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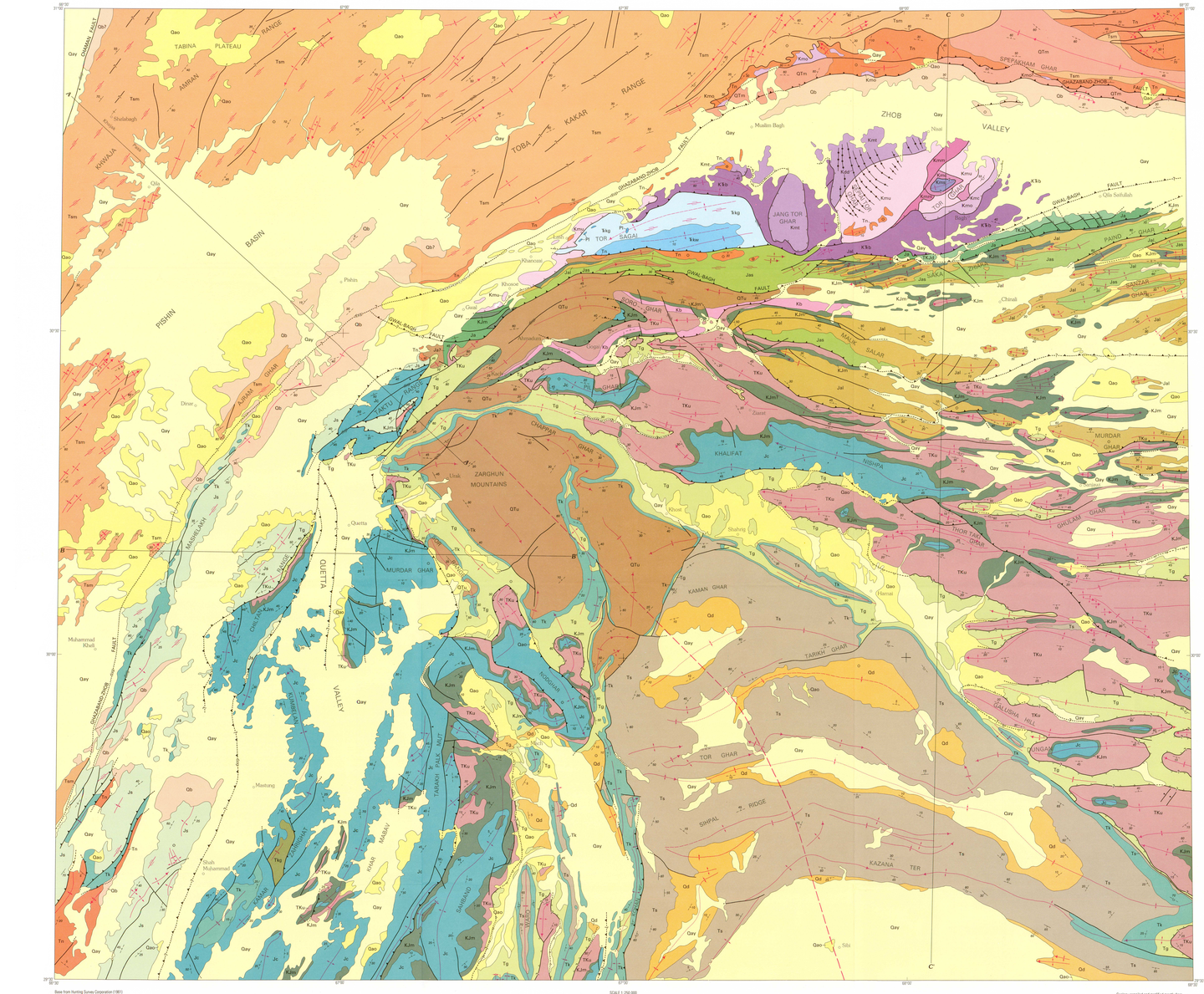
MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-2549 (SHEET 1 OF 2)



Base from Hunting Survey Corporation (1961)
1:250,000-scale maps modified to 1:256,000
using Landsat Thematic Mapper photo image

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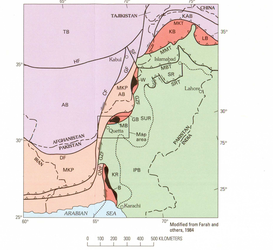

Figure 1. Index map showing map area and major tectonic boundaries of Pakistan and adjacent Afghanistan.

EXPLANATION

Eurasian Plate		MBT	Main Boundary thrust
Makran-Khojak-Pishin flysch belt		MKF	Makran-Khojak-Pishin flysch belt
Bela-Muslim Bagh-Waziristan-Ophiolite belt and Kohistan-Ladakh block		MKT	Main Karakoram thrust
India-Pakistan block		MMT	Main Mantle thrust
		ONF	Oman-Nappe fault
AB	Afghanistan block	SF	Sarobi fault
B	Bela Ophiolite	SR	Salt Range
CF	Chaman fault	SRT	Salt Range thrust
DF	Dalbandin fault	SUR	Sulaiman Range
GB	Gurel-Bagh fault	TB	Turan block
GF	Gardar fault	W	Waziristan Ophiolite
GZF	Ghazband-Zhob fault		
HF	Herat fault		
PB	India-Pakistan block		
IPB	Indus Platform block		
KB	Kohistan block		
KR	Kirthar Range		
LB	Ladakh block		
MB	Muslim Bagh Ophiolite		

Ophiolite
Fault
Thrust fault
Strike-slip fault
Concealed tectonic boundaries
International boundary

CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS: Qay, Qao

I. MOLASSE DEPOSITS: Qb, Qd, QTu

II. FLYSCH DEPOSITS (PIBRI FLYSCH PROVINCE): Tsm, Tem, Tm, Tn

III. PREDOMINANTLY MARINE SHELF SEQUENCE, THRUST FOLD AND FAULT BELTS: Ts, Tg, Tbg

IV. INTRUSIVE ROCKS (AFGHANISTAN BLOCK): TKu

V. OPHIOLITE, MELANGE, AND INTRUSIVE AND SEDIMENTARY ROCKS: Kmu, Kmc, Kmm, Kmo, Kmu, Kmt, Kdd, Kbs

Holocene; Pleistocene — QUATERNARY
Pliocene; Miocene; Oligocene — TERTIARY
Eocene; Paleocene — TERTIARY
Upper Cretaceous; Lower Cretaceous — CRETACEOUS
Upper Jurassic; Middle Jurassic; Lower Jurassic — JURASSIC
Upper Triassic; Middle Triassic; Lower Triassic — TRASSIC
PERMIAN; PENNSYLVANIAN; DEVONIAN — LATE PROTEROZOIC
BASEMENT ROCKS: Jt, Js, Ja, Jas, Jsu, Jl, Jal, Jaa, Jsa, Jaa (Base not exposed), Ꞓsu, Ꞓg, Pt, Ꞓ-Ꞓu, Zp, Zr

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 modern stream channels. 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 alluvium** (Holocene)—White, light-gray, red, maroon, and light-green clay and conglomerate. Clasts are pebble and cobble limestone, chert, quartzite, and sandstone. Conglomerate contains rounded pebbles and boulders of limestone, sandstone, and volcanic and ultramafic rocks. Sandstone is fine to coarse grained and has salt-and-pepper texture, sandstone beds show cross-bedding and contain thin bouldder conglomerate. Upper contact is unconformable and is marked by a change in topography. Lower contact is unconformable with Mashalaw formation (informal) and forms an angular unconformity on older strata. Dhaqab sandstone, Murghai Faqirzai shale, and Nisai formation (all informal), Shirinab Formation (Js), and Loralai Limestone (Jal). Exposed mostly in 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) measured a thickness of 750 m in the Pishin Basin

Qd **Dada Conglomerate (Pleistocene)**—Conglomerate and mitror gray-and-gray and brown sandstone. Conglomerate consists of limestone boulders and pebbles in a sandstone matrix, interlayered with subordinate sandstone lenses. Sandstone is coarse grained, poorly consolidated, and has a matrix that is commonly gradational into older alluvial deposits; its lower contact is conformable or disconformable. Exposed in the Sibi-Urak trough in southern part of map area. About 1,000 m thick in the Dak area (Hunting Survey Corporation, 1961) (fig. 2, loc. 3)

QTu **Urak Group, undivided (lower Pleistocene to Oligocene?)**—Includes, in descending order, the Chalt, Chil, Ghaznai, Ghaj, and Ghazabad formations (Kazmi and Rana, 1970). These three formations were not mapped separately. The basal part of the Urak Group, as mapped by Hunting Survey Corporation (1961), also contains ferruginous and argillaceous shally beneath some of the Gaj and Nari Formations. These two formations are included as part of the Urak Group in the study area because of scale and lack of mapping continuity. Exposed in the Sibi-Urak trough, in the Zhob Valley in most of map area (fig. 1), the Sonn, Dhok Pathan, and Nagri Formations in the upper part of the Siwalik Group (Gisman and others, 1977) are equivalent to the Urak. Sibin Matai, and Uidha Piha formations, respectively. The Siwalik Group represents a different basin of deposition from that of the Urak Group (Johnson, 1979). The Siwalik nomenclature is preferred for the map area. The Urak Group is exposed mostly in northern part of the Sibi-Urak trough (fig. 2) in central part of map area

Urak formation (lower Pleistocene and Pliocene)—Mainly conglomerate, interlayered with subordinate mottled-color siltstone, siltstone, and claystone. Conglomerate contains poorly sorted to well-sorted, subangular to well-rounded, boulder- and pebble-size clasts of limestone, sandstone, chert, and igneous rocks in a sandy clay matrix. Lower contact is conformable with Ghaj formation. Chesma and others (1977) reported that the equivalent Sonn 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

Ghaj formation (lower Pleistocene and Pliocene)—Mainly conglomerate, interlayered with subordinate sandstone, siltstone, and claystone. Conglomerate consists of limestone boulders and pebbles in a sandstone matrix, interlayered with subordinate sandstone lenses. Sandstone is coarse grained, poorly consolidated, and has a matrix that is commonly gradational into older alluvial deposits; its lower contact is conformable or disconformable. Exposed in the Sibi-Urak trough in southern part of map area. About 1,000 m thick in the Dak area (Hunting Survey Corporation, 1961) (fig. 2, loc. 3)

Chil formation (upper Miocene)—Gray to olive-gray, fine-grained sandstone and light-gray and light-olive-gray siltstone and claystone. Sandstone is fine grained and has salt-and-pepper texture, and siltstone and claystone are massive and contain thin beds of sandstone. Lower contact is conformable with Chalt formation. Exposed in 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) measured a thickness of 750 m in the Pishin Basin

Chalt formation (middle Miocene)—Light-gray, fine-grained sandstone and light-olive-gray siltstone and claystone. Sandstone is fine grained and has salt-and-pepper texture, and siltstone and claystone are massive and contain thin beds of sandstone. Lower contact is conformable with Bostan alluvium (Holocene). Exposed in 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) measured a thickness of 750 m in the Pishin Basin

Shaigalu sandstone (Miocene and Oligocene)—Mainly light-gray and greenish-gray sandstone, interbedded with gray shale and green shale. Sandstone is fine to coarse grained, locally gritty to pebbly, thick bedded to massive, calcareous, micaceous, and rarely ferruginous or carbonaceous, and exhibits cross-stratification and ripple marks. Shale is predominantly calcareous, in places arenaceous, and finable to flaky but locally blocky; locally carbonaceous, containing lenses of lignite. Thin beds of gray sandy limestone are present in upper part of unit. Sandstone and shale are conglomerate part of unit. 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 the informal Nisai formation (Tn). Unit is 950–1,900 m thick in the Khwaja Amran Range (Hunting Survey Corporation, 1961) (fig. 2, locs. 4 and 5). Cheema and others (1977) report that unit is 6,250 m in the Toba-Kakar Range (fig. 2, loc. 5) in northern part of map area

Murghai 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 finable; it is the predominant rock in unit and is more abundant than in other units. Sandstone is coarse 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 unit have been persistently metamorphosed to greenschist facies near contact with ophiolite. Lower contact is conformable with the informal Nisai formation (Tn). The Shaigalu sandstone and Murghai Faqirzai shale form a thick flysch sequence that filled a trough. Unit is 608–625 m thick in most areas (Hunting Survey Corporation, 1961), but it is about 1,250 m thick in the Dak area (fig. 2, loc. 3)

Nisai formation (lower Oligocene to lower Eocene)—Are informal unit; predominantly 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, nodal, shelly, brecciated, and locally argillaceous. Marl is well bedded and locally contains abundant pelecypod shell fragments and locally calcareous, laminic, and fossiliferous. Sandstone is calcareous, fine to coarse grained, poorly to well sorted, quartzitic, thick-bedded, and crossbedded. Conglomerate contains angular to rounded pebbles and boulders of limestone, marl, jasper, sandstone, and igneous rocks. Defined as the Nisai Group by Hunting Survey Corporation (1961) but redefined as the Nisai formation by Johnson (1979) (fig. 2, loc. 6). Lower contact of unit, map area, the Nisai includes the Wakabi and Nainwagh 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 in northeastern, central, and southeastern parts of map area. North of Nisai (fig. 2, loc. 16), thickness about 1,200 m (Cheema and others, 1977)

III. PREDOMINANTLY MARINE SHELF SEQUENCE

Tn **Nisai formation (lower Oligocene to lower Eocene)**—An informal unit; predominantly 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, nodal, shelly, brecciated, and locally argillaceous. Marl is well bedded and locally contains abundant pelecypod shell fragments and locally calcareous, laminic, and fossiliferous. Sandstone is calcareous, fine to coarse grained, poorly to well sorted, quartzitic, thick-bedded, and crossbedded. Conglomerate contains angular to rounded pebbles and boulders of limestone, marl, jasper, sandstone, and igneous rocks. Defined as the Nisai Group by Hunting Survey Corporation (1961) but redefined as the Nisai formation by Johnson (1979) (fig. 2, loc. 6). Lower contact of unit, map area, the Nisai includes the Wakabi and Nainwagh 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 in northeastern, central, and southeastern parts of map area. North of Nisai (fig. 2, loc. 16), thickness about 1,200 m (Cheema and others, 1977)

Tk **Kirthar Formation (middle and lower Eocene)**—Light-gray and pale-brown, thick-bedded to massive, highly fossiliferous limestone interbedded with gray and light-brown marl and chloe, brown, and dark-gray shale. Marl and shale locally contain abundant pelecypod shell fragments. Unit is equivalent to the Kirthar Formation of Fatmi (1973), but it is mapped as the Kirthar Limestone of Hunting Survey Corporation (1961), but later changed to the Kirthar Formation by Cheema and others (1977). Locally includes the Spintangi Limestone of Hunting Survey Corporation (1961). Lower contact is mostly transitional with the Ghazij Formation, but where the formation overlies Paleocene rocks, lower contact is unconformity; mostly along the edge of the Sibi-Urak trough. Thickness 1,270 m (Cheema and others, 1977) in the Gal River area, south of map area, but much less in map area

Tg **Ghazij Formation (lower Eocene)**—Divided into upper, middle, and lower zones by Hunting Survey Corporation (1961). Formation predominantly exposed around the flanks of the Sibi-Urak trough. Lower zone consists of light-gray, olive-gray, weathering claystone and minor conglomerate, sandstone containing clasts of limestone and chert, and brown, pink, and yellow, upper zone contains thin layers of bog iron. Lower contact is conformable and locally conformable (E.A., Johnson, and others, 1996). Thickness from about 215 m in the Mach area (fig. 2, loc. 7) to about 300 m near Harnai (Hunting Survey Corporation, 1961) (fig. 2, loc. 8). Thickness 300 m in the Ziarat area (fig. 2, loc. 9). Lower contact is transitional and conformable in the Bahlol area (Hunting Survey Corporation, 1961), approximately 100 km east of map area

Lower zone—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 Paleocene and lower Eocene units (Pa in this study), as an angular unconformity where the formation is underlain by Paleocene rocks (Johnson, 1979). However, Eocene foraminifers have been incorporated into the geologic map. Thickness from about 915 m in the Sor Range to about 1,220 m in the Mach area (Hunting Survey Corporation, 1961) (fig. 2, locs. 7 and 9). Thickness in Zhob Valley, approximately 20 km south of map area

Tbg **Kirthar and Bara Gali Formations, undivided (middle to lower Eocene)**—Isolated outcrop about 12 km east of Shah Muhammad (fig. 2, loc. 17) in southwestern part of map area

TKu **Tertiary and Cretaceous units, undivided (lower Eocene to Upper Cretaceous)**—Includes six lithologic units that are shown as undivided because of scale and lack of mapping. Units are, in ascending order, Dungan Formation, Sarbaz Limestone (informal), Dungan Formation of Cheema (1977), Kashi Group, and Brewery Limestone of Hunting Survey Corporation (1961). Exposed around the flanks of the Sibi-Urak trough, but predominantly exposed on northeast side of trough

Sazgai limestone (lower Eocene and Paleocene)—Light-gray, massive limestone; locally conformable with the Mors Formation (locally included with the Mughal Kot Formation, uppermost part of the Mona Jhal Group (Kmo)). Exposed in northeastern part of map area, west and south of Chinali (fig. 2, loc. 13). Maximum thickness 310 m (Hunting Survey Corporation, 1961)

Rodangi Formation (lower Eocene and upper Paleocene)—Pale-gray, sublithographic, massive limestone, marl, interbedded graphite-green shale, and subordinate sandstone. Upper and lower contacts not exposed. Exposed west of Shah Muhammad (fig. 2, loc. 17). Thickness 155–250 m (Hunting Survey Corporation, 1961)

Sanjawi limestone (lower Eocene and Paleocene)—Light-gray, massive limestone. Lower contact is conformable on rocks of the Mona Jhal Group (Kmo). Exposed in 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)—Predominantly light to dark-gray and brown limestone and minor dark-gray, brown, and olive shale. Limestone is fossiliferous and locally argillaceous. Lower contact with the Mughal Kot Formation (uppermost formation of the Mona Jhal Group (Kmo)) is mostly unconformable; contact is conformable in the Mach area. Locally, contact with the Bibai Formation (Ks) is unconformable. North of Quetta, contact is unconformable on Cretaceous and Jurassic rocks. Exposed along western and eastern flanks of the Sibi-Urak trough. More than 1,000 m thick in the Mach area (Johnson, 1979)

Kashi Group (lower Eocene and Upper Cretaceous)—Dark-gray, brown, and black limestone, yellow-weathering marl, conglomerate with clasts of limestone and chert, and reef-pebble conglomerate and olive shale interbedded with sandstone and minor mafic lava flows. Lower contact is conformable with the Mors Formation (locally included with the Mughal Kot Formation of the Mona Jhal Group (Kmo)) (fig. 2, locs. 10 and 11). Thickness 90–375 m (Hunting Survey Corporation, 1961)

Brewery Limestone (Paleocene and Upper Cretaceous)—Chocolate-brown and dark-gray limestone. Laterite locally present in lower part of unit in the Ziarat area (fig. 2, loc. 9). Lower contact is a fault contact and lower contact is unconformable. Exposed in the Chiltan Range (fig. 2, loc. 11) southwest of Quetta, and southeast of Kach (fig. 2, locs. 12) and Gogai (fig. 2, loc. 13). Thickness 25–60 m (Hunting Survey Corporation, 1961)

Mughal Kot Formation (Upper Cretaceous)—Dark-gray calcareous mudstone and calcareous shale intercalated with quartzose sandstone and light-gray argillaceous limestone. Lower contact is conformable with the Parh Limestone formatie (Fatmi, 1977). The Mughal Kot Formation is exposed in 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 Mors Formation of Hunting Survey Corporation (1961). Thickness 150–300 m in the Ziarat area (Fatmi, 1977)

Parh Limestone (Upper Cretaceous)—Light-gray, white, green, and brown, massive, fossiliferous, lithographic and argillaceous limestone interbedded with subordinate gray calcareous shale and greenish-gray marl. Limestone is characterized by porcellaneous texture and conchoidal fracture and contains Globotruncana spp. and other foraminifers. Lower contact with the Pab Sandstone is a disconformity, locally conformable, rarely around flanks of the Sibi-Urak trough. Thickness 300–600 m (Fatmi, 1977)

Goru Formation (Upper and Lower Cretaceous)—Light-gray to medium-gray and olive-gray, flat-bedded limestone interbedded with greenish-gray and locally maroon siltstone and shale. Lower contact with the Sembar Formation is conformable. Exposed mostly along flanks of the Sibi-Urak trough and near east and west end of Quetta (fig. 2, loc. 13). Thickness at the Ziarat-Kach (fig. 2, locs. 8 and 12), Sor Range (fig. 2, loc. 9), and Chiltan Range (fig. 2, loc. 11) areas, is approximately 135 m, but near southwest Quetta and Ziarat (fig. 2, loc. 9) Fatmi, 1977)

Sembar Formation (Lower Cretaceous and Upper Jurassic)—Black silty shale with interbeds of black siltstone and gray argillaceous limestone; generally glauconitic and pyritic, and (in the basal part) locally contains phosphatic nodules and gray to green shale. Belemnites are commonly present. Lower contact is conformable with the Upper Jurassic rocks (Fatmi and others, 1986). Lower contact with the Chiltan Formation (Jc) in western part of map area and the Loralai Formation (Jal) to eastern part is disconformable. Mostly exposed around flanks of the Sibi-Urak trough and near east and west end of Quetta (fig. 2, loc. 13). Thickness at the Ziarat-Kach (fig. 2, locs. 8 and 12), Sor Range (fig. 2, loc. 9), and Chiltan (fig. 2, loc. 11) areas, is approximately 135 m, but near southwest Quetta and Ziarat (fig. 2, loc. 9) Fatmi, 1977)

Jt **Toba Formation (Upper Jurassic)**—Predominantly light- to dark-gray, black, brownish- to bluish-gray, and in places white, massive to thick-bedded limestone; fine grained, oolitic, reefoid, and shelly. Lower contact is conformable and locally transitional with the Shirinab Formation (Js). Exposed predominantly in western part of map area and south of Quetta and of the Sibi-Urak trough. Approximate thickness 1,800 m in the Quetta area (Hunting Survey Corporation, 1961)

Js **Shirinab Formation (Middle and Lower Jurassic)**—Predominantly gray to dark-gray and black, thin-bedded limestone interbedded with minor light-gray to dark-gray, yellowish-gray, and black shale; locally contains white interbedded sandstone and tuff. Limestone is fine to coarse grained, shelly, oolitic, pelitic, and fossiliferous. Shale is calcareous and typically flaky. Base of formation not exposed. Originally included the Anjira, Loralai, and Sangsar Formations as members (Williams, 1959); Fatmi, 1977) the Loralai and Sangsar Formations are recognized as separate units in the part of the Akrab Group (Fatmi and others, in press). Exposed mainly in southwestern part of map area. Thickness greater than 1,500 m in the Quetta Valley area (Khan and others, 1986)

Jsa **Akrab Group, undivided (Middle and Lower Jurassic)**—In descending order, consists of the Loralai and Sangsar Formations (Williams, 1959; Fatmi and others, in press). Present in southwestern part of map area and south of Gwal (fig. 2, loc. 18). The Group was originally defined by Hunting Survey Corporation (1961) and included the Triassic Wolfcamp of Williams (1959). But formation is now included with the Khanozai Group

Jal **Loralai Formation (Middle and Lower Jurassic)**—Predominantly dark-gray to black, thin- to thick-bedded limestone interbedded with minor gray and brown, massive to thick-bedded limestone; fine grained and argillaceous, and contains algae and oolites in the upper part. Lower contact is transitional with the Sangsar Formation. Exposed in northeastern part of map area south of Bagh (fig. 2, loc. 19). Thickness 130–650 m (Hunting Survey Corporation, 1961)

Jas **Sangsar Formation (Lower Jurassic)**—Gray to dark-gray, thin- to thick-bedded limestone interbedded with greenish-gray to dark-gray shale. Limestone is more abundant than shale in upper part of formation and approximately in equal proportions with shale in lower part; limestone is finely crystalline and argillaceous in upper part of formation and arenaceous in lower part. Shale is finable and flaky and contains thin interbeds of calcareous siltstone. Lower contact is conformable and transitional with the Sinjaro Formation (Ꞓsu) and the Shirinab Formation (Js). Exposed in northeastern part of map area south of Bagh (fig. 2). Thickness 130–650 m (Hunting Survey Corporation, 1961)

Ꞓsu **Sinjaro Formation (Upper Triassic)**—Dark-gray to olive, maroon, and greenish-gray, silty, noncalcareous shale; locally contains interbeds of dark-gray, micritic, platy, thin- to thick-bedded limestone. Locally includes diabase lava flows. Crops out in northeastern part of map area southwest of Muslim Bagh. Base not exposed. Approximate thickness 480 m (Fatmi and others, in press) Paleontologic evidence indicates Norian age (Late Triassic) (Fatmi and others, in press)

Ꞓg **Quetta Formation (Middle Triassic)**—Gray to olive, maroon, and greenish-gray, silty, noncalcareous shale; locally contains interbeds of dark-gray, micritic, platy, thin- to thick-bedded limestone. Locally includes diabase lava flows. Crops out in northeastern part of map area southwest of Muslim Bagh. Base not exposed. Approximate thickness 480 m (Fatmi and others, in press) Paleontologic evidence indicates Anisian age (Middle Triassic) (Fatmi and others, in press)

Pt **Permian limestone**—Isolated blocks (olistostromes) of shallow-water limestone. Exposed in northeastern part of map area, where, enclosed by Late Jurassic Mamond and Abdul Gaddar Formations (Fatmi, 1977). Age of limestone is interpreted to be of seamount origin

Ꞓ-Ꞓu **Triassic to Cambrian rock units, undivided**—Shown only in cross sections. Thickness of units not known

Zs **Salt Range Formation? (Late Proterozoic)**—Shown only in cross sections. Consists of dolomite, limestone, marl, salt, gypsum, and shale (Gee, 1945; Jaswal, 1967). Exposed along southern end of the Salt Range (fig. 1)

IV. INTRUSIVE ROCKS

TKc **Chagai Intrusion (Eocene to Late Cretaceous)**—Shown only in cross section A–A′, northwest of Chaman fault. Composed mainly of quartz-hornblende diorite, diorite, and granite (Venkat-Rama Iyer, 1964). Intrudes rocks ranging from the Cretaceous Sirpiati volcanic rocks (not shown on map) (Hunting Survey Corporation, 1961)

V. OPHIOLITE, MELANGE, AND INTRUSIVE AND SEDIMENTARY ROCKS

Kdd **Dolerite dikes (Late Cretaceous?)**—Dark-gray, green-ish gray, and light brown. Contains plagioclase, pyroxene, and minor hornblende and ilmenite. Most of the dikes are altered to chlorite, epidote, calcite, magnetite, and leucoxene. Dikes are confined to the Muslim Bagh and Zhob Muslim Bagh Ophiolite Complex, mainly in the ultramafic tectonite (Kmo) and ultramafic cumulate (Kmu) of the complex. Mengal and others (1993) indicated that similar dikes also intrude the Bagh Complex (Ꞓ-Ꞓu). Exposed in northeastern part of map area south of the Zhob Valley (fig. 2, loc. 2). Dikes are 1–15 m wide

Mu **Muslim Bagh Ophiolite Complex (Late Cretaceous)**—Complex is divided into diorite dikes (Kmu), mafic cumulates (Kmc), and a mixed cycle sequence of mafic and ultramafic cumulates (Kmm), ultramafic cumulates (Kmu), and ultramafic tectonites (Kmo) (Ahmad and Abbas, 1979; Mengal and others, 1993). Locally, complex is shown undivided (Kmu). Age of emplacement was thought to be middle Paleocene to early Eocene (Williams, 1964; Ahmad and Abbas, 1979); but age of rocks was thought to be Early Triassic (Otsuki and others, 1989). It is now thought that age of emplacement onto continental margin of the Indo-Pakistan tectonic block is Late Cretaceous to early Paleocene (Kojima and others, 1994). Age of complex is Late Cretaceous, based on K-Ar age of 82–67 Ma (Sawada and others, 1992). Complex contains chromite, magnetite, and magnetite-bearing rocks. Exposed in northeastern part of map area south of the Zhob Valley (fig. 2, loc. 2)

Kmo **Muslim Bagh Ophiolite Complex, undivided**

Kmg **Sheeted dikes**—Light gray, diorite, and fine to medium grained, 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 (Bowman and others, 1971; Ahmad and Abbas, 1979). Thickness greater than 500 m

Kmc **Mafic cumulates**—Gabbroic, gray to dark green when fresh and dark brown to black when weathered; fine, medium, and coarse grained. Composed of hornblende gabbro to upper part and pyroxene gabbro in lower part. Characterized by compositional banding. Estimated thickness 600–1,500 m (Mengal and others, 1993)

Kmm **Mafic-ultramafic cumulates**—Composed of diorite, wehrlite, pyroxenite, and gabbro. Rocks are repeated several times; basal part is diorite that grades upward into wehrlite, then pyroxenite, and finally gabbro. Diorite contains pods of harburgite. Diorite is dark green to black when fresh and weathers brown to dark brown. Chromite deposits are present in the diorite. Pyroxenite is coarse grained, dark yellowish orange, color black, and weathers to dark yellowish brown, dark brown, and dark green when weathered. Estimated thickness 4,000–6,000 m (Mengal and others, 1993)

Kmu **Ultramafic cumulates**—Composed of repeated sequence of diorite, harburgite, wehrlite, and minor pyroxenite. Diorite resembles those rock types in the mafic and ultramafic cumulates unit (Kmm). Harburgite is coarse grained, color black, dark brown to black when weathered. Wehrlite is dark green when fresh and brownish green when weathered. Pyroxenite is yellowish to dark green. Estimated thickness 4,000 m (Mengal and others, 1993)

Kmt **Ultramafic tectonites**—Composed of diorite and harburgite. Diorite is greenish black, or dark green when fresh and light brown when weathered; medium to coarse grained. Harburgite consists of chlorite and minor pyroxene, partially or completely serpentinized. Harburgite is dark green when fresh and dark brown to black when weathered; medium to coarse grained. Both chlorite and pyroxene are serpentinized, but to a lesser degree than in the diorite. Thickness not known

Kbs **Bagh Complex (Upper Cretaceous to Upper Triassic)**—Composed of eight major fault-bounded units, which were mapped as units by Bowman (1971) units, which were not mapped separately, are, in structurally descending order: serpentine melange, mudstone melange, ultramafic and mafic rock, basalt-chert, hyaloclastite-mudstone, ophiolite rock, upper sedimentary rock, and lower sedimentary rock. The complex was originally mapped as the Bagh Series by Hunting Survey Corporation (Williams, 1961) as melange (Kemner, 1979; Ahmad and Abbas, 1979), and as the Triassic Bagh 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 overlying Muslim Bagh Ophiolite Complex and on the south by the Gaal-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 amphibolite, garnet-hornblende schist, and greenschist. Other rocks are similar to those in the mafic and ultramafic (Kmm) 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 not known

Mudstone melange unit (Upper and Lower Cretaceous)—Consists of blocks of various types of igneous and sedimentary rocks in a mudstone matrix. Blocks are as long as 100 m 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 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 southeastern periphery of the Muslim Bagh Ophiolite Complex. Unit is characterized mostly by thick basalt lava and basalt chert, micritic limestone, and hemipelagic mudstone. Basalt is mainly pillow lava, massive lava flows, and volcanic breccia; contains a few limestone beds. Chert is red, thin bedded, and contains radiolarian fossils. Limestone is dark gray, thin bedded, and contains a few chert beds. Age of unit is Late and Early Cretaceous (Sawada and others, 1992). Thickness 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, which are, in ascending order, upper, middle, and lower. Upper subunit is siliceous shale with limestone. Middle subunit contains the following volcanic rocks: an hyaloclastite, volcanic breccia, and minor pillow lava and lava sheets, basaltic, andesitic, and rhyolitic basalts and others, (1992). Lower subunit is siliceous mudstone and limestone. Age of unit is Late and Early Cretaceous (Sawada and others, 1994) based on radiolarian assemblages. K-Ar age of amphibole and biotite from volcanic rocks ranging from 68 to 81 Ma (Sawada and others, 1992), indicating a Late Cretaceous age. Thickness not known

Ophiolite rock unit (Lower Cretaceous)—Contains blocks of the basalt-chert unit and the ultramafic-mafic rock unit, which are interpreted as blocks, plagiogranite, and sheeted dike rocks embedded in a mudstone matrix. Dolerite dikes cross-cut ultramafic rocks. Tectonics and sedimentation of the Indo-Eurasian colliding plate boundary region and its influence on the mineral deposits in Pakistan. Hiroshima, Japan, Hiroshima University, p. 1–31.

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