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PRELIMINARY GEOLOGIC MAP OF PARTS OF LORALAI, SIBI, QUETTA, AND KHUZAR DIVISIONS, BALOCHISTAN PROVINCE, WEST-CENTRAL PAKISTAN

By

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INTRODUCTION

The area covered by this generalized geologic map is located in west-central Pakistan (fig. 1) and is a product of the Balochistan Coal-Basin Synthesis Study that was part of a cooperative program of the Geological Survey of Pakistan and the United States Geological Survey. Funding was provided by the Government of Pakistan and the United States Agency for International Development through Project 391-0478: Energy Planning and Development Project (Coal Resources Exploration and Assessment Project) component 2A; Participating Agency Service Agreement no. IPK-0478-P-I-1-5068-000. The sources of geologic map data are primarily 1:253,440-scale geologic maps obtained from Hunting Survey Corporation, Limited (1961) and the geologic map of the Muslim Bagh Ophiolite and Bagh Complex area (Mengal and others, 1993). The geology was modified based on reconnaissance field work and photo interpretation of 1:250,000-scale Landsat Thematic Mapper photo image. The description and thickness of map units were based on published and unpublished reports (mainly Hunting Survey Corporation, Limited, 1961; Fatmi, 1977; Cheema and others, 1977; and Shah, 1977). Informal unit names are indicated by a lower-case letter for the "rank" or lithic term (for example, Nasai formation and Shaigalu sandstone) following Geological Survey of Pakistan style. In the nomenclature of the Geological Survey of Pakistan Survey, there is a Urak Group and a Urak formation.

The cross sections were constructed using a passive roof-thrust duplex model that was first applied in the Sulaiman and Kirthar Ranges (fig. 1) by Banks and Warburton (1986). Humayon and others (1991) and Jadoon and others (1994) show cross sections for parts of the map area and areas contiguous with the map area. Bannert and others (1992) also show cross sections in their report that discusses the western fold belt of Pakistan that includes part of the map area at a scale of 1:500,000. The thrust faults are shown as high-angle faults (reverse faults) whose angles decrease with depth. Some of the faults have been folded so that their original geometries are not known. Cross section B-B' shows a hinge line that represents a change in apparent thrust fault vergent direction from east-southeast to south-southwest. This change in apparent vergent direction probably reflects subsequent bending (folding) or rotation of the terrane containing these thrust faults. The thrust faults prior to the subsequent deformation probably had similar vergent directions.

STRUCTURAL NOTE

The map area is divided into five major structural domains (fig. 2) (Maldonado and others, 1993). Except for the surficial deposits, the map units are largely described with the various structural domains, beginning with the youngest domain (I) and ending with the oldest (V) (see Description of Map Units). The five domains are as follows: (I) the Sibi-Urak trough (molasse deposits), (II) the Pishin flysch province (flysch deposits), (III) the Sulaiman fold and thrust belt (predominately marine shelf sequence), (IV) the Afghanistan block (intrusive rocks), and (V) the Muslim Bagh Ophiolite Complex and the Bagh Complex (ophiolite, melange, intrusive, and sedimentary rocks).

The map area contains two types of thrust faults: faults that predominately place older strata on younger strata and faults that place younger strata on older. The older-on-younger strata may represent deformation that resulted from the collision of the Indo-

Pakistan tectonic block with the Eurasian tectonic block during the Eocene (Powell, 1979). Some of the younger-on-older strata may represent (1) obduction of the Muslim Bagh Ophiolite Complex onto rocks of the Bagh Complex during the Late Cretaceous to early Paleocene (Kojima and others, 1994) and (2) formation of the roof-thrust fault as a possible result of the collision of the Indo-Pakistan tectonic block with the Eurasian tectonic block.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qay **Young alluvium (Holocene)**--Includes gravel, sand, silt, and silty clay derived from the surrounding mountains and older alluvium; present in areas of low relief in intermontane valleys and along present stream channels. The deposits show little dissection

Qao **Old alluvium (Holocene and upper Pleistocene)**--Gravel, sand, silt, and silty clay locally derived and deposited as valley fill. Locally covered by loess. Deposits are semiconsolidated and are presently being dissected by stream erosion

(I) MOLASSE DEPOSITS

Qb **Bostan Formation (Pleistocene)**--White, light-gray, red, maroon, and light-green clay, conglomerate, and gray, brownish-gray, and maroon sandstone. Clay is poorly consolidated, silty, gypsiferous, and of lacustrine origin. Conglomerate contains subrounded pebble- and boulder-size clasts of limestone, sandstone, and volcanic and ultramafic rocks. Sandstone is fine to coarse grained and has salt and pepper texture; sandstone beds are widely spaced and interlayered with boulder conglomerate. Upper contact is unconformable or transitional with alluvial deposits. Lower contact is unconformable with Multana formation (informal) and forms an angular unconformity on older strata (Shaigalu sandstone and Murgha Faqirzai shale, Nisai formation (all informal), Shirinab Formation, and Loralai Limestone, described below). Exposed mostly in the northern part of map area in the Pishin Basin and north of the Zhob Valley (fig. 2, locs. 1 and 2). Cheema and others (1977) report a thickness of 750 m in the Pishin Basin

Qd **Dada Conglomerate (Pleistocene)**--Conglomerate and minor green-gray and brown sandstone. Conglomerate consists of limestone boulders and pebbles in a sandstone matrix, interlayered with subordinate sandstone lenses. Sandstone is coarse grained, pebbly, and crossbedded. Upper contact is commonly gradational into older alluvial deposits; lower contact is conformable or is disconformable. Exposed in the Sibi-Urak trough in the southern part of map area. Unit is about 1,000 m in the Urak area (Hunting Survey Corporation, Limited (1961) (fig. 2, loc. 3)

QTu **Urak Group, undivided (lower Pleistocene to Oligocene?)**--Includes, in descending order, the Urak, Shin Matai, and Uzdha Psha formations (all informal) (Kazmi and Reza, 1970). The individual units of the Urak Group were not mapped separately. The basal part of the Urak Group, as mapped by Hunting Survey Corporation (1961) also contains ferruginous and argillaceous shelly limestone beds of the Gaj and Nari Formations (not shown on map). These two formations are included locally as part of the Urak Group in the study area because of scale and lack of mapping information. In the Salt Range area about 350 km northeast of the map area (fig. 1), the Soan, Dhok Pathan, and Nagri Formations in the upper part of the Siwalik Group (Cheema and others, 1977) are equivalent to the Urak, Shin Matai, and Uzdha Psha formations, respectively. The Siwalik Group represents a

different basin of deposition from that of the Urak Group; therefore, the Urak Group nomenclature is preferred for the map area. The Urak Group is exposed mostly in the northern part of the Sibi-Urak trough (fig. 2) in the central part of map area

Urak formation (lower Pleistocene and Pliocene)--Mainly conglomerate; interlayered with subordinate varicolored sandstone, siltstone, and claystone. The conglomerate contains poorly sorted to well-sorted, subangular to well-rounded boulder- and pebble-size clasts composed of limestone, sandstone, chert, and igneous rocks in a sandy clay matrix. Lower contact is gradational with Shin Matai formation. Cheema and others (1977) reported that the equivalent Soan Formation is 1,500-3,000 m thick in the Quetta area (fig. 2). However, a thickness of 470-940 m may be more accurate

Shin Matai formation (Miocene)--Composed of a cyclic alternation of gray, light-gray, white, reddish-brown, brownish-gray, greenish-gray, and buff sandstone and orange, brown, red, and yellowish-gray claystone, and conglomerate. Sandstone is fine to coarse grained, crossbedded, calcareous, and moderately cemented. Claystone is calcareous and sandy. Lower contact is transitional. Cheema and others (1977) indicated that the equivalent Dhok Pathan Formation (that we call the Shin Matai formation) is 120-300 m in the Quetta area

Uzdha Psha formation (Miocene? to Oligocene?)--Greenish gray, bluish gray, red sandstone; contains interbedded pale-brown, reddish-gray, and pale-orange claystone and conglomerate. Sandstone is calcareous, medium to coarse grained, massive, crossbedded, and moderately to poorly cemented. Claystone is sandy and silty. Conglomerate contains Eocene limestone pebble clasts. Lower contact is variable and transitionally conformable with Gaj Formation. In areas where the Gaj and Nari Formations are absent, the lower contact of the Uzdha Pasha formation and the Kirthar Formation (Tk), older Tertiary units, and Mesozoic rocks is an angular unconformity and a disconformity (Hunting Survey Corporation, 1961). The equivalent Nagri Formation is approximate 600 m thick in the Urak area (fig. 2, loc. 3) (Cheema and others, 1977)

Gaj Formation (Miocene? to Oligocene?)--Greenish-gray, variegated, gypsiferous shale with subordinate greenish-gray, brown, calcareous, feruginuous crossbedded sandstone, and brown, yellowish-brown, white, argillaceous and fossiliferous limestone. Lower contact is transitionally conformable with the Nari Formation. The Formation is 90 m thick (Williams, 1959, Cheema and others, 1977) in the Sor Range (fig. 2)

Nari Formation (Miocene? to Oligocene?)--Upper part is composed of grayish-brown sandstone interbedded with medium olive-gray calcareous claystone and lenticular arenaceous and clastic limestone beds. Lower part is white to gray-brown, shelly and nodular, thin to thick bedded and massive limestone with thin dark shale and brown sandstone stringers. Lower contact with the Kirthar Formation is conformable. The Formation is about 200 m thick in the Sor Range (Cheema and others, 1977)

QTm **Multana formation (Pleistocene to Oligocene?)**--Informal unit consisting of conglomerate, gray-green sandstone, and light- to dark-green, and maroon shale. Conglomerate contains well-sorted, rounded to subrounded pebble- and boulder-size clasts of sandstone, limestone, marl, diorite, gabbro, and jasper in a calcareous sandy matrix. Locally, lower contact is unconformable on the informal Nisai formation (Tn). Exposed north of the Zhob Valley in northeastern part of map area. About 6,770 m thick near the town of Naweoba, (Hunting Survey Corporation, 1961) approximately 110 km northeast of map area

Ts **Sibi Group (Pliocene to Oligocene)**--Green, grayish-orange, and maroon sandy shale interbedded with gray, green, and red sandstone and subordinate pebble conglomerate, and minor brown limestone. Sandstone is poorly sorted, coarse grained, gritty, pebbly, and crossbedded. Conglomerate contains well-rounded to subangular clasts of chert, limestone, and sandstone. Limestone is found only in the lower part of group. Lower contact is disconformable with the Spintangi Limestone, which is not mapped separately but is included with Kirthar Formation (Tk). Equivalent, in part, to the Urak, Shin Matai, and Uzdha Psha formations of the Urak Group (QTu). Exposed mostly in the southern part of the Sibi-Urak trough, southeastern part of map area. Hunting Survey Corporation (1961) reports unit is 7,190 m thick in the Sibi-Urak trough area (fig. 2)

(II) FLYSCH DEPOSITS

Tsm **Khojak group, undivided (Miocene to Eocene)**--An informal unit that contains the Shaigalu sandstone and Murgha Faqirzai shale (both informal)

Shaigalu sandstone (Miocene and Oligocene)--Mainly light-gray and greenish-gray sandstone interbedded with green, gray, and pale-green shale. Sandstone is fine to coarse grained, locally gritty to pebbly, and thick bedded to massive. It is calcareous, micaceous, rarely ferrugenous or carbonaceous, and exhibits cross-stratification and ripple marks. Shale is dominantly calcareous, in places arenaceous, fissile to flaky, but, is locally blocky; locally is carbonaceous and contains lenses of lignite. Thin beds of gray sandy limestone are present locally in the lower part of the unit and is conglomeratic in the upper part. Limestone is argillaceous (rarely sandy) and fossiliferous. Conglomerate contains pebble-, cobble-, and boulder-size clasts of sandstone, limestone, marl, jasper, and igneous rocks in a sandy matrix. Lower contact is transitional and conformable with Murgha Faqirzai shale. The unit is 950-1,900 m thick in the Khwaja Amran Range (Hunting Survey Corporation, 1961) (fig. 2, loc. 4), its maximum thickness is 6,250 m in the Toba Kakar Range (fig. 2, loc. 5) in the northern part of map area

Murgha Faqirzai shale (Oligocene and Eocene)--Pale-gray, greenish-gray, green, and pale-brown shale; contains gray to green sandstone, pale-brown and yellowish-brown limestone, and pebble conglomerate. Shale is calcareous and flaky; it is the dominate rock in the unit and is more abundant in the lower part. Sandstone is calcareous, fine grained, and present in widely spaced beds throughout the shale sequence, but it is more abundant in

upper part of unit. Limestone is shaly, argillaceous, and fossiliferous near base of unit. Conglomerate contains pebbles of limestone and igneous rocks and occurs near base of unit. Locally, igneous pebbles present at base of unit. Parts of the unit have been pervasively metamorphosed to chlorite-sericite slate, schist, and quartzite. Lower contact is conformable with the Nisai formation. The Shaigalu sandstone and Murgha Faqirzai shale comprise a thick flysch sequence that filled a trough. The unit is 468-625 m thick in most areas (Hunting Survey Corporation, 1961), but it is about 1,250 m thick in the Khojak Pass area (fig. 2, loc. 6)

Tn **Nisai formation (lower Oligocene to lower Eocene)**--An informal unit; predominately gray and grayish-brown massive limestone interbedded with minor light-gray marl, gray, green, maroon, yellow, and brown shale, and gray, green, brown, and white sandstone and conglomerate. Limestone is highly fossiliferous, reefal, shelly, brecciated, and locally argillaceous. Marl is well bedded and grades into limestone or shale. Shale is fissile and locally calcareous, lateritic, and (or) carbonaceous. Sandstone is calcareous, fine to coarse grained, poorly to well sorted, quartzitic, thickbedded, and crossbedded. Conglomerate contains angular to rounded pebbles and boulders of limestone, marl, jasper, sandstone, and igneous rocks. Defined as Nisai Group by Hunting Survey Corporation (1961) but redefined as Nisai formation by Cheema and others (1977). Near the southwest corner of map area, the Nisai includes the Wakabi and Naimargh Limestones of Hunting Survey Corporation (1961), which are too thin to show separately at the map scale. Lower contact is an angular unconformity above Mesozoic sedimentary rocks and rocks of the Muslim Bagh Ophiolite Complex. Exposed in the northeastern and southwestern parts of map area. North of Nisai (fig. 2, loc. 16), thickness is about 1,200 m (Cheema and others, 1977)

(III) PREDOMINATELY MARINE SHELF SEQUENCE

Tk **Kirthar Formation (middle and lower Eocene)**--Light-gray and pale-brown, thickbedded to massive, highly fossiliferous limestone interbedded with gray and light-brown marl and olive, brown, and dark-gray shale. Marl and shale make up approximately 50 percent of the formation. Shale is calcareous and highly fossiliferous. Unit previously called the Brahui Limestone by Hunting Survey Corporation (1961), but later changed to Kirthar Formation by Cheema and others (1977). Locally includes Spintangi Limestone of Hunting Survey Corporation (1961). Lower contact is mostly transitional with Ghazij Formation, but where the formation overlies Mesozoic rocks it is unconformable. Exposed mainly along the edge of the Sibi-Urak trough. Thickness is 1,270 m (Cheema and others, 1977) in the Gaj River area, south of map area, but is much less in the map area

Tg **Ghazij Formation (lower Eocene)**--Divided into upper, middle, and lower zones by Hunting Survey Corporation (1961). Formation predominately exposed around the flanks of the Sibi-Urak trough

Upper zone--Predominately composed of reddish-weathering claystone and minor conglomeratic sandstone containing clasts of limestone and chert.

Locally, the upper zone contains thin layers of bog iron. Lower contact is conformable and locally unconformable (E.A., Johnson, oral commun., 1994). Thickness is about 215 m in the Mach area (fig. 2, loc. 7) to about 300 m near Harnai (Hunting Survey Corporation, 1961) (loc. 18, fig. 2) and as much as about 535 m in the Sor Range (S.R. Roberts, oral commun., 1994) (loc. 19, fig. 2)

Middle zone--Consists of medium- to dark-gray sandstone, gray to brownish-gray shale, minor calcareous siltstone and brown-weathering shelly limestone, and locally minable coal. The sandstone is thick bedded, mostly coarse grained, pebbly, poorly sorted, and commonly crossbedded. Lower contact conformable and transitional (E.A., Johnson, oral commun., 1994). Thickness is 30 m (S.R. Roberts, oral commun., 1994) to about 90 m (Hunting Survey Corporation, 1961) in the Sor Range and about 300 m in the Much area (Hunting Survey Corporation, 1961). Possible as much as about 2,440 m thick in the Bahlol area (Hunting Survey Corporation, 1961) located approximately 100 km east of map area

Lower zone--Composed of olive-green calcareous shale interbedded with thin, buff, medium-grained calcareous sandstone. Lower contact has been generally interpreted as an unconformity with the Dungan Formation, a unit that has been included with the map unit Tertiary and Cretaceous units undivided (TKu) and locally, as an angular unconformity where the formation overlies Paleocene, Cretaceous, and Jurassic rocks (Hunting Survey Corporation, 1961). The lower contact has also been interpreted as a thrust fault by Banks and Warburton (1986) that we have incorporated it into the geologic map. Thickness is about 915 m in the Sor Range to about 1,220 m in the Much area (Hunting Survey Corporation, 1961). As much as 2,225 m in the Johan area (Hunting Survey Corporation, 1961) located approximately 20 km south of map area

Tkg **Kirthar and Ghazij Formations, undivided**--Isolated outcrop about 12 km east of Shah Muhammad (loc. 17, fig. 2) in the southwestern part of map area

TKu **Tertiary and Cretaceous units, undivided (lower Eocene to Upper Cretaceous)**--Includes six geologic units ranging in age from early Eocene to Late Cretaceous that are shown as undivided because of lack of geologic detail. Includes the Siazgi limestone (informal), Rodangi Formation, Sanjawi limestone (informal), Dungan Formation of Cheema (1977), Karkh Group, and Brewery Limestone of Hunting Survey Corporation (1961). Exposed around the flanks of the Sibi-Urak trough, but predominately exposed on the northeast side of the trough

Siazgi limestone (lower Eocene and Paleocene)--Composed of light-gray limestone. Lower contact is conformable with Moro Formation (locally included with Mughal Kot Formation, upper most part of Mona Jhal Group (Km)). Exposed in the northeastern part of map area, west and south of Chinali (fig. 2, loc. 15). Maximum thickness 310 m (Hunting Survey Corporation, 1961)

Rodangi Formation (lower Eocene and upper Paleocene)--Pale-gray sublithographic and marly limestone, marl, interbedded grayish-green shale, and subordinate sandstone. Upper and lower contacts not exposed. Exposed west of Shah Muhammad. Thickness 155-250 m (Hunting Survey Corporation, 1961)

Sanjawi limestone (lower Eocene and Paleocene)--Cream-white and light-brown limestone. Lower contact is conformable on rocks of the Mona Jhal Group (Km). Exposed in the east-central part of map area near Sanjawi (fig. 2, loc. 14). Thickness 60-125 m (Hunting Survey Corporation, 1961)

Dungan Formation (Eocene and Paleocene)--Predominately light- to dark-gray and brown limestone and minor dark-gray, brown, and olive shale; interlayered with nodular limestone in the lower part of the unit. Lower contact with Mughal Kot Formation (uppermost formation of Mona Jhal Group (Km)) is mostly unconformable; contact is conformable in the Mach area. Locally, the contact with the Bibai Formation (Kb) is unconformable. North of Quetta, the contact is unconformable on Cretaceous and Jurassic rocks. Exposed along the western and eastern flanks of the Sibi-Urak trough. More than 310 m thick (Hunting Survey Corporation, 1961)

Karkh Group (lower Eocene and Upper Cretaceous)--Contains dark-gray, brown, and black limestone, yellow-weathering marl, conglomerate with clasts of limestone and chert, and marl-pebble conglomerate and olive shale interbedded with sandstone and minor mafic lava flows. Lower contact is conformable with the Moro Formation (locally included with Mughal Kot Formation of Mona Jhal Group (Km)) near Mach. Exposed west of Mach. Thickness 90-375 m (Hunting Survey Corporation, 1961)

Brewery Limestone (Paleocene and Upper Cretaceous)--Composed of chocolate-brown and dark-gray limestone. Laterite locally present in the lower part of unit in the Ziarat area (fig. 2, loc. 8). Lower contact with Mona Jhal Group (Km) and Jurassic rocks is unconformable. Exposed in the Chiltan Range southwest of Quetta, and southeast of Kach (fig. 2, loc. 12) and Gogai (fig. 2, loc. 13). Thickness 25-60 m (Hunting Survey Corporation, 1961)

Kb **Bibai Formation (Upper Cretaceous)**--Divided into upper and lower zones. Upper zone is a thick sequence of volcanic-boulder conglomerate interbedded with ash beds and tuff units . The ash beds contain various amounts of volcanic and nonvolcanic material. Tuff units, also interfinger with a sequence of coarse sandstone, argillaceous tuff, and mudstone. Lower zone is composed of interbedded agglomerate, tuff, and basalt lava flows. Basal part of lower zone is interbedded with Parh Limestone of the Mona Jhal Group (Km). Formation is mapped northeast of Quetta, but in the eastern part of map area it is included in the lower part of the Mughal Kot Formation of the Mona Jhal Group. Bibai Formation was named by Kazmi (1979) after Bibai Peak in the Gogai area (fig. 2, loc. 13). Unit is approximately 3,000 m thick in the Ziarat region (Kazmi, 1979)

KJm Mona Jhal Group, undivided (Upper and Lower Cretaceous and Upper Jurassic)--Originally defined as the Parh Group by the Hunting Survey Corporation (1961), but it was renamed and redefined by Fatmi and others (1986) to include, in descending order, the Mughal Kot Formation, Parh Limestone, Goru Formation, and Sembar Formation; may include Bibai Formation below the Mughal Kot Formation in eastern part of map area. Predominately exposed along the flanks of the Sibi-Urak trough

Mughal Kot Formation (Upper Cretaceous)--Dark-gray calcareous mudstone and calcareous shale intercalated with quartzose sandstone and light-gray argillaceous limestone. Lower contact with Parh Limestone is unconformable (Fatmi, 1977). The Mughal Kot Formation is exposed in the northeastern part of map area, southeast of Muslim Bagh (fig. 2) and the Ziarat-Kach area (fig. 2, locs. 8 and 12). Locally, unit includes the Moro Formation of Hunting Survey Corporation (1961). Thickness is 150-300 m in the Kach area (Fatmi, 1977)

Parh Limestone (Upper Cretaceous)--Light-gray, white, green, and olive-green, thin-to medium-bedded, lithographic and argillaceous limestone intercalated with subordinate gray calcareous shale and greenish-gray marl. Limestone is characterized by porcellaneous texture and conchoidal fracture and contains *Globotruncana* sp., and other foraminifera. Lower contact with Goru Formation is transitional. Exposed predominately around the flanks of the Sibi-Urak trough. Thickness is 300-600 m (Fatmi, 1977)

Goru Formation (Upper and Lower Cretaceous)--Light-gray to medium-gray and olive-gray thin-bedded limestone interbedded with greenish-gray and locally maroon siltstone and shale. Lower contact with Sembar Formation is conformable. Exposed mostly along the flanks of the Sibi-Urak trough and near and east of Gogai (fig. 2, loc. 13). Thickness is 60 m in the Quetta area (Fatmi, 1977)

Sembar Formation (Lower Cretaceous and Upper Jurassic)--Black silty shale with interbeds of black siltstone and gray argillaceous limestone; generally glauconitic, pyritic, and (in the basal part) locally contains phosphatic nodules and gray to green shale. Belemnites are commonly present. Locally, lower part of unit contains some Upper Jurassic rocks (Fatmi and others, 1986). Lower contact with the Chiltan Formation (Jc) in the western part of the map area and the Loralai Formation (Jal) in the eastern part is disconformable. Mostly exposed around the flanks of the Sibi-Urak trough and near and east of Gogai (fig. 2, loc. 13). Thickness at the type section in the Marri-Bugti area, approximately 30 km east of the map area, is approximately 135 m, but thickness is less in the vicinity of Quetta and Ziarat (fig. 2, loc. 8) (Fatmi, 1977)

TKJd Dungan Formation and Mona Jhal Group, undivided (Eocene to Lower Cretaceous and Upper Jurassic)--Includes Dungan Formation of the Tertiary and Cretaceous units undivided (TKu) and Mughal Kot Formation, Parh Limestone, and Goru and Sembar Formations of the Mona Jhal Group

(KJm). Unit is present in northeastern part of map area southeast of Bagh (fig. 2, loc. 9)

Jc **Chiltan Formation (Middle Jurassic)**--Predominately light- to dark-gray, black, brownish-to bluish-gray and in places white, massive to thick-bedded limestone; fine grained, oolitic, reefoid, and shelly. Veins and nodules of chert present locally. Lower contact is transitional with Shirinab Formation. Exposed predominately in the western part of map area and on the northwestern end of the Sibi-Urak trough. Approximate thickness is 1,800 m in the Quetta area (Hunting Survey Corporation, 1961)

Js **Shirinab Formation (Middle and Lower Jurassic)**--Predominately gray to dark-gray and black, thin- to medium-bedded limestone interbedded with gray to dark-gray, yellowish-gray, and black shale; locally contains white interbedded sandstone at base. Limestone is fine to coarse grained, shelly, oolitic, pisolitic, and pelitic. Shale is calcareous and typically fissile. Base of formation not exposed. Originally included the Anjira, Loralai, and Spingwar Formations as Members (Williams, 1959; Fatmi, 1977); the Loralai and Spingwar now have formational status and are now considered to be part of the Alozai Group (Fatmi, in press). The Shirinab Formation is exposed mainly in the southwestern part of map area. Thickness is greater than 1,500 m in the Quetta Valley area (Khan and others, 1986)

Ja **Alozai Group, undivided (Middle and Lower Jurassic)**--In descending order, consists of the Loralai Formation and Spingwar Formation (Fatmi, in press). Present in the northeastern part of map area and south of Gwal (fig. 2, loc. 10). The group was originally defined by Hunting Survey Corporation, (1961) and included the Triassic Wulgai Formation of Williams (1959); that formation is now included with the Khanozai Group

Jal **Loralai Formation (Middle and Lower Jurassic)**--Predominately dark-gray to black, thin- to medium-bedded limestone and minor gray, red, and green splintery and calcareous shale. Limestone is fine grained, argillaceous, and contains algae and oolites in upper part. Lower contact is transitional with Spingwar Formation. Exposed in the northeastern part of map area south of Bagh (fig. 2, loc. 9). Thickness is 130-650 m (Hunting Survey Corporation, 1961)

Jas **Spingwar Formation (Lower Jurassic)**--Consists of gray to dark-gray, thin- to thick-bedded limestone interbedded with greenish-gray to dark-gray shale. Limestone is more abundant over shale in the upper part of formation and approximately in equal proportions with shale in the lower part; limestone is finely crystalline and argillaceous in upper part of formation and arenaceous in lower part. Shale is fissile and calcareous in upper part of formation. Diabase sills locally intrude unit. Formation was originally named by Williams (1959) and designated as the lower member of the Shirinab Formation by Fatmi (1977), but is now considered to be the lower formation of the Alozai Group (Fatmi, in press). Exposed in the north-central part of map area south of Muslim Bagh (fig.2). Base not exposed. Approximate exposed thickness 1,300-2,000 m (Hunting Survey Corporation, 1961)

Khanozai Group (Triassic)--Composed of the Wulgai Formation and underlying Gwal Formation. Rocks of these units were previously included in the Parh and Alozai Groups by Hunting Survey Corporation (1961), but have been redefined by Fatmi (in press)

Ṯkw **Wulgai Formation (Upper and Middle Triassic)**--Purple, olive, brownish-gray to greenish-gray, well-bedded, argillaceous, noncalareous, fissile, shale interbedded with limestone and siltstone. Gray to dark-gray, micritic, tuffaceous, thin- to medium-bedded limestone at base. Upper contact is a fault contact and lower contact is a disconformity. Exposed in the northeastern part of map area southwest of Muslim Bagh (fig. 2). Approximate thickness is 180 m (Fatmi, in press)

kg **Gwal Formation (Lower Triassic)**--Dark-gray to olive, maroon, greenish-gray, silty, noncalareous, fissile shale interbedded with gray to dark-gray, micritic, platy, thin- to thick-bedded limestone. Locally includes diabase lava flows. Crops out in the northeastern part of map area southwest of Muslim Bagh. Base not exposed. Approximate thickness is 480 m (Fatmi, in press)

Pl **Permian limestone**--Isolated blocks (olistostromes) of shallow marine fusulinid limestone. Present in the northern part of map area enclosed by rocks of the Khanozai and Alozai Groups (Japanese Pakistan Research Group, 1989). Interpreted to be of seamount origin

Ṯ-Cu **Triassic to Cambrian rock units, undivided**--Shown in cross sections only. Thickness of units not known

Zs **Salt Range Formation? (Late Proterozoic (Eocambrian))**--Shown in cross sections only. Composed of gypsiferous marl, salt, gypsum, and shale (Gee, 1945; Asrarullah, 1967). Exposed along the southern end of the Salt Range (fig. 1)

(IV) INTRUSIVE ROCKS

TKc **Chagai Intrusion (Eocene to Late Cretaceous)**--Composed mainly of quartz-hornblende diorite, diorite, and granite (Vredenburg, 1901). Forms batholith that intrudes the Sinjrani volcanic rocks (not shown on map) of Cretaceous age (Hunting Survey Corporation, 1961). The Chagai Intrusion is shown only in cross section A-A', northwest of Chaman fault in northwest corner of map area

(V) OPHIOLITE, MELANGE, INTRUSIVE, AND SEDIMENTARY ROCKS

Kdd **Dolerite dikes (Late Cretaceous?)**--Dark gray, greenish gray, and light brown. Contains plagioclase, pyroxene, and minor hornblende and ilmenite. Most of the dikes are altered to chlorite, epidote, calcite, magnetite, and hematite. Dikes trend northwestward and intrude the Muslim Bagh Ophiolite Complex, mainly the ultramafic tectonites (Kmt) and ultramafic cumulates (Kmu) of the complex. Mengal and others (1993) indicate that similar dikes also intrude the Bagh Complex. Exposed in the northeastern part of map area south of the Zhob Valley (fig. 2, loc. 2). Dikes are 1-15 m wide

Kmo **Muslim Bagh Ophiolite Complex (Late Cretaceous)**--The Muslim Bagh Ophiolite Complex is divided into sheeted dikes, mafic cumulates, a mixed cyclic sequence of mafic and ultramafic cumulates, ultramafic cumulates, and

ultramafic tectonites (Ahmad and Abbas, 1979; Mengal and others, 1993). Complex shown locally undivided on the geologic map and cross section C-C'. Age of emplacement was thought to be middle Paleocene to early Eocene (Allemann 1979; Otsuki and others, 1989) and the age of the rocks was thought to be Early Triassic (Otsuki and others, 1989). It is now thought that the age of emplacement onto the continental margin of the Indio-Pakistan tectonic block is Late Cretaceous to early Paleocene (Kojima and others, 1994). The age of the complex is Late Cretaceous, based on K-Ar age of 82-67 Ma (Sawada and others, 1992). The complex contains chromite, magnesite, and magnetite deposits. Exposed in the northeastern part of map area south of the Zhob Valley (fig. 2, loc. 2)

Kms **Sheeted dikes**--Light gray, dioritic, fine to medium grained and composed of feldspar, hornblende, and minor amounts of pyroxene and quartz. Main rock types are hornblende diorite, quartz diorite, and amphibolite. Intruded by plagiogranite or trondhjemite dikes not shown on map. Identified as sheeted dikes by previous workers (Rossmand and others, 1971; Ahmad and Abbas, 1979). Estimated thickness 2,000 m (Mengal and others, 1993)

Kmc **Mafic cumulates**--Gabbroic, gray to dark green where fresh and dark brown to black where weathered; fine, medium, and coarse grained. Composed of hornblende gabbro in the upper part and pyroxene gabbro in the lower part. Characterized by compositional banding. Estimated thickness 400-1,500 m (Mengal and others, 1993)

Kmm **Mafic and ultramafic cumulates**--Composed of dunite, wehrlite, pyroxinite, and gabbro. Rocks are repeated several times; basal part is dunite that grades upward into wehrlite, then pyroxinite, and finally gabbro. Dunite contains pods of harzburgite. Dunite is dark green to black when fresh and weathers brown to dark brown. Chromite deposits are present in the dunite. Pyroxinite is coarse grained, dark yellowish orange, olive black, and brownish black when fresh and yellowish green and dark green when weathered. Estimated thickness of 4,000-6,000 m (Mengal and others, 1993)

Kmu **Ultramafic cumulates**--Composed of intercalated sequence of dunite, harzburgite, wehrlite, and minor pyroxinite. Dunite resembles those rock types in the mafic and ultramafic cumulates unit (Kmm). The harzburgite is dark green when fresh and dark brown to black when weathered. Wehrlite is dark green when fresh and weathers to brownish green. The pyroxenite is yellowish to dark green. Estimated thickness of 4,000 m (Mengal and others, 1993)

Kmt **Ultramafic tectonites**--Composed of dunite and harzburgite. Dunite is greenish black, or dark green when fresh and light brown when weathered; fine grained and dense. Protolith mainly consists of olivine and minor pyroxene; partially or completely serpentinizied. The harzburgite is dark green when fresh and dark brown to black when weathered; medium to coarse grained. Both olivine and pyroxene are serpentinizied, but to a lesser degree than in the dunite. Thickness of unit not known

K$\overline{\text{k}}$b **Bagh Complex (Upper Cretaceous to Upper Triassic)**--The complex is in fault contact with the overlying Muslim Bagh Ophiolite Complex and composed of eight major fault-bounded lithologic units (Mengal and others, 1993). These units, which were not mapped separately, are, in structurally descending order, serpentine melange, mudstone melange, ultramafic and mafic rock unit, basalt-chert unit, hyaloclastite-mudstone unit, ophiolite rock unit, upper sedimentary rock unit, and lower sedimentary rock unit. The complex was originally mapped as part of Parh and Alozai Groups (Hunting Survey Corporation, 1961) as melange (Gansser, 1979; Ahmad and Abbas, 1979), and as the Triassic Parh Group by Otsuki and others (1989). Redefined as the Bagh Complex by Mengal and others (1993, 1994) for a complex of igneous, sedimentary, and metamorphic rocks exposed near the village of Bagh (fig. 2, loc. 9). The complex is bounded on the north by the Muslim Bagh Ophiolitic Complex and on the south by the Gwal-Bagh fault. Approximate exposed thickness 500 m

Serpentine melange unit (Upper and Lower Cretaceous)--Composed of blocks of various types of mainly ultramafic mafic rocks and metamorphic rocks widely distributed in a scaly serpentine matrix. Metamorphic rocks include ampibolite, garnet-hornblende schist, and greenschist. Other rock types are basalt, chert, limestone, and shale (Mengal and others, 1994). Unit is exposed structurally below the Muslim Bagh Ophiolite Complex. Age of unit is Late and Early Cretaceous (Sawada and others, 1992). Thickness of unit not known

Mudstone melange unit (Upper and Lower Cretaceous)--Consists of blocks of various types of rocks surrounded by scaly mudstone. Blocks are as much as 100 m in length and composed of mixed basalt and radiolarian chert, foliated limestone, interbedded limestone and shale, and massive limestone. Age of unit is Late and Early Cretaceous (Sawada and others, 1992). Thickness of unit not known

Ultramafic and mafic rock unit--Consists of ultramafic cumulate and mafic cumulate that occur as tectonic slices. Typically, unit forms higher ridges than other units in the Bagh Complex. No age data available for unit.

Basalt-chert unit (Upper and Lower Cretaceous)--Found on the southeastern periphery of the Muslim Bagh Ophiolitic Complex. Unit is characterized mainly by thick basaltic lavas and bedded chert, micritic limestone, and hemipelagic mudstone. The basalt is mainly pillow lavas, some massive lavas, and volcanic breccia; contains a few limestone beds. The pillow lavas are closely packed; individual pillows range from 10 cm to as much as 1 m in diameter. Basalt is considered to be tholeiitic and shows mid-ocean-ridge basalt characteristics (Sawada and others, 1992). Locally, the pillow lavas are overlain by a 30-50 m-thick limestone and chert sequence. The bedded chert is red, tuffaceous, rich in radiolarian fossils, and characterized by alternating thin chert and mudstone beds. The age of the unit is Late and Early Cretaceous based on radiolarian fossils in the limestone and chert sequence (Kojima and others, 1994). Thickness of unit not known

Hyaloclastite-mudstone unit (Upper and Lower Cretaceous)--composed mainly of basaltic volcanic rocks interbedded with siliceous mudstone and micritic limestone. Unit is divided into three subunits (Mengal and others, 1994), an upper, middle, and lower subunit. The upper subunit is siliceous shale with limestone. The middle subunit contains the following volcanic rocks that occur as hyaloclastite: volcanic breccia, and minor pillow lava and lava sheets, basanite, alkali basalt, and trachybasalt, (Sawada and others, 1992). The lower subunit is siliceous mudstone and limestone intruded by basalt and dolerite. Age of lower subunit is Early Cretaceous (Kojima and others, 1994) based on radiolarian assemblages. K-Ar dates of amphibole and biotite from volcanic rocks range from 68 to 81 Ma (Sawada and others, 1992) indicating a Late Cretaceous age. Thickness of unit not known

Ophiolite rock unit (Lower Cretaceous)--Contains blocks of the basalt-chert unit, ultramafic and mafic rock unit, melange with limestone blocks, plagiogranite, and sheeted dike rocks embedded in a mudstone matrix. Dolerite dikes locally intrude unit. Age of unit is Early Cretaceous (Kojima and others, 1993). Thickness of unit not known

Upper sedimentary rock unit (Upper to Lower Jurassic)--Composed of green and maroon fissile, siliceous shale interbedded with limestone. Limestone is gray to greenish gray and brown, micritic, and thin bedded in lower part and thick bedded to massive in upper part. In upper part, limestone is sandy and conglomeratic (calcarenite). Unit is Late to Early Jurassic based on radiolarian fauna (Kojima and others, 1994). Thickness about 500 m (Mengal and others, 1994)

Lower sedimentary rock unit (Upper Triassic)--Characterized by interbedded greenish-gray, dark-gray, and maroon shale, and greenish-gray thin- to medium-bedded limestone. Shale is siliceous, phyllitic, and may be either fissile or blocky; it is the dominant lithology in the lower part of the unit. Limestone is argillaceous or silty (calcilutite). Unit is Late Triassic in age based on ammonites, *Halobia* sp., and radiolarian fauna (Kojima and others, 1994). Thickness about 500 m (Mengal and others, 1994)

BASEMENT ROCKS

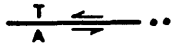
Zr **Late Proterozoic rocks**--Composed of metasediments and igneous rocks. Shown in cross sections only

MAP SYMBOLS

Contact

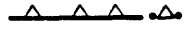
Fault of unknown geometry--May be thrust, reverse, or normal fault. Dotted where concealed; queried where existence or position is uncertain

Normal fault--Bar and ball on downthrown side



Strike-slip fault--Dotted where concealed; queried where location uncertain; arrows indicate relative movement. T, toward; A, away; shown only on cross sections

Thrust fault--Older-on-younger strata relationship. Dotted where approximately located or concealed; queried where uncertain; sawteeth on upper plate. Some faults (for example, Ghazaband-Zhob fault) have components of both thrust and of strike-slip movement



Thrust fault--Younger-on-older strata relationship. Dotted where approximately located or concealed; queried where uncertain; sawteeth on upper plate

GB **Gwal-Bagh fault**

GZ **Ghazaband-Zhob fault**

Trace of bedding plane-Shown schematically in cross section only

Anticline--Showing trace of axial plane and plunge of axis. Dotted where concealed

Syncline--Showing trace of axial plane and plunge of axis. Dotted where concealed; queried where location is uncertain

Closely-spaced folds--Showing strike of axial plane

Axis of Sibi-Urak trough

Attitude of beds, observed (Hunting Survey Corporation, 1961)

Horizontal

Inclined

Vertical

Overturned

Attitude of beds, from photo interpretation (Hunting Survey Corporation, 1961)

Horizontal

Inclined

Vertical

Overturned

■ **Town or village**

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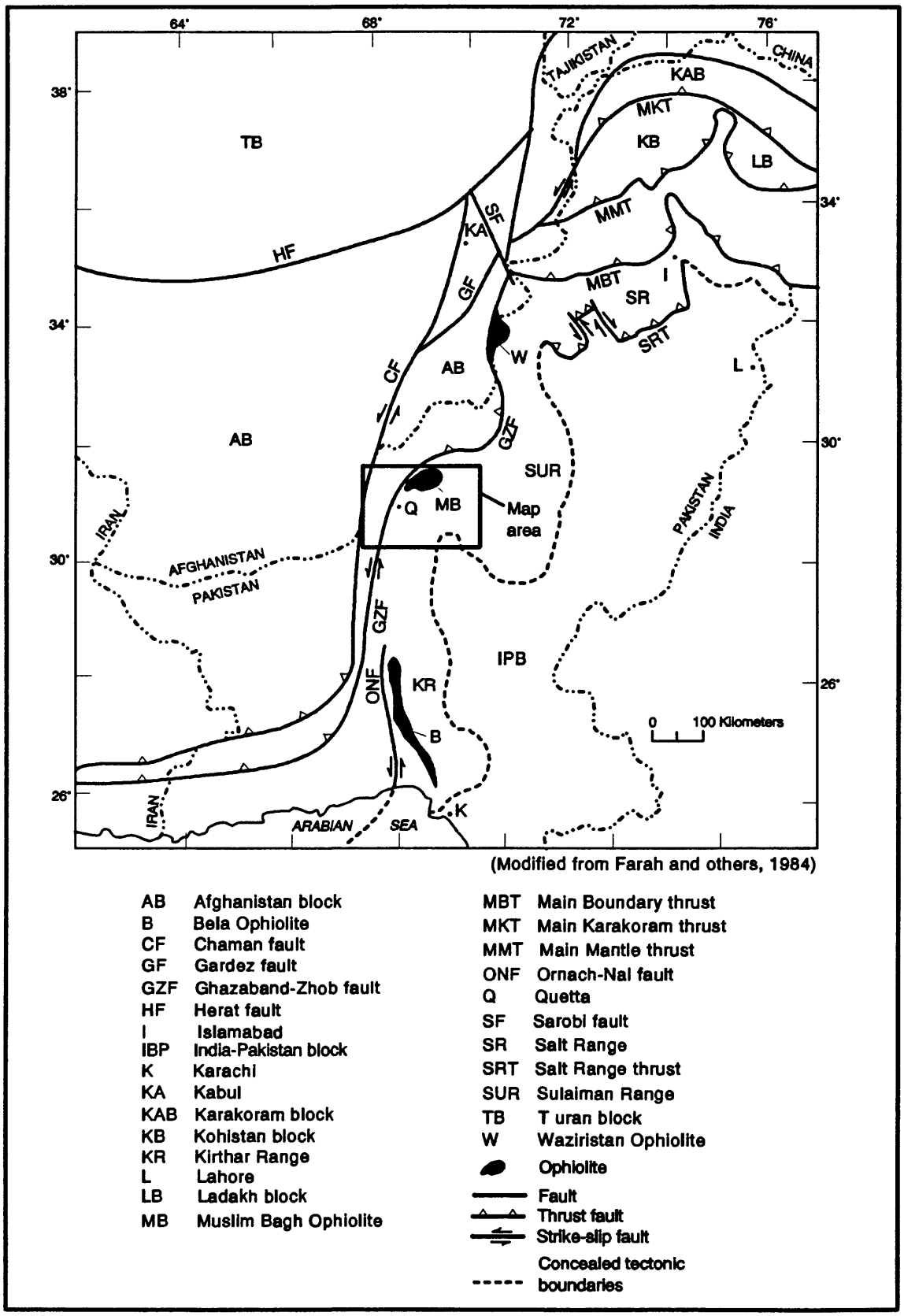

Figure 1. Index map showing map area and major tectonic boundaries of Pakistan and adjacent Afghanistan