Overview of the Geography, Geology, and Structure of the Potwar Regional Framework Assessment Project Study Area, Northern Pakistan

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Chapter A of
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Overview of the Geography, Geology, and Structure of the Potwar Regional Framework Assessment Project Study Area, Northern Pakistan

By Peter D. Warwick

Abstract

A 32,000-square-kilometer area in northern Pakistan, which includes the Salt Range and the Potwar Plateau, has been the subject of a multidisciplinary Regional Framework Assessment Project by the U.S. Geological Survey and the Geological Survey of Pakistan. The framework project was designed to produce a wide-ranging geologic data base for the coal-producing areas in the Potwar area of northern Pakistan and will, the authors hope, serve as a model for other multidisciplinary geologic studies in Pakistan. The following eight chapters in this Bulletin contain a compilation of the regional geology and structure of the study area, studies of the biostratigraphy and sedimentology of coal-bearing units, review of the economic minerals, and environmental studies.

These reports focus on a semiarid area that contains diverse physiographic features ranging from river flood plains to mountain ranges. Rocks exposed in the area range in age from Precambrian to Holocene and are part of the active foreland fold-and-thrust belt of the Himalayas of northern Pakistan.

Introduction

The purpose of this paper is to provide a geographic and geologic introduction to the Potwar Regional Framework Assessment Project (PRFAP) study area. The papers in this volume are products of a cooperative program between the Geological Survey of Pakistan (GSP) and the U.S. Geological Survey (USGS), sponsored by the Government of Pakistan and the U.S. Agency for International Development (USAID). The focus of the program, the Coal Resources Exploration and Assessment Program (COALREAP), is to explore and assess Pakistan's indigenous coal resources. As part of COALREAP, GSP and USGS geologists, from 1988 to 1991, conducted regional geologic studies (PRFAP) of the coal-bearing areas in the Potwar region of northern Pakistan outlined by lats 32°22′ N. and 34° N. and longs 71°30′ E. and 73°30′ E. (figs. A1, A2).

The PRFAP was designed to provide training to GSP geologists in various aspects of geology. The results of the project, contained in chapters B through I of this volume, consist of a series of papers and maps addressing the regional geology, paleontology and carbonate geology, environments of deposition for coal-bearing rocks, and energy and mineral resources of the study area. A detailed environmental study of the capital area of Islamabad is also provided. These maps and studies will, the authors hope, provide a valuable data base for further exploration and development.

Acknowledgments

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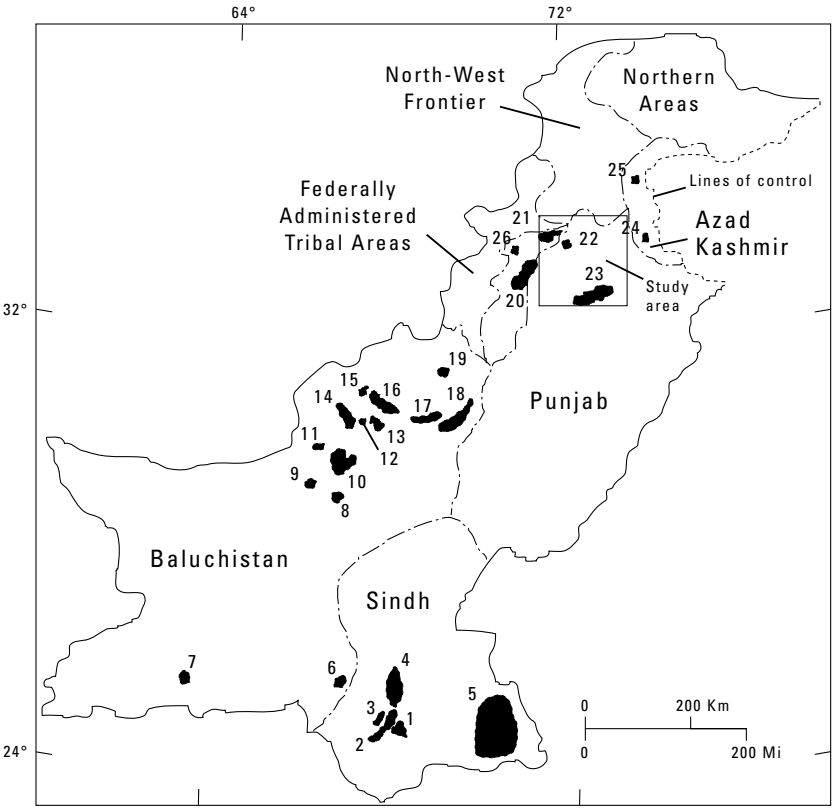
Cultural and Physical Geography of the Potwar Regional Framework Assessment Project Study Area

The PRFAP study area covers approximately 32,000 square kilometers (km^2) (fig. A1). The image base map (pl. A1) used by the various groups in this study is a geometrically corrected mosaic of Landsat MSS scenes. Most of the area is within the Punjab; however, parts of the northwestern and northeastern study area extend into the North-West Frontier Province (NWFP). The boundary for these two provinces

generally follows the Indus River. The largest cities within the study area are Rawalpindi, which is the second largest city in Pakistan; Islamabad, the capital of Pakistan; and part of Peshawar, the provincial capital of the NWFP. Other important towns in the area are Khewra and Mianwali in the southern part of the area; Kalabagh, Attock City, and Chakwal in the central part of the area; and Murree and Haripur in the northern part of the area (pl. A1).

The major cities and smaller towns are connected by a complex network of roads, most of which are paved but not always in good repair. Rail lines connect the major cities. An extensive network of irrigation canals provides water for agri-



Coal fields

1 Sonda East
2 Sonda West
3 Meting-Jhimpir
4 Lakhra
5 Thar
6 Dureji
7 Balgor
8 Sanni
9 Johan
10 Mach-Ab E Gum
11 Abi Gul
12 Margat
13 Pir Ismail Ziarat
14 Sor Range-Daghari
15 Kach
16 Khost-Sharig-Harnai
17 Duki
18 Chamalong
19 Badinzai
20 Makarwal-Kurd-Sho
21 Cherat
22 Choi
23 Salt Range
24 Kotli
25 Khilla Muzaffarabad
26 Hangu

Figure A1. Location of Pakistan coal fields and occurrences. Box shows Potwar Regional Framework Assessment Project study area (after Schweinfurth and Hussain, 1988).

culture in areas near the Indus and Jhelum Rivers. The central part of the study area, which includes the Potwar Plateau, is not irrigated but is arable.

The climate of most of the area is semiarid and has less than 25 centimeters (cm) of rainfall per year. The higher elevations of the northern part of the area receive more than 100 cm of rainfall per year (Ahmad, 1969). Minimum and maximum mean temperatures in Rawalpindi (at an elevation of 510 meters (m)) are 14.8°C and 28.9°C, respectively (Nyrop and others, 1975). Temperatures vary in the study area relative to elevation.

The greatest elevation in the Potwar area is located in the Southern Hazara Range (fig. A2), where elevations commonly exceed 1,200 m above sea level. The lowest elevations in the area are associated with the Indus and Jhelum River Plains, where river levels are lower than 300 m. The elevations on the Potwar Plateau are generally between 300 and 600 m.

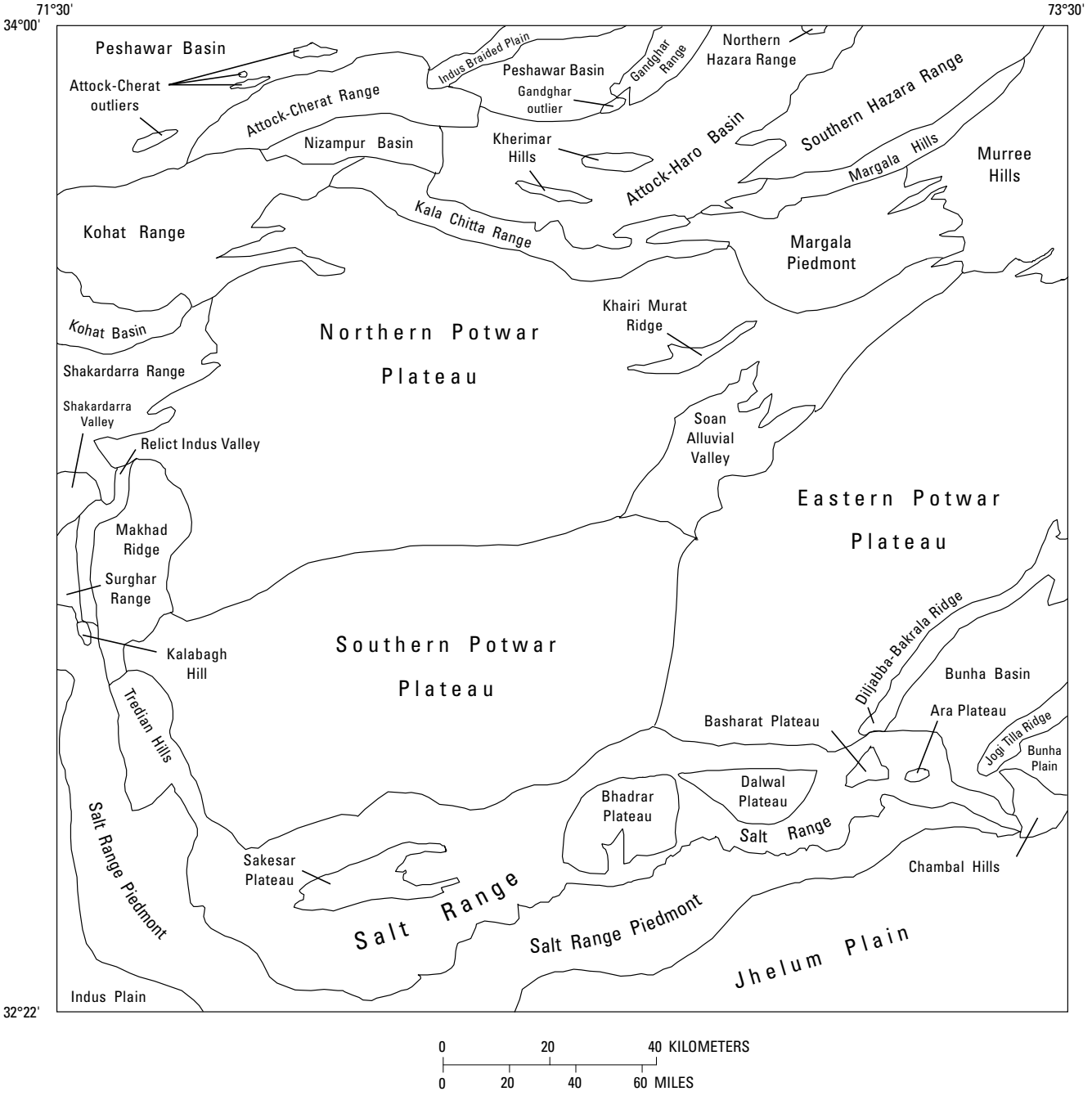


Figure A2. Generalized map showing the various physiographic features of the Potwar Regional Framework Assessment Project study area.

The principal river in the Potwar area is the Indus, which flows south through the western part of the study area (pl. A1). The Kabul River flows east out of Afghanistan and joins the Indus near Attock City in the northwestern part of the study area. The major drainage in the central part of the Potwar Plateau is toward the west via the Soan River, which joins the Indus River northeast of the town of Kalabagh. The Jhelum River joins the Indus River south of the study area.

Forty-two physiographic regions can be defined in the Potwar study area (fig. A2), including plateaus, flood plains, valleys, basins, hills, ridges, piedmonts, and ranges (table A1). The names of the physiographic features in this report were obtained from previously published names or from locality names in the area of the feature. The boundaries of the features were generally defined by the outline of the physiographic feature that can be observed on the 1:250,000-scale image base map of the Potwar region (pl. A1).

The dominant physiographic feature in the study area is the highly dissected Potwar Plateau, which covers about 18,000 km^2 in the central part of the area (Elahi and Martin, 1961). The southern part of the study area contains part of the Jhelum and Indus Plains, which extend for hundreds of kilometers south and east of the Salt Range. In the study area, these plains are covered by alluvium from the Jhelum and Indus Rivers. The Salt Range and its associated piedmont, plateaus, and hills lie north and east of these alluvial deposits. East of the Salt Range are the Bunha Basin and Plain, which drain into the Jhelum Plain a few kilometers east of the study area.

The western and northwestern parts of the study area consist of tectonically active ranges and valleys. The Relict Indus Valley (fig. A2) appears to have been the former position of the Indus River that was forced to occupy its present position due to tectonic uplifts (McDougall, 1989). The Kohat Plateau, as discussed by Fatmi (1973) and Yeats and Hussain (1987), has been divided into several regions, including the Shakardarra Valley and Range and the Kohat Basin and Range. North and east of the Kohat Range are the Attock-Cherat and Kala Chitta Ranges and the Indus Braided Plain. The Peshawar and Attock-Haro Basins extend along the northwestern and central borders of the study area. The northern and northeastern parts of the study area are characterized by several mountain and hill ranges, which include the Southern Hazara Range, the Margala and Murree Hills, and their associated piedmont aprons.

Table A1. Physiographic features and regions of the Potwar Regional Framework Assessment Project study area.

Feature	Area
Plateau	Sakesar
	Bhadrar
	Dalwal
	Basharat
	Ara
	Eastern Potwar
	Southern Potwar
	Northern Potwar
	Kohat (consists of the Shakardarra Valley and Range and the Kohat Basin and Range)
River flood plain	Indus Plain
	Jhelum Plain
	Bunha Plain
	Indus Braided Plain
Valley	Soan Alluvial
	Relict Indus
	Shakardarra
Basin	Bunha
	Kohat
	Nizampur
	Attock-Haro (Campbellpore)
	Peshawar
Hill	Tredian
	Kalabagh
	Chambal
	Kherimar
	Margala
	Murree
Ridge	Jogi Tilla
	Diljabba-Bakrala
	Makhad
	Khairi Murat
Piedmont	Salt Range
	Margala
Range	Surghar
	Salt
	Shakardarra
	Kohat
	Kala Chitta
	Attock-Cherat
	Gandghar
	Southern Hazara
	Northern Hazara

Geology of the Potwar Regional Framework Assessment Project Study Area

Stratigraphy

The stratigraphic succession exposed in the study area ranges in age from Precambrian to Quaternary. In the Attock-Cherat Range and the Hazara Ranges (fig. A2), Precambrian limestone, argillite, and quartzite form the base of the exposed stratigraphic section, which is thrust over younger strata in many places (Yeats and Lawrence, 1984; Hylland, 1990). In

the Salt Range area, thrusts and associated salt diapirism bring to the surface strata containing evaporites of Precambrian age (Gee, 1980, 1989). These ductile evaporites underlie the Potwar Plateau and form a zone of décollement for regional thrusting (fig. A3; Butler and others, 1987; Jaumé and Lillie, 1988; Pennock and others, 1989). The evaporites are locally interlayered with or intruded by igneous rocks of the Khewra Trap (Martin, 1956; Faruqi, 1986; M.Q. Jan, University of Peshawar, oral commun., 1992).

Overlying the Precambrian rocks in the study area is a sedimentary sequence of Cambrian, Permian to Middle Cretaceous, Paleogene, and Neogene strata (Shah, 1977; Gee, 1980; Baker, 1988). The absence of Ordovician through Carboniferous and Upper Cretaceous rocks across much of the area marks some of the major unconformities in the stratigraphy (Shah, 1977). However, limestone, shale, and quartzite of probable Silurian and Devonian age, which are intruded locally by diabase, are exposed in the Attock-Cherat Range (Yeats and Hussain, 1987, 1989). Oligocene sedimentary rocks are generally absent from the study area because of the major unconformity between Eocene and Miocene rocks. The Miocene clastic rocks were shed from the ongoing Himalayan uplifts associated with the collision of the Indian subcontinent and Asia (Yeats and Lawrence, 1984).

The sedimentary rocks exposed on the Potwar Plateau and adjacent Kohat Plateau are Eocene limestone, evaporites, and red beds; Miocene to Pleistocene fluvial sediments and terrace gravel and loess; and Holocene alluvium (Elahi and Martin, 1961; Wells, 1983, 1984; Rendell, 1988; Warwick and Wardlaw, 1992). Much of the area is covered by terrestrial Neogene foreland-basin deposits (Burbank and Raynolds, 1988).

The Paleozoic, Mesozoic, and Cenozoic sequence exposed in the Salt Range underlies the alluvial cover of the Jhelum and Indus Plains south of the study area (Yeats and Lawrence, 1984). Exploratory drilling immediately south of the Salt Range has shown that pre-Miocene erosion has removed Cambrian to Eocene rocks in that area (Baker and others, 1988).

Structure

The Potwar Plateau region is an area of active oil and gas exploration and production. Recent studies (Butler and others, 1987; Leathers, 1987; Baker and others, 1988; Jaumé and Lillie, 1988; Pennock, 1988; Pennock and others, 1989; Raza and others, 1989; Hylland, 1990; Jaswal, 1990; McDougall and Hussain, 1991) have combined seismic-reflection profiles, petroleum exploration well logs, Bouguer gravity anomaly maps, and surface geology to construct regional structural cross sections that detail the thrust-related tectonics of the area (fig. A3).

The study area (fig. A4) is part of the active foreland fold-and-thrust belt of the Himalayas of northern Pakistan (Burbank and Raynolds, 1988; Jaumé and Lillie, 1988; Pennock and others, 1989). The area consists of several structural-tectonic subdivisions (fig. A4), such as the Salt Range along the southern part of the area, the Kohat Plateau along the western part of the area, the Potwar Plateau in the central part of the area, and the Northern Folded Zone and the Kala Chitta Fold Belt along the northern part of the area (Khan and others, 1986; Gee, 1989).

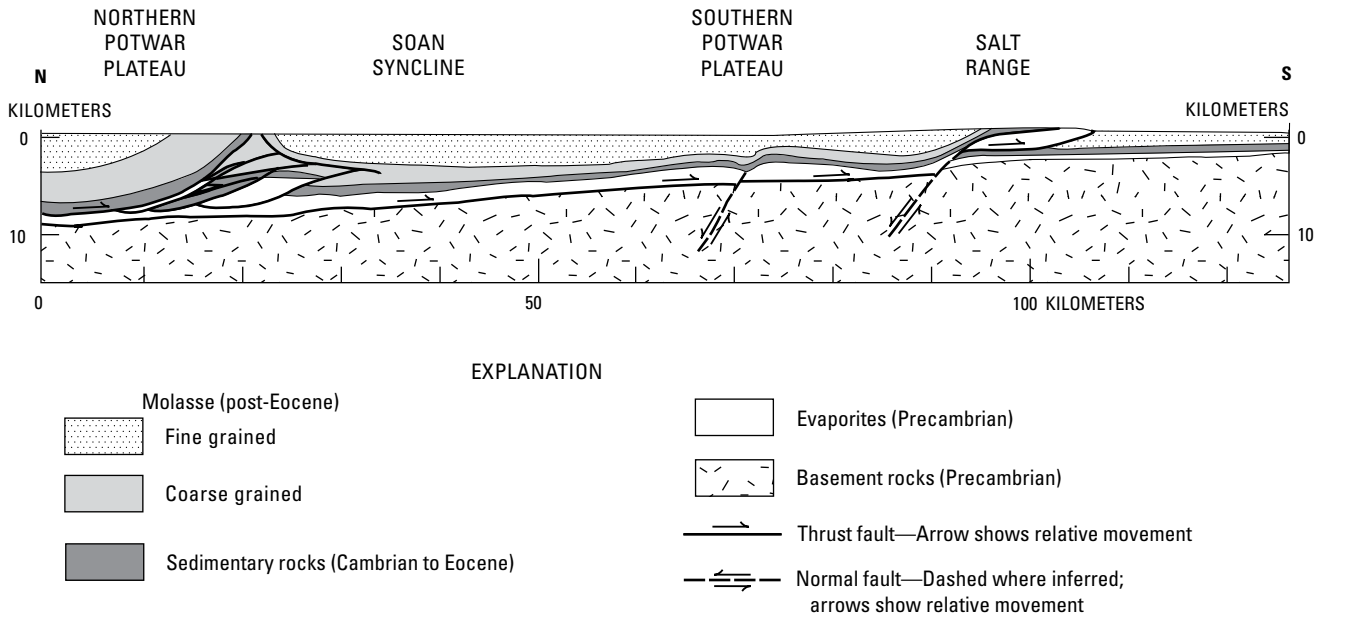


Figure A3. Generalized cross section across the western Potwar Plateau and the west-central Salt Range (after Jaumé and Lillie, 1988; Gee, 1989).

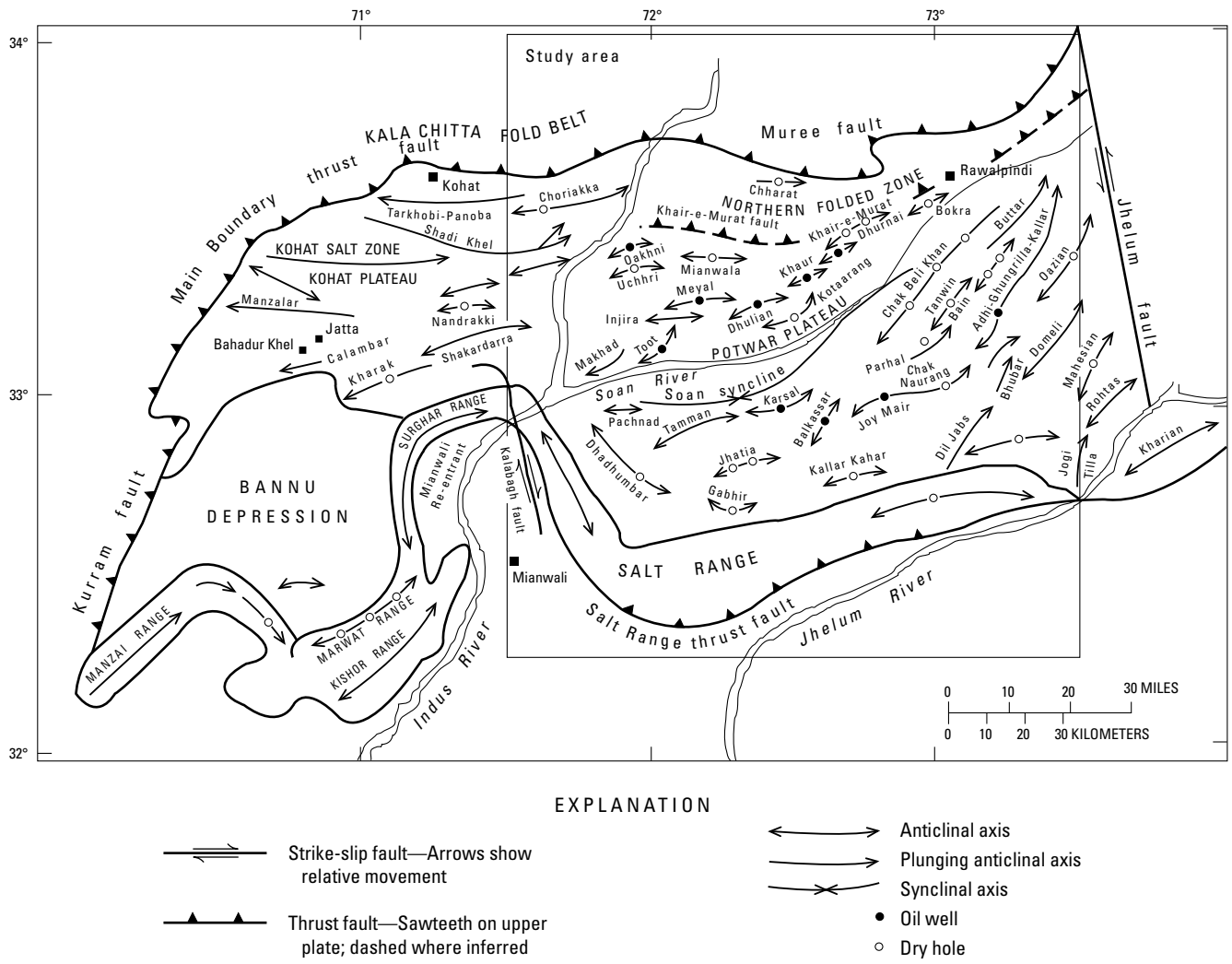


Figure A4. Structural map of the Kohat-Potwar Plateaus, northern Pakistan (after Khan and others, 1986; Gee, 1989).

The Salt Range is the surface expression of the leading edge of décollement thrusts over northward offsets of the crystalline basement (Crawford, 1974; Seeber and Armbruster, 1979; Yeats and Lawrence, 1984; Yeats and others, 1984). Seismic and drill-hole data indicate total southward displacement of the Salt Range and Potwar Plateau of at least 20 kilometers (km) (Farah and others, 1977; Johnson and others, 1986; Baker, 1988; Lillie and others, 1987; Baker and others, 1988). The western part of the Salt Range is characterized by a major strike-slip fault that extends along the western Salt Range and Indus River (Baker and others, 1988; McDougall and Khan, 1990).

In the central part of the study area, paleomagnetic data indicate that counterclockwise, thrust-related rotation of the Potwar Plateau rocks generally increases from less than 10° in the western part to more than 50° in the eastern part of the plateau (Johnson and others, 1986). The southern part of the Potwar Plateau is characterized by northward-dipping strata and local open folds of low structural relief and axes that generally parallel the trend of the Salt Range (fig. A4). The northern part of the Potwar area is characterized by strong folding and thrust faulting; the major structural trends change from east trending in the western part of the area to northeast trending in the eastern part of the area. The Soan River generally flows through the Soan syncline, which is a major structural downwarp with a sedimentary pile more than 5 km thick in the central part of the study area (Leathers, 1987; Baker, 1988).

The Northern Folded Zone is characterized by stacked imbricate thrusts within the sedimentary pile, which are separated by salt-glide zones (Jaswal, 1990). Thrust faulting in the Kala Chitta Fold Belt, which consists of the Attock-Cherat, Gandghar, and Hazara Ranges, brings Precambrian basement rocks to the surface (Yeats and Hussain, 1987, 1989; Hylland, 1990).

The Kohat region, west of the Potwar area, has not been a major target for oil and gas exploration in the past. However, preliminary results from recent seismic surveys in the area indicate that the regional thin-skinned thrusting common in the Potwar area may be replaced by transpressional structural

features with significant vertical displacements (>3 km) that bring Mesozoic and Cenozoic rocks to the surface (Pivnik and Sercombe, 1992).

Overview of the Potwar Regional Framework Assessment Project Studies

The following chapters in this Bulletin cover various aspects of the geology of the PRFAP study area. These study topics are paleontology and carbonate geology, environments of deposition for coal-bearing rocks, environmental geology, and energy and mineral resources of the study area.

Chapters B–F provide a basic biostratigraphic framework for the Paleocene and lower Eocene rocks within and surrounding the PRFAP study area. These contributions are discussed in the editors' preface by P.D. Warwick and B.R. Wardlaw. L.M. Bybell and J.M. Self-Trail (chap. B) examined nannofossil floras from the Nammal Dam area, western Salt Range, and from a drill hole located on the Dalwal Plateau, eastern Salt Range (fig. A2). L.E. Edwards (chap. C) discusses dinocyst occurrences from the Nammal Dam area, the Dalwal Plateau area, and the Basharat Plateau area of the eastern Salt Range (fig. A2). N.O. Frederiksen and others (chap. D) report spore and pollen assemblages from several stratigraphic sections and drill holes in the western, central, and eastern parts of the Salt Range. T.G. Gibson (chap. E) reports on benthic and planktic foraminifers from the Nammal Dam area and the Dalwal drill hole. B.R. Wardlaw and others (chap. F) describe the sections and selected drill holes sampled for paleontological examination around the Potwar Plateau and provide a preliminary sequence-stratigraphic model for Paleocene and Eocene deposition.

Chapter G, by Iqbal Sheikh and others, reviews the environmental geology of the Islamabad area. Environmental and geologic maps of the Islamabad-Rawalpindi area are presented at scales of 1:50,000 and 1:100,000. Harald Drewes and others (chap. H) discuss the occurrence of selected minerals and industrial commodities within the PRFAP study area and present the data on a 1:250,000-scale map. P.D. Warwick and Tariq Shakoor (chap. I) analyze the depositional environments of the coal-bearing Paleocene Patala Formation in the Salt Range, which is the primary coal-producing area in the PRFAP study area.

Finally, a review of the geology and structure of the PRFAP area may be found in Drewes (1995).

Conclusions

As the demand on water, energy, mineral, and agricultural resources of northern Pakistan continues to grow, planning agencies should have available to them geologic data on which to base informed decisions. The results presented in this volume on the geology of the Potwar Regional Framework Assessment Project area should serve as a tool for continued development and growth in the Potwar region and as a guide for future multidisciplinary, geologic evaluations of other areas in Pakistan.

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