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F.A. Shams

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Geologia. — *An anatectic liquid of granitic composition from Hazara Himalayas, Pakistan, and its petrogenetic importance.* Nota di F. A. SHAMS (*), presentata (**) dal Socio A. DESIO.

RIASSUNTO. — Viene descritta una roccia porfirica componente un filone granitico dell'Himalaya dello Hazara, nel Pakistan settentrionale.

I caratteri degli elementi maggiori e minori dimostrano che la roccia ha avuto origine per fusione anatettica di metasedimenti che furono soggetti a granitizzazione metasomatica di dimensioni batolitiche. Il liquido anatettico prodotto da tale processo è da considerarsi responsabile della impostazione di un gruppo più giovane di graniti intrusivi, i quali si presentano sotto forma di plutoni, filoni e vene, entro il gruppo più antico di rocce gneissiche e granitiche costituenti la parte prevalente del complesso granitico dello Hazara.

Ritengo che questi risultati siano applicabili ai complessi simili di altri settori della Himalaya.

INTRODUCTION

The Hazara granitic complex represents a major member of the so-called Himalayan "Central Gneiss" (Stolickza, 1865) which outcrops as batholiths for almost the entire length of the orogen. The origin of the Hazara granitic complex in the Mansehra District, N.W.F.P., had been the subject of an illuminating controversy claiming a metasomatic (Wynne, 1887) as well as an igneous (Middlemiss, 1896) origin. Recently Shams (1961, 1967, 1969) carried out a detailed investigation of the area, including large-scale mapping, which led to a subdivision of the complex into an older group of gneissose to granitoid rocks, with essential muscovite and biotite, and a younger group of granites, with essential muscovite and tourmaline (Fig. 1). Associated with both the groups are acid minor bodies such as pegmatites and aplites, while rare porphyry bodies—the subject of the present article—are restricted to a granitoid member of the older group.

The Hazara granitic complex is associated with predominently pelitic to psammitic metasedimentary formations of Palaeozoic age, having suffered Barrovian type metamorphism up to sillimanite grade. Field and laboratory investigations have proved that the granitic complex originated through regional metasomatism of the metasediments involving essential introduction of soda and lime (Shams, 1967, 1979). While reports have been published on the more common types of acid minor bodies (Shams and Rahman, 1966;

(*) Institute of Geology, Punjab University, Lahore, Pakistan.
(**) Nella seduta dell'8 marzo 1980.

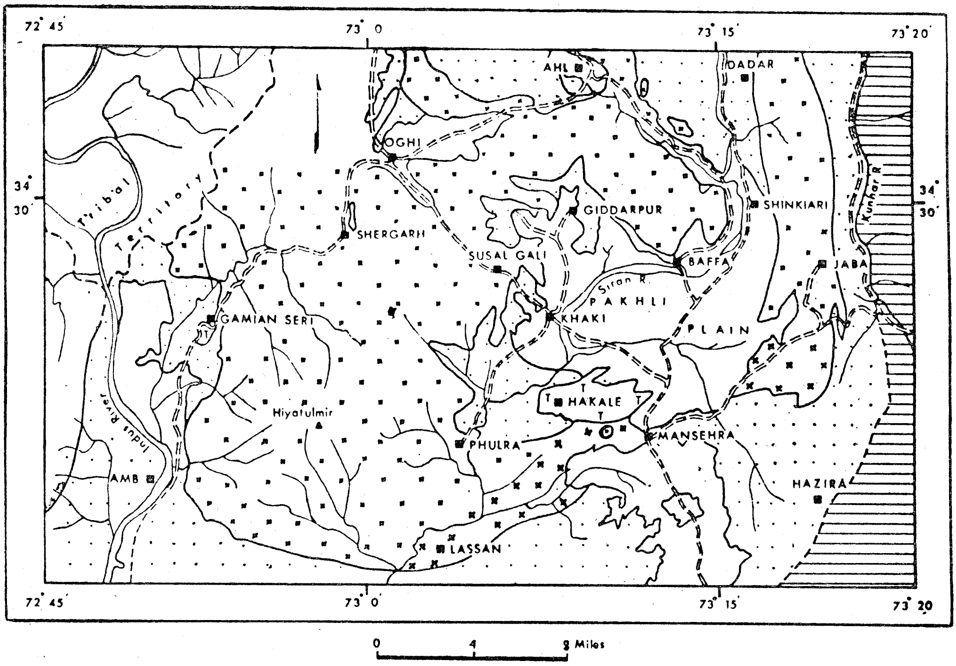

Fig. 1. – Geological map of area of the Hazara granitc complex, (Shams, 1967).

Ashraf, 1974, 1975), nothing has been reported so far on the porphyry rocks that hold rather special significance due to their status as the only undoubtedly silicic melt that had existed in the area.

The granitic porphyries

So far only three sills of granitic porphyry have been located. Two sills are present in metasediments near the southeastern edge of the granitc complex and the third sill occurs within the granite itself. The latter sill, located about 4 Km West of Mansehra Town, has been selected as representative of the group due to its occurrence within the granite and its mildly altered nature as compared with the other two bodies which are contaminated and considerably altered and sheared.

The Chitti Dheri porphyry sill is up to 30 ms thick and is traceable for a distance of over 300 ms, excluding minor branches. The rock is porphyritic and phenocrysts of quartz and feldspar are visible in hand specimens. In thin section the rock shows a glomeroporphyritic texture due to clustering together of plagioclase and alkali feldspar. Dominant plagioclase occurs as two types of fractions. Type–I is anhedral, with widely spaced twin lamellae and abundant mica inclusions arranged in criss-cross fashion; its composition varies in the oligoclase range (An_{20-28}) and shows extensive replacement by potash feldspar to the extent of remaining as irregular remnants. Type–II plagioclase occurs as euhedral laths with closely spaced twin lamellae and is free of mica inclusions; its composition varies in the albite range (An_{8-10}) and does not show replacement relations with potash feldspar. Type–I plagioclase is comparable in texture and compositional range to those of some of the granitic gneisses of the older group in the Hazara complex. In rare cases

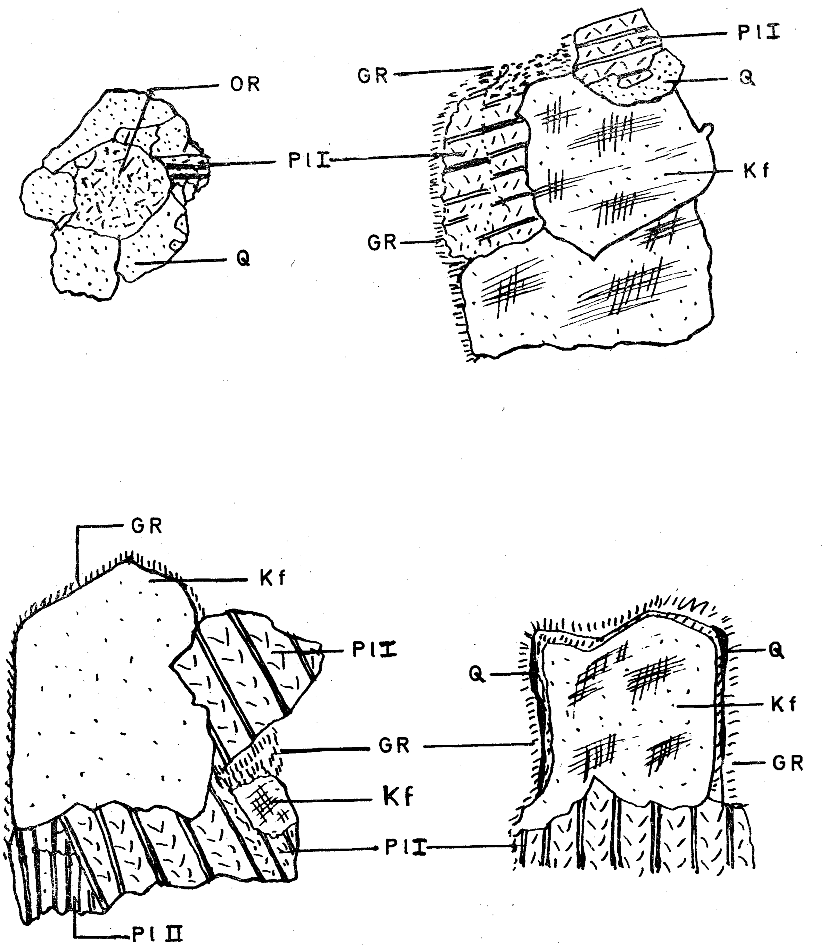

Fig. 2. – Sketch drawings of some paragenetic relations between quartz and feldspar minerals in the Chitti Dheri porphyry.

albitic plagioclase occurs as thin jackets around potash feldspar that has replaced Type–I plagioclase, surrounded by quartz veneers succeeded by quartz-potash feldspar intergrowth of myrmekitic to granophyric nature. The potash feldspar occurs as a phenocrystic phase, with euhedral outlines, as well as anhedral grains attached to Type–I plagioclase in replacement relations. Obliquity data (Δ) ranges from .05 to .95 (Shams, 1978) are also indicated by optical measurements combined with the range of twinning intensity.

Weakly twinned potash feldspar carries hair lamellae of plagioclase as perthitic intergrowths while highly twinned microcline phase is homogenous and among the younger phases of feldspar fractions. Fig. 2 shows sketch drawings of some of the notable textural relations between quartz and feldspar phases, as described above.

The groundmass of the rock consists of an aggregate of albite laths, microline grains, muscovite flakes and granophyric intergrowth. Rare flakes of strongly pleochroic biotite are present with trails of ore rods and granules. Schorlite prisms, individual as well as rossette-like growths, are intimately associated with partially replaced biotite. Needles of apatite, grains of clinozoisite, colourless garnet and opaque ore are present in traces.

Chemical composition

The chemical analysis of Chitti Dheri porphyry is given in Table I, along with the average compositions of granitic rocks of the older and the younger groups of the Hazara complex. Additional data are given for comparison from world sources. Except for higher SiO_2 and lower Al_2O_3, the Chitti Dheri

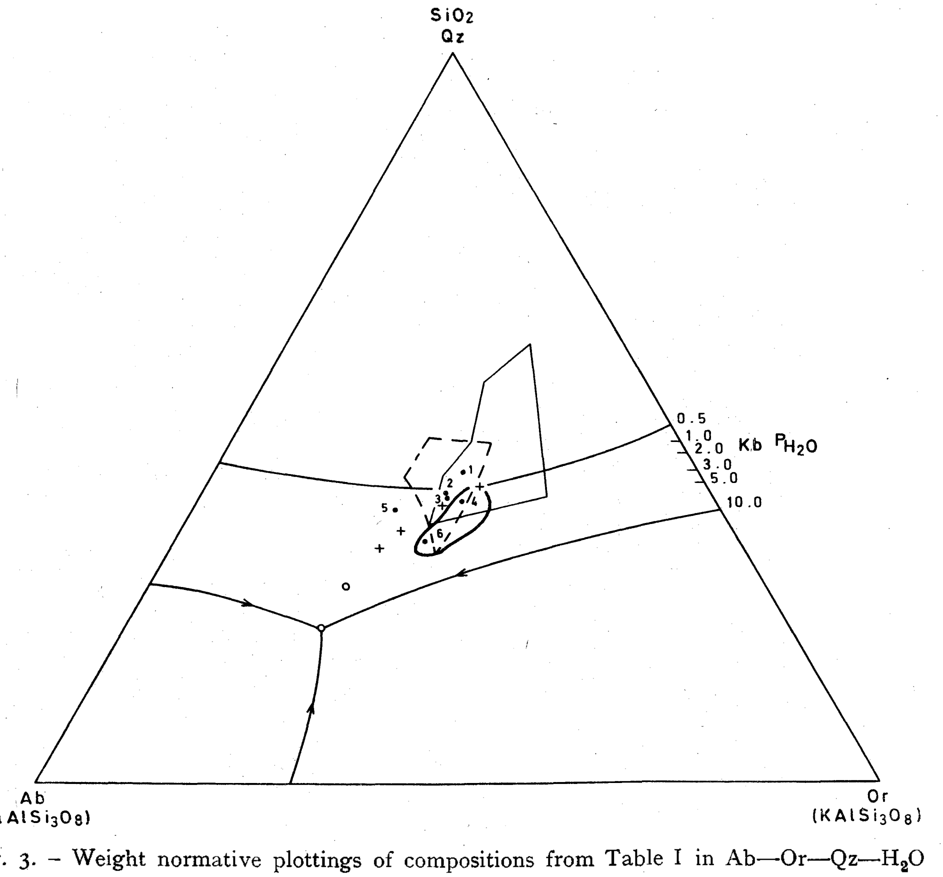

Fig. 3. – Weight normative plottings of compositions from Table I in Ab—Or—Qz—H_2O system (Tuttle and Bowen, 1958).

TABLE I

Chemical Composition of Chitti Dheri Porphyry and other rocks from Hazara, Pakistan and data for comparison from other sources.

OXIDES	1	2	3	4	5	6
SiO_2	70.44	72.07	74.87	75.75	75.03	74.57
TiO_2	00.51	0.16	0.13	0.09	0.31	0.17
Al_2O_3	14.67	15.61	13.75	13.01	13.17	12.58
Fe_2O_3	1.95	0.86	0.69 } 1.19	} 1.18	1.56 } 2.14	1.30 } 2.32
FeO	1.69	0.56	0.50		0.58	1.02
MnO	0.22	0.48	0.47	—	0.01	0.05
MgO	0.89	0.95	0.25	0.20	0.15	0.11
CaO	1.43	0.71	0.69	0.71	0.69	0.61
Na_2O	2.79	3.34	3.45	3.61	4.24	4.13
K_2O	4.24	4.12	4.45	4.66	3.85	4.73
P_2O_5	0.33	0.23	0.74	—	0.02	0.07
H_2O^+	0.76	1.11	0.22	—	0.28	0.66
Total	99.90	100.20	100.21	99.21	100.02	99.21

1. Average composition (22 analyses) of older gneisses and granites from Hazara, Pakistan (Shams, 1967).
2. Average composition (6 analyses) of younger granites from Hazara, Pakistan (Shams, 1967).
3. Average Granitic porphyry, Chitti Dheri, Hazara, Pakistan (Shams, 1967).
4. Average composition (8 analyses) of leucogranites, Snowy Mountains, New South Wales (Kolbe and Taylor, 1966).
5. Average composition of acid granophyre, Skaegaard Intrusion, E Greenland (Wager and Deer, 1939).
6. Average composition (21 analyses) of alkaline rhyolites plus rhyolite obsidian (Nickolds, 1954).

composition is comparable to the average composition of the younger granites, but significantly different from the older granites as regards all the oxides. On the other hand, the composition of the Chitti Dheri porphyry is remarkably comparable to that of the Snowy Mountains leucogranite but significantly different from both Skaergaard acid granphyre and Nockolds' (1954) average rhyolite and obsidian. The trace element patterns of the Chitti Dheri rock and that of some other rocks of interest are given in Table II. Once again, the Chitti Dheri rock compares satisfactorily with the Snowy Mountains leucogranite except for slightly lower values for Zr, Ba, Sr and a somewhat higher value for Cr. However, its difference from Skaergaard acid granophyre is so pronounced that any comparison can be easily ruled out.

TABLE II.

Trace element patterns (ppm) *of the Chitti Dheri porphyry, Hazara, Pakistan, and of other rocks for comparison.*

ELEMENT	1	2	3
Cr.	3	3.8	14
Zr.	32	88	850
Ga	10	13.5	30
Pb	—	32	—
Ba	25	270	1300
Sr	10	42	350
Rb	380	388	160
Li	56	7–65	13
Cu	n. d.	2	20
Cs.	32	12.3	10

1. Chitti Dheri porphyry, Hazara, Pakistan (Shams, 1967).
2. Average of 8 leucogranites, Snowy Mountains, New South Wales (Kolbe and Taylor, 1966).
3. Acid granophyre, Skaegaard Intrusion, E Greenland, (Wager and Mitchell, 1951).

Various sets of chemical data from Table I are plotted in a weight normative Ab(Na Al Si_3O_8)—Or(K Al Si_3O_8)—Qz(SiO_2)—H_2O diagram (Fig. 3). The position of the Chitti Dheri porphyry plotted at about 0.8 Kb P_{H_2O}, slightly outside the Tuttle-Bowen oval and the curve joining the 0.5 and 1 Kb isobaric minima. In relation to the Hazara granitic rocks, the Chitti Dheri porphyry plotted very close to the average position of the younger group of granites. Although the position of the Snowy Mountains leucogranite plotted fairly close to the plotted position of the Chitti Dheri porphyry it was still within the Tuttle-Bowen oval and slightly towards a higher Or value. On the other hand, plotted positions of both the Skaergaard acid granophyre and Nockalds' average rhyolite and obsidian were significantly shifted towards relatively higher Ab values.

DISCUSSION

The close comparison of the patterns of major and minor elements of the Chitti Dheri porphyry with the Snowy Mountains leucogranite is taken to mean an origin similar to the latter, which was shown to be by anataxis of pelitic-psammitic metasediments (Kolbe and Taylor, 1966) of the type associated with the Hazara granitic complex (Shams, 1967, 1969, 1979). That the Chitti Dheri liquid did not originate by differentiation of a basic magma is supported by its prominent difference of major and minor element compositions from Skaergaard acid granophyre.

Temperature estimation of the Hazara granitic rocks by Barth's (1956) two-feldspar thermometry gave a range of 580° to 670 °C. (Shams and Rahman, 1967) so that at least amphibolite facies p , t conditions were prevalent prior to the genesis of Chitti Dheri liquid by anataxis. Considering the presence of ex-solution textures in alkali feldspar phenocrysts of the porphyry, it is inferred that water vapour pressure reached a range of 4-5 Kb (Yoder *et al.*, 1957). This is also supported by extension to the 5 Kb P_{H_2O} isobaric curve of the area enclosing plotted positions of the younger granites of Hazara (Fig. 3). Such a conclusion is consistent also with the experimental anataxis of natural rock systems (Winkler, 1961; von Platen, 1965) and the views of Mehnert (1971) that anataxis is liable to initiate at temperatures of 640° to 750 °C. and a water vapour pressure of 2–4 Kb. The suggestion by Ashraf (1974, 1975) that the water vapour pressure increased to even higher than 10 Kb is not considered tenable at least in the problem under discussion. It is considered more important to know whether or not the P_{H_2O} was equal to Total, particularly as limitations on available water can seriously affect the melting capacity of a natural rock system (Brown, 1970; Brown and Fyfe, 1970). As the prograde metamorphism is essentially a dehydration process, water could become available only through structural breakdown of hydrous silicates such as micas in the case under study. Thin sections showed that biotite remained a stable phase and suffered only slight thermal breakdown as is evidenced by its deep colour and trail of tiny ore granules and rods. Therefore only muscovite is considered to be responsible for provision of structural water during the process of anataxis. Statistical counting of modal muscovite in the Hazara pelitic gneisses gave a range from 1.3 to 16.9 % (Shams, 1967, 1969) so that water contributed by muscovite breakdown could not have been more than 1 % even if it was entirely eliminated. As muscovite continued to persist in the porphyry, even if in traces, this showed that it was not completely destroyed. Thus, muscovite breakdown and anataxis could have overlapped (Lundgren, 1966). This is also consistent with the experimental results that muscovite+quartz reactions at 4–6 Kb P_{H_2O} initiate in the temperature range of 665° to 715 °C. (Evans, 1965) or 750° to 775 °C. when P_{H_2O} is less than P_{total} (Segnit and Kennedy, 1961). As such ranges of temperature are somewhat higher than those estimated from the Hazara granites (Shams and Rahman, 1967), there was ample opportunity for a proportion of muscovite to survive anataxis. Further stability to muscovite could have come about due to a drop in water vapour pressure from 5 to 0.8 Kb (Fig. 3). Besides remnant muscovite, Type–I plagioclase, rare aggregates of anhedral quartz around potash feldspar with mica inclusions and biotite flakes with ore granules and rods are taken to be the other residual phases from rocks that underwent anataxis.

The status of Chitti Dheri liquid, as of anatectic origin and charged with residual mineral phases, is comparable with those described from Bygland, south Norway (Sen and Mukherjee, 1973) and in conformity with results of of fusion experiments on natural rocks from Sierra Nevada Batholith, California (Piwinski, 1968). A point of special significance in the case of Chitti Dheri porphyry is the replacement of Type–I plagioclase by potash feldspar, showing a strong tendency towards chemical equilibrium in a crystal-liquid environment. Such textures are found to be characteristic features of all the younger group granites (Shams, 1967, 1969, 1979), evidenced also by convergence of their composition near that of the Chitti Dheri porphyry (Fig. 3). This is taken to prove that Chitti Dheri type anatectic liquid acted as parent to the younger group of granites of the Hazara complex. The sequence of events would then be progressive granitisation of metasediments leading to the formation of gneisses and granitoids of the older group and anatectic fusion to generate granitic liquid under suitable environments of p , t conditions; the anatectic liquid intruded to form plutons, sills and veins belonging to the younger group of granites including the rare porphyry sills. Such a scheme of events also explains the age relations of older and younger granites of the Hazara complex (Shams, 1966). It is believed that the above explanation will apply also to other similar complexes in the Himalayas (Misch, 1949; Gansser, 1964; Ohta *et al.*, 1973).

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