Jahrb. Geol. B.-A.	Bd. 119, H. 2	S. 97—128	Wien, November 1976

The Geology of the Nilaw Area in Central Nurestan, Afghanistan

By GERHARD FUCHS and ALOIS MATURA *)
With 25 figures, 2 plates (= Beilagen 7 and 8)

Schlüsselwörter
Afghanistan
Nurestan
Crystalline Complex
Be-Li-Pegmatites
Geological Map 1 : 50.000

CONTENTS

Abstract 97
Zusammenfassung 98
1. Introduction 98
2. Petrology and Regional Geology 99
2.1. The Migmatite Complex 99
2.2. The Complex of Metasedimentary and Metavolcanic Rocks 102
2.2.1. Metavolcanic and Non-carbonate Metasedimentary Rocks 102
2.2.2. Staurolite-Garnet Micaschists and -Gneisses 107
2.2.3. Carbonate Rocks 109
2.3. The Igneous Complex 111
2.3.1. Diorite and Gabbro 111
2.3.2. Hornblende-Biotite Granite and -Gneiss 116
2.3.3. Two-Mica Granite 120
2.3.4. Pegmatite 121
2.3.5. Lamprophyre 125
2.4. The Faults 126
3. The History of the Nurestan Crystalline 126
4. References 127

ABSTRACT

An area of about 700 square kilometers was mapped around Nilaw in Nurestan, Afghanistan, on a scale of 1:50.000. The migmatite complex is the oldest part and is composed of migmatite gneiss and augen granite-gneiss. Later a complex of volcanics, carbonate, and non-carbonate sediments was deposited. Extensive intrusions of diorites and gabbros, immediately followed by hornblende-biotite granite, caused contact metamorphism. Tectonic movements and related regional metamorphism succeeded. Diorite and hornblende-biotite granite were partly foliated in the southern parts of the mapped area. The metamorphism was of greenschist facies in the N and of staurolite-almandine subfacies of almandine-amphibolite facies of Barrow type in the S. The intrusion of the two-mica granite is the last plutonic event. This granite is the mother rock of remarkable rare-metal pegmatites in the country rocks especially in the diorite of Nilaw.

The regional strike is NNE—SSW, the dip commonly steep. Late tectonic movements caused faulting.

*) Anschrift der Verfasser: Dr. G. FUCHS und Dr. A. MATURA, Geologische Bundesanstalt, A-1031 Wien, Rasumofskygasse 23, Postfach 154

ZUSAMMENFASSUNG

Ein 700 km² großes Gebiet um Nilaw in Nurestan, Afghanistan, wurde im Maßstab 1:50.000 kartiert. Als ältester Teil gilt der Migmatitkomplex, der aus Migmatitgneisen und Augengranitgneisen besteht. Darauf wurden Vulkanite, karbonatische und nichtkarbonatische Sedimente abgelagert. Ausgedehnte Intrusionen von Diorit und Gabbro sowie anschließende Hornblende-Biotit-Granite bewirkten Kontaktmetamorphose. Tektonische Bewegungen folgten in Verbindung mit regionaler Metamorphose. Die Diorite und Hornblende-Biotit-Granite wurden im südlichen Bereich teilweise geschiefert. Im N herrschten Bedingungen der Grünschieferfazies, im S die der Staurolith-Almandin-Subfazies der Almandin-Amphibolit-Fazies des Barrow Typs. Die Intrusion des Zwei-Glimmer-Granits ist das jüngste plutonische Ereignis. Dieser Granit ist das Muttergestein jener bemerkenswerten Pegmatit-Lagerstätte im Diorit von Nilaw. Das regionale Streichen verläuft NNE-SSW, das Einfallen ist gewöhnlich steil. Einzelne Störungen sind das Produkt der jüngsten tektonischen Bewegungen.

1. Introduction

According to a bilateral development agreement between Afghanistan and Austria (IKFE-Projekt 500-Afghanistan) a team of four Austrian experts was delegated to Afghanistan. The Afghan authorities suggested the investigation of the Nilaw area in Nurestan, where Soviet experts had previously discovered occurrences of rare-metal pegmatites.

The field work was accomplished from July to November 1972. An area of about 700 square kilometers was mapped around Nilaw on a scale of 1:50.000 (Pl. 1) by G. Fuchs and A. Matura (both Geological Survey, Vienna). O. Schermann (Geological Survey, Vienna) and H. Grohmann studied the mineral distribution in the pegmatites and carried out an intensive sampling programme. Sheet numbers 505 C II—IV and 505 E I—IV of the official topographic map of Afghanistan 1:50.000 cover the mapped area.

A preliminary report based on the field observations was given already in early 1973 and was published later. After the microscopic investigation of 176 samples the petrology and regional geology can be presented more detailed. A special report on the pegmatites will be published as soon as the laboratory analyses are finished.

Nurestan is the region of the southern Hindukush ENE of Kabul near the Pakistan border. The highest peaks range above the 5000 m level but are almost non-glaciated. Up to 3000 m the slopes are covered by light forests (oak, pine, cypress, etc.). The fields on the terraced slopes around the sporadic villages are artificially irrigated. The larger valleys are deeply eroded. Some gorge-like courses are accessible only with great difficulties. The working area can be reached only on foot. It takes three or five days respectively to reach Nilaw from the ends of the motor roads.

The most prominent physiographic feature in our working area is the main valley, which is drained towards S. The different parts of its course have different names. The upper course running towards SW is called Darrahe *) Nurestan and marks the boundary of our working area towards NW and W. Further downstream at the lake Mundol, which is dammed up by a huge mountain slide, the main valley turns towards S, near Nespal towards E. At this place the Darrahe Bandol joins the main valley. The following course of the main valley is named Darrahe Posal. E of that point, where the Nilaw valley coming from the N joins it, the Posal valley turns towards SE.

* Darrahe = valley.

At Dahane Pyar there is the junction of the Darrahe Kolum and the Posal valley. The Kolum valley demarcates our working area in the E.

Nurestan is composed of crystalline rocks. Migmatites with subordinate zones of metamorphic sedimentary rocks build up wide areas. They are invaded by various granites and diorites. The country rocks are penetrated by swarms of dikes of granite, pegmatite, and aplite. Steeply inclined bedding planes and schistosity striking NNE—SSW are prominent structural feactures. The zones of metasedimentary rocks within the migmatite complex indicate narrow synclines. A system of vertical faults more or less follows the general strike.

2. Petrology and Regional Geology

Rock complexes are treated as to their assumed age beginning with the oldest. The microscopic, macroscopic, and field data of the various rocks are given. As the structural features are so closely related to the metamorphic and magmatic processes they are both dealt with in one chapter.

2.1. The Migmatite Complex

The migmatite complex consists of streaky, laminated, and also highly schistose gneisses with transitions to homogeneous, inequigranular, fine- to coarse-grained granite-gneisses (Fig. 1, 2). Augen gneiss texture is very common. The size of the augen may attain 5 cm.

Fig. 1: Migmatite gneiss. Southern face of Kohe Kajgal.

Under the microscope: Quartz, plagioclase, alkali feldspar, biotite, and muscovite are the main constituents. Plagioclase with 25 to 35% An is more frequent than alkali

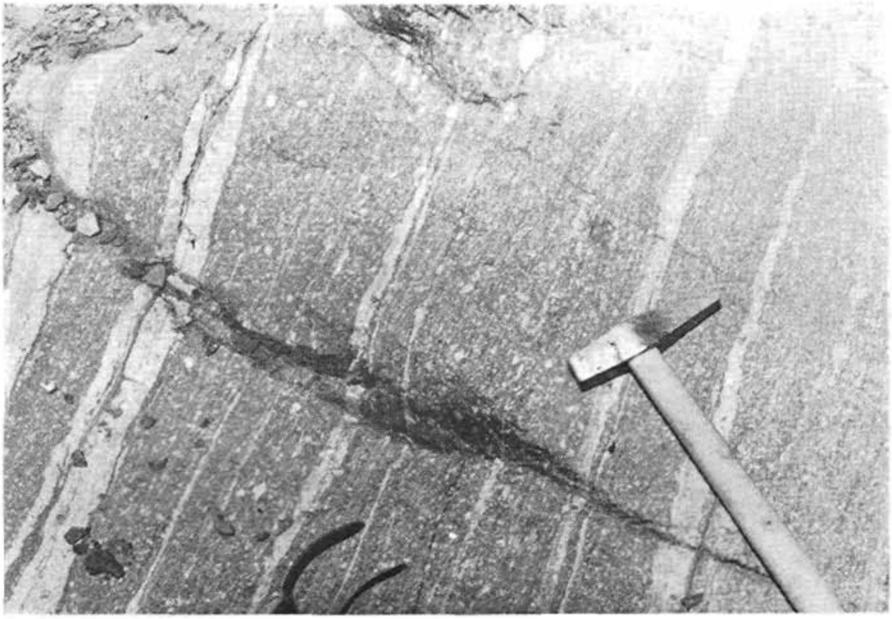


Fig. 2: Augen gneiss of the migmatite complex. Note aplitic laminae. ESE of Nalu.

feldspar. The accessory minerals are apatite, zircon, zoisite, monazite, and opaques. Garnet and graphite—the latter closely related to biotite—occur in the inhomogeneous migmatite types. Ilmenite was found in the augen gneiss varieties.

The microscopic texture reflects the macroscopic appearance. For the inhomogeneous gneisses the changing character of the textural features is typical. For example, some laminae display equigranular, fine-grained mosaic pattern and alternate with layers of inequigranular texture and distinct intergranular interlocking. The prefered orientation of the minerals and the inhomogeneous distribution show conform symmetry. The augen gneisses appear more uniform under the microscope too. The feldspar grains show simple contours with some trend to idiomorphic forms. Usually the alkali feldspars are bigger and contain non-oriented inclusions of plagioclase and biotite. Myrmekite attacks the alkali feldspar. Zoning is common in plagioclase. Inclusions of muscovite flakes follow the cleavage directions of the host plagioclase, forming sets of oriented flakes crossing each other. This is a remarkable phenomenon of the augen gneisses of the migmatite complex. To explain this special type of decomposition it is quite likely that the cleavage of the larger plagioclase crystals was activated by postcrystalline tectonic stress. The An-content of the plagioclases of the migmatites varies from oligoclase to andesine and is uniform all over the area. The micas, biotite predominating muscovite, form more or less continuous streaks along the schistosity, and bend around single feldspars or aggregates of feldspars. Postcrystalline squeezing of the micas is common. Among the accessory components monazite-apatite-zoisite aggregates are very peculiar and seem to be typical for all the varieties of the migmatite complex. They cause pleochroic haloes in biotite. In the ideal case xenomorphic monazite forms the core surrounded by successive zones of apatite and zoisite (Fig. 3). Usually only the zoisite cover appears in the sections, whereas the monazite core is rarely found. Concerning the relation of crystallization to deformation it seems that pre- to syncrystalline deformation predominates the post-crystalline deformation (micas).

Fig. 3: Monazite-apatite-zoisite aggregate in migmatite gneiss. Valley NW of Mangor (m = monazite, a = apatite, z = zoisite).

The migmatite complex has large extension in the western part of the area mapped. Both flanks of the Darrahe Nurestan from Nalu in the N towards Nespal consist of migmatites. More homogeneous augen gneiss varieties occur as more or less continuous zones in the tributary valley NW of Mangor and in the eastern flank of the Darrahe Nurestan. There are some minor bodies of younger granites in the migmatites of that zone, e. g. Nalu and Warestor. N of Nespal the migmatite belt splits and surrounds the Nespal diorite in the W and in the E. The latter branch becomes much reduced, whereas the migmatites in the W show a thick development in the Bandol valley and continue into the Darrahe Nawya.

This migmatite zone strikes NNE—SSW with generally steep inclinations towards WNW or ESE. The migmatites E of the Nespal diorite strike NNW—SSE and are vertical. This deviation from the regional strike is caused by the emplacement of the Nasdel diorite. Later tectonic movements may have accentuated these deviations.

The migmatites NW of the Atati fault in the northern corner of the area mapped appear to represent the continuation of the migmatite zone of the Darrahe Nurestan described above.

The rest of comparatively smaller migmatite occurrences is situated among younger plutonic bodies with locally very complicated spatial relations.

One migmatite belt in the Kohe *) Kajgal and the lower Bedak valley becomes very narrow towards N and pinches out between the Nilaw diorite and the granite-gneiss of the western side of the Bedak valley. Where this zone ends in an intrusive breccia quartzitic intercalations within this migmatites appear as most resistant. The generally N—S striking rocks dip towards the E against the Nilaw diorite. In the Posal valley S and W of the mouth of the Nilaw valley the internal structure of this migmatite belt is adapted to the form of the southern end of the Nilaw diorite.

Another zone of migmatites with frequent augen gneiss and episodic intercalations of marble and less migmatitic paragneisses crosses the Posal valley NW of Dahane Pyar. The rocks are intensely penetrated by small bodies and dikes of two-mica granite and pegmatite. The general strike direction is parallel to the contact of the Nilaw diorite. N of Dahane Pyar the strike is NE and turns towards N in the middle course of the Kolum valley between Alomari and Wecir. The schistosity is inclined against the Nilaw diorite. The cross-sections on plate 1 show that the latter is placed in the center of a fan-like structure. NE of Wecir the migmatite gneisses again attain NE—SW strike.

The migmatite gneisses of the Woser and Wonasgel valleys are completely surrounded by diorite and hornblende-biotite granite. The latter invaded the migmatites with numerous small bodies. Originally this occurrence of migmatites was connected with that of the Kolum valley.

At last the migmatites in the upper Darrahe Cono in the northeastern corner of the mapped area should be mentioned. They abut against the hornblende-biotite granite with intrusive contacts in the S, and along a steep fault in the W.

2.2. The Complex of Metasedimentary and Metavolcanic Rocks

As indicated in the title a very heterogeneous association of rocks is described in this chapter. The heterogeneity concerns the material as well as the type and grade of metamorphism. The subdivision in the following text was made with special respect to field observations. The order of succession is optional as the rock groups are of about the same age. Original succession as well as facies patterns are almost obliterated by later tectonic and metamorphic phases. Sharp contacts against the migmatites are common, suggesting that the migmatite complex is older. Local migmatization in meter dimensions, such as SW of Bandol or in the south-face of Kohe Kajgal, is rare within the metasedimentary rocks and is interpreted as a later event.

2.2.1. Metavolcanic and Non-carbonate Metasedimentary Rocks

The rock group consists of fine-grained gneiss, metasiltstone, phyllite, quartzite, metatuffite, metaagglomerates and metalavas of intermediate chemism. These rocks pass into each other. Their colours are light, grey, or greenish-grey. Fine granularity, streaking, and platy destruction are common. The described metasedimentary and

*) Koh = mountain.

metavolcanic rock series are distinctly thick-bedded. In the northern parts of the mapped area only low grade regional metamorphism seems to have affected these rocks. Locally contact metamorphic influence related to the younger plutonites can be observed.

The volcanic origin of some metatuffites and metaagglomerates is confirmed by microscopic investigations: Idiomorphic feldspar phenocrysts, rounded or angular quartz graines with intragranular corrosion-tubes, or very fine-grained lithic components appear within a fine-grained matrix. The composition of the volcanic components varies from dacitic to andesitic. The main constituents of these are quartz, plagioclase, alkali feldspar, and sometimes epidote. Minor constituents are hornblende, biotite, and muscovite. Tourmaline, orthite, opaques, leucoxene, apatite, and zircon occur as accessories. Some peculiar varieties contain carbonate, wollastonite, vesuvianite, garnet, or even glaucophane. Certain rocks with more or less idiomorphic phenocrysts and epidote-filled amygdales of cm-size can be recognized as metavolcanites with the unaided eye. The metaagglomerates are very conspicuous in the field. They contain dm-sized (up to 30 cm) elongated, but frequently still angular to subangular fragments of greenschists, metasiltites, gneisses, dark schists, light-coloured carbonate rocks, carbonate quartzites, and quartzites (Fig. 4).

Fig. 4: Metaagglomerate. 3 km ESE of Nalu.

Another group of rocks consists of fine-grained, banded gneisses, usually rich in quartz. S-planes transversal to the lamination were found locally. Preserved sedimentary structures such as graded bedding and current ripple cross-lamination were observed. This and the fine grain size give the rock more the appearance of a metasiltite than of a gneiss. Some varieties show relation to the metavolcanites. Usually the grain size is below 0.3 mm, frequently it is even below 0.01 mm. Preferred orientation and mineral distribution show the same symmetry under the microscope. The petrographic composition is rather variable. Main constituents: Quartz, feldspar, biotite and muscovite. Minor constituents and accessories: Hornblende, garnet, epidote, sphene, opaques, carbonate, apatite, tourmaline, and zircon. The major part of these rocks may be interpreted as former arkoses and siltstones.

The quartzites are white, yellowish, greenish, grey, or brownish. Inconspicuous banding is not seldom. In some places primary sedimentary structures such as graded bedding and cross-bedding are still preserved (Fig. 5, 6). The grain size changes from fine to middle, coarse-grained types are exceptional. Under the microscope quartz usually shows undulate extinction. In some cases clouds of fibrous microlites and/or gas and liquid bubbles within the quartz graines were observed. Minor constituents and accessories: Plagioclase, alkali feldspar, biotite, muscovite, hornblende, pyroxene, carbonate, epidote, tourmaline, garnet, sphene, apatite, and zircon.

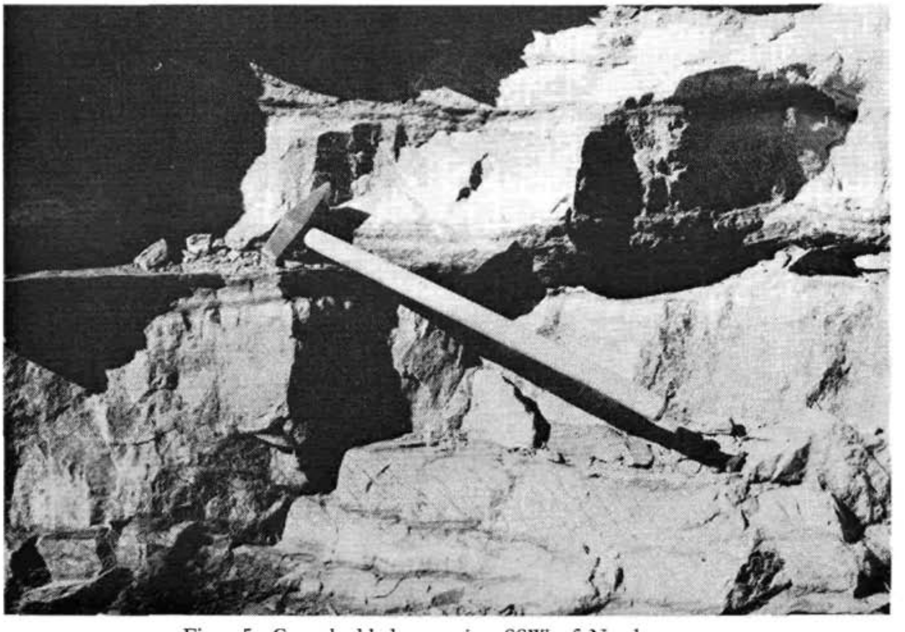


Fig. 5: Cross-bedded quartzite. SSW of Nawkozung.

In the mapped area the rocks described above form narrow zones. Most prominent is that which can be followed from the utmost northern corner as far as to the southern boundary of the area. The phyllites, carbonate rocks, and metatuffites, which cross the lower Darrahe Cono in a thickness of 300 to 400 m, show a low grade of metamorphism. This zone overlies steeply dipping migmatites, and abuts against the Atati-Pusal diorite along the Atati fault; it is highly squeezed NNE of Atati.

This zone probably is continous with that development E of Nalu. There, however, metavolcanics are prevalent. Metamorphic agglomerates, lavas, and tuffs alternate with metasiltstones, psammitic and psephitic rocks etc. rich in quartz. The extraordinary thickness of the series may be the result of the volcanic activity. The above series dips WNW at medium to steep angles, and thus overlies the marbles, quartzites, and metasiltstones. These latter rocks occur as components within the metaagglomerates, which indicates reworking. But alternation of typical rocks of the underlying series with the metavolcanics shows that apparently there was no larger time interval

Fig. 6: Graded bedding and cross-bedding in quartzite. SSW of Nawkozung.

between their deposition. Therefore we deduce that the deposition of the carbonate and clastic series was in part contemporaneous with the volcanism. The sharp vertical contact against the migmatites in the W may be tectonic.

SE of Warestor the series consists of quartzites, metasiltites, agglomeratic and tuffaceous rocks. As in the Nalu area the migmatite complex borders the metasedimentary zone in the W with sharp contacts. In the E the steeply WSW dipping beds abut against biotite granite-gneiss with unconformable intrusive contact (Fig. 7).

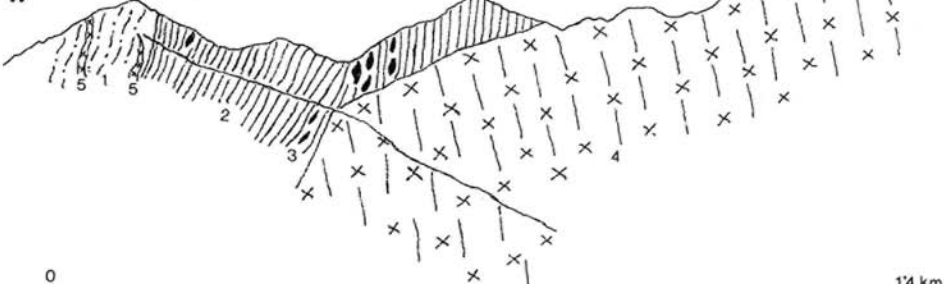


Fig. 7: Section across the metasedimentary zone. Kohe Mahikhana
1 migmatites
2 quartzites, metasiltites, etc. of non-carbonate metasedimentary series
3 agglomerates, tuffites etc.
4 biotite granite (near the margins leucogranite)
5 dikes of granite

Towards the SSW the metasedimentary zone becomes much reduced and finally ends E of the Kohe Gawati. In the same area another sedimentary zone starts in the E of the biotite granite-gneiss. This fact suggests that originally there was one continuous metasedimentary zone, which is crossed by the intrusion of the younger granite-gneiss.

In this new zone the metasiltites are replaced by biotite-rich schists and paragneiss, which, however, is already indicated in the southern parts of the zone W of the biotite granite-gneiss. S of the Posal valley in the western flanks of the Kohe Kajgal quartzites show preserved sedimentary structures such as cross-bedding (Fig. 5, 6). Also the graded bedding and laminations of the former siltstones and tuffs are still recognizable. The garnet-staurolite micaschists accompaning the quartzites are described in chapter 2.2.2.

Another occurrence of metasedimentary rocks is exposed around the Kotale *) Bandol. The series is intruded by the two-mica granite in the E and borders to migmatites in the W (see Fig. 8). Close to the migmatites the sequence consists of a thin-bedded alternation of light quartzites, metaarkoses, and fine-grained green-grey phyllites with sporadic larger grains of feldspar (Fig. 9). These beds are succeeded by sombre phyllites, finely layered metasiltites, impure fine-grained quartzites and carbonate quartzites. S of the pass metavolcanic rocks also occur in this rock assemblage.

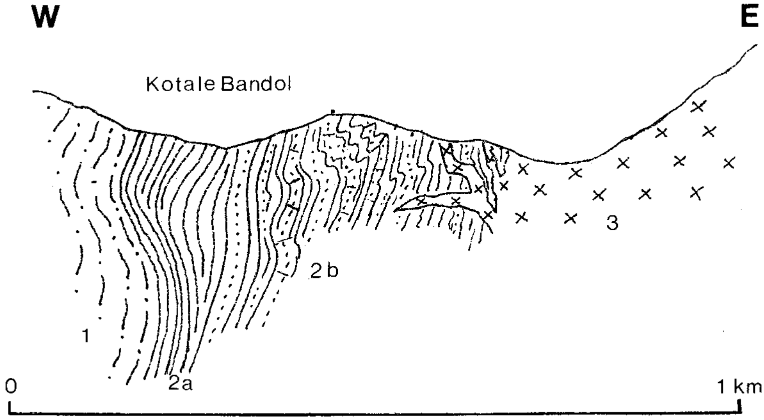


Fig. 8

Fig. 8: Section across the metasedimentary zone. Kotale Bandol.
1 migmatites (diaphthoritic)
2a alternation of quartzites, metaarkoses, and phyllites containing larger grains of feldspar.
2b metasiltites, quartzites, and carbonate quartzites
3 two-mica granite

Studying the contact with the migmatites at the Kotale Bandol one gets the impression that the metasedimentary sequence was deposited on the gneisses and that reworking produced the quartzitic and arkosic layers in the basal portion of the series.

In the upper Bedak valley and in the mountains between the Bedak and Nilaw valleys numerous bands and lenses of quartzite are exposed as relictic inclusions within the Nilaw diorite and the granite-gneiss.

---

*) Kotal = pass

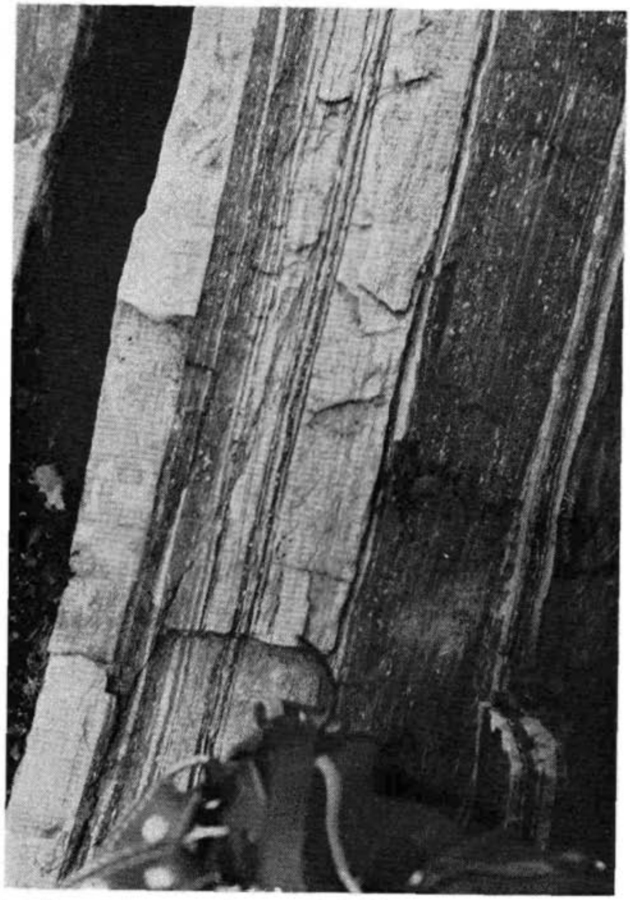


Fig. 9: Alternation of quartzites, metaarkoses, and phyllites with sporadic grains of feldspar. Kotale Bandol.

Other occurrences of the series described were found outside the mapped area on the approach march to Nilaw between Amire Sahid in the Alingar valley and Pasagar. Phyllites, quartzites, paragneisses containing pseudomorphs after chiastolite, graphite gneiss, amphibolite, and marble form a generally thin-bedded or laminated alternation.

2.2.2. Staurolite-Garnet Micaschist and -Gneiss

The chapter comprises inhomogeneous, equi- to inequigranular, fine- to coarse-grained para-rocks. Their colour is brownish-grey to middle-grey, the micas show strictly preferred orientation parallel to s with partly open-incontinuous partly continuous arrangement. Garnet as well as cm-sized idiomorphic staurolite can be recognized with unaided eye. Andalusite occurs less frequently. Locally fresh individuals attain a length up to 20 cm, but usually andalusite is replaced by aggregates of light mica, which form cm-sized more or less deformed pseudomorphs. Sometimes these aggregates show X-like arrangement of impurities, which is typical for chiastolite. Some rock types are graphitic (Fig. 10).

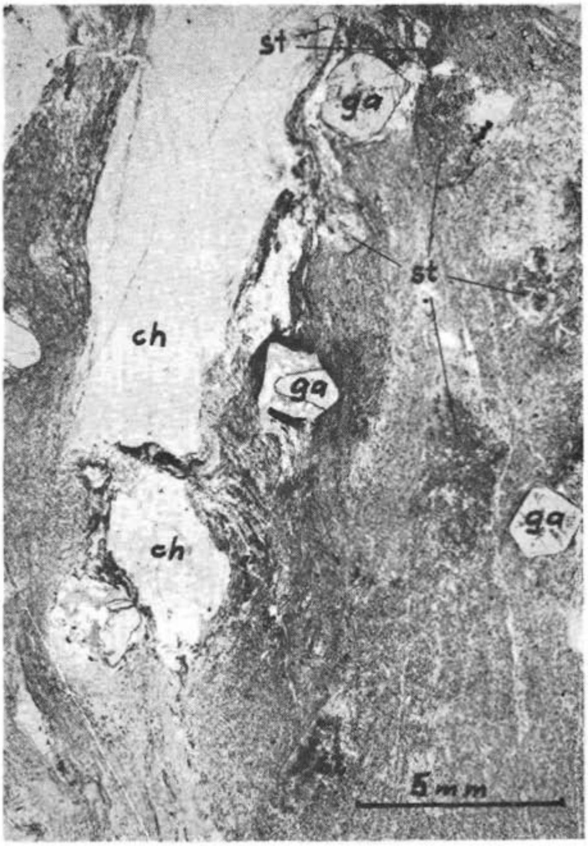


Fig. 10: Staurolite-garnet micaschist. Note light mica pseudomorphs after chiastolite (st = staurolite, ga = garnet, ch = former chiastolite).

Under the microscope the staurolite-garnet micaschist and -gneisses display inhomogeneous, inequigranular, anisotropic fabric. Main constituents are quartz, biotite, muscovite, and oligoclase, minor constituents: andalusite or its light mica pseudomorphs, garnet, and staurolite. Apatite, graphite and other opaques, zircon, monazite, tourmaline, and sillimanite occur as accessories. The preferred orientation of the fabric is particularly shown by micas and graphitic impurities.

Two different mineral generations can be distinguished. Andalusite and garnet belong to an older generation. Besides the X-like arrangement of impurities the fresh andalusites as well as garnets usually are free of inclusions. As the graphitic impurities are in some cases concentrated near the well-developed crystal faces of andalusite and garnet, the graphitic flakes seem to be pushed away selectively during blastesis. The general pattern of petrofabrics indicates that andalusite and garnet acted as rigid elements during later deformation. The second mineral generation is contemporaneous or younger than this deformation phase and comprises almost the total remaining mineral assemblage. Staurolite is critical for this second generation. But as some examples indicate staurolite partly began to grow already syntectonicly. It forms more or less idiomorphic crystals with sieve structure. Andalusites were altered to light mica aggregates. Some peculiar aggregates composed of staurolite, biotite, and quartz are well-defined against their neighbourhood by form and different grain-size. They might be interpreted as pseudomorphs after cordierite. Monazite-apatite-zoisite aggregates, similar to those mentioned in connection with the migmatites, also occur within the rocks described here. They cause pleochroic haloes within biotite. Occasionally chlorite was found attacking biotite as well as staurolite. The chlorite is probably the product of a late retrogressive metamorphism of low intensity.

From the microscopic observations the genesis of the staurolite-garnet micaschists and -gneisses might be interpreted as follows: An argillaceous sedimentary succession was metamorphosed at first under conditions of the hornblende-hornfels facies probably related to the intrusion of the diorites and hornblende-biotite granites. This event was succeeded by a period of regional metamorphism under conditions of the staurolite-almandine subfacies of the almandine-amphibolite facies of Barrow type. In the early phase of this period tectonic movements occurred. The intensity of the regional metamorphism was different from place to place. Towards the end of this period or during a later independent metamorphic event some diaphthoritic influence was active. Thus by their special composition the staurolite-garnet micaschists and -gneisses are very sensitive indicators of metamorphic conditions.

The occurrence of staurolite-garnet micaschists and -gneisses is restricted to the southern part of the mapped area. There they form distinct zones intimately related with the amphibolites and quartzites described already in chapter 2.2.1. That zone W of Kohe Kajgal is the direct continuation of the northern sedimentary zone dealt in chapter 2.2.1. Thus a gradual increase of metamorphic grade from the N to the S is indicated.

The contacts are generally sharp. Against the diorite and biotite granite or -gneiss they are intrusive, against the migmatite complex tectonic or quasi-transgressive.

In the south face of the Kohe Kajgal we found a 80 m thick zone of andalusite-staurolite-garnet schists and -gneisses within the migmatites. Definitely the contacts are not tectonic, though they are generally sharp. Occasionally, however, in the schists and paragneisses migmatitic banding and blastesis of feldspar were observed in a marginal zone up to one meter thick. Similar observation was made SW of the village Bandol. There graphitic andalusite-staurolite-garnet gneisses and -schists alternate with the migmatites. Our interpretation of the above observations is that the migmatite complex was partially rejuvenated in connexion with later metamorphic events. This has locally superimposed migmatitic phenomena on the former sedimentary contacts.

Staurolite-garnet schists and -gneisses are exposed as lens-shaped inclusions within the Nilaw diorite (e.g. tributary valley W of Nilaw and ridge between lower Nilaw valley and Darrahe Posal).

2.2.3. Carbonate Rocks

There are various rock types due to the changing quantities of primary silicate impurities or to the type of metamorphism. We found light-grey, yellowish, or white, coarse-crystalline marbles. Sporadic to frequent intercalations of sedimentary silicate impurities are common. Such silicate-rich varieties present coarse as well as very fine granularity with porcelain-like fracture-faces and streaking in light to yellowish colours. Another group of calc-silicate rocks is the contact metamorphic reaction product between carbonate rocks and diorite or granite.

Under the microscope calcite, quartz, oligoclase-andesine, diopside, and epidote can be found as main constituents. Biotite, muscovite, and alkali-feldspar are minor constituents. The occurrence of wollastonite and vesuvianite is restricted to the contact zones bordering to diorite and granite. Accessories are sphene, apatite, and opaques.

In the mountains between the three villages Nalu, Pesenta, and Nilaw we find a thick carbonate formation. It may be identified from afar because of its banded character, which is due to the alternation of marbles with calc-silicate rocks, carbonate quartzites, metasiltites, phyllites, etc. (Fig. 11). These rocks form beautiful isoclinal folds. Prevalent dip of schistosity is towards WNW.

Fig. 11: Marble with calc-silicate layers. Upper Nilaw valley.

There is a continuous outcrop of the carbonate series in the range between the villages Nalu and Pesenta (see Pl. 1). Towards the N the marble series ends abruptly along an intrusive contact against a stock of biotite granite. Almost on all sides the series is surrounded by intrusiva either metagranite or diorite. To the SSW the carbonate rocks may be followed into the Nilaw valley. But there the series dissolves more and more into relictic bands and lenses. These relics still show predominantly the NNE—SSW strike, which trend is apparent already from their occurrence. However, there are also deviations of the strike, which either go back to pre-intrusive folds or to magmatic distortion of the inclusions. The latter definitely is the case with the marbles in the southernmost portion of the Nilaw diorite, which show trends parallel with the boundary of the diorite.

It is interesting that these relics are much more numerous on crests of ranges and ridges than in neighbouring valleys and ravines. The fact that the frequency of the relics is related with elevation shows that the country rock is „swimming“ in the topmost portions of the diorite.

As to the relation of the carbonate series to the non-carbonate metasedimentary series and the metavolcanites we have already pointed out that we regard them penecontemporaneous, the carbonate rocks may be somewhat older (see chapter 2.2.1.).

Soviet experts (unpublished reports and Geological Map of Afghanistan, DENIKAEV et al, 1971) suggested a Permo-Triassic age for the "Alingar suite" which is identical with our complex of metasedimentary rocks and metavolcanites described in the last chapters. Similar series from other localities were designated by them as stratigraphic units of Palaeozoic as well as different Precambrian ages. Based on our observations we consider it quite likely that these various units are of almost the same age. In the case of the mapped area the difference in metamorphic grade is no evidence for different age. We do not have indications for the geological age of the formations in the area mapped, but regional correlations suggest Palaeozoic age.

2.3. The Igneous Complex

This chapter is dealing with different generations of intrusive rocks. The order of succession corresponds with the genetic sequence and begins with the diorites as the oldest.

2.3.1. Diorite and Gabbro

Homogeneous, equigranular, fine- to middle-grained, massive varieties predominate. But also slightly banded or schistose types are not rare. The diorites frequently show sandy disintegration and form smooth weathering surfaces of brown colour. Locally ellipsoidal "boulders" of diorite swim in a matrix of diorite differing in grain size as well as composition and thus give a "conglomeratic" appearance (Fig. 12). Like the mutual penetration of diorite varieties this indicates a formation of the diorite stock in several steps. Exceptionally the grain size may increase enormously, and hornblendes attain a length up to 40 cm (valley head of Darrahe Gamata).

Under the microscope the fabric appears homogeneous, non-oriented, or occasionally with more or less well-developed preferred orientation. Generally the primary texture is still preserved. The average grain size is about one millimeter. The main constituents are plagioclase and hornblende. Minor constituents are biotite, pyroxene (diallage), and quartz. As accessories we found magnetite, ilmenite, apatite, sphene, rutile, and occasionally forsterite and spinel. The anorthite content of the plagioclase ranges from 25% to 80%, andesine is the most common. Quartz never exceeds 10% of the rock volume. Colourless pyroxene is dimmed very often, or is more or less completely transformed into hornblende and biotite (Fig. 13). In such cases a thin rim of biotite flakes surrounds the secondary hornblende aggregate. The latter itself is zoned with a narrow greenish margin around an almost colourless core. Very often these secondary hornblende aggregates are dimmed by clouds of microlitic inclusions.

Fig. 12: Conglomerate-like diorite variety. About 3 km NNW of Alomari (Darrahe Kolum).

The hornblendes are predominantly pale green or colourless. Fine-grained aggregates of hornblende are by far more common than bigger individuals. Generally biotite is brown but a touch of green is not seldom. Biotite and hornblende often include xenomorphic magnetite or ilmenite. The sphene content occasionally attains 1% of rock volume, rutile is very rare. One gabbroic variety from the Darrahe Gamata contains 3% forsterite with traces of spinel. In one sample we found 10% of laumontite filling the interstice between the hypidiomorphic plagioclase crystals.

The contact of diorite and gabbro against the country rocks is sharp and discordant. Parts of the country rocks are enclosed. Along the contact plane contact metamorphic reactions took place. Against carbonate rocks calc-silicate rocks were formed with a mineral assemblage of calcite, quartz, garnet, epidote, diopside, vesuvianite, and wollastonite. Melilite, periclase, talc, sphene, apatite, and opaques occur as accessories. Exceptionally reactions between diorite and marble may be missing (Fig. 14). A hornblende-cordierite gneiss included in the southern part of the Nilaw diorite is another example for a contact metamorphic product. It exhibits a mineral assemblage of cordierite, hornblende, quartz, oligoclase, biotite, garnet, and opaques. Quartzite inclusions in the diorite are frequently coated by thin rims of hornblende. It may be expected that the metamorphic influence of the diorites was not confined to the immediate neighbourhood of the intrusions.

Other rocks in the diorite such as dikes of granite and pegmatite are discussed later.

In the mapped area diorites and gabbros form three major plutonic bodies. The one of Nilaw was in the center of our investigations. Its NNE—SSW longitudinal axis measures about 20 km, maximum width is 10 km. The eastern portions of the diorite are poor or free of inclusions of country rock, whereas the western parts are full of larger and smaller relics of the neighbouring series, with which the diorite is interton-

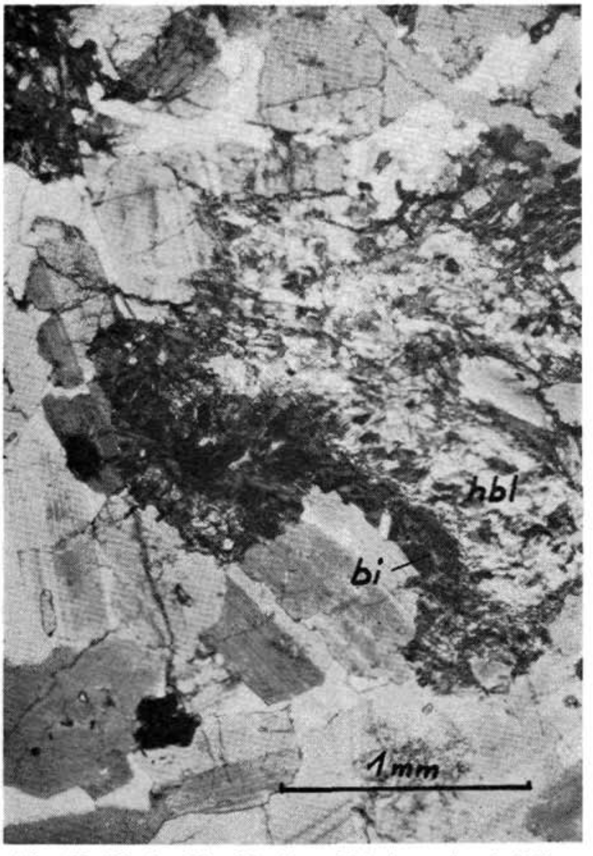


Fig. 13: Diorite. Hornblende and biotite replaced diallage.

guing locally (e.g. upper Nilaw valley). The contacts are generally steep and are frequently tectonized by later movements. Apart of the superimposed schistosity banding parallel to the contacts is recognizable in the diorite, which goes back to layering during the intrusion. The inclusions are also generally parallel to this banding and to the boundary of the diorite. These parallel structures dip steeply towards the ESE in the W and WNW in the E. This indicates fan structure of the diorite body (Pl. 1). In the NW the turn of the boundary against the younger biotite granite is an exception. There the diorite appears to dive at medium angles beneath the granite towards the W (e.g. head of Bedak valley).

The roof of the diorite is preserved in the crest of the range N of the Nilaw valley (Pl. 2). Discordant intrusive contacts are frequently observed there. Dikes of diorite in the surrounding rocks were observed in several localities though they are not frequent (Fig. 15).

Swarms of Li-Be-pegmatites invaded the Nilaw diorite, which is the reason of our special attention to that intrusion. The occurrence and genesis of these pegmatites are dealt in chapter 2.3.4. The dikes of granite, which penetrate mostly the northern parts of the Nilaw diorite are commonly thin.

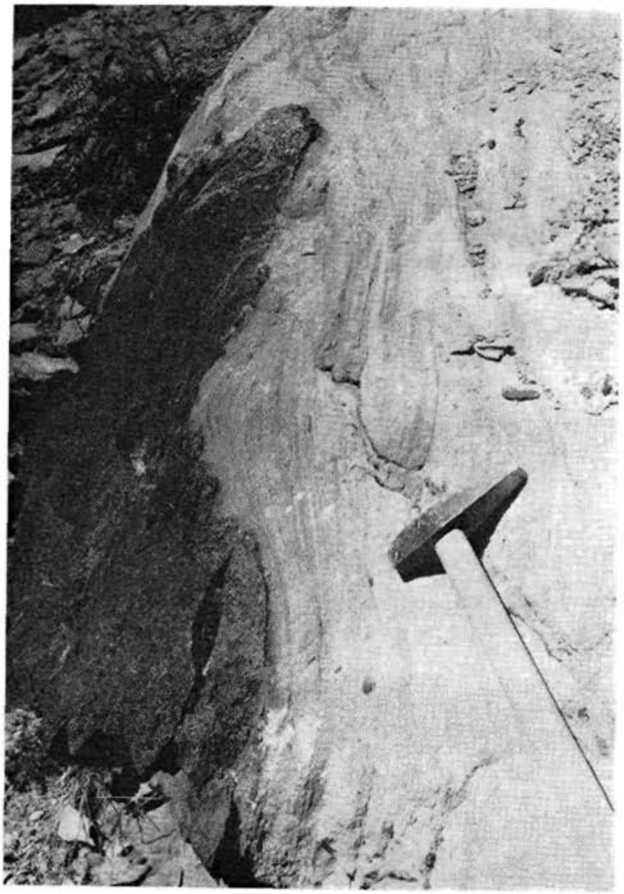


Fig. 14: Contact of diorite and marble without any reaction rim. Upper Nilaw valley.

The Atati-Pusal diorite in the northern portion of the mapped area was studied along a series of traverses. Migmatites and hornblende-biotite granite intrusions separate this diorite from the Nilaw diorite in the S. A continuation of the two diorite bodies in depth may be expected. S of Pusal we observed a transitional contact of the diorite and the hornblende-biotite granite. This is brought about by intermediate rock types. Intrusive breccias and dikes show that the granite is younger than the diorite. This age relation is particularly clear in the Cono and Wonasgel valleys where the granite invades the diorite with hundreds of sharply defined dikes. The age interval, however, appears to be small as gradational contacts were observed not only near Pusal, but also along the western boundary of the Nilaw diorite. Further there is a close relation in occurrence between the diorites and the hornblende-biotite granites, inasmuch as the latter are very common near the margins of the diorite.

Whereas transitions or intrusive breccias of huge dimensions make it sometimes difficult to draw the boundaries of the Atati-Pusal diorite, the diorite is well-defined where faults delimit it. N of Atati the diorite abuts against the metasedimentary series along a SW—NE striking fault. In the valley head of the Darrahe Wonasgel the diorite as well as the adjoining hornblende-biotite granite have become schistose in a broad

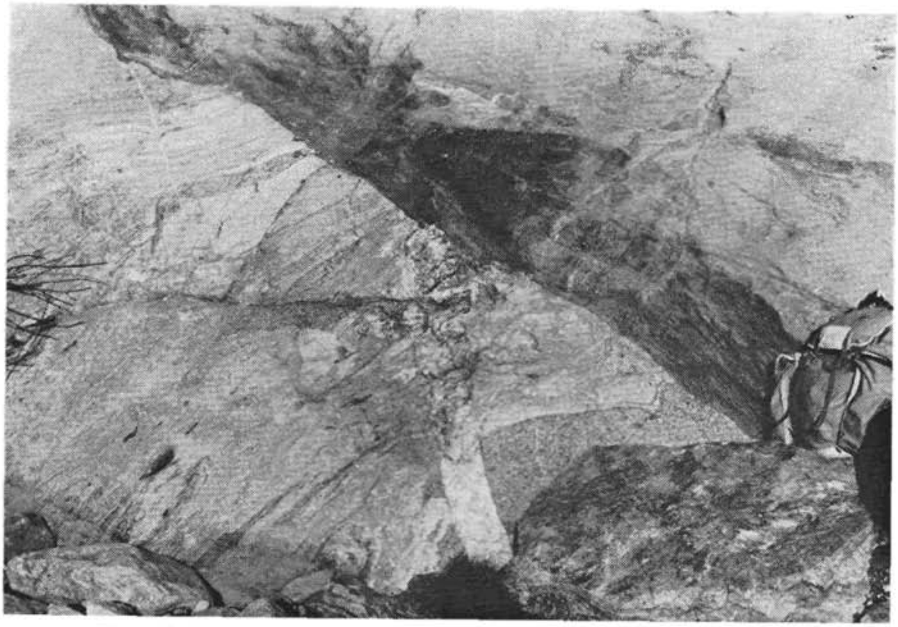


Fig. 15: Diorite dike crossing migmatite gneiss. N-face of Kohe Kajgal.

shearing zone. This strikes N—S and dips steeply towards E. Pegmatites as those of Nilaw are absent from the Atati-Pusal diorite.

The third diorite body is exposed around and S of Nespal in the southwestern portion of the mapped area. It builds up the major part of the Eskando and Gamata-Koraj valleys. It is surrounded by migmatites with generally steep contact planes. At its northern end, N of Nespal, the lower portions of the mountains consist of diorite, whereas the higher parts are built by migmatite gneiss. In this rugged terrain again we get a three-dimensional picture of the intrusions, which shows the preserved roof in the crest region of the mountains and the intrusive rocks in the adjacent valleys.

N of the Nespal diorite we find a series of smaller and larger lenses of diorite in the gneisses (e.g. Darrahe Doni, Kohe Gawati, Kohe Wazergawan). In part they represent small scale intrusions in continuation of the Nespal diorite, part of them are distorn blocks in the migmatites. Such block-like inclusions of diorite in the migmatites were occasionally observed also along the boundaries of the Nespal diorite. These peculiar occurrences may be interpreted as the result of local rejuvenation of the migmatites under a later phase of metamorphism and deformation.

Along the margins of the diorite in the western Darrahe Eskando biotite granite is found again. It intrudes the diorite and contains inclusions of diorite. Swarms of aplite and granite dikes are found throughout the Nespal diorite; they are generally thin. Regarding number and extension pegmatites are of no importance in the Nespal diorite. Just three occurrences are known in the Koraj valley.

The close genetic connexion between the diorite and the younger hornblende-biotite granite indicates that they belong to one magmatic cycle. Therefore with the description of the diorite a lot of features concerning the younger hornblende-biotite granite had to be anticipated. Moreover, before we enter the next chapter dealing with the hornblende-biotite granite, it is appropriate to refer to those specific rock types which are the product of interaction between diorite and hornblende-biotite granite.

Along the western margins of the Nilaw diorite we found a zone of massive or gneissic rocks of intermediate composition (e.g. dioritic, quartz-dioritic, monzonitic, granitic). Porphyric texture is very common.

Under the microscope inhomogeneous, fine-grained, inequigranular to porphyric, rather isotropic texture was observed. Main constituents are quartz, andesine, and microcline; minor constituents are biotite, hornblende, and leucoxene; accessories are orthite, zircon, opaques, and apatite. The primary hypidiomorphic texture is partly preserved, partly there are fine-grained domains with distinct intergranular interfingering. The feldspar phenocrysts may attain cm-sizes. Microcline is perthitic. Andesine usually shows zoning with epidote-filling in the core. Radial aggregates of leucoxene frequently surround a core of ilmenite. Biotite is ordinarily green. A conspicuous component is orthite, zoned red-brown to brown and with strong pleochroism. The frequent porphyric texture, the content of leucoxene and orthite, and the green colour of the biotites are characteristic features of this rock group.

2.3.2. Hornblende-Biotite Granite and -Gneiss

Under this heading homogeneous, fine- to coarse-grained, massive as well as gneissose granitic rock types are comprised. Biotite is accompanied very often by hornblende.

Under the microscope the massive rock types show granitic texture. Occasionally intergranular interlocking can be observed, which is interpreted again as a phenomenon of recrystallization. Major constituents are andesine, microcline, and quartz; minor constituents are biotite and hornblende; magnetite, ilmenite, apatite, sphene, sagenite, epidote, zircon, and orthite occur as accessories. Plagioclase shows zoning with about 70% An in the core and 40% An in the margins. Occasionally the core is dimmed, rarely filled with epidote as an alteration product. Microcline sometimes presents strong cross-hatching and is usually surrounded by myrmekite. Perthite is rather seldom. In one sample amoeboidic muscovite blasts occur together with microcline, which is interpreted as growth of the first at the expense of the latter. Biotite displays brown or green colour. Inclusions of sagenite, sphene, apatite, and magnetite are common. It can be surrounded sometimes by a peculiar myrmekite-like intergrowth of biotite and quartz accompanied by epidote. Aggregates or single individual crystals of hornblende prefer to occur together with biotite. The hornblende looks almost colourless or light-grey-greenish stained. The zircons are idiomorphic and oblong. Isometric, fresh orthite with strong pleochroism from pink to dark red-brown caused pleochroic haloes in biotite. Orthite is a characteristic component of the hornblende-biotite granites and -gneisses. Thus the microscopic studies prove the field observation that the formation of the transition zone between the diorite and the hornblende-biotite granite with its intermediate rock types is related with the intrusion of that granite.

The hornblende-biotite granite forms several larger or smaller intrusions around the Atati-Pusal diorite. The shapes of some of these intrusions are rather complicated. So it is impossible to draw the exact line of demarcation between granite and diorite in the Darrahe Cono, as the granite invades the diorite with a swarm of dikes and apophyses, and large inclusions of diorite are found within the granite. The individual dikes, however, are sharply defined. But, as mentioned above in chapter 2.3.1. there are also transitional contacts between the granite and diorite (e.g. S of Pusal, upper Darrahe Purdum, upper Bedak valley, etc.). Granodioritic rocks of various shades form the link between the diorite and the granite. Such types frequently make up the components of intrusive breccias, which are common along the diorite-granite contact (Fig. 16, 17, 18, 19).

Fig. 16: Diorite components swimming in hybrid hornblende-biotite granite. This intrusive breccia forms a zone several hundred meters thick. Upper Bedak valley.

Fig. 17: Hornblende-biotite granite with ghost-like inclusion of diorite, which itself contains inclusion of darker diorite variety. 4 km ESE of Nalu.

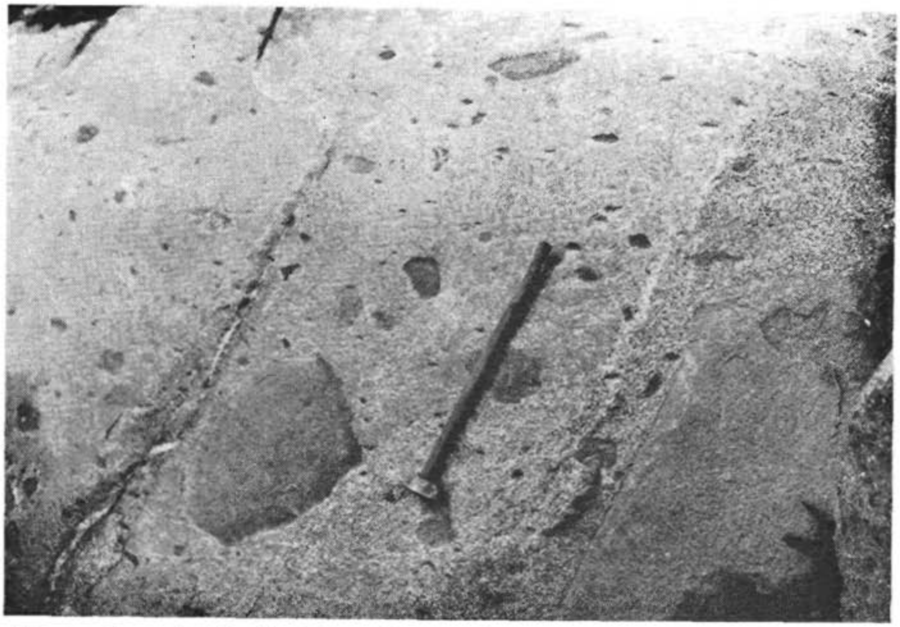


Fig. 18: Angular, well-defined inclusions of various diorite types within hornblende-biotite granite. Upper Bedak valley.

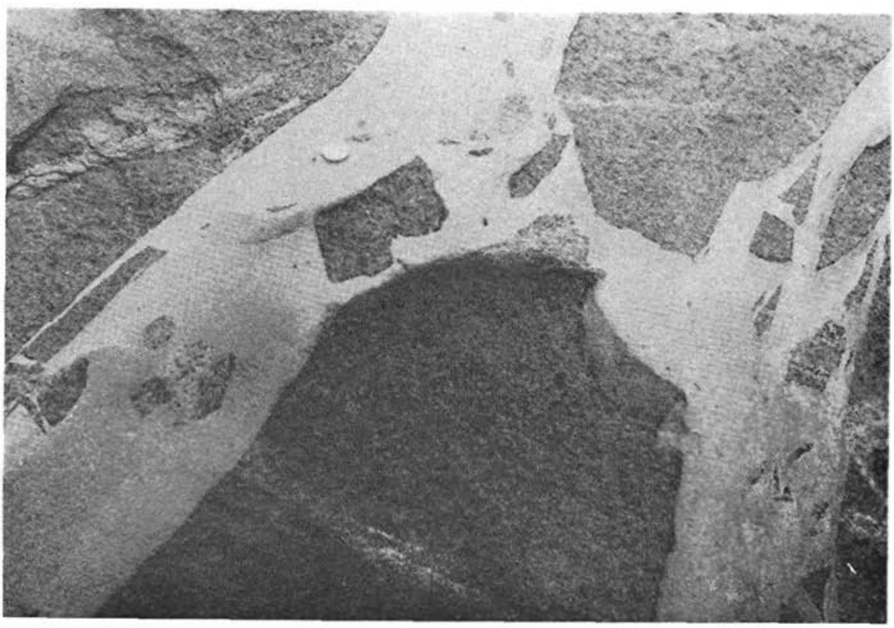


Fig. 19: Dikes of granite penetrate diorite. The latter is broken up into angular pieces. Upper Nilaw valley.

The granite bodies in the northern part of the mapped area are rather massive and are rarely foliated to gneiss. The same type of massive rock is found in the upper Bedak valley (Fig. 20, 21). When followed to the S, however, the granite becomes more and more foliated. There it is often very difficult to distinguish the granite-gneiss from homogeneous types of the migmatite complex. This internal structural features correspond with the shape of the different bodies. In the N the original intrusive form is still preserved, whereas in the S the granite-gneiss is generally conform with the neighbouring rock series (e.g. western Bedak valley, Pyar).

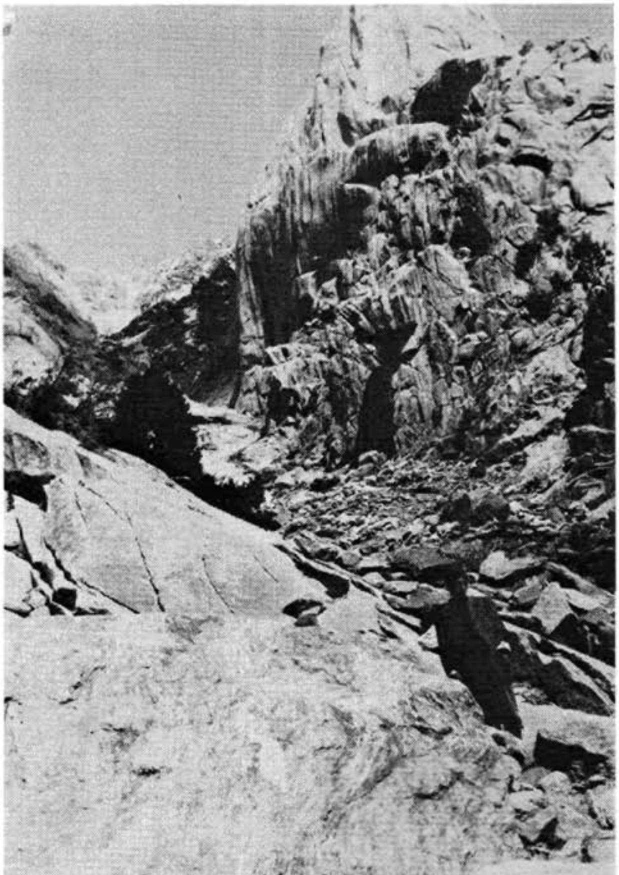


Fig. 20: Massive, homogeneous biotite granite-gneiss. Note the contrast to the migmatite block in the foreground. Kohe Wazergawan (Bedak valley).

The Pyar-Kajgal granite intrudes the Nilaw diorite unconformly. Here too transitional contacts were found. The pegmatites of that area intersect both rocks.

The granite dikes which penetrate the diorite in the upper Nilaw valley, in the Pesenta- and Nespal-Eskando areas are older than the pegmatites. Therefore it is reasonable to assume that these granite dikes are related with the intrusion of the biotite granite. The microscopic investigation indicates a curious relation with the migmatite complex: Some granite dikes contain the same radioactive zoisite aggregates which seem to us characteristic for the rock varieties of the migmatite complex. Thus the dikes seem to be either derived from the biotite granite directly or from material mobilized by that granite.

Fig. 21: Relics of metablastite of the migmatite complex in biotite granite-gneiss. Kohe Wazergawan (Bedak valley).

At last we have to note those deviating varieties of the granite which crop out in the Nawe Setaki and the western head of the Bedak valley. They display alkali-granitic or leuco-granitic composition. Under the microscope the fabric appears inequigranular with distinct intergranular interlocking. The alkali feldspars show pronounced perthitic exsolution. In the field the massive and light-coloured appearance is conspicuous.

2.3.3. Two-Mica Granite

This granite is homogeneous, massive, fine- to coarse-grained and light-coloured. Anisotropic textures such as preferred orientation of mica or banding are rare. Muscovite and biotite always occur together. Tourmaline seems to be a characteristic component of this granite.

The microscopic analyses demonstrate a typical granitic texture, which is hardly affected by later recrystallization or deformation. Interlocking of muscovite and biotite is the rule. Occasionally the oligoclase shows a dimmed core. Quartz, obligoclase, and microcline are major constituents, muscovite and biotite are minor constituents; apatite and zircon are accessories.

There are some smaller intrusions of two-mica granite in the Darrahe Nurestan, larger stocks are those of the Dahane Pyar area and E of Kotale Bandol-Darrahe Nawya.

This youngest granite cuts all described rocks with discordant contacts (Fig. 22). The Dahane Pyar intrusion shows complicated lobate forms unaffected by later tectonics. The relation of the granite to its roof is beautifully exposed in the steep slopes and rock faces of the deeply eroded Posal and Kolum valleys (Pl. 2 A). The lobe in the Posal valley, for instance, crops out only in the lowest parts of the slopes. The higher portions are composed of the gneisses of the roof. The country rock is intimately invaded by dikes of granite and pegmatite. Bands of gneiss are also enclosed in the granite (Fig. 22).

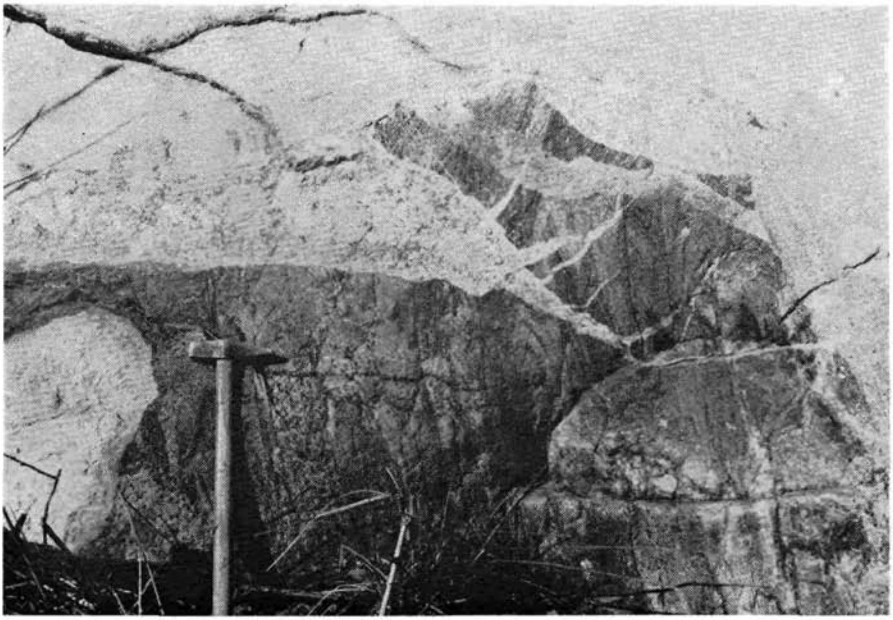


Fig. 22: Unconformable contact between migmatite gneiss and two-mica granite. Note pegmatitic margin of the dike. 3 km NE of Dahane Pyar.

The outcrops clearly show that the dikes have their source in the two-mica granite. They either purely consist of this granite or, as in many cases, it can be traced how a pegmatite develops from a granite dike (Fig. 23). Such transitional dikes are often composite, consisting of layers of two-mica granite as well as of pegmatite (Fig. 24). Although the granite dikes in the migmatite gneisses prefer the general N—S strike direction and steep dips towards the E they are comparatively irregular. But as soon as they enter the diorite, they become regular and subhorizontal.

2.3.4. Pegmatite

The most remarkable rocks in the mapped area are the pegmatites. The many par allel bands of light-coloured pegmatite somewhat like steps protruding the brownish slopes formed by the diorite, are a significant feature of the landscape around Nilaw.

As we mentioned in the introduction, a special report regarding the petrography of the pegmatites will be published as soon as the laboratory analyses are finished.

Fig. 23: Root of pegmatite in two-mica granite. Note the ill-defined boundary between pegmatite and granite. 4 km NE of Dahane Pyar.

The pegmatites are concentrated along the Nilaw valley, E and SE of its lower course. As noted above the pegmatites form a swarm of irregular steeply dipping veins in the gneiss complex. In the diorite they are gently dipping or subhorizontal and are continuous over great distances. The dikes are parallel to each other and are very regular. Occasionally a vein may split up into subparallel veins. Exceptionally, steeply dipping or vertical dikes intersect the regular dike system (e.g. S of point 2338 SW of Nilaw, area 3.5—4 km NNE of Nilaw). We have observed that locally one dike pinches out and close by another begins; a system of such lenticular veins gives the impression of "fiederkluft"-like tension joints. Commonly the thickness of the dikes is rather constant, but naturally there are also certain changes. Rapid swelling up and decrease of thickness are rare. Most of the dikes are from a few dm to 20 m thick, locally they attain thickness of 40 m (e.g. 1 km N of Posal-Nilaw valleys junction). Towards the margins of the pegmatite area the thicknesses decrease and the dikes finally pinch out.

The pegmatites dip SE in the south-eastern part of the pegmatite area within the diorite, and towards the SW in the lower Nilaw valley. Up that valley the direction

Fig. 24: Composite dike consisting of biotite pegmatite and granite zones. Darrahe Kolum.

of the dip turns to W and then to NW. In the western part of the uppermost Nilaw valley the dip towards W of the dikes prevails again. SE of Nilaw the veins are horizontal. The pegmatite system of southern Nilaw shows a foım similar to the glass of a watch (Pl. 2).

The pegmatites of the area around the Darrahe Mawi are different from those of Nilaw: They form a system of lenticular bodies. Only the thickest pegmatite (50 m) in the Darrahe Mawi may be traced over a distance of ca. 2 km. Dip of the dikes is towards the NW. N of the Darrahe Mawi area a few pegmatites were found W of Surič. The rest of the eastern diorite area is free of pegmatites.

The pegmatites penetrate the biotite granite as well as the diorite (e.g. Darrahe Posal N of Kajgal, eastern flank of Kohe Sopnal in the inner Nilaw valley). However, we observed that pegmatites end along the contact against gneiss (e.g. S of Darrahe Mawi) or marble (Nilaw valley).

The mineral composition and development of the pegmatites shows regional zoning.

Near their mother rock—the two-mica granite of Dahane Pyar—the dikes are either composed of granite, aplite, and pegmatite zones, or consist of biotite pegmatite (Fig. 24). Biotite, muscovite, black tourmaline, and sporadic beryl are characteristic.

In the diorite the above types disappear and the veins consist of fine-grained plagioclase pegmatite with mica zones, block pegmatite, block microcline, and rare quartz lenses. Beryl is sporadic, in the neighbourhood of block quartz it is relatively frequent. Further minerals are green-blue and black tourmaline, muscovite, phlogopite, fine-grained garnet, and cassiterite.

NW of Nilaw, in the higher veins, there is a slight change in mineral composition. Spodumene and lepidolite enter the mineral assemblage and beryl becomes unfrequent and is missing at last.

In the mountains W of the Nilaw valley and in the Bedak valley we find tension joints filled with quartz (±fine-fibrous tourmaline aggregates) or an alpine paragenesis of quartz, epidote, chlorite, adulare, and axinite. These thin veins form a W-dipping system, and thus show an orientation like the Nilaw pegmatites. Probably they are the westernmost representatives of the Nilaw vein system.

The Darrahe Mawi pegmatites not only form an exception as to their form and orientation, but also as to their mineral composition. Large crystals of beryl (30 cm) are found together with spodumene, lepidolite, black and blue-green tourmaline (Fig. 25). These pegmatites accompany biotite bearing types. The somewhat extraordinary pegmatite assemblage of the Darrahe Mawi seems to be caused by a telescoping effect.

All the described pegmatites are related with the two-mica granite of Dahane Pyar, and most of them occur in the Nilaw diorite. There are also pegmatites in the Bandol-Mundol (Darrahe Nurestan) area. Like in Nilaw these pegmatites show fine-grained albite-, mica-, block microcline- and block quartz zones. They contain also sporadic beryl crystals. The veins, which penetrate the migmatite complex, are very irregular, with respect to their form, thickness, as well as orientation, and are not so continuous as those of Nilaw. We assume that the pegmatites of that area are also derived from two-mica granite, though we only found minor intrusions of that granite.

Three occurrences of pegmatites are known from the Nespal diorite. In the middle course of the Darrahe Koraj a pegmatite, up to 1 m thick, contains black tourmaline and green beryl crystals (up to 1 cm). The N-dipping vein may be followed for ca. 100 m. In the upper course of the Koraj valley two pegmatite lenses, ca. 50 m long and 1 m thick, gently dip towards the NW. The fine-grained albite pegmatite contains coarse muscovite, microcline, and blue-green tourmaline.

After the description of the known pegmatite occurrences there remains the challenging problem of the genesis of the Nilaw pegmatites: Why are the veins so regular in the diorite, and how did they get their peculiar form (Pl. 2)?

Certainly the regularity of the dikes is related with the homogeneous character of the host rock, the diorite. The fact that several dikes end on the boundary against larger inclusions of country rock is consistent with this assumption. In other words the continuity of the veins ends were the homogeneity of the diorite is disturbed. The pegmatites in the biotite granite display the same characteristics.

It is reasonable to assume that stress and temperature differences caused tensions in the diorite, which led to a joint system. Later a certain set of these joints was used by the pegmatites as ways of least resistance.

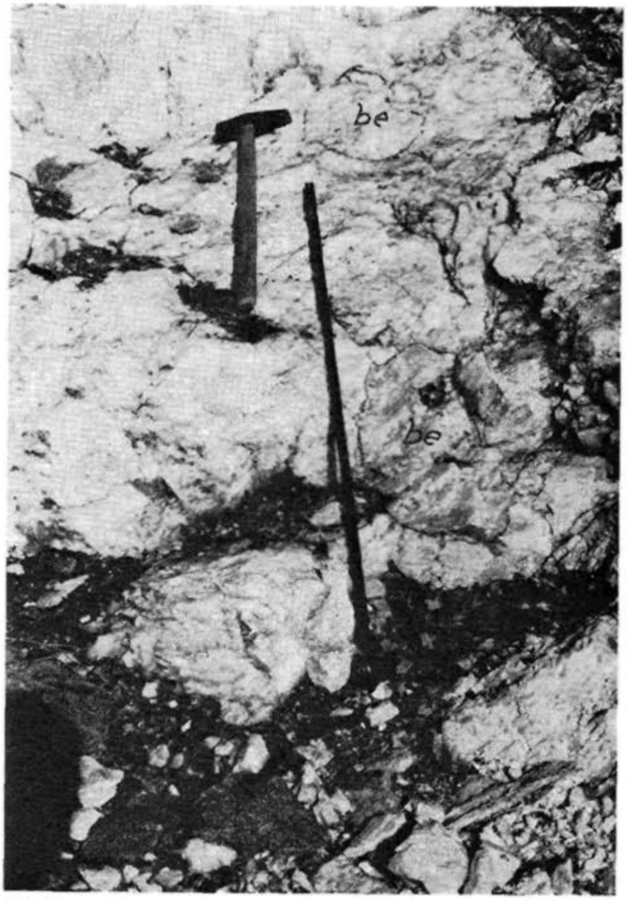


Fig. 25: Pegmatite containing 30 cm crystals of beryl (be) Darrahe Mawi.

Apart from the structural anisotropy (banding) due to the intrusion, deformation after the emplacement of the diorite caused foliation in certain zones. Thus N—S striking schistosity reflects fan structure, inasmuch as the dip is towards the E near the western boundary, towards the W near the eastern boundary of the diorite. Shrinkage of the cooling diorite in combination with E—W directed stress caused a system of vertical and horizontal joints. Upwarpening of the subhorizontal joint system to the above mentioned watch-glass pattern may be related to the formation of the fan structure (Pl. 2). The lateral compression of the diorite body kept the vertical joints closed, whereas it enabled the pegmatites to intrude the subhorizontal tension joint system. This explains the fact that the pegmatites keep to certain levels for several kilometers, but do not intrude the higher portions of the diorite.

2.3.5. Lamprophyre

The lamprophyres appear as homogeneous, massive, fine-grained, and dark-grey rocks.

Under the microscope one representative sample is of kersantitic composition with 65% andesine, 15% biotite, 10% quartz, 7% hornblende, 2% opaques, and 1% apatite. Rather sporadic phenocrysts of plagioclase are in the fine-grained hypidiomorphic matrix.

A few outcrops of lamprophyres where found in the northern parts of the mapped area (e.g. S of Atati, Darrahe Purdum, Kohe Purdum, and pass N of Wezir). The dikes invade the diorite and hornblende-biotite granite. Their thickness attains maximally few meters. Regarding quantity and extension of occurrences this rock group is not important. The strike of the dikes follows approximately the N—S direction. Obviously the lamprophyres belong to the youngest rocks in the northern part of the area mapped. The relation to the two-mica granite is unknown as these two rock types are not exposed together.

2.4. Faults

In certain areas steep angle faults are significant structural elements. N of Atati such a fault strikes SW—NE, and forms the boundary between the Atati-Pusal diorite and a low-grade metamorphic sedimentary series. The rocks in the neighbourhood of the fault show diaphthoresis, but some granitic dikes seem not to be affected.

A parallel fault crosses the Darrahe Nurestan at the junction with the Darrahe Wonasgel. Along a broad approximately N—S striking zone of disturbance the adjoining rocks—biotite granite and diorite—became highly schistose in the upper Cono and Wonasgel valleys. It appears that the eastern block has slipped towards the S.

3. The History of the Nurestan Crystalline

As the surrounding areas of Nurestan are only roughly investigated (Denikaev et al, 1971) it is somewhat difficult to deduce the geologic history from a comparatively small area.

Another critical point is the limited time of field work, and the fact that we were not able to prove the results of the laboratory analyses in another field season. Despite of this the amount of compiled data seem to be sufficient for presenting a genetic model of the investigated crystalline.

On a migmatite complex of probably Precambrian age carbonate and non-carbonate series were deposited. The sedimentary marine environment was shallow (marbles and quartzites) to medium deep (metasiltstones and phyllites). Basic to intermediate volcanism was active penecontemporaneously with the deposition of the sediments. Similar series in Pakistan have yielded fossils (Hayden, 1915; Pascoe, 1959; Geological Map of Pakistan, 1964); this and comparison with the sedimentary development in other parts of Afghanistan (Weippert et al., 1970) suggest a Palaeozoic (to Triassic?) age. In the same direction points the correlation of the metavolcanic rocks either with the Agglomeratic Slate of Kashmir (Permo-Carboniferous) or with the Doab Volcanism of Central Afghanistan (Triassic).

The sedimentary and volcanic rocks together with the migmatite gneisses have been involved in Alpine orogenic events. Physical age determinations of magmatic rocks have given Tertiary age (Harre et al, 1966/67, cit. in Weippert et al, 1970, p. 26). The structural pattern governed by NNE—SSW B-axes seems to have remained constant.

During the early stage of this orogenic period gabbro and diorite intruded, succeeded by hornblende-biotite granite. Where the diorite already had attained a solid state, the contacts against the granite are sharp, and the fragments in intrusive breccias are angular. But transitional contacts and intrusive breccias with rounded components, which consist of intermediate rock types, form a gradation between diorite and granite. This indicates that other parts of the diorite bodies were not yet consolidated, when the granite intruded. The country rocks were metamorphosed under conditions of the hornblende-hornfels facies. Corresponding phenomena are found far beyond the defined contact zones.

The following regional metamorphism was accompanied by tectonic movements in the beginning. The metamorphic effect of this period was not uniform. In the northern part of the mapped area the alteration was under conditions of the greenschist facies. The southern part, however, was metamorphosed under conditions of the staurolite-almandine subfacies of the almandine-amphibolite facies of Barrow type. Retrogressive transformations of primary pyroxene into biotite and hornblende in the diorite, for example, is due to this metamorphic phase rather than to late intrusive autometamorphic influence. Locally the diorites became schistose near the margins, and the Nilaw diorite got its fan-like structure (Pl. 1). The hornblende-biotite granite became a gneiss in the southern regions. After this tectonic activity the regional metamorphism continued. In appropriate rock types post-tectonic staurolite was formed. Local migmatitic phenomena might be related to the biotite-granite intrusion or to the regional metamorphism as well.

After a certain time gap the emplacement of the two-mica granite began. A swarm of granite and pegmatite dikes invaded the country rocks. Contemporary to lateral compression af the Nilaw diorite a set of subhorizontal joints opened the way for pegmatites. The lamprophyric dikes of the northern region are also unfoliated; the age relation to the two-mica granite is doubtful.

Later block movements occurred along vertical or steep angle faults.

It is worth to note that there are no indications of nappe movements, which are so important in the near Himalayas. So there is a marked difference in structural style between the Hindukush and the Himalayas.

4. References

BLAISE, J., BORDET, P., LANG, J., de LAPPARENT, A. F., LEUTWEIN, F. & SONET, J.: Mesures géochronologiques de quelques roches Cristallines d'Afghanistan central. — C. R. Acad. Sc. Paris, Série D, *270*, 2772—2775, Paris 1970.

BRÜCKL, K.: Die Minerallagerstätten von Ost-Afghanistan. — N. Jb. f. Min. Geol. Paläont., 1936, Beilagenbd. *72a*, 1—97, Stuttgart 1936.

DENIKAEV, Sh. Sh., FEOKTISTOV, V. P., ROSSOVSKY, L. N., AJRUDDIN, A., NARBAEV, Sh. N., KONEV, Yu. M. & BOGDANOV, V. V.: Geological Map of Northern Part of Eastern Afghanistan, 1:500 000 and unpublished reports, 1971.

GAMERITH, H. & KOLMER, H.: Untersuchungen an Intrusivgesteinen des östlichen Hindukush. — Geol. Rundschau, *62*, *1*, 161—171, Stuttgart 1973.

FUCHS, G., MATURA, A. & SCHERMANN, O.: Vorbericht über geologische und lagerstättenkundliche Untersuchungen. — Verh. Geol. B.-A., 1974, 9—23, Wien 1974.

Geological Map of Pakistan, 1:2,000.000. — Geol. Surv. Pak., 1964.

HAYDEN, H. H.: Notes on the Geology of Chitral, Gilgit and the Pamirs. — Rec. Geol. Surv. India, *45*, (4), 271—335, Calcutta 1915.

MENESSIER, G.: Afghanistan. Lexique Stratigr. internat., *III*, Fasc. 9 a, 171 pp, Paris 1961.

PASCOE, E. H.: A Manual of the Geology of India and Burma. — *2*, 1343 pp., 3. Edition Govt. Press, Calcutta 1959.

POPOL, S. A. & TROMP, S. W.: The stratigraphy and main structural features of Afghanistan. — Koninkl. Nederl. Akad. Wetens, Proc., sér. B, 57, Nr. 3, 370—394, 1954.

RAUFI, F. & SICKENBERG, O.: Zur Geologie und Paläontologie der Becken von Lagman und Jalalabad. — Geol. Jb., *B 3*, 63—99, Hannover 1973.

WEIPPERT, D., WITTEKINDT, H. & WOLFART, R.: Zur geologischen Entwicklung von Zentral- und Südafghanistan. — Beih., Geol. Jb., H. 92, 99 pp, Hannover 1970.

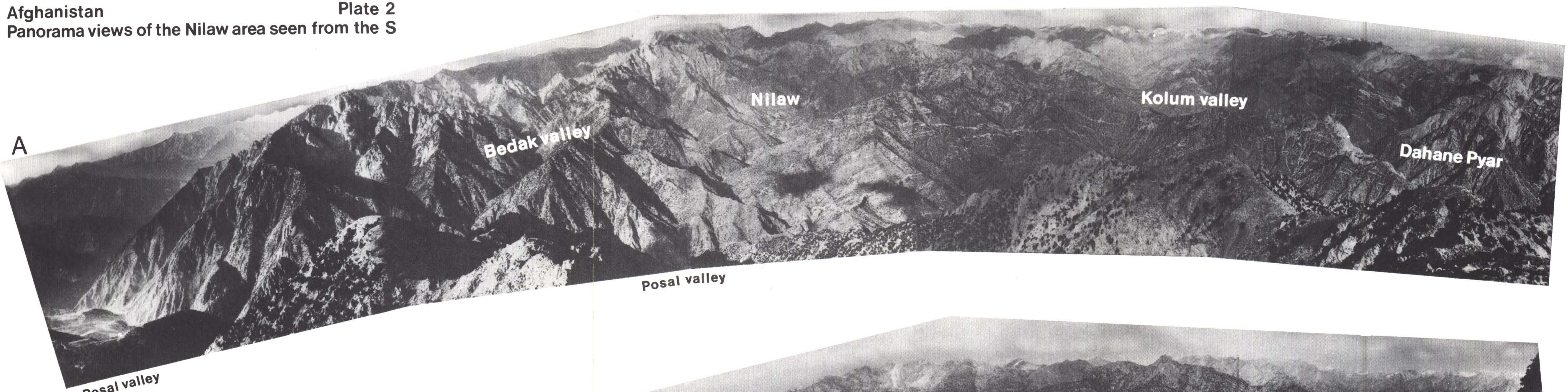
Manuscript received by the editor in January 1975.

DRUCK: FREYTAG-BERNDT u. ARTARIA, WIEN

Jahrbuch der Geologischen Bundesanstalt, 119. Band, 1976 – G. FUCHS und A. MATURA, Beilage 8

Afghanistan
Plate 2
Panorama views of the Nilaw area seen from the S

A



B