# PETROGRAPHY OF QUARTZ DIORITES TO THE SOUTH OF KALAM, SWAT

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## ABSTRACT

The quartz diorites of Swat Kohistan appear to be partial melting products of more mafic rocks during the collision of Asian-Indian landmasses and the Himalayan orogenic-metamorphic episodes. On the basis of texture and type of principal mafic mineral(s), at least four types of quartz diorites can be recognised in the area to the south of Kalam. One of these, with strongly pleochroic hypersthene relics, appears to be a retrograde type after pyroxene granulites. It is not clear whether or not the other types are a product of differentiation from a single parent magma; however, it is likely that they represent independent pulses of diorite (andesite) magma produced over a considerable length of time (Late Cretaceous to late Middle Tartiary), the earlier ones having been metamorphosed.

## INTRODUCTION

On the geologic map of north Pakistan (Tahirkheli and Jan, this volume), diorites have been shown to cover a much larger area than any other rock-type. However, it is still not clear how much of this area is occupied by quartz diorites *sensu stricto*. Unfortunately, the term diorite has been used by a number of geologists in a very vague and loose sense for a variety of rocks found in northern Pakistan. The term has been used for "igneous-looking" hornblende-plagioclase (± epidote ± garnet) rocks ranging from intermediate to basic or even ultrabasic in chemistry; whilst some of these rocks are igneous in origin, others are unequivocally metamorphosed diorites, gabbros and olivine gabbros. The term has also been used for pyroxene granulites (hypersthene-quartz dioritic and noritic) and their retrograde metamorphic equivalents (amphibolites). Thus the ambiguity of terminology has complicated the realisation of true extent of the diorites.

Quartz diorites are abundant in the northern Swat valley; they occupy large areas in Ushu-Gabral valleys and to the south of Kalam. The two diorite areas are separated from each other by a NE-stretching, thick sequence of metasedimentary and volcanic rocks belonging to the Kalam group and Utrot volcanics of Creto-Eocene age (Jan and Mian, 1971. Tahirkheli and Jan (1978) have shown that the two occurrences merge into one extensive diorite belt to the east, but this requires further field work. This paper describes the general features of the quartz diorites to the southern of Kalam. Those of the Ushu valley are being described by Khalil and Afridi (this volume).

## PETROGRAPHY

The rocks are medium- to coarse-grained and characterised by hornblende and/or biotite as their main mafic component. They can be readily identified from the pyroxene granulites (occuring in the south) by their non-pinkish feldspar, generally lower feldspar content, lack of layering, and local abundance of xenoliths. Foliation is developed only locally in some parts and its trend is not as consistant as in the amphibolites and granulites. Xenoliths of quartzite and amphibolite occur in many rocks and are locally aligned parallel to the foliation. In a few places, intrusive breccia with thin partings of dioritic material is also fonnd. Although some of the xenoliths have been digested to varying degrees, most of them have sharp contacts with the enclosing diorites and they do not seem to have substantially affected the composition of the magma. The quartzite xenoliths have a brownish colour, with green (? epidote and amphibole) margins, and may have been derived from the Kalam group; the amphibolitic xenoliths may also belong to the Kalam group unless they are banded amphibolites or altered pyroxene granulites of the south.

Veins of quartz, feldspar, epidote and, less frequently, hornblende + plagioclase, and simple pegmatites are common; however, the coarse hornblende + plagioclase pegmatites, so characteristic of the amphibolites and granulites, have not been found in the quartz diorites. Patchy concentrations, streaks, and schlieren of biotite and hornblende, slickensides and shear zones have been noticed in a number of places, and oxidised pyrite veinlets in a few places. Occasionally, a finer-grained dioritic material is included in a coarser type; it is possible that the former were the earlier surges of magma in the country rocks, followed by the emplacement of the main magma bodies, or chilled margins incorporated in the remaining magma. Less frequently, thin veins of dioritic and granitic material also occur in the rocks. Although the quartz diorites cover an area of the size of a small batholith, it appears that the rocks have not been formed by the *in situ* solidification of a single magma body; they are probably the products of repeated intrusions of small dioritic magma bodies which may or may not be comagmatic.

## FEATURES OBSERVED IN THIN SECTION

On the basis of mineral composition and texture, the quartz diorites can be divided into four major types:

i) those containing hornblende/biotite and a lesser amount of, usually, strongly pleochroic hypersthene ± clinopyroxene,

ii) those containing hornblende/biotite but no pyroxene,

iii) similar to (ii) but forming a distinctly coarse-grained intrusion in the middle reaches of the Kedam stream, and

iv) the subequigranular to porphyritic minor intrusions around Kalam that contain biotite and pyroxene(s) but little or no hornblende. Orthopyroxene of these rocks is mildly pleochroic compared to that of the first type. Further subdivisions of the diorites on the basis of texture/structure and dominant type of mafic mineral can be made but are avoided for want of detailed field work.

It has already been discussed (Jan, this volume) that in some of the granulites substantial quantities of hornblende and/or biotite have developed as products of retrograde metamorphism without the whole rock having been amphibolitised. Such rocks of intermediate composition are very difficult to distinguish, megascopically as well as in thin sections, from the first type of the quartz diorites. These rocks actually bridge the mineralogical gap between the pyroxene granulites and the second type of the quartz diorites and Jan and Mian (1971) were led to think that all quartz diorites and norites (pyroxene granulites) of the area are genetically related. Geochemical investigation (Jan, 1977a) suggests that while the first type of the quartz diorites may or may not be related to the granulites, the other three types are not comagmatic with the granulites. It is thus debatable whether the first type should be included in the granulites or quartz diorites; in the present work, only those of such rocks are included in the granulites which have a pinkish plagioclase, distinct foliation, and whose hornblende/biotite is unequivocally secondary. It is possible that the hydrous minerals of the first type of the quartz diorites are mostly secondary, *i. e.* metamorphic (Jan and Kempe, 1973), and most, if not all, of them are modified granulites. Since the area to the north of Asrit along the Swat river contains all types of the quartz diorites as well as intermediate granulites, the boundary between the two groups of rocks shown on various maps (e. g., Jan, 1977b) is quite arbitrary.

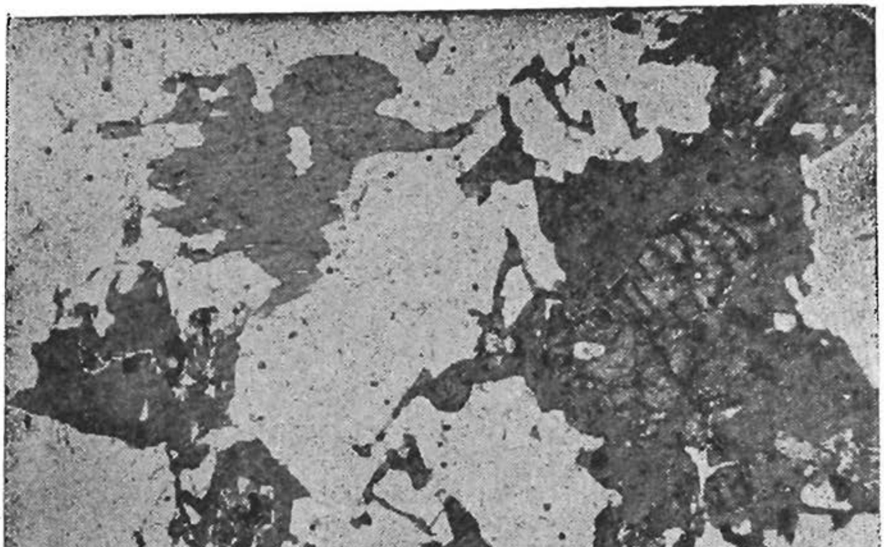
Modal composition of seven rocks is presented in Table 1. The diorites of the first type are represented by SH 37 and SK 647, those of the third by SK 525, and the second by the rest; point counting was not carried out on rocks of the fourth type because of their altered nature. The high plagioclase content of 647 is strikingly similar to that of the granulites.

**Hornblende-biotite-hypersthene-quartz diorites**

These rocks generally contain hornblende, biotite and, in some, hypersthene as their main mafic minerals; the clinopyroxene is usually in minor quantity or absent whilst some of the rocks contain only one of the two named hydrous minerals. Jan and Kempe (1973) regarded the rocks to have been originally, without exception, pyroxene diorites and the hornblende as secondary (metamorphic) after pyroxene. In some of the rocks, however, it is not easy to decide about the nature of the hornblende although the biotite seems to be secondary in most cases. The pyroxenes, more often hypersthene than clinopyroxene, have exsolution lamellae, again traced with iron oxide as in the pyroxene granulites, and often show a corroded or symplectic replacement texture (Pl. 1) with the hornblende. The hypersthene, when fresh, is usually strongly pleochroic and in this respect is similar to that of the pyroxene granulites.

The plagioclase of the rocks is generally well-twinned, medium andesine, and locally contains abundant opaque inclusions in the centre. In a few rocks it is antiperthitic and contains rounded quartz inclusions, thus resembling the feldspar of the Swat pyroxene granulites. K-feldspar is occasionally present; in the rocks with antiperthitic plagioclase, it is usually perthitic with strings of plagioclase. The biotite, usually dark brown but less frequently greenish yellow, may have myrmekitic quartz whilst in some rocks the hornblende is sieved by quartz. Other minerals in the rocks include quartz (up to 15%), opaque minerals (magnetite with some ilmenite and, rarely, pyrite), apatite and, in a few, secondary sphene, chlorite and epidote. Locally, as in the west of Laikot, the rocks are rich in dark minerals. The presence of pleochroic hypersthene,

**Plate 1**




Hornblende-biotite-hypersthene diorite (SH 37) showing hypersthene relics in hornblende. The rock may be a retrograde graunlite

(Photo : Courtesy of Dr. D.R.C. Kempe).

TABLE 1. MODAL COMPOSITION OF QUARTZ DIORITES

| Sample No. | No of points counted | Thin section(s) | Plg | Qz | Kf | Hbl | Bio | Opx | Cpx | Ore | Ap | Others |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SH 37 | 7096 | 1 | 58.3 | 12.2 | 3.2 | 13.4 | 11.3 | 0.6 | 0.1 | 0.7 | 0.3 | Tr |
| SK 443 | 7727 | 1 | 46.3 | 28.0 | 0.2 | 11.6 | 12.0 | ... | ... | 0.1 | 0.3 | 1.6 |
| SK 525 | 5441 | 2 | 57.3 | 18.8 | ... | 6.2 | 15.4 | ... | ... | 1.3 | 0.4 | 0.7 |
| SK 639 | 5695 | 1 | 52.1 | 18.0 | 1.5 | 18.0 | 7.1 | ... | ... | Tr | 0.3 | ... |
| SK 647 | 10392 | 2 | 70.1 | 5.4 | ... | 12.7 | 1.7 | 7.0 | 0.9 | 1.7 | 0.4 | ... |
| SK 705 | 5562 | 2 | 54.9 | 19.7 | ... | 11.6 | 12.0 | ... | ... | 0.4 | 0.3 | 1.2 |
| SK 731 | 2948 | 1 | 55.4 | 14.5 | 1.3 | 16.7 | 11.5 | ... | ... | 0.3 | 0.2 | 0.2 |

antiperthitic and/or high plagioclase content of some of the rocks, and the apparently secondary nature of much of the hydrous minerals suggest that this type of the quartz diorites may be retrograde granulites.

**Hornblende-biotite-quartz diorites**

The second and the third types of the diorites have no pyroxene; most of them contain both hornblende and biotite but a few have only one of the two as their main mafic component. The two minerals may be poikilitic, whilst, in rarer cases, the quartz (up to 20%) also grows in interstitial poikilitic patches. The plagioclase is well-twinned, altered to varying degrees, and shows minor zoning and some straining. Compositionally it is andesine and is not exsolved to antiperthite; minor quantities of K-feldspar also occur in some rocks. The biotite is yellowish to dark brown and occasionally cuts across or extends into the neighbouring minerals. Chlorite is a common alteration product after it and, in a few rocks, is accompanied by sphene ± muscovite and epidote, or prehnite. In SK 705, the biotite is completely altered to a fine-grained material composed of reddish iron oxide or hydroxide and sericite; this rock occurs near the contact with the Eocene volcanic rocks of Utror (Jan and Mian, 1971).

The amphibole is green to yellowish or brownish green hornblende some of which has intergrown quartz. In at least one rock, its cores have different optical orientations than the margins. Sphene is a more common primary accessory of these rocks than the first type of the quartz diorites whilst a few rocks also contain zircon. The opaque minerals are mainly represented by magnetite, with lesser ilmenite and occasional pyrite. The diorites of third type are similar to the second type in mineral composition but are distinctly coarser-grained and at places 'pegmatitic' with grain size reaching 2 cm. They usually contain minor quantities of well-shaped epidote and zircon, and inclusions of rutile in the quartz.

**Quartz diorites in the minor intrusions**

The quartz diorites of the fourth type are subequigranular to prophyritic and fine- to medium-grained rocks occurring in small dykes and sills that are confined more or less to the metasediments of the Kalam group. The plagioclase of these rocks is strongly zoned but the other minerals do not show so strong zoning. Alteration is a common feature; the plagioclase is either completely altered or only along certain zones and in the cores. The biotite is deep reddish brown and partly altered to chlorite whilst the amphibole is either a minor constituent or altogether absent. The pyroxenes, especially hypersthene, may be serpentinised or, rarely, uralitised. Some of the pyroxene grains are irreqularly surrounded by hornblende but in one rock the pyroxene cores are enclosed in the biotite, itself surrounded by the amphibole. The biotite and, in some, quartz may grow into poikilitic patches. Opaque minerals, apatite, and secondary epidote are present in small quantities. The orthopyroxene of the rocks is only mildly pleochroic when compared to those of the qranulites and diorites of the first type despite its similar composition (Mg 59) to the former; the clinopyroxene is light green augite (Mg 40.7 Fe 18.2 Ca 41.1). Whilst foliation has developed to varying degrees in the other types, these diorites generally are devoid of it. They appear to be the youngest (? Eocene) of the four types of quartz diorites.

## THE GRANITIC ROCKS OF SWAT KOHISTAN TO THE SOUTH OF KALAM

The granitic rocks are variable in texture and mineralogy and range from thin and short veins to sheets extending for some kilometres. Whilst some of them may contain xenoliths and have discordant, seemingly intrusive, contacts with the surrounding rocks, most of them are concordant. Whether or not some of the small concordant bodies are a product of metamorphic recrystallisation of quartzo-feldspathic sediments of appropriate composition and, like the felsic bands in the amphibolites, have not passed through a magmatic stage is difficult to assess. Most of the granitic rocks are small masses and cover an area of a few hundred sq. m., or less; some, however, are much larger.

Many of the granitic rocks seem to be plagioclase type (trondhjemitic) and the K-feldspar is either absent or only in small puantity. Some, however, are 'normal' granites with about equal proportions of quartz, K-feldspar(s), and sodic plagioclase as their main minerals. None of the granites contains orthopyroxene and, although some of them may have been metamorphosed, evidence of the granulite facies metamorphism is lacking. The absence of charnockites and syenites in the area, especially in the granulites which are leuco-norites to anorthositic norites, is in contrast to the anorthosite masses of the orogenic zones and granulite facies terrains (Berrange, 1965; Hargraves, 1969). The minor components of the various granitic rocks of Swat include biotite, hornblende, opaque minerals, apatite, zircon, in some garnet and epidote and, in one, alanite. Whilst the garnet, epidote and, in some cases, hornblende may have grown due to assimilation, or magmatic processes, the possibility of metamorphism cannot be ruled out in a few cases. It is possible that the granitic rocks have been emplaced over a span of time and the earliest ones, like some of the quartz diorites, may have undergone regional metamorphism in the amphibolite facies.

## CONCLUDING REMARKS

In contrast to the previous view (Jan and Mian, 1971; Jan and Kempe, 1973), chemical variation diagrams suggest that the quartz diorites (setting aside the strongly pleochric hypersthen-bearing type) and granitic rocks to the South of Kalam are not comagmatic with the pyroxene granulites (Jan, 1977 a). In fact the variation diagrams and petrography cannot even endorse the idea that the quartz diorites are mutually related directly. It is probable that they crystallised from dioritic (andesitic) magmas generated independently and at different sites during the collision of the Indian-Asian landmasses and the Himalayan orogenie/metamorphic episodes during Late Cretaceous to late Middle Tertiary period. The rocks may have formed in an ancient continental margin or an island arc, and the earlier of them have undergone regional metamorphism.

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