PETROGRAPHY AND GEOCHEMISTRY OF ROCKS FROM THE ACIDIC VOLCANIC BELT, NORTH OF *PESHAWAR PLAIN, N. W. F. P.*

BY

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بســـم الله الرحمٰن الرحيم

IN THE NAME OF

ALLAH

The Most Merciful

The Most Beneficent

سورة الفاتحة مكية وهي سبع آيات

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِيْمِ
اَلْحَمْدُ لِلّٰهِ رَبِّ الْعٰلَمِيْنَ ۝١ الرَّحْمٰنِ
الرَّحِيْمِ ۝٢ مٰلِكِ يَوْمِ الدِّيْنِ ۝٣ اِيَّاكَ
نَعْبُدُ وَاِيَّاكَ نَسْتَعِيْنُ ۝٤ اِهْدِنَا الصِّرَاطَ
الْمُسْتَقِيْمَ ۝٥ صِرَاطَ الَّذِيْنَ اَنْعَمْتَ عَلَيْهِمْ
غَيْرِ الْمَغْضُوْبِ عَلَيْهِمْ وَلَا الضَّآلِّيْنَ ۝٧

In the name of God, Most Gracious, Most Merciful.

Praise be to God, the Cherisher and Sustainer of the Worlds; Most Gracious, Most Merciful; Master of the Day of Judgment. You do we worship, and Your aid we seek. Show us the straight way, the way of those on whom You have bestowed Your Grace, those whose (portion) is not wrath, and who go not astray.

DEDICATION

With Genuine Humility, I Acknowledge Your Aid, O GOD!
In The True Spirit Of Islam, I Appreciate Your Grace, O GOD!
WITH All My Heart, I Thank You, O GOD!

Without Your Guidance And Love,
This Work Would Not Have Been Possible.
Were It Not For Your Help And Cause,
This Humble Contribution Would Have Never Become A Reality.

And If It Is Worth Dedicating,
Please Bless It With Your Acceptance;

It Is Dedicated To You, O GOD!

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وَقُلِ الْحَمْدُ لِلّٰهِ سَيُرِيْكُمْ اٰيٰتِهٖ فَتَعْرِفُوْنَهَا ۭ وَمَا رَبُّكَ بِغَافِلٍ عَمَّا تَعْمَلُوْنَ ۹۳

IN THE NAME OF ALLAH THE MOST MERCIFUL, THE MOST BENEFICENT

O Prophet! say to them, " Praise is only for Allah; very soon He will show you His Signs, which you shall recognize, and your Lord is not unaware of what you do. " (27/93)

1st of all I praise Allah Almighty for His beautiful creation and the hidden treasures of the earth, which He created for the mankind. I think that modern world scientists are in psychological crisis because they have sought to discover the world without appreaciating the Creator. The restoration of harmoney between the natural sciences and the Creator would in no way limit the rationale, the digging/ drilling of the earth and the discovery of the new secrets benefitting humanity and understanding Allah.

Because in every thing that the earth contains and every scene which the Heaven present, have lots of signs of deep import for man, if only he cares to notice them. When man reflects over the aim and purpose of the scheme behind the creation of universe, the way to reality opens out before him by itself and relieve him of all obsessions born of ignorance via intellectual &/or spiritual blindness. Allah guides the seeker after truth to the Right path by affording him the opportunity to make use of his knowledge for the purpose of discovering the Reality, and showing him the signs as a sort of introduction and recognition guiding towards Ultimate Reality. Let us view the subvolcanic-volcanic microporphyries in time and space.

ABSTRACT

Acidic microporphyries of Late Paleozoic age are intimately associated with appreciably larger volumes of acidic plutonic rocks of alkaline igneous province of Peshawar Plain. Field evidences and their partial intercalation in the metasedimentary sequence of Jaffar Kandao and Baroach Formations suggest an Early Carboniferous age.

Very coarse to fine-grained felsic phenocryst in fine-grained to glassy felsic groundmass clearly imparts a porphyritic texture to these rocks. On the basis of modal and chemical composition, majority of these rocks are classified as rhyolites on one side and basalt (now greenschist) on the other. Variables and their ratios based on major and minor elements classify these rocks as A-type, mildly alkaline and peraluminous in character.

On various tectonomagmatic discrimination diagrams, these rocks show a within plate continental rift environment, and this character is also supported by Hf/Th, Hf/Ta and concentration in Zr and Ta.

Sensitivity of Th, Hf and Ta due to crustal contamination is seen in tectonomagmatic discremination triangular diagrams based on these three elements. Eu-anomaly displays fluid-solid rock interaction confirming soda metasomatism due to late magmatic phases in these rocks.

ACKNOWLEDGEMENTS

I acknowledge ALLAH, The Exalted, most sincerely because this is entirely Allah's favour and benefisence that He blessed a humble servant of His with the grace to render this dissertation.

I seek Allah's refuge that I should commit a mistake with regards to Allah's creative masterpiece, or persist in a mistake delibrately.

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CHAPTER ONE

أَلْقٰى فِى الْأَرْضِ رَوَاسِىَ أَنْ تَمِيْدَ بِكُمْ وَأَنْهٰرًا وَّسُبُلًا لَّعَلَّكُمْ
تَهْتَدُوْنَ ﴿١٥﴾ وَعَلٰمٰتٍ ۚ وَبِالنَّجْمِ هُمْ يَهْتَدُوْنَ ﴿١٦﴾ (النحل ١٦)

(Allah is He) Who hath driven (emplaced) mountains firmly into the earth lest it should turn away from its usual course along with you,(1) caused rivers to flow, made natural ways so that you may be directed aright.(2) He has placed landmarks to direct peoples, and by stars, too, they are directed aright.

(1) Besides all other benefits and means of subsistence the real function of mountains is to regulate the motion and speed of the earth. Quran -in very simple words- consistently describes mountains as stabilizers for the earth's surface. It refers their outward protrusion for isostatic balance and emphasis their great downward extension within the earth's crust. Added further it mentions the exact role of mountains as pickets (or pegs)i.e. as means of fixation for earth's crust. Such knowledge was revealed more than twelve centuries before man started to wonder whether or not mountains could have roots below its outcropping parts, and before he could realize any value for the existence of mountains on the surface of our globe, a value that is only being currently conceived by a very limited number of specialists in the field of earth sciences.

(2) Natural ways are those routs which are formed along the banks of streams, ravines and rivers. Though the importance of these ways is great even in the plains, one feels their sore needs, in the mountain regions.

(3) This is a sign of Allah that He has broken the monotony of land by placing conspicuous landmarks on it to distinguish different regions from one another.These have many benefits and one of these is to help guide travellers and navigators to their destination. It is in the deserts and the seas that peoples realize the true importance of (--by stars, too, they are directed aright to their destination). The use of compass also realizes the significance of polar star.

(4) A critical study of all these along with other innumerable signs which are closely interconnected and are also indispensable to man's welfare and his very existence are clear proof that only one Being has designed the whole universe and created it in accordance with that design. It is He Who is all the time creating new things to fit in that scheme. Who can then claim , except a foolish or obdurate person, that all these have come into existence by a mere accident.

CHAPTER ONE

INTRODUCTION

1.1) LOCATION OF THE AREA:

The valley of Peshawar is surrounded by hills and mountains with the only exit for water discharge at south-east towards the Indus.The studied area is situated between longitude 72°18′and 72°25′E and latitudes 34°7′ and 34°11′N, a few km to the north-west of the confluence of the Indus and Kabul rivers and is covered by survey of Pakistan toposheet No-43B/8.

1.2) ACCESSIBILITY:

A network of metalled and unmetalled roads give an easy access to these outcrops. The area is approachable from Jehangira in the south, Swabi in the east and Mardan in the west.The outcrops of Turlandi and Gohatai lie on Mardan-Swabi Road. The rest of the outcrops are accessible through these two reference locations, 2km just to the south of Turlandi along Turlandi-Dagi Road,Tarakai outcrop is situated,1km to north-east and 2km to south-east of which Rashakai and Tora-Tiga outcrops are located respectively (Fig.1).

At a distance of 5km east of Tora-Tiga the outcrop of Mansurai is approachable, to the south of which at about 6km distance Gaju Ghundai breaks the monotony of the land on the other side of Upper Swat Canal.

1.3) PHYSIOGRAPHY:

The elevated Indus Ridge of Sari-Maira is an important physiographic feature of the area under investigation. This ridge comprises of sandstone, siltstone, mud and conglomerate, running from Gohatai as far as Jehangira, roughly parallel to the Swabi-Jehangira Road. This ridge about 1300 feet high above sea level, is a major geomorphic feature dividing the Swabi Plain into two i.e. eastern and western parts. The Sari-Maira Ridge slopes gradually towards Dagi-Yar Hussain plain in the west but has a rather steeper slope and abrupt junction with the plain towards east.

1.4) DRAINAGE SYSTEM:

The eastern torrent is the Badrai-Khwar, which meanders in an incised channel getting various other torrents and ultimately joins the Indus River, near Hund. While the western torrents i.e. Shagai, Narrangai Khwar, Badhkoar, Ballar and Burwazai fall into Kalpanrai and finally drain into Kabul River.

1.5) BED ROCK OUTCROPS:

The Swabi Plain ranges in height from 1000 to 2000 feet above sea level. Although the surface is generally a level plain, however, irregularities are found due to local relief. The most conspicuous topographic feature is the isolated outcrops of various elevations and lithologies. The main outcrops are Gohatai (1357 feet), Mansurai (1214 feet), Gaju Ghundai (1563 feet), Turlandai Ghundai (1222 feet), Tarakai Ghundai (1332 feet), Tora-Tiga (1230 feet), Rashakai Ghundai (1206 feet), Shah Mansur Ghar i.e. Misri Banda Quartzite (1464 feet), type locality of Ambar Formation (1280 feet) at Ambar and type section of Panjpir Formation (2053 feet) at Panjpir. The first seven outcrops comprises of the subvolcanic-volcanic porphyries and have been studied in detail.

1.6) METHODOLOGY:

Two folds study has been incorporated in this research;

A) Field work, B) Laboratory work.

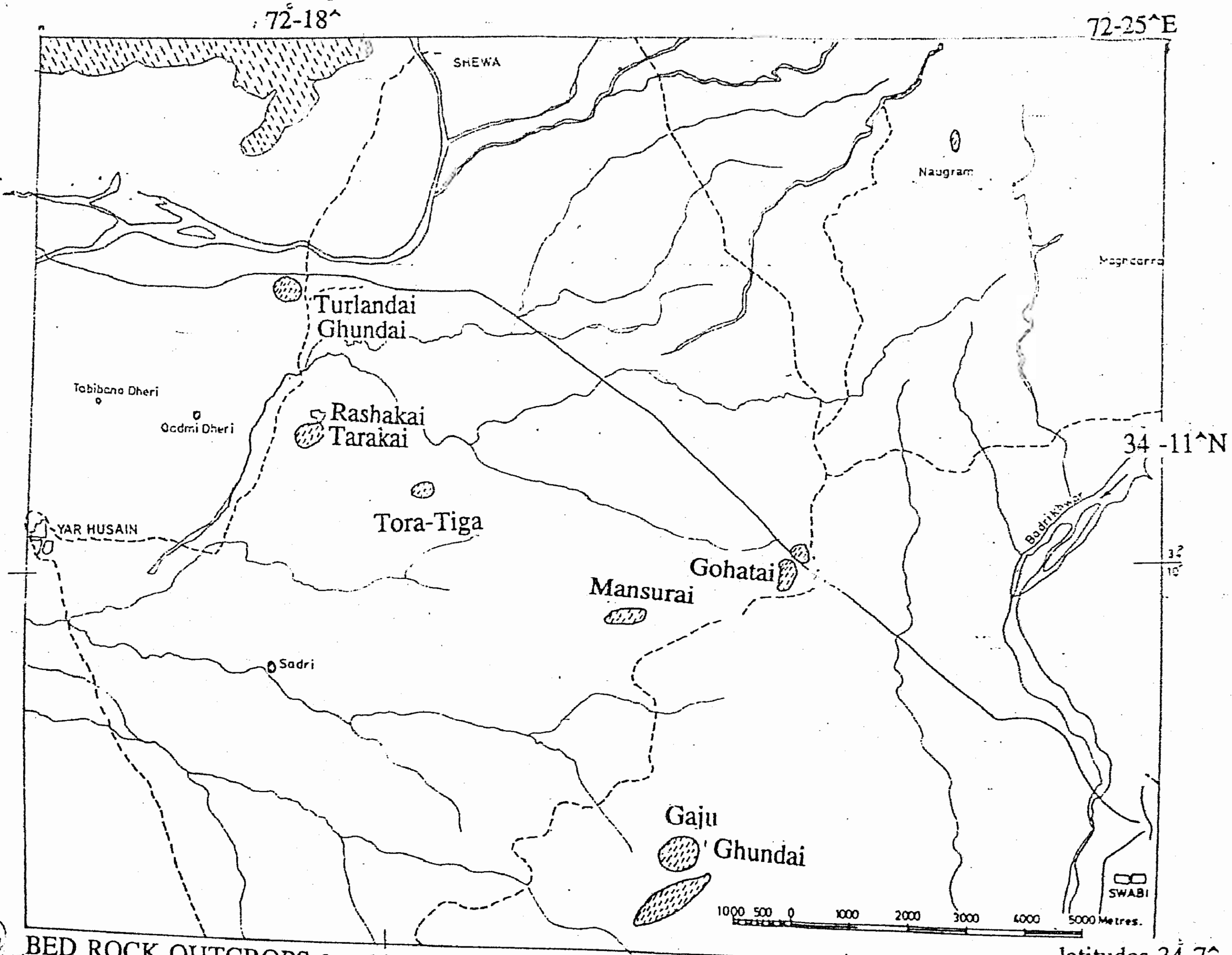
Field work:- Rock samples were collected from various units for the detailed petrographic and geochemical studies. Lithological and stratigraphic study was conducted to report the close association, both in space and time of the acidic and basic subvolcanic-volcanic rocks.

Laboratory Work:- More than hundred samples were collected from different outcrops and their thin sections were made. Twenty four samples were analyzed for major elements by classical wet chemical method. In addition to trace elements, FeO, Na2O and K2O were duplicated by Neutron activation at Radiation Centre Oregon State University USA.

1.7) PURPOSE OF STUDY:

The aim of the present study is to make an attempt to elucidate the genesis of the rock lithologies alongwith their proper nomenclature, petrological and petrogenetical model based on petrography and geo-chemistry.

Fig.1 Location Map of Subvolcanic-volcanic rocks.



(3) BED ROCK OUTCROPS, few kilometers to the NE of the confluence of the Indus and Kabul rivers latitudes 34-7^

CHAPTER TWO

أَنْزَلَ مِنَ السَّمَاءِ مَاءً
فَسَالَتْ أَوْدِيَةٌ بِقَدَرِهَا فَاحْتَمَلَ السَّيْلُ زَبَدًا رَابِيًا ۚ وَمِمَّا يُوقِدُونَ
عَلَيْهِ فِي النَّارِ ابْتِغَاءَ حِلْيَةٍ أَوْ مَتَاعٍ زَبَدٌ مِثْلُهُ ۚ كَذَٰلِكَ يَضْرِبُ
اللَّهُ الْحَقَّ وَالْبَاطِلَ ۚ فَأَمَّا الزَّبَدُ فَيَذْهَبُ جُفَاءً ۖ وَأَمَّا مَا يَنْفَعُ
النَّاسَ فَيَمْكُثُ فِي الْأَرْضِ ۚ كَذَٰلِكَ يَضْرِبُ اللَّهُ الْأَمْثَالَ ﴿١٧﴾

(ALLAH) sendth down water from the sky, so that valleys flow according to their measure (capacity),(1) but the flood bears away the foam that mounts up to the surface,(2) likewise there arises a scum out of the metals (ores) which is melted (smelted) in the furnace for the sake of ornaments and utensils. This is the way doth Allah depict truth and falsehood,(3) then as far the foam, it passes away as scum upon the banks, while, as for that which is of use to mankind, remains in the earth.(4) In this way Allah cites similes to make His Message clear.(5)

This verse is full of parables:-

1) This simile states that it is Allah Who sends rain and He sends it to all. See how it flows in different valleys and channels according to their capacities, some are sluggish (slow to respond), some have swift currents. Some form great rivers and irrigate wide tracts of country, some clear crystal streams,perhaps in hilly tracts,flow through the beds of clean pebbles. Then there are degrees and degrees among brooks, streams, channels, lakes, seas oceans etc. Similar is the case with the rains of Allah's revelation, which He sends. All can receive it but different ones respond according to their capacities.

(2) In the physical world, water is pure and beneficial. But froth and scum gathers according to local conditions. As the flood carries off the scum, the slurries (insoluble mud,lime, pastes) settles down to form various strata at the bottom. The froth makes a great show' refers to the hue and cries of the opponents of the islamic movement and has been likend to the swelling of scum that begins to dance about on the surface of flood water.

(3) Here Allah remarks that as ores are melted in furnace for purification, naturally scum appears on the surface, so likewise bad peoples would come to the surface and take the prominent role in persecuting the good peoples. And as the ore is full of baser admixture but the fire separates the wanted metals from the drass; similarly, the fire of Allah's test, either by adversity or affluence will search out the true ones to their conviction.

(4) In this simile,'survival of the useful' instead 'of the fittest one' is revealed. Allah assures that frothy knowledge frothy systems and frothy revolutions will soon disappear, but Allah's truth and real guidance will endure.

(5) All these similes refers to the processes of deposition, melting, crystallization from solution, fusion, sublimation and recrystallisation. The practical manifestation of these phenomena in natural outcrops at local and regional scales defines Local and Regional Geology.

أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَاوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا فَفَتَقْنَاهُمَا ۖ وَ
جَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ ۖ أَفَلَا يُؤْمِنُونَ ﴿٣٠﴾

'Have not the denoyer of Truth ever visualized the fact that the heavens and the earth were a single (nebular) mass in one piece, so We parted them both into fragments, and We made everyliving thing with (of) water. Will they not then believe.' {Al- Anbia-30}.

TECTONIC SETTING IN THE FRAMEWORK OF THE NORTH PAKISTAN:

The concept of Tethys as a geographic entity may not have changed much since its inception, but the concept of Tethys in geologic time has changed considerably. The end effect is in agreement that all Paleozoic systems have had a Tethyan like episode in their history. The Himalaya orogen is a product of convergence and collision of the Indian and Asian plates. A thick, vast sedimentary prism of early Ripheau (1600-680 Ma) to Late Creto- Eocene age on the passive continental margin of the Indian Craton gave rise to the Himalaya (Valdiya, 1989).

The common association of alkaline igneous rocks with extentional tectonics led Kemp and Jan (1980) to propose a rift origin for the Peshawar Plain Alkaline Igneous Province. Rafiq (1987) proposed that before disintegration, when the Indo-Pakistan plate was a part of the supercontinent (Pangea), the alkaline igneous province and its parental rift zone of the Peshawar basin might be a continuation of the East African rift system and the Alkaline Igneous Province of Nile. He also suggested that Ambela Granitic Complex (AGC) might be the product of an epicrustal phenomena in structural pattern (crustal swell), within the crustal basement before the disintegration of Gondwanaland began.

Baig etal.,(1988) demarcated the concordant basal intrusive contact of Ambela and Mansehra Granites with quartzite and phyllite of Tanawal Formation to the north of this area in the walls of the Indus Gorge which they interpreted as a continuous sheet like intrusion resembling Pre-Cambrian granitic basement of Indian plate. All the lithofacies relation of Late Precambrian-Carboniferous meatsediments indicate deposition in a northward deepening epicontinental graben, to the NE of which Late Cambrian-Early Ordovician tectonism i.e intrusion of Salkhala event created highlands from which Cambrian strata were eroded. The suspected left lateral Darband Fault of Himalayan age (Calkin, 1975) running parallel to Indus

Shallow marine sedimentation resumed in the Ordovicion and cotinued untill near the close of the Devonian. Two subparallel high-angle faults which offsets Precambrian-Silurian Formations north and south of Swabi may define a minor Carboniferous graben (Pogue etal, 1992). The parallelism of structural trends of these faults to the contacts between the individual granitic intrusions and the diabase dikes both comprising Ambela Complex (Rafiq, 1987) indicate a NW-SE orientation of maximum extention during its emplacement. As the acidic microporphyrites of the studied area are regarded as the first volcanic phase of Ambela Granitic Complex so the Devonian-Carboniferous tectonic episode suggest rifting and silicic (acidic) magmatism probably on knobs of which Nowshera Formation was deposited.

CHAPTER TWO

REGIONAL AND LOCAL GEOLOGY

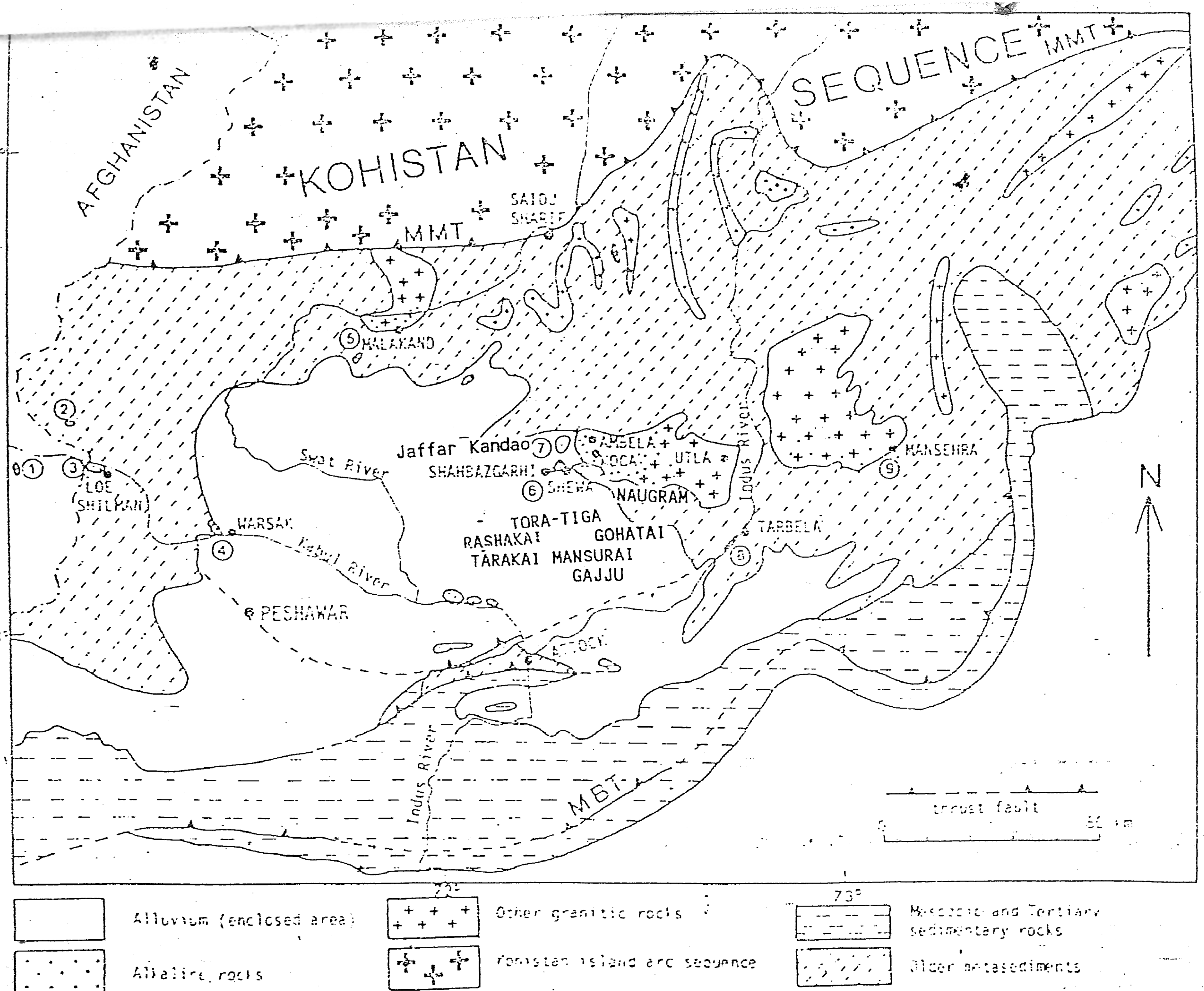
2.1 REGIONAL GEOLOGY AND TECTONIC FRAMEWORK.

The subvolcanic-volcanic rocks of acidic and basic composition are associated with the alkaline igneous rocks and are exposed throughout the alkaline igneous province (Kempe and Jan, 1970; 1980; 1983; Le Bas et al., 1987; Rafiq and Jan, 1989). This volcanogenic region in question is considered to be the early magmatic episode along rift zone extending some 200 Km east west and occupies a part of internal zone of Indian plate in NW Himalayas comprising Peshawar Plain. Though extensive outcrops of these microporphyries are not exposed, however, the sporadic distribution at Tarbela, within the host peripheral metasedimentary sequence of Ambela granitic complex (Jaffar Kandao Formation and Baroach Formation) at Gohatai, Turlandai, Tarakai, Rashakai, Mansurai, Naugram, along Totalai-Changlai roadside, DariDhob, Sorai-Malandrai, Ziarat, Nawe-Kali and Mula-Yusaf is indicative of a widespread volcanic activity in the region.

Beyond these localities, the acidic microporphyries and lavas (Known as greenschists) are exposed near Gajju Ghundai, Shewa-Shahbaz Ghari, Jaffer Kandao, Naugram, Nawekili, Krappa, Daridhob, Bajkata and extending uptill Warsak. Regional extension of these rocks represent a broad east-west extending volcanic province and mark the initial volcanic phases of alkaline igneous rocks along a rift zone. These microporphyries are interbedded within the metasediments of Jaffar Kandao Formation (6 Km east of Rustam) and Baroach Formation at Daridhob, Sorai-Malanderai, Nawe-Kili and Krappa area (west and northwest of Ambela granitic complex). In addition it is also believed that these rocks are extrusive equivalent of the microporphyries of Shewa-Shahbaz Ghari Complex and Warsak.

Dyke swarms of tholeiitic basic composition spread over the Pre-Cambrian to Late Paleozoic rocks and cross-cut even the late plutonic and volcanic phases, (for example Koga syenites of the Ambela granitic complex) are now believed to be Late Paleozoic or Early Mesozoic in age (Rafiq, 1987; Jan and Karim, 1990).

The region is bounded by MMT to the north and MBT to the south and comprises of pelites, quartzites and carbonate rocks, the "Swabi-Chamla Sedimentary Group" of Martin et al., 1962, in the NE, E, and SE. The rocks of Nowshera area were traced towards Swabi on the basis of similar lithologies and conodonts revelation. Hence the revised Paleozoic sequence



A regional map of the Peshawar plain and surrounding hillranges showing the position of various alkaline complexes (Kempe & Jan 1970, 1980, (Hussain and Pogue, 1986) encircling the area are as follows:-

Formation	Age
5) Jaffar Kandao Formation	Carboniferous.
---unconformity ------------	
4) Nowshera Formation	Devonian .
3) Panjpir Formation	Silurian.
----unconformity ---------	
2) Misri banda Quartzite	Early to Mid Ordovician.
----unconformity-----------	
1) Ambar Formation	Cambrian.

2.2 GEOLOGICAL SETTING

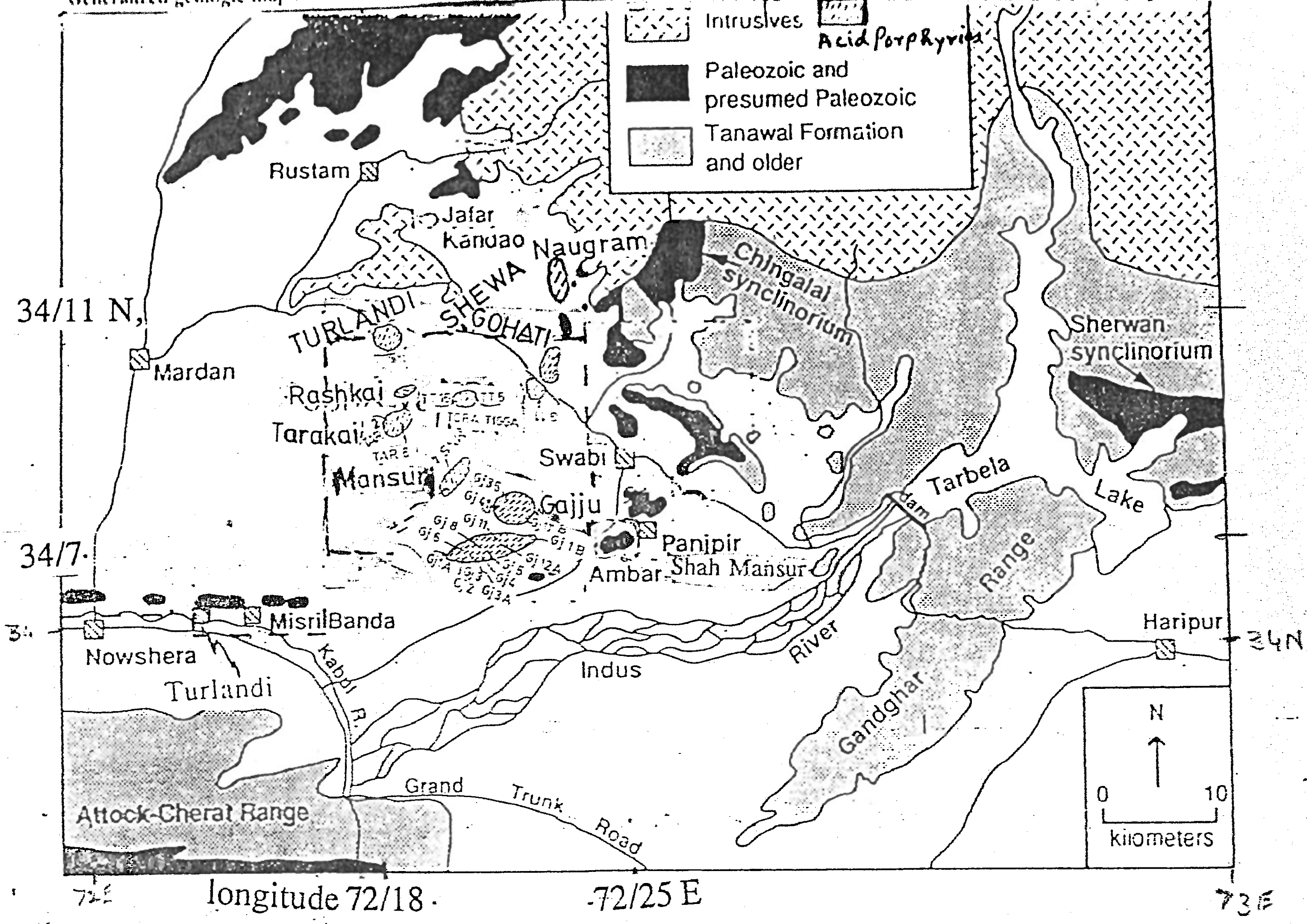
The sporadic outcrops of these subvolcanic-volcanic rocks constitute roughly an east west trending zone, extending from Tarbella in the east, through isolated outcrops north east of Peshawar Plain and around Ambella Granitic Complex to Warsak in the west, occupy the internal zone of the NW-Himalaya in northern most part of the Indian Plate.

Members of these microporphyrites exposed at Warsak and Shewa Shahbaz Gharhi are widely interpreted as a part of the alkaline igneous province (Kempe and Jan 1970, 1980). The microporphyrites of acidic composition are present as an interlayered sequence in the middle part of the Jaffer Kandao Formation throughout the western and northwestern margin of the Ambela Granitic Complex at Dhari Dhob, Sorai-Malanderai through Nawe Kili upto Bar Chinar. South of Ambela Granitic Complex these subvolcanic-volcanic rocks cut across the Ambar Formation (Cambrian), Misri Banda Formation (Early to Middle Ordovician) and Panjpir Formation (Early to Middle Silurian) along the Sawawi-Totalai road section, at Naugram and at many other places.

Field evidence, and previous studies (Kempe & Jan, 1970; 1980; Rafiq, 1987; Rafiq & Jan, 1990) suggest initiation of rifting and magmatism which probably started during Devonian and span over Carbonifereous and Permian (Rafiq, 1987). It is now believed that before disintegration, when the Indo-Pakistan plate was a part of the supercontinent (Pangea), the alkaline igneous province and its parental rift zone of the Peshawar basin might be a continuation of the East African rift system and the Alkaline Igneous Province of Nile.

The basic rocks of this volcanic sequence are exposed in Gajju Ghundai (10 km west of

Generalized geologic map of the eastern Peshawar basin



REGIONAL GEOLOGICAL SETTING & LOCATION OF THE AREA in the revised Paleozoic sequence (Hussain and Pogue, 1986)

Swabi) Jaffar Kandao, Sarai Malanderai, Nawe Kili and Krappa. Both acidic and basic rocks occur as plugs, lenses and dykes.

2.3) STRATIGRAPHIC SEQUENCE AND AGE OF SUBVOLCANIC-VOLCANIC ROCKS >

Field, geochronological and geochemical data suggest the following staratigraphic sequence in the region.

1) An early bimodal (basic and acidic subvolcanic-volcanic) rocks are formed within the early stage of rift zone, with intercalated deposition of conglomerates, argillites, thin bands of limestones and partly quartzite (Jaffer Kandao Formation). The sequence unconformably overlies the Nowshera Formation of early Devonian age (Pouge and Hussain 1986). Late Devonian to Late Pennsylvanian age was assigned to this mixed volcanic metasedimentary sequence called as Jaffer Kandao Formation, and can be correlated with early units of Panjal basic volcanic rocks. However, some isolated outcrops of acidic microporphyrites cut-across and flow over as sheet i.e. Gohati rhyolites suggest even younger ages. Shewa Shahbaz Garhi microporphyries have a Carboniferous (Probably Mississippian) age Pogue et al.,1990; Khan, S.R. et al., 1990).

2) The main plutonic phase of alkaline igneous province particularly the Ambela Granitic Complex formed within the rift zone initiated with granites and alkali granites as first plutonic episode. This is succeeded by the desilicified alkaline sequence of quartz-syenites, syenite, foidal syenites, carbonatites, ijolites etc of second phase (Rafiq, 1987; Rafiq and Jan 1989; 1990). Incorporation of roof sediments and microporphyrites which occur as xenoliths and enclaves (Sawawai & Bagh marbles of Nowshera formation) Rafiq et al., 1988) suggest that these microporphyrites were probably the early phase and are older than the main plutonic episode of Ambela granitic complex. Reliable Rb-Sr isochron ages of 297-315 Ma (Le Bas et al, 1987) for Ambela granitic complex, U-Pb systematics of Zircon in the Malakand Granite (Zeitler, 1988) suggest an early Carboniferous age for these subvolcanic-volcanic rocks.

3) Late magmatic episode of basic dykes intrude most part of the internal zone of Indian plate in Peshawar Plain, Swat and Hazara areas. The quartz-hypersthene normative continental tholeiitic basic dykes most probably of Permian or Early Triassic age (Rafiq, 1987; Jan and Karim, 1990) cut across the whole stratigraphic sequence of Paleozoic age in the area. (Rafiq and Jan, 1990). Furthermore, it is concluded that, these basic dykes have no genetic age correlation with the older microporphyries under discussion.

لِكُلِّ نَبَإٍ مُّسْتَقَرٌّ ۚ وَسَوْفَ تَعْلَمُونَ (الانعام ٦)

Every event preserves its prescribed time & space, by & by you shall know it

STRATIGRAPHIC SEQUENCE & AGE OF THE ROCKS.

[A] Rafiq, [1987] suggests 3 distinct episodes for AGC.

3) Late magmatic Permo-Triassic episode of quartz-hypersthene normative continental tholeiite basic dykes.

2) Desilicified alkali sequence of qtz syenite, syenite, foidal syenites, carbonatites,ijolites.

1) Main plutonic phase i.e granite/alkali granites.

[B] The isolated acidic micropophyries are interpreted as the 1st volcanic phase of AGC on the following grounds.

1] The **Ist** type suggests rather a wider span for acidic magmatic activity with lesser volume of their basic associates.

2] Kemp's (1986) repetitive concept of alkaline magmatism over a long period for PPAIP supports this interpretation & if his K/Ar date, [350±15Ma] on an amphibole albitite at Tarbela be accepted as an emplacement age then the initial riftting must have been occurred during or prior, to the Late Devonian.

3] Incorporation of the microporphyries & roof sediments i.e. Bagh marbles of Nowshera Fm. as xenoliths and enclaves in the 2nd phase suggest a contemporary age of main plutonic episode.

4] Reliable Rb-Sr isochron ages of 297-315 Ma [Early-Mid Pensyl. by Le Bas et al,1987) for AGC, U-Pb systematics of Zircon in the Malakand Granite (Zeitler, 1988) suggest an early

Carboniferous age [355±5 Ma] for the acidic microporphyries.

5] The quartz-hypersthene normative continental tholeiitic basic dykes of Permo-Triassic age cut across the whole stratigraphic sequence of Paleozoic age in the area (Rafiq and Jan. 1989).

وَأَلْقَىٰ فِي الْأَرْضِ رَوَاسِيَ أَن تَمِيدَ بِكُمْ وَبَثَّ فِيهَا مِن كُلِّ دَابَّةٍ (لقمٰن ۳۱)

'He set mountains in the earth lest it should tilt along with you & dispersed all kinds of moving creatures therein' [31/10]

6] Pogue et al.,1992 recovered Viscon [356-341 Ma] conodonts from the upper half of JKF & Westphalian-B, 308 Ma conodonts from metabasalt of Krappa Greenschist, 20 m above its contact with the underlying JKF. The Late Devonian-Late Pennsyl.[367-300 Ma] age assigned to this mixed volcano metasedimentry sequence favours an older age for the isolated rocks.

7] The whole spectrum of acidic microporphyries along with tholeiitic to ijolitic basic rocks indicate a tectonic setting in which an episode of intraplate rifting is going on which infers that the acidic intrusive, present throughout the Pre-Cambrian crystalline basement of Salkhala Fm. (Pepritz & Rey, 1989) along with the Paleozoic sedimentary cover, was reactivated by hotspot, resulting in partial melting producing A-type granitic magma ranging from alk-per/meta aluminous composition.

CHAPTER THREE

﴿٨٧﴾ وَتَرَى الْجِبَالَ تَحْسَبُهَا جَامِدَةً وَّهِيَ تَمُرُّ مَرَّ السَّحَابِ ۚ
صُنْعَ اللَّهِ الَّذِي أَتْقَنَ كُلَّ شَيْءٍ ۚ إِنَّهُ خَبِيرٌ بِمَا تَفْعَلُونَ ﴿٨٨﴾

Thou seest the mountains & thinkest them firmly fixed, yet they are flying over the flight of clouds.This is the artistry of Allah Who set everything with exactitude.'(27/88)

'Itqan, means 'to arrange the things in right perspective' which signifies that everything has its own beauty. Whereas the elements were created to give a form to the universe, even so were they invested with the qualities of color, light, shades, rythm of harmony & symmetry. Hence we see rocks, minerals & xls in various forms, shapes, & disposition which urges their

PETROGRAPHY

The newly investigated subvolcanic-volcanic rocks exhibit porphyritic texture with feldspar-quartz phenocrysts in either fine grained/aphinitic groundmass & are bimodal in composition from place to place based on mineral contents, phenocryst / groundmass ratio & types of phenocrysts. Volcanic glass is also common at various places.

CHAPTER THREE

PETROGRAPHY

Other than intercalated sheets, lenses and dykes associated with Jaffer Kandao Formation, isolated outcrops without exposing any metasedimentary sequence, is suggestive of an extensive subvolcanic volcanic region under the alluvium of Peshawar basin. This region may extend at least from Gajju Ghundai (Swabi) upto Warsak passing through Shewa-Shahbaz Garhi Complex.

The acidic microporphyrites have previously been described from the surroundings of the Ambela Granitic (Rafiq, 1987; Rafiq and Jan, 1986; 1989), and Shewa Shabaz Garhi Complexes (Chaudry and Shams 1982., Irshad et al., 1990). The newly investigated subvolcanic- volcanic rocks exhibit porphyritic texture with felspar-quartz phenocrysts in either fine grained or aphinitic groundmass. The rocks are bimodal in composition from place to place based on mineral contents, phenocryst/groundmass ratio and type of phenocryst. Volcanic glass is also common at various places.

3.1) GAJJU GHUNDAI AND NAUGRAM MICROPORPHYRITES:

These microporphyrites are composed of phenocryst of mostly perthetised alkali felspar (upto 5 mm in size), amphibole (richterite), epidote (Plate 3.1) and minor plagioclase (An; 12-20), ore, quartz and aegirine augite (in the order of decreasing abundance, Table-1). Epidote amygdales with chlorite±quartz and xenoliths of basic rocks are also present as secondary phenocrysts. Overgrowth/reaction rim along margins of amphibole (grains with brownish green core and green to greenish blue rim) is seen in most of the rocks. Fused margins of feldspar phenocrysts and concentration of fine blue amphibole and aegirine around their margin indicate metasomatic effect of late stage fluids and/or devitrification/reaction of phenocryst with ground mass (Plate 3.2).

The groundmass is either very fine grained, aphinitic or glassy and its constituents are dominantly felsic with secondary epidote, bleby to tiny crystals of reibeckite, aegirine augite, ilmenite and rare sphene. The phenocryst/groundmass ratio varies from 10/90 to 30/90. (Table-1). Blow vesicles are stretched in the direction of lava flow and mostly filled with limonite. Perlitic and variolitic structures are common in the groundmass.

Linear orientation of primary mineral constituents are also indicative of flow structures (Plate 3.3). Lenses ,interrupted bands, patches of ash and fracture fills are also noted.

وَإِن مِّن شَيْءٍ إِلَّا عِندَنَا خَزَائِنُهُ وَمَا نُنَزِّلُهُ إِلَّا بِقَدَرٍ مَّعْلُومٍ ﴿٢١﴾

And there is not a thing but with Us are the stores thereof. And We send it not down except in appointed measure. (15 : 21)

TABLE 1. MODAL COMPOSITION OF SUBVOLCANIC-VOLCANIC ROCKS OF THE PESHAWAR PLAIN

	S. No.	GJ1	GJ1A	GJ2	GJ2A	GJ3A	GJ4A GJ5A	GJ5	GJ7A	GJ8 GJ11	GJ9A GJ10A
PHENOCRYSTS	PAF	80	45	10	65	60	60	85	70	80	85
	Pg	10	5	-	5	3	-	7	10	10	5
	Qtz	7	5	90	10	7	10	8	5	5	5
	RF	3	45	-	20	30	20	-	15	-	-
	Epi	Tr	-	-	-	-	5	-	-	5	Tr
	Amp	Tr	-	-	-	-	5	-	-	-	5
	Ore	-	Tr	Tr	Tr	Tr	Tr	-	-	-	-
GROUNDMASS	FGM	80	80	85	70	68	65	88	90	85	95
	BIO	-	1	Tr	-	Tr	Tr	-	-	Tr	-
	EPI	Tr	3	2	-	1	7	3	-	8	-
	ORE	5	6	4	5	15	12	5	3	5	2
	HBL	-	1	-	-	-	5	-	Tr	1	2
	BAM	13	2	-	-	-	Tr	1	Tr	Tr	Tr
	AEG	Tr	Tr	-	-	Tr	-	Tr	-	-	-
	ORD	-	5	8	25	15	10	2	5	1	1
	SPH	1	1	-	-	-	-	-	-	-	-
	P/G	20	20	10	25	30	25	10	10	12	10
	RATIO	80	80	90	75	70	75	90	90	88	90

KEY:- Gj=Gajju, PAF= perthetised alkali felspar (5 mm in size), Amp=Amphibole(richterite), Epi= Epidote, Pg= plagioclase (An; 12-20), Qtz=Quartz, AEG= aegirine augite (in decreasing abundance), Epidote amygdales with chlorite±quartz and xenoliths of basic rocks as secondary phenocrysts. RF=Rock fragments, BIO=Biotite, HBL=Hornblende, BAM=Blue Amphibole SPH=Sphene, P/G= Phenocryst-Groundmass Ratios = 10/90-30/90. The groundmass is fine grained/aphinitic/glassy and its constituents are dominantly felsic with secondary epidote, bleby to tiny crystals of reibeckite, aegirine augite, ilmenite and rare sphene.

وَجَعَلَ فِيهَا رَوَاسِيَ مِن فَوْقِهَا وَبَارَكَ فِيهَا وَقَدَّرَ فِيهَا
أَقْوَاتَهَا فِي أَرْبَعَةِ أَيَّامٍ سَوَاءً لِّلسَّائِلِينَ ۝

He placed therein firm hills rising above it, and blessed it and measured therein its sustenance in four Days (in all), alike for (all) who ask. (41 : 9, 10)

Table 1 Contd.

	S.No.	TAR Ash	TAR Tuff	RAS4	RAS9	RAS15	RAS14	MNS2	MNS4	MNS10	MNS1' MNS13
PHENOCRYSTS	PAF	-	60	65	62	65	50	60	65	55	60
	Pg	-	30	10	12	2	15	5	5	5	8
	Qtz	-	-	7	12	30	30	15	15	20	12
	RF	-	-	15	14	-	5	10	7	15	7
	Epi	-	-	-	-	-	-	-	-	-	-
	Amp	-	-	-	-	-	-	-	-	-	-
	Ore	2	-	-	-	-	-	-	-	-	-
GROUNDMASS	FGM	96	88	89	87	78	95	77	80	88	85
	BIO	-	8	2	4	2	1	Tr	Tr	-	-
	EPI	-	1	1	2	12	1	2	1	1	1
	ORE	1	1	3	3	5	3	2	2	1	1
	HBL	-	-	-	-	-	-	2	3	1	2
	BAM	-	Tr	1	Tr	1	Tr	15	12	7	8
	AEG	-	Tr	Tr	-	Tr	Tr	Tr	1	Tr	1
	ORD	tR	Tr	Tr	-	1	-	1	1	1	1
	SPH	-	-	-	-	-	Tr	-	-	-	-
	ALT	3	1	1	1	1	Tr	1	1	Tr	1
	P/G	2	5	20	15	35	35	12	15	10	18
	RATIO	98	95	80	85	65	65	88	85	90	82

KEY:- TAR=Tarakai, RAS=Rashakai, MNS=Mansurai, ALT=Alteration;

In Tarakai rocks, phenocrysts are larger than Mansurai and are mainly of cloudy perthetized alkali-feldspar (2 to 10 mm), strained quartz, plagioclase (An=12-18%), the model proportion of richterite is more than 5% & most probably because of a more advanced metasomatic activity indicates flow structure.

Phenocrysts of alkali-feldspar are mostly corroded and show alteration along the margins and cracks

G=Gohatai Ghundai, TT=Tora Tiga, Cte=Chlorite;

أَلَمْ تَرَوْا أَنَّ اللَّهَ سَخَّرَ لَكُمْ مَّا فِي السَّمٰوٰتِ وَمَا
فِي الْأَرْضِ وَأَسْبَغَ عَلَيْكُمْ نِعَمَهُ ظَاهِرَةً وَبَاطِنَةً

See ye not how Allah hath made serviceable unto you whatsoever is in the skies and whatsoever is in the earth and hath loaded you with His favour both without and within. (31 : 20)

TABLE 1.
MODAL COMPOSITION OF MICROPORPHYRIES FROM SUBVOLCANIC VOLCANIC ROCKS OF THE PESHAWAR PLAIN

	S.No.	MNS14	MNS17	G1	G3	G8	TT1	TT2 TT3	TT5	TT7	TT13 TT14 TT15
PHENOCRYSTS	PAF	55	80	-	20	40	65	60	60	85	45
	Pg	10	5	-	50	40	10	7	5	15	25
	Qtz	20	10	90	10	10	15	20	25	-	20
	RF	7	-	-	-	5	5	8	7	-	5
	Epi	-	-	-	-	-	-	-	-	-	-
	Amp	8	-	-	-	-	-	-	-	-	-
	Ore	-	5	-	-	-	-	5	3	-	5
	Cte	-	-	10	10	5	-	-	-	-	-
GROUNDMASS	FGM	85	82	87	90	88	92	88	90	90	90
	BIO	Tr	-	-	-	2	Tr	4	1	-	4
	EPI	2	1	-	-	2	1	3	5	1	1
	ORE	1	1	5	5	7	3	1	2	2	3
	HBL	2	1	-	-	-	-	-	-	-	-
	BAM	9	12	-	-	-	1	4	-	-	-
	AEG	Tr	1	-	-	-	Tr	Tr	-	-	-
	ORD	Tr	2	5	3	Tr	1	Tr	1	6	1
	SPH	-	-	-	-	1	-	-	-	-	-
	ALT	Tr	-	3	2	-	1	Tr	1	-	Tr
	P/G	12	8	5	3	8	35	30	25	10	30
	RATIO	88	92	95	97	92	65	70	75	90	70

KEY:- Chl=Chlorite, Car=Carbonaceous material, Mus=Muscovite, Cly=Clay; The ratio between the phenocryst and the groundmass varies between 1:6 to 9:11 (Table-1). Perthetized alkali-feldspar phenocrysts are subhedral to anhedral in shape and vary in size from 1*1 to 2*3 mm. Plagioclase (An=15 to 20%) is fresh, however, saussuritized and kaolinized grains are also present. The groundmass consists of 70 to 90% of felsic and 30 to 10 % of mafic constituents (some of which are identified as biotite, and epidote). The texture of these rocks is felsophyric to spherulitic.

اَللّٰهُ الَّذِیْ خَلَقَ سَبْعَ سَمٰوٰتٍ وَّ مِنَ الْاَرْضِ مِثْلَهُنَّ

Allah it is Who hath created seven heavens, and of the earth like thereof. (65 : 12)

Table-1 CONTINUED

	S.No.	GJ12A	GJ13	GJ13A	GJ14 GJ15	GJ32	GJ35	GJ41	TARI TAR2	TAR8
PHENOCRYSTS	PAF	82	20	75	85	90	50	80	68	75
	Pg	10	70	5	5	5	10	10	12	10
	Qtz	5	5	5	5	5	10	10	12	5
	RF	-	-	15	-	-	-	-	5	5
	Epi	-	-	-	-	-	-	-	-	-
	Amp	2	-	2	5	-	-	-	-	-
	Ore	-	5	-	2	-	30	-	-	-
GROUNDMASS	FGM	96	92	85	88	95	95	95	92	88
	BIO	-	-	Tr	-	-	-	-	1	2
	EPI	-	3	7	1	-	Tr	Tr	Tr	3
	ORE	3	4	5	5	3	3	2	3	3
	HBL	Tr	-	2	2	1	-	1	-	-
	BAM	Tr	-	Tr	Tr	-	-	Tr	1	2
	AEG	-	-	-	-	-	-	Tr	-	Tr
	ORD	1	1	5	5	1	1	-	1	Tr
	SPH	-	-	-	-	-	-	Tr	-	-
	ALT	-	-	-	-	-	-	-	1	1
	P/G	20	20	10	25	30	25	10	10	18
	RATIO	80	80	90	75	70	75	90	90	82

The verse points out that everything in the universe of "the seven Heavens and the earth" as it styles it, is so beutifully set that one and all proclaim in unison the wisdom and glory of their Lord. One and all testify to the fact, under the divine scheme of things. In everything in the Quranic sense, the term 'shy~un' or thing referred to in the verse, applies not merely to the things of matter, but even to every aspect of human life and activity. There is a law of life at work appropriate to it. It was expected of man to understand these laws.

Here the seven heavens are referred to, which have been recently interpretted to imply seven concentric shells like entities, surrounding one over the other and with radii increasing in geometric progression, the first/lowest of these can be identified with Solar System (Sama-e-Dunya; Al-Mulk-5); as envisaged in the paper entitled,"Discrete Orders of Magnitudes of Various Types of Natural Phenomena" by M.M. Qureshi, in Pak.J.Sc vol-22,pp-300-302,(1970). In this paper, the ratio of the successive cocentric shells (Saba'a Samawat) was derived as being of the order of 20,000, and shown to be in agreement with a Hadith.

Moreover,the same ratio was shown to apply to the decreasing sizes of shells (down to sub-nuclear phenomena and this goes in concordance with the verse which states, "Allah is He Who hath created seven heavens and of the earth the like thereof"(65/12).

As mentioned by Al-Dhuhak in his book'Al-Futhohat-e-Allahia' "There are seven earths,one over the other, without cleaves as the heavens." Using seismic waves as earth probe to measure the changes occurring at distinct boundaries between crust and mantle and mantle and core. It was found that beside compositional other changes also occur at depths i.e. at 100Km, 400Km, and 670Km. Thus dividing the earth into seven distinct stratified layers like succesive concentric shells. Similarly, the study of atomic structures of the elements reveal unimaginable wisdom of Allah, Al-Mighty. All elements are built up of very minute particles. Each element has its own specific atom. A lovely world is built within atoms. Extremely small particles are prudently arranged in this world.

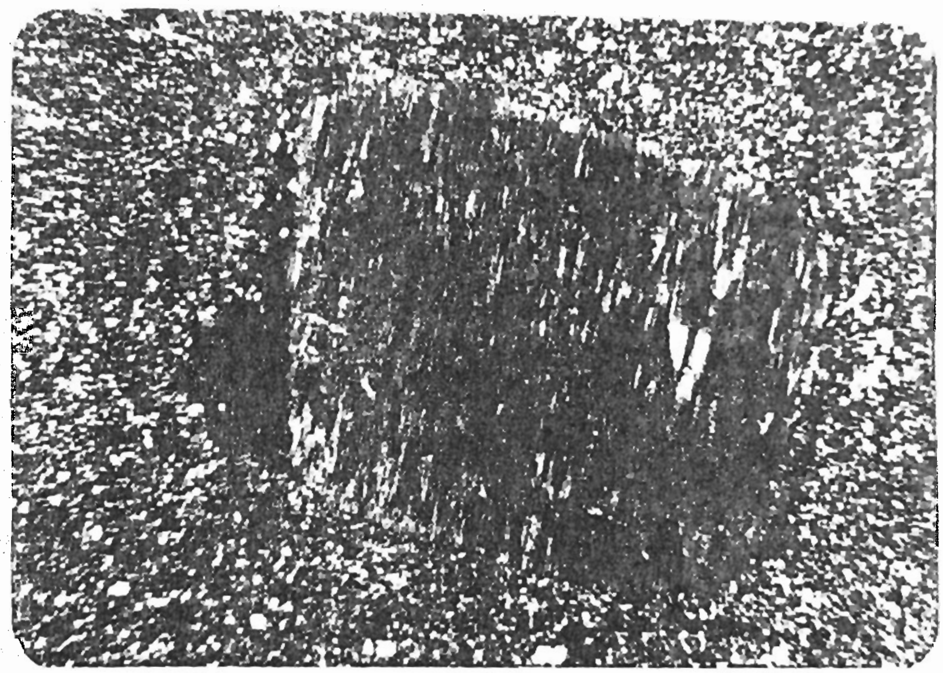


Plate 3.1 Micropophyrites; composed of phenocrysts of perthetised alkali felspar, amphiboles (richterites), epidote ore etc.

(With crossed Nicols: enlargement 45 x.

Plate 3.2 Fused margins of feldspar phenocrysts surrounded by concentration of fine blue amphibole and aegirine augite, showing reaction of phenocryst with groundmass.

(With crossed Nicols: enlargement 45 x.)

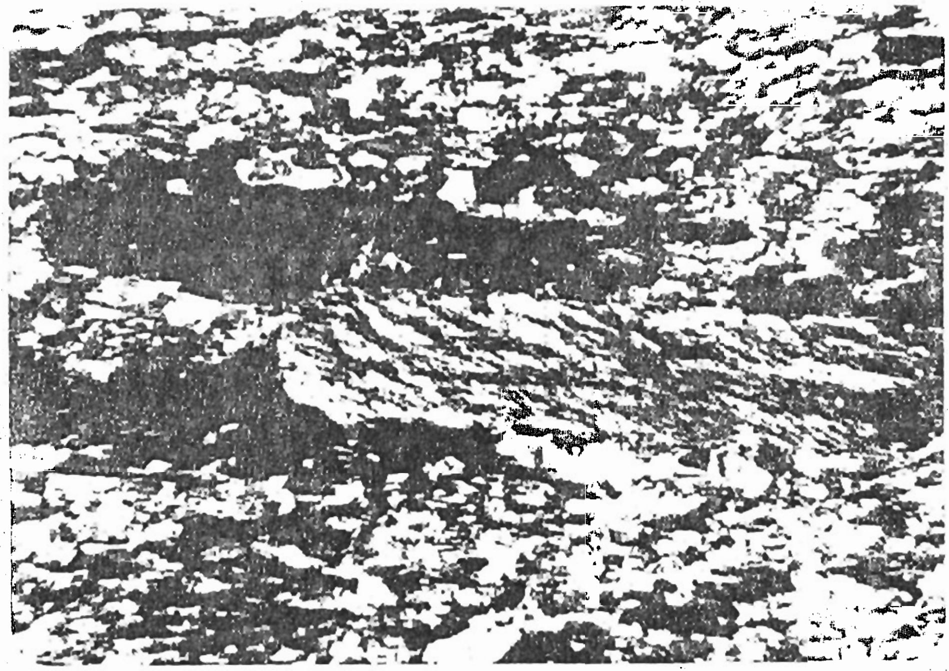


Plate 3.3 Linear (preffered) orientation of primary mineral constituents indicating flow structure of lava.

(With crossed Nicols: enlargement 75 x)

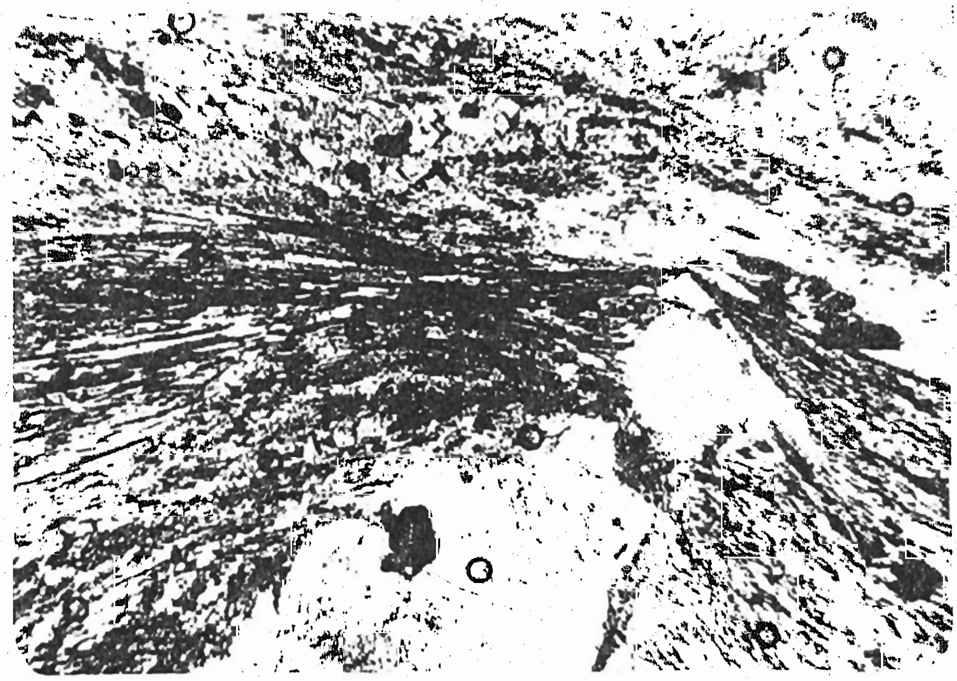


Plate 3.4 Fine needles of epidote richterite/arvefdsonite arranged parrallel to the phenocryst, showing flow structure.

(With crossed Nicols: enlargement 45 x)

3.2) MANSURAI GHUNDAI MICROPORPHYRITES:

Texturally these rocks show more phenocryst/groundmass ratio than that of Gajju Ghundai. Here the phenocrysts are comparatively larger, with more concentration of subhedral zoned phenocrysts (reaction rim formed by metasomatic fluids) of soda amphibole. This character is suggestive of more effect of metasomatism and proximity to the source of metasomatic fluid than that of Gajju Ghundai. In addition to the indistinguished felsic constituents in the groundmass, fine needles of epidote arfvedsonite/richterite are arranged parallel (Plate 3.4) to and turning around the phenocryst are indicative of flow structures (Plate 3.5).

Thin section study reveals a late stage generation of these secondary minerals, which might be the product of disintegration of soda rich glassy groundmass or an introduction of metasomatic fluids. However, more sodic overgrowth along the margins, fracture/cleavage planes in amphibole phenocryst and protrution of acicular needles of reibeckite in alkali-feldspar phenocrysts (Plate 3.6) favour the process of soda-metasomatism in these rocks. Here quartz is almost uneffected. Thin bands of volcanic ash are also present. Though the ash lenses are felsic in composition, some rock fragments of basic volcanic rocks are also seen in thin sections.

3.3 GOHATAI RHYOLITES

Rhyolites are exposed near Gohatai village, Sherdarra, southeast of Jaffar Kandao, Sorai Malanderai, Nawe kili along Totalai Chingalai roadside and in several other places. Texturally, these are different from the above described microporphyrites. The rocks show flow structures and characteristically marked with blow holes. These blow holes are of different sizes (1 mm to tens of centimeter) partially filled with epidote, secondary quartz and ore, are the result of puffing up of gases from lava drain surface. The rhyolites consist of thin and thick lava sheets, and well jointed and fractured with dimension blocks locally used as building stones.

These rocks are grey to light grey in colour with well marked manganese dendrites along fractures. Less than 5% of the total rock constituents are identified as plagioclase and alkali-feldspar which occur as phenocrysts. One percent fine clusters of quartz (polygonal), epidote, ore and chlorite probably amygdaloidal are also seen (Plate 3.7 a).

Rock samples from Nawe-kili are dense, hard and light grey in colour (Plate 3.7b). These rhyolites exhibit vesicles mostly with regular outlines (Plate 3.8) filled with alteration

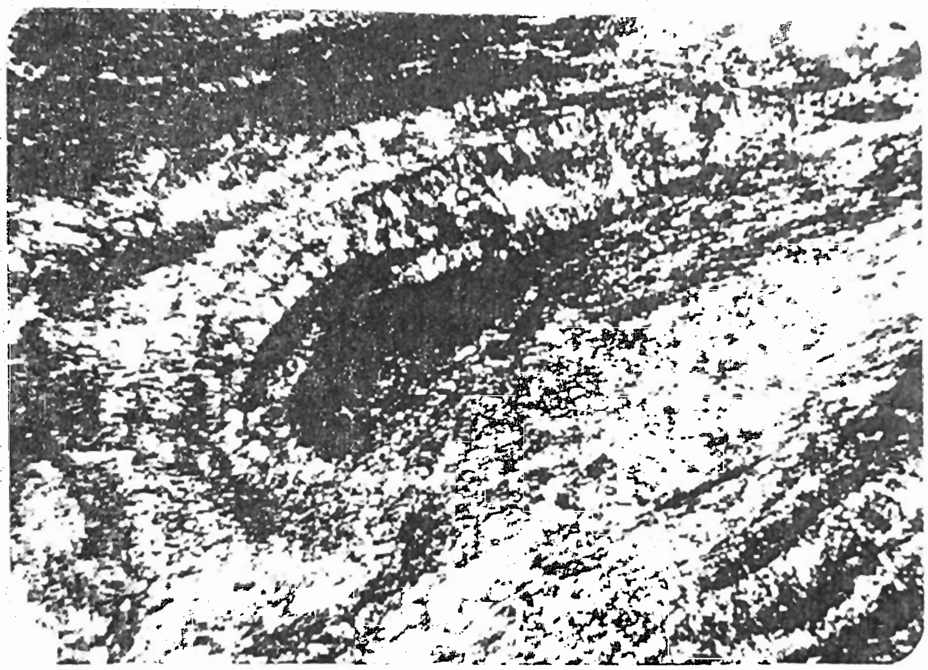


Plate 3.5 Fine needles of epidote richterite/arvefdsonite turning around the phenocrysts. (Fluxion structure superimposed on volcanic flows. With crossed Nicols:enlargement 72 x).

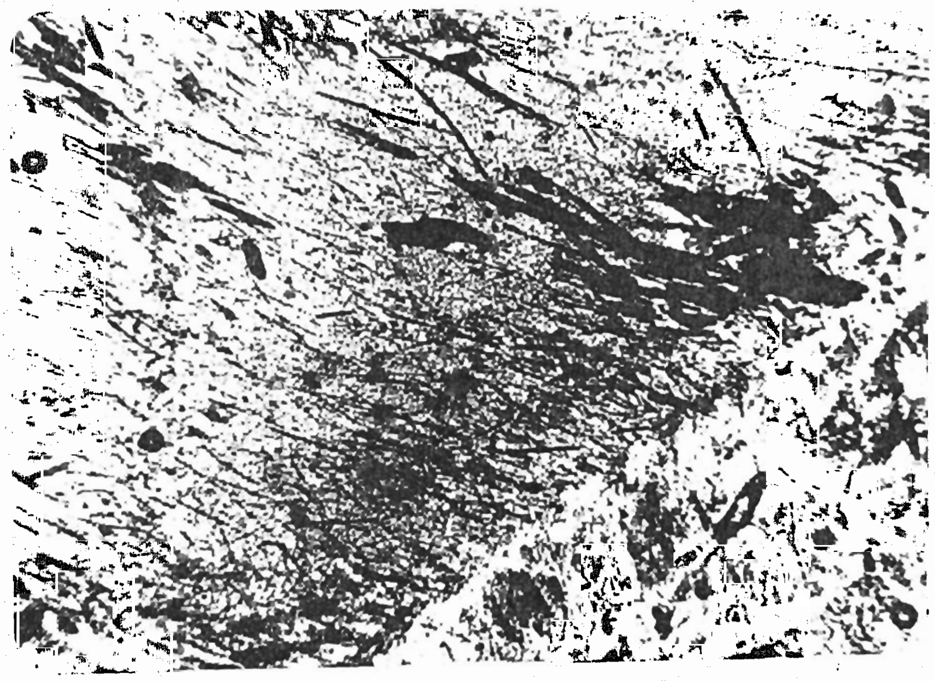


Plate 3.6 Protrusion of acicular needles of rechterite in alkali feldspar phenocrysts. (With crossed Nicols: enlargement 45 x). This spontaneously diverts my mind to the Quranic Edict:

وَالْأَرْضَ مَدَدْنَاهَا وَأَلْقَيْنَا فِيهَا رَوَاسِيَ وَأَنْبَتْنَا فِيهَا مِنْ كُلِّ شَيْءٍ مَوْزُونٍ ١٩

[The earth We spread out, emplaced the mountains into it and set almost all the suitable things to grow in proportionate balance therein].

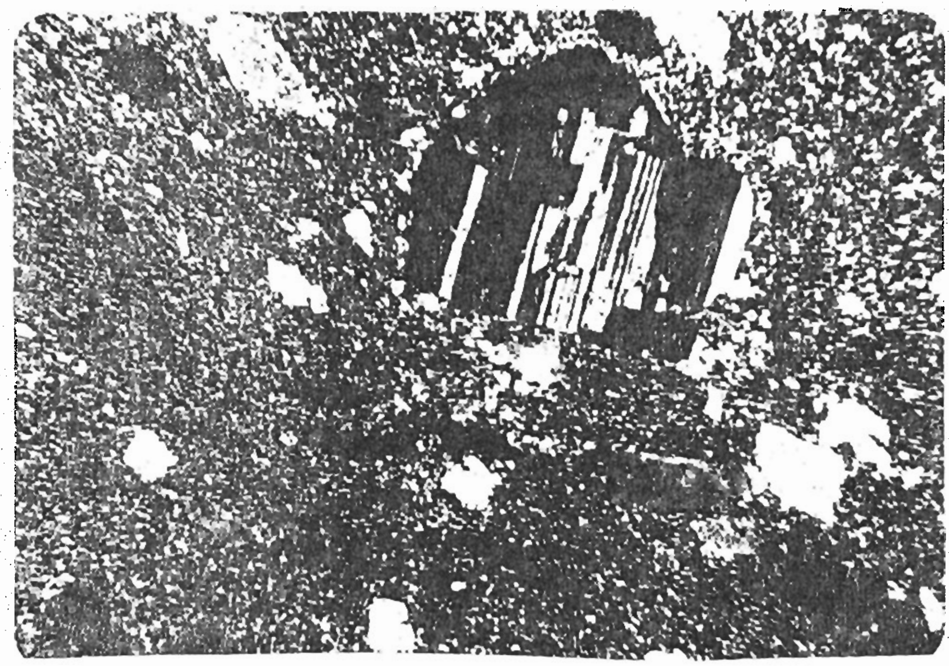


Plate 3.7a Fine clusters of (polygonal) quartz, albite, epidote, ore and amygdaloidal chlorites.(With crossed Nicols: enlargement 45 x)

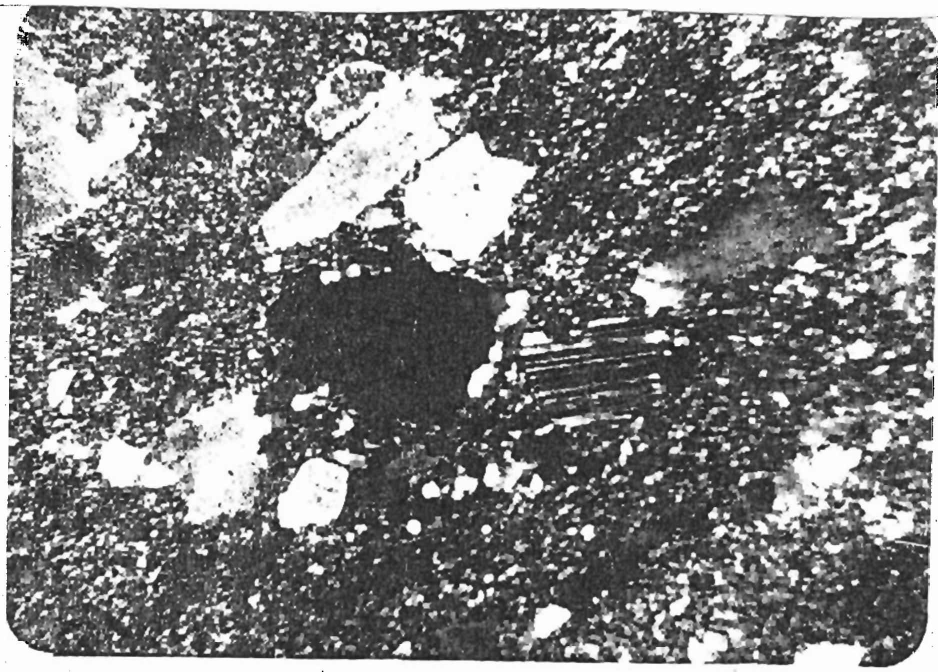


Plate 3.7 b Fine clusters of (polygonal) quartz, albite, epidote, ore and amygdaloidal chlorites.(With crossed Nicols: enlargement 45 x).

products. The groundmass is mostly glassy, at places devitrified to crystallites and composed dominantly (more than 90%) of unidentified felsic constituents. Epidote, sericite, ore dust and chlorite occur as secondary product in cluster and around elongated vesicles.

3.4) TARAKAI-RASHAKAI AND TORA-TIGA MICROPORPHYRITES.

These are porphyritic in texture with uneven distribution of comparatively larger phenocryst than Mansurai and are mainly of cloudy perthetized alkali-feldspar (2 to 10 mm), strained quartz, plagioclase (An=12-18%), granitic rock fragments and basic rock xenoliths, (see Table-1). Phenocrysts of alkali-feldspar are mostly corroded and show alteration along the margins and cracks. Penetration of glassy groundmass along cracks and cavities in phenocryst is common. Metasomatic acicular needles and fine irregular patches of richterite are present within the alkali-feldspar phenocryst. Overgrowth or reaction rims of sodic amphibole along cleavage partings in primary hornblende are seen. The groundmass is fine-grained to aphenitic and composed of felsic constituents, however, streaks of very fine grained aegirine, richterite, biotite, ore, sphene, and epidote are recognizable.

In Tarakai rocks, the modal proportion of richterite is more than 5% (Table_1), most probably because of a more advanced metasomatic activity indicates flow structures. Foliation character is among the commonly occurring features in the rocks. In Tarakai Ghundai ash beds and volcanic tuffs are interlayered with the acidic microporphyries. Thin section study of ash beds reveals that angular felsic grains are interlayered with biotite and muscovite.

3.5 AMBELA SUBVOLCANIC-VOLCANIC ROCKS.

Outcrops of acid and basic micropophyries intercalated within the metasedimentary sequence of Jaffer Kandao formation around Ambela granitic complex are exposed at Naugram, Ajmir Ghundai, Sherdarra, Ziarat, Dhari-Dhob, Sorai- Malandarai, Malandarai Kandao, Nawe-Kili, Beshpur -China, and Karapa. Type and concentration of phenocryst minerals classify acidic micropophyries by Rafiq, (1987) into the following two types:

A) Microporphyries with dominant alkali-feldspar phenocrysts;-

These are light grey to dark grey in colour. Randomly oriented phenocrysts of alkali-feldspar with minor quartz and plagioclase are embedded in a very fine grained groundmass of felsic minerals. The ratio between the phenocryst and the groundmass varies between 1:6 to 9:11 (Table-1). Perthetized alkali-feldspar phenocrysts are subhedral to anhedral in shape and vary in size from 1*1 to 2*3 mm. Plagioclase (An=15 to 20%) is fresh, however, saussuritized and kaolinized grains are also present.

The groundmass consists of 70 to 90 of felsic and 30 to 10 % of mafic constituents (some of which are identified as biotite, and epidote). The texture of these rocks is felsophyricto spherulitic.

B) Microporphyrites with dominant quarts phenocryst consist of 60 to 80% quartz by volume of the total phenocrysts. The other phases present as phenocrysts include alkali-feldspar, plagioclase and lithic fragments in lesser amount.

Phenocryst of quartz are medium to fine grained, subhedral with corroded margins (Plate 3.9). Most of the quartz phenocrysts are fresh, some are strained and contain cavities filled with felsic microlites (Plate 3.10). The groundmass is very much similar to microporphyries of the type (A). Besides some of the rocks show prominant flow layering producing a pseudo-microgneissose structure. The phenocrysts /groundmass ratio varies from 1:5 to 1:1 (Table-1).

3.6) MICROPORPHYRIES OF WARSAK.

The microporphyries of Warsak area are associated with the alkaline aegerine-reibeckite granite. They are exposed on the eastern side of Warsak guest house and extend upto the upper limits of the Warsak lake in the West. These are concordant bodies of regular shape, and extend for more than 5 km in the North-South direction. The microporphyrites are greyish in colour, strongly porphyritic in texture with phenocrysts of feldspar and quartz. Dark coloured patches of biotite and other ferromagnesian minerals are seen in some of the specimens.

Perthetized alkali-feldspar (45-60%), plagioclase (Ab=5-8%), quartz (20-25%) with or without biotite and sphene (1-8%)

The felsic constituents in the groundmass are indistinguishable. Zircon, apatite, aegirine, reibeckite and secondary alteration minerals (clay, chlorite etc) and, rarely, garnet are present as accessories. Magnetite and ilmenite may reach upto 12-60% at some places.

Plate 3.8 Microphotograph of rhyolite exhibiting vesicular structures with regular outline.

(With crossed Nicols: enlargement 72 x)

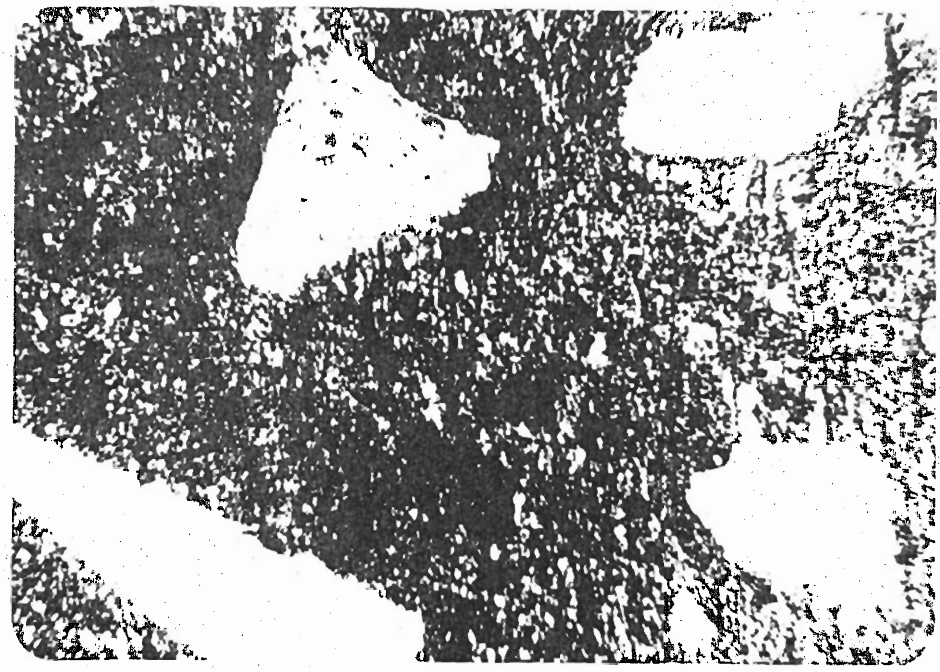


Plate 3.9 Medium to fine grained quartz phenocrysts subhedral with corroded margins.(With crossed Nicols: enlargement 45 x).

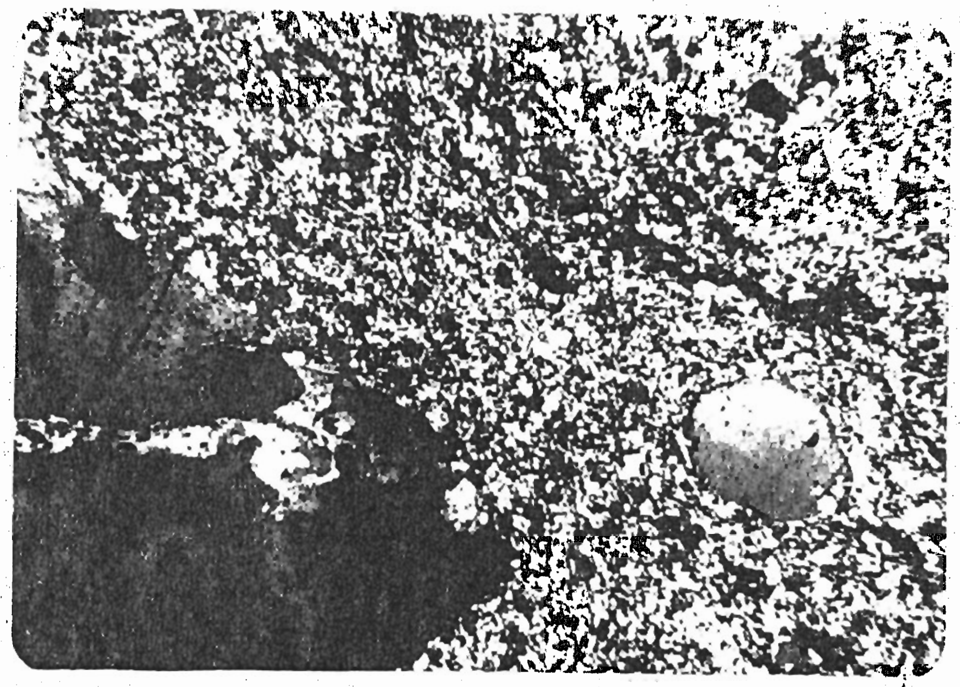


Plate 3.10 Fresh and strained quartz phenocrysts containing cavities filled with felsic microlitic felsic groundmass.(With crossed Nicols: enlargement 45 x).

In petrology and chemistry these rocks are very much similar to microporphyries of Sorai, Malandari, Tarakai, Rashakai etc. Ahmad et al., (1969), Kempe and Jan, 1979; 1980, and others described and correlated them with porphyries of Shawa-Shahbaz Garhi in detail.

3.7) MICROPORPHYRIES OF SHEWA- SHABAZGHARI

The Shewa-Shahbazgarhi complex in a triangular outcrop now considered to be a part of the volcanogenic region and consists of basic and acidic rocks. Acidic microporphyries are the main rock units including aegirine-riebeckite porphyritic microgranites and sheared microporphyries (cataclastic microporphyries).

Perthitized alkali feldspar, with subordinate albite and quartz are among the main phenocrysts phases , whereas biotite, ore, blue amphibole, sphene and aegirin occur as minor constituents. The indistinguishable cryptomicrocrystalline groundmass clearly show the evidence of devitrification and reaction with the phenocrysts. Several workers e.g. Siddiqui, 1965; Chaudhry and Shakoor, 1968; Kempe and Jan, 1970; 1980; Chaudhry et al., 1976; Irshad et al., 1990; and others have described these features in detail.

3.8 MICROPORPHYRITES OF TARBELA:

The acidic alkaline microporphyrites described from Tarbela Complex by Kemp and Jan (1970) are very similar to the microporphyrites of the area under investigation. These rocks, though no more exposed because of the construction related to Tarbela Dam, were described of very similar rock type to those of Shewa Shabazgarhi and Worsak area.

Plate 3.11 Porphyritic Texture, containing altered phenocrysts of plagioclase, and cavity fills of epidote and quartz.(With crossed Nicols: enlargement 45 x).

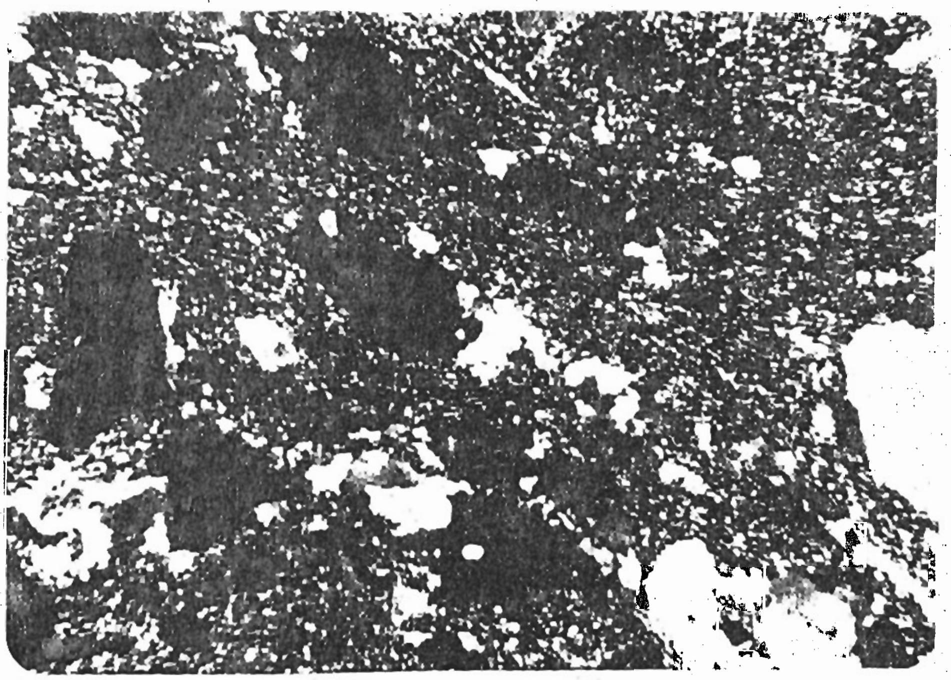


Plate 3.12 Microporphyrites showing felsic plagioclase, fine grained amphibole, epidote, chlorite and orange red ore. (With crossed Nicols:enlargement 45 x).

3.9 BASIC VOLCANICS OF GAJJU GHUNDAI, JAFFAR KANDAO, NAWEKILI, MALANDRAI, AND KARRAPA:

Basic volcanic rocks are exposed east of acid microporphyries at Gajju Ghundai, the metasedimentary sequence of Jaffar Kandao Formation at Jaffar Kandao, Sorai Malanderai, Malanderai Kandao, Nawe-Kili and Karrapa. Although the metamorphism has obliterated most of the primary features, the presence of porphyritic texture, amygdales and local inter-calations of sediments within the greenschists suggest their extrusive nature as lava flows. Gajju Ghundai rocks are porphyritic in texture and contain mostly altered phenocrysts of plagioclase(An=35-40% & 2-3 mm in size) and cavity fills of epidote and quartz (Plate 3.11). Epidote, chlorite, white mica in association with quartz occur as alteration products of phenocrysts. Epidote in some of the cavities is surrounded by alteration rims of chlorite, quartz and other minerals.

Chlorite schists containing phenocrysts of epidote (the product of alteration of plagioclase) exposed at Nawe-Kili, Malanderai Kandao and Cheena are more or less similar to Gajju Ghundai volcanics. The groundmass is very fine-grained, showing schistose texture in some thin sections. In addition to felsic constitents (plagioclase), fine grained amphibole, epidote, chlorite and orange red ore are recognized (Plate 3.12).

وَمِنَ الْجِبَالِ جُدَدٌ بِيضٌ وَحُمْرٌ مُّخْتَلِفٌ أَلْوَانُهَا وَغَرَابِيبُ سُودٌ ﴿٢٧﴾

['In the mountains, also there are streaks, white, red and jet black, with different hues'35/27].

[Can human mind percieve any relation/ proportion between these microscopic entities and the huge lofty mountains if it overlooks the hidden hand of the Primordial Painter, the more we think over the miaculous scene of creation, the more our hearts get closer to affirm the Quranic Edict, 'He alone is the Knower of the hidden and the manifest, Al-Mighty, the Gracious, Whose Grace doesnot satisfy on mere creation but goes on blessing everything He created the best of form, right disposition with exact structure as a paragon of beauty.']

ذَٰلِكَ عَالِمُ الْغَيْبِ وَالشَّهَادَةِ الْعَزِيزُ الرَّحِيمُ ﴿٦﴾ الَّذِي أَحْسَنَ كُلَّ شَيْءٍ خَلَقَهُ [السجدة ٣٢:٦]

CHAPTER FOUR

تُسَبِّحُ لَهُ السَّمٰوٰتُ السَّبْعُ وَالْاَرْضُ وَمَنْ فِيْهِنَّ ۭ وَاِنْ مِّنْ شَيْءٍ اِلَّا
يُسَبِّحُ بِحَمْدِهٖ وَلٰكِنْ لَّا تَفْقَهُوْنَ تَسْبِيْحَهُمْ ۭ اِنَّهٗ كَانَ حَلِيْمًا غَفُوْرًا ﴿٤٤﴾

"Extoll Him the seven heavens and the earth and all those who are therein. There is nothing which doth not celebrate His praising; only you donot understand their praising".17/44

Spectral analysis of light from the sun and other stars show that to a large extent the [i.e. 67] elements found on the earth also exist on other planets.Iqbal remarks:-'The ultimate cosmic essence of all the things, whether corpuscular or photonic, is so similar that even a nuclide transforms into a spontaneous source of solar emanations with the fission of its core'.

Thanks to Allah, Who has so kindly gifted man the unique mind with the help of which he is now a days reaching into the depths of atoms. Reaction principles are Allah's gifted means through which numerous substances are analysed to sort out the structural and compositional changes in mineral assemblages. These mysterious aspects of the earth is the field of

GEOCHEMISTRY

CHAPTER FOUR

GEOCHEMISTRY

4.1. ANALYTICAL PROCEDURES:

The samples for this study were collected from scattered exposures of the subvolcanic-volcanic rocks of the Peshawar Plain. After a detailed thin section study, 24 samples were selected for chemical analyses. Major element analyses were performed by atomic absorption and flame spectrophotometer.

To evaluate the effectiveness of this technique double runs were made of the duplicate samples. In addition to trace, minor and rare-earth elements, Na_2O, K_2O and FeO were analyzed by Neutron activation at Radiation center Carvallis Oregon, U.S.A. All the data were standardized against USGS standards (BCRI, G2, SRM, GSPI). The result of major and trace element analyses of these rocks are shown in Table-2.

4.2. MINERALOGICAL AND MODAL CHARACTERISTICS.

The felsic modal data is displayed on a Streckeisen (1976) QAP diagram (Figure C-1), the plots of mineral and modal composition for subvolcanic-volcanic rocks of Peshawer basin are scattered from Calc-Alkaline high K-field to aluminous in alkaline. An A-type affinity of these rocks is clear on the diagrams.

In addition to normative values, the modal proportion of orthoclase, albite and anorthite are plotted in Hietenen's (1963) and O'Conner's (1965) classification diagrams (C-2&b). Majority of these, plot into the granitic (Rhyolite) field. Keeping in view the omission of mafic constituents in the above mentioned diagrams R_1, R_2 classification diagram basis on parameters (R_1= 4Si-11(Na+K)-2(Fe+Ti) and R_2= (6Ca+2Mg+Al) of De La Roche (1976, 1980) is tried. Here majority of the rocks classify as rhyolites (Figure C-3).

These rocks on one side represent basalt while on the other side these represent the last fractionate rhyolites of curvilinear trend of basalt-hawaiite-mugearite-trachyte-rhyolite and/or rectilinear trend of basalt-andesite-rhyolite defining an alkaline magmatic lineage. This may be interpreted as two separate magmas of basaltic and rhyolitic composition.

The distribution of selected minor and trace elements (Ti, Zr, Y, Nb, Ce, Ga and Se) which are generally considered to remain inert during secondary processes can be used to classify rocks of alkaline and subalkaline series. Variation diagram based on SiO2 verses

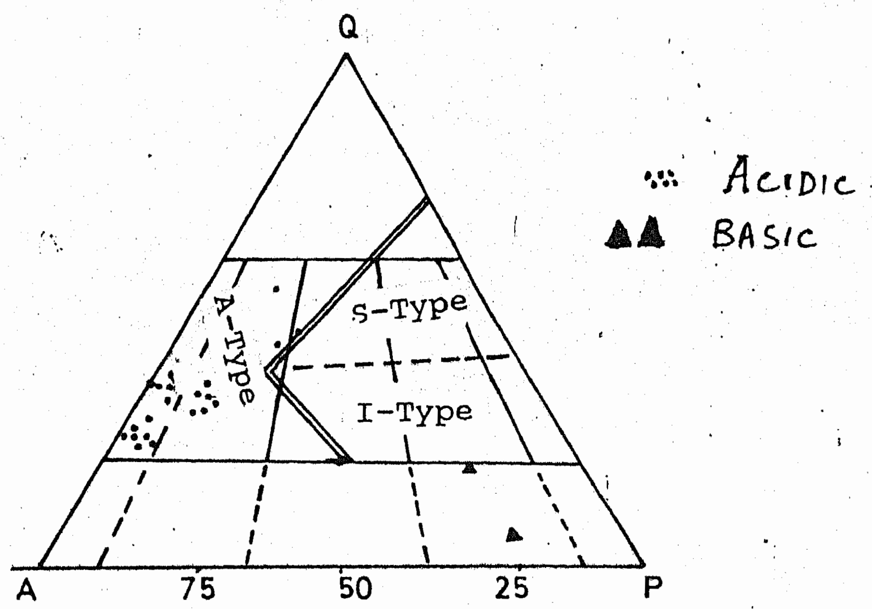
NG - 20

TABLE 2 - MAJOR AND TRACE ELEMENT ANALYSES OF SUBVOLCANIC-VOLCANIC ROCKS OF THE PESHAWAR PLAIN

S.NO	GJ1B	GJ2	GJ3A	GJ3	GJ4	GJ5	GJ6	GJ8	GJ11	GJ12A	GJ35	GJ41
Wt %												
SiO2	48.14	69.96	71.52	69:92	70.14	69.34	71.08	70.62	71.4	69.5	76.12	74.28
TiO2	---	0.12	0.13	0.13	0.13	0.14	0.12	0.13	0.72	0.13	0.13	0.12
Al2O3	19.36	14.09	12.8	12.76	13.22	13.31	14.32	13.1	14.01	13.86	13.8	13.89
Fe2O3	7.14	3.14	2.9	3.03	3.26	3.78	3	3.3	3.1	3.06	2.06	3.24
MnO	0.13	0.16	0.13	0.13	0.17	0.16	0.17	0.11	0.11	0.13	0.13	0.22
MgO	4.71	2.22	1.94	2.72	2.41	3.03	2.02	1.06	2.07	2.67	0.35	0.64
CaO	14.37	1.55	3.66	3.88	2.1	2.3	2.03	2.03	2.01	5.21	0.2	0.21
Na2O	1.32	3.89	1.08	1.38	5.76	5.59	3.41	4.53	4.24	1.81	0.84	2.32
K2O	3.62	2.71	4.91	3.94	2.52	2.27	4.11	6	3.23	3	4.73	5.43
P2O5	---	0.18	0.15	0.12	0.31	0.18	0.2	0.17	0.32	0.32	0.06	0.03
Ig.L	2.25	0.51	1.26	1.59	0.54	0.7	0.42	0.34	0.3	0.41	0.86	0.26
Total	99.27	98.53	100.48	99.65	100.56	100.72	100.88	101.39	100.91	100.1	99.31	100.64
ppm												
Sc	38.8	7.2	6.9	7.2	8	8.4	6.9	7.7	7.3	7.6	4.8	7.7
Cr	147	0.5	6	2	5	1	3	3	1	1	2	4
Co	42.4	0.4	0.6	8.3	0.4	1.7	0.5	0.2	0.2	0.8	0.2	0.3
Ni	71	29	6.6	7.5	37	38	37	51	22	26	16	40
Zn	156	124	70	84	89	98	88	95	110	87	85	142
As	5.5	1.8	4.9	4.2	9.9	7.6	5.4	1.1	3.6	3.5	7.5	5.4
Sb	0.3	0.3	1.3	1	0.4	0.5	0.2	0.4	0.3	1.2	1.1	0.4
Sc	4.5	13.3	13.4	12.9	15.1	9.9	12.4	13.3	13.5	13.6	9.4	12.5
Rb	24	121	134	113	33	68	139	156	120	91	140	174
Cs	0.43	0.88	3.2	5	0.25	3.5	0.4	0.8	0.6	2	4.3	1.6
Sr	263	1	419	358	2	211	99	1.4	1.3	479	1.1	1.2
Ba	227	767	534	695	560	1190	545	475	535	707	807	617
La	11.2	111	111	113	126	113	74.2	116	107	114	77.2	115
Ce	24.8	232	256	240	297	250	155.9	238	226	245	186.3	270
Nd	14.9	110	123	113	143	121	75.8	113	107	116	90.8	129
Sm	3.97	24.49	21.93	23.82	26.05	22.2	17.64	21.84	22:55	23.47	17.17	26.12
Eu	1.44	5.57	5.04	5.45	6.31	5.73	4.28	5.17	5.29	5.52	3.88	5.96
Tb	0.71	3.38	2.91	3.26	3.46	2.69	2.55	3.06	3.23	3.33	2.23	3.4
Yb	2.36	8.77	7.78	8.5	8.75	6.02	7.25	8.62	8.42	8.91	5.85	8.66
Lu	0.33	1.12	1.05	1.14	1.14	0.73	0.92	1.18	1.06	1.14	0.82	1.16
Zr	77	749	753	741	800	522	607	817	738	741	535	885
Hf	2.7	27.8	26.4	25.9	35	16.5	24.4	30.9	27.4	26.2	19.7	31.2
Ta	0.6	8.5	8.6	8.3	10.3	6	7.5	9.4	8.5	8.6	6.9	9.3
W	4.5	11	3	5.1	8.4	5.4	4.5	9.6	1	6.6	1	4.2
Th	1.6	20	19.1	19.7	21.9	14.3	18.2	21.9	20	20.4	17.2	23
U	2.1	2	4.8	4.7	5	4.1	3.2	3.4	3.5	5.1	2.8	4.9

Table 2 (contd.)

S.No.	TAR2	TAR8	RAS2	RAS15	MNS4	MNS19	TT5	TT16	G17B	G11
Wt %										
SiO_2	71.5	70.42	73.96	73.4	69.54	71.36	73.04	72.55	55.08	73.16
TiO_2	0.13	0.12	0.13	0.12	0.13	0.11	0.12	0.13	---	0.61
Al_2O_3	15.84	15.94	14.25	14.05	15.88	16.02	15.19	14.98	22.87	13.85
Fe_2O_3	3.05	3.25	3.27	3.19	3.78	3.46	2.3	2.69	10.92	0.33
MnO	0.15	0.13	0.13	0.11	0.12	0.14	0.11	0.12	0.12	0.15
MgO	0.13	0.13	0.11	0.13	0.14	0.13	0.08	0.09	2.27	0.26
CaO	0.49	0.45	0.13	0.2	0.5	0.31	0.32	0.11	9.52	1.2
Na_2O	5	4.8	4.42	4.65	3.02	3.96	4.79	3.95	1.51	4.8
K_2O	3.45	4.52	3.62	5.01	4.71	4.01	3.98	3.71	1.53	4.5
P_2O_5	0.13	0.11	0.12	0.05	0.17	0.04	0.05	0.07	----	0.26
Ig.L.	0.77	0.58	0.13	0.35	1.95	1.2	0.4	1.23	1.85	0.65
Total	100.64	100.45	100.27	101.26	99.94	100.74	100.58	99.63	100.61	99.71
ppm										
Sc	4.9	6.5	6.5	5.7	8.3	8	4.5	4.4	39.8	---
Cr	1	0.4	4	2	5	5	2	8	150	---
Co	0.7	0.7	0.8	0.3	1.1	1.1	0.2	0.8	39.5	---
Ni	7.8	29	35	26	7.5	33	28	27	84	---
Zn	113	60	123	92	169	148	133	111	171	---
As	6.6	9	3.6	7.2	4.8	6	6.3	5.7	8.1	---
Sb	0.4	0.2	0.2	0.3	0.3	0.6	0.5	0.6	7.2	---
Sc	12.8	11.9	9.8	11	13.1	12.9	11.4	12.3	4.8	---
Rb	91	124	106	129	121	148	111	144	42	---
Cs	7	0.72	0.74	0.79	0.51	1	0.5	1.5	0.86	---
Sr	170	90	1.3	9.6	1.3	1.6	8.7	1.9	282	---
Ba	965	547	466	500	587	646	666	678	266	---
La	114	112	111	110	30.8	110	105	134	11.5	---
Ce	251	256	242	260	130	282	252	227	23.7	---
Nd	121	116	115	123	61	129	119	125	13.8	---
Sm	24.99	20.42	21.27	22.29	14.46	25.58	22.77	26.87	3.91	---
Eu	6.24	4.69	4.8	4.81	3.54	5.94	4.66	6.06	1.42	---
Tb	3.18	2.71	2.89	2.91	2.28	3.34	2.93	3.31	0.73	---
Yb	7.56	6.70	6.14	7.01	8.18	8.29	7.03	7.47	2.56	---
Lu	97	0.87	0.83	1.03	1.17	1.17	1	1	0.33	---
Zr	823	580	638	680	900	894	697	766	188	---
Hf	27	21.2	20.6	24.2	32.2	29.4	24.3	27.1	2.9	---
Ta	8.2	6.8	7	8	9.5	9.5	8.5	9	0.58	---
W	2	3	2	6	3.9	,6	4.8	2	3	---
Th	17.8	15.9	17.4	18.5	24.9	21.7	18.9	22.2	1.9	---
U	3.6	4.4	3.7	4	6.4	5.3	4.4	3.6	1.1	---



(Figure C-1)

The felsic modal data though scattered from Calc-Alkaline to alkaline, but clearly show an A-type affinity on QAP diagram. Boundaries of A, S & I-type granites are from Bowden, 1985. 1]I-type= Mantle derived, 2] S-Type=Recycling of sediments [3] A-Type=Melting of sialic crust with mantle contamination.

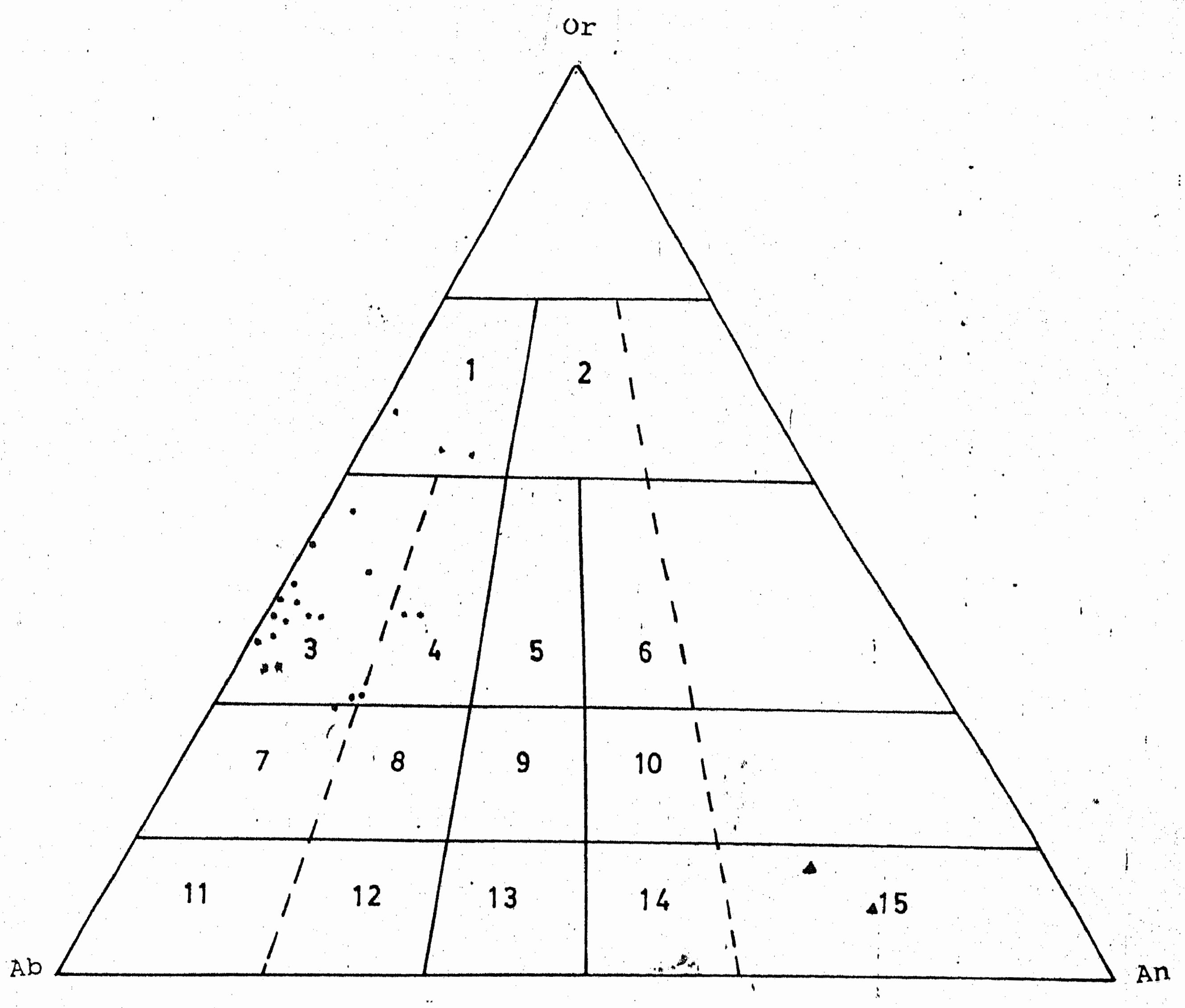


Fig. C-2a. Normative classification according to Heitanen (1963), of subvolcanic-volcanic rocks.

(1)Kaligranite (2)Calcigranite (3) Granite (4)Quartzmanzonite (5)Manzonite

(6)Calcimanzonite (7)Trondhjemite (8)Manzotonalite (9)Granodiorite (10)Granogabbro

(11)Trondhjemite (12) Tonalite (13)Quartzdiorite (14)Gabbro (15) Mafic gabbro

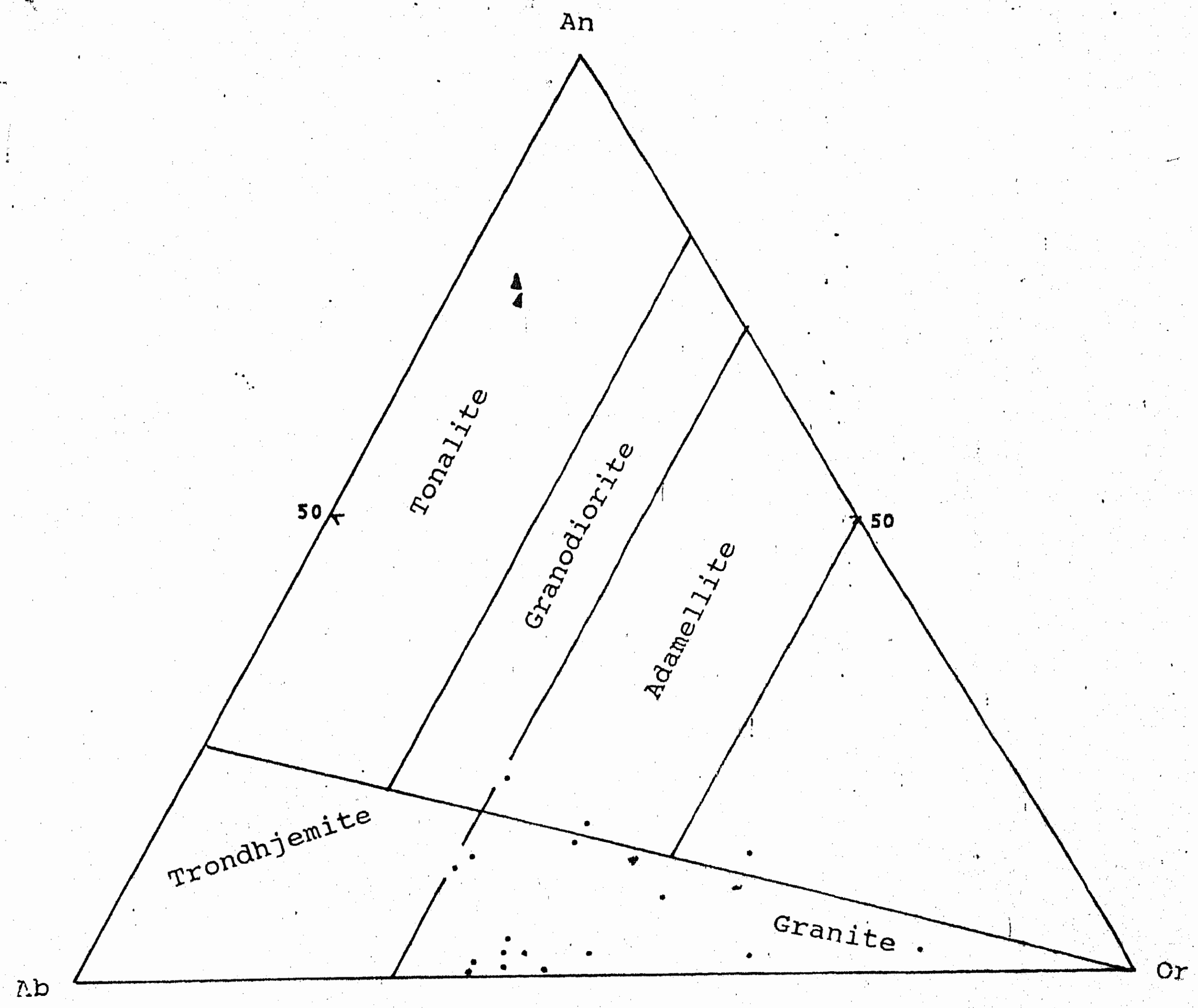


Fig.C-2b. Ternary plots of normative An-Ab-Or for subvolcanic-volcanic rocks from Peshawar plain according to O'conner (1965). Majority of these, plot as granites (Rhyolites).

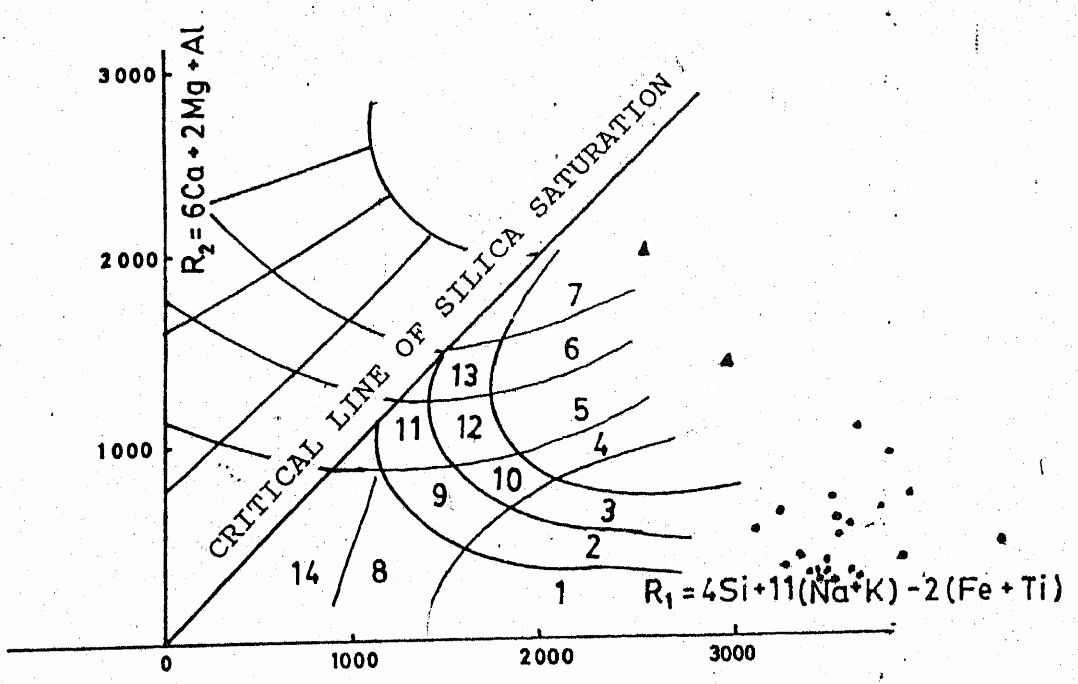


Fig. C-3. R1R2 Diagram after De la Roche, 1976; (1)Alkali Rhyolite (2)Rhyolite (3)Rhyodacite 4)Dacite (5)Andesite (6)Basalt (7)Tholeiite (8)Quartz trachite (9)Quartz latite (10)Latite dacite (11)Andesite latite (12)Latite andesite (13)Andesitic basalt (14)Trachyte.

These rocks on one side represent basalt while on the other the last fractionate rhyolites of curvilinear trend i.e basalt-hawaiite-mugearite-trachyte-rhyolite and/or rectilinear trend of basalt-andesite-rhyolite defining an alkaline magmatic lineage. This may be interpreted as two separate magmas of basaltic and rhyolitic composition.

R_1 R_2 classification diagram of DeLa Roche (1976) which is based on major elements and is particularly useful for rocks which are either fine grained or so much altered that original mineralogy is no more intact, was tried for mafic constituents. Majority plots as rhyolites.

Zr/TiO_2 is used to classify the rocks under discussion. Majority of the plots in the diagram (Figure-C-4A) proposed by Winchester and Floyed 1977 characterize the rocks as commendite and rhyolite. The concentration of plots in commendite near the line dividing the subalkaline and alkaline suites clearly show alkalic affinity of the rocks.

4.3. CHEMICAL CHARACTERISTICS:-

The Ce content is also used to differentiate between calc-alkaline and alkaline rocks. Many workers including Winchester and Floyed (1977) concluded that Ce in the rock type of calc-alkaline affinity remains broadly constant, where as in alkaline rocks Ce content increase markedly with differentiation. Plots of Ce versus Zr/TiO_2 clearly show a scatter and its higher content than rocks of calc-alkaline suites (Figure C-4b). The plots in commendite-pantelerite field show an alkaline affinity for the subvolcanic-volcanic rocks of Peshawar plain.

The characteristic mineral diagram (Figure C-5) based on parameters A=Al-(K+Na+2Ca) vs B=(Fe+Mg+Ti) of Debon et al., (1983) is adapted here to assess the aluminous character of the rocks under discussion. All these rocks plotting in the peraluminous domain and show higher concentration into sector I and II without a characteristic magma trend and this may be rather because of more constant proportion of dark minerals present in their modal composition (see table 1). In addition to modal composition the diagram C-5 also indicate more muscovite than biotite. Further characterization of these rocks can be made by using Q=Si/3-(K+Na+2Ca/2), B=(Fe+Mg+Ti) and F=(555-(Q+B) parameters of Moin 1974. The plots in Figure C-5 show a scatter distribution, no magmatic trend), however, the rocks show highly fractionation trend effected by late phase field alteration and more or less match with the rocks of Lesser Himalaya represented as (LH) line on the diagram (Figure C-5a).

On the basis of normative quartz content, variation of SiO_2 from 69-76%, these rocks are quartz rich, while the colour index range from 5-18%. Modal composition of the phenocrysts and normative values also show that these rocks contains higher concentration of perthetized alkali-feldspar. In alkalies ratio, the rocks are characterized as Soda-Potassic.

Characteristic based on Shand's index ($Al_2O_3/CaO+Na_2O+K20$ and Al_2O_3/Na_2O+K_2Oin A/CNK versus A/NK diagram of Maniar and Piccoli (1989) (Figure C-5b), these rocks vary from peraluminous to metaaluminous character. Majority of the rocks plot below 1.40 and above 1.00 Al_2O_3/Na_2O+K_2O ratio. Al_2O_3/Na_2O+K_2O ratio ranges from 0.7 to 1.5 (Figure C-5b).

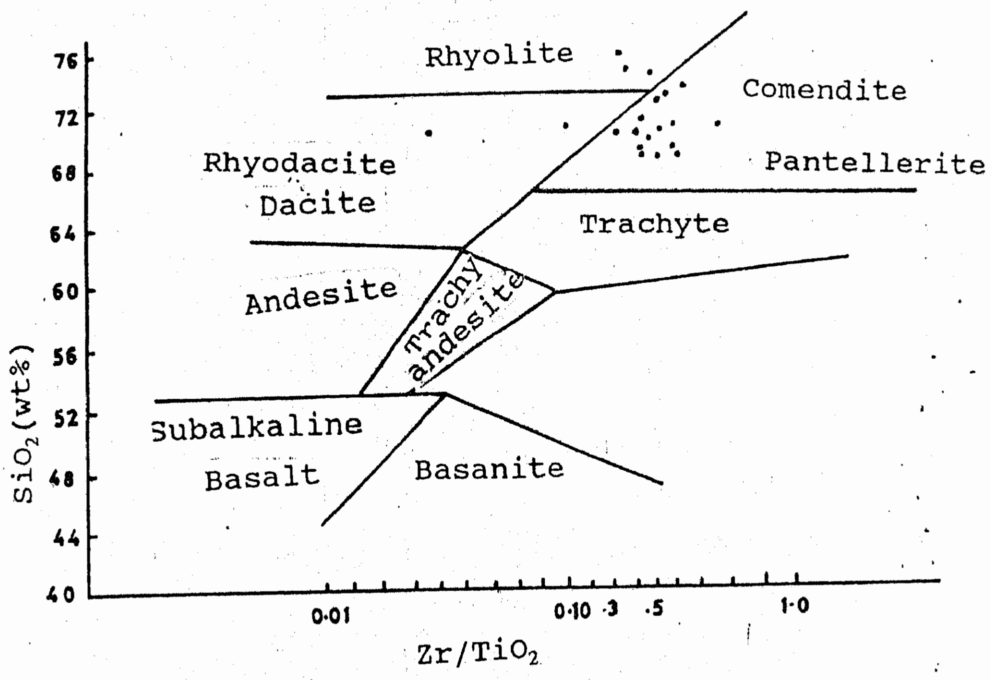


Fig. C-4a. Zr/TiO_2-SiO_2 diagram showing the limited fields for the subvolcanic-volcanic rocks from Peshawar Plain.
(Figure-C-4A) proposed by Winchester and Floyed 1977

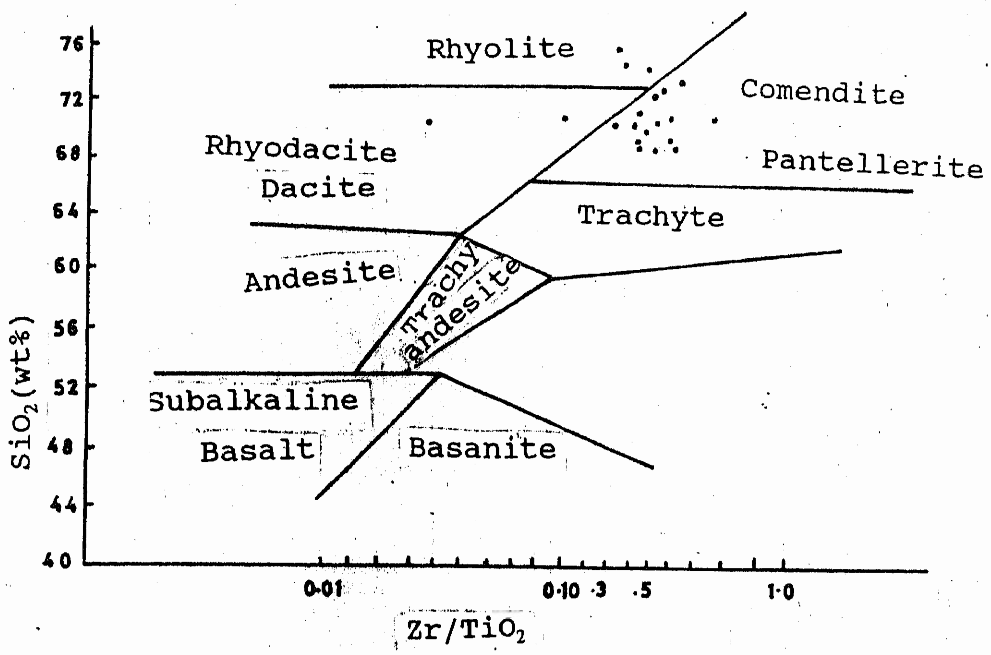


Fig. C-4a. Zr/TiO_2-SiO_2 diagram proposed by Winchester and Floyed 1977, showing the limited fields for the subvolcanic-volcanic rocks and characterizes the rocks as comendite.

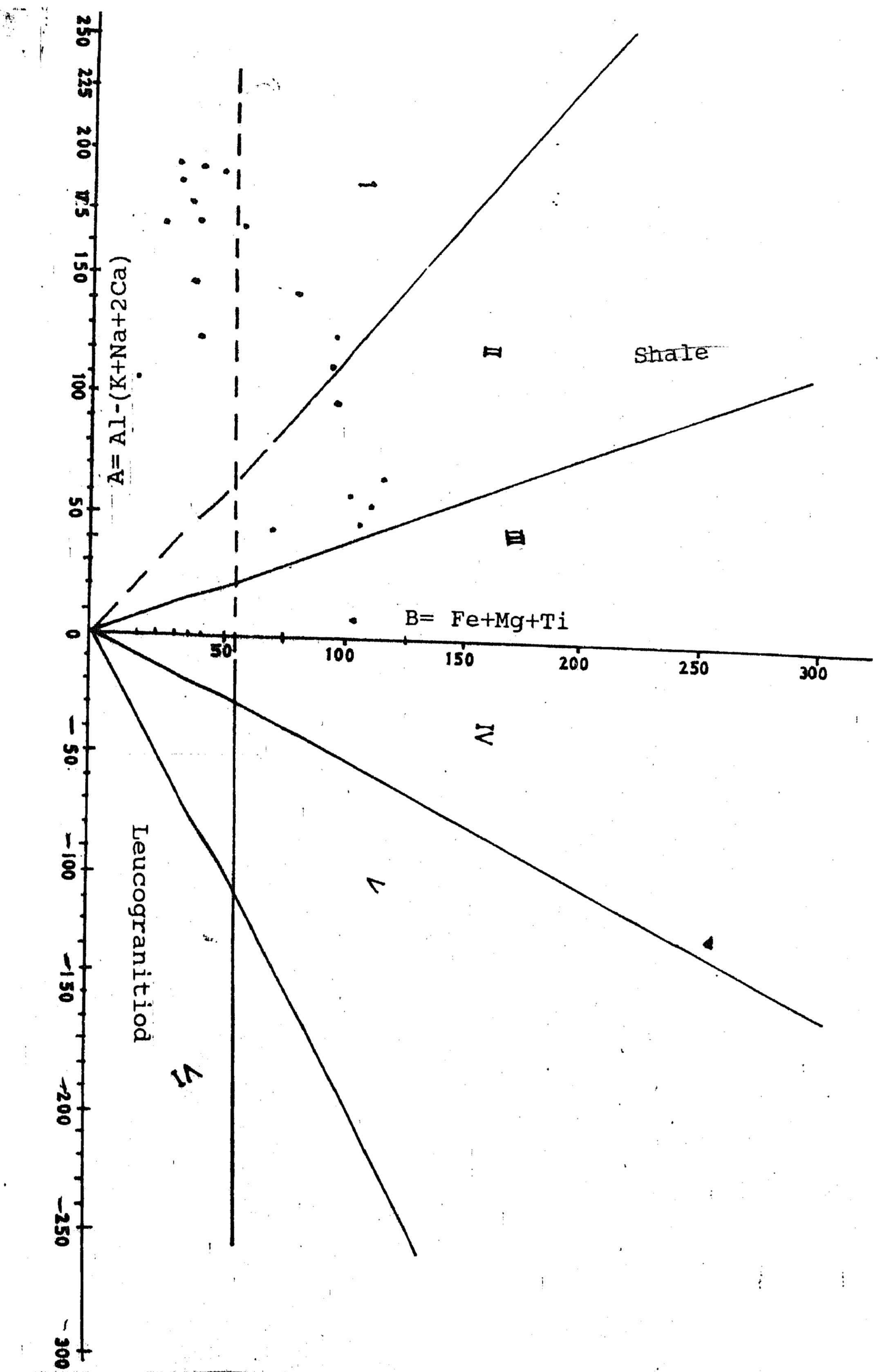


Fig. C-5. **Characteristic mineral diagram for the subvolcanic-volcanic rocks from Peshawar Plain. The diagram is divided into six sectors numbered from I-VI (after Debon et al., 1983).**

Sector I= Muscovite alone/ Muscovite biotite
Sector II= Biotite muscovite
SectorIII= Biotite alone
Sector IV= Variety of characteristic minerals. Biotite, Hornblende, Orthopyroxene, Clinopyroxene, Primary Epidote, Sphene.
Sector V= High proportion of clinopyroxene and/or primary epidote and/or sphene.

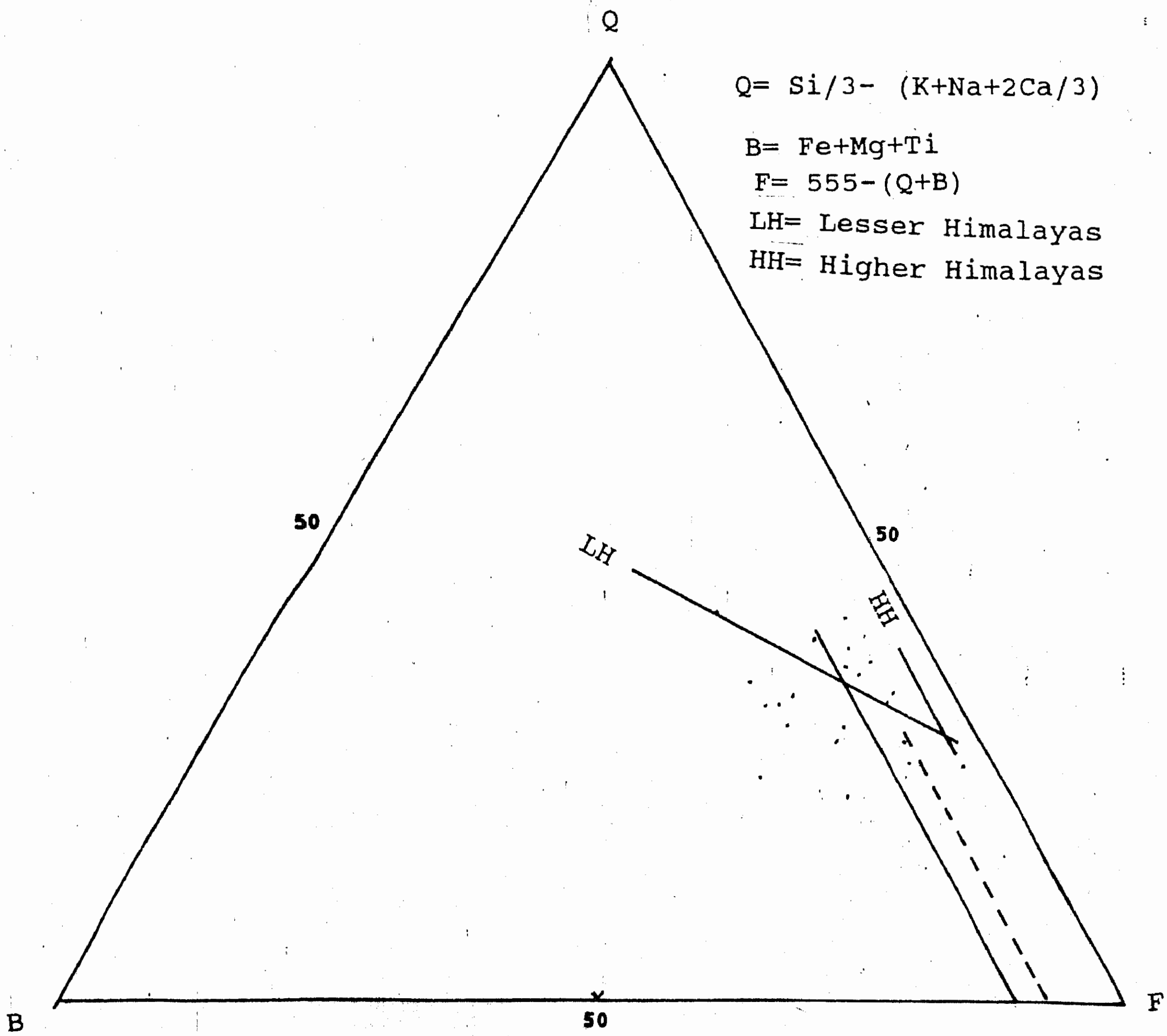


Fig. C-5a. Application of the Q-B-F diagram for subvolcanic-volcanic rocks from Peshawar Plain. The Q-B-F parameters are given as weight % (after Debon et al., 1983).

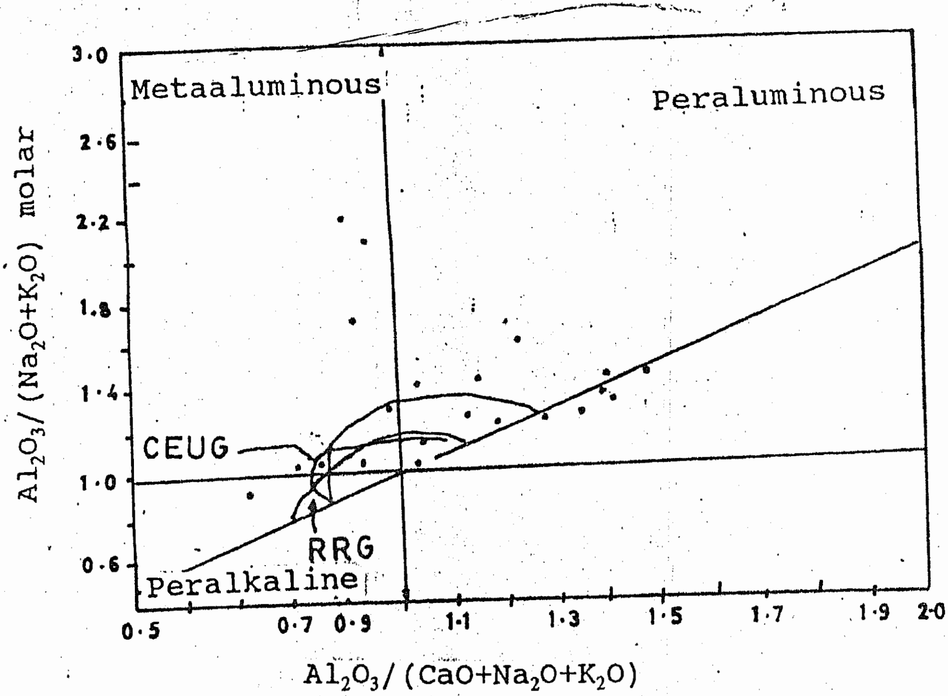


Fig.C-5b.A/CNK vs A/NK ($Al_2O_3/CaO+Na_2O+K20$ vs Al_2O_3/Na_2O+K_2O,diagram of Maniar and Piccoli, 1989) based on Shand's index for chemical and tectonic discrimination .

[A] These rocks vary from per/metaluminous character. Majority of these rocks show

[1] A/N+K=1-1.4

[2] A/N+K+C= 0.7-1.5.

[3]Normative corundum= .3-7.

[4] In alkali ratios i.e $K_2O/Na_2O=1$, the rocks are soda-potassic.

[B] The absence peralkaline plots;

[1] negates the trachytic magma source for these acidic rocks.

[2] links these rocks with the early phase of per/ metaluminous megacrystic rocks of AGC, cataclastic porphyries of Shewa-ShahBazGarhi and the garnetiferous microporphyries of Warsak

[3] separates it from the peralkaline magmatic episode in later phases of AGC.

[4] Figs. C-5, C-6a & C-7 elaborate such interpretation.

There is a quite wide range (0.3-7) in the normative corundum (Table-3), which signify the peraluminous to metaluminous character of the rocks.

Chemistry of the samples show bimodal distribution of SiO_2 i.e. on one side a basic composition (48-55% SiO_2), while others, by far the most voluminous of these rock are rhyolitic, which generally contain 69.5 to 76.0 % SiO_2. Molar ratio ($K_2O/Na_2O=1$) is broadly comparable to granitoid and related rocks from British Tertiary Central Complex of Thompson (1969), Walsh et al., (1979), Pankhurst et al., (1978), Meighan (1979) etc. The major element analysis along with other microporphyrites have been given for the purpose of comparison (Table-4).

On the alkalis-silica diagram (Figure C-6a) majority of the plot above the dividing line (defined by Miyashiro, 1978) in alkaline and some in the subalkaline fields. Scatter in the plots as shown already (in Dela Roche et al 1980) may indicate the effect by rock fluid interaction. However, classification based alkali-silica diagram (After Le Bas etal,1986), these rocks occupy the alkali-rhyotitic field (Figure C-6b).

To distinguish and characterize different rock type, Wright (1969) used alkalinity ratio (Al_20_3+CaO+ Total alkalies/ Al_2O_3+CaO-Total alkalies) versus SiO2 especially for more acid varieties. Eighty percent of the rocks under discussion classify into the alkaline and twenty percent into the calc-alkaline field (Figure C-7).

It has also been noted that the rocks correlate with the well documented alkaline igneous assemblages (see Wright 1969 p273). On the basis of alkalinity ratio, rock type and tectonic setting, these rocks correlate with younger granitic rocks of Northern Niger (Jacobson et al., 1958) the alkalinity ratio average is 3.5 (with a range from 2 to 5).

4.4) PALEOTECTONIC SETTING OF SUBVOLCANIC-VOLCANIC ROCKS.

Numerous studies on the geochemical characteristic of intermediate to acidic rocks from various tectonic environment have indicated that major and trace elements may be used as discriminants for understanding tectonics related to their generation (e.g. Petro et al., 1979; Pearce et al., 1981; Batchelor and Bowden, 1985; Harris et al., 1986; Maniar and Piccoli, 1989 etc)

To relate the chemical composition of the rocks to tectonic setting Christianson and Tipman (1972) used $CaO/(Na_2O+K_2O)$ ratio to distinguish rocks from orogenic and nonorogenic

Table-3. Major Element Analysis of the rocks.

S.NO	GJ1A)	GJ2	GJ3A	GJ3	GJ4	GJ5	GJ6	GJ8	GJ11	GJ12A	GJ35	GJ41
SiO2	70.74	69.96	71.52	69.92	70.14	69.34	71.08	70.62	71.40	69.50	76.12	74.28
Si	1179.0	1166.0	1192	1165.3	1169.0	1155.7	1184.7	1177.0	1190.0	1158.3	1268.7	1238.0
TiO2	0.13	0.12	0.13	0.13	0.13	0.14	0.12	0.13	0.72	0.13	0.13	0.12
Ti	1.625	1.5	1.63	1.63	1.63	1.75	1.5	1.63	9.00	1.63	1.63	1.5
Al2O3	14.67	14.09	12.80	12.76	13.22	13.31	14.32	13.10	14.01	13.86	13.80	13.89
Al	287.65	276.3	250.98	250.19	259.22	260.98	280.78	256.86	274.7	271.76	270.58	272.35
Fe2O3	2.63	3.14	2.90	3.03	3.26	3.78	3.00	3.30	3.10	3.06	2.06	3.24
Fe	32.87	93.3	36.25	37.88	40.75	47.25	37.5	41.25	38.75	38.25	25.75	40.5
MnO	0.14	0.16	0.13	0.13	0.17	0.16	0.17	0.11	0.11	0.13	0.13	0.22
MgO	1.66	2.22	1.94	2.72	2.41	3.03	2.02	1.06	2.07	2.67	0.35	0.64
Mg	41.5	55.5	48.5	68.00	60.25	75.75	50.5	26.5	51:75	66.75	8.75	16.00
CaO	1.55	1.55	3.66	3.88	2.10	2.30	2.03	2.03	2.01	5.21	0.20	0.21
Ca	27.7	27.7	65.36	69.28	37.5	41.07	36.25	36.25	35.89	93.03	3.57	3.75
Na2O	3.10	3.89	1.08	1.38	5.76	5.59	3.41	4.53	4.24	1.81	0.84	2.32
Na	50.00	62.7	17.42	22.26	92.90	90.16	55.00	73.06	68.39	29.19	13.55	37.42
K2O	3.76	2.71	4.91	3.94	2.52	2.27	4.11	6.00	3.23	3.00	4.73	5.43
K	40.00	28.83	52.23	41.91	26.81	24.15	43.73	63.83	34.36	48.38	50.32	57.77
P2O5	0.06	0.18	0.15	0.12	0.31	0.18	0.20	0.17	0.32	0.32	0.06	0.03
Ig.L	1.83	0.51	1.26	1.59	0.54	0.70	0.42	0.34	0.30	0.41	0.86	0.26
Total	99.27	98.53	100.48	99.65	100.56	100.72	100.88	101.39	100.91	100.10	99.31	100.64
A:	142.2	129.4	50.6	47.5	64.5	64.1	109.55	47.5	100.0	8.1	199.6	109.7
B:	76.0	96.3	86.4	107.5	102.6	124.7	89.5	69.4	99.5	106.6	36.1	58.0
R1:	13657.0	3575.6	3926	3876.4	3274.4	3266.9	3574.8	3116.4	3535.0	3692.5	4317.3	3820.9
R2:	536.8	553.5	740.1	801.9	604.7	658.9	599.3	527.4	761.2	963.4	369.4	326.8
C.I.P.W. Norms												
Qtz:	32.7	30.63	34.86	35.4	20.76	20.4	29.56	20.12	27.95	33.08	51.99	38.25
Or:	22.24	16.68	28.9	22.2	15.01	13.34	24.46	35.58	18.9	17.79	27.8	33.25
Ab:	26.2	31.4	10.48	11.53	48.73	47.16	28.82	38.25	35.63	15.19	7.07	19.38
An:	7.5	7.5	14.73	16.95	2.67	4.45	9.17	-----	8.16	20.85	0.67	0.85
Wo	-----	-----	1.04	0.58	2.48	2.55	-----	3.72	-----	1.32	---	----
En:	4.4	6.2	5.2	7.00	6.24	7.8	5.24	2.85	5.35	6.8	1.46	1.9
Il:	----	0.3	0.3	0.6	0.61	0.31	0.23	0.304	1.37	0.302	0.2432	0.228
He:	2.56	2.88	2.88	2.72	2.88	3.52	2.64	1.44	1.66	2.72	1.79	2.96
C:	2.65	2.14	-----	----	-----	----	0.816	----	0.58	----	7.05	3.67
Ap:	0.124	0.31	0.31	0.31	2.17	0.30	-----	0.37	0.62	0.62	0.372	0.062
AC:	-----	-----	-----	----	----	----	----	4.16	----	---	-----	-----
DI	81.14	78.68	74.24	69.17	84.5	80.9	82.84	93.95	82.5	66.07	86.15	90.88

Table 3 (Contd.)

S.No.	TAR2	TAR8	RAS2	RAS15	MNS4	MNS19	G3	G11	TT5	TT16	GJ1B	GJ17B
SiO2	71.5	70.42	73.96	73.40	69.54	71.36	71.40	73.16	73.04	72.55	48.14	55.08
Si	1191.7	1173.7	1232.7	1223.3	1159.0	1189.3	1190.0	1219.3	1217.33	1209.17	802.33	918.00
TiO2	0.13	0.12	0.13	0.12	0.13	0.11	0.70	0.61	0.12	0.13	—	—
Ti	1.63	1.5	1.63	1.5	1.625	1.375	8.75	7.63	1.5	1.625	—	—
Al2O3	15.84	15.94	14.25	14.05	15.88	16.02	14.60	13.85	15.19	14.98	19.36	22.87
Al	310.57	312.55	279.47	279.41	311.37	314.11	286.27	271.59	297.84	293.73	379.61	448.43
Fe2O3	3.05	3.25	3.27	3.19	3.78	3.46	2.12	0.33	2.30	2.69	7.1428	6.5714
Fe	38.13	40.63	40.88	39.87	47.25	43.25	26.5	4.525	28.75	33.625	89.285	82.1425
MnO	0.15	0.13	0.13	0.11	0.12	0.14	0.08	0.15	0.11	0.12	0.125	0.132
MgO	0.13	0.13	0.11	0.13	0.14	0.13	0.42	0.26	0.08	0.09	4.71	2.274
Mg	3.25	3.25	2.75	3.25	3.5	3.25	10.5	6.5	1.43	2.25	117.75	57.00
CaO	0.49	0.45	0.13	0.20	0.50	0.31	1.24	1.20	0.32	0.11	14.37	9.52
Ca	8.75	8.03	2.32	3.57	8.93	5.54	22.14	21.43	5.71	1.964	256.6	170.0
Na2O	5.00	4.80	4.42	4.65	3.02	3.96	4.05	4.80	4.79	3.95	1.32	1.64
Na	80.65	77.42	71.29	75.00	48.7	63.87	65.32	77.42	77.26	63.71	21.2	26.5
K2O	3.45	4.52	3.62	5.01	4.71	4.01	5.11	4.50	3.98	3.71	0.46	0.75
K	36.7	48.1	38.51	53.29	50.1	42.66	54.36	47.87	42.32	42.02	5.00	7.98
P2O5	0.13	0.11	0.12	0.05	0.17	0.04	0.03	0.26	0.05	0.07		
Ig.L.	0.77	0.58	0.13	0.35	1.95	1.20	0.56	0.65	0.40	1.23	---	----
Total	100.64	100.45	100.27	101.26	99.94	100.74	100.61	99.71	100.58	99.63		
A	175.73	170.97	163.96	143.58	194.71	196.57	122.28	103.42	166.82	184.07	-350.4	-150.48
B:	43.01	45.38	45.26	44.62	52.375	47.875	45.75	18.26	31.68	37.5	302.03	261.4
R1:	3396.3	3229.7	3626.2	3399.4	3451.45	3496.24	3373.0	3475.62	3493.3	3603.15	2551.14	2928.72
R2:	369.58	367.2	298.8	307.3	371.95	353.85	439.93	413.15	334.96	310.01	1964	1358
C.I.P.W. Norms												
Qtz:	28.15	24.31	33.0	26.54	27.83	32.32	25.34	26.117	28.96	35.12	---	13.96
Or:	20.41	26.74	21.4	29.47	27.8	23.74	30.02	26.58	23.91	21.96	2.78	4.44
Ab:	42.44	40.56	37.36	39.3	25.52	33.48	34.06	40.348	40.51	33.51	11.2	13.89
An:	8.16	1.48	0.188	0.68	1.39	1.27	5.92	3.058	1.259	0.082	45.26	47.99
Wo:	—	—	—	—	—	—	—	0.512	—	—	10.88	—
En:	0.53	0.51	2.18	0.48	0.52	0.515	1.1	0.85	.35	.394	11.97	5.7
Fs:	—	—	—	—	—	—	—	—	—	—	0.7524	10.72
Il:	0.24	0.23	0.24	0.23	0.24	0.2128	1.34	1.16	.228	.2432	—	—
He:	2.78	2.96	2.94	2.94	3.58	2.02	0.712	0.88	2.064	2.432	6.224	0.86
C:	3.22	2.57	2.96	0.77	5.33	4.84	0.275	—	2.46	4.43	—	1.99
Ap:	0.29	0.25	0.27	0.11	0.37	0.0868	0.062	0.558	0.1085	0.155	—	—
D.I.	91.00	91.61	91.76	95.31	81.15	89.54	93.05	93.38	190.59		14.35	32.29

TABLE 4. ANALYSIS (WEIGHT %) OF MICROPORPHYRIES FROM THE SURROUNDING OF AMBELA GRANITIC COMPLEX.

	Sm10	Sm11	Sm5	D11	Am408	Am524	GJ1(A)	C[illegible]	C11
SiO2	76.75	70.08	75.72	69.00	70.00	75.10	70.74	71.4	73.16
TiO2	0.35	0.34	0.21	0.51	0.70	0.18	0.13	0.7	0.61
Al2O3	7.85	14.54	13.34	13.97	16.10	13.58	14.67	14.6	13.85
Fe2O3	2.44	1.94	1.70	3.40	3.73	1.90	2.63	2.13	0.33
MnO	0.04	0.04	0.06	0.08	0.04	0.04	0.14	0.08	0.15
MgO	3.40	0.24	0.48	1.01	1.06	0.05	1.66	0.42	0.26
CaO	3.60	0.81	0.74	1.70	1.06	0.22	1.55	1.24	1.2
Na2O	1.60	5.80	3.81	3.93	2.01	4.50	3.1	4.05	4.8
K2O	2.25	5.56	4.33	4.74	4.62	4.70	3.76	5.11	4.5
P2O5	0.15	0.04	0.02	0.19	0.34	0.02	0.06	0.03	0.28
Ig.Ls	1.20	0.14	0.15	1.17	0.16	0.27	1.[illegible]	0.56	0.65
Toto	98.63	99.53	100.56	99.70	99.82	100.56	99.27	100.61	99.71

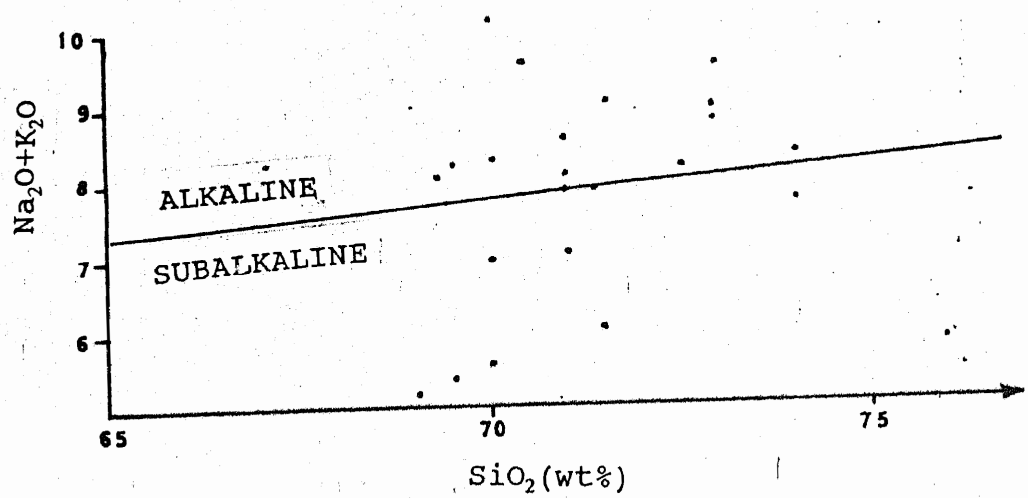


Fig.C-6a. Silica-alkali diagram (after Miyashiro (1978), for subvolcanic-volcanic acidic rocks from the volcanic belt. Line represents boundary of alkaline and subalkaline fields. Majority of the rocks plot above the dividing line in alkaline and some in the subalkaline fields. Scatter distribution in the plots might indicate the effect by rock fluid interaction, because of bimodel destribution of SiO2= 48-55% & 69.5-76% & Molar Ratio of K2O/Na2O=1.

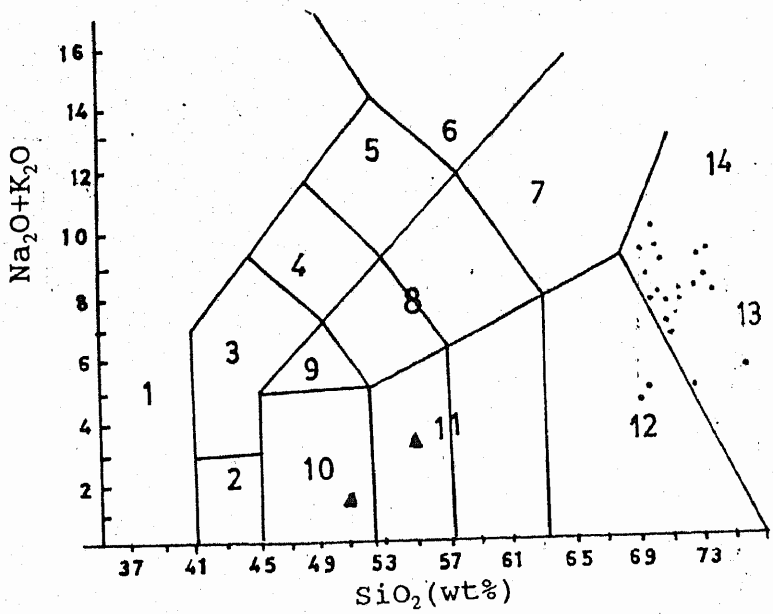
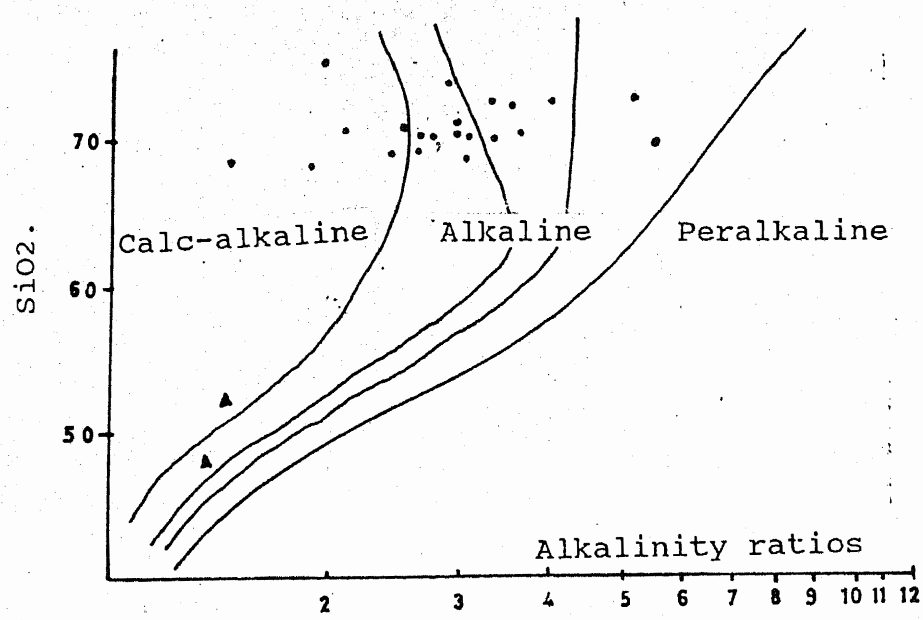


Fig.C-6b. Classification based on total alkalies-silica (Le Bas etal.,1986) for the acidic rocks.

(1)Foidite, (2)Picrite, (3)Tephrite-basanite, (4)Phonolite-tephrite, (5)Tephrite-phonolite, (6)Phonolite, (7)Alk-trachyte, (8)Trachy-andesite, (9)Trachy-basalt, (10)Basalt, (11)Andesite, (12)Dacite, (13)Rhyolite, (14)Alk-rhyolite.

Here also like Fig. C-3, the rocks classify as Alkali-rhyolite.



ALEOTECTONIC SETTING

Fig.C-7. Alkalinity ratios vs silica diagram (after Wright, 1969) showing plots of these rocks.

[A] To distinguish different rock types, especially more acid varieties, this diagram is used.

1. (80%) of the rocks classify into the alkaline & (20% into the calc-alkaline field,

2. average alkalinity ratio is 3.5 (with a range from 2 to 5).

3. Like Figs. C-5, C-5b, C-6a etc C-7 also exhibits the resemblance to the 1st phase per/meta aluminous magmatism as compared to the later peralkaline magmatism in the region.

environments. By plotting, the ratio against SiO_2 Petro et al., 1979 concluded that the rocks from these two environments produced distinct variation trends at ratio equal to 1 the SiO_2 content of the rocks in compressional environment (orogenic) is distinctly higher than that of extensional (anorogenic) environment.

The present rock have $CaO/(Na_2O+K_2O)$ values below 1 and their variation trend though scatter (figure C-8) but more or less matching with extensional suites (e.g. British Isles, East Greenland etc). In addition variable such as means of DI (Differentiation index) weight percent of CaO, total alkalies and CaO/Na_2O+K_2O are used to compare and discriminate these rocks as mildly alkaline from extensional tectonic suite (Table-5).

Characterizing the rock as alkaline, immobile elements and their ratios are already been used. Both the diagrams (Figure C-4a, 4b) based on Zr/TiO_2 ratio versus SiO_2 and Zr/TiO_2 ratio versus Ce clearly classify these rocks as alkaline, and show deviation from subalkaline or Calc alkaline field. This also support an anorogenic tectonic setting.

Discriminating the subvolcanic-volcanic rock minor elements such as Rb, Ta, Yb, Hf, and Th are used. In $Ta-SiO_2$ diagram, (Figure C-9a) 92 percent of the plots discriminate the rocks as WPG+ORG (i.e within plate granites + oceanic ridge granite. Further discrimination is based on Rb-SiO2 (Figure C-9b). Here the plots clearly show an anorogenic environment, matching the plots of WPG rather than ORG. This character (WPG) is also supported by the abundance of K_2O content in them. On K_2O-SiO_2 diagram (Figure of Colman (1976) these rocks classify as continental.

Pearce et al., (1984) have used certain elements to discriminate composition field in granitoids that correspond with tectonic setting. The WPG (within plate granite) character of these subvolcanic-volcanic rocks is well defined on the Yb-Ta diagram (Figure C-10a) of Pearce et al., 1984. Within plate magmatism usually en-riched in non-hydrous volatile such as CO2, and fractionation of magma under low water pressure (PH2O) will concentrate flourine in the residual melt (Aoki et al.,1981). This causes enrichment of HFS (high field strength) elements.

The HFS elements are plotted against SiO2. The region of the overlap between the low HFS element Island Arc field and the high HFS element within plate in Figure C-10b, Zr vs SiO2 is taken from Pearce and Gale (1977) who have determined its boundaries empirically from several hundred plots of volcanics from known tectonic setting. Figure C-10b demonstrates that magma identified as alkaline from subvolcanic-volcanic rocks of Peshawar Plain have a likely

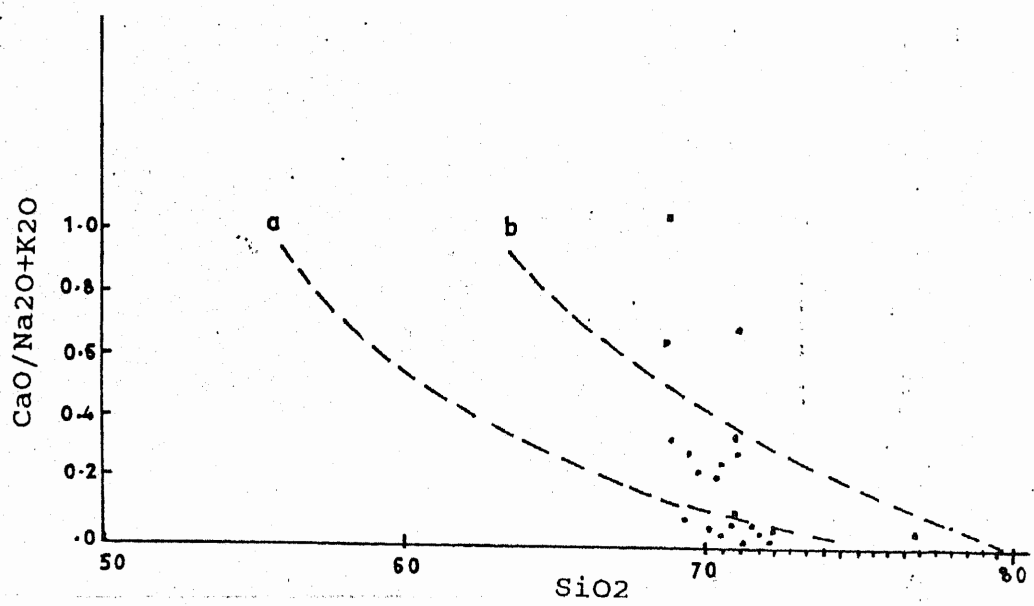


Fig.C-8. Variation diagram using CaO/(Na_2O+K_2O) vs SiO2 for the subvolcanic-volcanic rocks.

a) Extensional environment, b) Compressional environment,(after Petro etal. 1979).

[B] Discriminantion diagram for intermediate to acidic rocks show distinct variation trends at C/N+K =1, the SiO_2 content of the rocks in compressional environment (orogenic) is distinctly higher than that of extensional (anorogenic) environment. The present rocks have

[1] C/N+K values below 1], [2] variation trend though scatter but match with extensional suites.

[3] variables i.e. (a) means of DI, (b})weight %of CaO, (c) total alkalies (d) CaO/Na_2O+K_2O discriminate these rocks as mildly alkaline from extensional tectonic suite.

[4] Immobile elements ratios (Figure C-4a, 4b), also support an anorogenic tectonic setting.

Table 5. Comparison of means of variables for SiO_2 interval 70-75.

	L.P.S.R.	Ambela	B.I.T.	ISL	ARA	SCB
D1	85.36	90.00	88.87	91.97	83.10	83.34
CaO	1.44	1.00	1.24	0.86	2.40	2.22
Alkalies	7.76	8.75	8.57	8.40	6.68	6.91
CaO/Na_2O+K_2O	.185	0.11	0.15	0.10	0.36	0.34

L.P.V.S.R. = Late Paleozoic Subvolcanic-Volcanic Rocks.

B.I.T. = British Isles Tertiary.

ISL = Iceland.

ARA = Aleutian-Alaska Batholith.

SCB = South California Batholith.

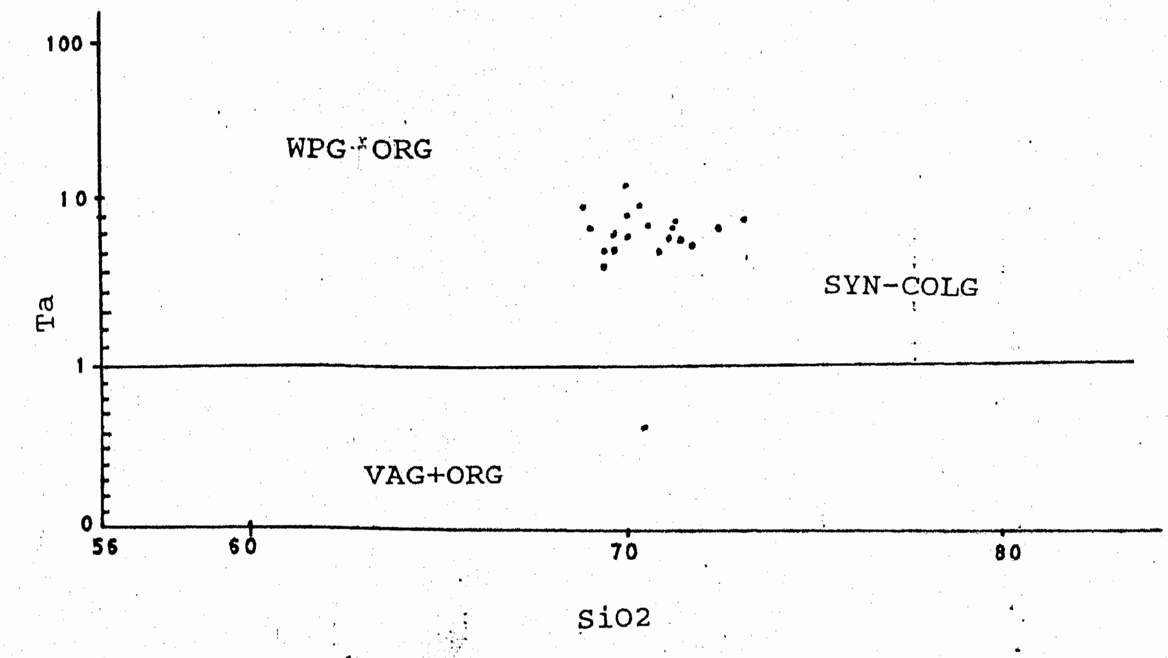


Fig.C-9a,TaS diagram, after Pearce etal.,1984; based on analysis of subvolcanic-volcanic rocks.

[C] [1] Minor elements i.e Rb, Ta, Yb, Hf & Th discriminate 92 % of the plots as WPG+ ORG

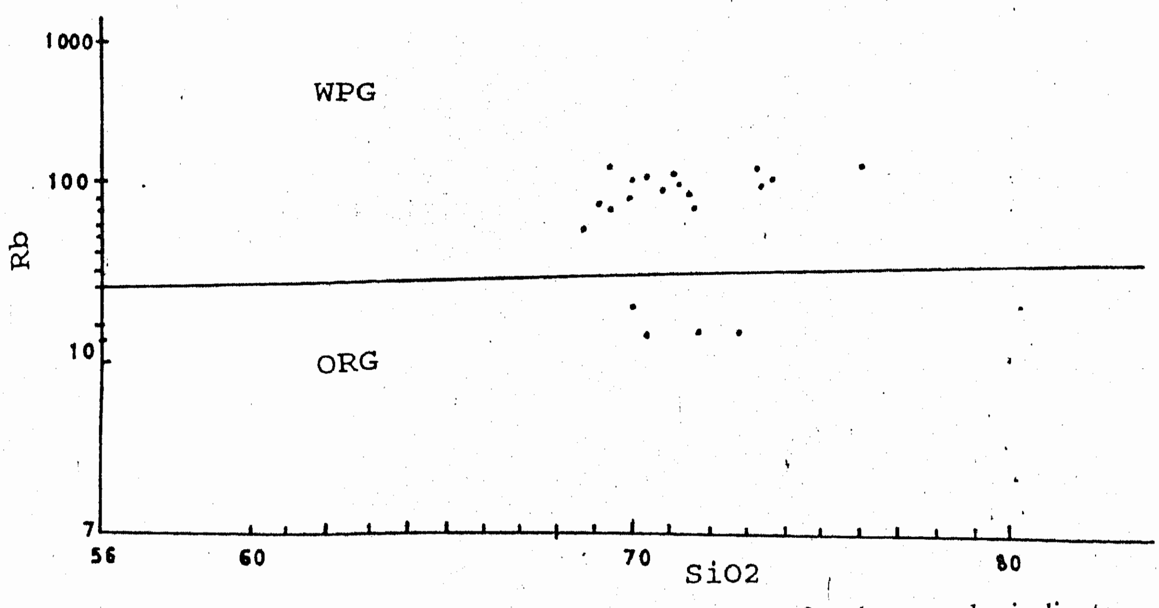
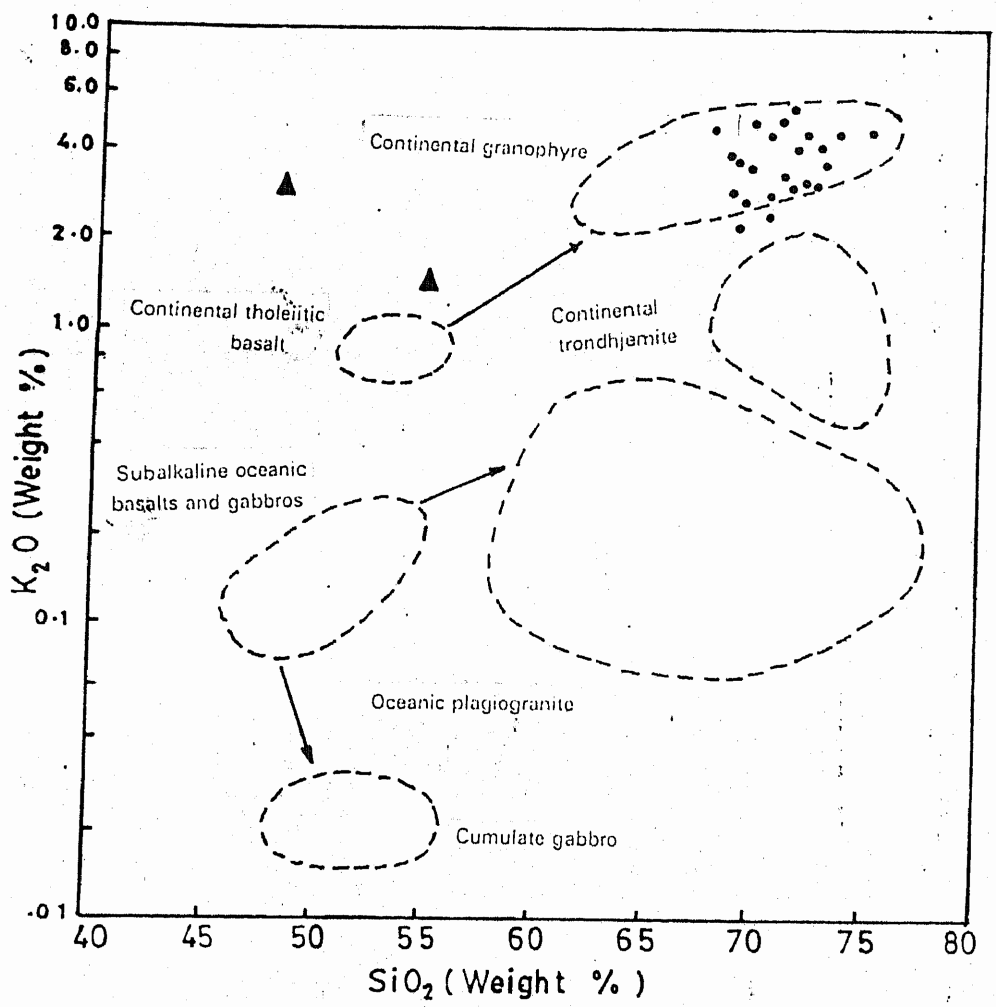


Fig.C-9b. SiO2-Rb diagram, after Pearce etal.,1984; for these rocks indicate

[C] [2] an anorogenic environment, matching the plots of WPG rather ORG.

[3] (WPG) character is also supported by the abundance of K_2O content in the rocks.

On K_2O-SiO_2 diagram, Fig.C-9c of Colman, 1976; these rocks classify as continental.



Figc-9c

Semilog plot of SiO_2 versus K_2O, illustrating the difference in K_2O in microporphyries as compared with equivalent continental rock types.

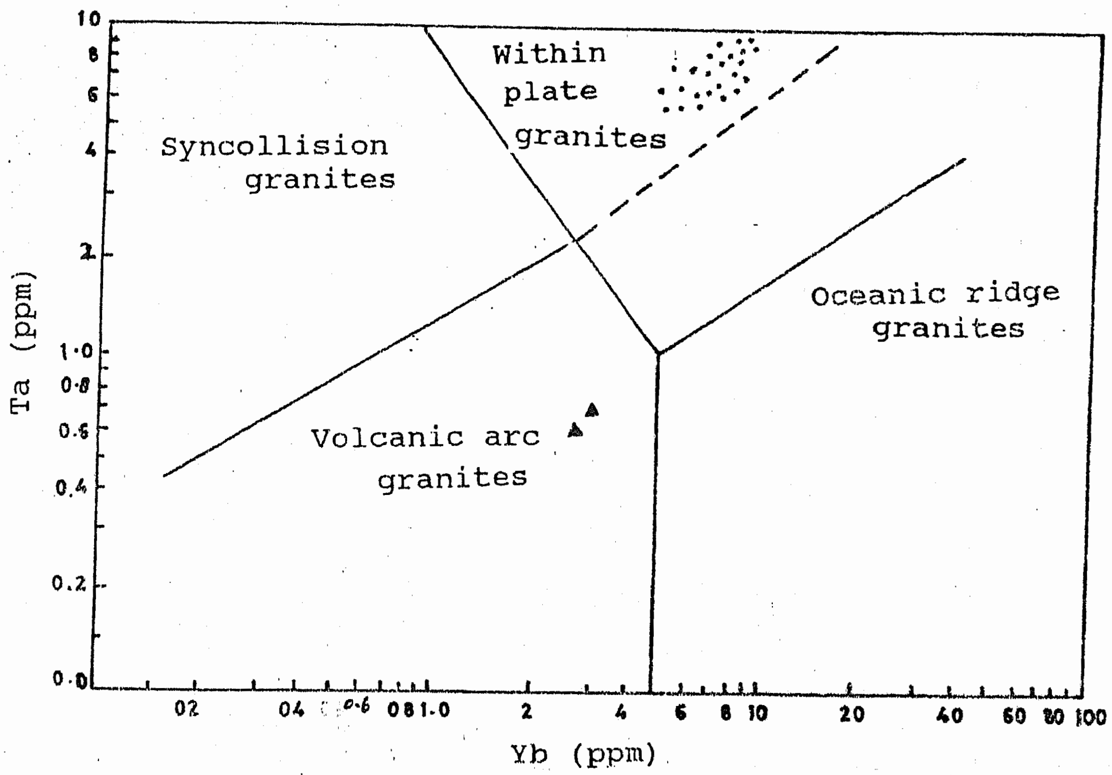


Fig.C-10a. Ta vs Yb plots for the subvolcanic-volcanic rock from Peshawar Plain (after Pearce et al., 1984).

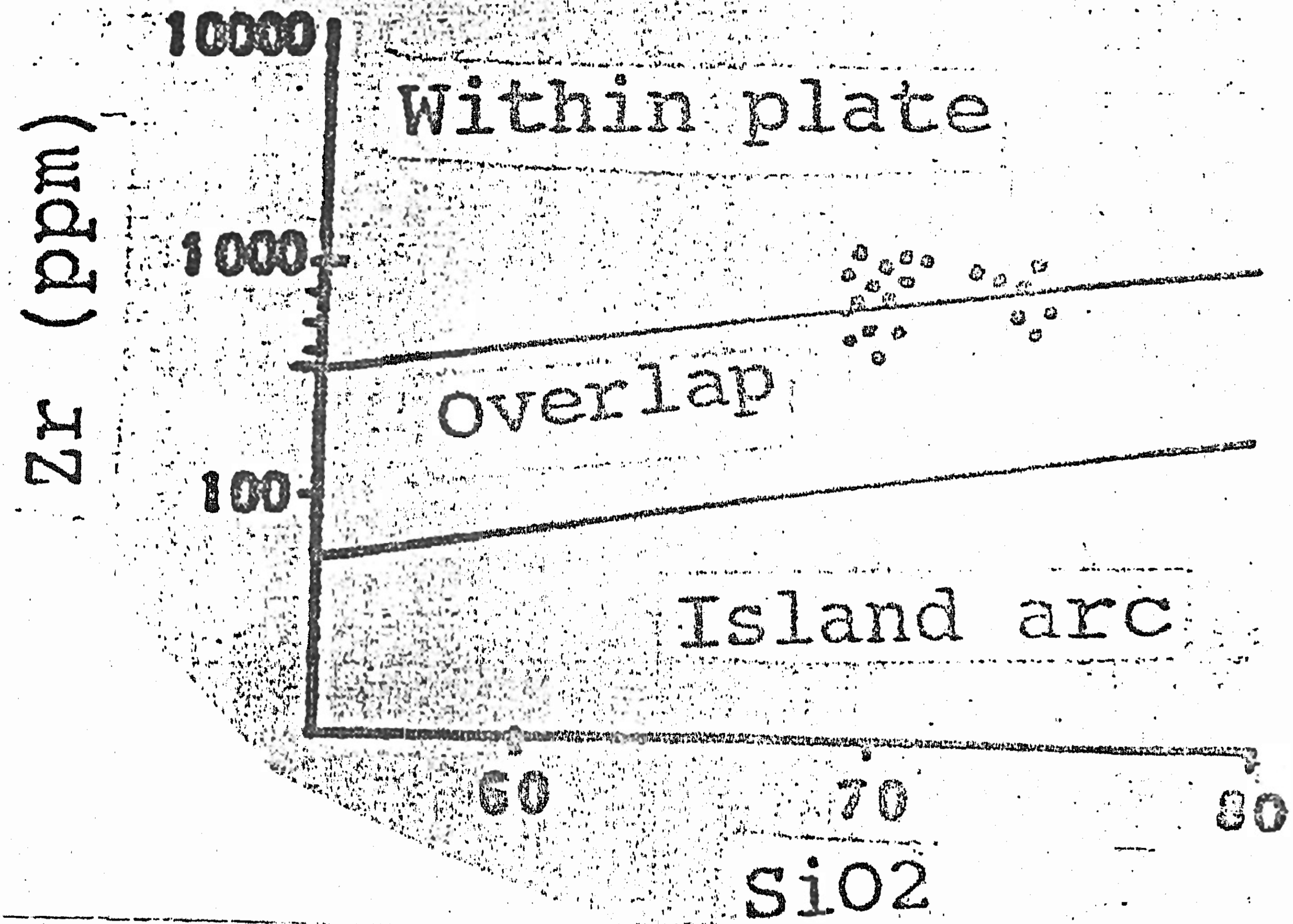


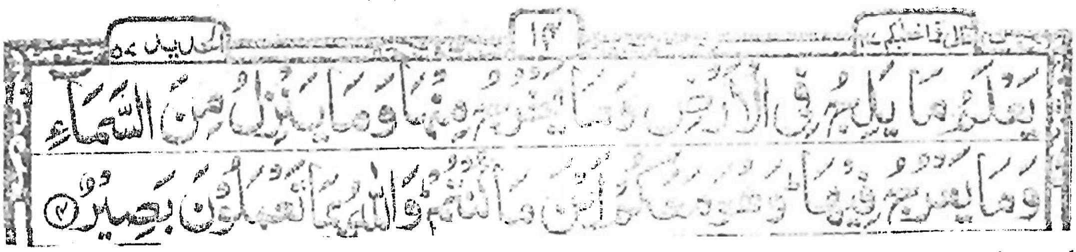
Fig.C-10b. Zr vs Silica plots for volcanic-subvolcanic rocks from Peshawar Plain (Pearce and Gale, 1977).

within plate setting.

Wood et al., (1979), and Wood, (1980) proposed triangular diagram based on Th-Hf and Ta which can be used as a mean of tectonomagmatic discrimination. In Th-Hf/3-Ta diagram (Figure C-11) the rocks under discussion plot at the boundaries of E-type MORB, tholeiitic within plate basalts and Alkaline within palte basalts. However, two rocks plot near the calc-alkaline boundary. These three element (Th-Hf-Ta) are very much sensitive indicators of both upper and lower crustal contamination of within plate basalt.

Plotting Th, Hf and Ta of basic and acidic granulites from Assynt NW, Scotland Weaver and Tarney (1980) emphasized the wide range of Hf/Th ratios involved. It has been well documented that the rocks subjected to granulite facies metamorphism release large amount of K_2O ,Rb, Th, and U (see Taylor and Mclennan (1979) and Tarney and Windley (1979) and accounts for the lower Th abundances is most of the granulites.

In addition Wood (1980) concluded that most granulite have high Hf/Th and Hf/Ta ratio. Figure C-11 for the subvolcanic-volcanic indicate depletion of Th and Ta both with respect to Hf. This shows contamination of magma caused a progressive increase in Hf/Ta ratio and a progressive decrease in Th and Ta abundance as the proportion of crustal material increased. However, the present data (Figure C-11) suggest a little higher level silicic crust which may have also effected the magma, deflecting the plots little toward the Hf apex as a whole.


يَعْلَمُ مَا يَلِجُ فِي الْأَرْضِ وَمَا يَخْرُجُ مِنْهَا وَمَا يَنزِلُ مِنَ السَّمَاءِ
وَمَا يَعْرُجُ فِيهَا وَهُوَ مَعَكُمْ أَيْنَ مَا كُنتُمْ وَاللَّهُ بِمَا تَعْمَلُونَ بَصِيرٌ ④

'Only He knows whatever goes into the earth and whatever comes out of it, and whatever comes down from heaven and whatever goes up into it. He is with you wherever you may be and sees whatever you do' [57/4]

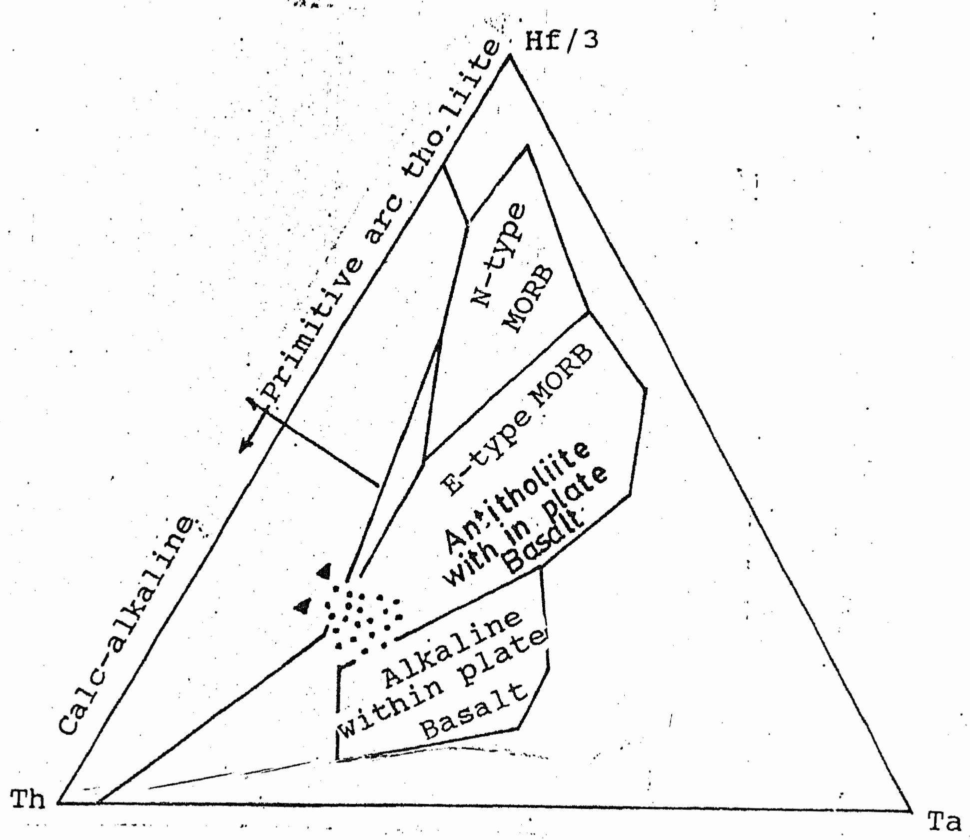


Fig.C-11. Th-Ta-Hf/3 plots, diagram after Wood, 1980; for the subvolcanic-volcanic rocks.

[D] [1] (Th-Hf-Ta) are very much sensitive indicators of both upper/lower crustal contamination of within plate basalt. [2] most granulite have high Hf/Th and Hf/Ta ratio (Wood, 1980). [3] metamorphism release large amount of K_2O ,Rb and U and accounts for the lower Th abundances in most of the granulites. [4] shows crustal contamination of magma caused a progressive increase in Hf/Ta ratio and a progressive decrease in Th and Ta abundance as the proportion of crustal material increased. [5] However, the present data suggest a little higher level silicic crust effected the magma, deflecting the plots little toward the Hf apex as a whole. [6] The mobility in alkali elements (Na, K, Rb), exemplified by alkalic-subalkalic signature (Fig. C-6a), the presence of both calc-alkaline and alkaline members, that display antitholiite within plate E-type MORB like pattern of these trace elements argues for an extentional system in which magma generated & erupted without significant crystal fractionation.

CHAPTER FIVE

﴿١٨﴾ أَوَلَمْ يَرَوْا كَيْفَ يُبْدِئُ اللَّهُ الْخَلْقَ ثُمَّ يُعِيدُهُ ۚ إِنَّ
ذَٰلِكَ عَلَى اللَّهِ يَسِيرٌ ﴿١٩﴾ قُلْ سِيرُوا فِي الْأَرْضِ فَانْظُرُوا كَيْفَ بَدَأَ
الْخَلْقَ ثُمَّ اللَّهُ يُنْشِئُ النَّشْأَةَ الْآخِرَةَ ۚ إِنَّ اللَّهَ عَلَىٰ كُلِّ شَيْءٍ قَدِيرٌ ﴿٢٠﴾

"Have these peoples never visualise'how Allah originates the creation and then recreates it.? Surely,this is easier for Allah. Say to them," Go about in the earth and observe 'how He has begun the creation; then Allah evolves the later evolution." Surely,Allah has power over everything. (29/19-20)

Palingenesis is rebirth [Barth,1961]. Buckland classified ultrametamorphic rocks into Venites-Augen gneisses-Arterites-Migmatites-Palingenites-Diapirites. " As compared to anatexis palingenesis more specifically refers to the genesis of new granitic materials in the environment." Petrological evidences show that granitic magma cannot become differenciated on a large scale from basalt, nor it can be derived directly from such a source by partial melting. The source of the bulk of these rhyolitic rocks must therefore lie in the sialic crust. Palingenesis operates on rocks in situ/emplaced at different tectonic levels.

{PALINGENESIS} =1)The volcanic belt is characterized by the dominance of acid magma. Basic rocks overall represent a small portion of the exposed material.

2) $Sm/Nd=.2$; which corresponds to calculated batch melting data of garnet/lherzolite that only provides melts with typical trace element characteristic to that of granite. Hence possible source for felsic magma lie in the crust/upper mantle, by partial melting followed by fractional crystallization /crustal contamination.

3) The high $SiO_2=69-76\%$, implies that direct melting of (dominently mafic contents) upper mantle was not involved in the origin of the parent melt.

Figs. C-1, 2(a & b) show the plots of the acidic rocks below the FE plane while C-3, 4(a&b), 6b etc assign them alkali rhyolite field. Added further 2-feldspar rhyolites with corroded/fused margins indicating resorption; confirm almost all the conditions & the requisites of Carmichal [1963-74] who assigned such rhyolites exclusively to anatexis not to fractional xlisation.

5) According to Gerasimosky [1974], rocks with low Sr contents form by palingenesis while with high Sr by xllization from the residual melt. 60% of our rocks have Sr=1.7 -9; & in 40% Sr=90-419 ppm, which favours palingenesis.

6) The alkaline and per/metaluminous nature of the rocks suggest derivation from a source with mainly I-type but locally S-type protolith, expected in the lower continental crust.

The release of pressure in rifting environments might have caused partial melting in a granulite source in the lower crust.

7) The mobile alkalies with sub/calc-alkaline signature that display antitholiite within plate E-type MORB like pattern of trace elements favor an extentional system in which magma erupted /emplaced at different tectonic levels without significant xl fractionation.

CHAPTER FIVE

PETROGENESIS

5.1 MAGMA SOURCE

As stated earlier, the subvolcanic-volcanic rocks of Peshawar Plain are characterized by a dominance of acid magma. Basics are present in some outcrops (Gajju Ghundai, Sheva-Shahbaz Ghari, Nawe-kili, Krappa etc.), but overall basic rocks represent a small portion of the exposed material. The preponderance of felsic magma also characterizes the Ambela Granitic Complex (AGC), (Rafiq, 1987; Rafiq and Jan, 1989). Possible source regions for felsic magma lie in the crust, by partial melting, or in the upper mantle, by partial melting followed by fractional crystallization and/or crustal contamination.

By computing the well documented data, Bouseily et al.,(1975) noted that there is a decrease of Ba from 100 ppm in the normal granites to 55 ppm in the strongly differentiated granites, and increase of Rb from an average value of 190 to 260 ppm. In the case of rocks under discussion the Ba content varies from 466 to 1190 ppm and Rb from 68-174 (average 118). These values more or less match with Ambella Granitic Complex (AGC) (Rafiq, 1987) and associated acidic microporphyries. Working on trace element data Gerasimovsky (1974) stated that rock having low content of Sr may be considered to be the product of palingenesis, and those with high Sr, the product of crystallization from residual melt.

Our result of 60% rocks show very low values for Sr (1.7-9 ppm) and other 40% are from 90-419 ppm. This data very much favour the palingenetic origin. Rocks with a little high Sr contents may have produced through hybridization of silicic melt by deeper source component (upper mantle).

The Sm/Nd ratio of these rocks is about 0.2, and simple batch-melting calculations of a garnet\herzolite (Hawkesworth et al.,1979) indicate that mantle of such a composition only provide melts with similar trace-element characteristic to that of granite (Hawkesworth et al., 1979). Such type of limited melting from mantle would result undersaturated melt (Green,1973). All the rock types (except basics) under study are oversaturated and require a quarts normative parent, with enriched LREE. This suggest:-

A) source in the crust (recently separated from LREE depleted mantle) or

B) source in the mantle which has undergone enrichment shortly before melting.

The mantle derived basic magmas produce several time more basic fraction than the acidic fractions. Looking into the voluminous silicic rocks exposed in the region with very minor basic fraction, it is therefore, proposed that these acidic subvolcanic-volcanic rocks had a crustal origin. The main features of the chondrite-normalized complete rare earth abundance pattern (Figure C-12) are enrichment in the light REE (La to Sm) relative to heavy REE (Gd to Yb); development of a negative Eu anomaly, and a small but distinct decrease of the heavy REE from Gd to Yb.

Marked negative Eu-anomalies are distinctive of all the rocks and, together with the slightly less steep HREE profile, are similar to many other granites (i.e. from the British Tertiary Volcanic Province (Walsh & Hinderson,1977; Meighan, 1979; Meighan et al.,1984).

The classical interpretation of Eu depletion is to ascribe this effect to fractionating plagioclase and alkali-felspar preferentially removing Eu from the residual liquid. However, the experimental work by Flynn and Burnham, (1978) have demonstrated that Eu is preferentially incorporated into the fluid phase. Based on this and other evidence Muecke and Clarke, 1981, have suggested that Eu leaching by fluoride or other fluids was the main mechanism of Eu-depletion in late stage granite from Nova Scotia. So Eu-depletion by fluids in subvolcanic-volcanic rocks from Peshawar Plain may not be considered only due to magmatic processes, but also owing to metasomatic changes induced by successive periods of rock-fluid interaction (Rafiq, 1987).

Albitization and sodium metasomatism in these rocks (see petrography) indicate that at higher temperature (probably 700-500 °C) the LREE and Eu are partitioned toward fluid and HREE are partitioned towards the rock. A substantial sub-solidus REE redistribution take place (after Bowden et al., 1979).

5.2 DISCUSSION

Schematic summary of our concept concerning the subvolcanic-volcanic rocks from Peshawar Plain is that of extensional environment as a result of thin skin continental rifting. In the emergence of continental setting generation of acidic rocks, may be summarized in terms of two end members:-

a) partial fusion of the crust, and

b) fractional crystallization of mantle derived basaltic magma.

However, complication arises in that which one either of these are contributed by the

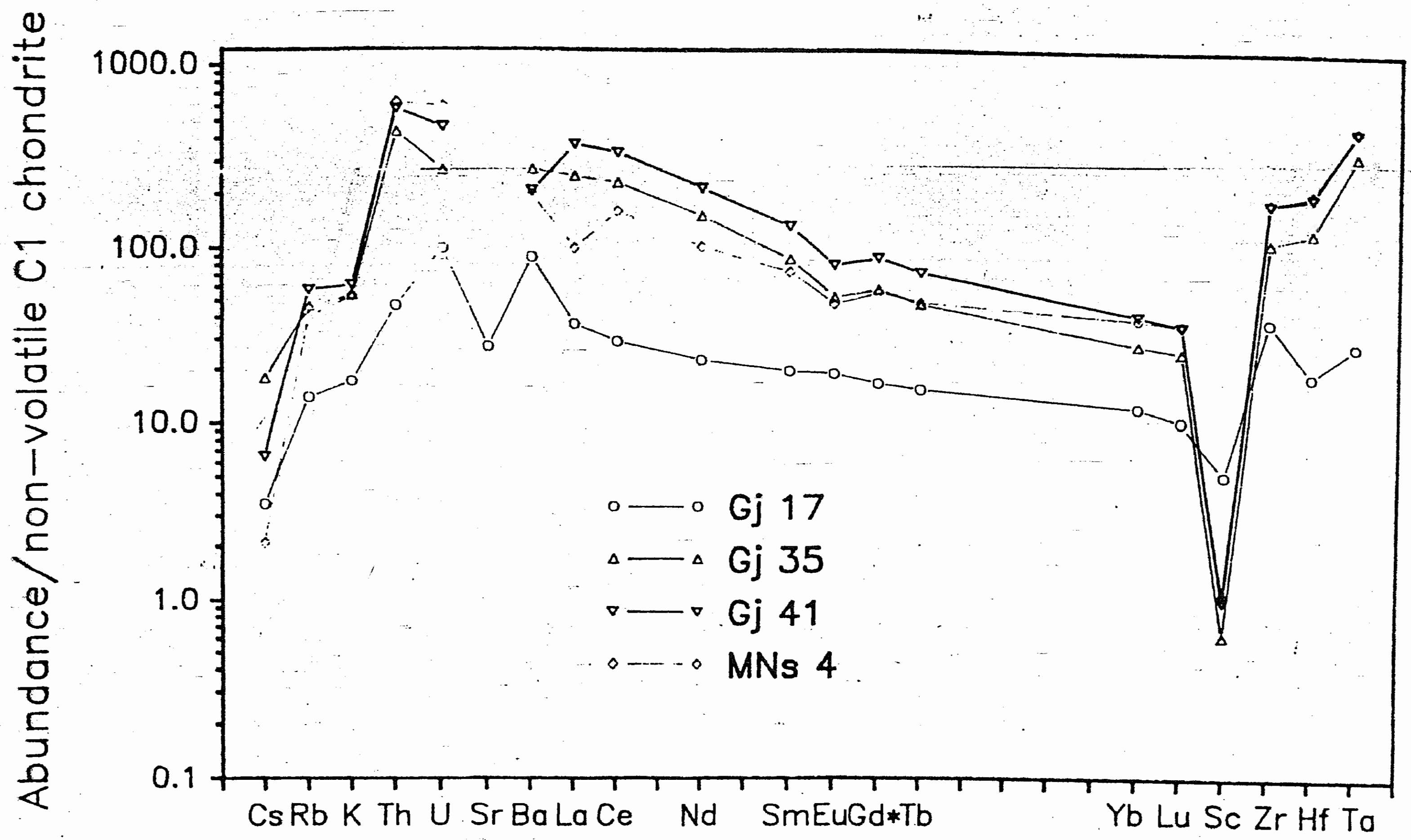


Fig.C-12 Plots of Rare earths and minor elements (normalised to Chondrite) for the subvolcanic-volcanic rocks.

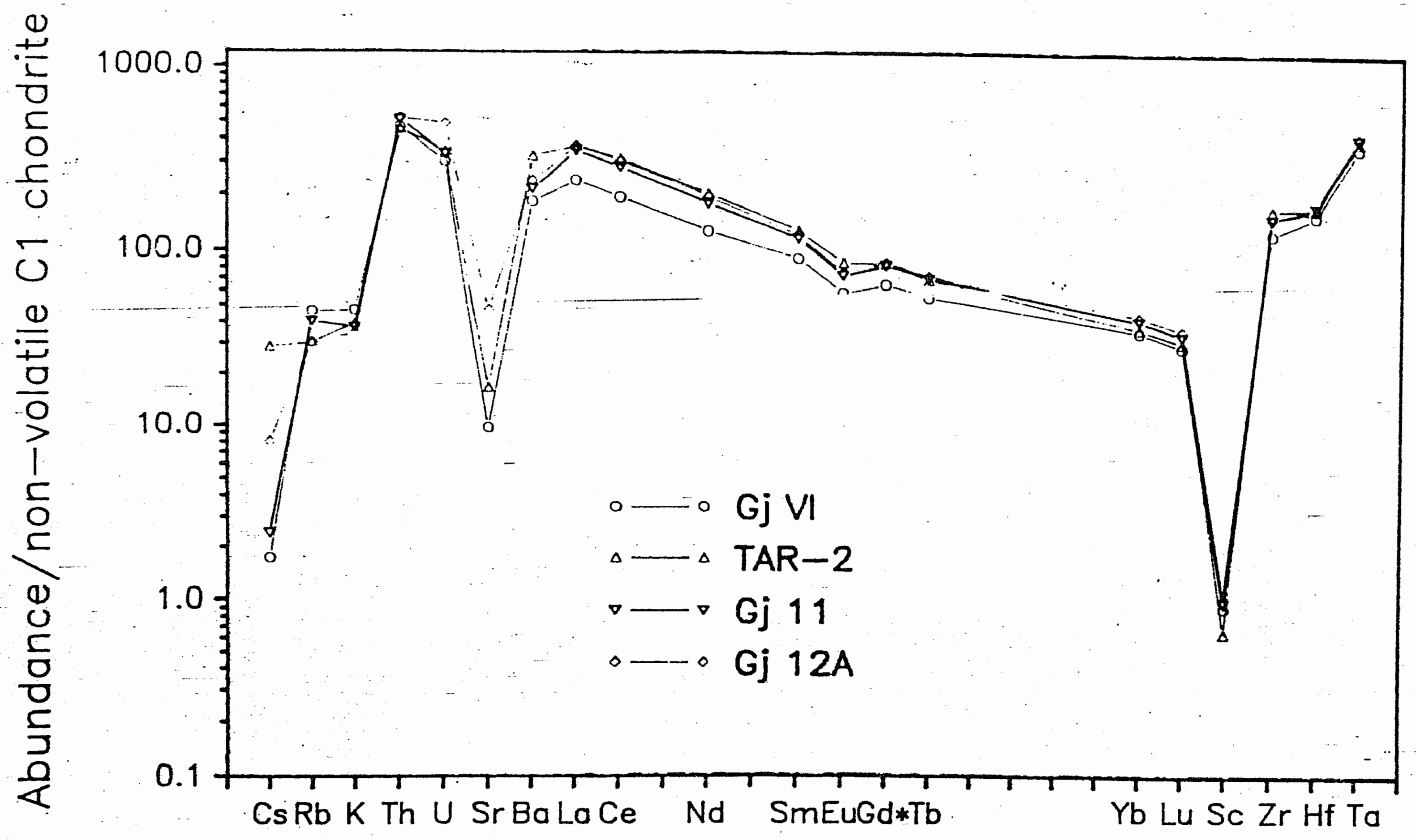
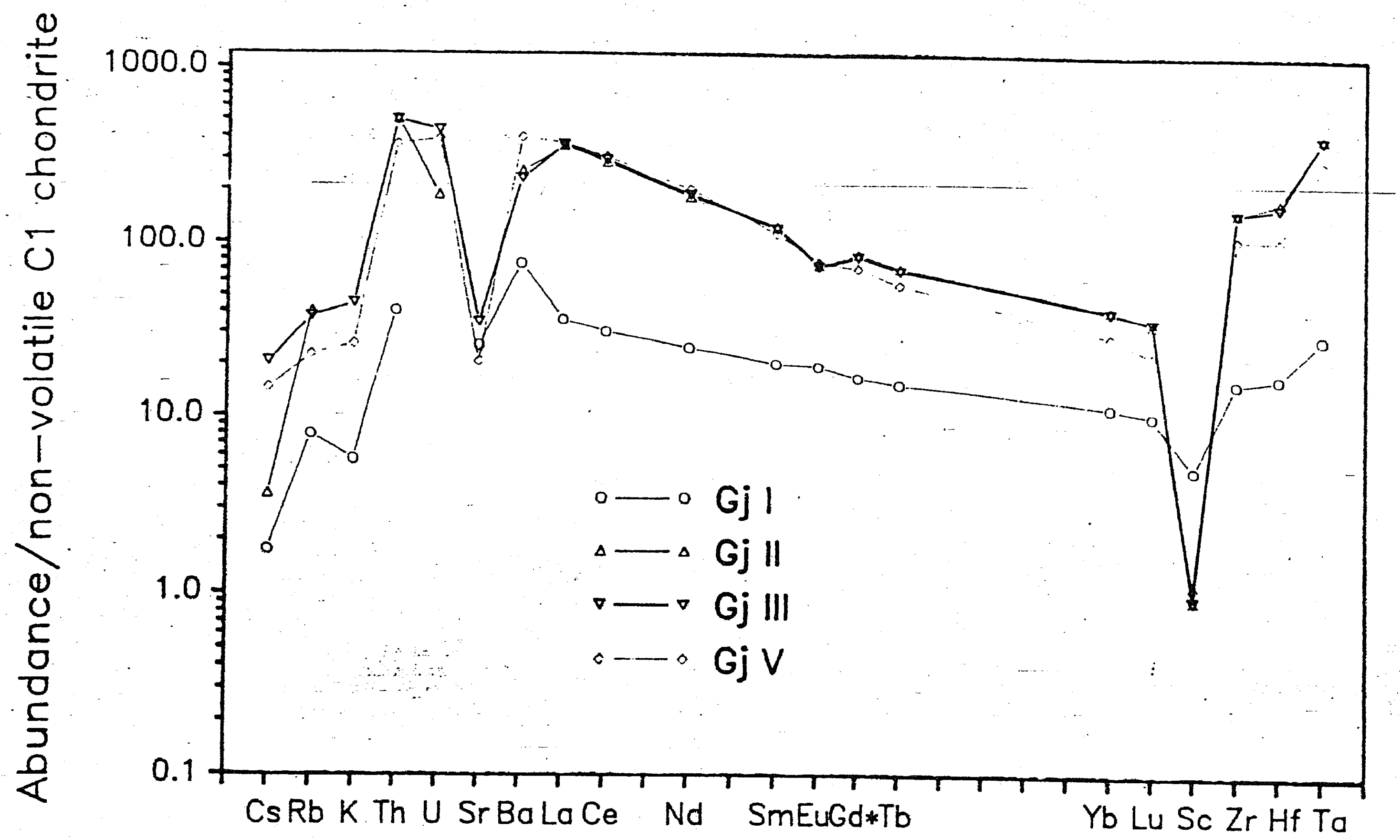
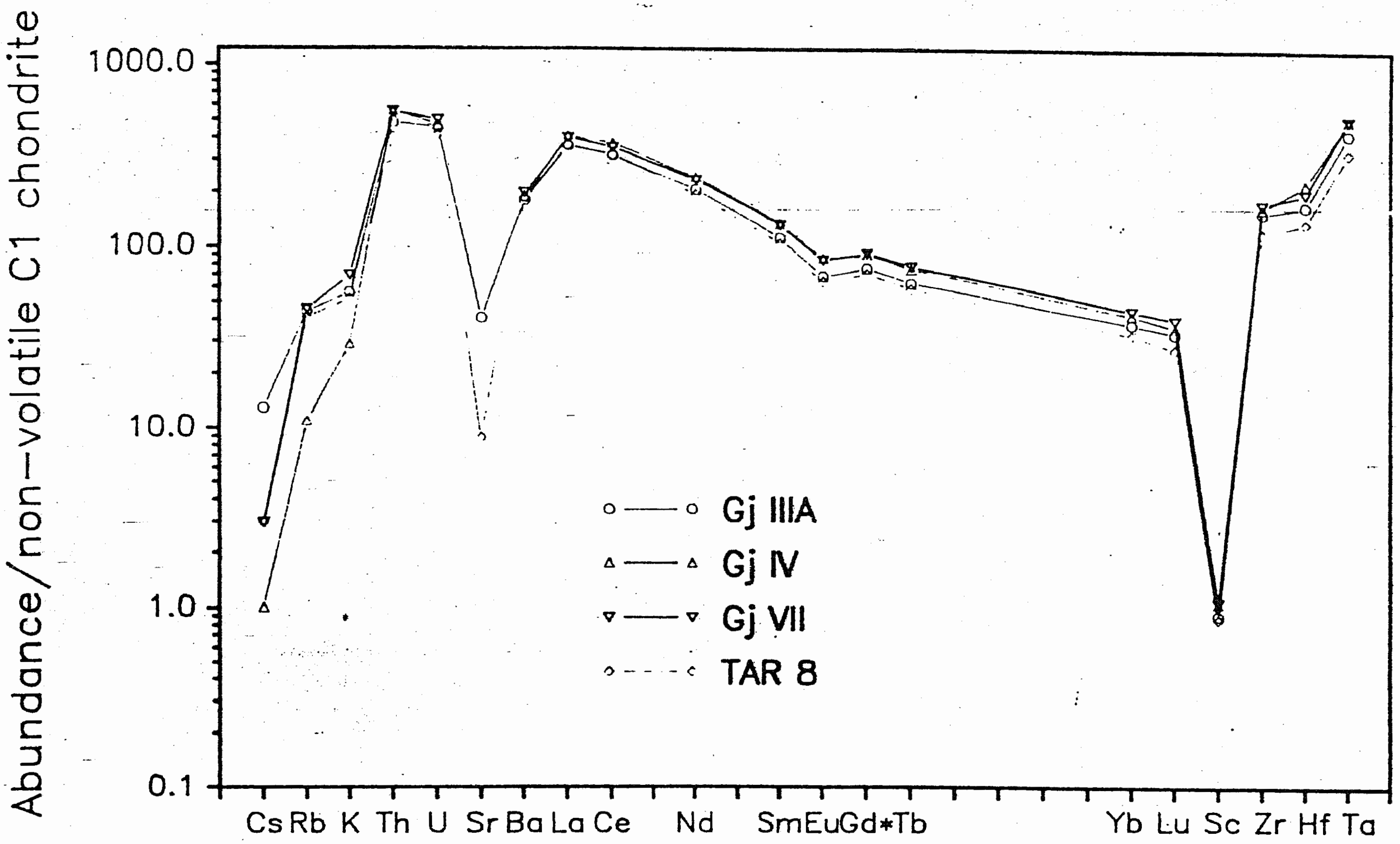
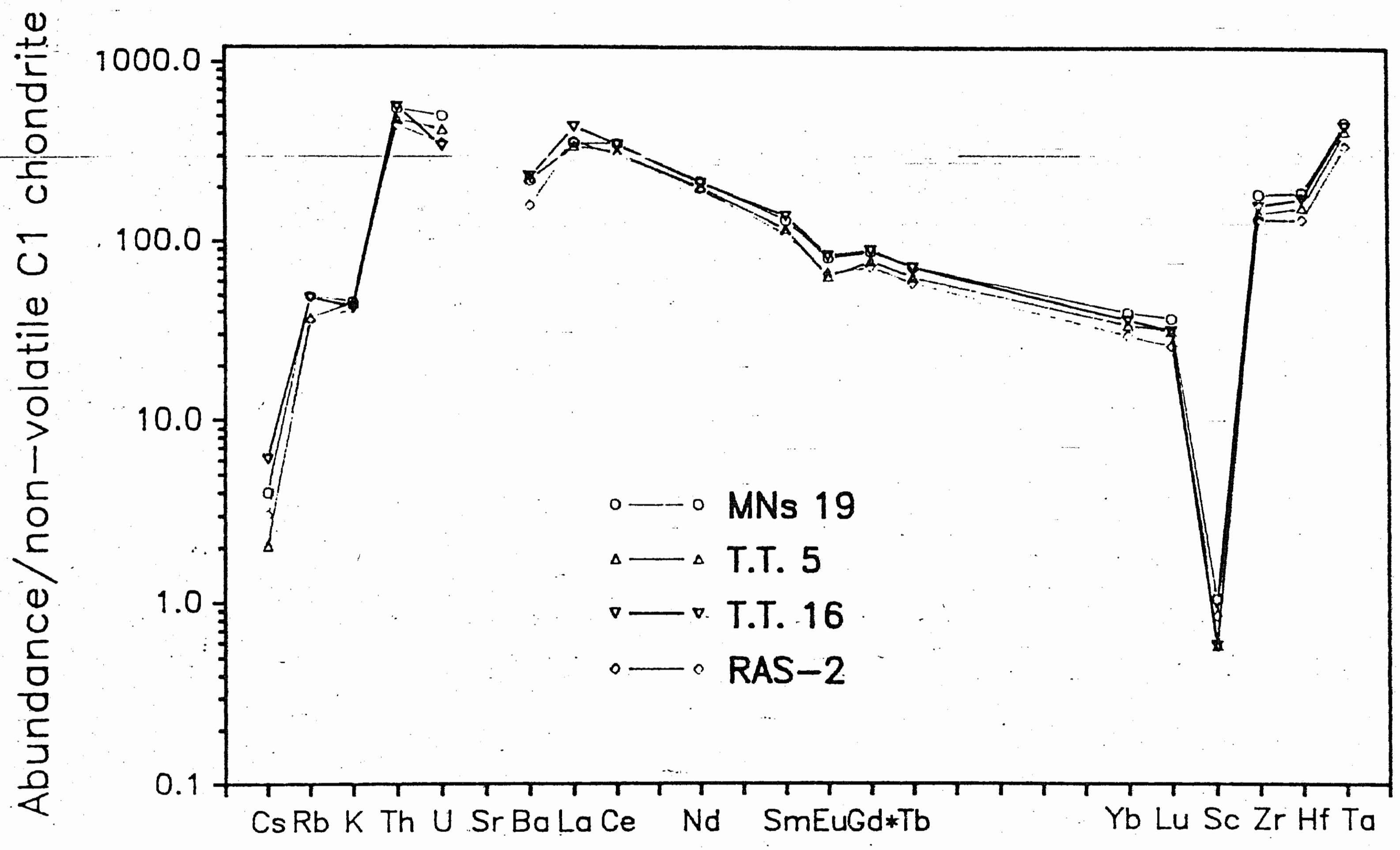


Fig.C-12 Plots of Rare earths and minor elements (normalised to Chondrite) for the subvolcanic-volcanic rocks.


Abundance/non—volatile C1 chondrite
1000.0
100.0
10.0
1.0
0.1
Cs Rb K Th U Sr Ba La Ce Nd SmEuGd*Tb Yb Lu Sc Zr Hf Ta
Gj I
Gj II
Gj III
Gj V


Abundance/non-volatile C1 chondrite
1000.0
100.0
10.0
1.0
0.1
Cs Rb K Th U Sr Ba La Ce Nd SmEuGd*Tb Yb Lu Sc Zr Hf Ta
Gj IIIA
Gj IV
Gj VII
TAR 8



Abundance/non-volatile C1 chondrite
1000.0
100.0
10.0
1.0
0.1
Cs Rb K Th U Sr Ba La Ce Nd Sm Eu Gd*Tb Yb Lu Sc Zr Hf Ta
MNs 19
T.T. 5
T.T. 16
RAS-2

other.

In the subvolcanic-volcanic rocks of Peshawar Plain the basic rocks which are exposed at Gajju Ghundai, Jaffar Kandao. Nawe-Killi and Krappa form a small volume of the total magma, which was dominated by hypabasal to extrusive acidic microporphyrites.

This observation has been similar to the development of petrogenetic model for the granitic rocks of the Ambbela Granitic Complex (Rafiq and Jan, 1987). Depletion in Th and Ta (Figure C-11, Hf/3 Hf-Th-Ta) of the parent magma suggested a high contamination from the curst. Magma generated due to swelling.

Major and trace element composition scatter in various variation diagram (Figure C-8) have been interpreted in terms of generation of basaltic magma dominated by incorporation of crustal melts (contamination).

5.3 CONCLUSION

Based on the evidences presented in this research it is concluded that the subvolcanic-volcanic rocks of the Peshawar Plain belong to the A-type spectrum.

Mineralogical and chemical characters classify these rocks as rhyolites and of peraluminous character as well. Major elements and their various ratios suggest a mildly alkaline character, while HFS element, Hf/Th and Hf/Ta ratio also support it.

The concentration of discriminating elements in the subvolcanic-volcanic rocks indicate an anorogenic environment of eruption, which took place in a rift setting representing the initial phases of fracture. Th-Hf-Ta diagram favours the generation of magma from a deep crustal reservoirs accumulated at higher limits in the crust and subsequently contaminated by more silicic rocks. This would have caused the residual liquids to move still further toward Hf apex (i.e, concentration in Hf and increase in Hf/Ta and Hf/Th ratio).

All samples display Eu anomalies more or less similar to aluminous and peralkaline anorogenic granitic rocks of Nigeria (Bowden etal,1979; Bowden, 1985) and demonstrate well support of fluid-solid rock interaction, confirming soda metasomatism due to late magmatic phases.

Intercalation of these rocks within Jaffar Kandao Formation (of Carboniferous age) and hosting the Ambela Granitic Complex (Carboniferous-Permian age) suggest an early Carboniferous acidic magmatism in the region.

SUMMARY & IMPLICATIONS =- The present study interprets the following facts on the available field and laboratoy data.

1) Acidic and basic microporphyries and lavas of Late Paleozoic age are intimately associated with a larger volumes of acidic plutonic rocks in the volcanic belt of the Peshawar plain.

2) Field evidence including the host metasedimentary sequence of Carboniferous age i.e.Jafar Kandao & Baroch Formations provides constraint on the dates of their origin.

3) Their sporadic distribution throughout the Peshawar plain at Tarbela in the east through Swabi in the centre upto Warsak in the west indicates extensive acidic volcanic belt in the region.

4) The rocks of the said belt is considered to provide a missing link in the form a lithological unit in the early classified Devon-Carbonif. stratigraphic set up of Peshawar Basin.

5) Besides providing clues to the lithological changes during volcanic activity, chemical and mineral analyses guides to the

nature & effect of various metasomatic/fluids changes in rocks

6) The acidic intrusive, present throughout the Pre-Cambrian xlline basement of Salkhala Fm. (Pepritz & Rey, 1989) along with the Paleozoic sedimentary cover, was reactivated by hotspot beneath the craton, resulting in partial melting producing A-type granitic magma ranging from alk-per/metaluminous composition.

7) As carbonate platforms commenly develop over a basal rift volcanics i.e. fringing reef complex of Devonian Slave Point Field, Alberta [Dunham, Crawford & Panasik, 1983], it is apprehended that during or prior the Late Devonian magmatizm of acidic volcanic belt probably provided knobs to the reef belt which along with the knobs were drowned by the later rifting events. The relics of the reefs are lying on the southren side of Kabul River between Ghundai Sar & Nowshera outcrops. It shows that Kabul River might have bereached the Granitic basement near Khuweshki area that supplies F - to the water .

Forsooth, each one of them wants to be given spread out scrolls (of revelation). 74/52.

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كَمَا بَدَأْنَا أَوَّلَ خَلْقٍ نُّعِيدُهُ وَعْدًا عَلَيْنَا إِنَّا كُنَّا فَاعِلِينَ ﴿١٠٤﴾ الانبياء ٢١

"As We had originated the first creation before, We will repeat/bring forth the creation again. This is the promise We made to Ourself and We have to fulfil it "

(1) That is 'On the one hand, countless new things come into existence from non-existence, and on the other, similar new members continue, coming into existence which means that things created by God's Competence and Skill are not created just once but He goes on creating new things repeatedly. This is suported by the verse (51/47-48) where it is explicitly explained that this huge universe which We created is not a finished work, but We are expanding it continuosely, new and ever new phenomena of Our creation are appearing in it every moment. Then how can you conceive that such a Marvellous Creator would be helpless to repeat/recreate His creation in the Hereafter.

(2) As science seeks to establish uniformity of experience i.e. the law of mechanical repetition. The Einstein's theory of relativity makes space dependant on matter i.e. in the absence of matter the universe would shrink to a point. Added further it conceives universe not as a thing but an act. So in modern physics what we call the thing (shy'un) is an event in the continuity of nature which thought spatialises and thus regards as mutually isolated for the purpose of action. Shah Waliullah writes, " God had inscribed before hand the doings and activities, deeds, behavior, conditions and circumstances of all the creatures; in short each and every thing that was going to happen in the world. Whatever is taking place in the world is, thus, preserved in'Lawh-e-Mahfooz' which can be conceived as the faculty of memory of the cosmos,as mind in human body."

Geological knowledge had seemed to provide for billions of years for the creation process, but cosmological theories based on modern physical concepts indicate an enormously contracted time scale in the initial stages of creation (e.g.Big Bang Theory) with several clear phases that correlate with Six Days (Periods).

Dr.Iqbal remarks,"Hence science can not comprehend life. The biologists who seeks mechanical explanation of life is led to do so because he confines his study to the lower forms of life whose behaviour discloses resemblances to mechanical action.If he studies life as manifested in himself.---he is sure to be convinced of the inadequacy of his mechanical concepts." A.A. Maududi remarks.

"The other thing that becomes apparent after a deep observation of the system of the universe is that nothing here is immortal. Everything has an age appointed for it after attaining which it dies and expires, and the same is the case with the universe as a whole. All the forces that are working here are limited. They can work only till an appointed term and they have inevitably to run out in time, and this system has to end. In the ancient days the philosophers and scientists who said that the world was eternal and everlasting could have their way, due mainly to lack of knowledge. But modern science almost definitely has cast its vote in favour of the God-worshippers in the debate that had been going on since centuries between them and the atheists regarding the eternal and the temporal nature of the world. Now the atheists are left with no leg to stand on. They cannot claim on the basis of reason and knowledge that the world has existed since eternity and will exist for ever and there is going to be no resurrection. The ancient materialistic creed rested on the belief that matter was indestructible, only its form could be changed, but after every change matter remained matter and no increase or decrease occurred in its quantity. Therefore, it was inferred that this material world had neither a beginning nor an end. But now the discovery of the atomic energy has demolished the entire materialistic edifice. Now it has come to light that energy changes into matter, and matter changes back into energy with the result that nothing persists, neither form nor appearance. The Second Law of Thermod-namics has proved that this material world has neither existed since eternity nor will last till eternity. It certainly began in time and has to end in time. Therefore, it is no longer possible to deny the Hereafter even according to science. And obviously, when science has surrendered, how will philosophy stand to deny the Hereafter?"