagell 1969. Ahmad 1975.
		-Shabi Ghundi 30°48´:68°10´ (Muslimbagh)	Magnesite		MgO-38-42%.	Very small 6,000 t.	—	Nagell 1969. Ahmad 1975.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Magnesite (contd.)	Ophiolitic thrust belt	-Tleri Md Jan 30°53′:67°42′	Magnesite					Ahmad 1969.
		-Sra Salawat 30°40′:67°53′ (Muslimbagh).	Magnesite	Associated with dolomite in Nisai Limestone which unconformably overlies ultramafic rocks. Massive magnesite grades into Eocene Nisai Limestone.	MgO-46-49%.	Very small 6,000 t.	—	Nagell 1969. Chem.Consult. Ltd. 1970.
		-Zhizha (Zhob) 31°24′:69°34′	Magnesite.	In ultramafic rocks.	—	Small	—	Ahmad 1975.
		-Loya Na Pani (Wad) 27°43′:66°09′	Magnesite.	In ultramafic rocks.	MgO-32-44%.	Trivial	—	Vloten 1963. Ahmad 1975. Chem.Consult. Ltd., 1970.
		-Sinchi Md Khan Bent (Wad) 27°15′:66°20′	Magnesite.	Veins in ultramafic rocks.	MgO 32%.	—	—	Vloten 1963. Ahmad 1975.
		-Baran Lak (Bela) 26°59′:66°18′	Magnesite.	Large number of veins in ultramafic rocks.	MgO 38%.	Small, 20,000+t.	—	Vloten 1963 Ahmad 1975. Chem.Consult. Ltd., 1970.
Marble		See text.						
Mica (Muscovite)	Karakoram block	-Baltit 36°15′:74°25′	Sheet mica.	Pegmatites near contact of Dumordo Formation and Karakoram Granite.	MgO-45.4%.	Trivial to small.		Heron and Crookshank 1954. Ahmad 1969.
		-Dassu 30°47′:68°06′		In pegmatites.				Kazmi and Donoghue 1990. Heron and Crookshank 1954.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Mica (Muscovite) (contd.).	Karakoram block.	-Mogh 30°01´:71°38´ 35 km E of Chitral.			—	—	In books up to 5cm across.	Calkins et al., 1981. Ahmad 1969.
		-Simik Gol 30 km upstream of Mogh.		In pegmaties.	Good	—	—	Heron and Crookshank 1954.
		-Kasu 12 km N of Drosh		In pegmatites.	—	—	—	Ahmad 1969.
		-Gabar-o-Boch 36°5´:71°22´ Chitral.		In Pegmatites.	Good.	Small.	In books up to 13" x 6"	Heron and Crookshank 1954.
		-Imirdin 36°07´:71°24´			—	Trivial to small.	mined sporadically.	Calkins et al., 1981
		-Khadan (Dir)	Sheet mica.	In pegmatites.	—	—	In books 9x2 inches	Ahmad 1969.
		-Khadong Banda 33°42´:71°52´		In pegmatites.	—	—	In books 9x6 inches	Ahmad 1969
	Himalayan crystalline belt.	-Bagarian 34°33´:73°10´			—	—	—	Ahmad 1969.
		-Hawa Gali 34°29´:73°06´			—	—	—	Ahmad 1969.
		(a) Rajdhawari 34°00´:73°06´			—	—	Mined for mica, beryl, feldspar and quartz.	Ahmad 1969.
		(b) Giddarpur	Sheet mica	In pegmatites.	—	Trivial to small.	—	Ahmad 1969.
		(c) Tangali Hill						Ahmad 1969.
		-Nilam Valley 34°56´:74°13´					In books 12"x10"	Ahmad 1969.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Nepheline Syenite	Himalayan crystalline belt	-Koga 56 km NE of Mardan		Forms part of the Ambela alkaline magmatic complex.	SiO_2 59-61%, Al_2O_3-20-23%, Fe_2O_3-1.7-3.13%, N_2O-6-10%, K_2O-4.7-6.9%.	V. large, 6,000 m.t.	—	Kazmi and Jan 1997.
		-Reshian (Azad Kashmir)	—	—	Good.	Medium.	—	Min. of Pet. & Nat. Res. 1977.
Ochres	Foreland sedimentary fold belt (Salt Range)	-Uchhali 32°32′:72°02′	red and yellow iron oxide	Beds in Jurassic sequence. Also in lateritic or pisolitic rocks in Paleozoic and Jurassic sequences of Salt Range.	—	—	—	Heron and Crookshank 1954.
		-Kutki 32°59′:71°02′						Heron and Crookshank 1954.
		-Jhol Dhand 24°52′:67°56′		Associated with Sonhari beds at the unconformity beween the Laki and Ranikot Formations.	—	—	—	Ahmad 1969.
		-Sonhari Dhand 25°00′:68°04′			—	—	—	Ahmad 1969.
Phosphate	Himalayan crystalline belt.	-Kakul 34°12′:73°17′ (Deposits at Dalola, Lagarban, Sherwan, and Sirban).	Siliceous phosphorite, carbonates, fluorapatite, glauconite, dolomite, silica, iron oxide, pyrite.	Phosphoritic beds in impure limestones of Abbotabad Formation.	P_2O_5-10-32%.	Small, (initial reserves 29 m.t.)	Mined and partly depleted.	McClellan and Hill 1983. Khan and Ahmad 1991.
	Kalachitta-Margalla thrust belt	-Kohat		Phosphatic limestone in Kawagarh Formation.	—	—	—	Raza and Iqbal 1977.
	Foreland sedimentary fold belt	-Khwari Gandad Khwar			—	—	—	Raza and Iqbal 1977.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Phosphate	Foreland sedimentary fold belt.	-Central & Eastern Salt Range		Phosphatic nodules in Patala Fm.				Raza & Iqbal 1977.
		-Rakhi Gorge (D. G. Khan)		Phosphate indication in Paleocene Khadro Fm.	—	—	—	Raza and Iqbal 1977.
		-Mari-Bugti Hills		Phosphatic nodules in Cretaceous to Paleocene Moro Formation.	—	—	—	Raza and Iqbal 1977.
		-Pabni Dhora to Shah -Bhilawal (Dist.Las Bela)		Phosphatic nodules in Paleocene Khadro Formation.	—	—	—	Heron and Crooksank 1954. Raza and Iqbal 1977.
Rock Salt	Foreland sedimentary fold belt	-Salt Range (a) Khewra 32°39´;71°45´ (b)Warcha 32°29´:71°51´ (c) Kalabagh 32°55´:71°59´		Evaporites in Billianwala Salt Marl Member of the Precambrian Salt Range Formation.	—	Large, 600 mt. 2 m.t.+ 1 m.t.+	Production 0.3-0.6 mt.	Bilgrami 1982 Shah 1980. Ahmad 1981.
Rock Salt (Potash)	Foreland sedimentary fold belt.	-Jatta, Bahadur Khel & Karak		Evaporites in Eocene Bahadur Khel Salt Fm., lying between Jatta Gypsum Fm., (above) and Panoba Shale (below).	—	—	—	Ahmad 1969.
		-Khewra 32°39´:71°45´	Halite, sylvite, kainite, langbeinite kieserite, polyhalite, mirabilite, glauberite.	Potash salt occurs as 240-400m wide layers and lenses along with thick beds of rock salt and salt marl in the Billianwala Salt Marl Member of the Salt Range Fm.	K_2O-7.83 to 9.4%.	Small 124,850 t.	—	Alam and Asrarullah 1973.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Sulphur	Karakoram block	-Muzhigram 36°06′:71°37′ (Chitral)		Associated with sulphurous springs.	—	Trivial	—	Nagell 1969.
	Kalachitta-Margalla thrust belt	-Margalla Pass 33°42′:72°53′		In pyritic shale.	—	Trivial	Minor mining in the past.	Nagell 1969.
	Foreland sedimentary fold belt	-Kohat (a) Panoba 33°37′:71°59′ (b) Jatta 33°19′:71°17′ (c) Dandi 33°36′:71°59′		In carbonaceous shales as an oxidation product of pyrite.	—	Trivial	Mined occasionally.	Nagell 1969.
		-Jaba 32°52′:71°44′ (Salt Range)		Associated with gypsum near oil seeps.	—	Trivial	—	Nagell 1969.
		-Sangar Pass 30°42′ :70°32′		As stringers and veins in Eocene limestone.	—	Trivial	—	Nagell 1969.
		-Domanda 31°36′:70°14′		In Paleocene limestone, formed through decomposition of pyrite.	—	Trivial	—	Nagell 1969.
		-Sanni 29°02′:67°29′		In Nari Fm. as veinlets and pore infillings in sandstone, being replacement of calcareous matrix of the sandstone. Underlain by tar deposits.	Sulphur 45%	Small, 58,000t.	Mined sporadically	Muslim 1973a.
		-Gokurth 29°33′:67°28′		In Eocene limestone.	—	Trivial.	—	Ahmad 1969,
		-Jacobabad 28°17′:68°28′			—	Trivial		
		-Gondahari Hill 29°06′:69°46′		In Eocene limestone, hot springs in the vicinity.	—	—	—	Nagell 1969.

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Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Metalogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Sulphur (contd.)	Foreland sedimentary fold belt	-Chhappar 29°06′:66°21′ (WNW of Kalat)		Fracture filling associated with nummulitic Eocene limestone.	—	Trivial	—	Nagell 1969.
		-Laki 26°16′:67°57′		Associated with hot springs near Laki town (Dadu Distt.).	—	Trivial	—	Nagell 1969.
	Balochistan flysch basin	-Khan Bevar 25°29′:66°03′ (Las Bela Distt.)		Associated with saline springs in Mio-Pliocene sedimentarry rocks.	—	Trivial	In the form of sulphur crystals.	Nagell 1969.
		-Karghari 25°27′:64°09′			—	Trivial	—	Nagell 1969.
		-Jiwani 24°05′:61°47′		Found in the vicinity of an active mud volcano and occurs in dark grey clay and sand in the form of pure yellow sulphur crystals.	—	Trivial	—	Nagell 1969.
	Chagai magmatic arc	-Koh-i-Sultan 29°07′:62°47′		Occurs as irregular and lenticular bodies in altered porphyritic andesitic lavas. Solfateric deposit.	Sulphur-50%	Small 738,000t.	Being mined.	Nagell 1969. Muslim 1971.
Talc (Soap stone)	Ophiolitic thrust belt	Zhob Vallev (a) Gach Inziakai (b) Shinghar Hill (c) Zamankar N. (Walgai Oba) (d) Bahram Khel		Small veins of soapstone in ultramafic rocks.		Trivial		Ahmad 1969.

(continued)

Table 10. (contd.) Non-Metallic deposits and showings: location, geological setting and potential. (m.t.=million tonnes; t.=tonnes).

Mineral	Tectono-metallogenic zone	Name of deposit & location	Minerals present	Geological setting	Quality	Size	Remarks	References
Vermi-culite	Kohistan magmatic arc	-Arin Valley (54 km N of Saidu).		—	—	Trivial	—	Ahmad 1969.
	Himalayan crystalline Zone	-Shinai Ghundai (NE of Michni Ft. Mohmand)		—	—	Trivial	—	Ahmad 1969.
	Chagai magmatic arc	-Doki River (21 km S. of Dalbandin).		Vermiculite schist in ultramafic rocks.	fair bloating quality.	Large, 11 m.t.	—	Bakr 1965b. Ahmad 1969.
Witherite	Forland sedimentary fold belt.	-Degari (SE of Quetta).		Veins and lenses in the Jurassic Chiltan Limestone.	Good.	Small.	—	Sispal Kella personal com.

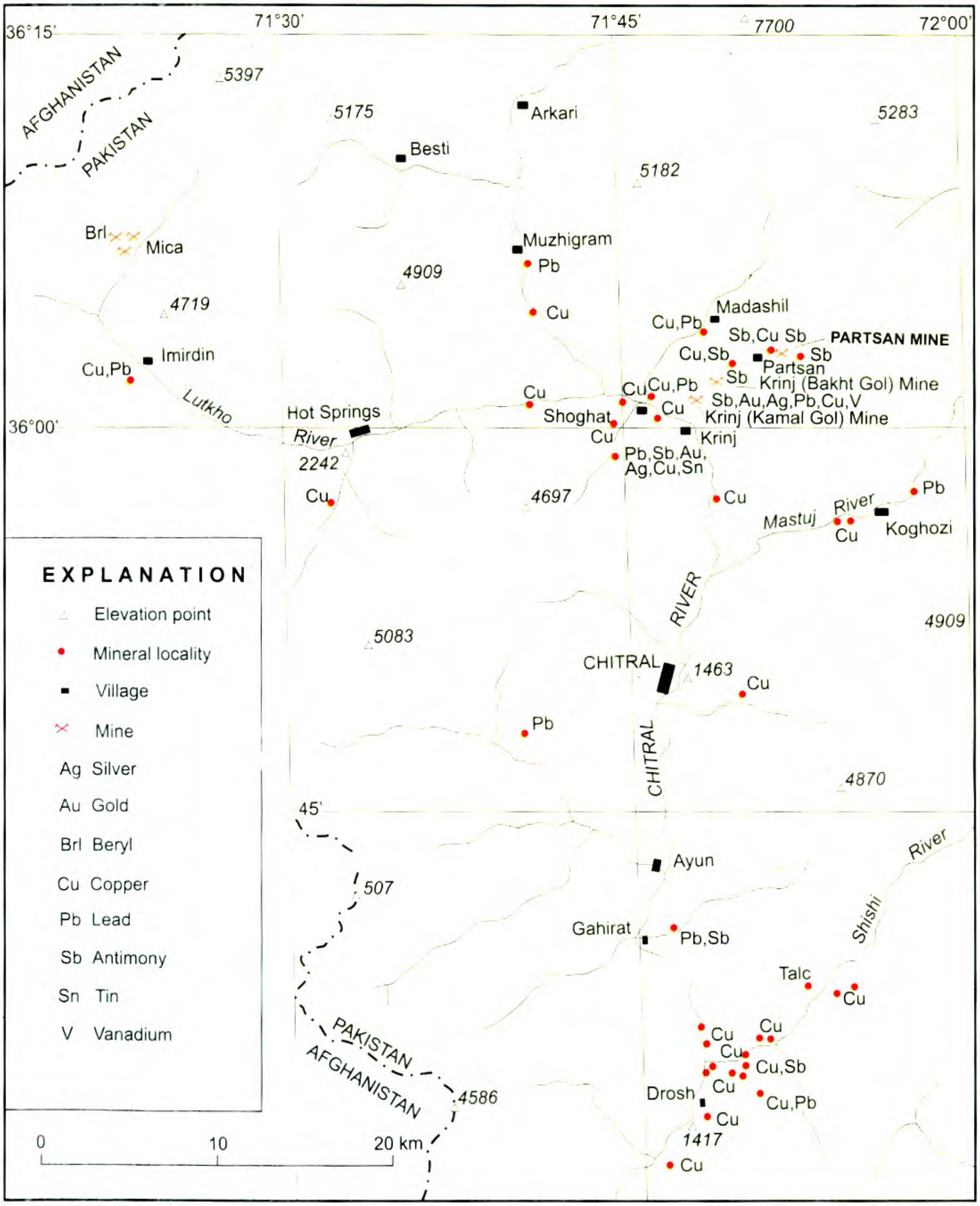


Figure 5.2. Mineral localities in the Chitral-Partsan area, northern Pakistan (from Calkins et al. 1981).

The annual production from the Krinj mines has varied from about 9 to 650 short tons and at times the mines have remained closed. Based on a reconnaissance survey, Calkins et al. (1981) estimated the ore reserves of the Kamal Gol mine at about 27,500 metric tons of which 4,000 tons were mined out. Detailed evaluation of this region is likely to reveal much larger ore potential.

BAUXITE AND LATERITE

Bauxite is a heterogeneous material comprised of various aluminum oxide minerals such as gibbsite, trihydrate, boehmite, diaspore and monohydrates. The mineral bauxite comprises the principal ore for extraction of aluminum, though in Russia nepheline syenite and in Sweden andalusite also have been used as ores for high aluminum. Bauxite has other uses also such as in the manufacturing of alum, bauxite bricks for furnaces and for making artificial abrasives.

Laterite is used as an iron ore when it has an appropriate chemical and mineralogical composition. It is used in manufacture of cement and in paints and pigments.

Bauxite and laterite are residual deposits and the result of weathering and leaching. They occur at several localities in the Foreland sedimentary fold-belt. They are mainly located along major unconformities. Bauxite deposits are rare and are confined to the Salt Range and the Lesser Himalayas. In many papers they have been described by various lithologic terms, e.g., clayey bauxite, bauxitic clay, bauxitic material, lateritic bauxite, lateritic clay, pisolitic clayey laterite, high-alumina clay etc., (Ahmad 1969). High-alumina residual deposits, which may be categorised as 'commercial bauxite' mainly occur in the Katha-Pail area of the Salt Range, the Chhoi-Akhori area of the Kalachitta Range and the Muzaffarabad-Kotli region of Azad Kashmir.

Katha–Pail deposits

A clay–bauxite–laterite bed, 1 to 7 metres thick, occurs extensively at the unconformity between the Permian sequence (Wargal and Amb Formations) and the Paleocene Hangu Formation (Fig. 5.3). It contains 35.5 to 72.5% alumina, 8.68 to 50% silica and 10 to 20% iron (Ashraf et al. 1972). There is considerable vertical and lateral variation in the composition of the deposit. Although it may be categorised as a low grade bauxite with high silica, moderate to low alumina and iron, it contains several large lenticular bodies of high-alumina bauxite (Al_2O 63%, SiO_2 9.5%, Fe_2O_3 4.18%). The ore contains boehmite and kaolinite, with minor amounts of diaspore and gibbsite. The reserves have been estimated at >100 million tonnes (Khan and Hussain 1970, Cheema 1974, Cruijs 1975).

Chhoi–Akhori deposits

These deposits occur in a 20-25 kilometres long belt in the highly tectonised and imbricated sedimentary sequence of the Kalachitta Hills. The deposits occur at the

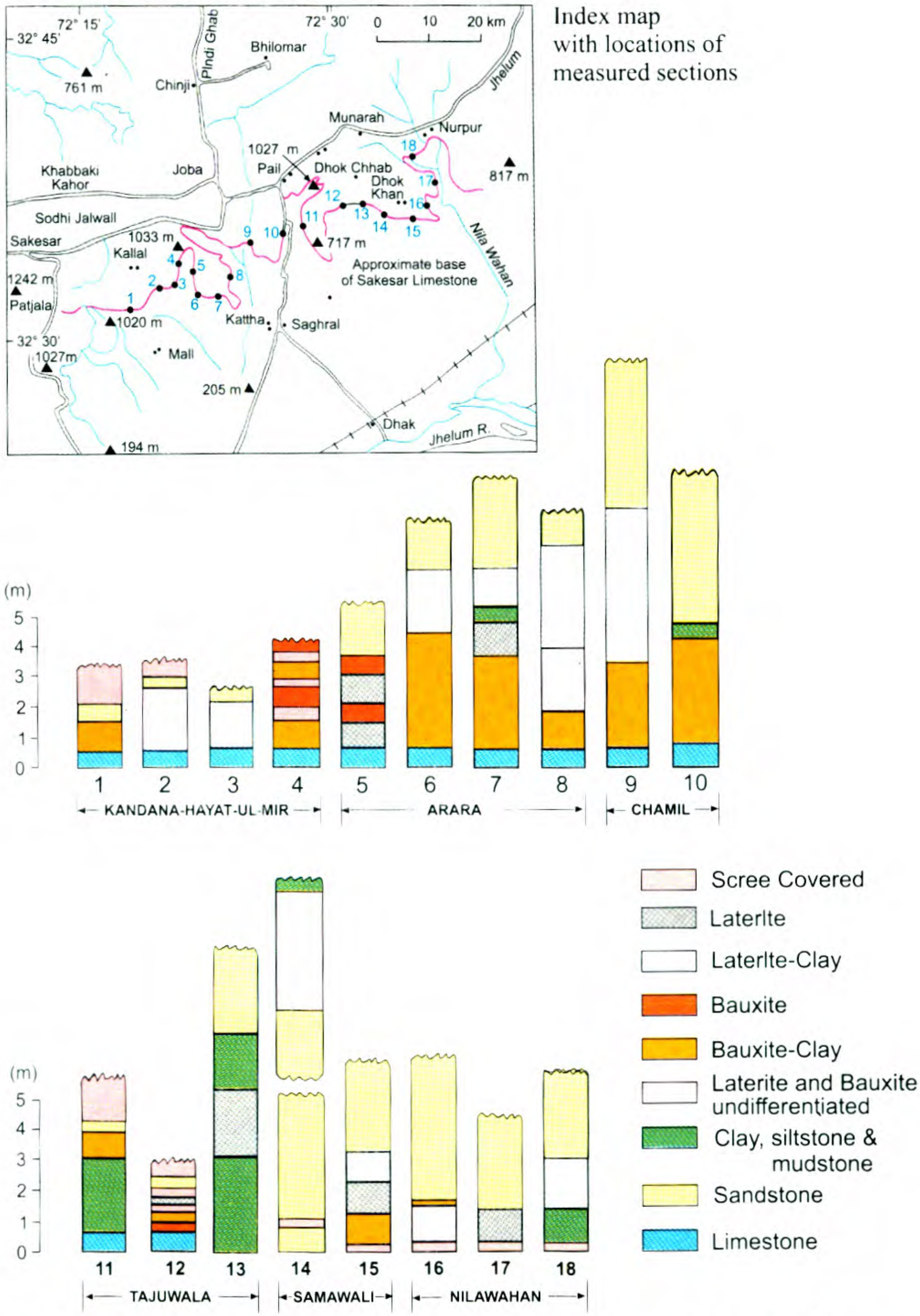


Figure 5.3. Measured laterite-bauxite sections in Katha-Pail area (base early Paleocene Hangu Formation) (From Shah 1980).

unconformity between Paleocene Hangu and Cretaceous Lumshiwal Formations and lower down at the unconformity between the Jurassic limestone and the Triassic Kingriali Formation. The upper horizon comprises an upper unit of up to 3 metres thick oolitic or pisolitic laterite and a lower unit of bauxite material up to 4 metres thick. In this zone aluminous clay, laterite, and bauxite occur as lenticular bodies associated with ironstone, ferruginous sandstone, claystone and quartzose sandstone. The bauxite contains approximately 32-76% Al_2O_3, 2.5-43% SiO_2, 0.25-12.00% Fe_2O_3 and 2.2-4.2% TiO_2 (Cruijs 1975). The lower lateritic horizon at the base of the Datta Formation, is more widely distributed and contains aluminous clays, claystones and alumina. The alumina clay samples from Chhoi contain 74.24–86.84% Al_2O_3, 0.64–0.74% Fe_2O_3, 6.0–7.0% SiO_2 and 3.65–4.28% TiO_2 (Hussain and Naqvi 1973). Some of this material is being mined and used as fireclay. Estimated reserves (down to 33 metres depth) are shown in Table 11.

Table 11. High alumina clay and bauxite deposits of Kalachitta Range. (From Hussain and Naqvi 1973).

Locality	Alumina content (%)	Reserve (m.t.)
Bagh Nilab	40-50	2.0
Chhoi	30-86	11.0
Surge	45	13.0
Buta	–	17.0
Akhori	55	3.5

Muzaffarabad–Kotli deposits

Small, scattered bauxite deposits are centred around the two outcrops of the Cambrian Sirban Formation of Abbottabad Group near Muzaffarabad (34°21' :73°30') and Kotli (33°31':73°54'). They occur along the unconformity between the Sirban Limestone and the overlying shales of the Eocene Patala Formation. The bauxite is pisolitic, embedded in a clayey matrix, varies in thickness from 0.5 to 1.2 metre and contains 51 to 89% clayey matter, 0–12% boehmite, 0–14% gibbsite, 1.5–10% quartz, 0–35% chalcedony, 2–89% iron oxides (Ahmad and Siddiqi 1992). The chemical contents and reserves of the ore at various localities are shown in Table 12. These deposits have been sporadically mined.

Bandi Kipla–Khanpur, Hazara. This deposit is located about 24 kilometres NW of Rawalpindi (33°53':73°11') and extends for about 22 kilometres south of the Haro River. It occurs at the Cretaceous–Eocene unconformity and its thickness ranges from 7 to 35 metres.

Margalla Hills. This deposit is located about 17 kilometres north of Rawalpindi. Here isolated pockets of ferruginous pisolitic laterite occur at the unconformity between Eocene limestones and Cretaceous sandstones. The lateritic layers are 7 to 700 metres long and 4 to 33 metres thick and the reserves are estimated at about 860,000 tonnes.

Surge. This deposit is located in the Attock–Surge area (33°42':72°15') and consists of ferruginous pisolitic–clayey laterite, 5–8 metres thick, located at the base of Eocene limestone. The reserves are estimated at 250,000 tonnes.

Table 12. Grade and reserves of Muzaffarabad–Kotli bauxite deposits.

Locality	Alumina (%)	Silica (%)	Iron (%)	Reserves (m.t)
Dhanwan	41–60	18–40	1–8	4.9
Kamroti (33°30':74°02')	50–70	9–28	1–2.5	1.36
Sawar	52–56	25	5	0.93
Dandili (33°22':73°58')	34–46	36–44	–	1.18
Nikial (33°29':74°04')	41–46	13–35	2–27	0.424
Goi	47	35	–	1.103
Shisetar (33°28':74°03')	NA	NA	NA	0.656
Bermoach	51	23	–	0.20
Balmi	46	31	–	0.209
Khandar Karela (33°26':74°06')	NA	NA	NA	0.209
Palan	NA	NA	NA	0.283
			Total:	11.454

NA=Data not available. (From ECL 1979).

Ziarat laterite

Very extensive deposits of laterite occur in the Ziarat area (30°23':67°43') about 90 kilometres east of Quetta. The laterite occurs at the unconformity between the Paleocene Dungan limestone and the Cretaceous Parh limestone (Kazmi 1988). The laterite crops out on the limbs of several anticlines between Ziarat and Sanjawi, a distance of about 30 kilometres. Laterite beds range in thickness from about 0.5 to 15 metres, though at most localities they are 1 to 3 metres thick. This is apparently the largest laterite deposit in Pakistan and is likely to have mineable reserves of hundreds of millions of tonnes.

The laterite is dark red to reddish-orange in colour, highly ferruginous, pisolitic, at places hematitic and with relatively high specific gravity (about 3.1–3.4). Its iron content is quite high, but high silica and titanium make it difficult to use as an iron ore (Table 13). However, it has been mined for use in cement factories (Ahmad 1969, 1975).

Table 13. Chemical analyses of Ziarat laterite (from Kazmi 1956).

Constituents	1	2	3	4
SiO_2	13.06	17.16	7.70	21.00
Fe_2O_3	37.36	48.66	51.70	34.40
Al_2O_3	32.48	18.62	32.00	27.72
TiO_2	2.66	0.56	–	–
H_2O	13.06	13.36	8.45	15.34

Laterite occurrences have been reported from many localities and the more significant ones are as follows (Ahmad 1969).

Laterite has been reported also from Moza Mungiwali (33°43':62°16'), Gakkar (33°39':72°37'), Pind Trer (33°45':72°28'), Daud Khel (32°53':71°43'), Kathwai (32°29':72°12') and at several localities in Kalachitta Range; in Kohat District at Mazari Tang (33°45':72°55') and Marai Bala (33°44':71°08'); in Samana Range 16 kilometres from Hangu; near Langrial 32 kilometres south of Abbottabad and near Kalabagh. The Langrial and Kalabagh deposits qualify to be treated as iron ores and have been discussed in detail in the following pages. In Sindh lateritic clay, pockets of limonite and ochre are found in the Eocene Sonari Formation at Lakhra (25°40':68°14'), Meting (25°09':68°12') and Makli Hills (24°43':67°53'). Another very extensive lateritic horizon has formed at the unconformity between the Jurassic and Cretaceous strata at Dilband in Kalat District and is being used as an iron ore. It has been discussed under that name.

CHROMITE

Chromite is a spinel-group mineral with a general chemical formula (Mg, Fe) (Cr, Al, $Fe)_2O_3$. It is the only source of chromium metal which is mainly used in the manufacture of stainless steel. It is also used in making chemicals and salts of chromium and has a wide range of industrial uses. The use of chromite as refractory material is also quite common.

Chromite is associated with ultramafic rocks which occur as layered intrusions or as ophiolitic sequences. Chromite ore in layered intrusions occurs as large extensive layers with huge tonnage while chromite ore bodies associated with ophiolitic type of rocks are generally irregular, podiform in shape and small in size. The chromite deposits associated with ophiolitic rocks are known as Alpine type.

The chromite deposits of Pakistan are largely of the Alpine type. They are associated with ophiolitic rocks emplaced along the colliding plate boundaries. The chromite is found as pods, lenses and irregularly shaped bodies in dunite. The dunite occurs in the basal part of the ophiolites, i.e., in ultramafic tectonites and ultramafic cumulates.

In Pakistan chromite was first reported by Vredenburg (1901) and its mining started in 1903 in the Khanozai area of Zhob District. Mining was extended to Muslimbagh area in 1915 and later in early twenties mining started in Sra Salawat area, 29 kilometres south of Muslimbagh. Presently chromite is largely mined in Balochistan and NWFP. Its deposits occur at the following localities.

1. Chilas (Chilas District).
2. Besham (Jijal), Kohistan (District Swat) (Fig. 5.4).
3. Dargai (District Malakand).
4. Pranghar, Bucha (Mohmand Agency).
5. Boya (North Waziristan).
6. Zhob Valley (Qila Saifullah and Zhob Districts).
7. Bunap, Rayo Valley (District Kharan).
8. Wad, Sonaro (District Khuzdar).

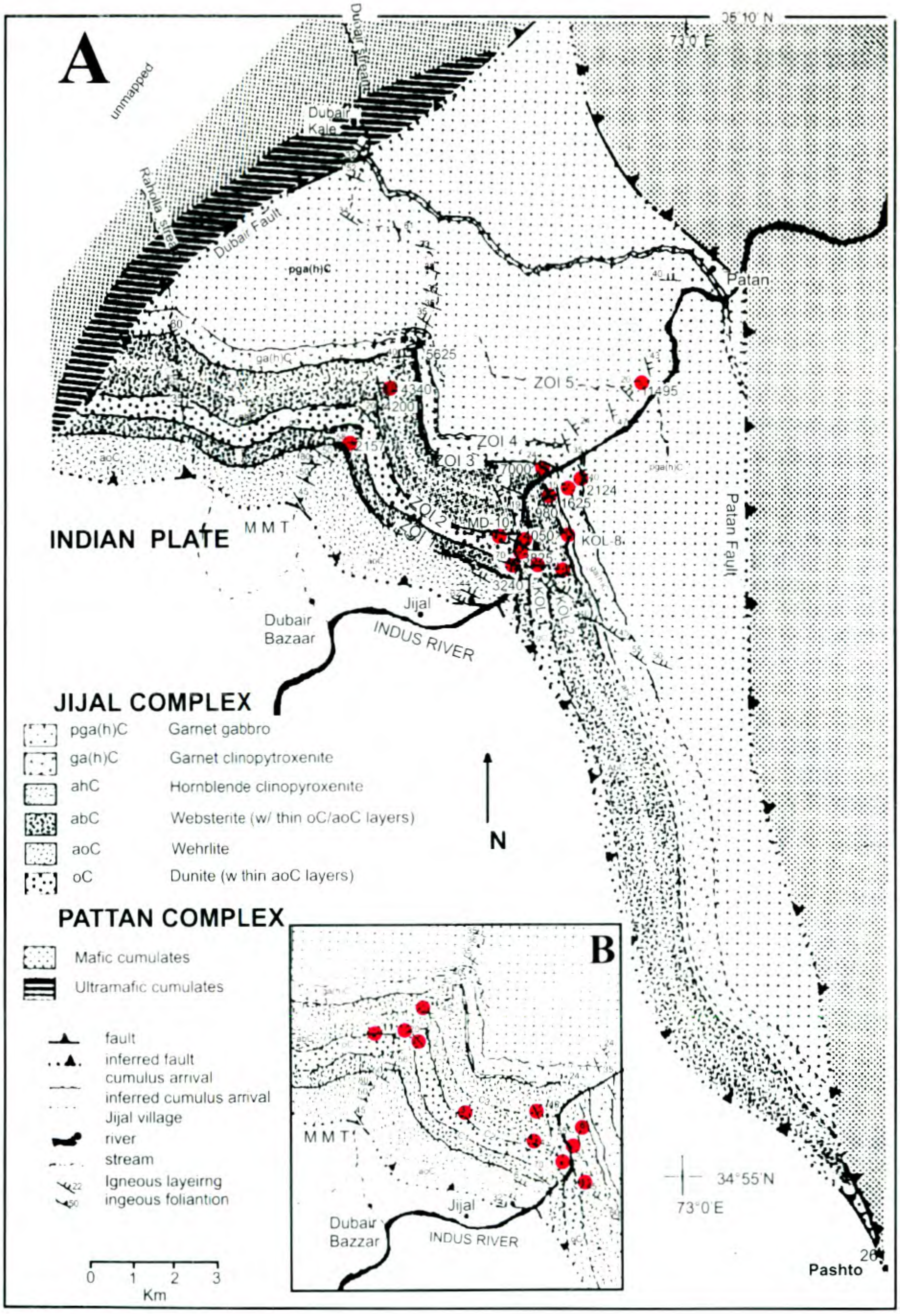


Figure 5.4. Geological map of the Jilal Chromite deposits and PGE showings. In (A) red dots with numbers indicate sites of precious metal-minerlised samples; zo 1 = zone of interest for precious metals. In (B) red dots with numbers show chromite mines/prospects: 1= Shungial, 2= Kuroo, 3= Gabara, 4= Manidara, 5= Kokial, 6 = Serai, C1, C2, C3, = chromite bearing units. (From Miller et at 1991)

These deposits occur in different tectonic, environments. The Zhob, Wad and Boya deposits occur in ophiolites which are fragments of oceanic crust and upper mantle and were obducted upon the sedimentary sequence along the Indo-Pakistan Gondwanic Domain during the Paleocene. The Bunap and Rayo valley chromites occur in ophiolites in the Ras Koh Range. These ophiolites are believed to be remnants of a subduction complex (Siddiqui 1996). Chromite bearing ophiolites in the Dargai and Pranghar areas in northern Pakistan are thrust slices of obducted masses located along the suture zone between the Kohistan magmatic arc and the Indo-Pakistan Gondwanic Domain. The Jijal ultramafic rocks are regarded as deep-seated island arc cumulates, while the chromite-bearing Chilas Complex is related to Kohistan arc and probably formed during intra-arc rifting in the initial stages of the development of a back-arc basin (Jan et al. 1989).

During the years 1994–1998, the total annual production of chromite from these deposits has varied from 15,035 to 37,472 tonnes.

Chilas chromite

A large outcrop of chromite bearing ultramafic rocks is situated near Chilas and forms a part of the 300 kilometres long and 40 kilometres wide stratiform Chilas Complex. The latter is mainly composed of norites, with subordinate ultramafic rocks, anorthosites, gabbros and diorites, metamorphosed in pyroxene granulite facies. The Chilas ultramafics are largely comprised of dunites with some peridotites, pyroxenites and rare amphibolites. According to Jan et al. 1984, the structure and mineral chemistry of the Chilas ultramafics suggests that they have broader similarity with stratiform rather than the alpine or concentric complexes. The Chilas chromite has not yet been explored. However, geological reconnaissance shows that within the dunite there are thin layers of chromite with 26% Cr_2O_3, 26% Al_2O_3, 37% FeO and 9% MgO (Jan et al. 1984).

Besham (Jijal) chromite

These deposits are located about 165 kilometres north of Abbottabad, near Jijal (Kohistan District), on the Karakoram Highway. Chromite occurs in the Jijal Complex, which consists of garnet granulites and ultramafic rocks (Fig. 5.4). These rocks form a 150 km^2 tectonic block which is the southern most and lower most stack in a succession of layered ultramafic-mafic cumulate complexes of the Kohistan magmatic arc. The ultramafics exhibit layering at many places and they are comprised of dunite, peridotite, diopsidite, vebsterite and chromitite (Jan and Windley 1990).

Several dozen chromite pods and lenses have been reported in the ultramafic rocks in the northwestern part of the Jijal Complex (Ashraf et al. 1980a,b, Jan and Windley 1990, Miller et al. 1991). The Chromite lenses are up to 2–3 metres thick and 50 metres in strike length. Other minerals associated with the ultramafics include chlorite, tremolite, anthophyllite, and talc. The ore reserves were estimated at 0.6 million tonnes by SDA and according to them, the Jijal chromite contains 40–45% Cr_2O_3 and 12–18% Fe_2O_3 (Khan and Ahmad undated) and the Cr:Fe ratio ranges from 2.8:1 to 3.6:1.

According to Ashraf et al. (1980a,b) important deposits occur near Jijal, Shungial, Kokial, Taghtai, Gabar, Mani Darra, Khairabad, Jag, Tangai, Chinarai, Kolai, Serai, Lomoto and Kot. Chromite mining has been carried out at Shungial, Kuroo, Gabar, Mani Darra, Kokial, and Serai (Miller et al. 1991).

Dargai (Malakand) chromite

The chromite bearing Dargai ophiolite complex is located about 60 kilometres NNE of Peshawar. This complex forms a thrust block overlying Paleozoic metasediments, It is comprised of (a) ultramafic cumulates consisting of harzburgite (80%) and dunite (20%), (b) mafic cumulates consisting predominantly of gabbro with a few layers of serpentine, and (c) ultramafic tectonites which mainly consist of harzburgite (90%+) and dunite (less than 10%).

In the Dargai complex, chromite occurs in three different modes:

(i) Laterally extensive layers are common and restricted to the upper part of the complex. Some of the chromite zones are 3 to 4.5 metres thick and may contain up to 50% chromite. Some layers may be traced intermittently for 2,000 metres. The Qila deposit which is 130 metres long and 9 metres thick is a good example.

(ii) Irregularly shaped massive bodies associated with crosscutting dunite, each less than one metre square are exposed in the western part of the complex. They are apparently of little economic value.

(iii) Podiform, massive and irregularly shaped deposits with sharp contacts are few and limited in size. The Hiru Shah deposit is a good example (Rossman and Abbas 1970).

The main deposits occur at Hiru Shah, Barjo Kanri, Landi Kand, Badasar and Qila and have been intermittently mined. The Dargai chromite is high in iron, low in chromic oxide and low in Cr:Fe ratio. However, some of the ore contains 30–40% Cr_2O_3 and the lower grade ores have been successfully upgraded to concentrates with over 45% Cr_2O_3 by SDA. The reserves are estimated at 0.67 million tonnes (Khan and Ahmad undated).

A feasibility study for the mining, beneficiation, utilisation and marketing of the Dargai chromite and its products was carried out by SDA, PCSIR and Messers Turk Pak International Consulting Engineers, Lahore in the mid-nineties. It was found economically feasible to process 20,000 tonnes of ore to produce 8,000 tonnes of basic chromic sulphate and 1,500 tonnes of sodium dichromate and 300 tonnes of sodium, sulphate annually. Presently these chemicals are being imported and there is a local market for them (Khan and Ahmad undated).

Mohmand chromite

A vast thrust sheet of a melange complex, the Kot-Pran Ghar Melange (Hussain et al. 1984), covers the Paleozoic metasediments in the east-central part of the Mohmand Agency, 57 kilometres north of Peshawar. The melange is comprised of randomly oriented blocks of greenstone, greenschist, pyroclasts and tuffites. In its southern part, from Bucha westward there are thrust slices of ultramafic rocks, similar to the Dargai ophiolites and these may be the westward (though discontinuous) extension of the Dargai sequence. Lenses, pockets and disseminations of chromite occur in the ultramafic rocks near the villages of Parai, Yousaf Baba, Auro Khawar, Balala, Bucha and Mamanai Gudar. This region has not yet been explored adequately.

Boya (Waziristan) chromite

Chromite bearing ophiolitic rocks occur west of Razmak, near Boya (32°57':69°57'). The ophiolitic sequence has been thrust eastward over the Jurassic to Cretaceous sediments of the Foreland sedimentary fold belt. A complete normal-order ophiolitic sequence is nowhere present, but at different localities various members of this sequence i.e., ultramafic rock, gabbros, sheeted dykes, pillow lavas, pelagic sediments and plagiogranites may be seen. The ultramafic rocks include harzburgite, dunite and pyroxenite.

Chromite is associated with the ultramafics and occurs as lenses, segregated stringers and disseminated grains. The chromite lenses are up to 6 metres long and 0.5 to 1.0 metre thick. The lenses are surrounded by a zone of ultramafic rocks up to 30 x 3 metres, containing high concentrations of accessory chromite (Jan et al. 1985).

Chromite occurrences have been reported from Mami Rogha, Sherkai, Madar Algad and Tut Nari (Khan et al. 1982). Detailed evaluation or exploration of these deposits has not yet been done.

Zhob Valley chromite

The region between Quetta and Zhob is comprised of thick imbricates of Mesozoic rocks, enormous slabs of obducted melanges and ophiolites and small nappes of Cretaceous, to Paleogene sedimentary rocks. This region contains the largest and best-known occurrence of ophiolites in Pakistan, which is known as the Zhob valley ophiolite belt. It extends eastward from near Khanozai up to Zhob, a distance of about 250 kilometres. Thrust blocks of ophiolites and melanges of varying sizes are scattered throughout this region. However, the larger out crops are located in the vicinity of Khanozai and Muslimbagh.

The ophiolites occur as tectonic klippe and thrust sheets overlying the Zhob Melange or the Mesozoic sequence or as thrust slices within the imbricated Mesozoic blocks (Kazmi and Jan 1997). The two large ophiolite bodies south of Muslimbagh, the

Saplai Tor Ghar and Jang Tor Ghar contain a classic sequence of ultramafic tectonites, ultramafic and mafic cumulates, a dyke complex and a dolerite dyke swarm.

In the Zhob valley, chromite occurs in the serpentinised dunites of the ultramafic tectonites and cumulates in different form and shape. There are massive ores surrounded by banded ores, grape-shot ores, banded deposits of disseminated ores, cigar-shaped ore bodies, dyke-like ore bodies up to 100 metres long and thin wiggly, irregularly shaped bodies. The reserves in these types of ore bodies range from 100 to 15,000 tonnes (Ahmad and Bilgrami 1987).

Chromite is being mined largely near Khanozai, Muslimbagh, Saplai Tor Ghar, Jang Tor Ghar and the town of Zhob. Since 1903, chromite has been produced from more than 350 mines in this region. During this period only 35 mines have each produced more than 1,000 tons and only three have produced more than 50,000, tons. However, according to Ahmad and Bilgrami (1987), the biggest potential (about 100,000 tons) is possibly concentrated in Mine 401 in Saplai Tor Ghar.

The Zhob chrome ores are aluminous chromite. Some of the ore (from Naweoba and Zizha (near Zhob town) is refractory grade, while most of the Jang Tor Ghar ore is of. metallurgical grade. The Cr_2O_3 content and Cr/Fe ratio of various Zhob chrome ores are as follows:

Locality	Cr_2O_3	Cr/Fe ratio
Naweoba and Zizha	36.7– 46.5	2.9 : 1
Khanozai	49.3–52.6	2.7 : 1 to 3.5 : 1
Jang Tor Ghar	48– 57	3 : 1.to 3.7 : 1
Saplai Tor Ghar	44– 52.5	3 : 1
Nisai	39 – 49	2.1 : 1 to 2.6 : 1

To show the range in composition, detailed chemical analyses of Zhob valley chromites are given in Table 14. The annual chromite production in Zhob valley has fluctuated widely, for example in 1918 it was 26,695 tons, in 1921-1931 it averaged 19,000 tons, in 1942 it reached the peak of 39,344 tons, from the end of World War II up to 1952 it averaged 18,000 tons, in the sixties and seventies it ranged from about 13,500 to 28,000 tons and in 1980-81 it declined to only 1,108 tons (Ahmad 1969, Ahmad and Bilgrami 1987). However, in recent years the annual production has again increased and is around 10,000 to 15,000 tons.

Until now more than 1.5 million tonnes of ore has been already produced and according to Rossman et al. (1971a,b) the present reserves are likely to exceed this amount.

Bunap–Rayo (Ras Koh) chromite

In the Ras Koh, chromite deposits occur at Bunap and Rayo valley (within a distance of 3 kilometres) about 30 kilometres NW of Kharan Kalat town. Chromite occurs as small chalcopyrite, and bornite are associated with hypogene secondary sulphides and oxides of iron and copper.

Ninety two test holes have been drilled to explore these deposits. The average copper content in these holes has been found to be 0.386 percent. The inferred reserves down to 159 metres depth, have been estimated at 120 million tonnes (Badshah 1983b, 1994).

Dir copper deposits

A number of copper showings occur in the Dir area (Table 9). The SDA has explored one of the more promising ones in the Bekarai-Rokhan area, a few kilometres north and west of Dir. The mineralised zone extends for more than 30 kilometres. It is located within the Kohistan magmatic arc. It occurs in the Dir volcanics. It is a fracture filling, brecciated, vein-type deposit, apparently located along a fault zone. It contains malachite, azurite, chalcopyrite and bornite. Extensive pitting, trenching and additing has been carried out and several hundred ore samples tested and analysed. The results indicate total reserves of about 45 million tonnes with 0.4 to 0.6 percent copper and 2 to 30 ppm silver (Khan and Ahmad, undated).

Drosh copper deposits

Within 8 to 10 kilometres of Drosh town, there are several showings of copper (Fig. 5.2). The mineralisation is in the suture zone (Main Karakoram Thrust-MKT) between the Karakoram Block, and the Kohistan Magmatic arc. The main mineralised localities are Gawuch Gol, Kaldam Gol, Gorin Gol and Langer.

At the Gawuch Gol locality 1.6 kilometres east of Shishi River, thin mineralised quartz veins occur in the vicinity of Shishi fault, in sheared alteration zones in chlorite schist of the Gawuch Formation. The Gawuch is intruded by diorites of the Kohistan batholith (Pudsey et al. 1985). Analyses of the ore-bearing quartz shows 150 ppm silver, 3% copper, 0.5% lead and small amounts of antimony, zinc and vanadium (Calkins et al. 1981).

At the Kaldam Gol locality, 4.8 kilometres east of Drosh, mineralisation occurs in a brown-weathering breccia zone, between marble and siltstone beds of the Gawuch Formation. The ore body extends for 100 metres and is 2.4 metres wide. It is apparently associated with a fault and contains chalcopyrite, galena and pyrite. Random analyses of the ore showed 8.9% copper, 39.5% lead, 5.6% antimony, 0.17% silver and 4.3 ppm gold (Calkins et al. 1981).

At Drosh, Shishi village, Pursat village, and Beorail Gol, copper and other sulphide minerals occur in porphyritic volcanic greenstone, olivine basalt and in carbonate veinlets in altered andesitic lava flows. Samples from these locations have revealed high contents of copper (up to 7%) and silver (up to 30 ppm). According to Khan and Ahmad (undated) the main copper-silver mineralisation occurs within carbonate rocks at the contact of granodiorite and also within the granodiorites. The main copper minerals are chalcopyrite, chalcocite, tetrahedrite and malachite. SDA has done some exploration and evaluation of the Drosh deposits. Based on 400 metres of additing and analyses of 900 samples, they estimated reserves of 24 million tonnes of ore averaging 0.5% copper with silver ranging from 3 to 130 gms/tonne.

Dasht–Kain copper deposit

This deposit is located 35 kilometres NW of Chagai village (29°33':64°29') in Chagai District. It is porphyry type copper prospect, associated with two tonalite porphyry stocks. The stocks are intruded into a diorite cupola which is a part of a large batholith comprised of quartz monzonite and diorite. The batholith has intruded the Cretaceous Sinjrani volcanic group. The host rock tonalite porphyry is centred by potassium silicate alteration and followed outwardly by quartz sericite and porphylitic alterations. There is a moderate to weak K-zone and the hypogene mineralisation has developed in two phases, the first phase produced pyrite, chalcopyrite, enargite and pyrrhotite and the second one introduced magnetite, molybdenite and chalcopyrite (Siddiqui 1984).

Three bore holes have been drilled in the western stock. Average copper values in quartz sericite zone vary from 0.1 to 0.17 percent and in the potassium silicate zone from 0.25 to 0.54 percent. The breccia pipe zone in the eastern stock contains surface values up to 4.5% copper, but it has not been drilled.

Talaruk copper deposit

This deposit is located 64 kilometres NW of Saindak in Chagai District. It is a massive Kuroko-type deposit and the mineralisation is of sub-marine exhalative origin. The copper ore occurs in two zones, one in rhyolite intrusives in which chalcocite is the main copper mineral and the other in volcanic breccia associated with gypsum, with malachite as the main copper mineral. Six bore holes were drilled at this deposit and its copper content has been found to be about 0.65% (Khan et al. undated, Saigusa 1977).

Saindak copper deposit

The Saindak porphyry deposit is located about 9.4 kilometres southeast of Fort Saindak (29°18':61°33'), in the Chagai District. The ore is hydro-thermally altered and the mineralised zone is known as Saindak alteration zone. It is developed in siltstone, sandstone and tuff of Amalaf Formation. The mineralisation is related to zonal patterns centred on three porphyry stocks of Mid-Miocene age and consequently there are three main ore bodies, the North, South and East ore bodies. These ore bodies have been explored and evaluated in detail (Fig. 5.6).

The North ore-body is developed along vein zones, though oxide mineralisation is

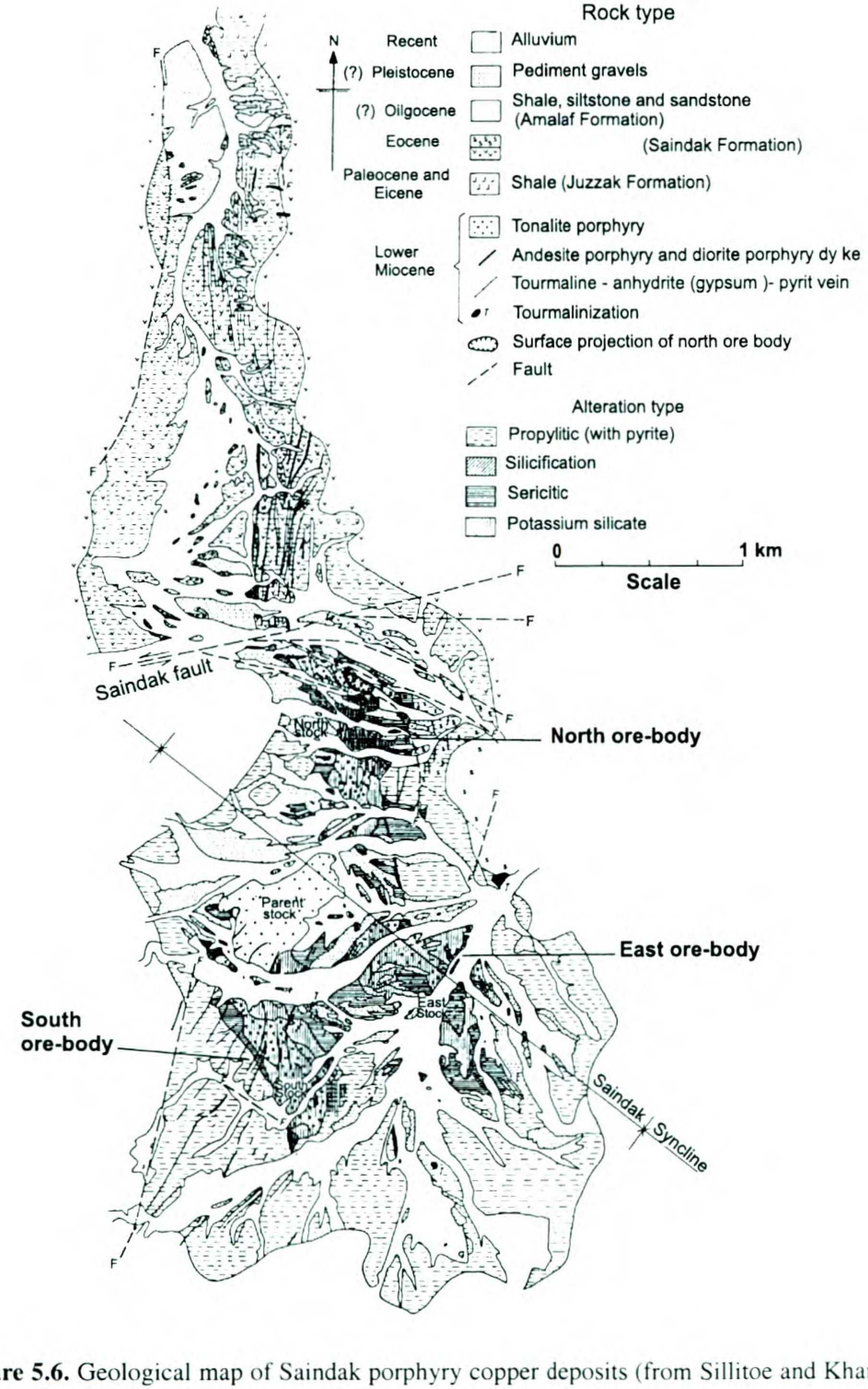


Figure 5.6. Geological map of Saindak porphyry copper deposits (from Sillitoe and Khan 1979).

Table 15. Summary of Saindak copper ore reserves at various cut-off grades (million tons), to a depth of 476 metres AMSL

Cut-off grade	Proved reserves	Probable reserves	Total reserves	Average expected grades
North Ore Body				
0.30 percent	15	4	19	0.498 percent copper
0.40 percent	10	2	12	0.587 percent copper
0.2 grams gold/ton	9	—	9	0.514 grams gold per ton ore
South Ore Body				
0.30 percent	54	—	54	0.488 percent copper
0.35 percent	41	—	41	0.538 percent copper
0.40 percent	27	—	27	0.639 percent copper
0.50 percent	18	—	18	0.725 percent copper
0.40 grams gold/ton	28	11	39	0.70 grams gold per ton ore
0.30 grams gold/ton	54	—	54	0.49 grams gold per ton ore
0.009 (Moly.)	29	—	29	0.019 percent
East Ore Body				
0.30 percent	207	57	264	0.388 percent copper
0.35 percent	118	34	152	0.430 percent copper
0.40 percent	74	15	89	0.50 percent copper
0.45 percent	32	1.0	34	0.572 percent copper
0.50 percent	20	0.59	21	0.621 percent copper
0.009 (Moly.)	55	—	55	0.017 percent molybdenum

Table 16. Copper-gold prospects explored in Chagai District (from Razique 2001).

Area name	(UTMWGS84) Location	Geology	Alteration	Surface geochemical anomaly	Remarks
Rekodiq	412562.3E 3220280 6N	Qtz-feldspar porphyry, andesitic volcanics, hydro-thermal breccias.	Phyllic (qtz-ser-py-clays)	0.05-0.1% Cu	Leaching and supergene enrichment is evident.
Buzzi Mashi Hole 7,8,27	411290E 2319029N	Diorite intruded in frag-mented andesitic volcanics.	Potassic (Chl. Bio, Ser, mag). Phyllic (qtz-ser-py)	0.08-0.15%Cu <0.1 g/t Au.	Weak hypogene Cu system.
Area W of Buzzi Mashi	Lat. Long. 29°9':62°11' 413696E 3218795E	Qtz-feldspar porphyry and diorite stock in andesite and pyroclastics.	Potassic (bio-K-Spr, Chl, Ser) with strong magnetite.	0.05-0.2%Cu 0.1 g/t Au.	Intruded by a late stage barren porphyry.
Western War Chah Porphyries.	408200E 3220700N	Porphyritic diorite intruded in andesite and pyroclastics. volcanics with contact breccias.	Potassic (bio, K-Spr, Chl,Ser) with str. mag Phyllic (qtz-ser-py)	Avg 0.18%Cu 0.15% g/t Au.	The core of the system is barren due to late stage porphyritic event.
Parrah Koh	415850E 3217805N	Medium grained diorite intruded in andesite.	Potassic (K-spr-bio Phyllic (qtz-ser) Prophyllitic (chl,epi)	Avg 0.15%-0.2%Cu 0.15 g/t Au.	Porphyritic system in sediments (Saindak/ Juzzak Fms.).
Borghar Koh	410518E 3224895N	Porphyritic diorite with sediments and pyroclastic volcanics as host rocks.	Potassic (bio, chl, ser, mag) Phyllic (qtz-ser, clays) Prophyllitic (chl,epi).	0.05-0.1%Cu <0.1 g/t Au.	Minor amount of leaching identified.
Koh-i-Dalil/ Sam Koh Prospects	421000E 3221500N Lat 29°7'10" Lon 62°11'17"	Medium grained diorite with sediments, pyroclastics and andesite as host, covered by dacitic volcanics of Koh-i-Dalil phase. Humai Lst. exposed at the peripheries.	Potassic (bio, K-spr Chl, mag) Phyllic (qtz-ser-py) Prophyllitic (chl, ep).	0.1-0.25%Cu <0.15 g/t Au.	System ore mostly covered by Koh-i-Dalil volcanic plug.

(contd.)

Table 16. Copper-gold prospects explored in Chagai District (continued).

Area name	(UTMWGS84) Location	Geology	Alteration	Surface geochemical anomaly	Remarks
Malaik Koh (Koh-i-Sultan)	Lat 29°5'35" Long. 62°45'10"	Quaternary volcanics (andesite), pyroclastics, dacites, with diorite stocks.	Intermediate argillic Chl. (ser, ± bio ?) Argillic (advance argillic), prophyllitic (Chl-epi, Carb).	0.05-. 15%Cu <0.08 g/t Au Some veins carry 0.3 g/t Au.	Shallow level epithermal system overprinted porphyry.
Ting Daragun Kaur Prospect	568800E 32219700N Lat 29°O5' Long. 63°40'	Diorite intrusions in andesitic hosts. Pyroclastic breccia and sediments (sst) at the margins of the system.	Potassic (bio, K-spr. chl str. diss mag) Phyllic (qtz-ser-clays) Porphyllitic (Chl, ep, carbonates).	0.10%Cu 0.08 g/t Au.	Moderately mineralised g/t Au. porphyries.
Machi Prospect	633699E 325922N	Qtz diorite ? intruded in andesitic volcanics.	Potassic (Chl, bio ± K-spr) with mag. Phyllic (qtz-ser-clay) prophyllitic (Chl, ep).	0.05-0.12%Cu 0.06 g/t Au	Au at surface is dead because of minor leaching.
Ziarat Pir Sultan Prospect	633699E 3259227N Lat 46~2'43" Long. 29~7'19"	Diorite, granodiorite, syenite intrusions in andesitic volcanics and intrusive batholith of granitic composition.	Potassic (Chl, ser, bio, K-spr) moderate magnetite.	0.1-0.2 Cu 0.5-0.1 g/t Au.	There is no pervasive alterationn and mineralisation but in alternate bands.
Kirtaka Prospect	536400E 3249800N Lat. 63°7'24" Long. 29°7'24"	Medium grained diorite intruded in massive volcanics (Sinjrani), breccia pipe in the south.	Potassic (bio, chl, mag ± K-spr) Phyllic (qtz-ser) Prophyllitic (chl, epi, Carb).	0.15% Cu 0.08 g/t Au.	Ideal (typical) porphyry Cu system for academic studies.

also present in patches. Nineteen bore holes were drilled on this body and 19 m.t. of ore averaging 0.498% copper (cut off grade 0.3%) has been proved (Table 15).

The South ore-body lies, 2 kilometres south of the North body. In this ore-body also, the oxide zone is developed in patches. The ore is developed within a few metres of the surface and has been proved to depth of 328 metres. Twenty seven holes were drilled and reserves of 54 m.t. of ore averaging 0.488% (cut off grade 0.3%), including 27 m.t. of 0.64% copper at cut off grade of 0.4%, have been proved. Significant gold and molybdenum values are associated with this ore-body.

The East ore-body is one kilometre SE of the South ore-body. A lean, patchy copper oxide zone with 0.4–0.5% copper is developed over the ore-body. In this area 37 bore holes have established reserves of 264 m.t., averaging 0.388% copper at cut-off grade of 0.3% (Table 15).

From Table 15 it would be seen that the total reserves at Saindak comprise 412 million tonnes of ore containing on an average 0.38% copper and 0.3228 gram/tonne of gold. At Saindak an open cast mine with infrastructure, crushing plant, concentrators and smelter has been developed and trial production of blister copper has been done. It is planned to produce annually 15,800 tonnes of copper blister, 1.47 tonnes of gold and 2.76 tonnes of silver (Bizenjo 1994).

Other porphyry copper deposits in Chagai District

Recently a number of prospective copper occurrences in Chagai District were explored and evaluated by BHP. Their results suggest that the western part of the District has a greater potential for development of porphyry copper deposits. Based on the results of 80 test holes, it is estimated that this region has reserves of 500 million tonnes (Razique 2001) of ore averaging 0.4 to 0.6% copper and 0.2 to 0.5 gm/tonne of gold. According to BHP besides Rekodiq, Buzzi Mashi and Western Ware Chah, other localities such as Parrah Koh, Borghar Koh, Koh-i-Dalil, Koh-i-Sultan, and Ting Daragaun look promising and merit detailed exploration (Table 16).

Tethyan Copper Company has recently drilled 30 holes at Rekodiq (Koh-i-Dalil) and has encountered a chalcocite blanket and hypogene zone. In this zone alone reserves of 70 million tonnes of ore with 0.85% copper are indicated.

GOLD, SILVER AND PLATINUM

Gold and silver are precious metals being used by mankind for jewellery and as a status and power symbol since times immemorial. In the present day world along with its major consumption in Jewellery, these metals are being increasingly used as important industrial raw materials also. The platinum group comprises six closely related metals– platinum, palladium, rhodium, ruthenium, iridium, and osmium. Along with gold and silver, they are known as noble metals. They are refractory, chemically inert and exhibit excellent catalytic activity. They are used in the automobile, chemical, petrol refining, electrical, ceramic and glass industries as well as in jewellery.

Gold occurs mainly as native metal, or alloyed with silver and other metals as tellurides. It is commonly associated with sulphides of iron, silver, arsenic, antimony and copper. The richest gold deposits commonly occur in small fissure veins though much larger quantities are contributed by more extensive medium-grade deposits. Gold deposits occur as hydrothermal, metamorphic and replacement deposits or as cavity fillings in fissures, stockworks, saddle reefs, breccias and conglomerates. Gold also occurs as nuggets and grains in residual or placer deposits.

The most important use of silver is in production of various photographic materials and in refrigeration and air conditioning industry. Silver is commonly associated with copper, lead and zinc deposits or occurs with gold in combination with gold in the type of deposits mentioned in the above paragraph.

Platinum group of minerals (PGM) are mainly used in the automobile industry (to reduce CO emission), in chemicals, petroleum refining, ceramics and glass, electrical and electronic industries, in jewellery and they also have dental and medical uses (treatment of cancer, arthritis, radiotherapy, production of denture etc.). The PGM are associated with mafic and ultramafic rocks and they also occur as placer deposits.

In Pakistan showings and deposits of gold, silver and PGM have been noted at several localities (Table 9). Gold panning is carried out at several places in the northern areas along the course of Indus River and its tributaries and a small amount of gold is produced in these areas. Production of gold (1.47 tonnes per annum) along with copper and silver is expected to start from Saindak porphyry copper deposits in the near future.

As given in preceding chapter on metallogenic setting of Pakistan, several tectono-metallogenic provinces are favourable for the occurrence of these important precious metals in the country (Table 17).

Chagai District

In the Chagai Magmatic Arc, Geological Survey of Pakistan has identified a number of porphyry type deposits which may contain appreciable quantities of gold along with copper and silver (Ahmad 1986). Favourable environment for telethermal vein type and skarn type deposits also occur in the Chagai Arc area. Broken Hill Propriety (BHP) of Australia, in collaboration with Balochistan Development Authority, is exploring for gold deposits in the area and have located several drilling targets. The drilling of first target has started and it is expected that world class gold deposits may be discovered in Chagai District of Balochistan Province. A tabulated summary of data on some of the prospects identified by them is given in Table 17. Lake Resources, another Australian company has

Table 17. Gold and silver deposits and showings (also see under Cu, Fe and Pb-Zn ores in Table 9).

TECTONO-METALLOGENIC ZONE	DEPOSIT	GRADE (PPM) GOLD	Silver	REMARKS
Indus Platform (buried shield).	Kirana Hills (near Sargodha)	up to 6	–	Associated with hematite deposits in meta-volcanics of the Kirana Group (Shah 1973).
Himalayan crystalline zone	Hall (34°11':73°03')	1.7	–	Associated with galena.
Bela ophiolitic thrust belt.	Malkhor-Ranj Laki	–	7	
	Gunga	–	2,500	Associated with Pb-Zinc ore.
	Surmai	–	15	
	Duddar	–	<2-7	
Kohistan magmatic arc.	Nomal	0.65-1.03	69	Associated with Cu ore.
	Gawuch	–	150	
	Drosh	4.3	1700	
	Dir (Zaluka)	3-11	0-200	Associated Cu. (Hussain et al, 2000)
Karakoram block.	Kaldam Gol.	43	100	
	Shishi.	–	5	
	Madashil.	0.6	–	
	Shoghot.	20	3.6	Associated with Cu ores.
	Pir. Burhanuddin.	–	4.7	
	Kogozi.	0.2	15	
	Baig.	0.3-0.6	–	Associated with Pb-Zn ore.
	Awireth.	5	980	
Chagai magmatic arc.	Saindak.	0.15	0.17	Associated with Cu ores.
	Chilghazi.	2.8	–	Associated with Fe ore.
	Dirang Kalat.	0.56-2.8	22.6-40.8	Associated with Pb and Zn ores.
	Makki Chah.	–	15	
	Ushu.	–	127-834	
	jijal.	0.0035-2.45	–	Associated with ultramafic complex.

recently started exploration work in Chagai district and has identified several targets with the help of satellite imagery which may be alteration zones related to copper and gold mineralisation.

Northern Areas

Due to frequent occurrence of gold in placer deposits and existence of favourable metallogenic environment for gold mineralisation in Northern Areas, a Gold Exploration and Mineral Assessment Project (GEMAP) was undertaken in these areas with the help of Australian financial and technical assistance during the years 1992-1995. Integrated drainage sampling was carried out under the programme and geochemical anomaly maps were prepared. Results of these studies show that hundreds of drainage cells carry detectable gold. Twenty four of these anomalies have been classified as high order and indicate areas of significant gold mineralisation. These anomalies are generally associated with major shear zones such as the Main Mantle Thrust and some are associated with porphyry type intrusives or altered carbonates (Clavarino, et al. 1995).

Sargodha District

The Precambrian shield rocks exposed in Chiniot area of Punjab and Thar Parkar area of Sindh are also favourable for the occurrence of gold. Traces of gold have been found in the volcanogenic hematitic iron ore near Chiniot (Shah 1973, Alam et al. 1990, Hasan et al. 1997).

Chitral District

SDA has reported valuable gold and silver prospects in the Awireth–Shogor–Sewakht region of Chitral, 6–8 kilometres west, northwest and north of Krinj (Fig. 5.2). The mineralisation is in the Sewakht Formation of Leak et al. (1989).

Here the Sewakht Formation forms a narrow wedge faulted on either side. To the east the Reshun fault separates it from Krinj limestone and to the west it is faulted against the Lutkho Formation along the Pasti fault (Fig. 5.7). The Sewakht Formation consists of greenschists, limestones, ferruginous dolomitic carbonate, phyllites, sandstones and breccias. This prospect contains significant amounts of boulangerite, which mainly consists of antimony, lead, gold and silver. Boulangerite samples from Shoghor have shown gold up to 56 gm/tonne, silver up to 700 gm/tonne and antimony up to 20%.

The ferruginous dolomitic carbonate bed contains appreciable amount of gold and silver. Between Sewakht and Awireth, it crops out for 15 kilometres and is up to 16 metres thick. It has been prospected by SDA through exploratory adits and channel samples have been analysed for gold and silver. The results reveal proven reserves of 50,000 tonnes boulangerite with gold values up to 70 gm/tonne and silver up to 180 gm/tonnne. The estimated reserves of the gold and silver bearing ferruginous carbonates are to the tune of 50 million tonnes (Khan and Ahmad undated).

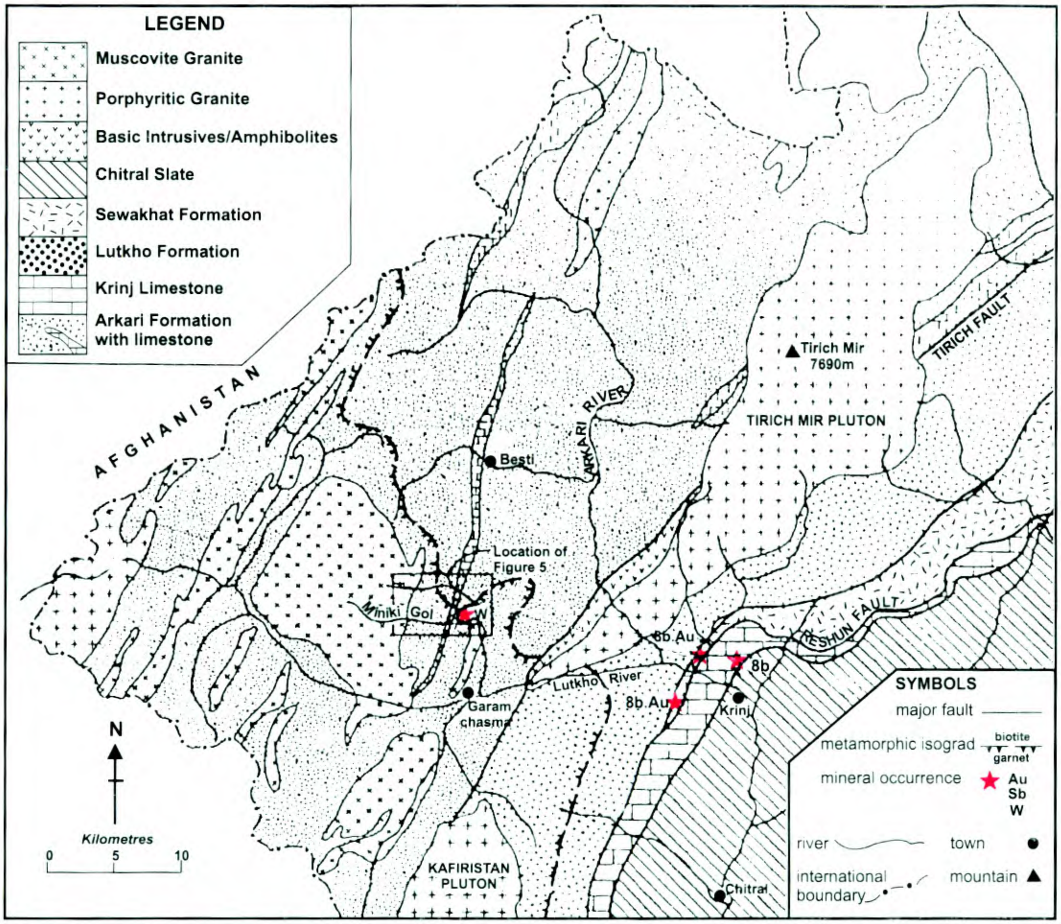


Figure 5.7. Geological map of Chitral region showing location of some of the gold, antimony and tungsten deposits (from leake et al, 1989).

Dir District

Significant gold, silver and copper anomalies have been reported in the Dir Volcanic Group, near Zaluka village, 250 kilometres north of Peshawar (Hussain et al. 2000). The host rock comprises a subporphyritic to porphyritic sequence. There is a 6 metre wide alteration zone, containing visible malachite and azurite. The ore minerals include covellite, bornite and chalcocite. Twelve samples from this zone yielded 3 to 11 ppm gold, 6 to 200 ppm silver, 1 to 6.5% copper and 30 to 198 ppm lead.

Muslimbagh area

Platinum group elements have been reported in the chromitites from the Muslimbagh ophiolites of Saplai Tor Ghar (Table 18). Preliminary investigations suggest that the primary deposits may not be economic, though there are good chances of locating economic placer deposits in the vicinity of Muslimbagh (Nakagawa et al. 1996).

Table 18. PGE analyses of chromite from Saplai Tor Ghar, Muslimbagh Ophiolite (in ppb). From Nakagawa et al., 1996.

9111-	host	Os	Ir	Ru	Rh	Pt	Pd	Au	Total PGE
1601	T	24	30	85	10	35	15	2.5	179
1709	C	41	35	100	16.8	<5	4	9.1	202
2004	C	13	24	55	11.1	<5	3	7.4	111
2005	T	36	45	130	13.3	33	46	7.4	303
3001	C	6	7.7	9	4.5	18	<2	1.3	47
D. L.		2	0.1	5	0.2	5	2		
CI		514	540	690	200	1020	545		

T : tectonite, C : cumulate, D,L, : detection limit, CI : CI-chondrite value

Besham area

Platinum group of elements (PGE) associated with gold are found near Besham (NWFP) (Fig. 5.4), in the Jijal layered ultramafic complex (Miller et al. 1991). A summary of the various minerals and the different types of host rocks in which they occur is given in Table 19.

Table 19. Characteristics of PGE and gold mineralisation in the Jijal layered ultramafic complex (from Miller et al., 1991).

Zone	Minerals	Host Rock	Precious Metals (ppb)				
			Au	Pt	Pd	Rh	Total
V	Pyrite, chalcopyrite, bornite, millerite, pentlandite.	Sulphide cumulate in garnet-gabbro with 5-10% sulphide.	339	723	1,730	<2	279
IV	Chalcopyrite, bornite clinopyroxene cumulate	Garnet-hornblendite	7 to 2,130	64 to 221	80 to 417	<2	647 to 2,284
III	Chalcopyrite, pyrrhotite, pentlandite,lesser pyrite and millerite, tetraauri-cupride and atheneite.	Hornblende-clinopy-roxenite-ilmenite+ postcumulus garnet.	76 to 2,457	15 to 715	144 to 2,275	<2 to 3	293 to 3,597
II	Pyrrhotite, pentlandite, chalcopyrite as inclu-sion in chromite and clinopyroxene.	Wehrlite and chromite-dunite.	35 to 275	99 to 402	40 to 720	2 to 10	365 to 1,405
I	Chalcopyrite, bornite, pentlandite, supergene violarite, magnetite	Clinopyroxene with 10-15% bronzite, 2-3% disseminated sulphide.	86 to 146	56 to 90	47 to 70	<2	246 to 249

IRON ORE

Iron ores are used for the extraction of iron which is the most commonly exploited metallic mineral in the modern world. Iron is used for making steel and a number of other alloys.

Iron, being the third most abundant element on the earth's crust, is found in a variety of geological environments. All three major class of rocks, i.e., igneous, metamorphic and sedimentary, serve as host for the mineralisation of iron ore.

Iron ore occurs in banded sedimentary iron formations of Precambrian age as residual or replacement deposits, depending upon whether removal of silica was accompanied by introduction of additional iron oxide. Such ores contain 50% to 68 % iron. Iron ore also occurs as oolitic ironstone in Paleozoic to Cretaceous sedimentary sequences and mostly contain 25% to 35% iron. Massive iron ore deposits of igneous origin, comprising magnetite and hematite, occur in Precambrian rocks. These type of deposits form as magmatic segregations of magnetite crystals in magma or as sheet like-bodies formed by injection of magnetite-rich solutions into the host rocks. They also occur as pyrometasomatic deposits formed due to replacement of limestone or volcanic rocks by magnetite, at or near their contact with intrusive igneous rocks. Such deposits contain up to 65% iron.

Occurrences of iron ore are widespread in Pakistan. These are largely in the form of lateritic beds along major unconformities, volcanogenic ores or contact metasomatic deposits. Showings or deposits have been reported from the Indus platform zone (at Kirana Hills), Foreland sedimentary fold-belt (at Mazar Tang, Kalabagh, Pezu, Samana Range, Rakhimunh, Nizampur and Dilband), Himalayan crystalline belt (near Abbottabad, Galdanian, Langrial and Besham), Ophiolitic thrust belt (at Shekran and Monar Talar), Kohistan magmatic arc (at Ghazanosar, Manarsi, Munda and Dammer Nissar), and from Chagai magmatic arc (near Saindak, Mashki Chah, Durban Chah, Amir Chah, Chilghazi, Gorband, Kasanen Chapar, Kundi Baluchap, Pachin Koh, Chigendik, Bandegan and Nok Chah). Relevant available information about these occurrences has been tabulated in Table 9. The total available iron ore reserves in Pakistan are estimated at about 897.96 million tonnes (Table 20).

Table 20. Location, reserves and grade of iron ores in Pakistan.

Area/Locality	Reserves (million tonnes)	Quality	
		Chemical	Mineralogical
1. Dammer Nissar, Chitral District	6.5	up to 60% Fe	Magnetite, hematite.
2 Langrial, Hazara District	30	30-40% Fe	Primarily a silicate oolitic ore, oxidised to lateritic ore.
3. Kalabagh/Chichali, Makarwal area, Mianwali District.	300	25-35% Fe	Silicate-carbonate ores, containing siderite, glauconite, chamosite,
		limonite, hematite, goethite.	
4. Pezu, NWFP.	66	30-34% Fe	Sedimentary ore similar to Chichali ore.
5. Nizampur, NWFP.	100	25-35% Fe	Sedimentary ore with predominant hematite.
6. Dilband, Kalat District.	200	35-45% Fe	Sedimentary ore with predominant hematite.
7. Pachin Koh, Chagai District.	45	35-48% Fe	Magnetite.
8. Chilghazi, Chagai District.	23.36	10-55% Fe	Magnetite.
9. Chigendik, Chagai District.	5	20-60% Fe	Magnetite.
10. Amir Chah, Chagai District,	12.1	50-60% Fe	Magnetite, hematite.
* 11. Kirana, Sargodha District.	110	Up to 66% Fe	Oxides, hematite.
Total:	897.96		

* At Chiniot and Rajoa. Investigatios in progress.
RDC International Ltd. & Australian Geoscience Ltd. (2000).

Dammer Nissar iron ore

This deposit is located 32 kilometres south of Drosh in Chitral District. It has been explored and prospected by Geological Survey of Pakistan (Kidwai and Imam 1958), WPIDC (1970a) and Austrominenal (1978). It occurs close to the Main Karakoram Thrust and is a contact-metasomatic deposit of magnetite that occurs in garnet-epidote meta-volcanosedimentary rocks intruded by granodiorite. The magnetite-bearing skarn bodies are lenticular or irregular in shape. The ore contains small amounts of specularite. The gangue minerals include garnet, epidote, calcite, quartz and rock fragments.

The ore contains Fe 50-65% (average 48.6%), SiO_2 4-15%, CaO 1-5%, Al_2O_3 0.5-4% and Mn>0.5%. It is a small deposit and the reserves are estimated at about 6.5 million tonnes.

Langrial iron ore

This deposit occurs about 32 kilometres south of Abbottabad. It is a lateritic deposit hosted within limestone beds at the Cretaceous-Paleocene boundary. The ore forms layers of oolitic, lateritic or ferruginous sandy material as much as 6 to 7 metres thick. The ore is spread along a distance of 45 kilometres and due to structural complications has been repeated 22 times. It varies both vertically and laterally. Between Kohala Gali and Dartian, over a distance of about 20 kilometres, its upper horizon is a ferruginous laterite, mostly hematitic, with small amounts of pisolitic material, whereas the lower horizon, which occurs in a ferruginous sandstone, is largely oolitic, sandy hematite (Klinger et al. 1967).

Accessory minerals include limonite, calcite, iron silicates, quartz and kaolinite. Mineralogically, the deposit has been classified into three main types: chamositic-limonitic type, hematitic-limonitic type and lateritic type. The ore contains 9-50% iron (average about 30%), 9 to 60% silica, 5.7 to 30.05% alumina, 1.0 to 12.0% lime, 0.03 to 10.65% phosphorous and 0.01 to 0.82% sulphur (Khan and Ahmed 1966).

According to Klinger et al. (1967), the deposits in the Durban-Kalabagh belt are spread over a distance of about 32 kilometres and are of economic interest because substantial tonnages of ore containing 40 to 45% iron appear to be available at several localities. The Langrial ore reserves are estimated at about 30 million tonnes.

Kalabagh iron ore

Iron ore deposits are located in the Surghar Range in the vicinity of Kalabagh (32°55':71°32'). These are the largest deposits of iron ore (about 300 million tonnes) in Pakistan and occur in the Cretaceous Chichali Formation which is largely comprised of glauconitic sandstone and shale. This formation is exposed along a belt from Makarwal in Surghar Range to Kalabagh and Sakesar in the Salt Range.

The ore is of low-grade and varies considerably in mineralogy and chemical composition. It has been classified into three mineralogical types: chamosite-siderite type, transitional type and glauconite-siderite type (Table 21).

Table 21. Kalabagh ore-types, their composition (%) and reserves (m.t.)

Type	Fe	SiO_2	Al_2O_3	CaO	P	TiO_2	S	Reserves
1. Kuch (chamosite-siderite)	34.2	21.8	12.1	2.7	0.25	0.68	0.33	34.60
2. Chichali (glauconite-siderite)	33.0	24.0	6.0	3.5	-	-	-	206.00
3. Chuglan (transitional) between 1 & 2)	32.0	25.0	6.8	2.8	0.30	0.34	0.26	52.00

(Modified from Ahmad 1969).

Tests on Kalabagh ore (by Koppers of U.S.A., U.S. Bureau of Mines, Hogahna of Sweden, Carpo and M. W. Kellogg of U.S.A. etc.) indicate that this complex ore is not amenable to physical beneficiation. Krupps of Germany tested the ore in 1959 by Krupp Renn process and found that the ore burden adheres to the kiln wall, threatening damage to the kiln. In 1964 Institute de Recherches de la Sierurgi Francaise (IRSID) conducted semi-commercial test on 1,500 tonnes of Chichali ore after sintering by blending it with imported high-grade ore in a conventional blast furnace at Liege, Belgium. The results suggested that the Acid Blast Furnace Process would suit the ore and may be considered as the exclusive feasible method of reducing the Chichali ore (PMDC 1970b). Since then no serious effort has been made about the development of this ore.

Pezu Iron Ore

Chichali type, low grade, lateritic iron ore occurs in Sheikh Budin Hills about 2.5 kilometres southeast of Pezu village. The iron ore beds are formed in Cretaceous strata similar to the Chichali Formation. The deposit is comprised of an upper, reddish, ferruginous bed which has a lower iron content and a lower yellowish brown bed, which has a higher iron content ranging from about 30 to 34 percent and it is comparable to the Chichali ore. The average chemical composition of the lower beds is given in Table 22.

Table 22. Chemical composition of Pezu iron ore (%).

Location	Fe	SiO_2	Al_2O_3	CaO	MgO	Ignition loss
1. Jatan	34.4	21.9	7.51	4.0	2.3	11.5
2. Khaurai	30.3	30.5	8.67	2.2	3.27	9.2

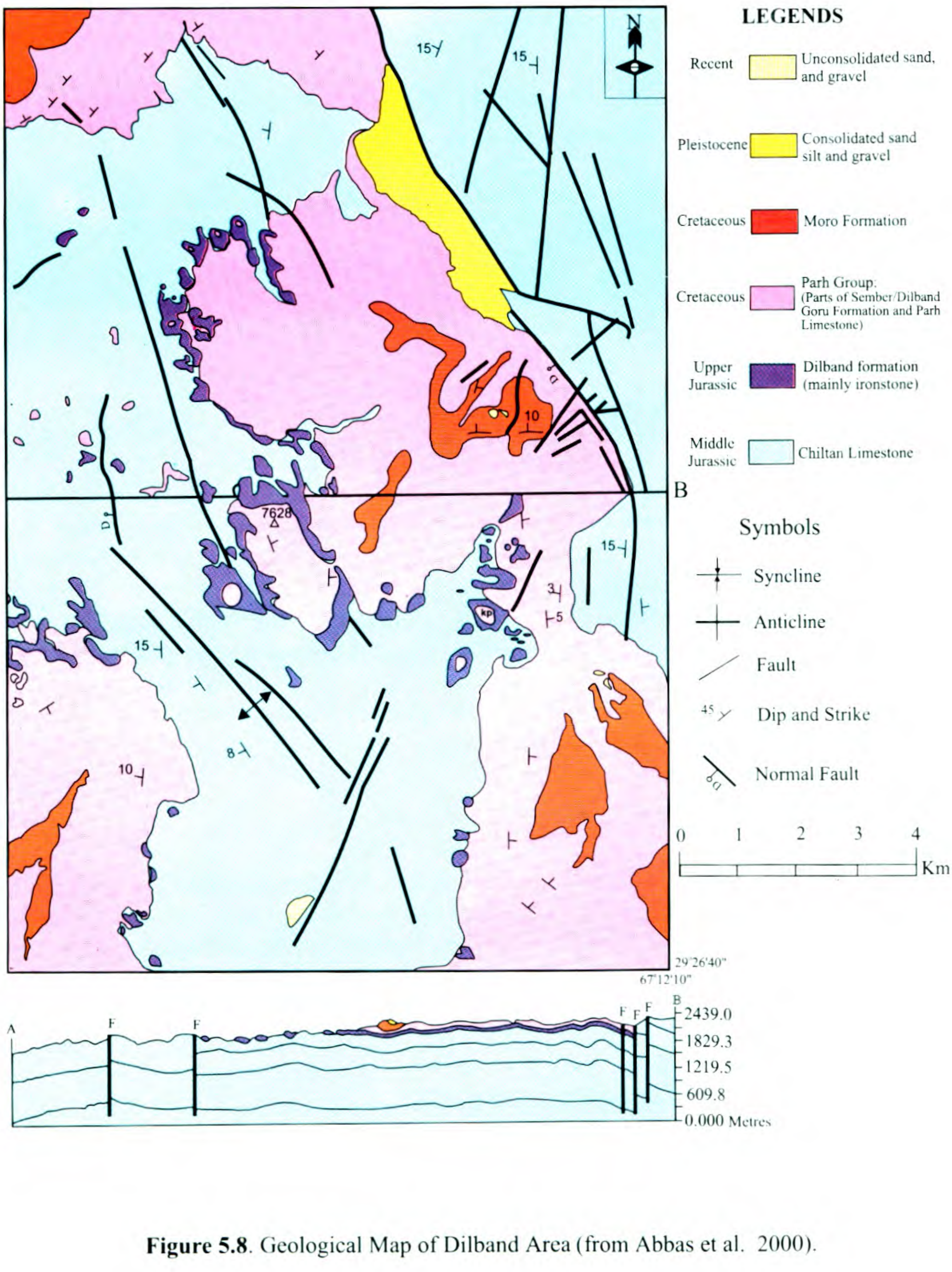


Figure 5.8. Geological Map of Dilband Area (from Abbas et al. 2000).

The total iron ore reserves of Pezu down to an incline depth of about 260 metres is 66 million tonnes (WPIDC 1970b).

Nizampur iron ore

The Nizampur deposits are 24 kilometres from Kharan bridge of the National Highway on Indus River. The ore is of the sedimentary type and is found at the base of Datta Formation of early Jurassic age. The reserves are estimated at about 100 million tonnes of ore consisting predominantly of hematite. The iron content varies from 25 to 35 percent. The location-wise data regarding the Pakistani iron ores is shown in Table 20 (Hussain and Karim 1993).

Dilband iron ore

The iron ore deposits recently discovered by the GSP at Dilband are of considerable economic significance. The Dilband deposits are exposed on Dilband Plateau, 100 kilometres from Kolpur railway station and 65 to 70 kilometres from the National Highway and RCD Highway. The ore horizon occupies the top of Chiltan Limestone of Jurassic age and is overlain by Parh Group sediments of Cretaceous age which have very low to gentle dips (Fig. 5.8). This horizon is 1 to 7 metres thick, with an average thickness of about 2 metres and is exposed in a wide area. Mineralogically it predominantly consists of hematite with calcite, quartz and chlorite. It has been found to contain 35 to 48 percent Fe (Table 23). The reserves of iron ore have initially been estimated at 200 million tonnes. Owing to its relatively large tonnage, favourable location, open cast mineability, simple mineralogy and acceptable grade, the Dilband iron ore is considered better than any other iron ore known to occur in Pakistan. According to Abbas et al. (1998), it compares favourably with ironstone-type ores which are now being mined in Europe, North America, Russia and China. The Pakistan Steel Mills have successfully blended 10 percent of raw Dilband ore with the imported iron ores to produce sinter and pig iron. Laboratory scale experiments indicate that this ratio can be raised to 15 percent and possibly up to 70 percent after beneficiation.

Table 23. Chemical analyses of Dilband iron ore (%).

Sample	Fe	FeO	SiO_2	CaO	MgO	MnO	Al_2O_3	TiO_2	P	Cu	S	Zn	LoI
1	48.03	2.30	14.60	2.40	2.2	0.09	5.30	0.35	0.24	0.01	.012	0.07	4.5
2	45.7	2.95	13.7	2.23	1.6	0.11	6.04	0.32	0.34	.012	.019	0.07	7.45

Pachin Koh–Chigendik iron ores

These deposits are located 88 kilometres and 40 kilometres NW of Nokkundi town respectively, in Chagai District. The ore is largely comprised of magnetite and hematite. It is volcanogenic and occurs as intercalations with andesites of the Sinjrani volcanics. There are magnetite-actinolite plugs accompanying two main magmatic flows. The ore contains Fe_2O_3 67-82%, SiO_2 9-22%, Al_2O_3 1.4-4.4% and CaO 1.2-2.2% (Asrarullah 1978, Kazmi and Abbas 1991).

There are 27 small magnetite-hematite bodies at this locality. At Pachin Koh 62 holes have been drilled, whereas 29 holes have been drilled at Chigendik. The ore reserves are estimated at 5 million tonnes at Chigendik and at Pachin Koh 45 million tonnes, of which 30 million tonnes are proven. Geological and geophysical investigations suggest that the indicated iron ore prospects at this locality are likely to be 100 million tonnes. Metallurgical tests on Pachin Koh-Chigendik iron ore have been carried out by different organisations in Pakistan and abroad and the results prove the suitability of this ore for use in the Pakistan Steel Mills, which can eventually substitute 47% of the imported ore. Hussain (1983) has suggested that this ore is suitable for the direct reduction plus electric arc furnace process combination. This process can produce steel billets at about 30% lower cost.

Chilgazi iron ore

The Chilgazi iron ore deposit is located about 52 kilometres northwest of Dalbandin town in Chagai District. The area is underlain by the Cretaceous Sinjrani volcanics, which are intruded, by small bodies of diorite, quartz monzonite and granodiorite. The deposit occurs in the Sinjrani volcanics which form an asymmetrical, gently dipping anticline. The iron ore is largely comprised of massive magnetite and layers of disseminated magnetite. The ore occurs at three horizons. The upper one, near the top contains the main deposit. The other two are 166 and 500 metres below the first one. The lower ore bodies are largely comprised of magnetite disseminations in volcanic rocks and are lean in their iron content (10-12%).

The deposit has been drilled and the results indicate that main ore body contains 32-55% iron (average 45%), 0.1-1.96% copper (in one hole up to 7% copper was present), and up to 0.1% phosphorous. Some portions of the ore body contain up to 1 oz/ton of gold (Faroque and Rahman 1970, Ahmad 1975). It is estimated that at this locality the reserves of high-grade ore are about 3.36 million tons (2.46 proven and 0.90 probable). The low-grade ore reserves with 25-30% iron are estimated at 20 million tonnes (Schmitz 1974).

LEAD AND ZINC

Lead and zinc, due to their normal close association in nature, are being dealt with together. Both these metals form important alloys having varied industrial uses. Lead is an important strategic mineral as it is used in ammunitions. A number of oxides, carbonates

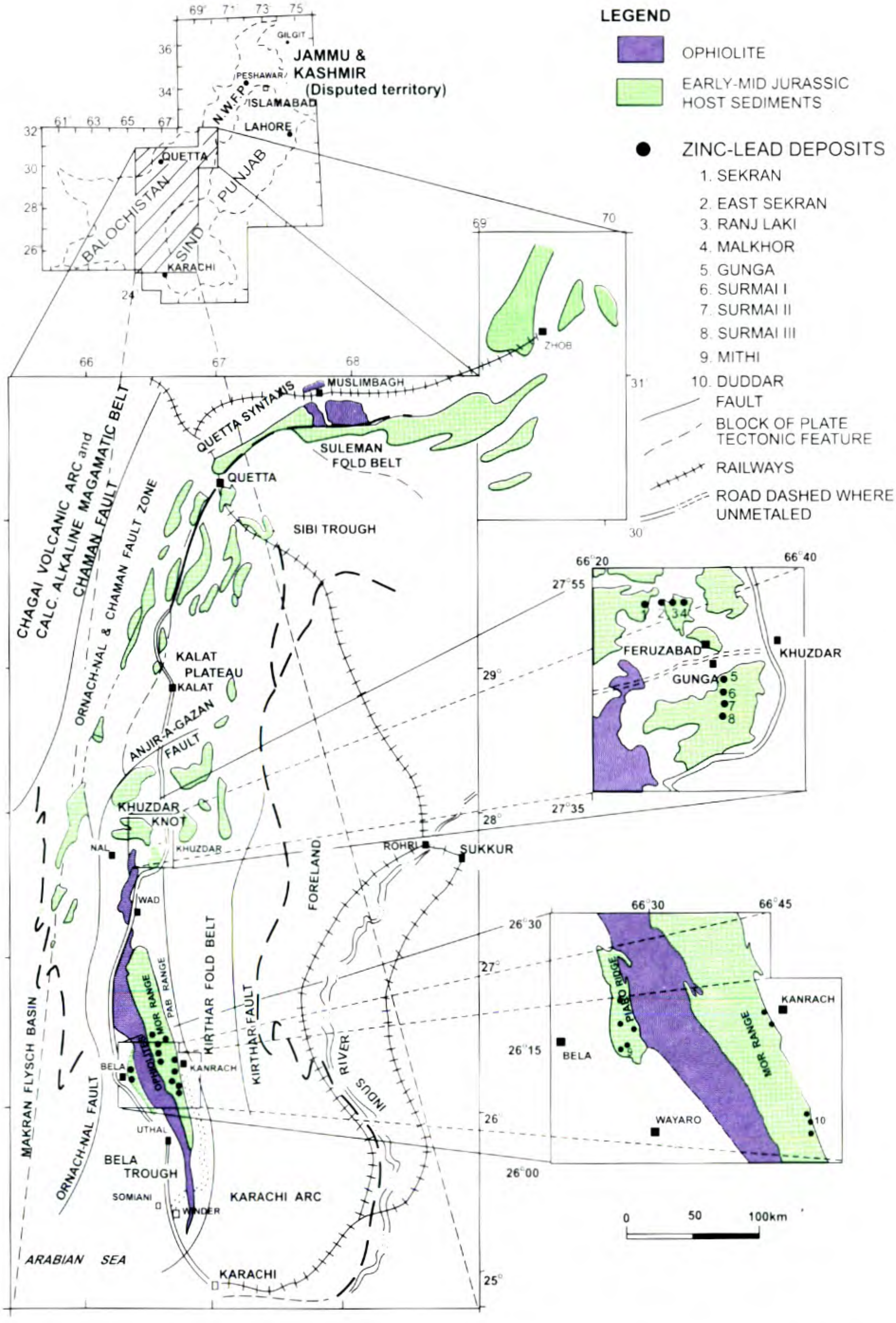


Figure 5.9. Map showing distribution of Lead-Zine deposits and prospects in the Bela-Khuzdar area (modified from Ahsan and Khan 1994).

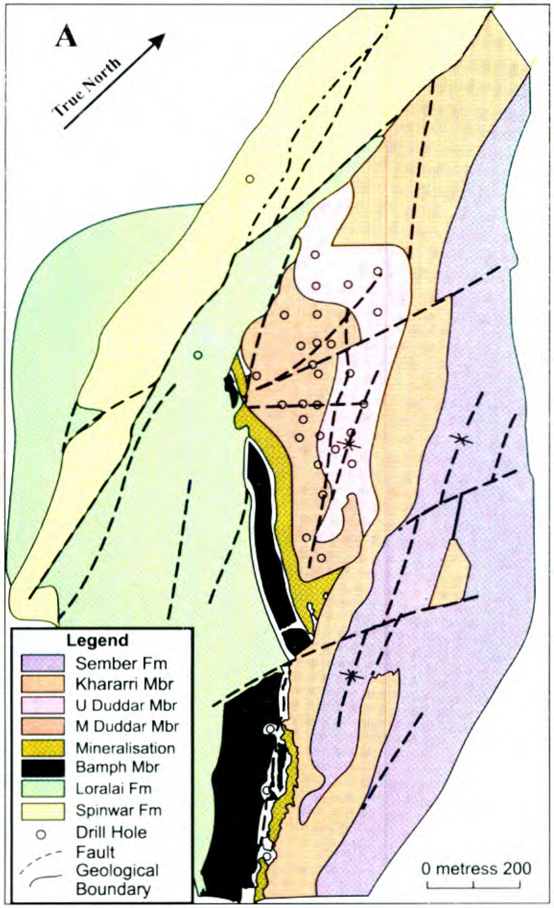
and sulphates of lead and zinc occur in nature and are being exploited for commercial extraction of lead and zinc. Lead is mainly used in the manufacture of lead-acid storage batteries, in petroleum industry as gasoline antiknock additive and octane enhancer, in construction industry, in making various type of protective devices against radiation and to provide corrosion protection, in glass industry, porcelain enamel and in glaze of ceramics, etc. Uses of zinc are based on its properties of low melting point, high electrochemical activity and its ability to alloy readily with copper to make brass. It is mainly used in paints, volcanising rubber, photocopying, inks, dyes, in construction of industrial plants, in die-casting, in making brass and several other uses.

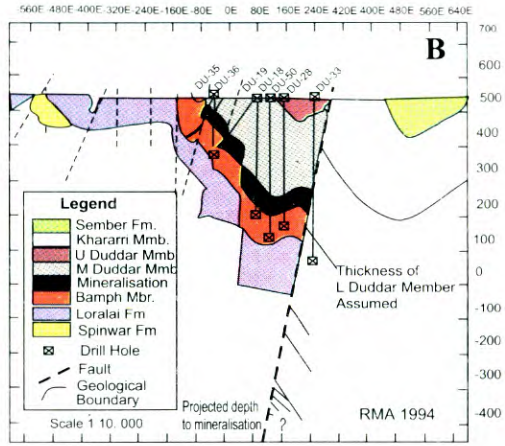
The most common minerals of economic significance are galena (PbS) and sphalerite (Zn, Fe)S. Lead and zinc deposits largely occur as stratabound deposits, volcano-sedimentary deposits, as veins or contact metamorphic deposits. The stratabound deposits are commonly hosted in limestone or dolomites, whereas the volcano-sedimentary deposits comprise massive sulphide bodies interlayered with volcanic or sedimentary rocks.

The Geological Survey of Pakistan has discovered a number of deposits of lead and zinc ore in Las Bela-Khuzdar region of Balochistan (Fig. 5.9). An extensive lead-zinc-barite belt characterises the Bela Ophiolitic thrust belt, between Khuzdar and Karachi. Mineralisation is entirely in the upper part of the Lower Jurassic Shirinab Formation. Main deposits are located at Shekran, Ranj Laki, Mal Khor (NW of Khuzdar), Gunga, Surmai (SW of Khuzdar), and Duddar (SE of Bela).

The Gunga, Surmai and Duddar deposits have been explored and evaluated in detail. Surmai is a stratabound Mississippi-type deposit hosted in the middle part (Loralai Member) of the Shirinab Formation. The Gunga and Duddar deposits occur in the upper part (Anjira Member) of the Shirinab Formation and are of the sedimentary-exhalative (sedex) type. The deposits are constrained between major faults and have been intersected by smaller faults (Fig. 5.10). The Duddar deposit shows a well-defined stratigraphy. The lower part comprises a Zn-Fe sulphide zone, followed by a middle high-grade Zn-Pb sulphide zone which is overlain by the upper Fe-sulphide zone (Fig 5.10). Barite is independent of the sulphides and forms a separate body. The Duddar deposit also bears evidence of multiphase mineralisation and overprinting of later phases on the earlier ones.

At **Duddar**, barite is probably exhalative and formed on the ocean floor, whereas the sulphide mineralisation is syn-diagenetic and formed by displacement or replacement of the host from siliceous fluids. Deformation of sulphide layering and pressure solution feature show that the ore was emplaced before early deformation and is, therefore, pre-Tertiary. At Duddar proved reserves of 6.86 million tonnes and inferred reserves of 3.43 million tonnes with 11.34% zinc and 2.01% lead have been established (Jones and Shah 1994).





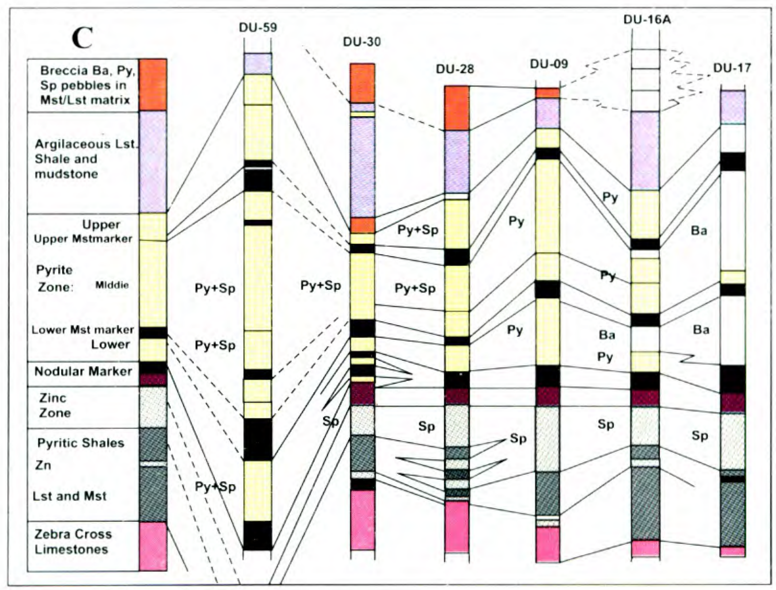


Figure 5.10. Geological map and sections of the Duddar lead-zinc deposits. A. Geological map. B. Cross-section along line A (east-west). C. Mineral zonation (north-south, along line B). From Jones and Shah 1994.

The **Gunga** deposit, 11 kilometres SE of Khuzdar, is hosted by the Early to Middle Jurassic Anjira Formation. The mineralisation is stratiform, stratabound and open-space filling type. The mineralised zone extends over a distance of 1,200 metres and is easily distinguished as a silicic gossan. The gossan contains 3-4% Pb and Zn. The deposit was explored through 14 drill holes. The ore body contains over 6% Zn and 1.5% Pb, with proven reserves of 6.5 m.t., probable reserves of 3.0 m.t. and possible reserves of 3.3 m.t. (Jankovic 1983, Ahsan and Qureishi 1997).

The **Surmai** deposit is located about one kilometre south of the Gunga deposit. Here the mineralisation is hosted in limestone of Loralai Formation and is of the Mississippi Valley type. The deposit has been explored by GSP and JICA and reserves of 2.93 million tonnes of ore with average metal content of 6.5% have been established. This deposit also contains, 10 to 20 gm/tonne of silver (Subhani and Durrazai 1989, Ahsan et al. 1994).

In addition to the above deposits, at least 23 other showings of Pb-Zn ore have been located in the Piaro and Mor Ranges, east of Bela (Fig. 5.11). Geochemical exploration in these ranges has further delineated areas with high Pb-Zn anomalies (Akhtar et al. 1989).

Significant lead-zinc deposits have been located in the **Lahor-Pazang** area, near Besham (NWFP). These are located within a fault zone in a highly tectonised region, close to the MMT. The ore occurs in veins and as disseminations in the metavolcanics and metasediments of the Proterozoic Pazang Formation. The region is intruded by Proterozoic to Permian granites. On an average the ore contains 3.1 to 3.4% lead and 4.2 to 6.2% zinc. The reserves are estimated at 1.5 million tonnes (Siddiqui et al. 1988).

Bench scale processing studies on the Lahor-Pazang ore has been successfully carried out by the PCSIR, Lahore and metal concentrates of up to 50% lead and 50% zinc were obtained with a recovery of 57.78% and 56.45% respectively. From this ore, lead and zinc chemicals, namely litharge, lead-nitrate, lead-dioxide, lead-acetate, zinc-carbonate, zinc-oxide and zinc-chloride were manufactured (Table 24).

An economic and commercial feasibility study and market survey by SDA has been carried out. It shows that it would be feasible to economically exploit the Lahor-Pazang lead-zinc ore locally if annually 24,000 tonnes of the ore is mined and processed to produce 240 tonnes of lead concentrates and 2,000 tonnes of zinc concentrates. These concentrates will in turn produce 28 tonnes of lead nitrate, 500 tonnes of zinc, 735 tonnes of zinc oxide and 7,000 tonnes of zinc chloride (Khan and Ahmad undated).

Lead-zinc mineralisation has been reported from several localities in the **Northern Areas** of Pakistan (Karakoram block, Kohistan magmatic arc, Himalayan crystalline belt and the Foreland sedimentary fold belt). These occurrences have been summarised in Table 9. Although the estimated lead-zinc reserves of Pakistan are about 16 million tonnes, only small, sporadic mining of the smaller deposits in Chitral and Chagai Districts has been carried out.

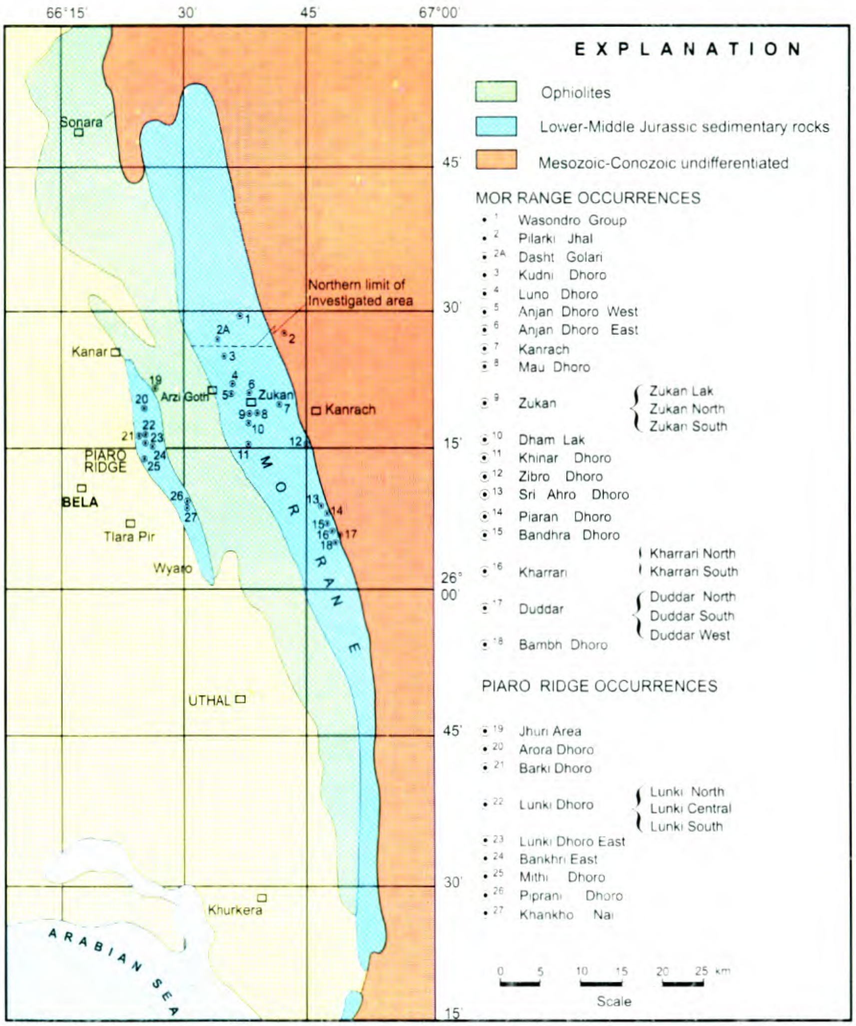


Figure 5.11. Lead–zinc–barite occurrence map of Mor Range and Piaro Range, Las Bela District (from Ahsan 1989)

Table 24. Chemicals manufactured from lead-zinc concentrates of Lahor-Pazang lead-zinc ore.

Chemical	Grade	Purity %	Recovery %
Letharge (lead mono-oxide)	Commercial	92 - 95	90
Lead nitrate	Commercial	95	80 - 85
Lead dioxide	Commercial	95 - 96	95 - 96
Lead acetate	Commercial	94 - 96	94 - 96
Zinc carbonate	Commercial	95 - 97	85 - 90
Zinc dioxide	Commercial	94 - 96	85 - 90
Zinc chlorite	Commercial	94 - 95	80 - 85

MANGANESE ORE

Manganese ore has been in use since antiquity. The ancient Egyptians and Romans made the first use of manganese when they applied its ore mineral, pyrolusite (manganese dioxide) to decolourise glass, and to control and produce colour in glass and pottery. Manganese is still used in the glass, ceramics and chemical industry. However, today its main use is in the production of iron and steel as an alloying element with several nonferrous metals, mainly aluminum. It is extensively used to make dry cell batteries.

The main minerals which comprise manganese ores are pyrolusite (manganese dioxide), rhodochrosite (manganese carbonate), rhodonite (manganese silicate) and braunite (manganese oxysilicate). Manganese deposits occur as marine, chemically precipitated sedimentary ores, as secondary enrichment deposits and as hydrothermal deposits.

Several small deposits of manganese ore occur in Pakistan, mainly associated with the volcanic rocks in the ophiolitic thrust belt extending from Bela through Zhob and Waziristan to Parachinar (Table 9). In this belt, veins and lenses of manganese ore occur in the volcano-sedimentary sequences of various melanges, commonly at the

Table 25. Manganese ore deposits of Bela-Khuzdar area (from Ahsan and Quraishi 1997).

Name of deposits	Location	Size of mineralised zone	Grade	Reserves
Kharrari Nai	Lasbela 25°54' N, 66°45'E, 35-K/9.	Two separate pods having an exposed surface of 70 and 7 square metres respectively.	Mn 42% (Nasim 1996)	34,000 long tons (Abbas 1980a)
Siro Dhoro	Lasbela 26°17'N, 66°33'E, 35-J/11.	Manganese in irregular veins/ lenses ranges from one to six inches in thickness.	Mn 36% (Nasim 1996)	950,000 long tons (Master 1960)
Sanjro	Lasbela, 26°28'N, 66°26'E, 35-J/7.	Mineralisation in discontinous lenticular bodies having 0.5km strike length and 1 to 5 meters thickness.	Mn 15% (Nasim 1996)	65,000 long tons Dhoro (Ahmad 1969)
Bhampani Dhoro	Lasbela, 26°11'N, 66°33'E, 35-J/12.	The ore is exposed in a vertical cut, made by open cut mining. It is almost square in shape,	Mn 41% (Nasim 1996)	5,800 (H.S.C. 1960, Abbas 1980a)
Gadani Ridge	Lasbela, 26°05' N, 66°34'E.	Undetermined	Mn 48% (Nasim 1996)	Undetermined
Dadi Dhoro	Lasbela, 26°05'N, 66°37'E.	Undetermined	Mn 35%	Undetermined

contact of volcanic flows and the overlying sedimentary rocks. The occurrences are largely characterised by cherty or jasperoid layers. Only two minor showings are reported from the Chagai magmatic arc and two small deposits are located in the NW Himalayan fold and thrust belt near Abbottabad. In this region several discontinuous lenses occur in a red-bed hematitic sequence in the Cambrian Hazara Formation.

In the Bela ophiolitic thrust belt, lenticular manganese ore bodies are associated with volcanic rocks. They occur in ferruginous and siliceous horizons overlying basaltic pillow lavas. The more important localities are Kharrari Nai, Siro Dhoro, Sanjro Dhoro, Bhampani Dhoro, Gadani Ridge and Dadi Dhoro (Table 25).

The total estimated reserves of manganese ore in Pakistan are about 0.5 m.t. and the annual production has varied from 100 to 600 tonnes (Butt and Latif 1992). Most of this production comes from the Las Bela region.

RADIOACTIVE MINERALS

Radioactive minerals, mainly those containing uranium, occur as showings or small deposits at several localities in the Foreland sedimentary fold-and-thrust belt and the Himalayan crystalline zone. They are linked with a wide range of metallogenic environments, which include occurrences in granitic rocks, alkaline magmatic complexes and carbonatites, migmatites and pegmatites, graphitic schists and Neogene to Recent placers (Table 26). The main economic deposits are, however, located at Baghal Chur in Dera Ghazi Khan District.

The fluviatile, cross-bedded sandstones of the Dhok Pathan and Nagri Formations host the uraniferous placers. Radioactive anomalies have been traced along a 190 kilometres long stretch of the N-S oriented outcrop of the Dhok Pathan Formation along the foot-hills of the Sulaiman Range, in Dera Ghazi Khan and Dera Ismail Khan districts. Seven of these anomalies have shown strong radioactivity and one of these, at Baghal Chur, has been developed as a producing mine (Moghal 1974b).

The mineralisation largely occurs in small lenses or pockets which are commonly located in cross-beds. The main source of uranium are the interstratified ash beds, which contain uranium-bearing feldspar (Moghal et al. 1997). The main radioactive mineral is metatyuyamunite - a hydrated vanadate of calcium and uranium. It occurs in the interstices of sandstone as coating on sand grains and pebbles. Uraninite and coffinite also occur in the proximity of water table (Basham et al. 1974). The ore resource potential is likely to be much higher (Nuclear Fuel 1986).

In the Salt Range the Warcha Sandstone of the Permian Nilawahan Group is reported to have significant uranium potential (Syed and Azizullah 1997). Several uranium and thorium anomalies have been noted in the Warch Sandstone, in the eastern Salt Range. This sandstone is arkosic, porous and permeable. A carbonatitic vitric lava

Table 26. Uranium occurrences and their geological setting.

Metallo-genic Zone	Name of deposit & location	Minerals present	Geological setting	Quality/grade	References
Himalayan crystalline zone	-Karakar (Swat Dist.)	Monazite, urano-thorite.	Quartz-uranothorite-sulphide-monozite veins within the contact aureole of the Cambrian Ilum granite gneiss.	—	Butt 1989a.
	-Ahl (34°32':73°09')		Secondary uranium mineralisation in shear zones in Cambrian Mansehra granite gneiss. Also Pleistocene placers overlying the granite.	U_3O_8- 0.03-0.2%	Butt 1989b
	-Rajdhwari (34°40':73°08')	Billibinite, beryl, mica, pyrochlore.	In pegmatites cutting Mansehra granite.		Khan 1964.
	-Loe Shilman (30 km W of Warsak).		Uranium occurs as disseminations in in isolated patches, in amphibole carbonatite associated with the alkaline magmatic complex.	U-200 ppm	Butt 1989a. Shabbir and Naeem1976.
	-Silai Patti (35 km W of -Dargai) (34°28':71°54')	Pyrochlore	In carbonatites associated with Malakand granite.	U_3O_8- 0.1-0.2%	Butt 1989a.

(Continued)

Table 26. Uranium occurrences and their geological setting. (Continued).

Metallo-genic Zone	Name of deposit & location	Minerals present	Geological setting	Quality/grade	References
Kohistan magmatic arc	Thakot (near Besham)	Uranium	U occurs as disseminations in biotite pegmatites and sulphide bearing veins near the contact of Thakot Fm. and Lahor granite gneiss (both Proterozoic).	Low grade	Butt 1989a. Baig 1990.
Foreland fold and thrust belt	Reshian ESE of Muzaffarabad	Brannerite, xenotime, uraniferous limonite.	In pyrite bearing graphitic schist, inter-bedded with pelitic schists and quartzitic schist of Precambrian Salkhala Fm.	Low grade	Butt 1989a.
	Parachinar Kurram Agency		Uranium mineralisation in accessory alla-nite in anatectic granites and pegmatites.	Low grade, small showings.	Butt 1989a.
	Baghal Chur 30°15':70°17') (NW of Dera Ghazi Khan)	Metatyuya-munite, uraninite, coffinite.	Placer-type uraniferous lenses in sand-stones of Mid. Siwalik Dhok Pathan Fm. in Baghal Chur syncline. Presently being mined. Reserves approx. 100t Uranium.	Low grade (0.03-0.1% U_3O_8).	Moghal 1974a,b. Moghal et al. 1997.
	Qubul Khel (Bannu Basin)	Pitchblende coffinite.	Placer-type deposit in Dhok Pathan Formation.	Low grade	Baig 1990.
Kohistan magmatic arc.	Bunji (34°40':4°39')	Uraninite	In pegmatite, intruding metasediments, metavolcanics (Hanuchal Fm.) and diorites (Shuta Gabbro).	Trivial	Shams 1995, Madin et al., 1989.

flow, highly enriched in uranium, occurs in the Warcha Sandstone.

Reconnaissance hydrogeological survey for uranium has revealed three anomalous zones in the Charsadda, Mardan and Swabi region of the Peshawar Basin. Against a general background uranium value of 5 ppb in groundwater, the Peshawar Basin has a concentration of 9 ppb. The threshold value is about 23 ppb and in the anomalous zones values ranging from 25 to 170 ppb have been obtained. The Peshawar Basin is covered by Quaternary deposits. It is believed that the uranium anomalies may be due to buried uranium deposits that may be occurring in the subsurface alkaline rocks and microporphyries, Paleozoic sedimentary rocks and the Siwaliks. Several fault traces have been observed in the anomalous zones and these are likely to have provided the pathway for the surface appearance of the hydrothermal solutions (Khaliq et al. 2000).

In the northern areas, uranium occurs extensively, though in minute quantities in the placers of the Indus and its tributaries Khaliq et al. (2000b). Ahmad et al. (1976) have reported uraniferous placers from the following localities (U_3O_8 in %):-

Indus River-	Skardu-Oldhang section	0.045
	Shigar Valley	0.062
	Astor Valley	0.015
Hunza River-	Hunza section	0.0215
Chitral River-	Kunhar Valley	0.0025
	Chitral Valley	0.0025

TUNGSTEN

Tungsten is a silvery grey metal noted for its high melting point of 3,410°C, which is the highest of all metals. Also at high temperatures (above 1,650°C) it has the highest tensile strength of all metals. It is one of the heaviest elements (density 19.3) and has good corrosion resistance and good thermal and electrical conductivity. These properties enable its extensive use in the manufacture of drill bits, cutting edges of various machines, in electrical and electronic industries, in manufacture of X-ray tubes, heating elements, aerospace industry, and in armour-piercing artillery shells. It is also used in the manufacture of chemicals, dyes, paints, enamels and colouring glass.

The main tungsten-bearing minerals are scheetite ($CaWO_4$), ferberite ($FeWO_4$), huebnerite ($MnWO_4$) and wolframite (Fe, Mn)WO_4. Most of the tungsten deposits in the world are contact-metamorphic deposits, pegmatites, replacement deposits, or occur as hydrothermal fissure veins and stockworks and related deposits, or as placers. The tenor of tungsten ores is mostly less than 1.0%. Thus the low metal content and its irregular and erratic distribution in the deposit, makes it difficult to use large-scale, low-cost mining methods.

In Pakistan a tungsten occurrence has been reported from Oghi (34°10':74°19') in Hazara District. The occurrence is in pegmatites and aplites cutting the Precambrian Susagali granite. Some samples showed up to 3.2% W (Shams 1995). Placer scheelite occurs in the Siran River sand, in Mansehra District (Zeschke 1959b) and in the Indus River sediments in the northern areas, where Austrominerals (1976) have estimated 96 tonnes of detrital tungsten minerals in about 40 million tonnes of placers. Another occurrence of tungsten ore has been recorded by Siddiqui et al. (1986) from Amlaf (29°18':61°37') in Chagai District. The ore is found in pyroclastic rocks of Saindak Formation, intruded by quartz porphyry. The ore minerals are scheelite and tungstite associated with molybdenum and tin minerals. The mineralisation is attributed to xenothermal alterations in the host rock.

Promising tungsten ore deposits occur in the Miniki Gol area, 35 kilometres NW of Chitral. Stream-sediment sampling has revealed high tungsten anomalies spread over an extensive region, north of Chitral town (Fig. 5.12). Tungsten mineralisation occurs in the Arkari Formation which is mainly comprised of metasediments that have been metamorphosed to a lower amphibolite facies. Scheelite is the only tungsten mineral in the ore. Stratabound mineralisation is hosted in calcsilicate quartzites, tourmaline-quartz gneisses and in massive marbles.

According to Leake et al. (1989) there are atleast four scheelite-bearing calcsilicate quartzite horizons that extend along the strike for about 7 kilometres. Their thickness varies between 0.4 and 4.5 metres. The most prominent horizon is up to 4.5 metres thick. The mineralised zone in this quartzite is 1.32 to 2.13 metres thick and contains 0.08 to 0.39%W, though some thin layers contain up to 1%W. Another quartzite horizon is 0.4 to 1.0 metre thick and appears to be mineralised throughout. It contains 0.46 to 0.85% W.

Table 27. Scheelite reserves in the Miniki Gol–Besti Gol area (million tonnes). (From Khan and Ahmad undated).

	Locality	Indicated	Inferred	Proved	Total
1.	Miniki Gol	4.1	18	—	22.1
2.	Besti Gol	1.5	4	—	5.5
3.	Miniki Gol Quartzites Zn I & II	4.1	18	0.3	22.4
4.	Besti Gol				
	Limestone	—	58.5	—	58.5
	Quartzite	—	15	—	15
	Total	9.7	113.5	0.3	123.5

Scheelite mineralisation in tourmaline-quartz gneisses is restricted and there is little lateral continuity of the ore in these rocks. The tungsten content in this host-rock varies from 0 to 2%. In the Miniki Gol area the tungsten concentration in the massive marble and associated rocks is low (1 ppm to 14 ppm).

The SDA has carried out extensive exploration over a wide area for scheelite between Miniki Gol and Besti Gol (Fig. 5.12). Extensive trenching, pitting, aditing and channel and bulk sampling of the mineralised quartzite horizons has been done and the mineralisation has been traced for over 20 kilometres between Miniki Gol and Besti Gol. Near Besti Gol good mineralisation has been found in a limestone. In this region SDA estimates the occurrence of about 123.5 million tonnes of scheelite ore (Table 27), with an average content of 0.5% WO_3 (Khan and Ahmad undated).

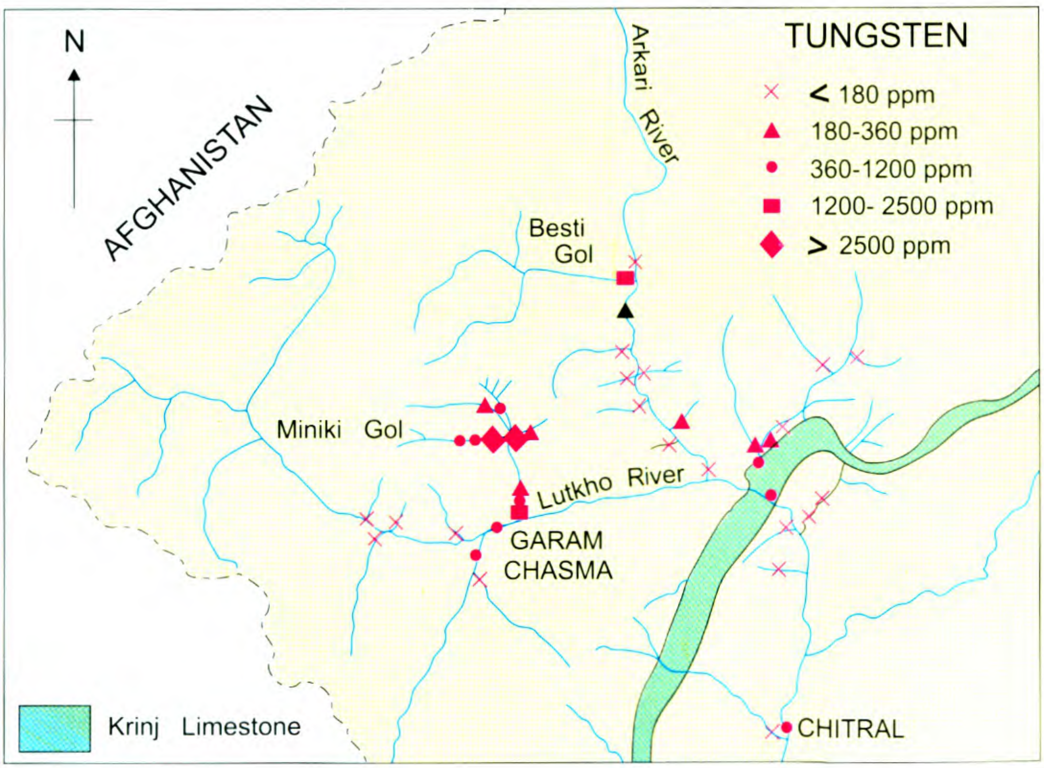


Figure 5.12 . Distribution of tungsten in panned heavy mineral concentrates from the Garam Chasma area (from Leake et al., 1989).

Photo. 1. Chromite mine Jangtorghar, near Muslimbagh, Balochistan.

Photo. 2. Chromite mine Ornach near Bela, Balochistan.

Photo 3. Chromite mine Badasar, near Dargai, NWFP.

Photo. 4. Dilband iron ore. Balochistan. The iron-stone bed over 2.5 in thick (red beds in the ridge in the foreground) are overlian by Sember, Goru and Parh sediments (background)

Photo. 5. Dilband iron-ore at Gorjet Nala. Here its thickness is more than 3 metres. Note the clay bed at the base.

Photo. 6. A view of the Moro Gorge, District Mustung. Chiltan limestone is exposed in the gorge, overlain by the Dilband iron ore (sloping ground above the cliff).

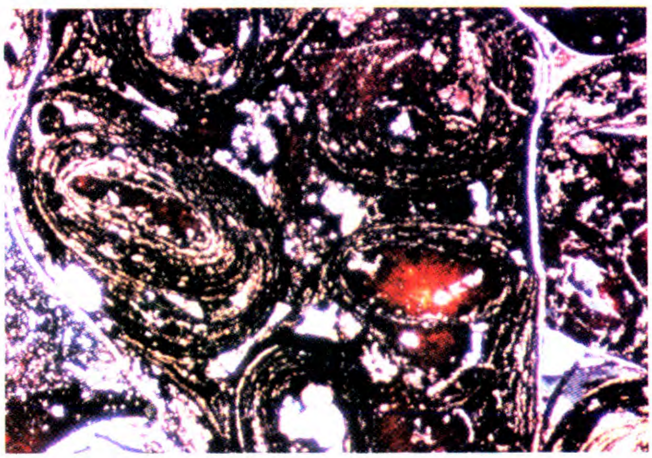


Photo. 7. Photomicrograph of Dilband iron ore showing the oolitic structure.

Photo. 8. Fluorite mine, Dilband Balochistan. The ironstone (dark grey) is seen in the back-ground and overlies the flourite deposite.

Photo. 9. Emerald crystal in calcite, from Mingora mines in Swat, NWFP.

Photo. 10. Cut and polished Swat emeralds.

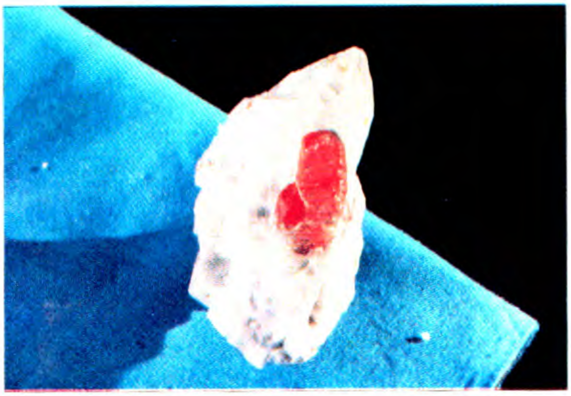


Photo. 11. Ruby crystal from Hunza.

Photo. 12. Rough and-cut-polished rubies from Hunza.

Photo. 13. Pink topaz from Katlong NWFP.

Photo. 14. Cut-and-polished pink topaz from Katlong, NWFP.

Photo. 15. Quartz crystal from pegmatites in Hunza.

Photo. 16. Bicolour tourmaline crystals from stak mines in the Gilgit-Skardu area.

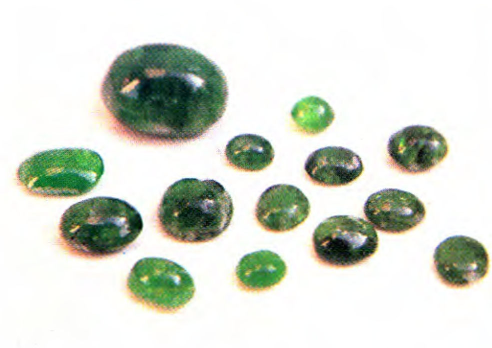


Photo. 17. Pargasite cabochons from Hunza.

Photo. 18. Peridot crystal with mother-rock from Kohistan, NWFP.

Photo. 19. A view of the Mingora emerald mines, Swat, NWFP.

Photo. 20. The stak mine in the Indus gorge, northern areas.

Photo. 21. Kaoline (China clay) deposits, Nagar Parkar, Sindh

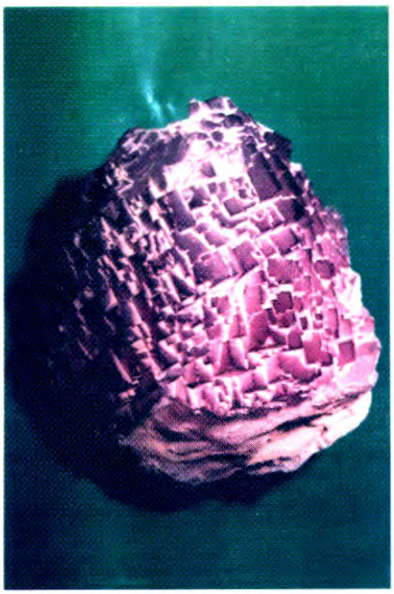


Photo. 22. Fluorite crystals from Dilband, Balochistan.

Photo. 23. Barite mine at Gunga, Balochistan

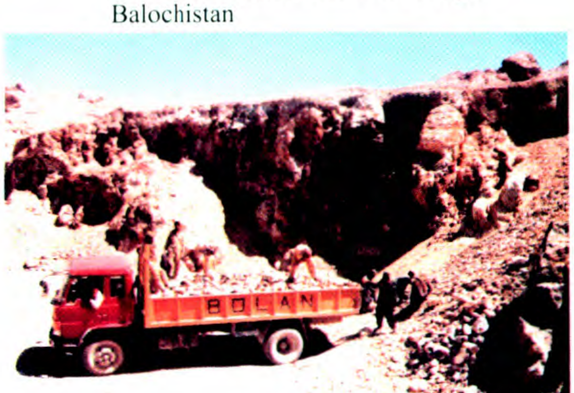


Photo. 24. Barite mine at Gunga, Balochistan

Photo. 25. Barite mine at Gunga, Balochistan. Lead-zinc gossan zone may be seen in the background.

Photo 26. Magnesite mines at Ornach, Balochistan.

Photo. 27. Koh-i-Sultan sulphur deposits, near Nokkundi, Balochistan.

6

MINERAL FUELS

COAL

Coal is a sedimentary rock largely consisting of organic plant remains. It is an important source of energy in the world as its contribution to the world energy out-put is over 30 percent.

Coal is formed by the accumulation and burial of plant material along old river banks, deltas, lagoons, marshes, etc. In Pakistan conditions favourable for the formation of coal existed during the Paleocene - Eocene age. Coal is being commercially exploited from rocks of the Hangu Formation and Patala Formation (Paleocene) in NWFP and Punjab provinces. Ghazij Formation (Eocene) is the coal bearing rock formation in Balochistan while Bara Formation (Paleocene) and Sonhari Beds of Laki Formation (Eocene) contain large deposits of coal in Sindh. Some Permian coal has been reported from Punjab.

In recent years production of coal in Pakistan has ranged between 3.0 and 3.8 million tonnes (Table 28). Most of the indigenous coal is being used for firing brick kilns. Two coal-fired power plants with 7.5 MW capacity each were installed in 1964 near Quetta and three coal-fired power plants each of 50 MW capacity based on fluidised bed technology have been set up at Khanot near Hyderabad. At present the coal consumption by various users is as follows: brick kilns 68.2%, coking 23.3%, power 8.4% and domestic 0.1% (Pakistan Energy Year Book 1999).

At the time of independence, thin coal beds with difficult mining conditions were known to occur in Khost-Sharigh-Harnai, Sor Range-Deghari and Salt Range areas of Pakistan (Fig. 6.1). These deposits were being mined on a small scale and no estimates of reserves were made. In 1962, GSP discovered the large coal field of Lakhra (Ghani and Harbour 1966) (Figs. 6.2 and 6.3). In the early eighties GSP discovered the Sonda coal field (Figs.6.4 and 6.5), and in the year 1992, Thar, the largest coal field of Pakistan was discovered (Figs. 6.6 and 6.7). The Thar coal field contains over 175 billion tonnes of coal (lignite) having up to 1.5% sulphur and 15% ash. Proving of reserves in this field is continuing. Drilling in Cholistan (Punjab) has indicated the presence of thin coal beds at depth of over 500 metres in the area explored so far. Recently coal has been discovered in the Chappursan Valley, north of Hunza.

Table 28. Coal production by various coal fields (tonnes).

Province/Field	1993-94	1994-95	1995-96	1996-97	1997-98
BALOCHISTAN					
Sor Rage	167,438	134,287	148,719	170,425	155,330
Deghari	94,501	82,712	86,004	77,963	65,199
Sharigh	143,375	100,987	133,952	109,884	119,589
Sinjidi	156,770	191,186	158,242	164,186	175,790
Mach	337,197	254,089	352,286	351,166	224,141
Harnai-Khost-Nakus-Zardalu	186,960	185,690	211,315	242,432	184,025
Duki	310,679	290,918	278,067	285,517	261,867
Pir Ismail Ziarat	259,173	264,586	366,162	358,816	344,478
Abegum	60,761	60,454	63,719	67,330	43,979
Sub-Total	1,716,854	1,564,909	1,798,467	1,827,719	1,574,398
PUNJAB					
Makerwal/Salt Range	465,402	413,186	514,914	425,300	365,605
Sub-Total	465,402	413,186	514,914	425,300	365,605
SINDH					
Lakhra	1,258,347	993,095	1,241,965	1,217,207	1,154,329
Jhimpir	25,812	30,224	35,035	20,926	10,498
Sub-Total	1,284,159	1,023,319	1,277,000	1,238,133	1,164,827
NWFP					
Makerwal/Gula Khel/Kohat	67,456	41,425	47,445	61,762	53,875
Sub-Total	67,456	41,425	47,445	61,762	53,875
Total: Tonnes	3,533,871	3,042,839	3,637,825	3,552,914	3,158,705
TOE	1,581,054	1,361,366	1,627,563	1,589,574	1,413,205

Source: Provincial Directorates of Mineral Development.

Coal reserves

The first assessment of the coal available from all the known coal fields of Pakistan was made by the Geological Survey of Pakistan in 1950 and the resource base was estimated to be 500 million tonnes (Khan 1950). In the year 1986, estimates of all categories of known coal resources amounted to 824 million tonnes (Ahmed et al. 1986). As a result of the coal resources evaluation work carried out at Lakhra, Sonda, Salt Range and other coal fields of Pakistan during the years 1987-1991, coal resource base was estimated at over 9 billion tonnes in 1989 (Kazmi and Siddiqi 1990). The latest estimates indicate the measured coal reserves at over 194 billion tonnes (Table 29).

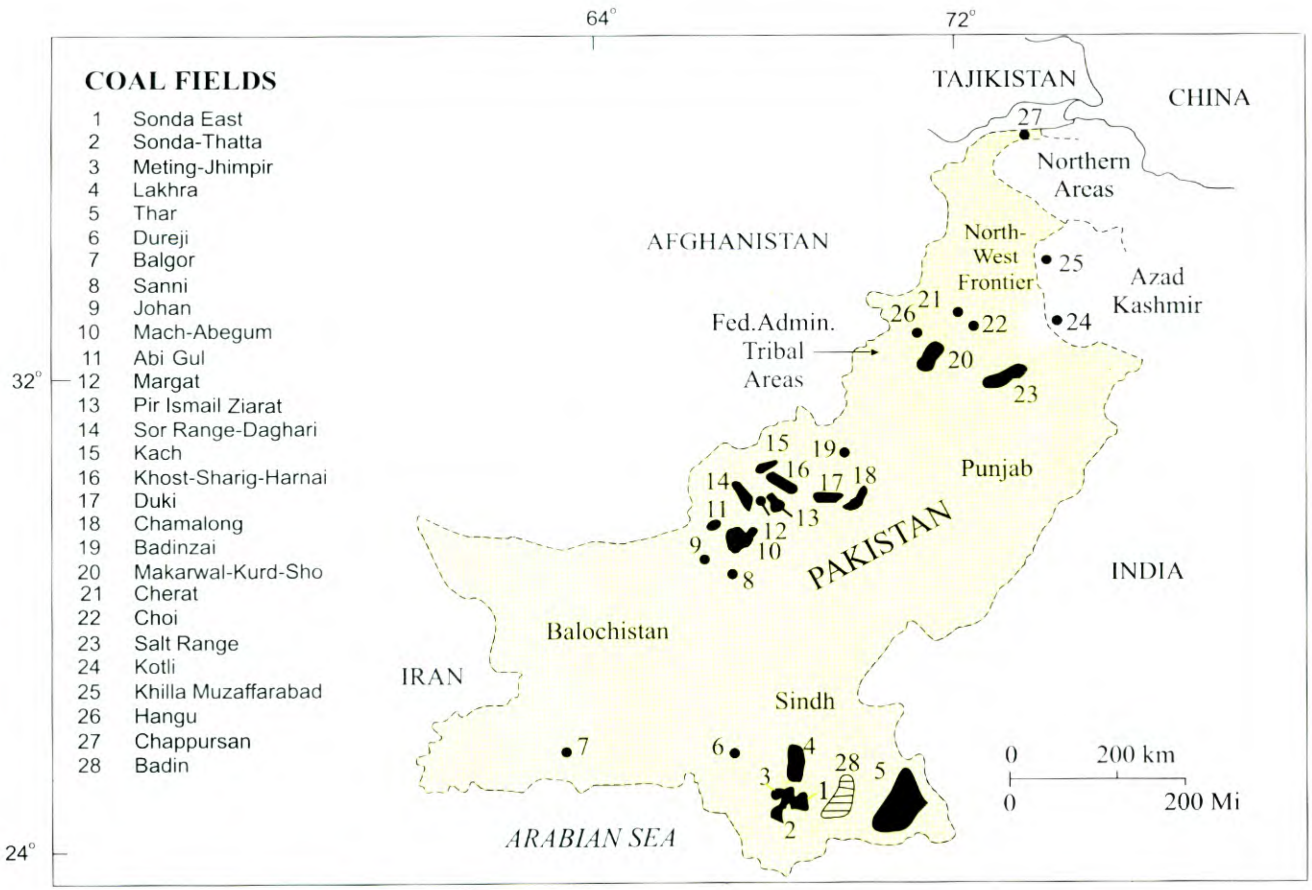


Figure 6.1. Map showing coal fields and coal occurrences in Pakistan (from Kazmi and Jan 1997).

The recent work by GSP has proved that Sindh Province has very large reserves of coal. The coal resource base of this province alone exceeds 193 billion tonnes (Table 29). Sindh Province is the main future hope of Pakistan for production of thermal energy based on coal-fired power stations. The coal resource base of the Punjab Province is over 250 million tonnes. The coal seams are, however, thin and large scale coal production needed for big power plants will not be possible. Possibility of installing small coal fired thermal power plants, however, cannot be ruled out. Balochistan Province has a coal resource base of over 195 million tonnes but again due to thin and steeply dipping coal seams, obtaining large production is not possible. Small power plants based on local coal may, however, be planned for Mach, Sor Range-Deghari, Pir Ismail Ziarat, Khost-Sharig-Harnai and Duki areas.

Sindh Coal: Out of the known coal fields of Pakistan (Fig. 6.1) the Thar coal field, the largest coal field of Pakistan, contains lignitic coal with average sulphur content of 1.5%, ash 15%, and moisture 45%. The Thatta-Sonda coal field, the second largest coal field of Pakistan, contains sub-bituminous B to lignite A, low to medium sulphur and medium to high ash coal (Table 30). Lakhra coal is generally lignitic with high sulphur and high ash. Jhimpir coal is generally sub-bituminous C and B with medium to high sulphur and medium to high ash content.

Balochistan Coal: Coal found in Balochistan coal fields is generally high volatile sub-bituminous B and C type with medium to high sulphur and medium to high ash. Coal from Punjab is similar to Balochistan coal (Table 30). Balochistan has been producing the major share of coal in Pakistan since Independence but now Sindh has overtaken it. This is due to the fact that coal seams in Balochistan are thin and steeply dipping, the mines are underground and their efficiency decreases with increasing depth. If sufficient reserves can be brought to the mineable category the efficiency of the present mines can be increased.

Punjab Coal: Tertiary coal of Salt Range is found as thin lenticular bodies, ruling out the possibility of large scale production from this area. However, its nearness to thickly populated centers with good road network has provided it a ready market with high demand. It has been thus possible to mine with profit coal seams which are 12 inches thick or less. This trend will continue as long as the brick industry grows and thrives.

NWFP and Azad Kashmir Coal: Coal also occurs in Kotli district of Azad Jammu and Kashmir and in Cherat and Hangu area, and Orakzai Agency in NWFP. The preliminary investigations carried out so far indicate that Cherat coal occurs in the Patala Formation and is up to 1.0 m thick. It is similar to Salt Range coal in quality but the thickness variations of beds are quite rapid and structure of the coal bearing area is quite complex. Coal occurs in the Hangu Formation also at Karak and Hangu (Gauhar 1988). The Hangu area appears to have some potential for mining and development. The coal found in Orakzai Agency NWFP and Azad Jammu and Kashmir is of low quality and has small resource potential.

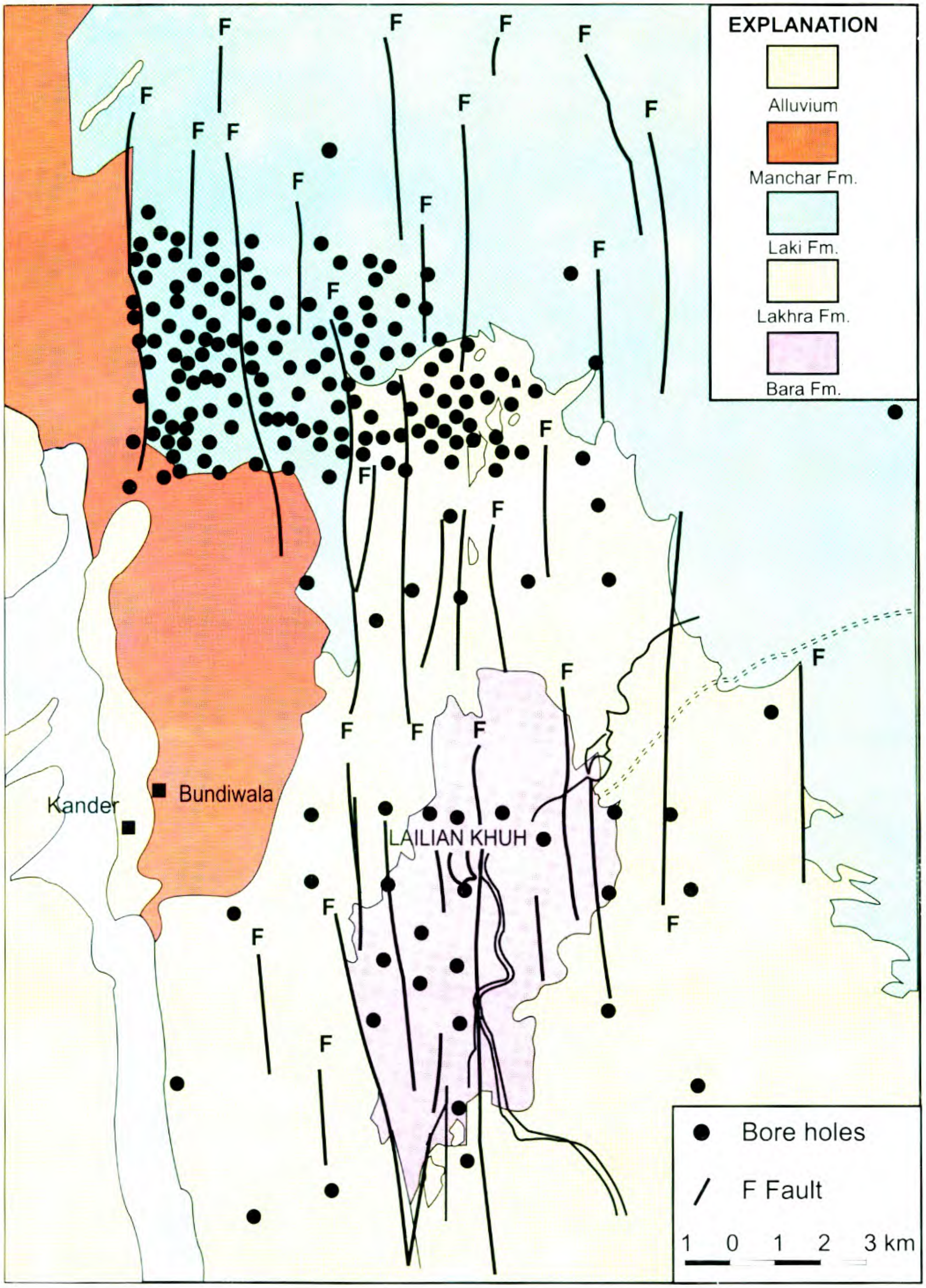


Figure 6.2. Geological map of Lakhra coal field with bore hole location (from Kazmi et al. 1990).

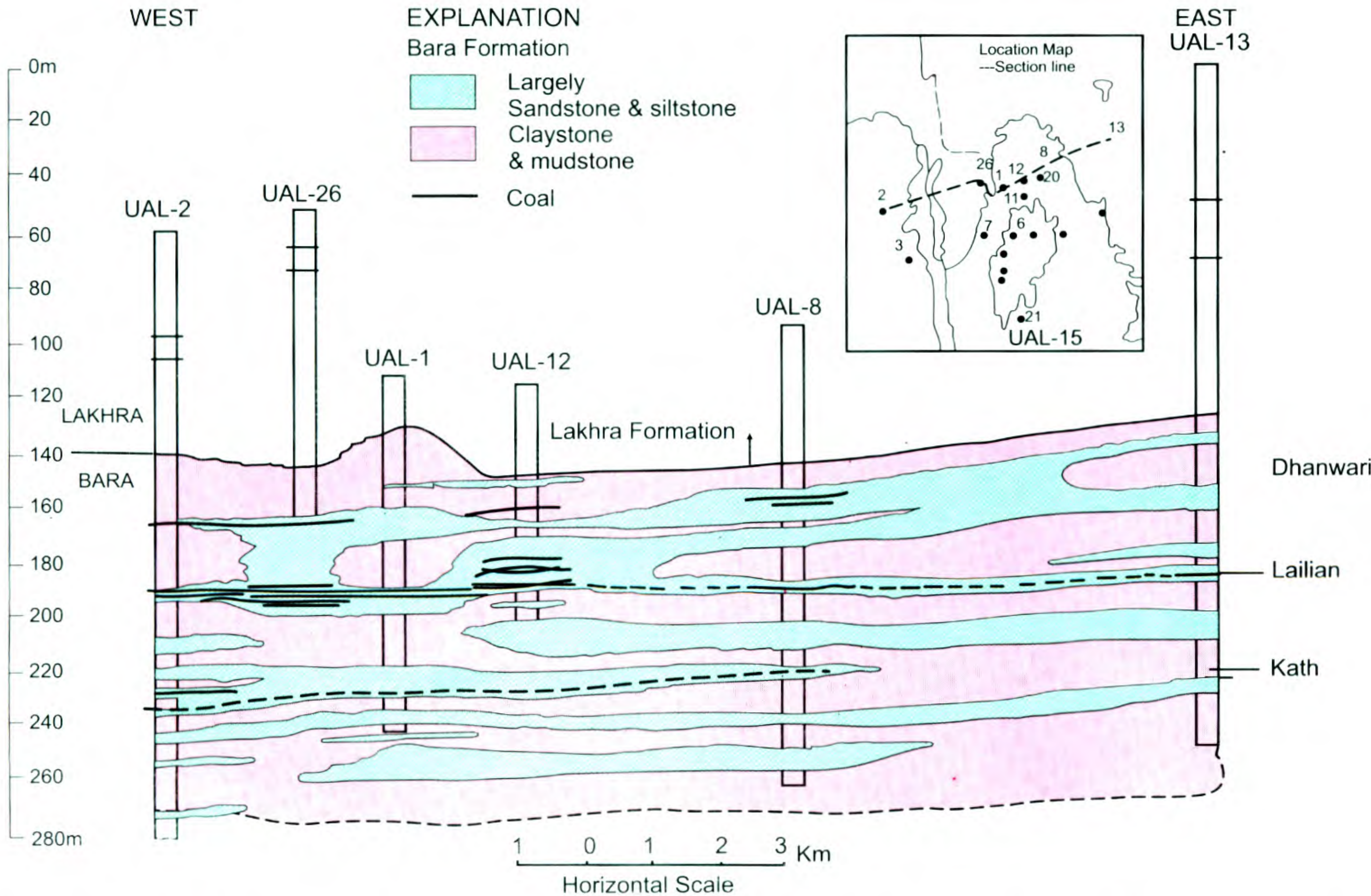


Figure 6.3. Geological cross section of Lakhra coal field based on selected bore hole logs showing stratigraphy of Bara formation and correlation of coal seams (from Kazmi et al.1990)

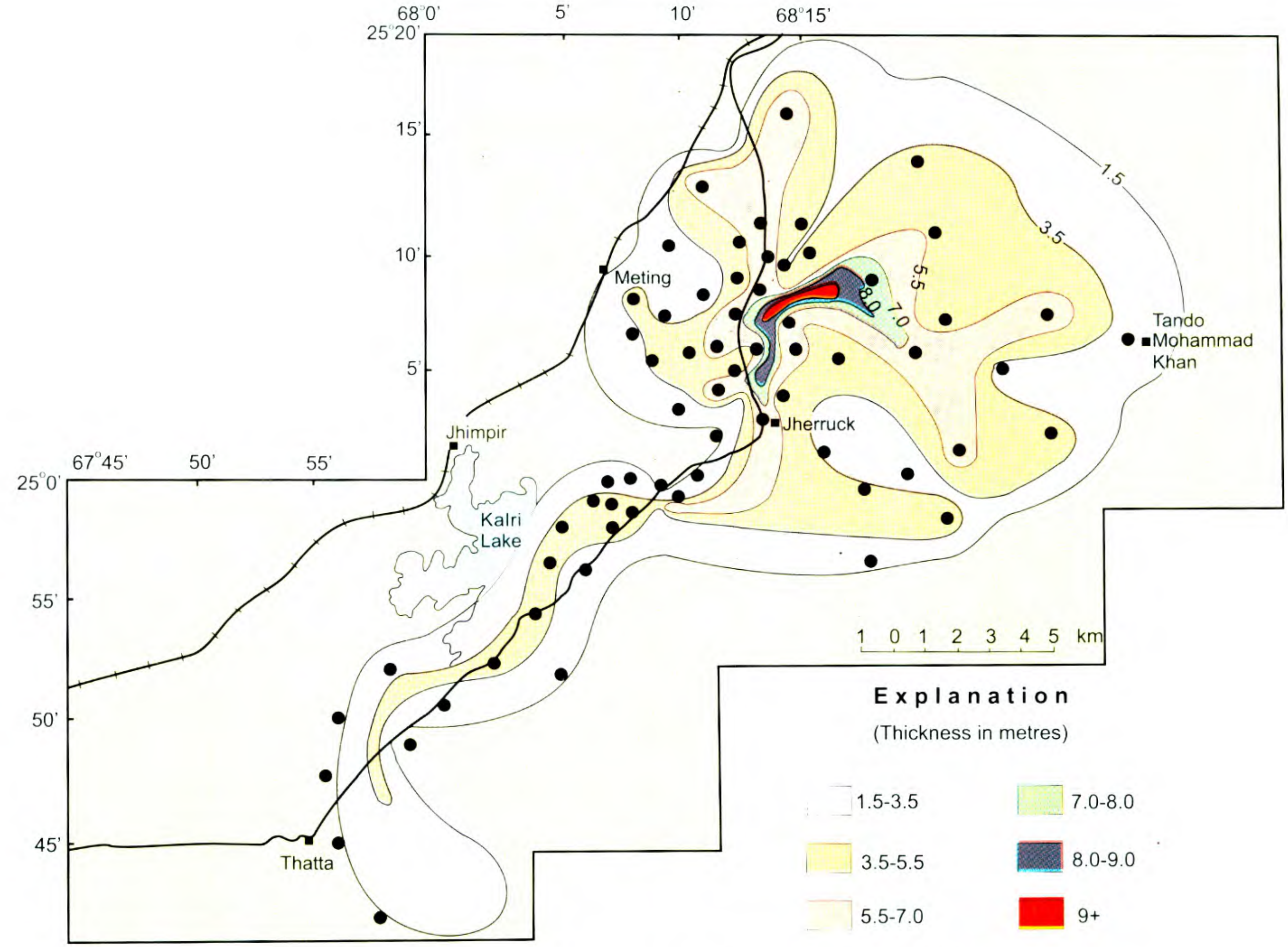


Figure 6.4. Coal isopach map of Sonda Coal field (from Kazmi et al. 1990)

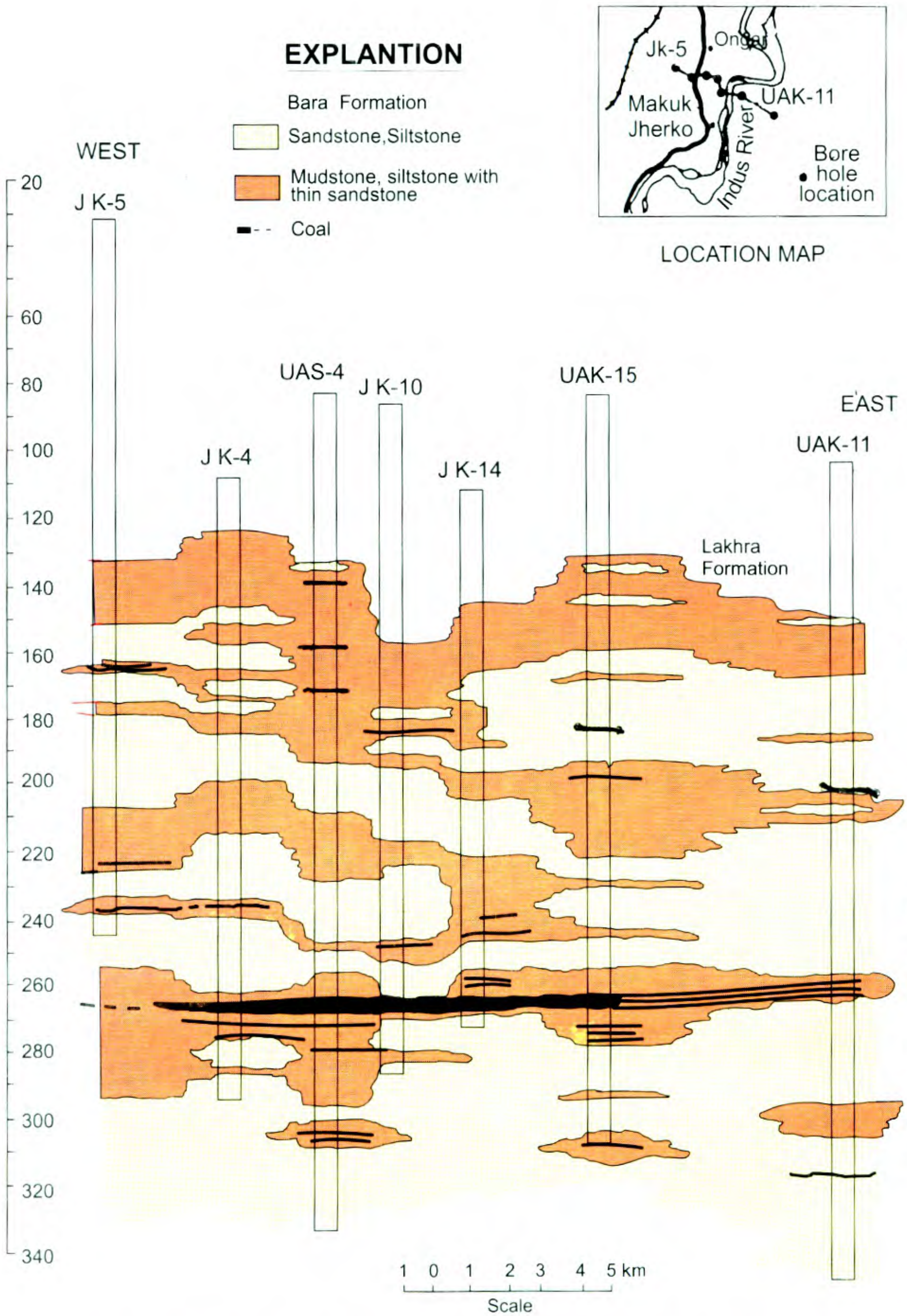


Figure 6.5. Geological cross section of Sonda coal field based on selected bore hole logs showing the stratigraphy of the Bara Formation and correlation of the coal seams (form Kazmi et al. 1990).

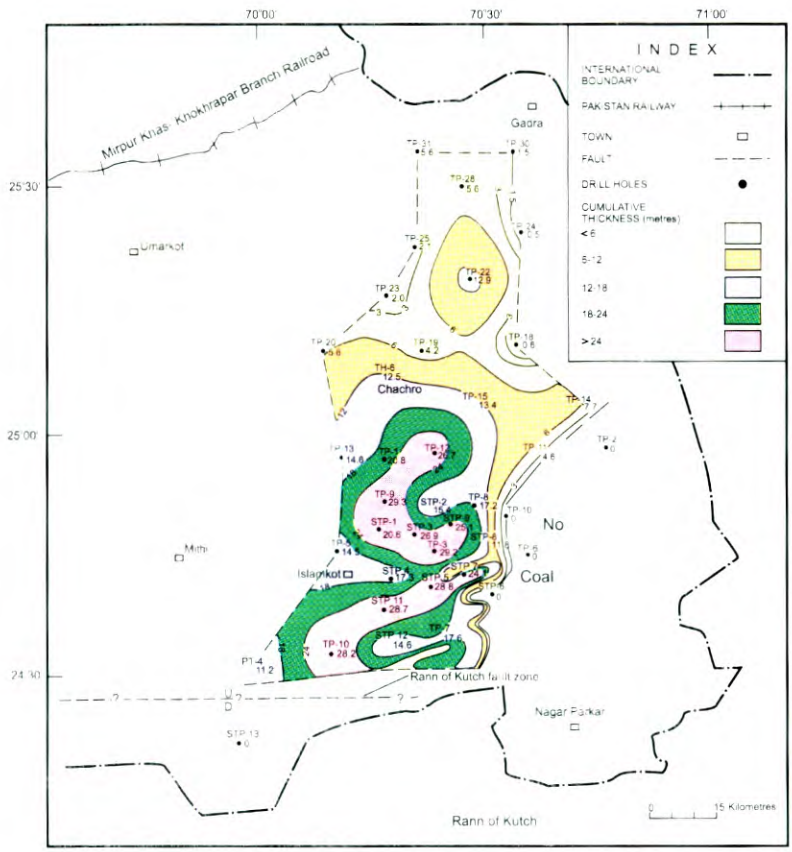


Figure 6.6. Isopach map of total coal thickness in the Thar coal field. Contour interval in metres. Black circles show drill and numbers indicate cumulate thickness of coal seams **(from Jaleel et al. 1999).**

The coal resources of the NWFP have not been explored fully as yet. The main reason being that the coal bearing rocks in this province are tightly folded, highly fractured and fissured rendering exploration difficult and costly. Further more, the geological conditions suggest that mining also would be difficult and expensive.

Coal in Northern Areas: Graphitic coal has been recently discovered in the Reshit area of the Chapursan valley, about 60 kilometre west of Sost in upper Hunza. The coal occurs in a thick formation of weathered, dark grey, thick bedded, hard and compact carbonaceous limestone. The coal seams range in thickness from a few centimetres to six metres. They are largely vertical, highly folded and faulted and their thickness varies over short distances (Faruqi 1997). The coal seams may be traced for several kilometres on either side of Reshit Nala. The reserves are likely to be large but mining will be difficult. Data on coal quality is given in Table 30.

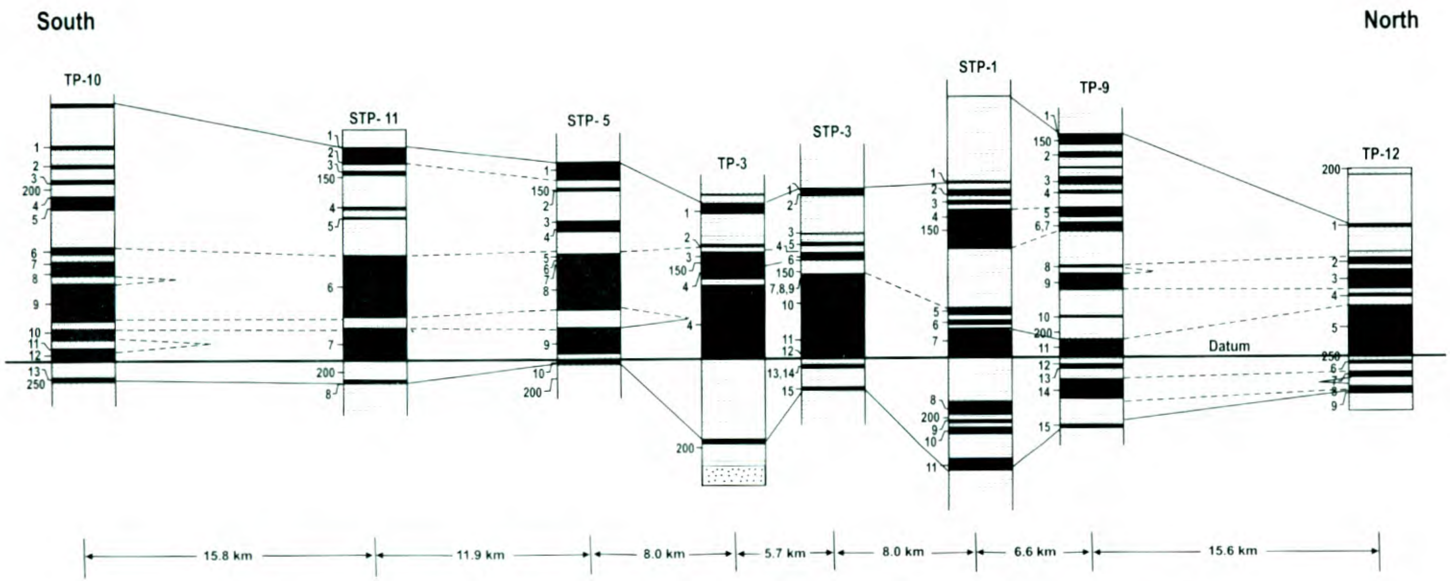


Figure 6.7. Coal correlation section through the Thar coal field (from Fassett and Durrani 1994)

Table 29. Summary of coal resources of Pakistan (in million tonnes) (Modified from Kazmi and Abbas 1991).

Coal field	Average mine-able thickness (metres)	Reserves					Coal-rank (ASTM)
		Proved	Indicated	Inferred	Hypothetical	Total	
BALOCHISTAN							
1. Duki	0.5	14	11	25	...	50	SubC- SubA
2. Mach-Abegum	0.75	9	...	14	...	23	SubC- SubB
3. Sor RangeDeghri	0.75	15	...	19	...	34	SubB- SubA
4. Pir Ismail Ziarat	0.5	1.5	1.5	8	...	11	hvCb
5. Khost~Sharigh-Harnai	0.75	13	...	63	...	76	hvBb-hvAb
PANJAB							
6. Makarwal	0.75	5	8	9	...	22	hvCb-hvBb
7. Salt Range	0.5	43	13	-	178	234	hvCb
NORTHERN AREAS							
8. Chappursan	...	...	...	...	10	10	
SINDH							
9. Lakhra	1.5	244	629	739	28	1,640	LigA-SubC
10. Sonda	0.65	188	1,388	5,724	...	7,300	LigA-SubB
11. Jhimpir	0.5	10	4.3	108	...	122	LigA-SubC
12. Badin	...	...	...	...	9,000	9,000	...
13. Thar	0.3-30	2,350	8,638	44,798	119,720	175,506	LigA-SubC
Total		2,892.5	10,692.8	51,517	128,926	194,028	

Table 30. Range of Proximate Analyses of Pakistan Coal (modified from Kazmi and Abbas 1991).

Coal field Value	Moisture%	Volatile Carbon%	Fixed	Ash%	Sulphur%	Calorific Cal/kg.
BALOCHISTAN						
Duki	03.70 - 04.81	32.77 - 38.37	46.49 - 50.82	09.11 - 16.03	04.31 - 06.15	2,826 - 6,748
Mach	7.1 - 12.0	34.5 - 39.4	32.4 - 41.5	9.6 - 20.3	3.2 - 7.4	5,104 - 5,717
Sharigh- Harnai	1.53 - 12.0	30.29 - 43.69	28.49 - 53.14	6.33 - 30.34	2.8 - 2.63	4,173 - 7,531
Sor Range	5.1 - 21.2	31.0 - 43.1	36.0 - 43.0	2.7 - 14.3	0.4 - 5.6	4,822 - 6,049
PANJAB TRAN-INDUS						
Makarwal	2.8 - 5.3	42.4 - 48.1	36.7 - 44.9	6.4 - 11.5	2.8 - 6.8	6,328 - 6,769
PANJAB CIS-INDUS						
Salt Range	3.2 - 7.6	26.3 - 38.8	29.8 - 44.8	12.3 - 37.7	3.5 - 10.7	3,941 - 6,161
NORTHERN AREAS						
Chappursan	2.84 - 10.5	17.78 - 19.3	50.35 - 54.56	21.37 - 23.88	2.18 - 2.37	8,913 - 9,675
SINDH						
East of Indus	39.07 - 40.91	16.67 -28.61	23.80 - 28.91	2.94 - 11.65	0.23 - 1.84	3,836 - 4,268
Jherruck (Sonda)	27.24 - 39.26	18.07 - 31.07	20.21 - 44.51	4.88 - 29.27	0.52 - 4.89	3,003 - 5,488
Jhimpir-Meting	15.4 - 29.8	29.8 - 39.9	31.0 - 36.3	8.2 - 14.6	3.4 - 7.4	4,106 - 5,439
Lakhra (north central, south)	26.4 - 33.3	22.4 - 39.0	22.3 - 35.7	6.7 - 26.6	2.9 - 9.0	2,840 - 4,990
Sonda	7.0 - 26.98	15.94 - 48.1	12.58 - 64.9	3.96 - 39.2	0.56 - 8.25	3,646 - 6,957
Thar	38.49 - 43.75	29.44 - 31.87	18.82 - 21.38	6.5 - 10.12	0.82 - 1.96	5,991 - 6,515

PETROLEUM AND NATURAL GAS

Petroleum has been known to occur in the Kohat area since 1833. In 1870 survey for petroleum in the Punjab reported many oil seepages (Heron and Crookshank 1954). Since those early times several oil and gas seepages have come to light from various localities in the NWFP, Punjab, Sindh and Balochistan (Fig. 6.8). In the early days these oil shows were considered important guides to locate economic oil deposits. Nowadays, though they have lost their importance, they are still of interest to companies in search for oil.

The history of exploratory oil drilling goes back to 1866 when the first well was drilled at Kundal in Khisor Range (NWFP). In 1864 it was followed by borings near Khattan (29°34':68°31') in Balochistan, which went down to depths of 20 to 130 metres. A small quantity of oil was produced and in 1889 it amounted to 218,490 gallons (Heron and Crookshank 1954). The first commercial oil discovery, however, was in 1920, when the Attock Oil Company discovered the Khaur oil field in the Potwar Plateau. By the time of Independence (1947), three more oil fields (Dhulian, Joya Mair and Balkassar) were in production. In the early fifties, the average annual production of oil from these sources was about 1.158 million barrels (approximately 2,173 barrels/day). Since then many oil and gas fields have been discovered (Fig. 6.9). Until July 1998 about 479 exploratory wells had been drilled resulting in 134 discoveries, 56 of oil and 78 of gas and condensate. These oil fields are, however, small and their production ranges from less than 50 to about 4,000 barrels/day. In recent years the annual crude oil production has varied from about 53,482 to 64,349 barrels/day (Fig. 6.10).

Four of the gas fields (Sui, Mari, Uch and Qadirpur) are giants and two majors (Pir Koh and Khairpur). Recently a large gas field has been discovered at Bhit in the Kirthar Piedmont zone and the prospects are that it may prove to be a major (Aslam 1997). In recent years the annual production of natural gas has shown a steady increase from 1,195 million cubic foot in 1987-88 to 1,916 million cubic foot in 1997-98 (Fig. 6.11).

Sedimentary basins and oil and gas fields

Inasmuch as the sedimentary formations are the natural habitat for oil and gas the sedimentary basins are of particular significance from the stand-point of the occurrences, exploration and development of these deposits. Pakistan comprises two sedimentary basins– the Balochistan and Indus basins. Based on tectonostratigraphic considerations these basins have been divided into various zones by Raza et al., (1989a) as shown in Figure 6.12.

Balochistan Basin

The Balochistan Basin which comprises the Makran accretionary zone and the Makran offshore trench, contains 5,000–15,000 metres thick flysch-type terrigenous slope and shelf sediments and turbidites. This is the least explored region of Pakistan. Very limited seismic

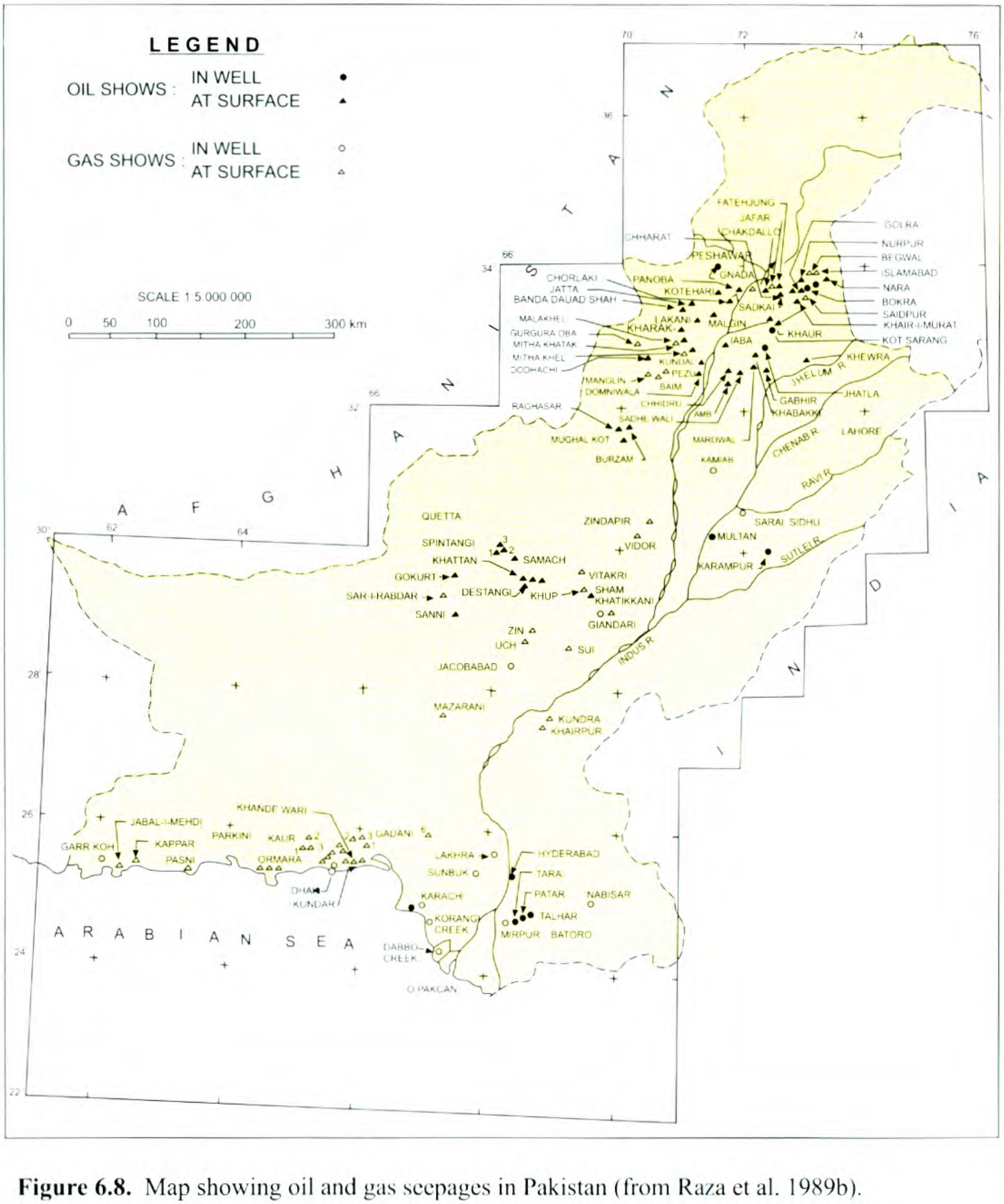


Figure 6.8. Map showing oil and gas seepages in Pakistan (from Raza et al. 1989b).

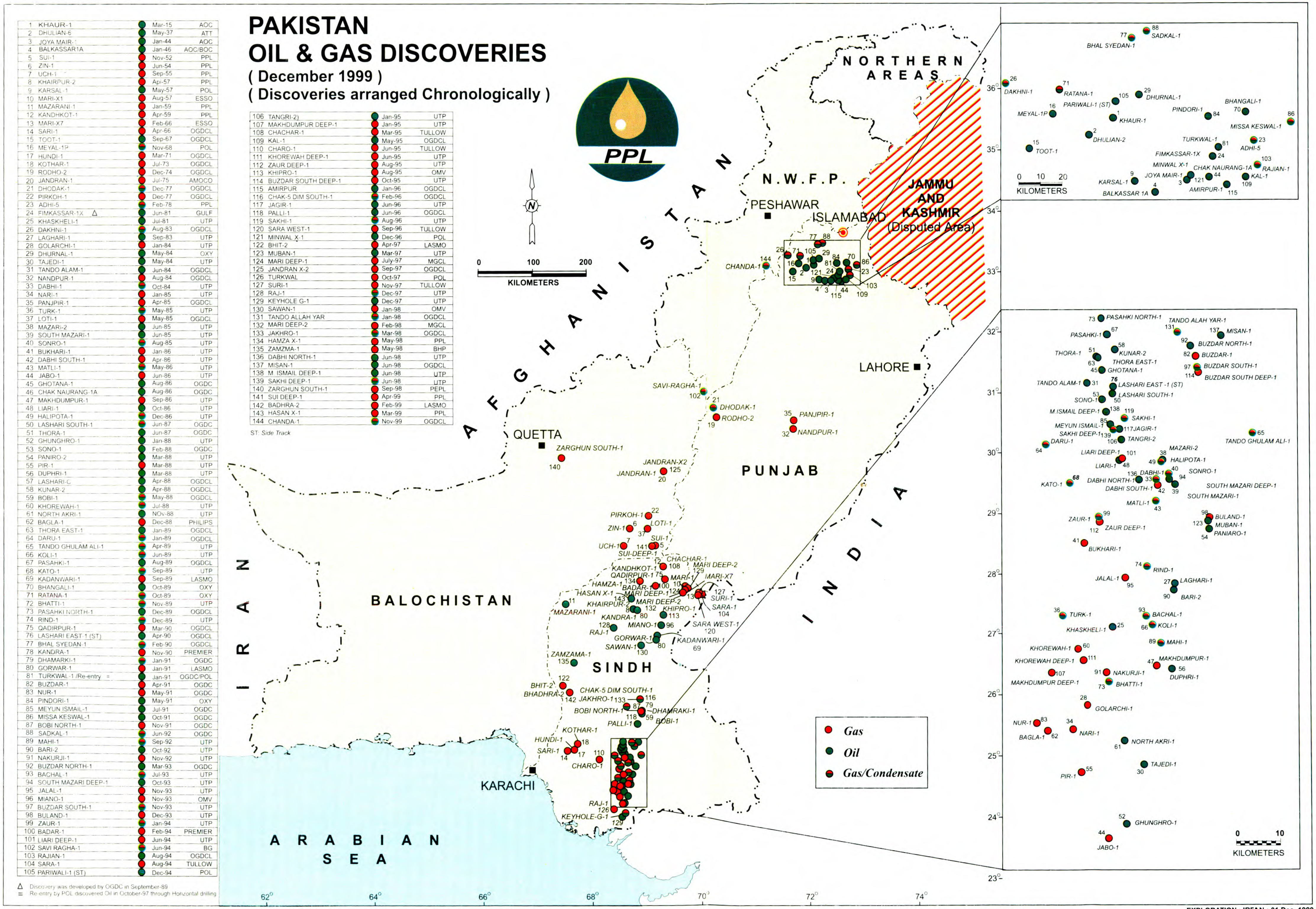


Figure 6.9. Map showing Oil and Gas fields of Pakistan (courtesy Pakistan Petroleum Ltd).

survey has been done and only six wells have been drilled in this vast basin of over 300,000 km². Despite several gas shows along the Makran Coast, no commercial hydrocarbons have been found in the basin so far.

Attractive structures comprising long, asymmetrical to overturned, parallel to en echelon anticlines occur in the Makran coast and offshore area. Extensive source rocks (Parkini, Panjgur and Siahan Formations) suitable reservoir rocks (Talar and Panjgur sandstones) and appropriate cap rocks have been identified in the basin (Malik et al. 1988, Raza and Ahmad 1990). Data on maturity, however, are meagre. According to Khan and Raza 1986, the geothermal gradient seems to be relatively low (1.5° to 2.5°C/100 m). Presently the hydrocarbon prospects in the Makran Basin are rated as average, though the Makran Coast is likely to hold better prospects (Raza et al. 1989b).

Indus Basin

The Indus Basin covers an area of about 533,500 km² and contains more than 15,000 metres thick sediments ranging in age from the Precambrian to Recent (Fig. 6.13). Oil and gas fields have been discovered in the inner folded zones of the Sulaiman and Kirthar Ranges, Kohat-Potwar Plateau, Sulaiman-Kirthar depression (foredeep), Karachi depression, and the Indus platform (Punjab monocline, Sukkur rift and Sindh monocline). The Jacobabad-Khairpur and Mari-Khandkot highs (Sukkur rift zone) and the Sargodha high (Sargodha-Shahpur buried ridge) divide the Indus Basin into three main tectonostratigraphic zones (Fig. 6.12).

Northward, the region between the Sargodha high and the MBT forms the northern zone which includes the Kohat-Potwar Plateau, the Bannu Basin, the Cis- and Trans-Indus Salt Range, and the northern Punjab monocline. The region between the Sukkur rift zone and the Sargodha high, comprising the Sulaiman fold belt and foredeep and the southern Punjab monocline constitutes the central part of the Indus Basin. The southern zone lies to the south of the Mari-Khandkot horst and comprises the Jacobabad-Khairpur high, Kirthar fold belt and its depression and the Sindh monocline (Raza et al. 1986a, Raza and Ahmed 1990, Kadri 1995).

Northern Indus Basin: This basin is characterised by complex structural styles and a stratigraphic sequence ranging from Precambrian to Recent (Fig. 6.13). A number of oil-fields occur in this zone (Fig. 6.9). The Dhurnal oilfield is the largest and has reserves of about 52 million barrels of oil and 0.13 TCP of gas. The main oil and gas producing horizons, possible source and cap rocks have been shown in Figure 6.13 and Table 31. Geothermal gradients in this zone vary from 1 to 2°C/100 m. The oil window occurs at depth of 2,750-5,200 metres (Khan and Raza 1986) and this is reflected in the occurrence of oil at depths greater than 2,750 metres.

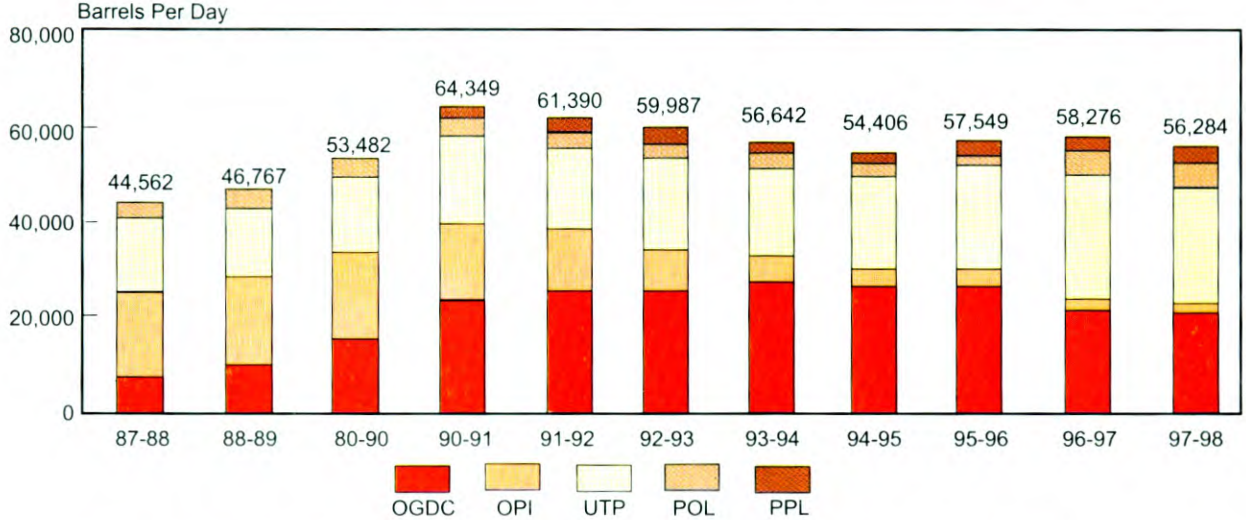


Figure 6.10. Crude Oil Production (from Government of Pakistan, Energy Year Book 1999).

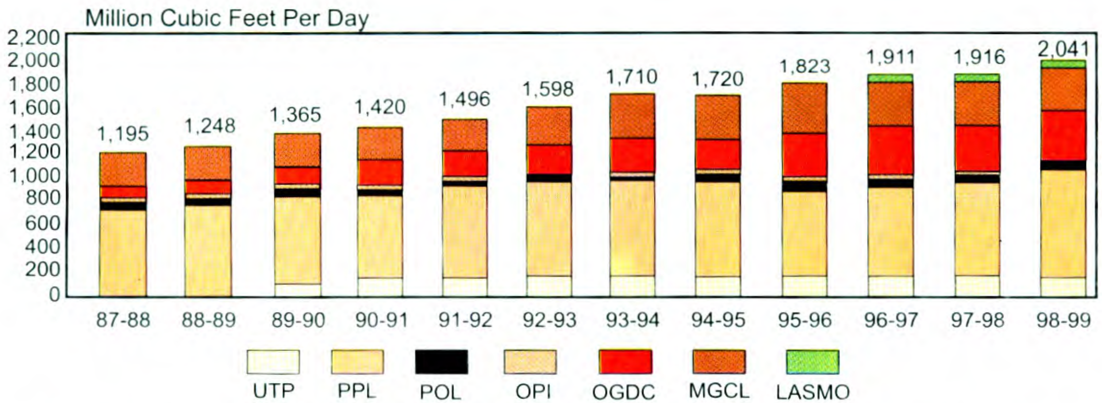


Figure 6.11. Natural gas production (from Government of Pakistan, Energy Year Book 1999).

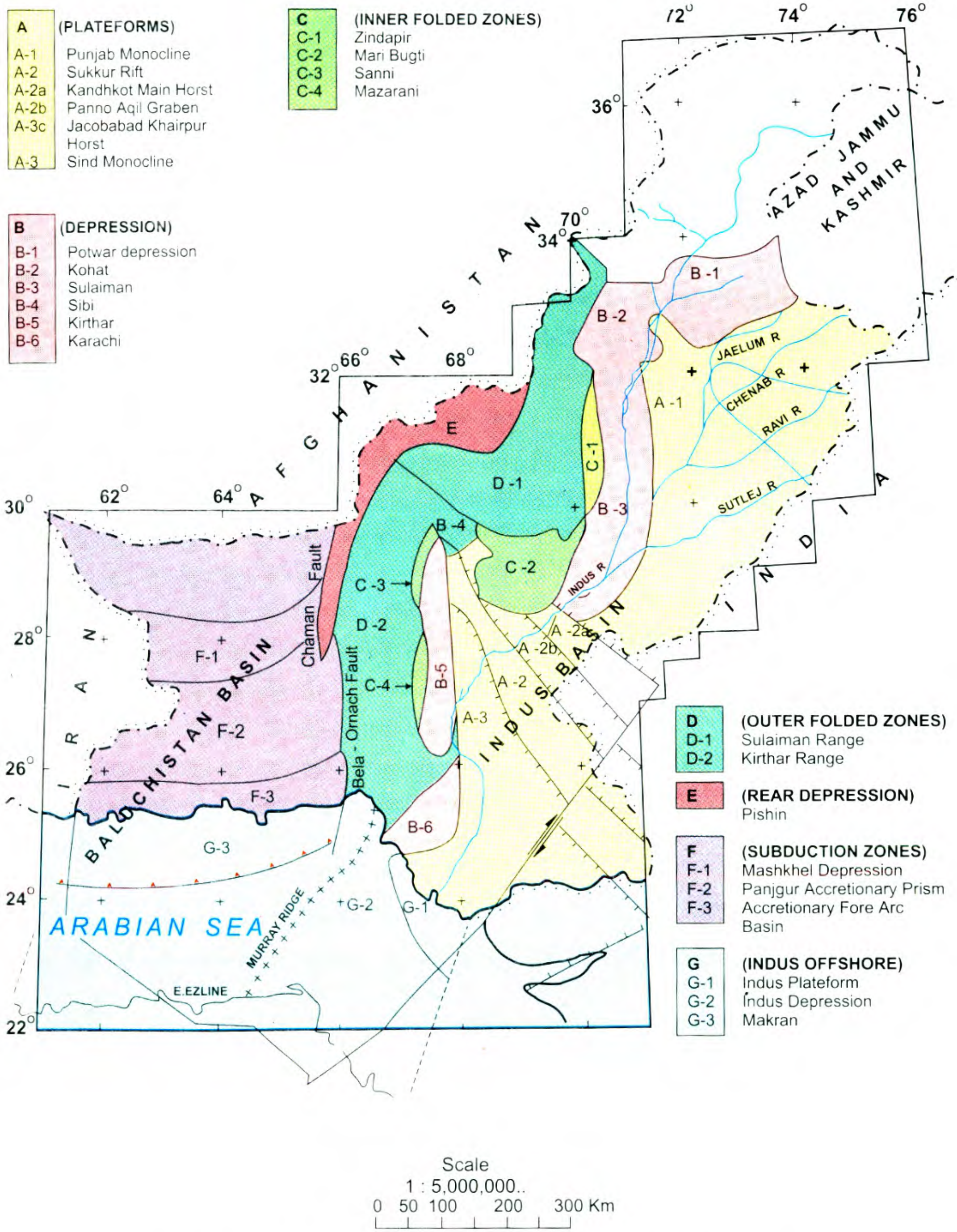


Figure 6.12. Sedimentary zones of Pakistan (from Raza et al. 1989b)

Central Indus Basin: This basin is comprised of duplex structures characterised by large anticlines and domes in the passive roof sequence of the Sulaiman fold belt, followed eastward by gently dipping strata of the Punjab monocline which has few tectonic folds and faults. The basin contains a sedimentary sequence ranging from Precambrian to Recent. It is essentially a natural-gas bearing zone and contains fifteen gas fields, including one giant field (Sui) with 8.6 TCF recoverable reserves and one large field (Pirkoh) with 2.6 TCF recoverable reserves. The main producing strata range in age from Cretaceous to Eocene (Fig. 6.13). This basin is characterised by wide variations in geothermal gradients. Low (1.2°C/100m) geothermal gradients occur in the eastern part (Fig. 6.14). It has been observed that there is a zone of very low geothermal gradient around the Sargodha-Shahpur buried ridge, which may be due to the high thermal conductivity of the shield (Khan and Raza 1986). However, in the central part of this basin, in the Sulaiman depression, there is a zone with the high geothermal gradient 4.1 °C/100 m. The main gas fields of Mari, Khandkot, Sui, Uch, Loti, Zin, Pirkoh and Jandran are concentrated in this region and it is likely that the heat-flow from this 'hotspot' has contributed to the development of these fields. Khan and Raza (1986) are of the view that in this region the 'oil window' may be below the gas-producing horizon with the possibility of oil occurrences in the Cretaceous sediments below the gas horizons.

Southern Indus Basin. This basin is characterised by passive-roof duplex-type structure and a passive backthrust along the Kirthar fold belt, a passive roof thrust forming a frontal culmination wall along the margin of the fold belt and the Kirthar depression, and out-of-syncline intra-molasse detachments in the Kirthar depression sequence. The Kirthar and Karachi depressions contain several large anticlines and domes and some of these contain small gas fields (Mazarani, Sari, Hundi and Kothar). The eastern part of the basin comprising the Sindh monocline (Indus Platform) is largely comprised of faulted and tilted blocks of Mesozoic rocks which form structural traps and contain small oil and gas fields (Fig. 6.9). The fault blocks are unconformably overlain by Deccan Trap Basalts and Tertiary sedimentary rocks. The northern margin of the Southern Indus Basin comprises the Sukkur Rift zone which bears large anticlinal structures and contains the Khandkot and Mari gas fields. The latter is a giant field with 6.3 TCF of reserves.

The main reservoir rocks in the Sindh monocline are Cretaceous Lower Goru sandstone. In the Karachi depression production is from Paleocene Ranikot limestone and sandstone. In Kirthar depression and Sukkur Rift zone it is from Eocene Sui Main/ Habib Rahi Limestone. The potential source, reservoir and cap rocks in this basin are listed in Table 31.

The Southern Indus Basin is also characterised by high geothermal gradients which range from 2 to over 4°C/100 metres The highest gradient has been recorded from the Damiri I well (Fig. 6.14).

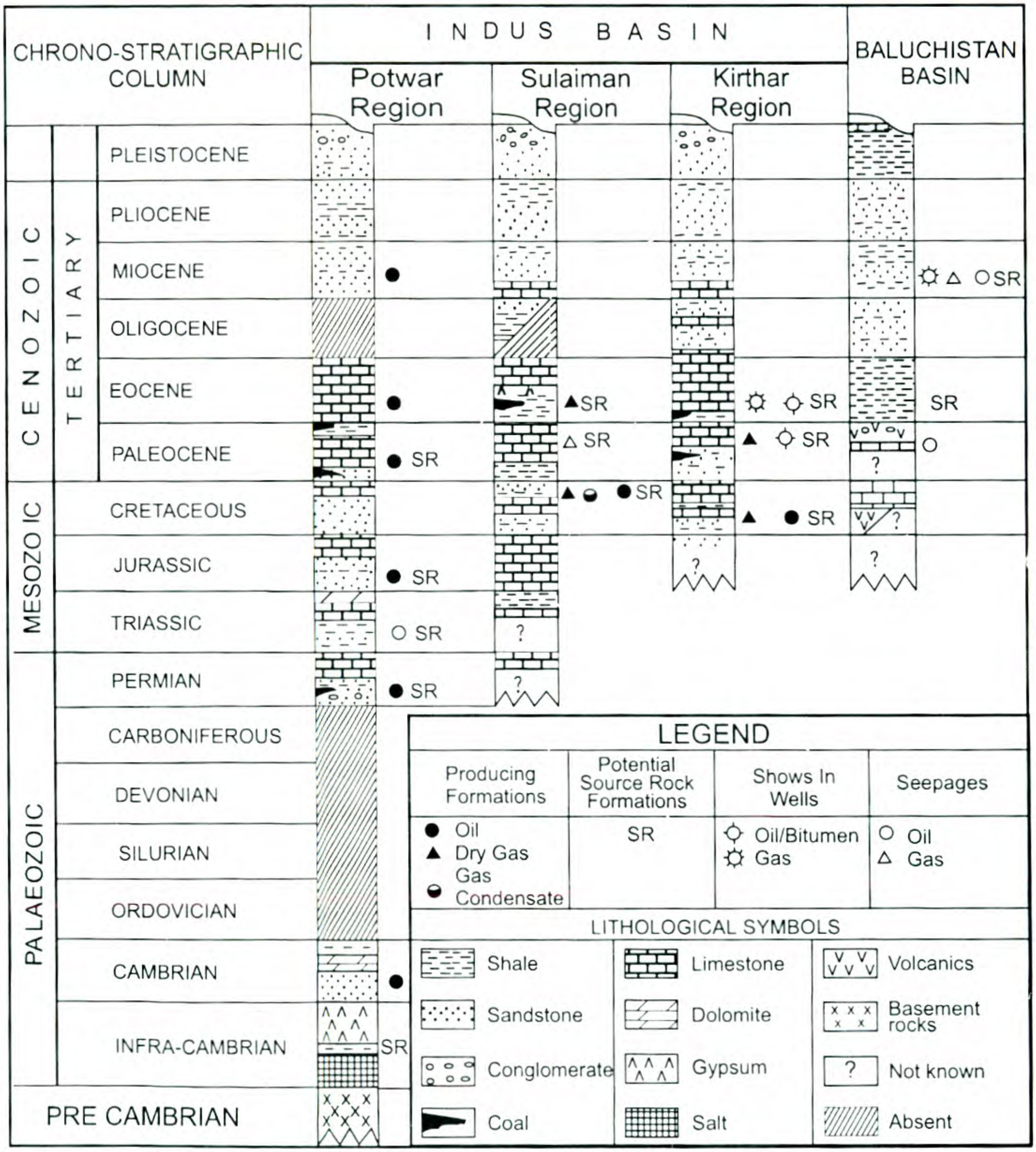
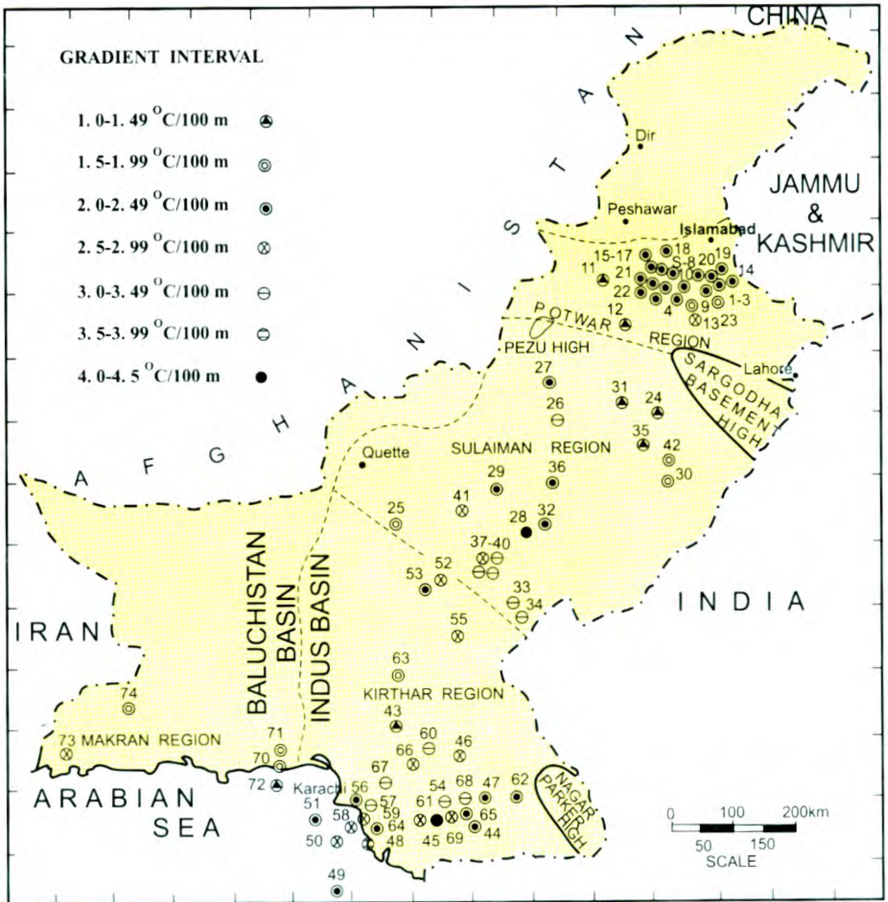


Figure 6.13. Generalised stratigraphic columns showing occurrence of hydrocarbons in Pakistan (from Khan and Raza 1986).



WELLS SHOWN IN THE ABOVE MAP

1. Adhi-3
2. Adhi-5
3. Adhi-6
4. Balkassar-1
5. Dhulian-2
6. Dhulian-3
7. Dhulian-42
8. Dhulian-43
9. Kallar Kahar-1
10. Karsal-4
11. Karak-1
12. Kundian-1
13. Lilla-1
14. Mahesian-1
15. Meyal-4
16. Meyal-5
17. Meyal-6
18. Mianwala-1
19. Qazian-1
20. Tanwin-1
21. Toot-5
22. Toot-9
23. Warnali-1
24. Budhuana-1
25. Bannh-1
26. Dhodak-2
27. Domanda-1
28. Giandari-1
29. Jandran-1
30. Karampur-1
31. Kamiab-1
32. Kot-Rum-1
33. Mari-2
34. Mari-3
35. Sarai Sidhu-1
36. Sakhi Sarwar-1
37. Sui-20
38. Sui-22
39. Sui-23
40. Sui-25
41. Tadri Main-1
42. Tola-1
43. Badhra-1
44. Badin-1
45. Damiri-1
46. Dasori-1
47. Digh-1
48. Dabbo Creek-1
49. Indus Marine-Al
50. Indus Marine-Bl
51. Indus Marine-Cl
52. Jacobabad-2
53. Jhatpat
54. Khaskheli-1
55. Khairpur-2
56. Karachi-1
57. Karachi-2
58. Karachi South-Al
59. Korangi Creek-1
60. Lakhra-1
61. Mirpur Batoro-1
62. Nabisar-1
63. Phulji-2
64. Paitiani Creek-1
65. Patar-1
66. Sunbak-1
67. Sari Singh-1
68. Talhar-1
69. Tarai-1
70. Dhak-1
71. Dhak-2
72. Jal Pari lA
73. Gar Koh-1
74. Kech Band-1

Figure 6.14. Geothermal gradientd in selected oil and gas wells in the Indus Basin (from Khan and Raza 1986).

Table 31. Potential source, reservoir and cap rocks in the Indus Basin. Producing reservoir rocks marked by asterisks. (Data from Raza et al. 1990, Kadri 1995).

Age	Source Rocks			Reservoir Rocks			Cap Rocks		
	Upper Indus	Middle Indus	Lr. Indus & offshore	Upper Indus	Middle Indus	Lr. Indus & offshore	Upper Indus	Middle Indus	Lr. Indus & offshore
Pleistocene									
Pliocene									
Miocene			Gaj (shale) (offshore only)	Murree (sandstone)		Gaj (shale) (offshore only)	Murree (clays)		Gaj (shale) (offshore only)
Oligocene			Nari (shale) (offshore only)			Nari (sst/lst) (offshore only)			Nari (shale) (offshore only)
Eocene	Jatta Gypsum (shale) Nammal (shale)	Kirthar (limestone) Laki/Ghazij (lst/sh)	Kirthar (sh & lst) Laki/Ghazij (sh & lst)	Chorgali* Sakesar* Shekhan (limestone)	Kirthar* (limestone) Laki/Ghazij (limestone) Sui Main (lst)*	Kirthar (limestone) Laki/Ghazij (limestone)	Kohat Kuldana Nammal (shales)	Kirthar Laki Ghazij (shales)	Kirthar Laki Ghazij (shales)
Paleocene	Patala (shale) Lockhart (limestone)	Dungan/ Ranikot (shale)	Lakhra (shale) Bara (shale)	Patala (limestone) Lockhart* (limestone)	Dungan Ranikot* (sandstone)	Lakhra (limestone) Bara (sst)	Patala Hangu (shales)	Dungan Ranikot (shales)	Lakhra Bara Khadro (shales)
Cretaceous	Chichali (shale)	Moghal Kot (lst/marl) Chichali/ Sembar (shale)	Moghal Kot (Limestone) Goru(shale) Sembar(shale)	Lumshiwal (sandstone)	Pab (sst)* Chichali Goru (sst)* Sembar (sst/lst)	Pab (sst)* Goru (sst)* Sembar (sst)	Datta (shale)	Moghal Kot Chichali Sembar (shale)	Moghal Kot Goru (shale)
Jurassic	Datta (shale)			Samana Suk* (limestone) Datta* (shale)					
Triassic									
Permian				Nilawahan-Zaluch Gr.*(sst/lst) Tobra (conglomerate)			Datta (shale)		
Cambrian	Salt Formation	Salt Range Formation		Khewra* (sandstone)	Khewra (sandstone)	Khewra (sandstone)	Khewra (shale)	Khewra (shale)	

Table 32. Crude oil reserves (million US barrels) as on June 30, 1999 (from Pakistan Energy Year Book 1999).

	FIELD	Operator Company	Original Recoverable Reserves	Cumulative Production	Balance Recoverable Reserves
1.	Savi Ragha (c)	BG	1.350		1.350
2.	Bagla	OGDC	0.070		0.070
3.	Bhal Syedan (c)	"	0.173	0.069	0.104
4.	Bobi (c)	"	8.400	1.820	6.580
5.	Buzdar & Buzdar North (c)	"	0.276	0.014	0.262
6.	Chak-5 Dim South	"	0.118		0.118
7.	Chak-Naurang	"	5.090	4.179	0.911
8.	Dakhni (c)	"	10.556	2.538	8.018
9.	Daru	"	0.425		0.425
10.	Dhamraki	"	0.150		0.150
11.	Dhodak (c)	"	29.800	4.234	25.566
12.	Fimkassar	"	26.290	10.520	14.770
13.	Ghotana	"	0.400	0.166	0.234
14.	Kal	"	3.660	2.421	1.239
15.	Kunar	"	12.400	2.123	10.277
16.	Lashan Centre	"	9.630	6.103	3.527
17.	Lashan East	"	0.037	0.037	
18.	Lashan South (c)	"	0.044		0.044
19.	Missakasal	"	11.860	8.380	3.480
20.	Missan	"	0.314	0.051	0.263
21.	Mithrao	"	1.050		1.050
22.	Nur	"	0.057		0.057
23.	Palli	"	1.000	0.090	0.910
24.	Pasakhi	"	21.080	12.380	8.700
25.	Qadirpur	"	4.200	0.365	3.835
26.	Rajian	"	9.813	2.255	7.558
27.	Sadkal (c)	"	2,930	2.611	0.391
28.	Sono	"	14.600	8.374	6.226
29.	Tando Alam	"	22.419	11.082	11.337
30.	Thora	"	22.980	12.346	10.634
31.	Toot	"	15.800	12.033	3.767
32.	Bhangali	OPI	3.628	2.664	0.964
33.	Dhurnal	"	52.339	48.178	4.161
34.	Ratana (c)	"	9.263	1.047	8.216
35.	Balkassar	POL	35.200	33.280	1.920
36.	Dhulian	"	42.500	41.890	0.610
37.	Joyamair	"	10.450	7.340	3.110
38.	Khaur	"	4.310	4.200	0.110
39.	Meyal	"	49.300	38.320	10.980
40.	Minwal	"	3.740	0.300	3.440
41.	Pariwala	"	1.920	1.110	0.810
42.	Pindora	"	12.850	1.840	11.010
43.	Turkwal	"	3.790	0.640	3.150
44.	Adhi (c)	PPL	35.000	8.424	26.576

(continued)

Table 32. Crude oil reserve as on June 30, 1999 (contd.).

	FIELD	Operator Company	Original Recoverable Reserves	Cumulative Production	Balance Recoverable Reserves
45.	Akri North	UTP	4.057	2.777	1.286
46.	Bachal	"	0.031	0.026	0.005
47.	Bari	"	2.175	2.000	0.175
48.	Bhatti (c)	"	2.166	1.105	1.061
49.	Bukhtari (c)	"	1.623	1.268	0.355
50.	Buzdar South & South Deep	"	1.470	0.381	1.089
51.	Dabni & Dabhi South	"	9.692	4.815	4.877
52.	Dabhi North	"	3.460	0.327	3.133
53.	Duphri	"	0.025		0.025
54.	Ghungro	"	3.089	2.470	0.619
55.	Golarchi (c)	"	0.205	0.167	0.038
56.	Halipota	"	1.504	0.937	0.567
57.	Jabo	"	0.187	0.146	0.041
58.	Jagir	"	4.401	1.513	2.888
59.	Jalal	"	0.233	0.177	0.056
60.	Kato	"	0.205	0.192	0.013
61.	Keyhole G	"	0.969	0.038	0.931
62.	Khaskheli	"	11.383	10.164	1.219
63.	Khorewah & Khorewah Deep	"	1.760	0.955	0.805
64.	Koli (c)	"	0.457	0.359	0.098
65.	Laghari	"	21.253	20.603	0.650
66.	Liari & Liari Deep	"	6.250	5.333	0.917
67.	Mahi	"	0.048	0.025	0.023
68.	Matli	"	0.286	0.281	0.005
69.	Mazari	"	22.480	20.611	2.029
70.	Mazari South & Deep	"	20.118	12.611	7.507
71.	Meyun Ismail	"	1.309	0.759	0.550
72.	Meyun Ismail Deep	"	0.005		0.005
73	Mukhdumpur	"	0.495	0.323	0.172
74.	Mukhdumpur Deep	"	0.116	0.104	0.012
75.	Muban	"	0.003	0.003	—
76.	Nakurji	"	incl'd in Bhatti		
77.	Nari	"	0.085	0.042	0.043
78.	Paniro	"	0.575	0.246	0.329
79.	Pir	"	0.138	0.053	0.085
80.	Raj	"	0.038		0.038
81.	Rind (c)	"	0.321	0.191	0.130
82.	Sakhi & Sakhi Deep	"	5.460	0.794	4.666
83.	Sonro (c)	"	0.965	0.356	0.609
84.	Tajedi	"	1.726	1.464	0.262
85.	Tando Ghulam Ali	"	0.072		0.072
86.	Tangri	"	7.549	4.571	2.978
87.	Turk & Turk Deep (c)	"	2.001	1.367	0.634
88.	Zaur & Zaur Deep	"	1.796	0.003	1.793
	Total: Million Barrels		634.443	393.815	249.628
	Million TOE		*86.32*	*52.83*	*33.49*

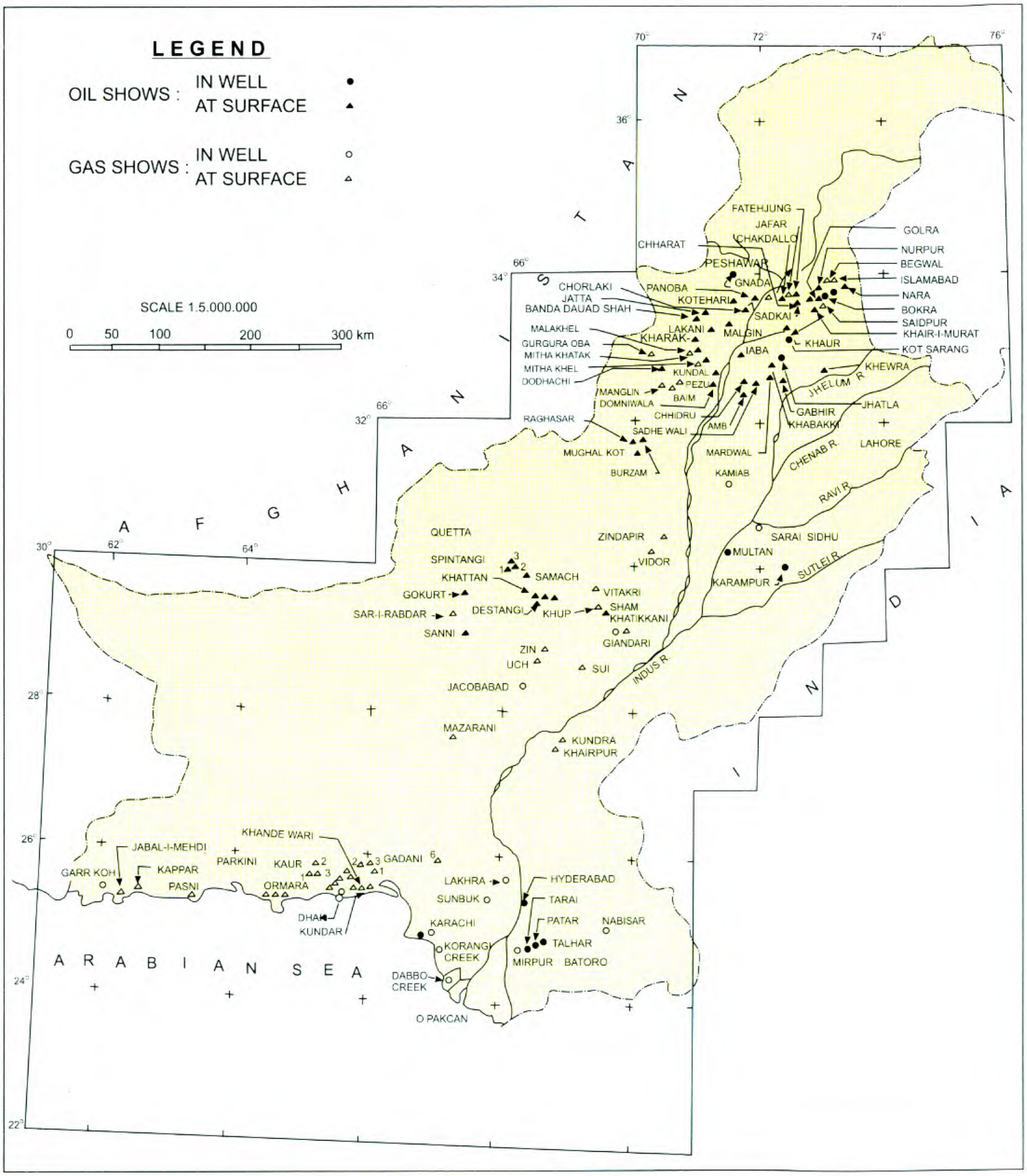


Figure 6.8. Map showing oil and gas seepages in Pakistan (from Raza et al. 1989b).

Table 33. Crude oil production by field (from Pakistan Energy Year Book 1999).

Unit: Million CFt

Province/Field	Opertor	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	ACGR
PUNJAB								
Balkassar	POL	163,612	122,859	102,538	138,244	143,619	136,470	-3.6%
Dhulian	"	6,671	7,001	7,118	6,881	10,463	34,709	39.1%
Joyamair	"	133,819	108,787	104,332	113,518	95,665	80,658	-9.6%
Khaur	"	1,796	2,198	2,256	2,403	2,128	1,876	1.2%
Meyal	"	760,091	495,655	549,339	584,748	282,918	124,465	-30.4%
Minwal	"				97,004	171,083	151,497	
Pariwali	"			262,944	307,045	271,325	366,867	
Pindori*	"			94,741	669,519	571,768	548,602	
Turkwal	"					374,180	468,844	
Chak Naurang	OGDC	372,918	351,441	338,362	314,031	321,207	262,452	-83.4%
Dakhni	"	229,778	209,330	233,392	209,124	222,971	229,544	0.0%
Dhodak	"		630,830	999,528	810,458	903,984	923,157	
Fimkassar	"	971,621	923,233	824,772	1,139,890	1,411,751	1,124,915	3.0%
Kal	"			573,840	665,438	590,695	602,623	
Missa Keswal	"	208,731	1,646,619	1,128,533	537,869	353,864	244,081	-34.9%
Rajian	"		455,214	587,026	415,472	503,427	237,720	
Sadkal	"	1,190,633	847,863	517,586	191,027	90,599	79,655	-41.8%
Toot	"	169,679	117,661	166,26	131,978	108,255	86,140	-12.7%
Bhangali	OPI	216,891	196,996	186,588	168,940	85,010	263,725	4.0%
Dhurnal	"	1,307,849	977,971	805,432	585,113	391,381	425,158	-20.1%
Ratana	"	317,714	249,078	211,917	169,801	72,400	48,042	-31.5%
Adhi	PPL	870,632	882,454	889,054	895,801	953,035	922,479	1.2%
Punjab Total		8,797,406	6,225,190	8,585,924	8,154,304	7,931,728	7,363,949	-3.5%
SINDH								
Allah Dino & Ghotana	OGDC							
Bobi	"	136,472	150,651	266,660	222,696	188,134	62,007	-14.6%
Buzdar North	"	5,905						
Kunnar	"	578,080	403,026	443,804				
Lashari Centre	"	568,940	738,382	679,185	402,843	288,706	108,007	-28.3%
Mazari	"						99,083	
Palli	"				89,520		4,245	
Pasakhi	"	1,373,644	1,274,692	1,143,739	578,585	726,991	1,563,405	2.6%
Pasakhi North	"				413,150	419,603	330,035	
Qadirpur	"			65,957	102,199	100,627	94,528	
Sono	"	872,384	707,601	778,738	684,553	691,933	774,925	-2.3%
Tando Alam	"	428,675	321,159	367,042	294,962	381,661	538,768	4.7%
Tando Alla Yar	"						5,954	
Thora	"	989,745	837,686	800,492	780,820	551,137	494,871	-12.9%
Kandhkot	PPL				18,450	16,561	16,177	
Sui	"				14,048	13,186	9,651	

(continued)

Table 33. Crude oil production by field (Continued).

Unit: Million CFt

Province/Field	Opertor	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	ACGR
Akri North	UTP	569,832	479,733	432,597	372,455	490,486	453,147	-4.5%
Bachal	"	2,474	4,056	16,777	1,772		701	
Bari	"	798,931	636,905	137,881	169,773	101,773	68,848	-38.8%
Bhatti	"	11,266	243,620	266,103	223,629		177,913	-19.7%
Bukahri	"	303,795	148,891	117,798	134,463		126,788	-20.6%
Buzdar South Deep	"	10,333	3,374	19,892	121,401	162,,695	105,166	59.0%
Dhabi & Dhabi N & S.*	"	125,149	150,763	153,956	468,833	487,568	1,305,220	59.8%
Ghungro	"	191,179	243,523	388,323	808,894	680,442	354,526	13.1%
Golarchi	"	8,426	8,038	5,187	3,559		4,631	-20.2%
Halipota	"	109,061	113,232	178,231	119,746	123,186	57,936	-11.9%
Jabo	"				473	109,480	48,492	
Jagir	"				772,275	520,044	400,184	
Jalal	"		23,764	87,500	40,606		3,872	
Kato	"					159,780	43,829	
Keyhole-G	"					37,630	21,977	
Khaskheli	"	263,987	311,412	392,586	391,497	532,750	468,734	12.2%
Khorewah & K. Deep	"	100,899	283,210	192,975	123,957	1,493	159,753	9.6%
Koli	"			180,229	124,498		49,320	
Laghari	"	461,210	556,031	457,589	356,416	282,161	239,773	-12.3%
Liari	"	593,449	296,938	173,567	135,959	113,931	224,496	-17.7%
Mahi	"			16,565	709			
Makhdumpur	"	102,556	82,052	56,081	16,386		7,187	
Matli	"	11,636	10,189	6,392	3,120		379	
Mazari	"	1,906,825	1,860,041	1,373,836	1,505,051	933,125	457,543	-24.8%
Mazari South	"	1,064,889	949,111	1,302,907	1,438,896	1,263,692	1,196,391	2.4%
Mazari South Deep	"	49,172	40,245	134,882	164,590	146,427	228,792	36.0%
Meyun Ismail*	"	27,931	302,089	221,843	128,765	62,211	32,770	3.2%
Muban	"				817		24,646	
Nari	"	9,733	81				9,223	-1.1%
Paniro	"			10,732	95,005	99,709	123,186	
Pir	"				565	47,662	6,876	
Rind	"					159,216	34,254	
Sakhi	"				216,942	287,068	593,554	
Tajedi	"	32,711	200,530	428,086	327,834	369,321	227,407	47.4%
Tangri	"		169,624	1,174,970	1,193,966	1,453,256	1,056,662	
Turk	"	164,971	82,038	66,933	51,526	607,616	112,366	-7.4%
Turk Deep	"						477	
Zaur	"	3,010						
Sindh Total		11,877,170	11,632,687	12,477,071	13,116,168	12,611,446	12,621,728	0.1%
Grand Total: Barrels		20,674,576	19,857,877	21,062,995	21,270,472	20,543,174	19,985,677	-1.8%
TOE		2,773,622	2,664,056	2,825,730	2,853,565	2,755,993	2,681,202	
Barrels Per Day		56,643	54,405	57,549	58,275	56,283	54,755	

* Operated by OGDC before 1994-95. Source: DGPC.

Table 34-A. Natural Gas Reserves as on June 30, 1999 (from Pakistan Energy Year Book).

Unit: Trillion Cubic Feet

	Non-associated Gasfield	Operator Company	Original Recoverable Reserves	Cummulative Production	Balance Recoverable Reserves	Heating Value Btu/cu ft
1.	Savi Ragha	BG	0.03000		0.03000	1159
2.	Kadanwari	LASMO	0.16700	0.8454	0.08246	950
3.	Mari	MGCL	6.30000	196500	433500	740
4.	Bagla	OGDC	0.00837		0.00837	1075
5.	Bhal Syedan	"	0.00290	0.00052	0.00238	1156
6.	Bobi	"	0.03100	0.00466	0.02634	1303
7.	Buzdar	"	0.00730		0.00730	934
8.	Chak-5 Dim South	"	0.00250		0.00250	1191
9.	Dakhni	"	0.31246	0.06761	0.24485	1060
10.	Daru	"	0.02250		0.02250	1205
11.	Dhamraki	"	0.00130		0.00130	1249
12.	Dhodak	"	0.62310	0.06124	0.56186	1019
13.	Hundi	"	0.02576	0.02213	0.00364	860
14.	Jandran	"	0.01862		0.01862	1002
15.	Kothar	"	0.01200		0.01200	930
16.	Lashkari South	"	0.00061		0.00061	1168
17.	Loti	"	0.29245	0.15613	0.13632	842
18.	Mithrao	"	0.01900		0.01900	1189
19.	Nandpur	"	0.29524		0.29524	330
20.	Nur	"	0.01449		0.01449	1016
21.	Panjpir	"	0.17623		0.17623	330
22.	Pirkoh	"	1.50371	0.77808	0.72563	895
23.	Qadirpur	"	2.80000	0.22363	2.57637	890
24.	Rodho	"	0.00383		0.00383	1080
25.	Sadkal	"	0.05300	0.04113	0.01157	1162
26.	Sari	"	0.01783	0.01647	0.00136	860
27.	Uch	"	3.10000		3.10000	425
28.	Zin	"	0.10000		0.10000	484
29.	Miano	OMV	0.32000		0.32000	918
30.	Sawan	"	0.50000		0.50000	915
31.	Ratana	OPI	0.44498	0.02395	0.42103	1140
32	Kandhra	PEPL	1.70000		0.70000	150
33.	Badar	"	0.02530		0.02530	571
34.	Zarghun South	"	0.37400		0.37400	854
35.	Adhi	PPL	0.23400	0.05734	0.17666	1175
36.	Khandkot	"	1.06900	0.31900	0.75000	835
37.	Mazarani	"	0.03320		0.03320	1010
35.	Sui	"	9.62500	6.83900	2.78600	925
39.	Chachar	Tullow	0.10140		0.10140	747
40.	Suri	"	0.03870		0.03870	800
41.	Sara	"	0.03200		0.03200	802
42.	Bhatti & Nakurji	UTP	0.07565	0.02703	0.04862	1010
43.	Bukhari	"	0.08079	1.07110	0.01869	1238
44.	Buzdar South	"	0.13090	0.00563	0.12528	951
45.	Buzdar South Deep	"	0.01307		0.01307	946
46.	Golarchi	"	0.06590	0.04745	0.01845	1031
47.	Jabo	"	0.07978	0.00487	0.07491	911
48.	Jalal	"	0.02235	0.01539	0.00696	1051
49.	Kato	"	0.00440	0.00391	0.00049	1232
50.	Khorewah	"	0.00391	0.07068	0.06213	1075
51.	Khorewah Deep	"	0.00306	0.00306	0.00142	1041

Table 34-A. Natural Gas reserves as on June 30, 1999. (continued)

Unit: Trillion Cubic Feet

	Non-associated Gasfield	Operator Company	Original Recoverable Reserves	Cummulative Production	Balance Recoverable Reserves	Heating Value Btu/cu ft
52.	Kotli	Ump	0.01910	0.01114	0.00866	1016
53.	Liari Deep		0.00340		0.00340	1109
54.	Mahi	"	0.00693	0.00515	0.00182	1006
55.	Mukhdumpur	"	0.04537	0.03134	0.01403	1115
56.	Mukhdumpur Deep	"	0.02463	0.00874	0.01589	865
57.	Matli	"	0.04823	0.04734	0.00089	1010
58.	Pir	"	0.00922	0.00494	0.00428	1068
59.	Raj	"	0.01172		0.01172	966
60.	Rind	"	0.00245	0.00091	0.00155	978
61.	Sakhi Deep	"	0.00642		0.00642	1016
62.	Sonro	"	0.01793	0.00651	0.01142	878
63.	Tando Ghulam Ali	"	0.00398		0.00398	917
61.	Turk	"	0.15823	0.12318	0.03503	1138
63.	Turk Deep	"	0.05732	0.01372	0.04361	937
66.	Zaur	"	0.03749	0.00001	0.03748	1221
67.	Zaur Deep	"	0.02667		0.02667	1123
	ASSOCATED GASES*		0.99672	0.67958	0.31714	
	TOTAL: TCF		32.53444	11.92365	20.61078	
	Normalization TCF at 900 btu/cu.ft.		29.02906	12.11781	16.91125	
	Million TCF		623.61	260.32	363.29	

*See table 34-B for details. Source: DGPC

Table 34-B. Associated Gas reserves as on June 30, 1999.

Unit: Trillion Cubic Feet

	Oil	Operator	Original Recoverable Reserves	Cummulative Production	Balance Recoverable Reserves	Heating Value Btu/cu ft
1.	Chak Naurang		0.001		0.001	1100
2.	Fimkasar	"	0.049	0.010	0.039	1200
3.	Kunar	"	0.068	0.002	0.065	1202
4.	Missakaswal	"	0.029	0.017	0.012	1220
5.	Tando Alam*	"	0.033	0.015	0.018	1337
6.	Toot	"	0.037	0.030	0.007	1127
7.	Bhanbali	OPI	0.003	0.002	0.001	1312
8.	Dhurnal	"	0.112	0.100	0.012	1207
9.	Dhulian	POL	0.213	0.200	0.013	1232
10.	Meyal	"	0.273	0.246	0.028	1191
11.	Pariwal	"	0.030	0.011	0.019	1185
12.	Pindori	"	0.048	0.006	0.043	1302
13.	Turkwal	"	0.004	0.001	1.003	1340
14.	Dhabi & Dhabi South	UTP	C.034	0.010	0.024	1017
15.	Halipota	"	0.009	0.002	0.006	930
16.	Mazari**	"	0.016	0.014	0.002	1174
17.	Sakhi***	"	0.037	0.013	0.024	1070
	TOTAL: TCF		0.997	0.680	0.317	
	Normalization TCF at 900 btu/cu. ft.		1.328	0.908	0.421	
	Million TOE		*28.53*	*19.50*	*9.04*	

* Includes Buzdar North, Kal, Lashari Centre, Missan, Pali, Pasaki, Rajian, Sono and Thora.

** Includes Mazari South and Mazari South Deep.

Table 35-A. Non-Associated Gas Production by field (from Pakistan Energy Year Book 1999).

Unit: Million CFt

Field (Province)	Opertor	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	ACGR
Kadanwari (Sindh	LASMO	–	1,943	29,954	27,686	24,964	25,429	
			44,106	*679956*	*628,472*	*566,683*	*577,238*	
Mari (Sindh)	MGCL	141,460	138,836	133,167	135,860	136,632	139,908	0.2%
		2,503,842	*2,457,397*	*2,357,056*	*2,404,722*	*2,418,386*	*2,476,372*	
Dakhni (Punjab)	OGDC	5,382	5,134	5,660	5,299	5,464	5,552	-0.6%
		136,165	*129,890*	*143,198*	*134,007*	*138,239*	*140,466*	
Dhodak (Punjab)	"		7,078	14,630	12,040	13,526	18,302	
			171,995	*355,509*	*292,584*	*328,682*	*444,739*	
Loti (Balochistan)	"	15,954	15,926	16,142	15,163	14,780	16,087	0.2%
		320,675	*320,113*	*324,454*	*304,776*	*297,078*	*323,347*	
Nandpur/Punjpir (Punjab)	"						659	
							5,206	
Pirkoh (Balochistan)	"	74,864	69,888	61,515	53,256	47,529	38,697	-12.4%
		1,602,090	*1,495,603*	*1,316,421*	*1,139,689*	*1,017,121*	*828,116*	
Qadirpur (Sindh	"			46,128	76,917	78,904	75,690	
				982,526	*1,638,343*	*1,680,655*	*1,612,197*	
Sadkal (Punjab)	"	7,407	9,637	10,567	7,071	4,269	3,401	-14.4%
		205,174	*266,945*	*292,706*	*195,880*	*118,251*	*94,208*	
Sari/Hundi (Sindh)	OGDC	2,159	1,752	1,347	1,023	1,207		-100.0%
		44,260	*35,916*	*27,614*	*20,972*	*24,744*	*0*	
Ratana (Punjab)	OPI	7,009	5,515	4,945	4,797	2,124	1,484	-26.77%
		190,645	*150,008*	*134,504*	*130,478*	*57,773*	*40,365S*	
Adhi (Punjab)	PPL	5,924	6,153	6,896	6,569	6,988	6,942	3.2%
		165,872	*172,284*	*193,088*	*183,932*	*195,664*	*194,376*	
Kandhkot (Sindh)	"	34,224	33,857	33,726	35,780	36,019	32,393	-1.2%
		681,058	*673,754*	*671,147*	*712,022*	*716,778*	*642,631*	
Sui (Balochistan)	"	259,881	260,174	226,408	242,800	256,848	305,063	3.3%
		5,743,370	*5,749,845*	*5,003,617*	*5,365,880*	*5,676,341*	*6,741,892*	
Bhatti (Sindh)	UTP	23	3,865	6,986	8,497	5,439	3,157	167.6
		554	*93,147*	*168,363*	*204,790*	*131,080*	*76,084*	
Bukhari (Sindh)	"	19,809	12,089	6,405	5,526	5,702	7,275	-17.9%
		586,346	*375,834*	*189,588*	*163,584*	*168,779*	*218,300*	
Buzdar S. & Deep (Sindh)	"				5,636		104	
					127,948		*2,361*	
Golarchi (Sindh)	"	4,503	2,973	1,214	943	917	1,079	-24.90%
		110,774	*73,136*	*29,864*	*23,210*	*22,558*	*26,543*	
Jabo (Sindh)	"				60	3,822	1,280	
					1,302	*81,937*	*27776*	
Jala (Sindh)	"		1,923	6,830	4,907	1,608	278	
			48,267	*171,433*	*123,178*	*40,361*	*6,978*	
Kato (Sindh)	"					3,039	1,198	
						87,523	*35,221*	
Khorewah (Sindh)	"	6,111	18,496	16,773	8,972	11,776	13,749	17.6%
		157,053	*475,347*	*431,066*	*230,593*	*302,643*	*353,349*	
Khorewah Deep (Sindh)	"				1,213	1,291	958	
					30,095	*32,017*	*23,758*	

(continued)

Table 35-A. Non-Associated Gas Production by field (continued).

Unit: Million CFt

Field (Province)	Opertor	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	ACGR
Koli (Sindh)	"			4,093	4,543	1,529	3,21	
				99,460	*110,407*	*37,155*	*78,052*	
Mahi (Sindh)	"			4,037	213	895		
				96,888	*5,124*	*21,480*	*0*	
Makh'pur (Sindh)	"	9,296	7,636	4,736	3,401	618	3,209	-19.2%
		191,498	*157,302*	*97,562*	*70,071*	*12,731*	*66,105*	
Matli (Sindh)	"	5,102	3,226	1,922	915	785	130	49%
		122,958	*77,747*	*46,320*	*22,063*	*18,919*	*3,133*	
Pir (Sindh)	"				47	3,841	1,635	
					1,178	*95,257*	*41,693*	
Rind (Sindh)	"						172	
							4,008	
Turk (Sindh)	"	12,173	6,667	2,666	4,436	10,782	9,891	-4.1%
		331,106	*181,342*	*72,515*	*120,673*	*293,270*	*269,035*	
Turk Deep (Sindh)	"		1,200	5,599	2,890	2,365	4,609	
			26,880	*125,418*	*64,747*	*52,976*	*103,242*	
Total:		611,281	613,968	652,346	676,469	683,663	721,543	3.4%
		13,093,438	*13,158,859*	*14,010,273*	*14,450,822*	*14,640,593*	*15,456,791*	
Annual growth rate		8.95%	0.44%	6.25%	3.70%	1.06%	5.54%	

*Include 423 MMCFT produced from Rind   Source: DGPC

Table 35-B. Associated Gas production by field.

Field (Province)	Opertor	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	ACGR
Fimkasar (Punjab)	OGDC					146	493	
Missa Keswal (Punjab)	"	3,013	2,967	1,829	957	655	1,616	-11.7%
Toot (Punjab)	"	771	618	533	4,132	489	676	-2.6%
Bhangali	OPI	288	240	221			602	
Dhurnal (Punjab)	"	3,762	3,484	3,441	2,665	2,015	1,915	-12.6%
Dhulian (Punjab)	POL					293	1,404	
Meyal(Punjab)	"	2,191	4,854	3,711	3,163	2,823	3,726	-11.2%
Panriwali (Sindh)	"			2,954	3,211	2,660	3,374	
Pindori (Punjab)	"			156	2,071	2,053	2,056	
Turkwal (Punjab)	"					448	643	
Bachal (Sindh)	UTP	9	298	671	759	-	387	112.2%
Dabhi, Dabhi N. (Sindh)	"	161	*	-	2,831	2,485	835	39.0%
Dabhi S. (Sindh)	"						1,288	
Halipota (Sindh)	"	198	382	-	202	329	173	-2.7%
Khaskheli (Sindh)	"						443	
Laghari (Sindh)	"						86	
Liari (Sindh)	"	174	100	-	26	44	134	-5.1%
Mazari (Sindh)	"	855	973	718	1,000	1,027	1,012	3.4%
Mazari S. & S. Deep (Sindh)	"	191	207	-	-	570	782	32.6%
Nari (Sindh)	"	1,335	44	-	-	9	508	-17.6%
Sakhi (Sindh)	"	-	-	-	-	-	480	
Tangri (Sindh)	"	-	76	-	-	-	478	
Others (Sindh)**								
Total: Million CFt		12,948	14,243	14,234	21293	16,046	23,399	12.6%
TOE		362,865	403,212	404,033	589,272	450,526	654,807	
Annual growth rate		-42.47%	10.00%	-006%	49.60%	-24.64%	45.82%	

* Production from Dhabi is included in production from Mazan.

** Includees Akri North, Bari, Ghugro, Jagir, Meyun Ismail, Muban, Paniro, Tajedi.   Source: DGPC.

Oil and gas reserves and production

The total crude oil recoverable reserves as on June 1999 were stated to be about 249,6 million barrels (Table 32). The annual production from 1992-93 up to 1997-98 has ranged from 19.85 to 21.89 million barrels or about 54,642 to 61,390 barrels per day (Table 33, Fig. 6.10). The most productive oil fields have been Fimkasar. Missa Keswal, Dhurnal, and Adhi in Punjab The Fimkasar field has given consistently high annual production ranging from 0.824 to 1.411 million barrels. The highest production however has come from Mazari (0.933 to 1.906 million barrels) and Mazari South fields (0.949 to 1.438 million barrels).

The total recoverable natural gas reserves as on June 30, 1998 were 20-97 trillion cubic feet (Table 34). Between the years 1992-93 and 1997-98, the annual production of natural gas has varied from 584,545 to 699,709 million cubic feet (Pakistan Energy Yearbook 1999). By far the largest production (226,408 to 264,141 million cubic feet has come from Sui (Table 35) Since June 1998 six new gas fields have been discovered (Fig 6.9). The gas reserves have been thus further enhanced and the production also is expected to be increased appreciably.

7

PRECIOUS AND DECORATIVE STONES

Gemstones are minerals which, when cut and polished, become precious gems. They all share four common features: they are extremely beautiful, rare, durable and amenable to cutting and polishing. Although more than 2,000 species of minerals are known today, only about 100 of these are commonly fashioned into gems. Out of these only 25 to 30 types are more commonly known and may be easily found in a jeweller's shop.

Gemstones have been used as objects of adornment, symbol of power and glory and exchange in trade since time immemorial. Gemstones were not known to occur from the area comprising Pakistan at the time of independence in 1947. However, beginning from 1955 a series of discoveries of gemstones have been made and Pakistan has become a recognised supplier of precious and semi-precious stones to the international gem market.

Presently the gemstones being commercially produced in Pakistan, besides the mineral specimen, include emeralds, rubies, peridot, topaz, tourmaline, aquamarine, pink topaz and pargasite (Fig. 7.1). Many other gemstones are reported from different parts of Pakistan and have a potential for future development (Table 36).

Table 36. Precious and semi-precious stones of Pakistan.

Agate	Garnet	Ruby
Aquamarine	Pargasite	Spinel
Emerald	Peridot	Topaz
Epidote	Pink topaz	Tourmaline
Feldsper (moonstone)	Quartz	Vesuvianite

The gemstones of Pakistan occur under four main categories (Kazmi and O'Donoghue 1990) namely suture associated, pegmatite associated, hydrothermal vein-type and miscellaneous gemstones. All the gemstones occur in northern part of Pakistan as shown in figure 7.1. A brief description of some of the important gemstone occurrences is given below.

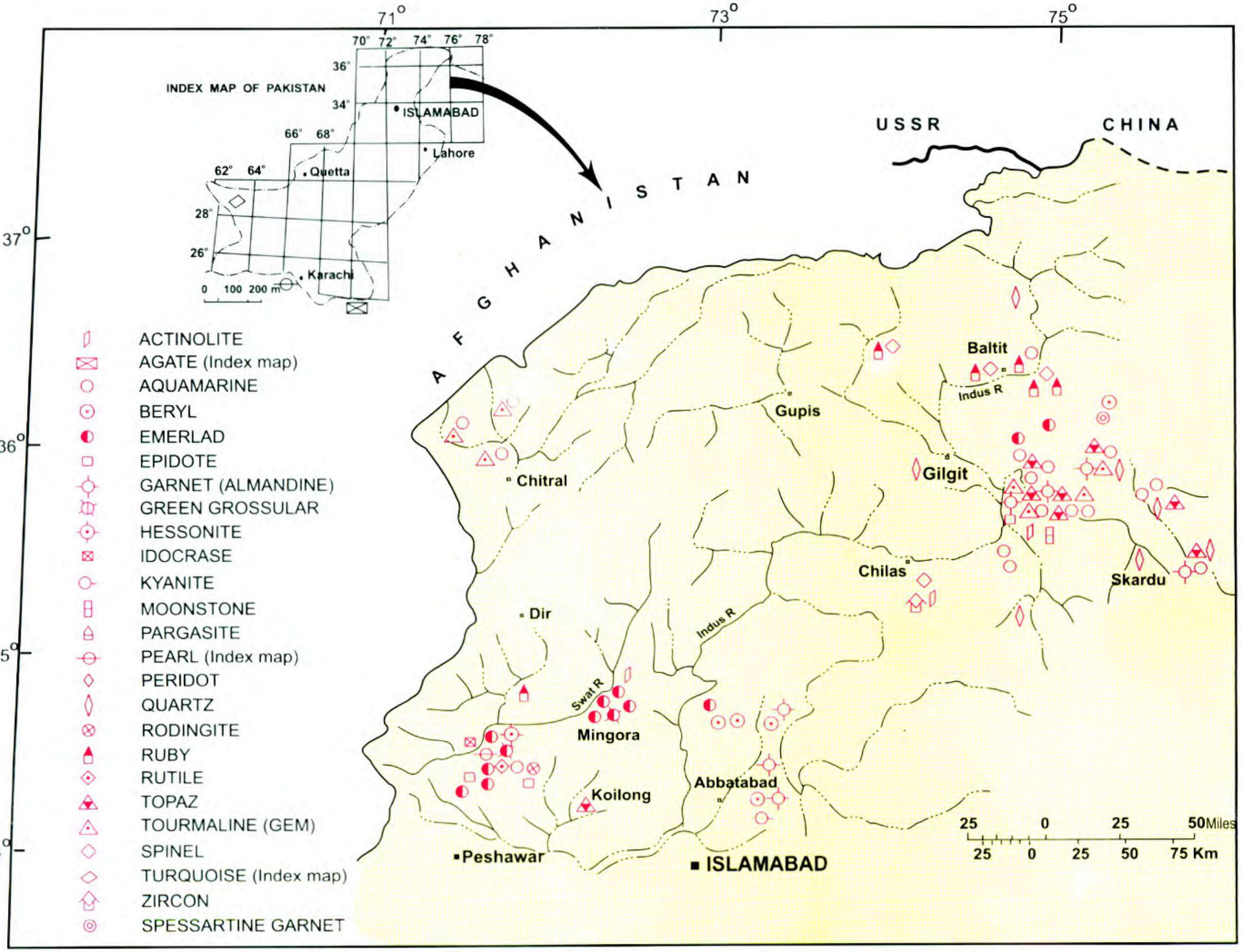


Figure 7.1. Map showing gemstone occurrences in Pakistan (from Kazmi and O' Donoghue 1990)

AQUAMARINE

Aquamarine is a silicate of beryllium and aluminium and belongs to the beryl group of minerals. It is an attractive gemstone fancied for its exquisite light to medium, sparkling blue colour and for its clarity and brilliance. Aquamarine occurs commonly in the vast pegmatite fields of the Karakorams and the NW Himalayas (Table 37). Light blue, clear, euhedral crystals of aquamarine are most abundant in the gem pegmatites of Gilgit–Skardu area (Kazmi and O'Donoghue 1990). The better known deposits are:

Iskere .... (35°54′:74°45′)
Shingus .... (35°43′:74°48′)
Dusso .... (35°42′:74°29′)
Tisgtung .... (35°43′:75°20′)

Deeper colour varieties occur at Gabor-o-Bakh (36°05′: 71°21′) in Chitral. Apparently this region has a good potential for deeper colour, high priced aquamarine and merits further exploration and development.

EMERALD

Emerald is a member of the beryl group of minerals and is cherished and fancied for its exquisite verdant green colour. The best and most precious colour is the intense and clear dewy green of fresh spring grass. It owes this magical colour to traces of chromium. In fact a green beryl, without chromium would not be accepted as an emerald. Emerald is believed to posses healing power and to some people it is known as the "healing stone".

In Pakistan, Mingora, Gujarkili and Shamozai areas situated in Swat District are now well known for producing top quality emerald. The emerald is found in ophiolitic melange zone along the Main Mantle Thrust (Fig. 7.2). Emerald also occurs at Dandao Kandao, Nawe Dand, Gandao, Kot, and Mor Dara in Mohmand Agency, Arang Barang in Bajaur Agency, Makhad and Charbagh in Swat District and near Khaltaro in Gilgit area (Fig 7.1).

Mingora emerald deposits: These are the best known deposits located at the northern edge of Mingora city, 200 kilometres northeast of Peshawar. Emeralds occur in Mingora ophiolitic melange, which appears in the form of highly tectonised fault blocks. Two parallel north-trending normal faults run through the deposits and are believed to be the principal conduits for mineralising fluids. The Swat deposits are producing excellent quality material which have been described by Gübelin (1968, 1982) as being some of the finest emeralds in the world. The stones have become well known for their brilliant, medium to deep green colour as well as for their unique transparency and are comparable to the finest Colombian specimens from Muzo (Gübelin, 1968).

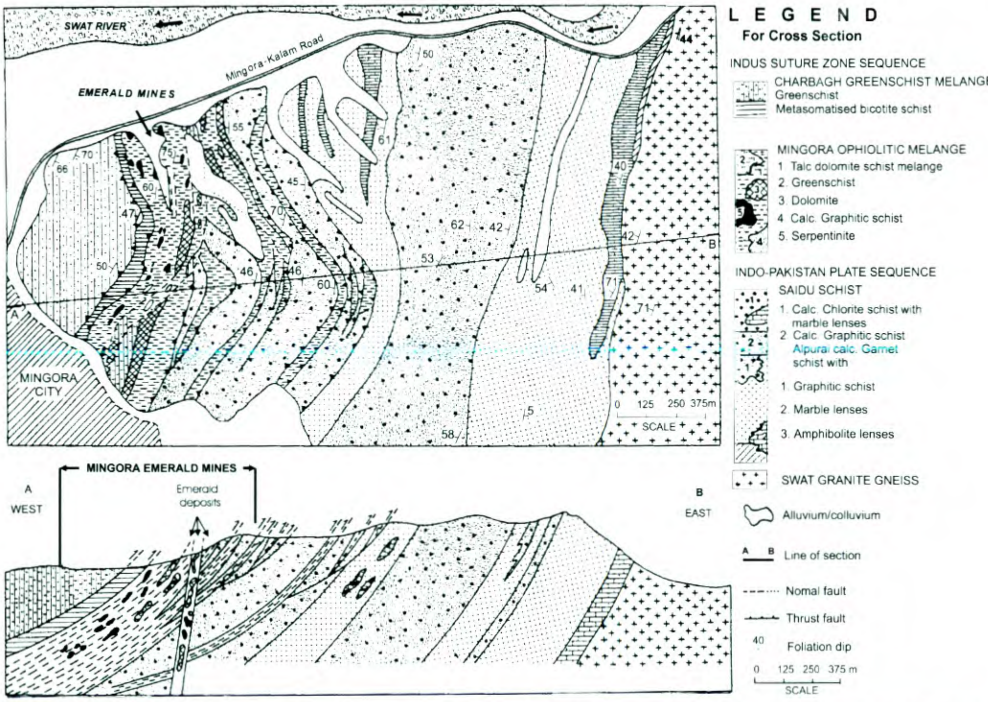


Figure 7.2. Geological map and cross section of the Mingora emerald-min area (from Kazmi et al. 1984).

The average size distribution of emeralds in production is approximately of the following order (Kazmi, 1995):

Size (Carats)		Percent
a. Mellee	...	45.8
b. 0.5-1	...	32.7
c. 1-2	...	6.8
d. above 2 ct	...	14.7

Average grade-wise distribution of the rough gem-grade emeralds produced from the Mingora mines (excluding the industrial grade) is approximately as follows (Kazmi, 1995):

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

Gujarkili emerald deposit: This deposit is located near Gujarkili village 24 kilometres east-northeast of Mingora, 12 kilometres south-southwest of Alpurai, in Swat District. The emerald deposit occurs in a small triangular outcrop of ophiolitic melange which is surrounded by Saidu graphitic schist. The deposit covers an area of about 10 acres.

A number of small northwest-trending faults with cross-cutting fractures and joints cut through the mineralised block and the emeralds largely occur along these faults and fractures. Open cast mining has been done and in recent years. Emerald production increased from 5,939 cts (1986-87) to 78,330 cts (1990-91). Emeralds are largely in the form of large well formed, dark green euhedral crystals up to 100 to 200 cts in weight. This is a very promising deposit, which merits proper scientific mining method and mine development. There are good prospects for obtaining much larger production from this deposit (Kazmi 1995).

Shamozai emerald deposit: Located about 24 kilometres west of Mingora, the deposit occurs at an altitude of about 1,500 metres. The mineralisation is traceable for about 2 kilometres along the general strike. Mineralisation occurs in talc-carbonate schists of Indus Suture Melange group under geological conditions very similar to Mingora and Gujarkili. Emeralds are transparent and of good green colour. An oddity reported from this mine is the presence of bicolour emeralds. Private companies have intermittently mined the deposit.

Other emerald deposits: Emerald occurs also at Dandao Kandao, Nawe Dand, Gandao, Kot, and Mor Darra in Mohmand Agency; Arang Barang in Bajaur Agency; Makhad and Charbagh in Swat District and near Khaltaro in the Gilgit area (Fig. 7.1). These deposit (except Charbagh and Makhad) have not been explored as yet (Kazmi and Snee 1989).

There is, therefore, great potential for enhancing emerald production in Pakistan by increasing mining activity in Mingora, Gujarkili and Shamozai and by bringing new mines under production, particularly in the Mimola and Mor Darra region (Barang) of Bajaur Agency. Discovery of several more emerald deposits in the 150 kilometres long "Emerald Belt" between the Indus and the Mohmand Agency is a distinct possibility.

GARNET

Garnets comprise a large mineral group whose members have different names corresponding to their appearance. The more common gemstones of the garnet group are *pyrope*, which has a glowing red colour; *almandine* has a brownish red to reddish violet colour; *rhodolite* commonly has a rose-red colour and strong lustre; *spessartine* has an exquisite orange hue and is one of the most exquisite garnet; *grossularite* varies in colour from brown, reddish brown, clear sparkling copper-gold to green; and lastly green *demantoid*, which is the most unusual and rare amongst the garnets and fancied for its brilliance and fire (refractive index 1.89). As a birthstone for those born in January, it symbolises fidelity, friendship, and constancy.

Gem quality almandine (red garnet) is found in Chitral District, red spessartine is associated with pegmatites of Dusso and Shingus in Northern areas. Tsavolite or green grossularite is associated with graphitic schist in Jambil area of Swat, near Kot in Malakand District and near Targhao in Bajaur Agency. Beautiful honey-yellow euhedral crystals of hessonite are found in quartz-mica schist near Targhao in Bajaur Agency.

A high quality, orange-red spessartine garnet has been recently discovered in pegmatites in Neelam Valley of Azad Kashmir. This deposit has yielded large transparent crystals (Kazmi and Jan 1997).

MOONSTONE

Moonstone belongs to the ranks of the rock-forming feldspar family. The feldspars are one of the most widely distributed minerals. The moonstones vary in colour from misty soft grey to spring clear, shimmering silvery white, reddish-brown to light blue. It is the birthstone of June and is believed to bring happiness and good fortune.

In Pakistan moonstone has been mined from the pegmatites of Shingus and Bulechi in Gilgit Agency. The deposits are large and of good quality.

PERIDOT

Peridot is the aristocratic representative of the olivine family and is a complex silicate of magnesium and iron. It is admired for its golden olive green colour and glittering lustre. It is the birthstone for the month of August and it is said to put ghosts and demons to flight, dispel melancholy and foolishness and to show the eternal paths to wisdom.

In Pakistan an important deposit of peridot has recently been found near the Kohistan-Kaghan watershed to the NE of Naran. The gemstones occur along shear zones and in pockets in dunitic host rocks, and are associated with clinochlore, magnetite and local magnesite. The host rocks occur in the immediate hanging wall of the Indus suture. They represent the basal cumulates of the Sapat mafic-ultramafic complex and presumably belong to Kohistan magmatic arc (Jan et al., 1993. Kausar and Khan 1996).

The peridot is transparent to translucent and pale to dark yellowish green or, rarely, greenish yellow. A good proportion of the specimens is of brilliant gem quality and adequate size, and is thus suitable for faceting. It is medium- to coarse-grained with largest crystals reportedly measuring more than 10 cm in length and up to 2 kg in weight. Koivula et al., (1994) and Jan and Khan (1995) have presented physical data and microprobe analyses of the minerals. The peridot is mostly Fo_{91} in composition but ranges from Fo_{90} to Fo_{94}. Jan and Khan (1995) suggest that the mineralisation may be related to hydrothermal solutions possibly derived from post-tectonic Himalayan leucogranites of Eocene age.

QUARTZ

Quartz is silicon dioxide (SiO_2) and is a common rock-forming mineral but also includes a number of ornamental varieties. The ornamental varieties can be crystalline, such as amethyst and citrine or cryptocrystalline, such as opal, agate, chrysoprase, chalcedony and cornelian. The violet quartz or amethyst is the birthstone for the February born and symbolises durability, friendship and stead fastness in love.

Clear and well formed crystals of quartz occur in gem pegmatites in Skardu, Gilgit and Chitral areas, and in Azad Kashmir. Smoky quartz is also commonly found in these areas. Rose quartz is abundant in Dusso pegmatites near Skardu. Agate and chalcedony are found near Nagar Parkar (24°10′:70°23′2′′) Sindh, while jasper occurs in Las Bela area (Balochistan).

RUBY

Ruby belongs to the corundum family and owes its popularity to the gorgeous glowing red colour which is the embodiment of the most beautiful red. It is believed to symbolise the highest of fortune's gift—love. It is believed that it endows children born in the month of July with priceless gifts, namely freedom, kindness, honour, and dignity. Presently good quality ruby is a fairly rare gemstone and hence the most costly of all the precious stones.

In Pakistan the main ruby deposits occur in a dolomitic marble belt extending for over 100 kilometres from Hunza valley to Ishkoman, close to Main Karakoram Thrust (Fig. 7.3). Mining is, however, presently confined to 13 mining centres spread over a length of 15 kilometre in Hunza Valley. Ruby deposits of Azad Jammu and Kashmir (AJK) are located in Nangimali-Khora-Katha, Chitta Ratta and Naril Nala areas. They are associated with meta-limestone and occur in calcite veins along bedding planes. The rubies are transparent to translucent and brownish pink to pinkish red or deep red. The deposits are being mined and the reserves are estimated at about 24.9 million grams (Malik 1995). Ruby also occurs in a 30 kilometres long belt of amphibolites extending from Timurgarha to Kohat in NWFP. The rubies in this belt, however, are of a lower grade.

After Burma, Hunza area is the only other region of the world that has produced "blood red" ruby. Cabochon grade violet or indigo-coloured sapphires also occur with rubies. The ruby deposits of Azad Kashmir are also similar to Hunza but rather with a very slight touch of pinkish hue. The blood red rubies in present day gem market fetch the highest price. Thus there is great potential for development of ruby deposits of Pakistan.

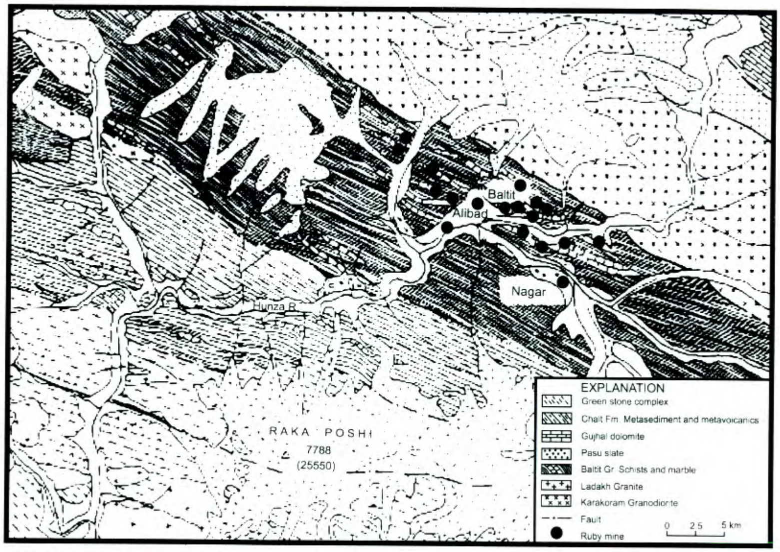


Figure 7.3. Geological sketch map of Hunza area showing ruby mines (from Kazmi and O' Donoghue 1990, Kazmi 1995

In addition to rubies the host marble of this region also contains the following minerals: sapphire, spinel, pargasite, margarite, phlogopite, chlorite, graphite, pyrite, rutile, dolomite, sphene, apatite, tourmaline, plagioclase, pyrrhotite, quartz, calcite and goethite (Okrusch et al., 1976, Gubelin 1982, Kazmi et al., 1990). Spinel and pargasite from Hunza are of gem grade.

SPINEL

Spinel is a magnesium aluminate ($MgAl_2O_3$) and occurs in sharply defined octahedra. Spinel is admired for its lovely vibrant colours, strong brilliance and striking clarity. It can withstand great heat without change and occurs in all degrees of the red to rose-red. The orange-coloured fire spinel is an extremely beautiful variety. Purple to blue and blue-green varieties are also common.

Spinel with its ruby red colour is closely associated with Hunza ruby deposits. The Hunza spinels occur in a wide variety of colours ranging from brown, red, plum red, violet to blue. These colour variations are mainly due to slight changes in their chemical composition. For example the red colour is largely due to the presence of chromium, whereas the bluish and plum-coloured varieties owe their colour to the presence of iron (Kazmi and O'Donoghue 1990).

The Hunza spinels are larger than those customarily found in Burma and are far more attractive. They are often euhedral showing recognisable crystal forms.

PARGASITE

Pargasite is a monoclinic amphibole. Exquisite deep pistachio green crystals of pargasite are found in the metamorphosed crystalline marbles along with ruby and spinel in the Hunza valley. The stones are translucent to opaque and are commonly fashioned into beautiful cabochons. Locally they are sold as "Hunza emeralds".

TOPAZ

Topaz is a fluo-silicate of aluminium and is fancied for its glowing, fiery sparkle and its wide range of exquisite colours ranging from yellow to golden brown, rose-red to peach-pink, blue to shining azure-blue and colourless to pure white. The yellow variety resembles citrine (yellow quartz), but it is incomparably more beautiful and attractive mainly due to its higher refractive index (1.62), hardness (8) and specific gravity (3.5-3.6).

Topaz found in gem pegmatites ranges from colourless to slightly yellowish brown to a deeper sherry colour and large perfectly euhedral crystals are quite common. They mostly appear in a microcline-quartz-muscovite matrix. Topaz bearing pegmatites are largely found at Bulechi (35°41´30´´:74°48´35´´), Shingus (35°43´50´´:75°31´5´´) (Fig. 7.4) and Gone (35°41´58´´:75°31´30´´) near Dusso in the Skardu area (Fig. 7.5).

Pink topaz

Pink topaz ranging in colour from deep red, orange-rose or cyclamin colours is unique to Katlang topaz deposit (34°21´20´´:72°04´01´´). In fact, this is the only known naturally deep red or deep pink coloured topaz in the world. The colour of these Katlang stones ranges from colourless to very pale beige to light brown and from very pale to deep pink to bright red. Even violet coloured crystals have been found (Gübelin et al., 1986; Kazmi and O'Donoghue 1990).

The Katlang deposit is located in the Ghundao hillock 4 kilometres north of the town of Katlang, about 20 kilometres north of the city of Mardan, 60 kilometres NE of Peshawar. The Ghudao hillock comprises a small anticilinorium with fold axes trending east-west. It is comprised of grey, thin to thick bedded Palaeozoic crystalline limestones which have been drag folded and extensively faulted. The limestone contain extensive stockworks of calcite and quartz veins which host the topaz mineralisation. The gem bearing veins mostly occur along a series of parallel, normal and reverse faults near the crest of tightly folded anticlines.

Pink topaz of Katlang is a unique stone unparalleled in the world. It is found in Pakistan and if properly and correctly promoted in world market, its price can be very greatly enhanced.

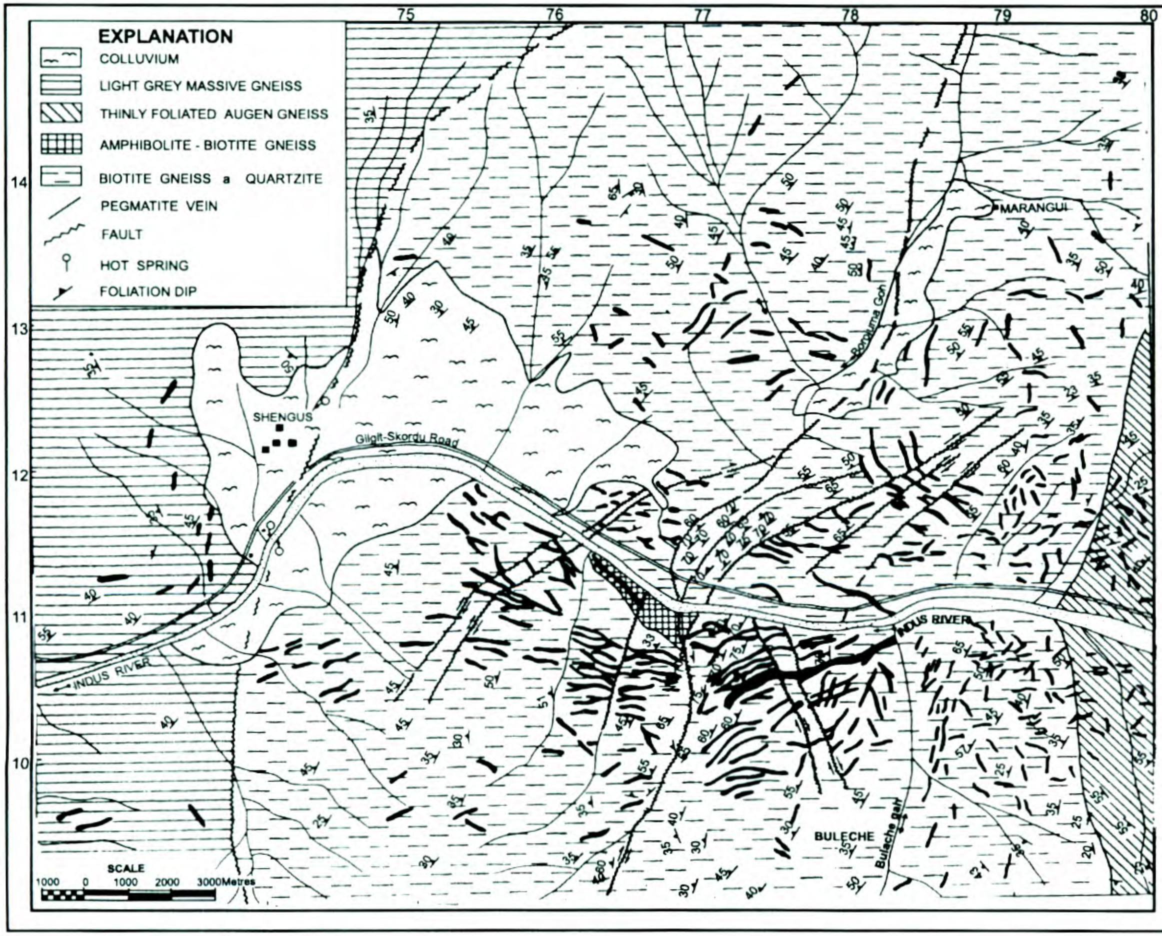


Figure 7.4 . Geological sketch map of the Shingus-Buleche pegmatites (From Kazmi and O' Donoghue 1990).

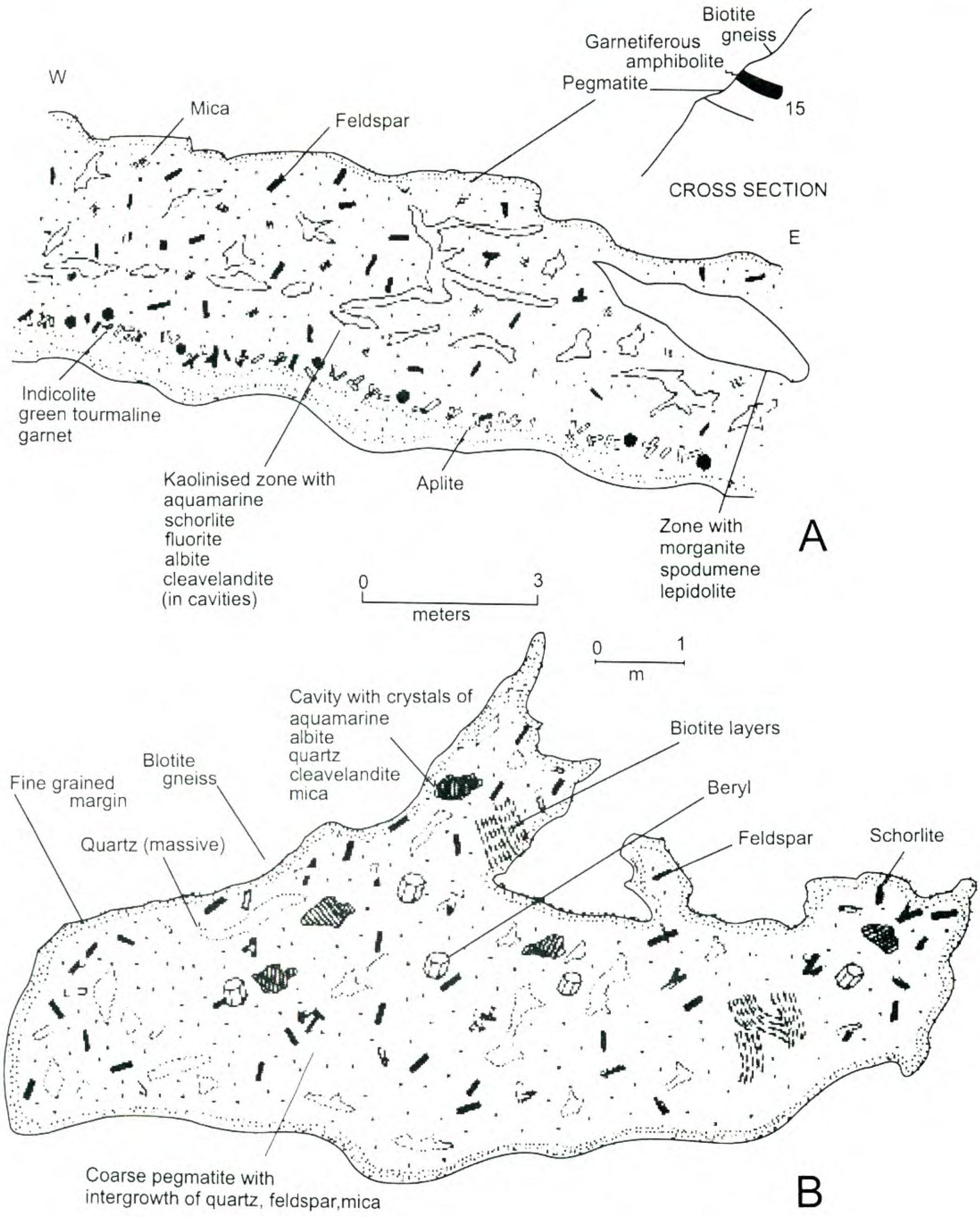


Figure: 7.5 . Strike sections of (A) Shingus and (B) Dusso pegmatites (diagrammatic) from Kazmi and O'Donoghue 1990.

TOURMALINE

Tourmaline is a complex borosilicate of aluminium and as a gemstone it is famous for its beautiful colours, occurring in all possible hues and shades. It is found even in mixed colours as a bicolour or tricolour gemstone. The more common hues are ruby-red (*rubellite*), orange through brown to yellow, green and blue (*indicolite*). Tourmaline comprises several distinct mineral species, and many of these provide specimens of gem quality. The gem varieties include *rubellite, dravite, elbaite* and *liddicoatite* (Kazmi and O'Donoghue 1990). Tourmaline is believed to be a stone for the October–born and is said to speed the writers flow of thought.

Deposits of gem quality tourmaline (pink, blue, and green varieties) are found in the pegmatites of the Haramosh Range, near Gilgit. The best known deposits are located in Stak Nala (between Gilgit and Skardu). This locality is now famous for bicolour and tricolour tourmaline. Gem grade tourmaline also occurs at Bulechi and Shingus (Gilgit Division). Indicolite (blue tourmaline) is found in the pegmatites of Garm Chashma (Chitral). Green tourmaline has been found in pegmatites of Donga Nar in Azad Kashmir. Some of the best and fairly large specimens of bi-colour and tri-colour tourmaline have been found in these pegmatites (Kazmi 1995).

PEGMATITE GEMS AND MINERAL SPECIMEN

The attraction of mineral specimen as distinct from a facetted stone lies in its form and colour. Mineral specimens do not have to be of gem quality, though the gem crystals that escape cutting are admittedly most beautiful. In recent years a large and a flourishing market for good mineral specimen as collector's items has developed world wide.

The pegmatite fields of the Northern Areas have yielded excellent mineral specimens including light pink crystals of fluorapatite, green fluorite, spessartine, hambergite, green microcline, aquamarine, tourmaline, topaz, and garnet. Exquisite mineral specimens of ruby, spinel and pargasite are found in the Hunza valley. Beautiful pyrite, malachite and azurite specimens can be collected near Gilgit. Attractive violet fluorite crystals occur in the Koh-e-Dilband fluorite mines (29°30′:66°55′) in Kalat District.

DECORATIVE STONES

A variety of exquisite decorative stones are found at several localities in Pakistan. The ones most commonly used and which are mined in large quantities are marble, various types of limestones and igneous rocks, mainly granite. Marble is extensively used in the construction industry, for decorative purposes in building facings, bath rooms and for floor tiles. It is also used for making handicraft items.

Table 37. Gem pegmatites of northern areas and their mineral content (from Kazmi and O'Donoghue 1990).

Location	Altitude (metre)	Gemstones	Other minerals
KARAKORAM			
Dusso	2,800-3,000	Aquamarine Rose quartz	Plagioclase feldspar, quartz, muscovite, biotite, schorl, beryl.
Nyet Bruk	4,600-5,000	Brown topaz	Plagioclase feldspar, quartz, tourmaline, muscovite, beryl.
Gone	2,600-3,000	Aquamarine Brown topaz	Plagioclase, orthoclase, quartz, muscovite, beryl, biotite, schorl.
Tigstun	2,600-3,000	Aquamarine Garnet	Plagioclase, quartz, muscovite, biotite, schorl, beryl.
HARAMOSH			
Stak Nala	3,300-4,000	Bicolour tourmaline Aquamarine	Felspar, quartz, mica, fluorite, apatite, schorl, beryl.
Skere Shah Batot Shingus	2,300-4,000	Aquamarine Topaz Goshenite Morganite	Feldspar, quartz, mica, garnet, schorl, tourmaline, beryl.
Khaltoro	4,600-5,000	Emerald Aquamarine	Feldspar, quartz, mica, schorl, beryl.
DEOSAI MOUNTAIN			
Bulechi	2,600-4,000	Topaz Aquamarine Green tourmaline Bicolour tourmaline Moonstone	Feldspar, quartz, mica, schorl, garnet. beryl.
NANGA PARBAT			
Astore	2,500-4,000	Smoky quartz Green quartz	Quartz, feldspar, schorl, garnet, beryl, large books of mica.
Buldargah	2,600-3,300	Aquamarine	Quartz, feldspar, mica, schorl, garnet.
HINDU KUSH			
Gobar-o-bakh (Luthko)	5,000-6,000	Aquamarine Tourmaline Garnet Quartz	Quartz, feldspar, mica, tourmaline, beryl.
Dao Ghari	4;000-5,600	Aquamarine Garnet	Quartz, feldspar, mica, tourmaline.

In addition to above listed minerals, stray specimens of fluor-apatite, manganotantalite, hydroxyl herderite and hambergite also have been reported from Kakarkoram and Haramosh pegmatites (Kazmi et al. 1985).

Large reserves of re-crystallised limestone and marble occur widely in the Gilgit and Skardu region, in Chitral, Khyber Agency, Swat and Mardan Districts of NWFP, Bajaur and Khyber Agencies of FATA, in Azad Jammu and Kashmir (Asrarullah and Hussain 1985). Vast reserves of onyx marble of high quality is found in Chagai District of Balochistan Province (Ahmed, 1965). This marble has been mined extensively and besides local consumption, it has been regularly exported in great quantities.

Attractive and good quality granitic rocks occur in Gilgit, Chitral, Swat, Hazara, Raskoh, Chagai, Las Bela and Nagar Parkar areas. Large reserves of good quality gabrro is found in Muslimbagh–Nisai area. Dolerite dykes from several localities provide jet black slabs for tiles and wall facings. Milk-white granite has been mined from a locality 18 kilometres north of Gilgit.

Several kinds of multicoloured, exquisite brecciated rocks are mined from the Bela and Kanar melanges in Bela–Khuzdar area. Several varieties of fossiliferous limestone with beautifully oriented designs of foraminifers, mollusc shells and quartz and calcite veins, ranging in shade from cream to fawn, light brown to shades of grey occur extensively in the Paleocene to Eocene sequences in Las Bela area and various parts of Sindh and in the Salt Range. These are being mined and marketted under exotic trade names such as Golden, Trevera, Boutecenne, Verona, Black and Red Zebra, Oceanic etc.

During 1997-98 about 344,000 tonnes of marble was produced. The private sector exclusively deals with the production, processing and marketing of marble and other decorative stones.

8

CERAMIC MINERALS

CHINA CLAY

China clay is white kaolin formed due to alteration of feldspars. It is mainly used in the manufacture of tablewares, sanitary fittings, tiles and electric insulators. It is also used as paper filler and in the manufacture of special type of cement.

China clay deposits are found at Shah Dheri in the Swat District of NWFP, and in Nagar Parkar and Islamkot areas of Sindh (Fig. 8.1). Smaller deposits have been found in Dir, Hazara and Gilgit also. The Geological Survey discoverd the Shah Dheri, Nagar Parkar and Islamkot deposits (Moosvi et al., 1974, Kazmi and Khan 1973, Jafry undated) and investigated these deposits in detail with the help of detailed geological mapping, channel sampling and physical and chemical tests. The Shah Dheri deposits have been evaluated to contain 2.8 million tonnes of raw China clay (Moosvi et al., 1974). Plagioclase rich quartz diorite is the parent rock from which kaolin has been formed as a result of weathering of feldspars. Kaolin zones occur as patches, pods and streaks in unaltered rock. Typical analysis of Swat China clay is given in Table 38.

Table 38. Chemical composition of Shah Dheri (Swat) China clay, (Moosvi et al. 1974).

Constituents	Raw	Washed
SiO_2	42 to 58%	46 to 48%
Fe_2O_3	1 to 5%	1 to 5%
Al_2O_3	31 to 36%	34 to 37%
CaO	9 to 13%	3 to 7%
MgO	1 to 3%	1 to 2%
Na_2O	1 to 2%	1 to 2%
K_2O	Traces to 0.2%	Traces to 0.2%
Loss on ignition	4 to 5%	9 to 12%

In Nagar Parkar area deep weathering and alteration of granitic rocks have produced China clay. The clay is in the form of several large pockets which occur in a plain area at shallow depths (a few centimetres to 2 metres below ground surface). The deposits are largely covered by a thin veneer of soil. Deposits occur at Dhed Vero, Parodhoro, Karkhi, Dungri, Motijo-Vandio, Ramji-jo-Vandio, and Didwa - Surachand area.

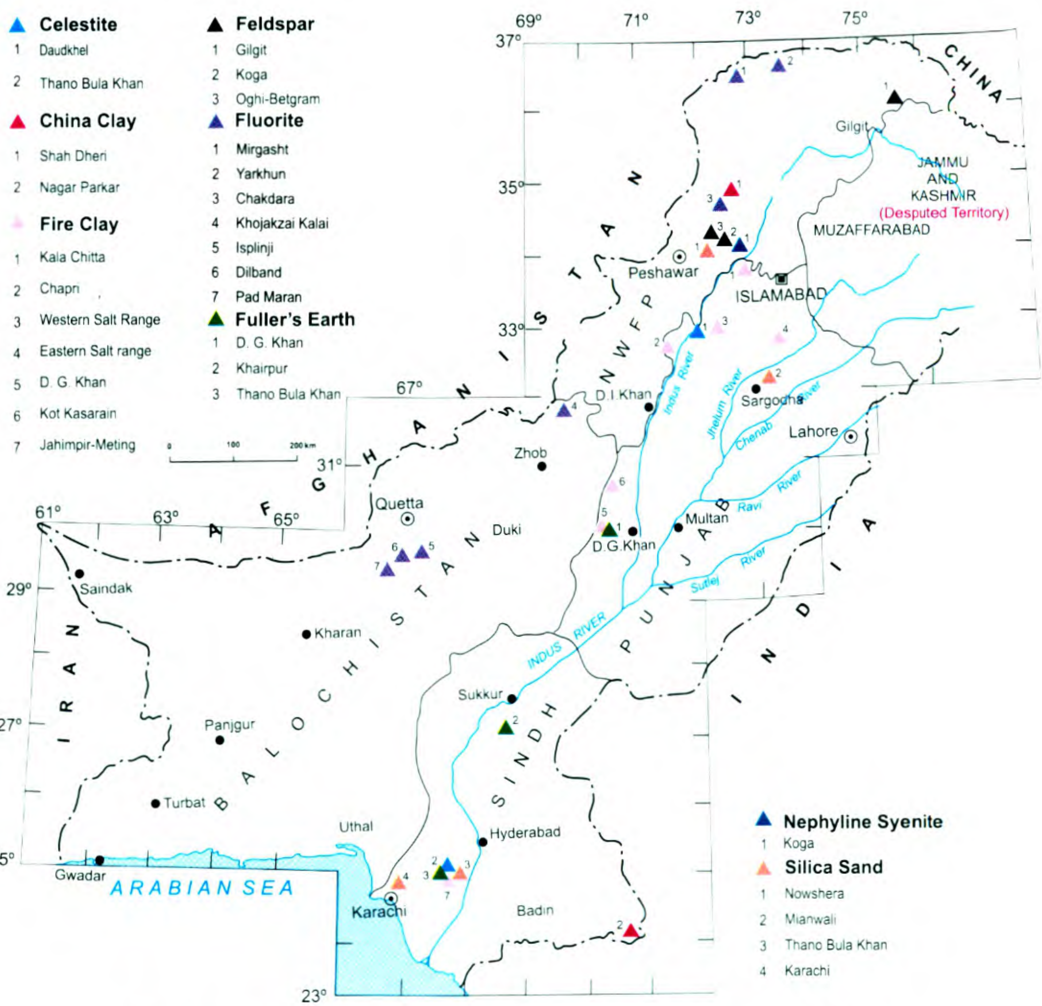


Figure 8.1. Map showing main deposits of ceramic minerals in Pakistan.

Laboratory studies have shown that the alteration of feldspars into kaolinite is complete. The China clay is coarse grained and 31–40 percent particles are below 3 microns and 12.3 to 19.1 percent below 2 microns. X-ray analysis shows that kaolinite and quartz are the major constituents, with some gypsum, calcite and dolomite and traces of zircon, rutile, hematite and amphiboles. Differential thermal analysis shows a large exothermic peak between 970°C and 990°C, further confirming that kaolinite is the major constituent of the Nagar China clay. There is no mica in this clay. The measured reserves are 3.6 m.t. (Kella 1983).

The Nagar clay contains up to 2.56% CaO, which is, however, reduced to 1.31% on washing (Table 39). The CaO is likely to have been introduced subsequent to the formation of kaoline, largely due to percolating groundwater. Most of the China clay lenses are located on flat playa like ground, where rain water stands for a long period.

Table 39. Chemical composition of Nagar Parkar China clay, (Griffith, 1987).

Constituents	Raw	Washed
SiO_2	66.46%	46.06%
Fe_2O_3	0.38%	0.85%
TiO_2	0.86%	
Al_2O_3	21.57%	35.70%
CaO	2.56%	1.31%
MgO	0.34%	0.34%
Na_2O	0.05%	0.15%
K_2O	0.21%	0.21%
Loss on ignition	–	14.23%

Beneficiation studies have revealed that the Nagar China clay separates easily from quartz, calcite, dolomite, gypsum etc. by simple washing and there is high recovery of kaolinite (88 to 95 percent) when seived through 240 mesh.

Drilling for evaluation of Thar coal in Sindh has revealed large deposits of China clay in the Islamkot area. Here the clay occurs in beds 0.4 m to 7.1 m thick, overlying and underlying the coal beds. This is apparently a transported type of clay derived from the residual clays that have been encountered at a deeper horizon, just above the granitic bed-rock. The clay has been encountered at depths of 133 to 201 metres. Chemical analyses of some of the core samples is given in Table 40. Geological reserves of about 200 million tonnes of China clay have been estimated in the Islamkot area (Jafry undated).

Table 40. Chemical analyses (in %) of subsurface kaoline samples from Islamkot area (from Jafry undated).

No.	Test hole No.	Depth (metre)	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO
1.	STP-8	157.28	14.18	44.84	37.58	1.52	0.7	2.10	0.1
2.	"	168.4	13.9	45.40	35.18	1.52	0.5	3.39	0.2
3.	"	195.5	14.86	41.72	39.70	1.20	0.5	1.96	0.1
4.	"	201.0	19.32	36.56	33.80	2.00	0.2	7.29	0.4
5.	"	133.2	14.12	42.80	36.21	1.59	0.6	3.58	0.3

CELESTITE

Small to medium-size celestite deposits are being mined at Daud Khel in the Salt Range and near Thano Bula Khan in the Kirthar fold belt. Near Daud Khel celestite occurs in irregular veins associated with a massive gypsum bed at the top of the Eocene Sakesar Limestone. The ore contains 82.7% $SrSO_4$, 9% SiO_2 and 3.5% CaO and reserves were estimated at 10,000 tonnes down to 6.5 m (Heron and Crookshank 1954).

The Thano Bula Khan deposit occurs in the Eocene Laki Formation in the form of a celestite-calcite vein along a major strike fault. The ore contains 98.75% $SrSO_4$ and the reserves were estimated at 320,000 tonnes (Moosvi 1973). The annual production of celestite in Pakistan varies from about 1,000 to 3,000 tonnes (Butt and Latif 1992).

FLUORITE

Fluorite is chemically CaF_2 (calcium fluoride) but naturally occurring fluorite contains some Mg and Fe ionically replacing Ca. Impurities such as silica and calcium carbonate are usually associated with it. It is mainly used as flux in steel making and is the only source of fluorine which is required for hydrofluoric acid and other fluorine compounds.

Balochistan province is the main producer of fluorite in Pakistan. Fluorite is found in Maran, Pad Maran and Dilband areas of Kalat district, Balochistan (Fig. 8.1). These deposits were discovered and evaluated by the Geological Survey of Pakistan (Bakar 1965b; Subhani 1973; Abbas et al. 1980). Fluorite is found as bedded replacement, shear veins and fracture filled bodies in Chiltan limestone of Jurassic age. The hydrothermal solutions depositing fluorite also deposited calcite along with fluorite in Maran and Dilband areas while silica and barite occur as important gangue minerals in Pad Maran area. The reserves are estimated at over 0.1 million tonnes (Abbas et al. 1980). High grade ore (over 96% CaF_2 and less than 5% SiO_2) is mined from Maran and Dilband areas while low grade ore with less than 35% CaF_2 and high SiO_2 content is found at Pad Maran.

Fluorite has been reported near Mirgasht and Yarkhun in Chitral, in the northern sedimentary fold-and-thrust belt of the Karakoram block (Mining World 1959). In the Himalayan crystalline zone, two small deposits near Chakdara (Dir) comprise fluorite-quartz veins cutting two-mica granite gneiss (Sillitoe 1979). In the Khyber-Hazara metasedimentary fold-and-thrust belt a small showing of fluorite has been reported from Bichoha Kurds (34°11': 73°03') near Sherwan, where it occurs as disseminations in silicic dykes cutting schists of the Hazara Formation (Nagell 1971). Trivial showings occur in the Zhob ophiolitic belt at Brunj Kili and Khojakzai (31°33':69°31') where fluorite-calcite veins cut the Triassic Wulgai Formation (Heron and Crookshank 1954, Nagell 1969).

The total production of fluorite during 1997-93 was about 1,400 tonnes.

FULLER'S EARTH

Fuller's earth is a nonplastic clay or clay like material, usually containing appreciable magnesia (Table 41). It is valued for its decolorising and purifying properties. Locally Fuller's earth is used in oil industry and in foundries.

Table 41. Chemical composition of Fuller's earth (Ahmad et al., 1987).

Constituents	D.G. Khan	Khairpur
SiO_2	49.60	46.20
Fe_2O_3	6.66	8.76
Al_2O_3	11.94	22.86
CaO	9.12	2.43
MgO	3.13	1.94
Na_2O	0.25	1.25
K_2O	1.94	2.62
Loss on ignition	16.18	12.65
Total:-	98.37	98.71

Punjab and Sindh provinces have very large resources of Fuller's earth. In Sindh these deposits occur at Thano Bulla Khan (District Dadu) and Shadi Shahid (District Khairpur) while in Punjab the main deposits are found in D.G. Khan (Fig. 8.1). Fuller's earth has formed along the flood plains of ancient river channels. The Paleocene-Eocene rivers which deposited coal in NWFP, Punjab, Balochistan and Sindh also deposited Fuller's earth in the adjoining areas. In recent years the production has varied from 15,000 to over 21,000 tonnes and it is being utilised in oil refining and other industries in the country. With activation this clay may be used in the vegetable oil and ghee industry. It is also being used by insecticide, foundries and steel industries. Thus a sharp rise in the demand of Fuller's earth may be expected in the future.

FIRE CLAY

Fire clay is resistant to shrinkage, abrasion and corrosion under high temperatures and withstands thermal spalling. It is very low in iron oxide content (<2%) and high in alumina (24-45%).

Punjab is the main producer and consumer of fire clay, where sizable deposits occur in Mianwali, Sargodha and Attock Districts. Fire clay is also found in Thatta and Dadu Districts of Sindh and D.I. Khan District of NWFP. These are residual sedimentary deposits generally found at the base of Patala Formation of Paleocene age in the Punjab and at the base of Sonhari beds of Eocene age in Sindh. Fire clay is associated with bauxite and high alumina clays in the Kalachitta Hills (described earlier). The main deposits are at Bagh, Chhoi and Surge. Large deposits are also located in the eastern part of the Salt Range at Manhiala (32°42':73°00'), Wehali (32°45':73°03'), Nali (32°42':73°02') and Dalwal (32°42':72°52'), where the clay occurs at the base of the Paleocene Patala Formation near the unconformity above the Permian Warcha Formation. At Ara (32°45':73°13') near Khewra, it occurs at top of the Tobra Formation. At Karauli and Ratucha (32°42':72°59'), it is in the form of underclay associated with Dandot coal seam (Ahmad 1969). A number of these deposits are being mined.

In the western side of the Salt Range, fire clay is found in Datta Formation of Jurassic age and the main deposits are at Dhak Pass (32°40':71°47'), Manza Bazar (32°38':71°48'), Chabil (32°40':71°47'), Dama (32°39':72°48') and Gole Wali (32°30':71°50'). In the Trans-Indus Salt Range, fire clay occurs at the same stratigraphic horizon and the main deposits are at Chapri near Isa Khel, Paniala (Dera Ismail Khan), and at Kot Kasarain (D. G. Khan) farther to the south.

The total reserves of fire clay in Pakistan are estimated to be over 100 million tonnes (Griffiths, 1987). The bulk of the present production (100,000–150,000 tonne) is derived from Mianwali and Sargodha deposits which could be classed as heavy duty refractory clay. It is used mainly for furnace lining in cement and other industries.

The fire clay deposits of Punjab have been investigated in detail by the Geological Survey of Pakistan. The detailed studies included large scale mapping, channel sampling, chemical analyses and estimation of reserves (Hussain and Sibghatullah, 1966; Akhtar and Cheema, 1989).

In Pakistan there is a wide range of variation in chemical composition of the material being mined and marketed as fire clay. The high grade Pakistani fire clay contains as much as 65% Al_2O_3 while the low grade as low as 35% Al_2O_3 (Griffith 1987). The fire clays of Pakistan are slow slacking and moderately plastic. Their firing shrinkage varies from 0.66 to 10.14% and water absorption 31% to 40%. Their firing behaviour is good (Ahmad, et al., 1987).

The range of chemical composition exhibited by these clays is given in Table 42. The production of fire clay during the year 1997-98 was about 94,395 tonnes.

Table 42. Chemical analyses of selected Pakistani fire clays (raw basis, Hussain and Naqvi 1973), in percent.

Locality	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alkalies	LOI	Calculated PCE*
Musa khel	59.82	25.40	2.89	1.32	1.10	0.23	1.47	7.73	1659
-do-	48.49	35.14	0.61	2.79	Nil	Trace	0.78	12.19	1714
Katha-Saghral	13.19	64.58	2.07	0.69	2.88	-do-	0.11	16.46	1836
Chhoi	6.00	74.24	0.64	3.65	0.76	-do-	0.20	14.51	1881

* Pyrometric cone equivalent.

FELDSPAR

Feldspars are complex silicates of sodium, potassium and calcium (Table 43), naturally occurring as an important group of rock forming minerals. The potash feldspars are associated with acidic group of rocks while sodic and calcic feldspars are important constituents of intermediate and basic group of rocks. Feldspars are used in ceramic and glass industry.

Table 43. Chemical analyses of feldspar from Swat (Griffiths 1987).

Constituents	Contents %
SiO_2	65.00%
Al_2O_3	18.70%
TiO_2	0.05%
MgO	0.09%
CaO	0.08%
K_2O	14.74%
Na_2O	0.11%

Large deposits of both sodic and potassic feldspars occur near Mingora and Bunair in Swat District of NWFP (Badshah 1994). Feldspar is widespread in pegmatites in Chitral, Gilgit and Skardu. Deposits of orthoclase feldspar are also present in Nagar Parkar area of Sindh. A total of 26,360 tonnes of feldspar was produced during the year 1997-98.

LIMESTONE

The term limestone includes those rocks which contain more than 50% mineral calcite ($CaCO_3$). Limestones form extensively on continental shelves as detrital, biogenic or chemical precipitates.

The rock is extensively used as crushed stone, for concrete aggregates, road metal, and rail road ballasts. It is the basic raw material for portland cement. Limestone is also used in steel mills as fluxing agent, soil conditioner, as a source of lime, chemical raw material and as dimension stone.

Pakistan has literally inexhaustible reserves of limestone extending from the coastal region near Karachi to as far north as the Khyber Pass, Swat, Chitral, Hunza and Skardu. In most places the limestone is exposed near the railway track or road, making its utilisation easy. These rocks generally contain over 50% calcium oxide, less than 5% silica and less than 1% iron oxide making them suitable raw material for the manufacture of cement. However, the existing cement factories utilise only a fraction of the vast resource available in the country and different types of cements worth US$ 16.53 million were imported during the year 1993-94. Pakistan has the lowest per capita consumption of cement, 70 kg per annum as compared to 92 kg in Indonesia, 113 kg in Philippines, 249 kg in Iran and 438 kg in Malaysia. In addition imports of calcium chemicals cost the country several hundred million rupees every year.

In view of the above facts it is highly desirable that steps be taken to boost the production of cement, lime and calcium chemicals in the country so that the country not only becomes self sufficient in these finished products of limestone but starts exporting them. The consumption of limestone has gradually increased from 5.8 million tonnes in 1990-91 to 10.35 million tonnes in 1997-98. There is yet vast scope of further increase in utilisation and production of this important industrial raw material.

NEPHELINE SYENITE

Nepheline syenite is a rock largely consisting of albite and microcline feldspars and nepheline. It is used in the manufacture of glass, ceramics, alkali carbonates, portland cement and for the extraction of aluminum.

Deposits of nepheline syenite occur in Swat and Mardan districts of the NWFP province. The rock occurs as intrusive bodies at several localities. Major occurrences are located at Agarai, Landi Patao, Miane Kadao, Shola and Kharkai.

The Agarai deposit (Koga) being the largest one has been investigated in some detail by Engineers Combined Limited (1979) and on an average has been found to contain microcline perthite (39%), nepheline (30.6%), albite (12.9%), sodalite (3.9%), magnetite (1.6%), garnet (0.6%) and calcite (6%). Tests carried out on bulk samples show that the rock is suitable for the manufacture of colourless glass and for ceramic purposes. Range analysis of the Koga syenite deposit is given in Table 44.

Table 44. Chemical composition of Koga nepheline syenite (from Khan and Ahmad undated).

Constituents	Percent
SiO_2	59.92 - 61.65
Al_2O_3	20.35 - 23.46
Fe_2O_3	1.35 - 03.13
Na_2O	6.12 - 10.68
K_2O	4.70 - 06.93

The alkaline composition and significant alumina content makes this rock a good substitute for feldspar in the glass and ceramic industry (Mikrch 1976). In Russia such rocks have been used for extraction of alumina, manufacture of portland cement and soda ash. Pilot plant tests by the Sarhad Development Authority (SDA) and industrial-scale tests by the industry have established the feasibility of its large scale use in glass industry and ceramics. Mechanical treatment reduces the iron content to less than 0.1%. The total reserves are estimated at about 6,000 million tonnes. Reserves of material suitable for glass and ceramics is estimated at 82.78 million tonnes (Khan and Ahmad undated).

According to the Sarhad Development Authority (SDA) the ceramic industries have successfully manufactured china wares and have marketed this product. SDA has also supplied calcined nepheline syenite for use in the continuous steel casting. In Russia nepheline syenite is being used in their Alkali Complex for extraction of alumina. Samples of Kòga syenite have been tested in Russia. The results suggest that an alkali complex based on this ore would be feasible if an alumina plant of 270,000 tonne capacity is installed, with production of 3.9 million tonnes of portland cement, and 220,000 tonnes of potash and soda ash per annum.

SILICA SAND

Quartzose sand, free of impurities, is used as silica sand or glass sand (Table 45). Silica sand deposit of Mianwali District of Punjab is the main producing deposit of the country, but large deposits of silica sand also occur in Nowshera, D.I. Khan, and Abbottabad districts of NWFP and Dadu District of Sindh.

Silica sand is used as an abrasive, for the manufacture of glass and some chemicals. It is also used in refractory, in sinter and allied complexes of steel mills and has metallurgical applications. Datta Formation of Jurassic age and its equivalent formations contain thick beds of silica sand in Khisor and Marwat Ranges, between Paniala and Pezu, over a length of 16 kilometre with an estimated reserves of 20 million tonnes (Raza and Iqbal 1977). In Salt Range and Surghar Range glass sand beds, 73 to 730 metres long, occur in Datta

Formation and Patala Formation (Late Paleocene). Near Mallakhel, glass sand beds with over 99% SiO_2 occur in Lumshiwal Formation of Lower Cretaceous age (Ahmad 1969, Shah 1980). In Hazara high grade silica sand (Table 45) occurs as thick layers within a 150 metres thick sequence of metamorphosed calcareous sandstone at Mand Kachcha (Raza and Iqbal 1977). Large deposits of glass sand are found near Thano Bula Khan in Dadu District of Sindh province in Eocene and Oligocene sediments. Large lenticular bodies of silica sand occur in meta-sediments in Mohmand Agency with reserves of over 537 million tonnes.

The present consumption and requirements of silica sand are mainly met from the local production which has varied from about 106,000 to 222,000 tonnes annually between 1994 and 1998. Pakistan Steel alone uses about 80,000 tonnes of silica sand annually, mainly from Thano Bula Khan. The demand for silica sand is likely to rise with increase in the production of iron and steel and with expansion of glass and other user industries.

Table 45 Chemicals analyses of silica sand (%). (Griffiths 1987, Hussain 1976, Hussain undated).

Constituents	Mianwali	D.I.Khan	Hazara
SiO_2	95.00 - 96.33	92 - 99	95 - 98
Fe_2O_3	0.53 - 00.83	0.1 - 1.2	0.02 - 11.0
Al_2O_3	2.62 - 03.07	0.18 - 5.77	0.1 - 4
CaO	0.35	0.38 - 1.68	0.1 - 0.5
MgO	0.14 - 00.57	0.10 - 1.60	-

9

FERTILISER AND INDUSTRIAL MINERALS

ASBESTOS

Asbestos is the fibrous form of mineral silicates belonging to the serpentine and amphibole group of rock-forming minerals. Due to its fibrous and fire-proof nature it has several industrial uses, more significantly in the production of fire-proof textiles, clothings, brake linings, gaskets, electrical insulation materials, paper and other products. Asbestos is associated with health hazard (Jehan and Hamidullah 1997) because persons involved in prolonged occupational exposure to heavy concentrations of asbestos dust, without proper protective devices, are liable to contract asbestosis and even lung cancer.

In Pakistan, small deposits and showings of chrysotile and tremolite asbestos are found in serpentinites of the ophiolitic complexes near Wad, (Khuzdar), Muslimbagh and Naweoba (Zhob); Boya, Kaniguram (Waziristan); and Sakhakot-Qila area (Mohmand). The main economic deposits are located in the Sakhakot-Qila area and most of the production comes from Prang Ghar, Qila, Behram Dheri, Narai Obe, Bucha, Newe Kili and Hero Shah. This belt of asbestos bearing rocks extends westward into Khyber Agency.

The asbestos from the Sakhakot-Qila area is largely chrysolite with local occurrences of antigorite and tremolite. There are about 15 mines in this region and the annual production is estimated at about 50,000 tonnes (Jehan et al., 1997).

BARITE

Barite is a mineral with chemical formula $BaSO_4$ but naturally occurring barite contains minor quantities of impurities such as silica, limestone or dolomite. It is mainly used as weighting agent in oil well drilling mud. It is also used for making barium chemicals, white pigment and in paper industry.

Barite is deposited by hydrothermal solutions generated during the time of sedimentation or thereafter. In Pakistan it is found as bedded replacement, fracture filling and shear veins in limestone formations of Mesozoic or earlier age.

The barite deposits of Balochistan were discovered by the Geological Survey of Pakistan (Ahmad and Klinger, 1967). They are located in the area between Uthal and

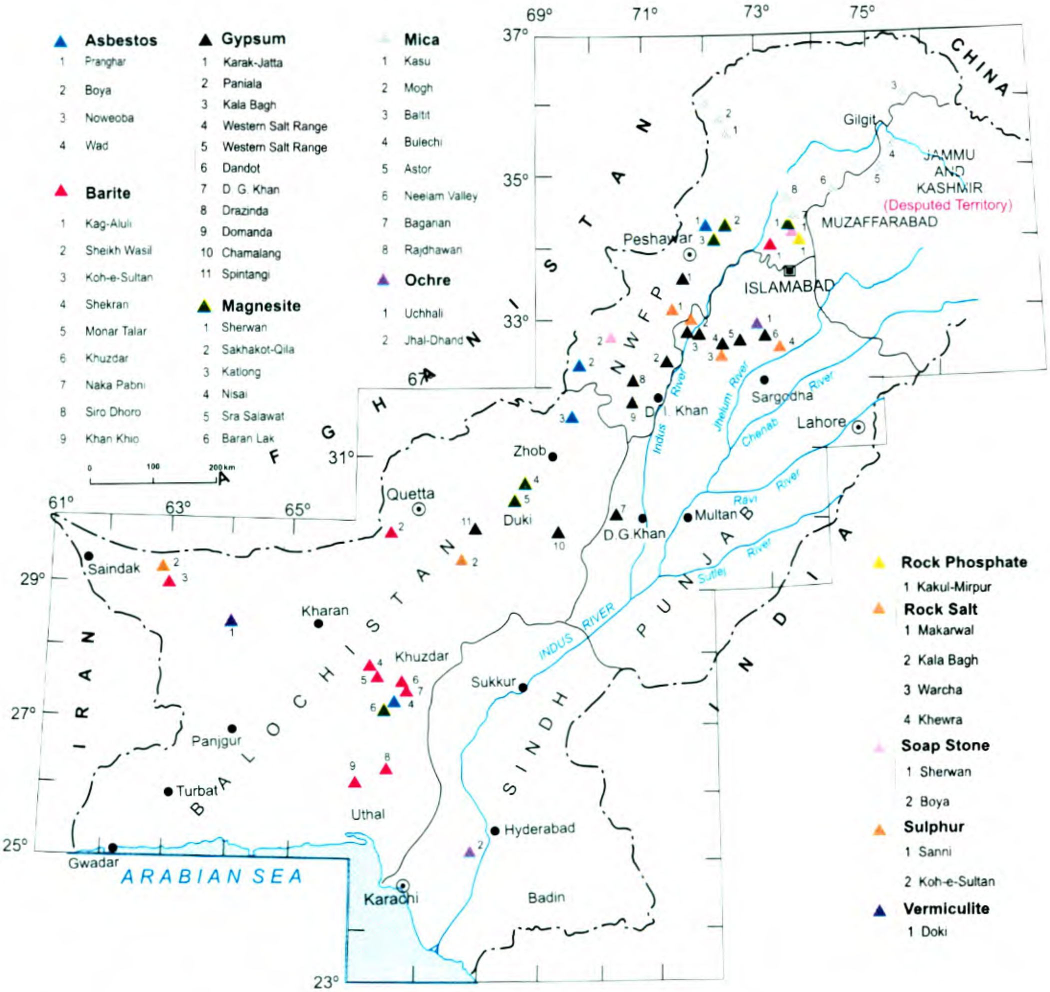


Figure 9.1. Map showing location of some of the main deposits of fertiliser and industrial minerals.

Table 46. Range analyses of barite. (Klinger and Richards 1967, Klinger and Ahmad 1967, Afridi 1986).

Locality	Sp. gravity	$BaSO_4$%	SiO_2%	Fe_2O_3%	CaO%	MgO%
Kohala-Hazara	3.45-4.2	88.92-92.76	0.45-3.34	0.09-0.2	0.28-2.73	0.26-1.04
Gunga-Khuzdar	3.96-4.35	91.86-95.92	1.84-2.48	0.02-0.03	0.49-0.98	0.67-1.63

Khuzdar. The barite is found in Zidi, Shirinab and Windar Formations (Triassic-Jurassic) forming bedded replacement or shear veins of hydrothermal origin. The ore bodies generally contain large tonnage. Deposits at Gunga near Khuzdar and Duddar in Bela district have been investigated in detail with the help of large scale mapping and drilling. It has been estimated that at these two localities over 12 million tonnes of barite is present (Ahsan and Khan, 1994). The Khuzdar deposits have been developed and are being mined through a joint venture between Balochistan Government and Pakistan Petroleum Ltd.

Barite reserves estimated at over 30 million tonnes are available mainly from Las Bela-Khuzdar area. The production from indigenous deposits meets the total requirement of barite for oil well drilling and barium based chemical plants of the country.

The deposits from Las Bela-Khuzdar area produced about 29,000 tonnes during the year 1997-98.

Small vein-type deposits in Precambrian Tanawal Formation, with estimated reserves of up to 1,000 tonnes, were reported from Kag-Alui and Kachi area, 10 kilometres NW and 20 km NE of Haripur respectively (Hussain et al., 1990).

Another vein-type deposit in Precambrian Hazara Formation, 5 kilometres SW of Kohala (34º73′:73º27′) with estimated reserves of about 30,000 tonnes, has been mined (Ahmad and Siddiqi 1992). During 1997-1998, 1,326 tonnes of barite was produced from this deposit.

The barite deposits of the country are sufficient and suitably located for large scale production provided export market could be developed.

GYPSUM AND ANHYDRITE

Hydrated sulphate of calcium ($Ca\ SO_4\ 2H_2O$) known as gypsum, and its unhydrated form ($CaSO_4$) anhydrite, is found as bedded deposit associated with sedimentary rocks. It is formed as a result of increased salinity in starved marine basins in which input of fresh water is very low. It is mainly used for the conditioning of saline soils, manufacture of cement and fertiliser. Minor quantities are used as filler in paints, paper and rubber industries and for manufacture of gypsum board.

Pakistan has very large reserves of gypsum/anhydrite, found in all the provinces of Pakistan (Fig. 9.1). Major deposits are those of Daud Khel, Khewra and D.G.Khan in the Punjab, Kohat Region in N.W.F.P. and Spintangi and Chamalang in Balochistan. Smaller deposits occur in Dadu district of Sindh and Las Bela District of Balochistan. Large gypsum deposits are found in the Salt Range and occur with dolomite and marl in the Precambrian Salt Range Formation and the limestone and shales of the Eocene Sakesar Limestone. Here the gypsum is largely massive, white to light grey and commonly interbedded with anhydrite. The gypsum-anhydrite contact is sharp at places and gradational.

Thus the anhydrite deposits have not yet been evaluated and estimated separately. At Daudkhel, in various bore holes, cumulative thicknesses of 8 to 70 metres have been reported, whereas at Khewra in the New Low Level Tunnel alternating beds of gypsum and anhydrite have been measured (in metres) as follows (Alam and Khan 1982):-

Gypsum: 15.24, 15.2, 60.8, 61, 15.3, 423 (mixed zone at base)
Anhydrite: 76.26, 106.7, 15.2, 30.4

The Salt Range contains at least 137 million tonnes of gypsum. Though the anhydrite and gypsum reserves of the Salt Range have not been separately evaluated there are vast reserves of anhydrite also.

Very large reserves of gypsum (4.7 billion tonnes) have been reported from the Kohat region of NWFP. Here extensive deposits of gypsum form part of the Jatta Gypsum Formation of Eocene age. Gypsum beds are 15 to 60 metres thick and extend in a 55 kilometres long belt. Main deposits occur at Braghdi, Shiwakki, Jatta, Nashpa–Chanda, Mami Khel, Banda Daud Shah, Lachi, Bahadur Khel, Karak, Banda Spina–Dhand, Idal Khel and Malgin.

Recently large deposits of gypsum have been discovered by GSP in the Sulaiman Range and Marri-Bugti Hills of Balochistan. In this region the gypsum occurs in the Eocene Baska and Domanda Formations. Estimated reserves of gypsum at various localities in Pakistan and their chemical composition is given in Table 47.

In the Dadu District of Sindh, gypsum occurs in the Gaj Formation of Miocene age. Three beds ranging in thickness from 0.33 to 0.93 metres occur in shales, near Johi and K. N. Shah (Alizai et al. 2000). The gypsum is stated to be of good quality and the reserves are estimated at 10.4 million tonnes. The gypsum-bearing formation extends laterally for a very long distance and the available reserves are thus likely to be much larger.

At present about 296,000 to 500,00 tonnes of gypsum is being mined annually from Punjab and N.W.F.P. provinces of Pakistan but there is a large scope for increasing the utilisation of gypsum in agricultural and construction sectors of the country and exploring international market for this commodity.

MAGNESITE

Magnesite is chemically a carbonate of magnesium with chemical formula $MgCO_3$. Naturally occurring magnesite contains minor amounts of silica and calcium carbonate as impurities. Fe and Ca may replace Mg to some extent. Magnesite is used as refractory in steel industry and foundries and in manufacture of mangnesium salts.

Magnesite occurs as alteration product of serpentinised ultramafic rocks or as replacement deposits in dolomite or dolomitic limestone. There are several occurrences

Table 47. Reserves and chemical composition of gypsum deposits (from Alam and Khan 1982, Malkhani 1999).

Localities & deposits	Reserves (Million tonnes)	Insoluble %	Fe_2O_3	CaO	MgO	SO_3	H_2O %	$CaSO_4$ %	$CaSO_4$ %
PUNJAB									
Daudkhel*	52.274	0.45 - 0.38	0.24 - 0.16	34.00 - 32.39	0.06 - 0.35	48.12 - 45.86	15.06 - 20.62	76.73 - 98.58	21.15 - 00.07
Khewra	78.076	1.40 - 0.80	1.80 - 0.60	30.46 - 30.60	2.81 - 2.10	41.90 - 43.60	17.17 - 19.60		
Burikhel	2.076	—	—	—	—	—	—	—	—
Chhidru	0.515	—	—	—	—	—	—	—	—
Warcha	0.542	—	—	—	—	—	—	—	—
Jabbi	0.180	—	—	—	—	—	—	—	—
Makrach	0.599	—	—	—	—	—	—	—	—
Dandot	0.848	—	—	—	—	—	—	—	—
Jutana etc	2.004	—	—	—	—	—	—	—	—
Safed Koh (D. G. Khan)	21.0	0.46 - 0.22	0.48 - 0.20	35.30 - 32.60	0.05 - 0.04	47.29 - 45.83	73.39 - 98.33	15.36 - 20.58	22.37 - 00.18
BALOCHISTAN									
Spintangi	0.5	0.30 - 0.60	0.50 - 0.40	32.30 - 32.67	0.68 - 0.32	47.30 - 27.44	18.20 - 19.10		
Barkhan	171.5	—	—	—	—	—	—	—	—
Rakhni	28.72	—	—	—	—	—	—	—	—
SINDH									
Johi	10.4	—	—	—	—	—	—	—	—
NWFP									
Braghdi		1.77 - 0.20	0.14 - 0.03	31.72 - 32.24	0.88 - 0.40	43.90 - 45.01	15.19 - 20.03	72.58 - 95.78	17.26 - 00.02
Siwakki		1.34 - 1.14	0.50 - 0.54	30.81 - 32.29	1.66 - 0.26	42.92 - 44.92	18.80 - 20.63	—	—
Jatta	4,698.00	0.72 - 2.06	0.56 - 1.34	31.54 - 30.84	1.00 - 1.36	46.08 - 44.51	18.79 - 19.19	—	—
Lachi		2.46 - 2.48	0.86 - 0.38	31.54 - 30.14	0.71 - 1.02	41.81 - 43.63	19.02 - 19.63	—	—

* Includes 137 million tonnes of anhydrite.

in the ultramafic rocks of the ophiolitic thrust belt but these comprise small deposits or trivial showings. The stratabound replacement-type deposits in dolomitic sequences, however, are fewer but larger, and of greater economic value (Table 48).

Table 48. Magnesite deposits: location, geology and potential.

Locality	Geological Setting	MgO%	Reserves (tonnes)
Sakhakot (37°24′:71°56′)	Veins in serpentinised ultramafic rocks of the Dargai klippe (Indus Suture zone).		Very small
Spin Kan (Nasai) (30°47′:68°06′)	In serpentinised ultramafic rocks of Zhob ophiolitic thrust-belt.	43.38 to 45.4	60,000
Shabi Ghundi (30°48′:68°00′)	(as above)	38.04 to 42.36	6,000
Tlerai Mohd Jan (30°53′:67°42′)	(as above)	N. A.	Very small
Zizha (31°3′:69°37′)	(as above)	N. A.	Very small
Kakru (27°43′:66°09′)	Vein in serpentinised ultramafics of the Bela opiolitic thrust-belt.	32.8	Very small
Loya Na Pani (27°15′:66°20′)	(as above)	32.84 to 44.56	Very small
Baran Lak (26°59′:66°18′)	(as above)	18.08	20,000
Sinchi Bent (26°30′:66°21′)	(as above)	N. A.	Very small
Sra Salawat (30°40′:67°53′)	In Eocene dolomite unconformably overlying the Zhob ophiolites.	46.49	16,000
Nal (27°41′:66°11′)	Replacement veins in limestone of Shirinab Formation, Bela ophilitic thrust-belt.	N. A.	Very small
Sherwan (Kumhar)	Replacement deposits in dolomitic limestone of Cambrian Abbottabad Formation.	44.9 to 46.7	11,268,000

The main magnesite deposits occur at Wad (Khuzdar) and Muslim Bagh in Balochistan, and Malakand and Hazara in NWFP (Fig. 9.1). Magnesite is found along fractures, joints, and faults in ultramafic rocks. It is formed by deep alteration of ultramafic rocks, dolomites and even limestones. The Sherwan (Kumhar) magnesite deposit of Hazara, NWFP, has been estimated to contain 11.2 million tonnes of total reserves. It is of good quality (Table 49). The magnesite from this deposit has been found suitable for the production of refractory bricks and fused magnesium phosphate (Hirayama et al., 1995).

Table 49. Chemical analyses of magnesite (%) (Nagell 1969, Min-Koh 1981).

Constituents	Muslim Bagh	Kumhar
SiO_2	0.38 to 2	1.72 to 1.75
Fe_2O_3	0.79 to 4	0.48 to 1.16
CaO	1 to 10	1.76 to 2.26
MgO	38 to 44	43.97 to 44.06
Loss on ignition	49 to 51	50.19 to 50.26

The magnesite resources in Pakistan have been estimated at 12 m tonnes (GSP, 1989), whereas the annual production was about 3,427 tonnes in 1997-98.

MICA

Mica belongs to a group of minerals which exhibit a high degree of cleavage making it easy to split them into extremely thin sheets that are strong, flexible, chemically inert, and transparent. They posses useful electrical and thermal properties. Mica occurs in pegmatitic rocks in large, flat blocks or books. It is mainly used in electronic and electric industries. Mica also occurs as small flakes and scrap. This type is generally processed into ground mica and used in gypsum plaster board, cement, paint and rubber industry and in mica paper and well drilling industry.

Muscovite sheet-mica occurs in pegmatites at several localities in Pakistan (Heron and Crookshank 1954, Ahmad 1969, Kazmi and Donoghue 1990). The mica sheets are rather small, usually less than 0.3m in size. In the Karakoram block limited and sporadic mining has been done near Baltit (36°15′:74°25′), Dassu (35°20′:73°20′), Mogh (32 km NE of Chitral), and Kasu (35°34′:72°52′), NE of Drosh. In the Kohistan magmatic arc, mica has been worked at Khadong Banda (near Dir). In the Himallayan crystalline zone, mica deposits have been reported from Astor, Bagarian (34°33′:73°10′), Hawa Gali (34°29′:73°06′), and in the Neelam Valley of Azad Kashmir. Amongst these the better deposits are the ones in Neelam Valley and near Astor.

OCHRE

Ochre is a commercial name for hydrated oxides or silicates of iron which can be used for imparting colour.

Yellow and brown to reddish coloured ferruginous clays are of widespread occurrence along lateritic horizons in the sedimentary sequences of the Foreland fold-and-thrust belt (Heron and Crookshank 1954, Ahmad 1969). Deposits of economic value, some of which are being mined, occur in the Reshian region of Azad Kashmir and at several localities in the Salt Range e.g., Uchhali (32°32′:72°02′), Kutki (32°59′:71°21′), and Pirkahar (32°39′:72°43′). Small deposits occur in the southern part of the Kirthar Range near Jhal Dhand (24°52′:67°56′) and Sonhari Dhand (25°00′:68°04′).

The lateritic beds found in Katha Nasral area, district Sargodha, Punjab, in Dadu and Thatta districts, Sindh and in Ziarat area, Balochistan, contain lenticular pockets of ochre, which is being used locally for paint making and other industries. These deposits were formed as residual soils on the erosional surfaces in the geological past. The base of Ranikot Formation in Sindh and Dunghan Formation in Balochistan, and the base of Hangu Formation in Punjab contain lateritic horizons which can be used as ochre.

The lateritic deposits of Punjab and Balochistan provinces and other areas have been investigated in some detail by the Geological Survey of Pakistan.

ROCK PHOSPHATE

Phosphate occurrences have been reported from the Cretaceous sequence near Kohat (Chichali Formation), near Chhoi in Kalachitta Range (Kawagarh Formation), from the Paleocene and Eocene rocks in the Salt Range (Patala Formation), in the Sulaiman Range (Khadro Formation and Ghazij Group), and in the Oligocene sequence in southern Kirthar Range (Nari Formation). These are of little or no economic value due to low P_2O_5 content (Ahmad 1969, Raza and Iqbal 1977). The main economic deposits of rock phosphate occur in the Cambrian Abbottabad Formation and the Precambrian Hazara Formation, northeast of Abbottabad, along the western flank of the Hazara-Kashmir Syntaxis (Hasan and Ghaznavi 1980, Khan and Ahmad 1991).

Hazara Phosphate Deposits

The phosphate deposits of Hazara lie between latitudes 34°5' to 34°30' N and longitude 73°00' to 73°30'E. They cover an area of about 155 sq km. Phosphate occurs in cherty dolomite of the Abbottabad and Hazira Formations of Cambrian age. The phosphorites are of pelletal type and commonly contain collophane, dahlite, francolite, glauconite, dolomite, iron oxide and pyrite in various proportions (Hasan and Ghaznavi 1980). These deposits may be divided into two major lithological types:

(i) Cherty-phosphorite of Abbottabad Formation.
(ii) Silty, calcareous-phosphorite of Hazira Formation.

The major deposits are located at Kakul-Mirpur, Kalu-de-Bandi and Lagarban, Dalola and Sirbun Hill areas.

Kakul-Mirpur Area

This deposit is located 9.5 kilometres east of Abbottabad and covers an area of about 13 sq km. The main phosphorite horizon has a strike length of about 516 to 607 metres and an average thickness of about 4.5 metres. In this region there are 2 phosphorite horizons, an upper one, at the contact of Hazira and Abbottabad Formations and a lower one, in the cherty dolomite of Abbottabad Formation. The host rocks are tightly folded and faulted. In this deposit the P_2O_5 content ranges from 24-32% and the measured reserves are around 1.08 million tonnes (Hasan and Ghaznavi 1980).

Kalue-de-Bandi and Lagarban area

Lagarban is about 40 kilometre northeast of Abbottabad. The phosphorite is located on both the limbs of a synclinal structure. Outcrop length of the deposit on the western limb is about 3,033 metres and on the eastern limb about 1,062 metres. Its thickness varies from 3 to 8 metres. Southward, near Kalue-de-Bandi, 32 metres below the main deposit there is another phosphorite horizon which is 305 metres long. The P_2O_5 content of this deposit ranges from 19 to 39%. At Kalue-de-Bandi the P_2O_5 content is 24-34% and the measured reserves are about 8.3 m.t. At Lagarban the high grade ore contains an average of 31% P_2O_5 with measured reserves of 0.3 m.t., while the low grade ore has an average of 21% P_2O_5 and measured reserves of about 1.7 m.t.

Dalola area

Dalola village is located about 6 kilometre south of Garhi Habibullah. In this region there are three phosphorite zones in the Hazira Formation, with strike lengths of 1692, 152 and 303 metres. Their thickness varies from 3 to 23 metres. The Dalola phosphorite is different from others. It is black, dense, silty, calcareous, cherty, non-pelletal and contains small amounts of manganese. The P_2O_5 content varies from 9 to 17% and reserves are estimated at 9.2 m.t.

Sirbun Hill area

The deposit is located in the Sirbun Hills, 6 kilometres from Abbottabad. Its strike length is about 455 metres and average thickness about 3.9 to 3.6 metres. The P_2O_5 content varies from 3 to 25% and the measured reserves are 1.9 million tonnes.

Mining

The Sarhad Development Authority (SDA) developed a mine near Kakul and a production of about 40,000 tonnes per year was achieved. A crusher was also installed at site and the material was supplied to the National Fertilizer Corporation (NFC) at their Haripur Plant. Between 1985 and 1987, 74,000 tonnes of ground rock-phosphate was also supplied to NFC plant at Jaranwala.

The SDA developed another mine at Rehala in the Tarnavi-Lagarban area for the supply of 60,000 tonnes of rock-phosphate to the NFC Haripur Plant annually. During the period 1990 to 1995 the annual production of rock phosphate from Hazara had ranged from 12,700 to 23,250 tonnes. However, at present mining of Hazara phosphate deposits is at a stand still pending negotiations and agreement between SDA and NFC. It is hoped that mining may be resumed shortly.

ROCK SALT

Chemically rock salt is chloride of sodium (Nacl) (Table 50). In pure crystalline form it is known as halite. Salt is an essential nutrient for the existence of life and is an important industrial raw material. In the chemical industry it is used as a primary raw material for several products.

Table 50. Chemical analyses of Khewra rock salt (%) (Griffiths 1987).

Constituents	Percent	Constituents	Percent
$NaCl$	98.65	Moisture	0.11
$CaSO_4$	0.41	Insolubles	0.03
$MgSO_4$	0.40	Undetermined	0.16
Na_2SO_4	0.24		

Rock salt is formed by the evaporation of sea water in restricted shallow basins. Thick sedimentary beds of salt occur in the Salt Range Formation of Precambrian age in Punjab. In NWFP, Bahadar Khel Salt Formation of Eocene age contains thick beds of rock salt.

Pakistan has immense deposits of rock salt located in the Salt Range in the Punjab province and in Kohat district of NWFP. Salt mining has been traditionally carried out by the government since the annexation of Punjab and NWFP by the British, but recently some private parties have also started salt mining.

In the late fifties, the mining engineers working in Khewra salt mines had reached a conclusion that the salt deposits of the area were nearing exhaustion and that the mining operations would be closed down within a short period. Consequently GSP was requested to evaluate the salt deposits of Khewra. Detailed exploration and evaluation of these deposits by GSP proved the existence of inexhaustible reserves of rock salt in the Salt Range (Asrarullah 1962).

The present annual production of rock salt is about 106,000 tonnes. Rock salt is mostly used in the country. About 40% of the total output is consumed by soda ash, caustic soda and leather industries and the rest is marketed for human consumption. A certain amount of rock salt has been exported to Afghanistan and India from time to time.

Potassium salts are present in the rock salt and salt marl of the Billianwala Salt Member of the Salt Range Formation and occur as layers and lenses up to 4 m thick and 240-400 metres wide. These lenticular bodies contain 7.83-9.4% K and the reserves at Khewra are estimated at 124,350 tonnes (Alam and Asrarullah 1973). Similar occurrence of potash salt is reported at Warcha and Kalabagh (Alam et al., 1975). Selective mining of these deposits is uneconomic owing to the low potash content and lenticular nature of the potash-bearing bed.

SOAPSTONE AND TALC

Talc is a hydrous silicate of magnesium while soapstone is an impure talcose rock in which talc is intimately mixed with various impurities such as dolomite, serpentine and calcite. Soapstone is formed by hydration of nonaluminous magnesium minerals. Soapstone and talc are mainly used in ceramics, paints, paper, cosmetic, plastic and insecticide industries.

Soapstone deposits occur in Parachinar area, Kurram Agency; Jamrud, Khyber Agency; Derai, Swat District and Sherwan, Abbottabad District. The Sherwan deposit is the major producer of soapstone in the country but other deposits of NWFP have also started producing and are expected to increase the production as the demand rises. Soapstone deposits of Kurram Agency have been estimated to contain 1.6 million tonnes of reserves (Badshah 1994). Total production achieved during 1994-95 was about 24,500 tonnes.

SULPHUR

Sulphur is a soft, light, yellowish substance, one of the few elements that occurs in the native state, though most of it occurs compined with other elements. It is one of the more important industrial raw materials. About 85% of the world sulphur production is used in the manufacture of sulphuric acid. More than 65% of the sulphuric acid is used in agricultural products, mainly phosphatic fertilisers. It is used in the manufacture of ammonium sulphate and several other chemicals, plastics and synthetics, paper products, paints, nonferrous metals, petroleum refining, iron and steel, insecticides, matches, fireworks, gunpowder and other industrial products.

In Pakistan there are two small deposits of native sulphur, one near Sanni south of Sibi and the other at Koh-i-Sultan near Nokkundi, both in Balochistan.

Sanni Deposit (29°02′:67°29′): This small sulphur deposit is located along the Kirthar foot-hills. Sulphur occurs as veins or as replacement of sandstone matrix in the Nari Formation. The ore contains 45% sulphur and the reserves are estimated at about 58,000 tonnes (Muslim 1973a).

Koh-i-Sultan Sulphur Deposit: This is a large solfataric type deposit, occurring in the extinct Koh-i-Sultan volcano. Massive layers and lenses of sulphur are interbedded with Pleistocene volcanic ash. The ore contains 50% sulphur and the reserves are estimated at 738,000 tonnes (Muslim 1973b).

VERMICULITE

Vermiculite is a mica-like mineral that expands upon heating to produce a low-density material. It is used extensively as lightweight aggregate, thermal insulator, as a fertiliser carrier, soil conditioner in agriculture, and as a filler and texturiser for plastics and rubber. It is a mineral commodity which is not being exploited in Pakistan as yet but the available reserves and excellent exfoliation character may make it possible to commercially exploit the available source.

Vermiculite deposits are reported from Doki River on the northern edge of the Western Raskoh. Vermiculite bearing rocks occur in a cliff 160 metres long 140 metres wide and 40 metres high. The reserves are estimated at about 11 million tonnes (Grundstoff-technik, 1993). The vermiculite content of these rocks varies from 5 to 20%. Exfoliation tests (at 775° C) resulted in a tenfold increase in the particle size (Hussain, 1970). The average analysis of vermiculite from this area, based on composite surface samples is given in Table 51.

Table 51. Chemical analysis of Doki vermiculite % (Grundstoff-technik 1993).

Constituents	Percent
SiO_2	42
TiO_2	1.38
Al_2O_3	19.05
Fe_2O_3	13.16
MgO	10.30
H_2O	10.75

WITHERITE

Witherite is barium carbonate ($BaCO_3$) and has a specific gravity of 4.3. It occurs as a gangue mineral, associated with galena and barite. It is a source of barium salts and is also employed in the pottery industry. Owing to its high specific gravity, it may be used in the drilling industry.

A deposit of witherite has been recently discovered a few miles west of Degari in Balochistan. Witherite occurs as veins and lenses in the Chiltan Limestone of Jurassic age and the mineralisation extends laterally for about one kilometre (Sispal Kella, verbal communication).

DOLOMITE

Dolomite deposits of dolomite occur in the Foreland fold-and-thrust belt and are found in sedimentry sequences ranging from Precambrian to Eocene. The main lithostratigraphic units which contain large deposits of dolomite are the Precambrian Salt Range Formation, the Cambrian Jutana and Khisor Formations, the Devonian Shagai Limestone, the Triassic Kingriali Formation, the Jurassic Samana Suk and Takatu Limestone and the Eocene Chorgali Formation. In the Paleozoic sequence of the Karakoram block, dolomite is found at several localities, particularly in the Devonian Kuragh dolomite sequence. The major dolomite deposits have been listed in the table given below.

Deposits	Formation	MgO%	CaO%	Reserves
Kachhi (Haripur)	Abbottabad Fm.	NA	NA	Large
Sherwan	Abbottabad Fm.	NA	NA	Large
Wagh	Precambrian	21.02	31.43	Large
Nilawahan	Salt Range Fm.	19.72	28.71	Large
Saidu Wali (Khisor Range)	Salt Range Fm.	20.11	31.05	Large
Ghundai Tarako (Mardan)	Paleozoic	19-21	31-33	Not known
Khyber Agency	Khyber Fm Shagai Lst.	20.1	30.1	Large
Kuch (Kalabagh)	Kingriali Fm.	21.8	30.8	0.5 m.t.
Makarwal (Datta, Doya-Lunda, Narmai-Punnu)	Kingriali Fm.	20.2 to 21.6	28.9 to 31.3	900 m.t.
Burikhel (Mianwali)	Kingriali Fm.	16.8	31.5	Large
Kalachitta	Kingriali Fm.	NA	NA	Very Large
Chiltan Range	Takatu Lst.	20	32	250 m.t.
Kohat (NW of Pail)	Chorgali Fm.	17.95	26.32	Large

NA= data not available. (From Raza and Iqbal 1977, Kazmi and Jan 1997).

10

FUTURE PROSPECTS

From the stand point of utilisation and development potential, the mineral occurrences in Pakistan comprise four main categories:-

1. *Mineral showings which are numerous but of limited extent.* When considered individually most of these are apparently of no economic value, but when considered collectively on a regional basis, they become indicators and path finders for larger, buried deposits. Thus they warrant detailed exploration. To this category belong the several mineral showings in the Chagai region, the Bela-Muslimbagh-Waziristan ophiolitic thrust belt, the Indus suture zone in the Mohmand-Malakand-Besham-Chilas region, the Kohistan magmatic arc and the Karakoram block. Systematic geoscientific exploration of these localities is bound to lead to discovery of economic deposits of gold (along with sulphide minerals, copper, silver, antimony, arsenic, lead, zinc etc.), chromite, PGE minerals, tungsten, iron ore, asbestos, and gemstones. Uptil now, despite the fact that mineral exploration in Pakistan has received the lowest priority, the efforts put in this direction have yielded excellent results, as is clearly borne out in the discussions in previous chapters. Unfortunately the results are not so apparent to the common man or reflected in the national economy, because most of the discoveries have been scuttled without going on to the development, marketing and utilisation stage.

2. *Very small mineral deposits.* These deposits would normally be considered of little or no value and would be discarded by investors. Yet such small deposits with mineable reserves of only a few thousand tonnes each have been mined and marketed by local villagers and over the years collectively they have made a positive contribution to the economy and have been the cornerstone of a large number of local mineral based industries. To this category belong minerals such as antimony, chromite, iron ore, lead-zinc ore, manganese, asbestos, celestite, magnesite, mica, ochres, and talc (soapstone). Such small deposits have now been rapidly depleted and exhausted. But more are still abundantly available. How long this trend will continue depends largely upon the socio-economic condition of the people in rural areas, particularly the tribal areas. In any case, credit must go to those uneducated, hardworking and enterprising people in our remote mountain ranges for their back-breaking hard labour. The provincial governments must provide them facilities and incentive.

3. ***Small to medium-size deposits.*** A large number of these deposits have been measured or proven, but only a few of these are being mined at present (Table 52). Those which are in production include chromite, asbestos, barite, bentonite, fluorite, gypsum, magnesite, rock phosphate, gemstone, and sulphur. Unfortunately there are several other good mineable deposits of this category which are not being mined and utilised. These include lead, zinc and barite deposits of Bela-Khuzdar area, boulangerite deposits of Shogor (Chitral), gold and silver deposits at Sewakht and Awrith (Chitral), lead-zinc deposits of Besham (NWFP), iron ores of Chagai, gypsum in Kohlu, Mari Bugti and Dera Ghazi Khan and vermiculite in Ras Koh.

Table 52. Economic minerals of Pakistan.

Large deposits	Medium to small deposits	Showings with good prospects
* Barite	* Antimony	Antimony
* Bentonite	* Asbestos	Arsenic
Beryl	* Bauxite	Bismuth
* Chromite	* Celestite	Cadmium
* Copper	* China clay	Cobalt
* Coal	* Fluorite	Chromite
* Dolomite	* Gemstones	Copper
* Fireclay	Gold	Lead
* Gypsum	Graphite	Iron ore
* Iron ore	* Magnesite	Gold
lead	* Manganese	Graphite
* Limestone	Mica	Manganese
* Marble	* Petroleum	Nickel
* Natural gas	Potash salt	Platinum
* Nepheline syenite	* Radio active minerals	Silver
* Ochre	* Rock phosphate	Tungsten
* Quartz	Silver	Zinc
* Rock salt	* Soapstone	
* Silica sand	Sulphur	
Zinc	Vermiculite	

Asterisks indicate minerals in production.

4. ***Large proven mineral deposits.*** The ones which are being mined and utilised in substantial quantities include natural gas, bentonite, Fuller's earth, gypsum, coal, rock salt, marble, limestone and dolomite. There are, however, many large mineral deposits which remain unutilised and present the saddest picture. Some of these are briefly discussed below.

There are large proven reserves of copper, the Saindak copper-gold-molybdenum deposit in Chagai District which has been developed into an open-cast mine with infrastructure, crushing plant and smelter. Trial production of blister copper has also been carried out. This mine is expected to produce about 15,800 tonnes of copper blister, 1.47 tonnes of gold and 2.76 tonnes of silver annually, which at current prices may be valued at about US $42 million. Since 1996 this project has been lying idle merely for want of a working capital of about Rs. 1.5 billion. The exploration, mining feasibility and mining plans were completed in mid-seventies and at that time the project was estimated to cost only Rs. 2.4 billion. However, no funds were provided and it was kept in hibernation till 1990, when development started and the mining project was completed in 1996 at a cost of Rs. 14 billion. This clearly reflects upon the low priority we have given to the mineral sector. The government has now, however, leased out the project to a Chinese group and production of copper blister may start soon..

Apart from Saindak we have several other deposits of porphyry type copper with gold, silver and molybdenum. Production from these deposits will not only provide valuable foreign exchange, but will give impetus to industrialisation, and will induce installation of heavy industrial complexes.

Pakistan has large reserves of iron ore (Table 20), yet we are importing iron ore to the tune of Rs. 1.2 to 1.3 billion per annum. Whereas some further metallurgical research may be warranted on the Kalabagh iron ore before it is used for the steel industry, the Dilband ore and the iron ore deposits of Chagai are of good quality and it has been shown that these may be used in the Karachi Steel Mill. These valuable ores need to be mined and utilised most expeditiously.

The vast deposits of nepheline syenite in NWFP are lying unutilised. These have the potential for extensive development for use in glass, ceramics, steel (steel casting), cement, potash and soda ash industries and manufacture of alumina. A beginning can be made by first using this ore for less costly ventures (glass and ceramics) and then gradually work our way to the more complex process of alumina extraction.

With large economic, albeit unutilised deposits of five of the most important metals, iron, copper, aluminium, lead and zinc, along with substantial deposits of chromite (which we are not using but exporting), we have most of the resources needed to rapidly develop medium to heavy industries. One would say that the main impediment is the lack of capital investment. Every developing country has faced this problem and some have solved it through wise pragmatic national policies. We need to examine these success stories and evolve our own strategies. For our survival it is now a matter of now or never.

Pakistan is fortunate in having large gas reserves (recoverable reserves 20.66 trillion cubic feet or about 365 million TOE). However our crude oil reserves are very meagre (recoverable reserves only about 253 million barrels or 34 million TOE). The pace of our oil and gas exploration has been relatively slow. Our prospective sedimentary basins have an area of approximately 827,000 sq kilometres and in the last 50 years only about 480 exploratory wells have been drilled, averaging about 10 well/year or one well per 1,725 sq kilometres. Yet we have been lucky and our success rate has been much above the normal average, having made 135 discoveries (56 oil, 79 gas) with a success rate of 1: 3.6. Considering our vast sedimentary basins, extensive development of source, reservoir and cap rocks and favourable geothermal gradients, theoretically a resource potential of 200 TCF (4,600 million TOE) of gas and 40 billion barrels (about 5,360 million TOE) of oil is possible (Pakistan Energy Year Book 1999, Kadri 1995). However, these figures are highly speculative. Up to date exploration results show that there are small oil-fields in the upper Indus Basin (Potwar and surrounding region) and in the Lower Indus Basin (Badin and vicinity) and that natural gas is largely concentrated in the middle part of the basin, in the vicinity of the Sui-Jacobabad-Khairpur High.

In our view there are bright chances of finding more gas-fields in the middle part of the Indus Basin. Our hope of finding large oil-fields is now largely centred around the lesser explored areas of the offshore and the unexplored Kharan and Kakar Khorasan Basins. Oil exploration in these inaccessible regions would not only be expensive, but is fraught with risk. Foreign oil companies can only be attracted to these areas if the government further liberalises its policies and provides greater incentives.

We now come to our largest mineral resource, the coal. Our measured coal reserves are estimated at over 194 billion tonnes, which puts us as a country with the sixth largest coal reserves in the world:-

1.	USSR(former) - - -	4,405 billion tonnes
2.	USA - - - - -	1,570
3.	China - - - - -	1,566
4.	Australia - - - -	785
5.	Germany- - - - -	285
6.	Pakistan - - - - -	194
7.	Great Britain - - -	190
8.	Poland - - - -	184

We are however, using a mere 3 million tonnes of coal annually. The true significance of our coal resources becomes apparent when we consider that these resources, in terms of provision of energy are equal to about 7,000 million TOE. As compared with this our total recoverable natural gas reserves today are a mere 20.66 trillion cubic feet which is about 365.7 million TOE (Pakistan Energy Year Book 1999). Even more important is the fact that about 175 billion tonnes of coal is located just in one coal field - the Thar. For our energy requirements we are at present heavily dependent on imported oil which is costing us US $ 1.5 billion (20% of our export earning), and we are now contemplating to substitute as much of the imported oil with indigenous natural gas as possible. Our present utilisation of natural gas is over 950 billion cubic feet annually (about 22 million TOE). This demand is projected to grow to about 1,570 billion cubic feet annually (about 36 million TOE) in the next 10 years (Pakistan Energy Year Book 1999). Our gas reserves would therefore have a sharp decline. It is thus imperative that the development of our coal resources be given high priority. Power generation from low grade coal is a well established technology now. We in Pakistan seem to suffer from some form of coal phobia, when other countries of the world relie heavily on coal for energy as may be seen from the following data regarding coal-fired power generation in various countries:

Share of coal % in power generation (1998).
(From World Coal Institute, London)

Poland	96	Greece	70
S. Africa	90	Denmark	57
Australia	86	UK	58
China	81	USA	56
India	75	Germany	51
Czech Rep.	73	Overall	37

In terms of cost also the coal based power generation is relatively less expensive as may be seen from the following data:-

USA Electricity generation costs
(Data from Sindh Coal Authority)

Fuel source	Cost (US cents/MWH)
Coal	1.9
Gas	2.0
Oil	2.5
Wind	4.0
Biomass	7.0
Thermal Solar	16.0

In recent years with the installation of 150 megawatt power plants at Lakhra a beginning has been made in the generation of coal-based power. Lakhra coal field has reserves of 1.64 billion tonnes of coal. It is very conveniently located close to the railroad, highways, power transmission lines, River Indus and the power load centres. Hundreds of test holes have been drilled to prove the coal reserves and enable preparation of mine plans. This source can be very quickly and easily developed to produce sufficient coal for a number of medium-size 300-500 megawatt power plants.

Close to Lakhra and south of it lies the Sonda coal-field with coal reserves of about 7.3 billion tonnes. A significant part of the reserves contain low sulphur (below 3%). Like Lakhra, this deposit is also very conveniently located along the super-highway, the main railway line, power transmission lines, the Indus River and areas of major power load. For exploitation of Lakhra and Sonda coal, a minimum of infrastructural development would be needed. However, mining feasibility studies need to be done expeditiously so that an early decision could be taken for its development. Subject to a favourable feasibility study this coal field can be opened up within a reasonably short time.

The Thar coal-field is significant from the standpoint of its vast reserves, thick, massive coal seams at relatively shallow depths which can be economically and conveniently mined through open cast mining method. Unlike Lakhra and Sonda, development of this field will require a large outlay on infrastructure, and mining and power generation would be economical only if very large quantities of coal (in the range of 10-50 million tonnes) are produced. Apart from coal, there are excellent chances of tapping large quantities of potable water in the desert region, as well as obtaining some kaoline as byproduct. Mining and power development feasibility studies should be undertaken at the earliest so that decisions may be taken for its exploitation.

From the above account and as may be seen from the discussions in the previous chapters, Pakistan may now be included amongst the mineral rich countries of the world. We have a large number of proven deposits that are not being exploited and we have excellent prospects of finding and discovering other valuable mineral deposits. This mineral wealth can enrich the nation only when it is utilised. We need to give high priority to mineral exploration, development and utilisation. To achieve this goal it is essential that we review and revise the present policies on a national basis. They should be made more realistic, effective and capable of taking up the task of mineral exploration, development and utilisation on an emergent basis. They should produce results within a reasonable span of time. Uptil now almost the entire mineral production has been in the private sector. Given the necessary incentives, support, technical assistance and a climate of confidence and trust, the private sector in Pakistan is capable of much investment and development, at least of the small to medium size deposits and will surely play an active role in harnessing the larger ones also.

All our mineral wealth is of no value or benefit to the nation if it continues to lie buried and unutilised.

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