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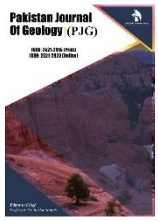
Pakistan Journal of Geology (PJG)

DOI: http://doi.org/10.26480/pjg.02.2025.117.120

ISSN: 2521-2915 (Print)
ISSN: 2521-2923 (Online)
CODEN: PJGABN



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RESEARCH ARTICLE

DETAILED PETROGRAPHY AND IDENTIFICATION OF MICROSTRUCTURES IN SUSALGALI GRANITE GNEISS MANSEHRA AREA KHYBER PAKHTUNKHW, PAKISTAN

Hasnain Haider[a*], Shamim Akhtar[b], Enayatollah Emami Meybodi[a]

[a]Yazd University Iran
[b]University of Sargodha Pakistan
**Corresponding Author Email: haider.cca@gmail.com*

ARTICLE DETAILS

Article History:

Received 23 April 2025
Revised 09 May 2025
Accepted 23 June 2025
Available online 04 July 2025

ABSTRACT

Granite gneiss is the highest grade of metamorphic rock that exhibits prominent metamorphic structures. Susalgali granite gneiss has a foliated texture and contains small crystals of alkali feldspar (orthoclase or microcline). During field studies in this area few kinds of variations were also observed in granite gneiss i.e. highly porphyritic coarse-grained mica granite gneiss, medium grained micas granite gneiss, and leucocratic tourmaline-bearing granite gneiss. The petrographic studies of the granite gneiss indicate the presence of quartz, feldspar, biotite, hornblende, plagioclase and muscovite. Thin section studies also show fractional crystallization and zoning in plagioclase. In Pakistan, granite gneiss rocks are of diverse colors, mineralogy, textural characteristics, and mechanical properties could be found but limited literature available on the micro structures identification to explain the pressure-temperature conditions of granite gneiss. Microscopic techniques such as polarizing microscope and Scanning Electron Microscope (SEM) are combined to analyzed mineral composition, rock microstructure, and degree of metamorphism of selected quartz-rich samples. High-temperature recrystallization is indicated by the deformation and recrystallization of quartz. Microstructure identification indicates that feldspar boudins and quartz recrystallization occur at highest temperature and pressure.

KEYWORDS

Boudinage structure, Foliation, Granite Gneiss, Microstructures, Recrystallization

1. Introduction

The study area is located in Mansehra district, Hazara region, Khyber Pakhtunkhwa, between longitudes 73°12'3.82"E and latitudes 34°20'1.98"N. Susalgali is a mountain pass located in close proximity to Nartob, Dabbi Mar, and Chata areas. The pass is situated at an altitude of 1,477 meters above sea level. The study area comprised of Meta sedimentary rocks and regionally metamorphosed into quartzite and quartz schist and gneiss. The MGC is mainly comprised of Mansehra Granite, Hakale Granite, leucogranites, and microgranites in the Mansehra area (Naeem et al., 2016). According to zircon U-pb dating, the crystallization ranges from 476 to 483 million years ago (Naeem et al., 2016). The region between Mansehra, Oghi, and Darband is geologically characterized by a layer of Granite that includes several other types of rock formations such as Hakale granite, quartzite, Mansehra dolerite, Pegmatite, and leucogranitic masses are a few examples of Mansehra granite gneiss (Ashraf, 1974). As suggested that the Mansehra Granite was originated by the Late Neoproterozoic to Cambrian sedimentary protoliths (Ogasawara et al., 2019). The major country rock unit (Susalgali granite gneiss) are encircling by Tanawal formation of Neo Proterozoic age that has been intruded at places by dykes like dolerite and also by pegmatite veins around the different location of study area. The granite contains restites of variable shapes and sizes which are uniformly dispersed possessing similar composition to the enclosing rocks of the Tanawal Formation (Naeem et al., 2021). Susalgali granite gneiss has a foliated texture and contains small crystals ofalkali feldspar. It also has a gneiss structure characterized by alternating bands of light and dark minerals. This region is being identified to contain the basic composition such as dolerite dykes and sills. The predominant minerals which make up granite gneiss are quartz, feldspar and mica. Biotite, muscovite, chlorite that is being laterally replaced by sataurolite, tourmaline and Apatite are minor minerals. Some prominent minor minerals are zircon, rutile, monazite, and epidote (Shams, 1971). However, the study of micro-structures and pressure temperature conditions of metamorphism of granite gneiss is very limited in literature. So, the objective of this study is to explore detailed petrography, micro structure identification and interpretation of PT condition for granite gneiss in this area.

2. Map Of Study Area

The Study area of Susalgali is located in District Mansehra, Khyber Pakhtunkhwa, Pakistan. The study area lies between coordinates of latitude 34°20'1.98"N and longitudes 73°12'3.82"E. The altitude of Susal Gali is 1,477 meters above sea level. It is surrounded by high mountain range in North. Due to High Mountain and high relief of the area, it is prone to rocks fall and debris fall in the area. Map 1 below shows the exact location of the study area where the samples were taken and studies were done.

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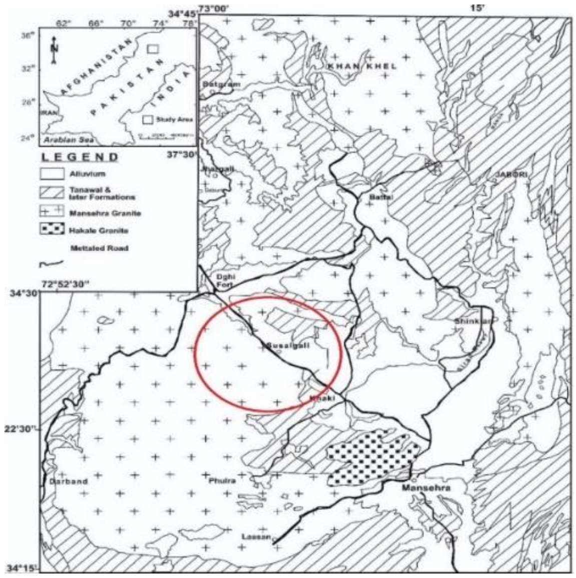

Map 1: Geological map of study area (Manshera KPK) modified after (Naeem, Khalid, and Anwar, 2015).

3. Material And Methods

The first step is to collect the samples from the outcrop. The information preserved in igneous and metamorphic rocks, particularly Mansehra area was observed and recorded. The field work activities were comprised of reconnaissance at the area, section measurements, outcrop observation and sample collection. These samples are collected from Susal Gali Granite gneiss NW Himalayas, Mansehra Pakistan. The igneous and metamorphic rocks in field area have maximum height along road section. Selected samples were collected on the basis of physical characteristics and texture. The detailed samples were taken by using Nichols methods and samples were collected at the interval of 0.5m to 1m. The stratigraphic units were measured with the help of measuring tape. Each bed was studied individually regarding its thickness, bed form lithology, igneous and metamorphic features, and color etc. Field photographs were taken as per requirement and recorded as shown in Figure 1. Bed to bed representative sampling was carried out. In these sections a total of 60 rock samples were collected in sterile plastic bags and vials in a random manner. After collection, the samples are transported to the laboratory for further processing and analysis. 20 samples were used to make thin section for petrography

3.1 Petrographic Study of Thin Sections

Petrographic studies are crucial and beneficial for examining the depositional fabric, encompassing the specimen's mineralogy, modal composition, grain morphology, orientation, size and microstructures. Furthermore, it proves highly valuable in determining the digenetic fabric, encompassing the mechanical and chemical composition, dissolution and replacement process. Polarized and reflected light microscope techniques were used to study the transparent and opaque mineral varieties (Tucker, 1988).

Figure 1: Showing rock samples of granite gneiss, Mansehra Area, Pakistan.

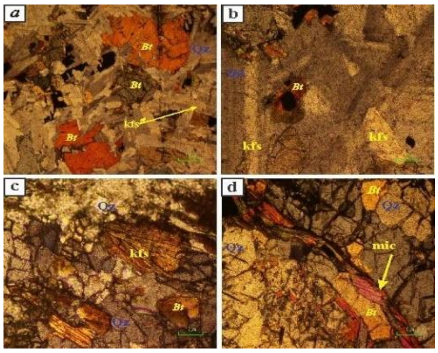

Figure 2: Petrographic images of thin sections of study area (a) quartz, biotite, potash feldspar. (b) quartz, biotite, K-feldspar. (c) quartz, biotite, K- feldspar. (d) quartz, biotite and mica.

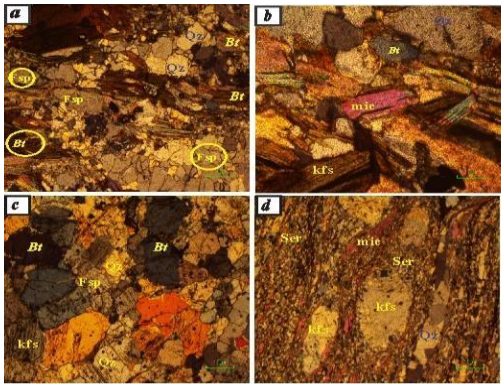

Figure 3: Petrographic images of thin sections of study area (a) quartz, biotite and feldspar (b) quartz, mica and potash feldspar (c) biotite, quartz, potash feldspar (d) mica, sericite, potash feldspar and quartz.

i. Quartz.

Quartz grains exhibit a subhedral morphology, appearing as small, transparent crystal. Quartz displays diverse deformation and recrystallization characteristics, making it a key indicator of the degree of metamorphism in the included minerals. Quartz is irregular to sub-round in shape. We observed colorless quartz with an anhedral form, exhibiting occasionally a tabular appearance. The quartz displays uniform extinction.

ii. Biotite

The biotite observed displays its characteristics brown color and distinct one directional perfect cleavage. Additionally, Sericite inclusions are visible within the biotite. The minerals exhibit various properties. In the gneiss banding or schistose layering, biotite is typically well-oriented. It displays pleochroism, ranging from grayish yellow to light to moderate brown and yellowish brown.

iii. K-Feldspar

The K-feldspar lacks twinning, yet it exhibits some perthitic texture and occasionally displays myrmekitic intergrowths with plagioclase. The ratio of plagioclase to K-feldspar varies significantly, and certain darker biotite-rich layers are notably abundant in K-feldspar. The K-feldspar in the rock is partly grid twinned, with some portions displaying perthitic texture. Additionally, the rock contains minor amounts of grayish-yellow to moderate brown biotite and trace of olive-brown biotite. The minerals appear colorless to cloudy, displaying low to moderate relief and is distinguished by weak cleavage.

iv. Hornblende

Hornblende is present in thin section only in certain samples. The sample displays moderate pleochroism, ranging from green to olive green to yellowish green for the hornblende mineral. The crystal habit is elongate, and some grains are twinned. It has a stubbier crystal shape. The hornblende member is characterized by coarse grained nature, featuring interlocking and elongated quartz crystals, as well as large megacrysts of microcline.

3.2 Quantitative and SEM Analysis

SEM analysis shows the compaction and orientation of rock minerals which were highly compacted and close to each other and also shows the fractures between the rock minerals and its contact. Feldspar, quartz, biotite, and amphibole make up the majority of the orthogenesis rock types studied. Less isometric grains are elongated, have smooth boundaries, and have a moderate preferred orientation. High-temperature recrystallization is indicated by the deformation and recrystallization features of quartz (the grain boundary migration recrystallization mechanism).

Table 1: Quantitative (XRF) Chemical Analysis Of Susalgali Granite Gneiss Using SEM.

Sample No	SiO_2	Al_2O_3	FeO	MgO	CaO	K_2O	Na_2O
01	72.04	13.76	3.00	1.05	2.32	4.78	3.05
02	72.03	13.7	2.85	1.10	2.40	4.66	3.26
03	71.90	14.05	2.80	1.25	2.45	4.35	3.20
04	71.69	13.87	3.17	1.00	2.47	4.52	3.28
05	72.74	13.45	3.05	1.07	2.23	4.45	3.01
06	71.10	14.86	2.88	1.37	2.14	4.20	3.45
07	71.68	14.23	3.09	1.41	2.21	4.15	3.23
08	73.05	13.04	2.90	1.23	2.13	4.53	3.12
09	72.42	13.17	3.34	1.14	2.17	4.43	3.33
10	71.45	13.81	3.56	1.53	2.21	4.31	3.13
11	68.36	15.47	4.27	1.33	2.57	4.74	3.26
12	70.16	15.66	3.24	1.16	2.14	4.41	3.23
13	72.13	13.15	3.63	1.09	2.73	4.09	3.18
14	73.06	13.03	2.78	1.23	2.14	4.53	3.23
15	71.81	13.46	3.33	1.43	2.17	4.63	3.17

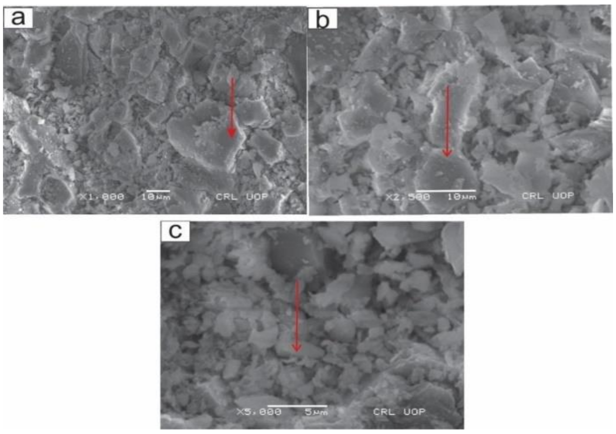

Figure 4: SEM images of Granite Gneiss samples

3.3 Microstructures Identification

In order to accurately describe the mineral composition and micro-structural parameters of metamorphic rocks, various methods can be used. Polarizing microscopy combined with image analysis allows for quantitative analysis of mineral composition and micro-structural parameters (Heilbronner, 2000). Fully- automatic image analysis distinguishes objects based on color differences, while semi- automatic image analysis involves operator input (Přikryl, 2006). The aim of study is to use these methods to quantify their mineral composition, micro-structure (grain size and shape), grade of metamorphism, and determine the tectonic history of the investigated metamorphic rocks. Estimation of metamorphic conditions will rely on observations of mineral assemblages, deformations features and recrystallization characteristics (Le Maitre et al., 1989; Mason and Mason, 1990; Robertson, 1999).

3.4 Micro structural Modeling and Identification

Microstructural modelling required a detail understanding of rock microstructure. Thin sections of various types of rock are made to examine the microstructure under a microscope. The photos are collected using a polarizing microscope to record mineral information and to determine between fine grain, cleavages, fractures and grain boundary. It is difficult to notice the mineral grains and fissures in those microstructures. Image analysis is a useful method for simplifying microstructures, determining mineral composition and obtaining morphological data. To the microstructural picture, segment the constituent phases and characteristics the mineral and fracture morphologies in this research, thin section analysis was utilized. As a result microstructural modeling combines microscopic observation, image analysis, and numerical modeling.

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Susal gali granite gneiss has mostly linear and perpendicular structures to one another due to fractures present in bands of minerals which occurs during flow of minerals due to high temperature and pressure. On the basis of comparison of micro pictures we can see easily linear structures, trans granular structures boundary grain structures and intra boundary structures.

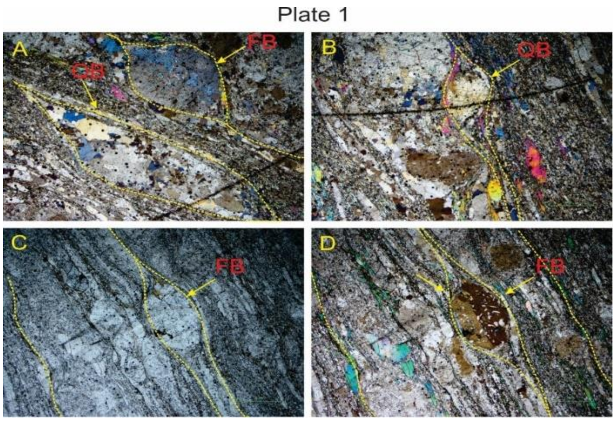

Figure 6: Photomicrograph showing (A) Quartz Boudins (QB) and Feldspar Boudins (FB) surrounded by the fine grain recrystallized quartz grains of granitic gneiss in cross-polarized light (CPL). (B) Quartz Boudins (QB) surrounded by the fine grain recrystallized quartz to the right and coarse grain quartz to the left within the granitic gneiss in cross-polarized light (CPL). (C) The Feldspar Boudins (FB) surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in plane-polarized light (PPL). (D) The Feldspar Boudins (FB) surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in cross-polarized light.

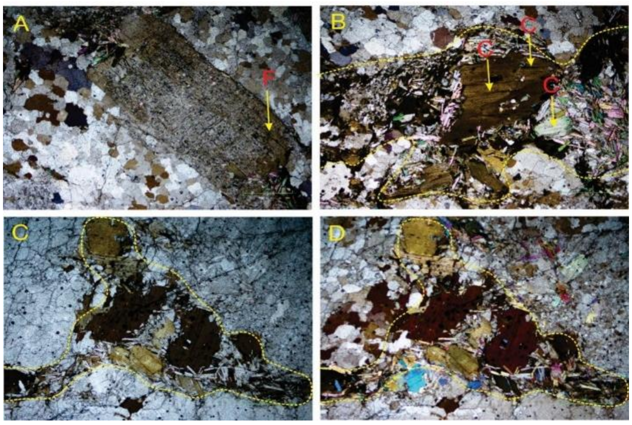

Figure 7: Photomicrograph showing (A) Feldspar Boudins (FB) surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in cross-polarized light (CPL). That show the intense shearing of the rock. (B) The cleavages (C) within the biotite mica that are surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in cross-polarized light (CPL). (C) Muscovite and biotite mica that are surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in plane-polarized light (CPL). (D) The cleavages (C) within the biotite mica that are surrounded by the fine-grain recrystallized quartz grains of granitic gneiss in cross-polarized light (CPL).

4. Discussion And Conclusion

The current research focuses on the petrography, microstructures and Prediction of pressure temperature conditions of metamorphism of the Susal gali granite gneiss Mansehra area Khyber Pakhtunkhwa, Pakistan. Petrographic observation based on the microstructures and occurrence of metamorphic formations due to different tectonic activities. The process of discovering and exploring profitable projects have been heavily influenced.

The petrographic observation in thin sections shows quartz, biotite, hornblende, muscovite, feldspar, and plagioclase are the major minerals while the sericite, zircon, albite and beryl are the accessory minerals. Thin section examinations has shown a variety of microstructures including cleavage, fractures, feldspar boudins, quartz boudins that recrystallizations of grains of quartz and feldspars, intrangranular microstructures, trans- granular microstructures and boundaries microstructures. The rock composition, microstructures and metamorphism stage have all been studied using laboratory methods. Quartz, feldspar, biotite, hornblende, muscovite are the most common minerals in the research area, according to petrographic identifications. The petrographic analysis of the granite gneiss reveals that the mineral composition 60% quartz, 47% feldspar, 35% biotite, 15% muscovite and 3% sericite.

High temperature recrystallization is indicated by the deformation and recrystallization features of quartz and feldspar. The presence of biotite muscovite, hornblende quartz and feldspar are the indicated of high grade metamorphism. The study area through analysis demonstrate through area is medium to high grade metamorphic and tremendous potential for mineral exploration, rare earth elements, exploration based on the observation, methodologies and experiments. The deformation and recrystallization features of quartz that is metamorphism occurred at high temperature and pressure. The study area through analysis demonstrate that area is high grade metamorphism. The microstructures of deformed rocks in micrograph shows basic understanding of brittle and ductile deformation, recovery and recrystallization, effects of metamorphic reaction and the origin of foliation, cleavage, fracture, crenulation cleavage, quartz grains boudins, feldspar boudins, gneiss layering as well as fluid transfer and vein formation.

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