RECENT RESEARCHES IN THE GEOLOGY OF NORTHWEST WEST PAKISTAN

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ABSTRACT

The northwest part of West Pakistan has seen detailed geological investigation in several areas during the past ten years. In this paper, an attempt has been made to give a brief account of the research work (much of which has already been published) carried out in Peshawar and Malakand Divisions, and in Gilgit Agency since 1947. *A summary of economic investigations is given and a detailed account of the bibliography has been presented in the end to provide an easy source of references for future workers.*

The important conclusion that the authors have reached from this work is that many of the more or less regionally metamorphosed rocks, previously considered Precambrian, are mainly Siluro-Devonian and, to a lesser extent, Carboniferous in age, with a relative abundance of reef complexes. Many of these rocks were intruded by various types of igneous rocks (mainly granites), mostly during the Late Cretaceous and Early Tertiary periods.

INTRODUCTION

Northwestern West Pakistan, largely a mountain terrain, is comprised mainly of the northwestern Himalayas and Karakoram, and the eastern Hindukush. It has always attracted earth scientists and mountaineers because of its interesting but complex geology and challenging mountains. The region has seen detailed work in several areas during the past decade, mainly carried out by the Universities of the Panjab and Peshawar, and the Geological Survey of Pakistan. This work builds on the more general geology of the country given by Krishnan (1956), Mehdiratta (1962), Pascoe (1950), Wadia (1966) and Gansser (1964), and has taken place principally in Hazara, including the granitic areas of Mansehra and Amb; Swat, including Kohistan; and the surrounding areas of the Peshawar plain. The W.P.I.D.C. and the P.C.S.I.R. have carried out detailed work on some of the economic minerals of the region; and a number of foreign expeditions have worked in Gilgit Agency.

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This paper is intended to present a brief account of the published research work carried out in the Peshawar and Malakand Divisions and in Gilgit Agency. In this review, the stratigraphy of Hazara, Swat and Peshawar areas (much of which concerns rocks affected by the Himalayan regional metamorphic episode) will be considered together, followed by a discussion of the igneous rocks to be found in them. This is followed by accounts of the general stratigraphy of the Kohat area and Gilgit Agency; and the economic minerals of the whole region. In conclusion, the authors have tried to present a detailed bibliography of recent work much of which has appeared in print since 1947. A large number of papers dealing with the geology of the region are awaiting publication by the Geological Survey of Pakistan, but they are not included here. Many of the references given are cited in the text; some, however, could not be used for various reasons, mainly the unavailability of the papers.

The need for a detailed bibliography arises from the fact that most of the north-western region, particularly the tribal belt, is geologically the least studied portion of Pakistan, and the various agencies concerned in the search for minerals will probably concentrate on this region in the future.

HAZARA, SWAT AND PESHAWAR REGION

The Hazara region is a metasedimentary area intruded by granitic rocks. The oldest formation is the Hazara Slate, considered to be Precambrian and shown as such on the Geological Map of Pakistan (Bakr and Jackson, 1964). The stratigraphic succession of the region is:

4. The Triassic System
3. The Infra-Trias Group
2. The Tanol Formation
1. The Hazara Slate Formation

Marks and Ali (1961) described the stratigraphy and structure of the area and considered that the age of the Hazara Slate Formation must be at least Palaeozoic, whilst the Tanol Formation may be the same age or even older. The Infra-Trias is thought possibly to be Upper Palaeozoic whilst, on fossil evidence, the Triassic System is tentatively assigned a Jurassic-Triassic age. Ali (1962) has re-examined the Infra-Trias Group in the southwestern Tanol area and after comparing the rocks with the Abbottabad Infra-Trias and the Swabi-Chamla Sedimentary Group (see Martin, Siddiqui and King, 1962), designated both sets of Hazaran rocks as the Abbottbad Formation. Further notes (Ahmad, 1961; 1962; Marks and Ahmad, 1962; Marks and Ali, 1962; and Latif, 1962) on the stratigraphy and palaeontology of Hazara confirm the Jurassic age of part at least of the uppermost ('Triassic System') formation and elaborate on other aspects.

Further work on the Swabi-Chamla Sedimentary Group, especially the Kala Limestone in which orthoconic nautiloids have been found (Davies and Ahmad, 1963a; Davies, 1964b;) suggests that the upper part of the Swabi Group may be Siluro-Devonian in age, whilst the underlying Swabi Quartzite, and therfore, by correlation, the Quartzite Member of the Abbottabad Formation, may be Silurian or Devonian also.

Work on Hazaran stratigraphy continues (see Davies and Ahmad, 1963b; Butt, 1970; Davies, 1963; Ahmad, 1963; Davies and Gardezi, 1965a; Davies *et al.*, 1967; Gardezi, 1968; 1970; Gardezi and Ghazanfar, 1965; Davies and Gardezi, 1965b; Cheema, ibid., and Latif, 1963; 1964; 1968; 1970a; 1970b; 1970c) and to quote Davies and Ahmad (1963a, p. 5): "In the meantime, it becomes essential to search carefully for fossils in the Abbottabad Formation and its possible equivalents with a view to clarifying the whole problem".

More recently, detailed investigations by Latif (1969) have shown that the rocks of the Hazara district can be divided into seven major groups ranging from Eocambrian to Recent in age. Five of the groups are further subdivided into various formations. The sequence is shown in Table I; for comparison, rocks from other regions have also been presented. Structural and related studies in Hazara have been carried out by Shams (1964c), Khan (1952), Abdullah and Calkins (1968), and Ofield *et al.*,(in press).

In the adjoining region of Swat, the stratigraphy of the Swabi area (Martin *et al.*, 1962; Davies and Ahmad, 1963a) has already been mentioned. This district has been correlated with that of Hazara and systematic mapping continued to the north and east by Jan and Tahirkheli (1969; see also King, 1961). As in Hazara, the age of many of the sedimentary rocks is tentatively considered to be Siluro-Devonian. This age is also becoming widely accepted as applying to much of the area surrounding the Peshawar plain, where strata previously assigned to the Precambrian are now thought coeval with rocks always considered to be Siluro-Devonian. This is especially true of the Attock Slates, a formation firmly regarded as consisting of undifferentiated argillaceous Precambrian rocks for many years. Work by Tahirkheli (1965b; 1967a; 1968b; 1968c; in press, a; 1970c and 1970b) has shown that the Attock Slates may be differentiated into at least thirteen mappable units, of which five are placed in the Palaeozoic, four in the Mesozoic and five in the Tertiary. Concerning the Palaeozoic units, recent fossil discoveries suggest, again, a Siluro-Devonian and Carboniferous age (Tahirkheli, 1970c). The pattern of joints and other structures in the Attock Slates have been described by Ashfak and Wakil (1969), and some associated Tertiary rocks by Davies (1964a). Alongside this work has been the recent discovery of four fossiliferous Palaeozoic (Siluro-Devonian) reef complexes: two at Nowshera(Teichert and Stauffer, 1965a; 1965b; Stauffer, 1967; 1968; Barnett *et al.*, 1966; Ali and

Anwar, 1969); one at Tangi (Tahirkheli, 1969); and one at Jamrud (Khan *et al.*, 1970; M. A. Khan, 1969; 1970). Latif (1970) refers a part of the Pir Sabak Dheri reef at Nowshera to the Lower Carboniferous on the basis of a specimen of *Amplexus* sp. found in dolomitic limestone.

The rocks of the Landikotal area, Khyber Agency, have been divided into three major parts by Stauffer (in review). Two of them, i.e. the lower Landikital Slate and the upper Shahgai Limestone—including coralline limestones—have been assigned a Siluro-Devonian age, whereas the topmost Ali Masjid Formation has been tentatively placed in the Carboniferous. More recent work (Stauffer, in review) in the Khyber Pass shows that the oldest two of the three (slate and limestone) may range from Ordovician to Carboniferous and the third (Ali Masjid Formation) from Devonian to Permian. This is overlain by the Khyber Limestone (Carboniferous to? Jurassic) which underlies undivided Palaeocene sedimentary rocks, the Eocene Kohat Formation, and the Oligo-Miocene Murree Formation. Shah (1969) has reported the presence of uppermost Devonian ammonoid *Platyclimenia stufie* in the limestone from the upper part of the Ali Masjid Formation. Jan (1969) published a brief note on the geology of the Shilman area. Recent work near Jamrud (Khan, 1970) has shown that the rocks range from Ordovician/Lower Silurian to Carboniferous; many units have very similar lithologies to those of the Nowshera reef area, and can be directly correlated (see Table I). In the adjoining Warsak area, Ahmad *et al.* (1969) have tenatively placed the rocks in the Siluro-Devonian, Carboniferous, and Upper Palaeozoic. The eastern portion of Mohmand Agency and the central part of Malakand Agency is shown by Stauffer (1967) to be at least partly of Devonian age. In the light of the above information, the writers consider that the metamorphic belt covering most of the two agencies probably ranges in age from Siluro-Devonian to Carboniferous.

Thus the outstanding feature in stratigraphical research in the Hazara-Swat-Peshawar region has been the realisation, based on recent fossil finds, that many of the more or less regionally metamorphosed rocks previously considered to be Precambrian are of Siluro-Devonian and Carboniferous age, forming a major belt of strata (mainly limestones and dolomites above, and slates, phyllites and quartzites below). They include massive reef complexes, suggesting that much of northern Pakistan was covered during the Devonian by warm, shallow seas (Stauffer, 1967).

Stratigraphic and related studies outside the main areas include those on the Potwar Basin and sub-Himalayan area (Gill, 1951a; 1951b; Wadia, 1951; Elahi and Martin, 1970; Martin, 1962a; Allen, 1964; Beg and Samad, 1966); Cherat (Jan, 1968b); and Kalam (Porter, 1970). Notes on the Khewra Trap, the only igneous rock found within the Salt Range, are given by Martin (1956; 1962b).

Research into the igneous rocks of the Hazara region has been centred on the Mansehra and Amb granitic complex. Shams (1961) gave a preliminary account of the geology of the Mansehra area which was followed by detailed work on the geology of the Mansehra and Amb areas (Offield *et al.*, in press; Shams, 1968b). Detailed work on the mineralogy, petrology, chemistry and other aspects of the granitic rocks of the Mansehra-Amb area has been carried out (Rahman, 1961; Shams and Rehman, 1966; 1967b; Shams, 1964b; 1965c; 1965d; 1967c; 1968a; 1969; Shams and Shakoor, 1967; Rehman, 1968a; 1968b; 1969). Shams and Rehman (1966) divided the granitic complex into an older group of granitic gneisses and granitoid granites, and a younger group of tourmaline-bearing granites, with associated aplitic and porphyry bodies. The series shows progressive enrichment in soda. Radiometric age determinations on micas from three granite types give tentative ages, subject to certain reservations, ranging from 79 to 165 million years, placing them in the Jurassic-Cretaceous (Shams, 1967b). Offield *et al.* (in press) consider them to be early Tertiary. Doleritic intrusions from the area have also been investigated (Khan, 1965; Shams, 1957; Shams and Ahmad, 1968). Aspects of the metamorphic rocks from Mansehra-Amb area have been studied; kyanite pseudomorphing andalusite (Shams, 1964a; 1965b), chloritoid-staurolite schists (Shams, 1967a); mineral differentiation in crenulated schists (Shams, 1965a); and other topics (Shams, 1963b; 1963c).

The igneous and metamorphic rocks of Swat, a hitherto unmapped region, were described in part, as far north as the red and green lavas of Kalam by Martin *et al.* (1962). They divided the rocks of Lower Swat into six groups (two of which, viz. the Swabi-Chamla Sedimentary and the Lower Swat-Buner Schistose Groups, have already been referred to), which have formed a framework for subsequent work:

6. The Shewa Formation
5. The Amb: a Granite
4. The Swabi-Chamla Sedimentary Group
3. The Swat Granitic Gneisses
2. The Lower Swat-Buner Schistose Group
1. The Upper Swat Hornblendic Group

The Upper Swat Hornblendic Group, part igneous and part metasedimentary, and including norites, diorites, granites and syenites, has been worked on further by Davies (1965), Rehman and Zeb (1970), and Jan and Tahirkheli (1969), who have extended the mapping of Swat to the north and east, into Kohistan, adding a further two divisions, above and below the Swat Granitic Gneisses:

c. The Shang Granodiorite Gneiss

b. (3. The Swat Granitic Gneisses)

a. The Jijal Ultramafics

Jan and Tahirkheli (1969) show that the Siluro-Devonian rocks of the Lower Swat-Buner Schistose Group were intruded during the Himalayan orogeny firstly (? Cretaceous) by pyroxenites, dunites and serpentinites (the Jijal Ultramafics), and later (? Tertiary) by the abundant Swat Granites and Granite Gneisses, and lesser Shang Gneissic Granodiorites. These events were followed by the thrusting of the Upper Swat Hornblendic-Group over the Schistose Group. Gravity and magnetic surveys have been carried out in Swat by Saleem (1963).

"The relationship of the Swabi-Chamla Group to the rocks east of the Karora gneiss is unknown, and the answer probably lies in the unmapped area to the east of the Indus River in northern Hazara tribal territory" (Martin *et al.*, 1962, p. 10). The metamorphic rocks of the Mansehra quadrangle are those of the Tanawal and Abbottabad Formations of Palaeozoic age (Offield *et al.*, in press). Stauffer (1967) considered these rocks to be in part Devonian. Jan and Tahirkheli (1969) tentatively placed the metamorphic rocks east of Karora and west of the Indus River in the Lower Swat-Buner Schistose Group. It may be pointed out here that they reported the occurrence of a meta-conglomerate "with boulders of igneous and metamorphic rocks in a phyllitic matrix" near Shang and Bhesham Qala in Kohistan. Although close attention was not paid to correlate these rocks with others, it is possible that they may be the equivalent of the Silurian Tanaki Boulder Bed.

Shams (1963a) described the production of skarns by reaction between a calcareous xenolith and the granite-gneiss of Manglaur, in the Lower Swat-Buner Schistose Group. The Kalam volcanics have been briefly described by Sultan (1970), who correlates them with the Panjal volcanics. The granite of Malakand has been described by W. M. Khan (1965), Ahmad (1967), and Chaudhri and Shams (1970). An occurrence of rodingite near Dargai, Malakand, has been recently reported by Qaiser *et al.* (1970). King (1964) studied the igneous and metamorphic rocks of part of Lower Swat and considered that the granitic material was "injected largely as a crystal mush, syntectonically from the south during some period in the Mesozoic which was later than the Triassic". Stauffer (1967), however, considered the granites to be mainly Early Tertiary. Within the Ambela granite, nepheline syenites were subsequently discovered at Koga, Chamla (Siddiqui, 1965) and within them, intrusive veins of carbonatite (Siddiqui, 1967; Deans and Powell, 1968; Siddiqui *et al.*, 1968). Considered to be related to the syenites are the alkaline porphyritic microgranites of the Shewa Formation (Martin *et al.*, 1962) Tarbela and Warsak, and the alkaline Warsak granite (Ahmad *et al.*, 1969; Kempe and Jan, 1970), forming an alkaline

igneous province, 100 miles long, possibly of Tertiary age. The nepheline syenites, carbonatites and alkali granites are the first of their kind to be found in West Pakistan and are of considerable interest. Associated with the Warsak granites are earlier intruded metagabbros and metadolerites (Ahmad *et. al.*, 1969).

GEOLOGICAL RESEARCHES IN KOHAT

Fatmi and Khan (1966) gave a detailed account of the stratigraphy of western Kohat in Samana, Darsamand, and Thal sections. Their work mainly confirms and adds to the sequence established by Davies (1930). The sequence established by them, from bottom to top, is: Shinwari Formation, and Samana Suk Limestone (Jurassic); Chichali, Lumshiwal, and Darsamand Formations (Late Jurassic to Cretaceous); Hangu Formation, Lockhart Limestone, Patala Shale, and Thal Formation (Palaeocene). The rocks consist "of shale, sandstone and limestone with subordinate marls, conglomerates, and breccias indicative of environments which vary from shallow agitated marine waters (glauconite, oolites, phosphatic nodules, corals, and other marine benthonic fauna, current bedding, ripple marks etc.) to quiet marine waters (fine muddy limestone, shale, absence or paucity of benthonic fauna, graded bedding etc.)," (Fatmi and Khan (1966, p. 8). Red and greyish green sandstones and shales (probably of the Murree Formation) also occur in minor quantities in the valley between Raisan and Kohat.

The eastern Kohat region on the other hand is characterised by abundant Tertiary and less abundant Mesozoic sedimentary rocks. The stratigraphic sequence, worked out by Rashid *et al.* (1965), is: Jurassic and Cretaceous limestones; Palaeocene shales, limestone, and sandstone; Eocene Bahadur Khel Rock Salt, Panoba Shale, Sheikhan Formation (limestone with minor gypsum), and Chharat Group (Mamikhel Clay and Kohat Limestone); Miocene Rawalpindi Group (Murree and Kamlial Formations, mostly of sandstones); and the Pliocene Siwalik Group of Chingi, Nagri, and Dhok Pathan Formations. Recent sediments occur in various parts of the district; some of the most spectacular of these are probably the megaconglomerates and the underlying clays occurring in the valley between Raisan and Chikarkot (M.Q.J., personal observation). The succession at the southern slope of the Handyside Fort, Kohat, is comprised of limestones, sandstones, and shales ,ranging from Late Jurassic to Palaeocene (Khan, 1968).

Jurassic and Early Cretaceous megafossils from Mazri Tang (Fatmi, 1966a; 1968), dimorphism in some Jurassic ammonites from western Kohat (Fatmi, 1969), and *Assilina* in the Lower Eocene Laki Series of the Kohat-Potwar basin(Gill, 1953) have been described. The study of the geology and fauna (lamellibranchia, cephalopoda, gastropoda, etc.) of the Eocene of Kohat (Eames, 1950; 1951a; 1951b; 1952a; 1952b)

is one of the most outstanding contributions to the stratigraphic geology of northwest West Pakistan.

It is interesting to note that apart from the minor metamorphic rocks in the northeastern and northwestern parts of the district, the area is surprisingly free of any igneous and metamorphic rocks.

THE GILGIT AGENCY

The Karakoram and Hindukush Ranges, covering most of Gilgit Agency and Chitral, have been investigated in some detail by many European and Japanese expeditions, and a number of papers have been published. The reader is referred to Gansser (1964) who has summarised the work of the main contributors (particularly those of Dasio, Schneider, and others, which are not available to the authors of this paper), along with a detailed bibliography on the geology of the Karakoram and Himalayan Ranges.

The NW Karakoram has been subivided, lithologically and structurally, into five zones by Schneider (1957). Gattinger (1961) subdivided the whole range into seven units, including the various zones of Schneider (see Table II). A more generalized subdivision of the entire range has been proposed by Gansser (1964) as follows:

1. A northern sedimentary zone (Tethys Karakoram)—Upper Carboniferous to Upper Cretaceous with younger intrusives.
2. A central metamorphic zone with a plutonic core—Palaeozoic.
3. A southern volcanic schist zone—Upper Palaeozoic to Cretaceous (latter in eastern Hindukush).

All the three units are separated by steep thrust zones with marked parallelism to the regional strike (Gansser, 1964, p. 31).

A team of Australian geologists (Ivanac, Traves and King, 1956) investigated the geology and mineral resources of the northwest part of Gilgit Agency. Later, Bakr (1965) confirmed and added to their work. The sequence established by them is:

Ladakh Granodiorite)	
Karakoram Granodiorite)	Tertiary
Darkot Pass Granodiorite)	
Yasin Group	Lower Cretaceous
Greenstone Complex	? Triassic
Darkot Group	Lower Permian and/or Upper Carboniferous

The Darkot Group, according to Stauffer (1967, p. 555), may in part be Devonian in age.

TABLE II

Comparison of Zonal Arrangements of the Rock Formations in the Western Karakoram (from north to south) by various authors Modified and enlarged after Matsushita and Huzita (1966).

Between Gilgit and Batura district (Schneider, 1957)	Between Skardu and Shaksgam (Gattigngcr, 1961)	Western Karakoram (Matsushita and Huzita, 1966)	Northwestern portion of Gilgit Agency and Baltistan (Ivanac *et al.*, 1956; Bakr, 1965)
			Darkot Pass Granodiorite (Tertiary)
	Tethys-zone		
V Tethys-Karakoram	Tethys-thrust zone (stronger metamorphosed Tethys sediments thrust southwards)	(E) Tethys zone (Marine Permo-Carboniferous and Lower Triassic formations)	Darkot Group (Lower Permian and /or Upper Carboniferous)
IV Axial Zone (Batura-Mustagh hornblende granite)	Achsen-zone (Tertiary granitic intrusions)	(D) Axial zone (Tertiary granite of Baltoro)	Karakoram Granodiorite
III Kristallinschiefer (Older schists and gneisses)	Zentral Kristallin (Palaeozoic metamorphics and younger Variscan granites)	(C) Central Schist-gneiss zone (Mica-schists and gneisses—derived from marine Middle Palaeozoic and Carboniferous, younger Variscan granite)	Darkot Group (slates, limestones, quartzites, conglomerates, schists, marbles, gneisses, volcanics, Lower Permian and/or Upper Carboniferous)
II Chalt Schiefer-serie (schist zone) I Rakaposhi Range	Schuppen-zone	(B) Green phyllite-limestone zone (limestone, dolomite, phyllite—derived from Lower Cretaceous marine sediments and volcanics)	Yasin Group–Lower Cretaceous, and Greenstone Complex—(?) Triassic (lavas, tuffs, agglomerates, limestones, sandstones, quartzites, gneisses)
(H) Hornblende-gneiss	Sudrand Kristallin Intrusive-Ligament	(A) Gilgit gneiss zone (hornblende gneiss—derived from Lower Cretaceous green rocks and Creto-Palaeogene granite) H- Haramosh Invader (schists and gneisses derived from Palaeozoic sediments; Tertiary Granite)	Ladakh Granodiorite (Tertiary)

More recently, the publications of the Japanese expedition (Matsushita and Huzita, 1964; 1965; 1966) have substantially added to the geology of the western Karakoram. Table II shows the zonal arrangement of rocks in the region among various authors. The last column in this table is derived from the geological map of the northwestern portion of Gilgit Agency by Ivanac *et al.* (1956).

It may be pointed out here that the above-mentioned authors have not recorded many pre-Palaeozoic rocks in the region. Sokolov and Shah (1966, p. 191), on the other hand, think that the Karakoram median mass "is made of pre-Palaeozoic granites of various types, gneisses, crystalline schists and other highly metamorphosed rocks. Along the northern and southern margins of the median mass the narrow (limited by faults) strings of outcrops of Upper Palaeozoic, Mesozoic and even younger rocks appear....."

The granitic rocks of the Nanga Parbat area (northwestern Himalayas of the southern part of Gilgit Agency) are considered to be a product of syntectonic metasomatic granitization (Misch, 1947). These granites—The intrusive ligament of Gattinger — missing from NW Karakoram are supposed to have welded the Karakoram to the Himalayan orogene. West of Nanga Parbat in Gilgit Agency, and Hazara and Swat Kohistan occur abundant norites, diorites, amphibolites, minor granites and ultramafic rocks. Jan (Ibid.) has presented the petrography of these rocks (belonging to the Upper Swat Hornblendic Group of Martin *et al.*, 1962) and considered that the group extends from Chilas (Gilgit Agency) to, at least, western Dir. The rocks are thought to be mostly magmatic in origin and older than the Nanga Parbat granites. Dunites, occurring near Chilas, were first reported by Shams (1956).

ECONOMIC GEOLOGY OF NORTHWEST WEST PAKISTAN

Economic minerals from different parts of the region have been described. Lead mineralisation (Shams, 1963d; Rahman, 1964), manganese (Quraishi and Imam, 1960; Quraishi and Abdullah, 1960) and tungsten-molybdenum (Shams and Rehman, 1967a) from Hazara; lead-zinc from Ushu, Swat (Tahirkheli, 1959a); stibnite from Chitral (Ali, 1959); chromite from Tangi-Malakand area (Bogue, 1962; Ali and Amin, 1963) and copper from Dir (Ahmad, 1962a; 1962b) have been investigated. Iron ores of Dammen Nissar, Chitral (Kidwai and Imam, 1958); Langrial, Hazara (Khan and Ahmad, 1966); Shah Dheri, Swat (Ashraf, 1969) and Khyber Agency (Bukhsh *et al.*, 1961); iron-bearing beds in Smana Range (Fatmi, 1966b), eastern Kohat (Rashid *et al.*, 1965) and Devonian laterite from Chitral (Stauffer, 1969) have been discussed. A magnetic survey of the Pirkhel iron ore, Malakand (Rahman and Choudhuri, 1966); benificiation of the low grade lead-ores of Hazara, Swat, and Chitral (Bhatti *et al.*, 1967); chemical and other studies of rion ores from northwest

West Pakistan (Nowshervi and Khan, 1966; see also Bhuiya *et al.*, 1963; and Chowdri, in press, 1970) have also been carried out. Occurrence of asbestos, nickel, sulphur, pyrite, talc, clay, lead, fluorite and ruby garnet from NE Baltistan (Afridi, in press, 1970) and galena, stibnite, copper, gold and mercury from Chitral (Bhuiyan, in press, 1970) have been recently reported.

Pegmatities near Rajdhawari, Hazara (Khan, 1964); Talash, Dir (Nabi, 1968) and Sarok Gal, Chitral (Alauddin, 1969) were studied for mica, feldspar, beryl, etc. Detailed studies have been made of feldspars, mainly from Hazara (Mahmood *et al.*, 1964; Qureshi *et al.*, 1965; Faruqi *et al.*, 1968)and kaolinite from Shah Dheri, Swat and Ahl, Hazara (Shah *et al.*, 1964; Faruqi and Qureshi, 1965; Faruqi and Ahmad, 1967; Naz *et al.*, 1964; Moosvi *et al.*, 1966). Faruqi and others (1970a; 1970b) have compared the china clay from Swat with those of imported clays and found that the former can successfully replace the latter after washing and thus can be used in ceramic industries. The Government has decided to set up a small factory to process this clay in the N.W.F.P., and the deposit is under extensive investigation by the W.P.I.D.C.

Reports have been presented on rock salt (Rashid *et al.*, 1965), gypsum and anhydrite (Gauhar, 1966)and on the development potentialities of the Trans-Indus Salt Range (Tahirkheli and Khan, 1970) of Kohat. Diamond core drilling in the salt anticline at Bahadurkhel (Rashid and Hussain, 1967) shows that the salt is 1950 feet thick. Phosphate deposits of Nizampur (Meissner, 1965) and of western Kohat (Stanin and Hasan, 1966) in the Chichali Formation have been studied. Investigations on the talc deposits of Jamrud (Abbas *et al.*, 1967), soapstone of Sherwan (Anwar, 1964), dolomite of Ghundi Tarako (Akhtar *et al.*, 1969) and other areas (Ashraf *et al.*, in press), vermiculite (Javaid and Amin, 1967), barytes from Hazara (Safdar and Hassan, 1965), kyanite from Swat (Tahirkheli, 1959b), the benificiation of Hazra glass sand (Faruqi *et al.*, 1966) and the mineralogy of asbestos from the northwest (Qaiser *et al.*, 1967; Qaiser and Khan, 1969) have also been carried out. Qaiser and others (1968) also conducted DTA studies on some local minerals. Attention has been paid to the decorative and building material (Coulson, 1937; Asrarullah, 1962; Ahmad, 1965; Mian, in press, 1970) and limestone resources(Saif, in press, 1970) of the N.W.F.P.

Emerald and other beryls from Swat (Davies, 1962; Shams, 1963c; Jan, 1968a) and Mohmand Agency (Ahmad, 1966; Jan, 1968a; Hayat, in preparation); Cr-tourmaline from Swat (Jan, Kampe and Symes, in preparation) and ruby-corundum (Jan *et al.*, 1969; 1971) from Dir have been discussed. The Upper Swat Hornblendic Group has been shown by Jan *et al.* (1969) to extend into Dir,

where related rocks contain corundum. (The ruby-corundum has also been investigated by W.P.I.D.C. and G.S.P.). Butler (1963) collected nephrite jade pebbles, possibly derived from the Siwaliks, in Teri Toi, Kohat. Hayat (in press, 1970) reported beryl, silica sand, etc. from Mohamnd Agency, and Jan (in press, 1970) described emerald, Cr-tourmaline, Cr-spinel, litharge, scapolite and other interesting minerals recently reported from Peshawar region and pointed out their potential economic importance. Ali (1967) has reported most of the gemstones found in the northwest, and Mian (1970) summarises all the Cr-bearing minerals discovered in the region.

Detailed investigation has been carried out for gold, radioactive and other heavy minerals in the sands of the Indus and other rivers. The economic potentialities and other aspects of the sands of the Indus River have been discussed in detail by Tahirkheli (1960; 1965a; 1968a; and in press, 1970b) and Davidson (1962); and of the Indus, Gilgit, Nagar, and Hazara Rivers by Danilchik and Tahirkheli (1959). Tahirkheli (1967b) also carried out a reconaissance survey for radioactive minerals in the Dardistan, Baltistan and Haramosh areas of the Gilgit Agency, and Ahmad (1957) has reported radioactive minerals from parts of Hazara. A reconnaissance radiometric survey of the Kaghan valley (Khan and Sabri, 1966) and a radioactivity study of the Hunza River (Ahmad, 1962) have also been conducted. Akhtar and Siddiqui (1965) studied the Kabul River sand near Charsadda for heavy minerals. Khan (in press, 1970) gives a summary of the search for radioactive minerals in Pakisan.

In addition to these, it will also be of interest to mention about the occurrence of a number of interesting minerals on which literature, if at all any, is not available. These include fluorite from Chat Pat, Dir, ruby-spinel, marble, copper and baryte from Mohmand Agency, talc from Kurram, ruby-corundum from Tirah, deep pinkish corundum in association with carbonate from Hunza, lapis lazuli from Chitral and Tirah, baryte and glass sand from Khyber, aquamarine form Swat and Gilgit, and green beryl and spodumene from Bajaur, Dir. In addition, a number of localities in Mohmand Agency have rodingites of greenish colour which are sold as "Jade". A partially serpentinized dunite of green colour from Mohmand is sold in Hong Kong as decoratic stone under the name of *Pakonite* (Arif Khanzada, personal communication).

Generalized accounts of the economic minerals of the region have been given by Coulson(1940), Gee (1947), Heron (1954), Brown and Dey (1955), Ali (1959), Ali *et al.*, (1964), Ahmad (1969), and Tahirkheli (1970a). Industrial rocks and minerals of the region have also been discussed in CENTO Symposeum, Lahore (1962).

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TABLE 1

Correlation of rock units in various areas

Area	Jamrud and Khyber Pass Modified after Khan, 1970, Stauffer (in review)	Nowshera Stauffer, 1968	Swabi-Lower Swat Martin *et al.*, 1962	Hazara Latif, 1969
Post-Triassic	Alluvium (Quaternary)		Alluvium (Quaternary)	Havelian Group (Lower Pleistocene t Recent)
	Murree Formation (Oligo-Miocene)			Rawalpindi Grou (Miocene)
	Kohat Formation (Eocene) Undivided Palaeocene sedrocks (like those of western Kohat)			Galis Group (Lr. Paleocene to Up Eocene)
				Hothla Group (Up. Jurassic to Up. Cretaceous)
	Khyber Limestone (Carboniferous to ? Jurassic)			Thandiani Grou (Lr. to Mid./Up. Jur
Upper Palaeozoic	Ali Masjid Group: Metasedimentary Formation (Lr.to Mid. Carboniferous)			Abbottabad Group: Hazara Formatior (Permo-Triassic) Galdanian Format (Permo-Carbonifer
	Ali Masjid Group: Misri-Banda Quartzite (Devonian to Lr. Carboniferous)	Misri Banda Quartzite (? Carboniferous)		Abbottabad Group: Sirban Formation (Devonian to Lr. Carboniferous)
	Ali Masjid Group: Ghundai Sar Reef (Nowshera Fm. Up. Silurian to Lr. Devonian)	Nowshera Formation (Reef Complex)	Swabi-Chamla Sedimentary Grp.: Kala Limestone and dolomite (Reef debris)	Abbottabad Group: Kakul Formation (Siluro-Devonian)
	Ali Masjid Group: Kandar Phyllite (Up. Silurian)	Kandar Phyllite	Swabi-Chamla Sedimentary Grp.: Swabi Quartzite Swabi Pebbly Shale	
Devonian	Ali Masjid Group: Quartzite Formation	? Not exposed	Swabi-Chamla Sedimentary Grp.: Chamla Quartzite (Siluro-Devonian)	Tanawal Formatio (Cambrian and/or Or vician to Silurian)
	Shahgai Limestone (Lr. to Mid. Silurian)		Swabi-Chamla Sedimentary Grp.: Chamla Phyllitic Schist.	
	F——F Landikotal Slate (Ordovician to Silurian)		——?——?—— Lower Swat-Buner Schistose Group	
				Hazara Group (Eocambrian)