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PRELIMINARY REPORT ON THE GEOLOGY OF THE MIDDLE PART OF AMBELA GRANITIC COMPLEX, LOWER SWAT, PAKISTAN

FUZAIL A. SIDDIQUI, A. MAHMOOD* and IJAZ HUSSAIN UPPAL

Department of Earth Sciences, University of Islamabad, Islamabad

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Abstract. Geological map and petrographic and field descriptions of various rock-types of the middle part of the Ambela granitic complex and the associated rocks are presented. Basing upon the structural relationships between various kinds of rocks, it is inferred that both the granitic and metasedimentary rocks were involved in a single tectonic event, whereas the unsheared syenitic rocks represent a post-tectonic phase of igneous activity in the area.

This is the first of a series of reports on the geology of the Ambela Granitic Complex and its surrounding rocks. Ambela Granitic Complex is the name given to a body of acid plutonic rocks of batholithic dimensions (app. 30 × 10 miles) exposed in the Buner–Chamla and Khudukhel areas of southern Swat district of North West Frontier Province. The boundaries of the complex were first mapped on a reconnaissance basis in 1959–1961.[1]

Detailed mapping of the Complex was undertaken in 1965 by Siddiqui. The present report is based on field work carried out during summers of 1966 and 1967. The area described is outlined in Fig.1 (index map). Mapping was carried out by Mahmood and Uppal under the joint supervision of Siddiqui and Shakoor. Laboratory work was carried out at the Department of Geology, University of the Punjab by Siddiqui, Mahmood and Uppal.

The mapped area lies between latitude 34°16′-34°25′ and longitude 72°30′–72°41′. The area lies at a distance of about 35 miles from the nearest railhead Mardan and can be approached by bus via the Mardan–Rustam–Ambela road. Within the area, good unmetalled roads connect the important villages of Ambela, Koga, Nawagai, Nagrai, Chingalai and Swawai. Topographically the area consists of moderately high hills and wide intermontane valleys. The highest point, Dandar Sar (alt. 5770 ft), lies in the northeast and is about 6 miles from the lowest, 1539 ft in the southwest near Swawai.

General Geology

A wide belt of plutonic rocks, mainly granitic (known as Ambela Granitic Complex) is exposed in the middle part of the area from east to west (Fig.1). Metasedimentary rocks are exposed in the northeastern and southwestern part.

Koga feldspathoidal syenite is partly exposed in the western extremity of the area 2–4. A small part of granitic rocks north of Chamla valley is also included in the area mapped.

Two broad, alluvium-filled valleys namely Chamla valley and Khudukhel valley traverse the area in a roughly east west direction.

Rocks of Ambela granitic complex have been subdivided into 4 main petrologic types as (1) Chingalai granite gneiss; (2) Khudukhel granite; (3) Babaji syenite and granite; and (4) Koga feldspathoidal syenite.

Minor intrusions of aplitic and pegmatitic rocks occur at many places in the area. Dolerite and meta dolerite sills and dykes are widespread in the granitic complex as well as in the metasedimentary rocks.

In the southwestern part of the area, the metasedimentary rocks consist of an undifferentiated succession of quartzites, marbles and phyllites, belonging to the Swabi–Chamla sedimentary group of Martin *et al.*[1] These rocks dip under the Khudukhel granite and the contact is strongly discordant at a regional as well as local scale. Spotted-hornfels develop locally at the contact of the granite indicating thermal metamorphism due to intrusion of the Khudukhel granite-magma. In the hill between the villages Kalan and Chingalai, calcareous metasediments, in contact with Chingalai granite gneiss, consist almost wholly of skarn. Southeast of Chingalai, there occurs a curious brecciated zone (mixed zone) which continues northwestward, outside the present area, to come to an abrupt end at the contact of Koga feldspathoidal syenite.

Metasediments to the north of the area are dominantly argillaceous though a few quartzite bands, similar to the quartzites of Swabi–Chamla sedimentary group are also present. At places these quartzite bands are garnetiferous. Staurolite and staurolite–garnet schists are exposed around Nagrai. The grade of metamorphism increases westwards to sillimanite schist grade. In the same continuation across the Chamla valley, one encounters sillimanite gneisses which abut against Babaji syenite and granite outcrop.

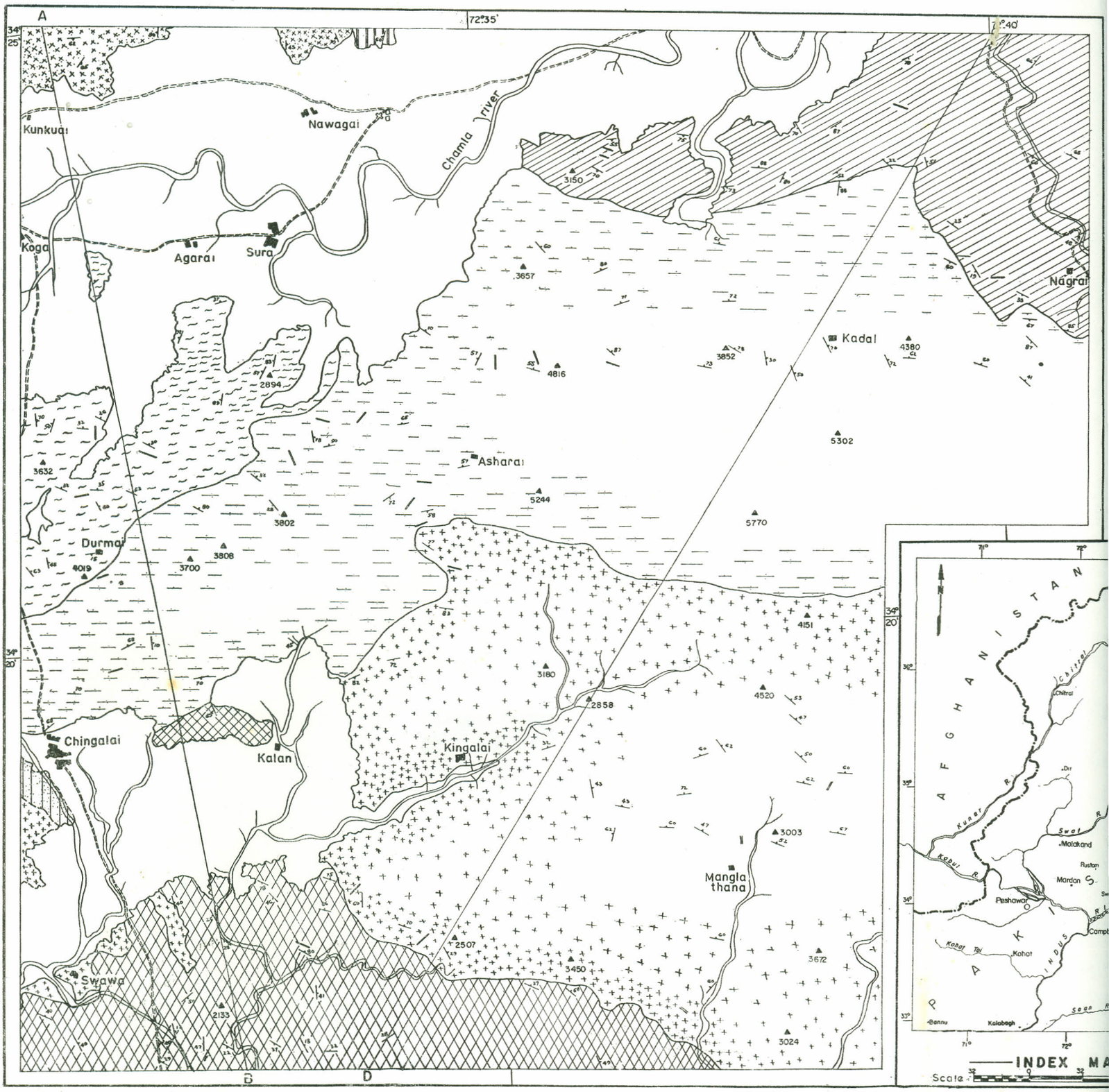
The alluvium in Chamla and Khudukhel valley consists of a succession of fine clayey silt, gravel beds and sand. Little, if any, bed rock is exposed in the Chamla valley. However, the alluvial cover in the Khudukhel valley is quite thin as shown by exposure of bed rock at many places particularly in the eastern part of the valley.

Petrography

Pelitic Schists of Nagrai Area. These rocks are part of the siliceous schist formation of Martin, Siddiqui and King.[1]

(a) Garnet and Staurolite Schist: This rock-type

*Now at Division de la Geologie, DMGE, Ministere du Commerce, de l'Industrie, des Mines et de la Marine Marchande, Rabat, Morocco.


A
72°35'
34°25'
Kunkuai
Nawagai
Chamla river
Koga
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3150
3657
Nagrai
Kadal
4380
3852
4816
2894
5302
3632
Asharai
5244
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Durmai
3808
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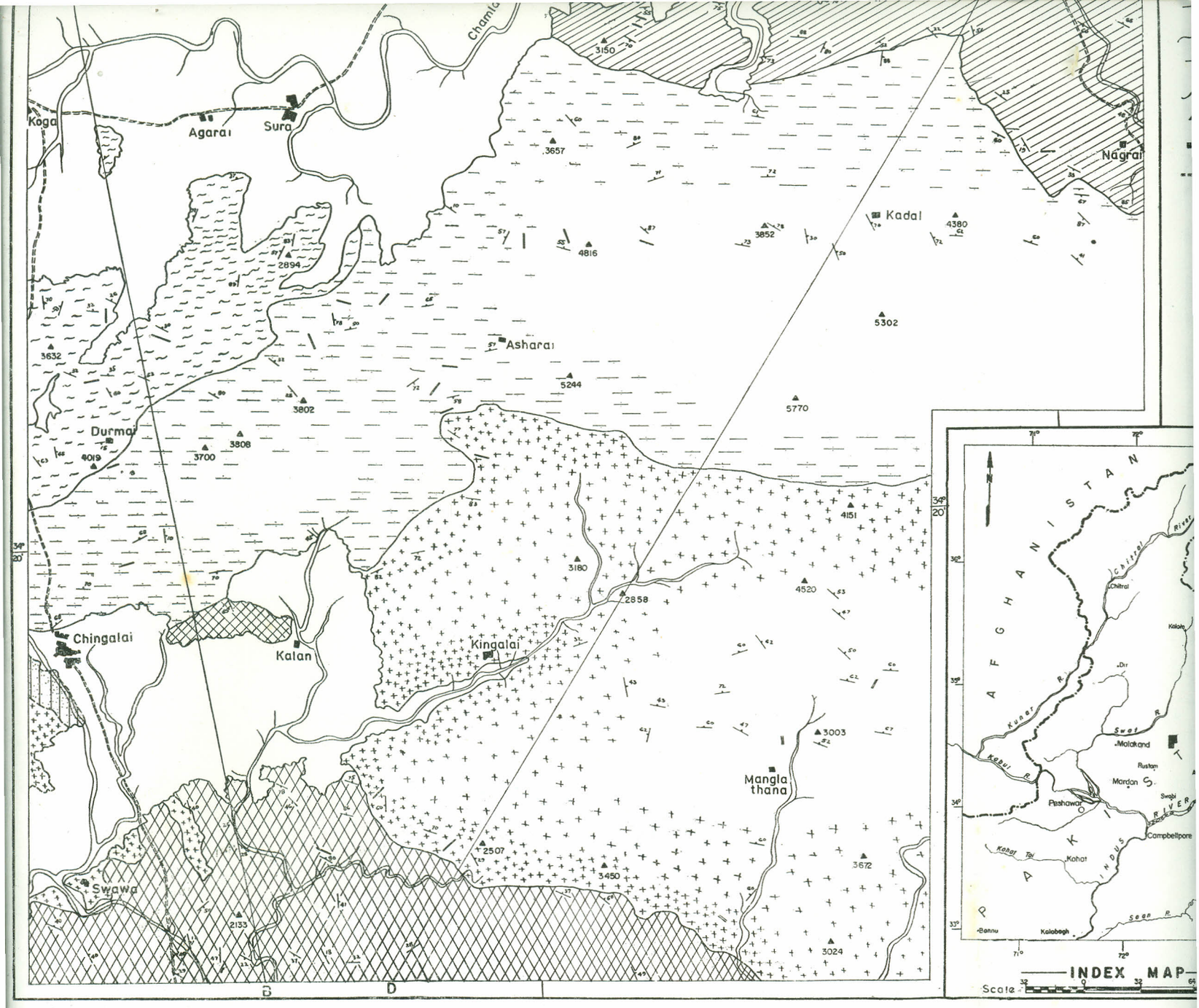
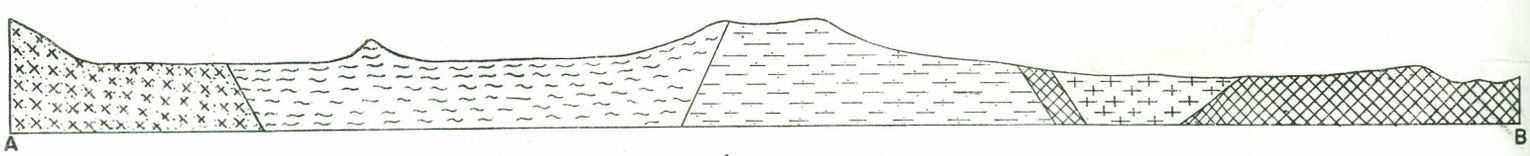
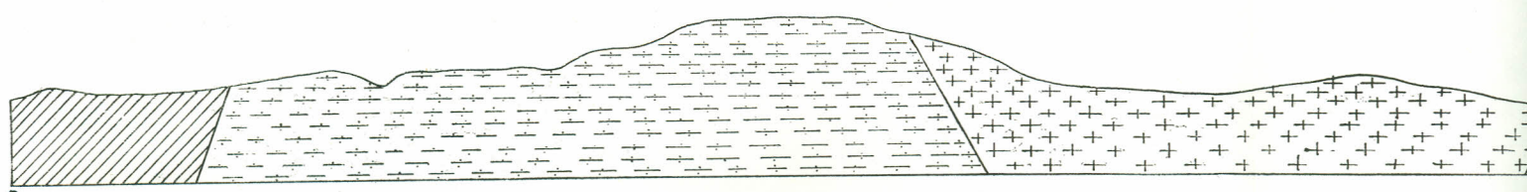




Section along A B

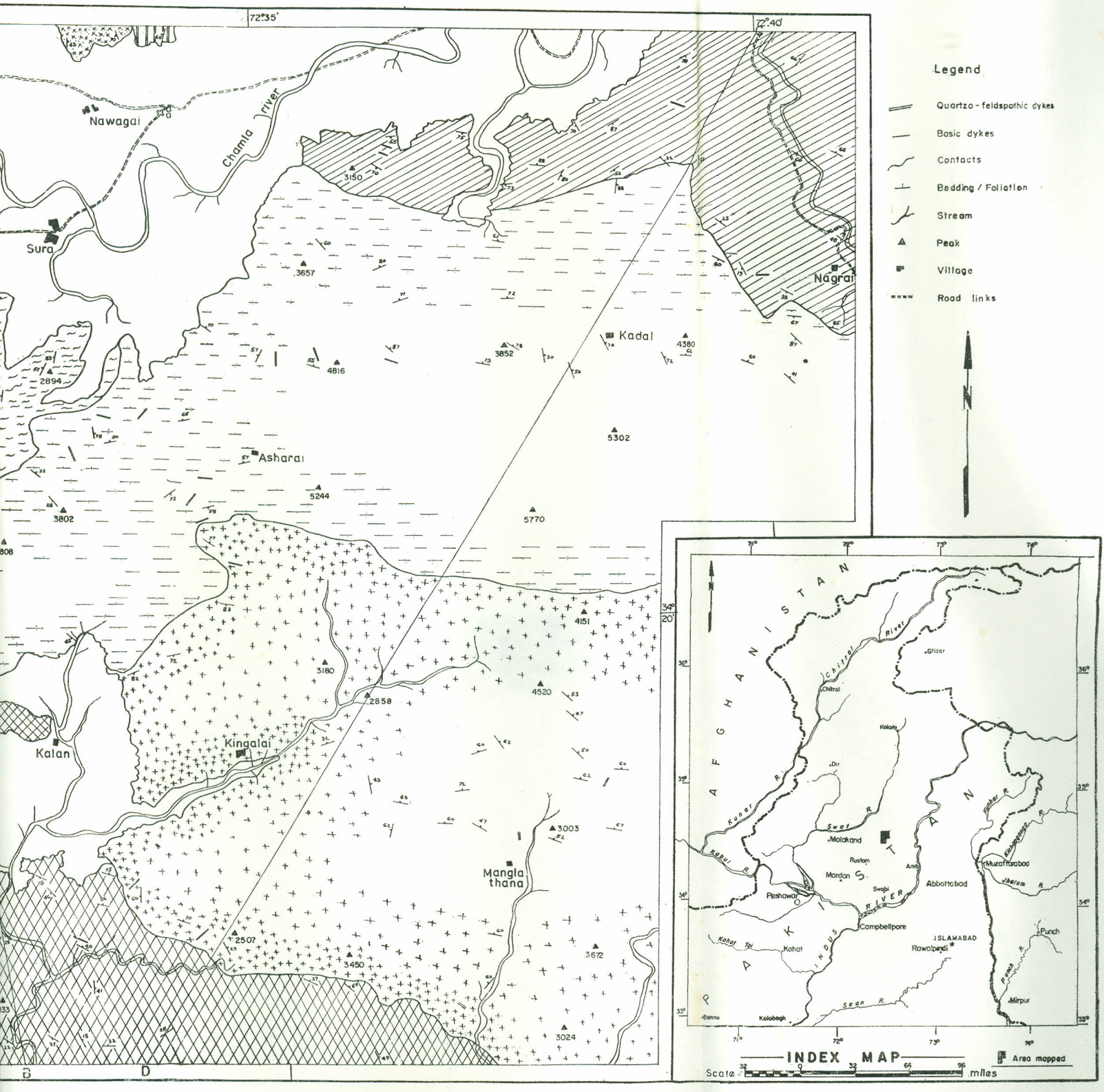


Section along C D

Nagrai schists | Chingalai gneiss | Babaji syenite | Mixed zone | Alluvium | Swabi-Chamla sedimentary group | Khu

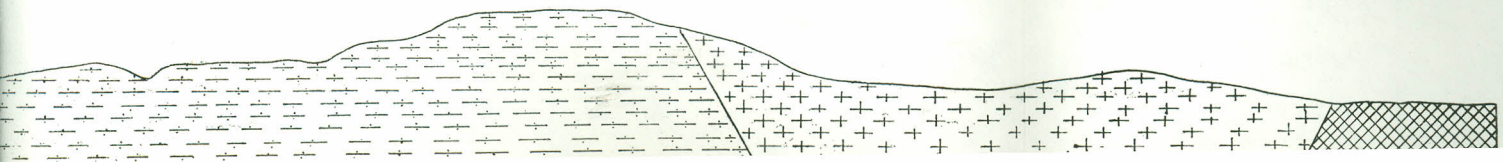
Migmatite | Koga feldspathoidal

Fig. 1. Geological map of the middle part of Ambela Granitic Complex and its associated rocks, Lower Swat, Pakistan.



Scale in miles

Section along A B



covers more than one-third of the area occupied by pelitic schists. The rocks are dark grey with lustrous schistosity plane. Three types of lithologies may be recognized in the field: garnet staurolite schist, garnet schist and staurolite schist. Best exposures of these rock-types are found around Nagrai in the Amazai Khwar (stream) and at Marne Kandao northeast of Bakro Banda.

Staurolite occurs as coarse porphyroblasts, which stand out on weathered surfaces of the rock. In thin section staurolite shows a poikiloblastic texture with abundant inclusions of quartz and micas.

Garnet, where present is a minor constituent and rarely exceeds 2 mm in grain-size. Among the micas, muscovite is more abundant than biotite. Quartz forms small rounded grains, which may be flattened parallel to schistosity.

(b) Sillimanite Schists and Gneisses: These outcrop in the western two-third of the area covered by pelitic schists. With coarsening of grain-size to the west, the schists grade into sillimanite gneisses. Pegmatitic lenses containing tourmaline, quartz and muscovite are locally present.

Thin section of a typical sillimanite schist specimen reveals the following mineralogy: quartz, sillimanite, muscovite, biotite, garnet and andalusite orthoclase, perthite, albite and tourmaline. Modal analyses of specimens of sillimanite schist are given in Table 1.

Quartz (usually about 35%) normally occurs as lenticular grains flattened parallel to the schistosity. Garnet is present in a few specimens and forms spindle-shaped grains. Sillimanite usually constitutes about 25% of the rock and almost always replaces biotite.

Andalusite occurs as subhedral grains, partly or completely pseudomorphed by greenish fengitic mica.

Feldspar is present in almost all the specimens. It is usually perthitic but albite and orthoclase may also occur as independent grains. The amount of feldspar increases with coarsening of grain-size of the rock.

(c) Chemistry of Pelitic Schists: Chemical analysis of 5 specimens of pelitic schists (two each of sillimanite schist and garnet-staurolite schist and one of garnet schist) was carried out at PCSIR Laboratories, Lahore, by A. Wahid Qureshi. The analyses are presented in Table 2.

Quartzites, Marbles and Phyllites of Khudukhel Area. As mentioned earlier these rocks belong to Swabi–Chamla sedimentary group of Martin *et al.*[1]

They consist of an undifferentiated succession of quartzites, marbles and phyllites of mid-Palaeozoic age. Quartzite is by far the dominant component, followed by marble. Contact hornfels forms a thin but prominent zone along the granite contact.

(a) Quartzites. This rock-type is concentrated more toward the east of the area. The best exposures are seen around Karore village and in stream southeast of Chingalai. Quartzites are thinly or thickly-bedded with thin shale partings. The colour of quartzite is variable from black to brown, rusty brown, greyish white to dirty white.

Towards Mali Kandao, along the granite contact, the rock is pebbly and passes into conglomerate.

TABLE 1. MODAL ANALYSES OF PELITIC SCHISTS OF NAGRAI AREA SWAT.

	Specimen No.					
	9083	10157	10176	10180	10181	10196
Quartz	50.3	43.7	34.0	39.4	31.3	34.6
Garnet	5.0	4.5	—	—	—	—
Staurolite	16.3	—	—	—	—	5.2
Sillimanite	—	—	22.5	33.0	23.3	27.0
Muscovite	3.2	36.1	2.5	Present	2.6	4.2
Biotite	19.0	13.3	24.5	20.3	14.0	22.5
Feldspar	5.2	Present (Albite)	16.5	6.6	21.3 (Perthite)	6.5 (Albite)
Iron ore	Present	—	—	—	—	—
Andalusite	—	—	—	—	6.6	—
Tourmaline	—	—	—	—	Present	—

TABLE 2. CHEMICAL ANALYSES OF PELITIC SCHISTS OF NAGRAI AREA, SWAT.

	Specimen No.				
	10157	10162	10169	10176	10180
L/I	1.58	1.20	1.61	1.60	00.99
SiO_2	69.96	69.12	68.01	68.19	68.89
Al_2O_3	19.35	18.34	18.94	18.83	19.92
Fe_2O_3	3.05	6.17	5.06	5.56	5.85
CaO	00.48	00.23	00.70	00.47	00.46
MgO	00.85	1.08	1.52	1.66	1.35
Na_2O	2.10	1.95	1.94	1.83	0.45
K_2O	2.31	2.56	2.04	2.69	2.02
Total	99.68	100.65	99.82	100.83	99.93

These quartzites can be classified as orthoquartzites with 90% or more quartz and a little muscovite. Tourmaline and red iron ore are constant accessories.

(b) Marbles. White and greyish white banded-marbles are a common rock-type of the Khudukhel area. Mineralogically, the marbles consist of calcite (about 90%) with minor amounts of diopside, microcline, idocrase, epidote, tremolite and occassionally muscovite. At places carbonaceous matter may colour the marble patchy black.

(c) Phyllites. Thinly bedded, dark greenish, grey phyllites are exposed near Swawai. These are composed of quartz, muscovite, sericite, chlorite, pyrite and graphite.

Chingalai Granite Gneiss. This rock-type forms the biggest geological unit of the area (Fig.1). It runs, in an east–west direction, for about 10 miles without appreciable change in mineralogy or texture.

The petrography and chemistry of this rock, from the western part of the area, have been described by Siddiqui *et al.*[4] The same will not be repeated here. It may, however, be mentioned that Chingalai gneiss is mainly granitic in composition. As such the name 'Chingalai granite gneiss' is preferred and supersedes the previous name 'Chingalai granodiorite gneiss' as given by Siddiqui *et al.*[4] Table 3 gives the modal composition of 7 specimens of Chingalai granite gneiss.

Of interest, here, are the regional contact relations of the Chingalai granite gneiss with the surrounding

rocks. The contact with metasediments of Khudukhel area is highly discordant. Dykes of granitic and aplitic composition shoot out into the metasediments. The metasediments dip under the gneiss.

The northern contact with pelitic schists of Nagrai area is a gradational one. Sills of granitic rocks are present in the schists for some distance from the main granite gneiss body. The trend of the sills parallels the general gneiss–schist contact.

Contact of granite gneiss with Khudukhel granite is not sharp, except in the west between Kalan and Asharai. The foliated porphyritic granite gneiss gradually passes southward into porphyritic granite and finally into coarse, even-grained granite. The foliation of the gneiss dips under the granite.

Xenoliths are quite abundant in granite and granite gneiss. These are generally of pelitic composition and are metamorphosed to biotite schist and at places feldspathized.

Khudukhel Granite. This light-coloured porphyritic and rather massive granite outcrops in the hills west of Kalan and continues to the east outside the present area. It occupies a belt of about 4 miles width, between Khudukehl metamorphics and Chingalai granite gneiss. Near the villages of Kingalai and Mangal Thana the rock is very corase-grained. Khudukhel granite is characterized by the presence of tourmaline.

A distinctive aplite with black spheroidal tourmaline segregations (up to 5 cm dia) outcrop as a narrow belt between Kingalai and Mangal Thana. Similar tourmaline aplite is seen in a narrow outcrop along Koga syenite–granite gneiss contact between Durmai and Kuai. At other places tourmaline is seen replacing the feldspar crystals in granite.

Myrmekitic intergrowth of quartz and feldspar and Rapakivi texture is quite commonly seen in this granite. Orthoclase perthite is the dominant feldspar and only rarely plagioclase exceeds it. Microcline perthite is less common. Biotite is the chief mafic mineral and is usually accompanied by muscovite. Accessory minerals include apetite, ilmenite (altered to leucoxene) and hornblende. Tourmaline stands out as a major accessory. Table 4 gives modal analyses of 5 specimens of Khudukhel granite.

Babaji Granite. This granite outcrops in the extreme northwest corner of the area and is part of the Babaji syenite body (alkali syenites and granites) described by Siddiqui *et al.*[4] This rock-type occupies the hills separating the Chamla valley from the Buner valley to the north.

The granite has a sharp contact against sillimanite gneiss. It displays two lithological varieties, namely a coarse-and a medium-grained. The latter rock-type occurs as irregular bodies, measurable in yards, enclosed by the former. Babaji granite is distinguished from Khudukhel granite by absence of tourmaline and presence of hornblende as an important mafic. Porphyritic texture is also generally lacking in Babaji granite. Modal analysis of a specimen of Babaji granite is as follows: orthoclase 25%, plagioclase 19%, perthite 15%, quartz 29%, horn blende 8%, sphene 2% and iron ore .

TABLE 3. MODAL ANALYSES OF CHINGALAI GRANITE GNEISS.

	Specimen No.						
	9061	9062	9068	9077	10004	10121	10242
Quartz	33	30	30	37	27	36	38
Orthoclase	34	40	27	—	31	—	—
Plagioclase	8	7	4	14	9	33	—
Antiperthite	—	—	—		—	18	42
Perthite	5	3	30	19	21	—	—
Biotite	14	11	6	14	8	9	12
Muscovite	6	9	3	6	4	2	6
Tourmaline	Present	—	—	10	—	—	Present
Zircon	—	Present	—	—	Present	—	—

TABLE 4. MODAL ANALYSES OF KHUDUKHEL GRANITE.

	Specimen No.				
	10010	10011	10027	10033	10106
Orthoclase	24	24	5	21	—
Plagioclase	—	8	37	16	7
Perthite	20	36	11	15	12
Antiperthite	—	—	—	—	47
Quartz	44	23	25	41	23
Biotite	5	5	22	5	2
Muscovite	5	4	—	2	8

Koga Feldspathoidal Syenite. These rocks have already been described by Siddiqui *et al.*[4] and the reader is referred to their account of the general geology, petrography and geochemistry of these rocks. A preliminary account of the associated carbonatites is given by Siddiqui.[3] A brief description is given here for the sake of completeness and ready reference.

Koga syenites occupy an oval-shaped area of which only the eastern half is exposed in the present area. The syenites intrude Chingalai granite gneiss with a discordant contact. The contact dips towards Koga syenite. Lithology of the syenites is quite varied and includes rocks of the following types: litchfieldite, foyaite, nepheline syenite (sensu stricto), nepheline–cancrinite syenite, sodalite syenite, nepheline–sodalite–zircon–ilmenite pegmatite, hornblende–sphene lamprophyre.

Veins and Dykes. (a) Basic dykes: Dolerite and metadolerite dykes are quite common in the area. These are most abundant in granite gneiss. The dykes range in thickness from 1 to 10 m. Fresh and unsheared dolerite dykes consist of plagioclase (andesine–labradorite), augite, hornblende and biotite. Accessory minerals include sphene and ilmenite. In metadolerite dykes, the rock is slightly foliated. Minerals present include plagioclase (oligoclase–andesine), hornblende with inclusions of epidote and feldspar and minor ilmenite, sphene, biotite and augite.

(b) Felsic Veins and Dykes: These do not exceed 7 m in thickness and may be quartzose, quartzo–feldspathic or feldspathic in composition. The first two types are found in granitic rocks and the last

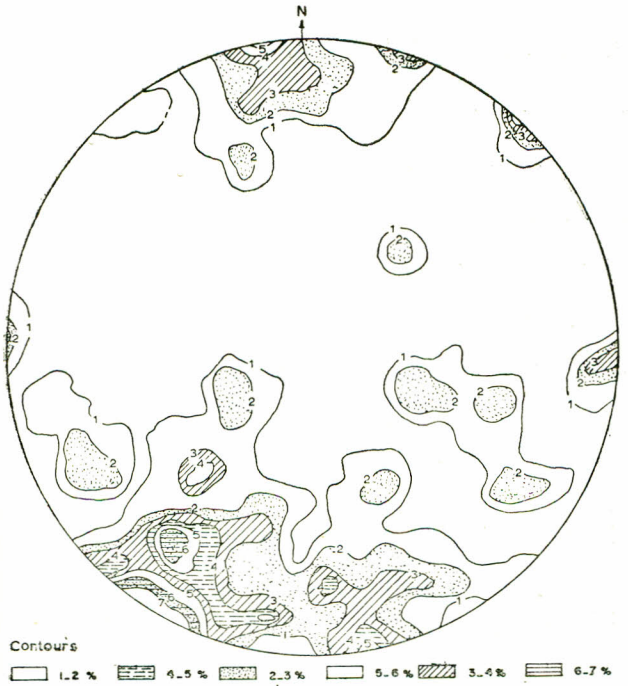


Fig. 2a. Plot of 116 poles to foliation planes in Chingalai gneiss.

Fig. 2b. Plots of 76 poles to foliation planes in Khudukhel granite.

one in Koga syenite. Swarms of quartz veins occur near granite-metamorphic rocks contact. A sheared tourmaline–plagioclase–calcite pegmatite, a few feet thick, outcrops in the skarn outcorp near Kalan.

Structure

The most prominent feature of the structure of the area is the generally persistent east–west strike of the foliation bedding of the granitic and metasedimentary rocks. The dip is generally to the north. Fig.2 (a) is a plot of 116 poles to foliation in Chingalai granite gneiss. Fig. 2 (b) is a plot of 76 poles to foliation planes in Khudukhel granite. Comparison of the two plots shows a close coincidence of foliation maxima, indicating a general strike of about N 70° E with a northwards dip.

Flow plane of Koga syenite (marked by parallel alignment of feldspar crystals) has a more varied trend. Regarding the structure of Babaji granite and syenite, its outcrop in the present area is too small to allow expression of any general statement.

The stereographic projections were made on Schmidt's equal area net.

Conclusion

Schists of Nagrai area represent a succession of shales and sandstones, metamorphosed up to sillimanite grade of regional metamorphism. Comparison of chemical analyses of sillimanite schists, garnet schists and garnet–staurolite schists (Table 2) indicates the essential identity of their compositions. More work is required to understand the genesis of the curious sillimanite–andalusite schists.

The grade of metamorphism of Swabi–Chamla sedimentary group, south of Ambela granitic complex is much lower than that of pelitic schists of Nagrai area. Phyllites associated with quartzites and marbles exhibit chlorite grade of regional metamorphism. Ambela granitic complex is intrusive into the metasedimentary rocks as indicated by its strongly discordant contact and hornfelsing of the country rocks.

In the contact aureole of the granite, spotted andalusite hornfels and unspotted biotite hornfels have been observed.

The age of the Swabi–Chamla sedimentary group is placed as Silurian–Devonian. The question of the age of pelitic schists of Nagrai area remains. The essential parallelism of the foliation of the granitic and metasedimentary rocks indicates that they have all been involved in a single tectonic event. The east–west foliation, marked by parallel alignment of micaceous minerals, indicates that the dominant stress was a compression in a roughly north–south direction. Koga syenites, being unsheared and with discordant contacts against granite gneiss, are thought to represent a post-techonic phase of igneous activity.

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