CHAPTER - VII

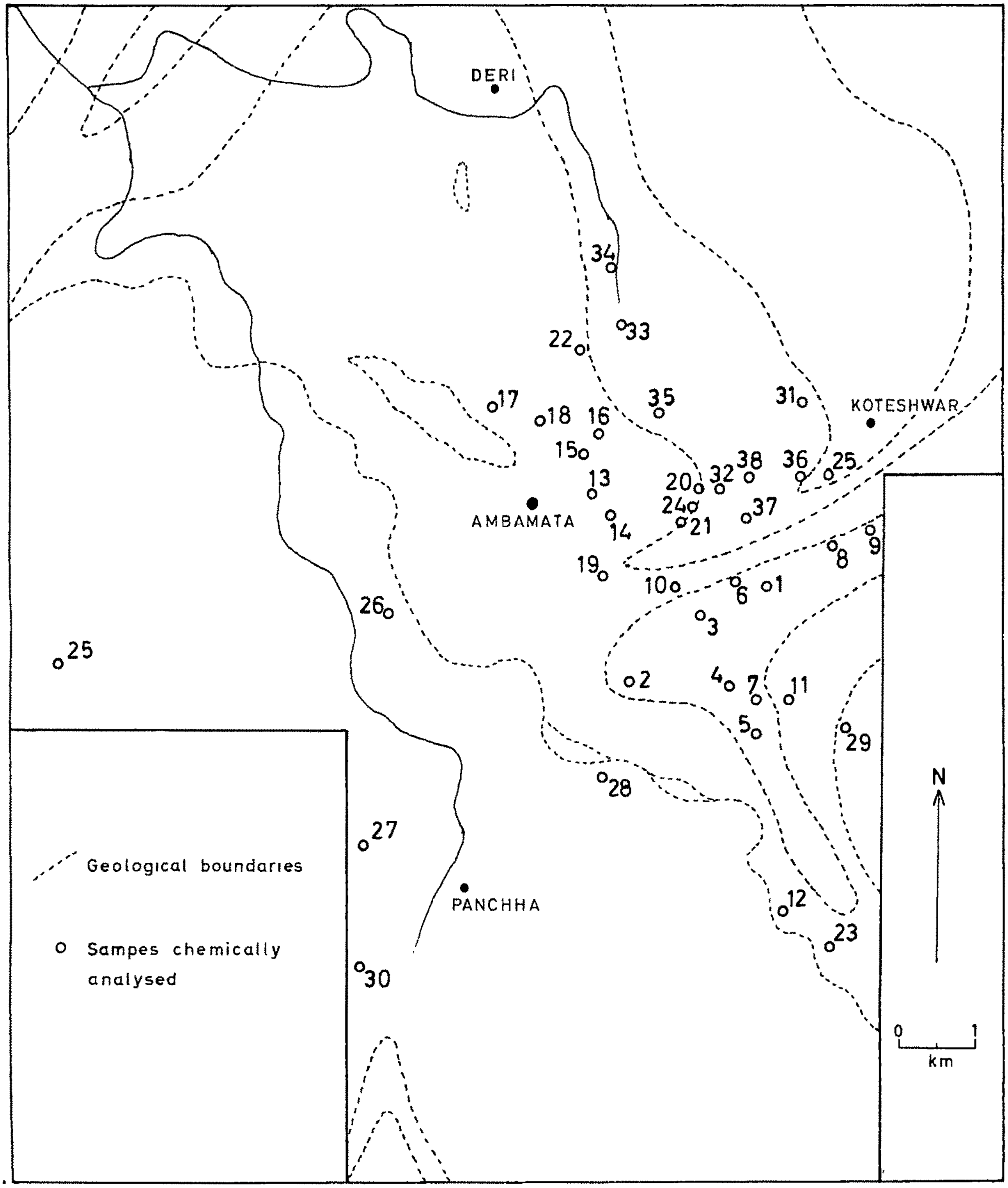
PETROCHEMISTRY

SCOPE

Only a limited chemical study has been undertaken, and the data obtained has been utilised for properly evaluating certain specific phenomena related to the metamorphism of the area. Chemical analyses of ortho-amphibolites, hornblende gneisses, biotite gneisses and pelitic schists, have been considered (Fig. VII.1) to understand the following aspects :

1) True nature of the magma which gave rise to ortho-amphibiotites.
2) Derivation of hornblende gneisses
3) Origin and nature of biotite gneisses
4) Nature of the original metasediments that gave rise to pelitic schists.

MAP SHOWING THE LOCATION OF SAMPLES SELECTED FOR CHEMICAL ANALYSES



Representative samples were analysed and the data plotted on various appropriate diagrams. The information obtained from the chemical data has been interpreted in conjunction with petrography and field details. Chemical analyses of the meta-dolerites and alkali-basalt have been given just for the sake of information and to ascertain their probable parentage.

ORTHO-AMPHIBOLITES

These metamorphosed linear bodies occurring as fold cores represent the oldest rocks and have been interpreted as the oceanic basement (= plate) over which the Ajabgarhs were deposited. The chemical composition of 5 representative samples is given in the Table VII.1; and the percentage of major elements and their atomic proportions, computed from the major oxides, are given in Table VII.2. The overall oxide percentages point to the alkaline nature of the original rock. The ratio between Fe_2O_3 and Feo (Table VII.1) is more than 0.2, and that between Na and K (Table VII.2) is less than 10. These two are obvious indications of a basic magma of alkali basalt type (Engel et al., 1965, p. 719). The original alkaline nature of the parent rock also becomes clear on the graph showing weight percent of SiO_2 on arithmetic scale against that of K_2O on logarithmic scale (Fig. VII.2); all the plots lie in the alkali basalt region (Engel et al., 1965, p. 728).

TABLE VII.1

CHEMICAL ANALYSES OF ORTHO-AMPHIBOLITES

	1	2	3	4	5	Average of 5(from study area)	Average* of 200
SiO_2	49.25	50.56	50.30	46.03	51.40	49.51	50.30
Al_2O_3	14.33	15.57	16.43	15.70	16.53	15.71	15.70
Fe_2O_3	4.76	4.16	2.12	4.52	2.96	3.70	3.60
FeO	8.09	8.08	8.22	9.33	10.69	8.88	7.80
MgO	7.95	6.37	7.89	6.91	6.22	7.07	7.00
CaO	8.08	7.21	8.94	9.45	9.80	8.70	9.50
Na_2O	3.20	3.92	3.30	2.97	2.77	3.23	2.90
K_2O	1.82	1.72	1.93	0.81	1.62	1.58	1.10
Total	97.48	97.59	99.13	95.72	101.99	98.38	97.90

* A. Poldervaart, Geol. Soc. Am. Spec. Paper 62, p. 136; 1955 (in Walter T. Huang 1962 - P. 418)

The values of atomic proportions of the elements like Si and Al (Table VII.2) also furnish supporting evidence; a Si content that varies between 21.73 and 24.26, with an average of 23.37, when considered in conjunction with Al values averaging 8.32, also suggest the derivation of ortho-amphibolites from a magma of oceanic affinity. The Fe and Mg values further substantiate their oceanic setting. The FMA diagram (Fig. VII.3) after Ringwood (1975) provides an interesting tholeiitic differentiation trend, the FMA values from the study area being computed in Table VII.3. May be that the parent magma which gave rise to the alkali basalt, was tholeiitic. Of course, this is just a conjecture.

TABLE VII.2

MAJOR ELEMENTS AND THEIR ATOMIC PROPORTIONS(ORTHO-AMPHIBOLITES)

	1	2	3	4	5	Average of 5(from study area)	Average* of 200
Si	23.25	23.86	23.74	21.73	24.26	23.37	23.74
Al	7.59	8.24	8.70	8.31	8.75	8.32	8.31
Fe^{+3}	3.33	2.91	1.48	3.16	2.07	2.59	2.52
Fe^{+2}	6.29	6.28	6.39	7.25	8.31	6.90	6.06
Mg	4.80	3.84	4.76	4.17	3.75	4.26	4.22
Ca	5.77	5.15	6.39	6.75	7.00	6.22	6.79
Na	2.37	2.91	2.45	2.20	2.05	2.40	2.15
K	1.29	1.22	1.37	0.57	1.15	1.12	0.78
Total cation	54.69	54.41	55.28	54.14	57.34	55.18	54.57
Total oxygen	42.79	43.18	43.85	41.58	44.65	43.20	43.33
Total cation +oxygen	97.48	97.59	99.13	95.72	101.99	98.38	97.90

Fig. VII . 2 .

$K_2O:SiO_2$ DIAGRAM FOR THE ORTHOAMPHIBOLITE

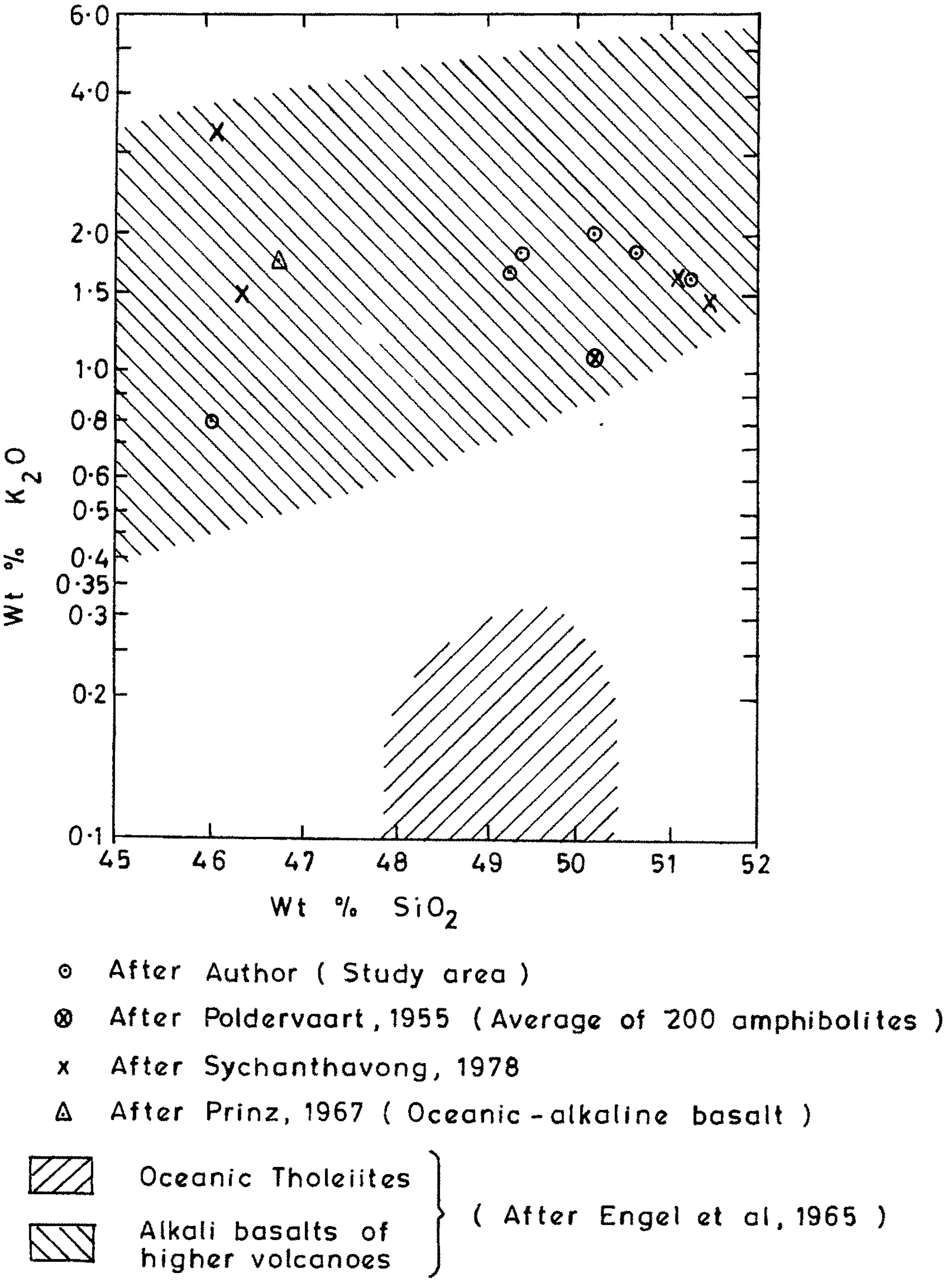
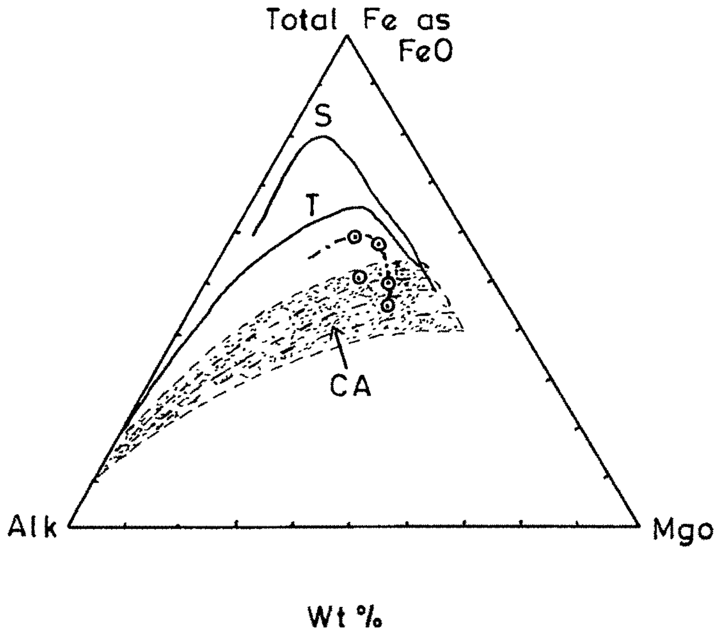


Fig. VII.3.

FMA DIAGRAM SHOWING CHARACTERISTIC THOLEIITIC AND CALC-ALKALINE TRENDS (After Ringwood, 1975).



Curve S represents the skaergaard differentiation trend and Curve T the Thingmuli.

Shaded calc-alkaline band represents the differentiation trends displayed by magmas from the Cascade, Aleutian, and New Zealand calc-alkaline provinces.

-·-·- Curve shown by the orthoamphibolites of the study area.

TABLE VII.3

FMA VALUES (ORTHO-AMPHIBOLITES)

	1	2	3	4	5
F ($FeO+Fe_2O_3$)	49.77	50.47	44.07	56.44	56.27
M (MgO)	30.79	26.27	33.63	28.16	25.64
Alk (A) (K_2O+Na_2O)	19.44	23.26	22.30	15.40	18.09

For the purposes of comparison, the author has given in Table VII.4, the average values of weight percentage of oceanic alkali basalts from the main oceans of the world (Manson, 1968)

TABLE VII.4

AVERAGE VALUES OF THE OCEANIC ALKALIC BASALT

Major oxides	Pacific, Atlantic and Indian oceans (After Manson, 1968)	Study area
SiO_2	46.9	49.51
Al_2O_3	15.5	15.71
Fe_2O_3	3.1	3.70
FeO	8.6	8.88
MgO	6.9	7.07
CaO	10.4	8.70
Na_2O	3.0	3.23
K_2O	1.3	1.58

Considering the above facts, it can be concluded that the amphibolites of the study area comprise metamorphosed derivatives of oceanic basalt of alkaline nature.

HORNBLENDE GNEISSES

These streaky hornblendic rocks consist of alternating layers rich and poor in hornblende. The leucocratic hornblende poor layers comprise quartz, oligoclase and microcline. On the other hand, hornblendic layers contain in addition to hornblende, andesine and quartz. The chemical data of hornblendic bands only are given in Table VII.5.

TABLE VII.5

CHEMICAL ANALYSES OF HORNBLENDE GNEISSES

Sample No.	6	7	8	9
SiO_2	56.99	61.46	60.40	66.14
Al_2O_3	15.82	16.72	15.07	13.12
Fe_2O_3	4.32	3.85	3.96	5.28
FeO	3.84	2.64	3.79	1.72
MgO	4.43	4.15	3.75	3.15
CaO	2.10	3.08	1.54	1.40
Na_2O	4.35	3.82	3.71	3.87
K_2O	5.43	4.25	4.31	4.87
Total	97.28	99.97	96.53	99.55

It is observed that the chemical composition is broadly comparable with that of the amphibolites, and no significant chemical change is revealed. This leads to an important conclusion that the leucocratic layers definitely represent the granitic material injected lit par lit in the amphibolites, the granitic constituents having been derived from the overlying granitised metasediments. Actual granitisation and transformation of amphibolite to biotite gneiss is nowhere seen either in the field as is revealed in the chemical data.

BIOTITE GNEISSES

The chemical analyses of the biotite gneisses are most revealing (Table VII.6), and typically point to their derivation from the pelitic schists (Table VII.7).

TABLE VII.6

CHEMICAL ANALYSES OF BIOTITE GNEISSES

Sample No.	10	11	12
SiO_2	61.94	62.45	70.00
Al_2O_3	14.32	14.11	14.76
Fe_2O_3	3.14	3.41	3.70
FeO	1.48	0.88	0.80
MgO	4.36	4.35	2.12
CaO	3.36	3.49	1.35
Na_2O	4.19	4.99	4.24
K_2O	4.24	5.62	2.75
Total	97.03	99.30	99.72

As compared to the coarse non-foliated biotitic granite (Erinpura granite proper), these (which were originally supposed to be foliated varieties of the former) show a relatively high percentage of MgO and FeO (Table VII.12). On the other hand, the chemical composition of gneisses compares well with those of biotite schists etc.

A critical appraisal of the chemical data of all the three varieties leads to the following conclusions :

1. The biotite gneisses have chemical composition almost comparable to that of the overlying meta-sediments.
2. No significant addition of any constituent is seen in the gneisses, and the transformation of schists to granite gneisses appears to be a transformative process of internal readjustment of constituents only.
3. The relatively high percentage of MgO in gneisses reflects the original magnesian richness of meta-sediments.

PELITIC SCHISTS

The chemical composition of biotite schists and related rocks (Table VII.7) throws some light on the original composition and nature of the meta-sediments.

TABLE VII.7

CHEMICAL ANALYSES OF PELITIC SCHISTS

Sample No.	13	14	15	16	17	18	19
SiO_2	70.10	65.34	65.85	66.14	67.69	72.86	67.29
Al_2O_3	12.31	12.46	12.35	18.01	13.67	14.21	12.56
Fe_2O_3	3.97	5.68	3.63	2.88	5.07	1.46	4.04
FeO	1.28	1.00	0.96	1.00	1.72	1.20	1.04
MgO	1.72	1.10	2.17	1.45	1.77	1.99	3.65
CaO	0.56	4.35	3.50	0.28	0.70	0.28	3.93
Na_2O	4.08	3.19	3.82	3.98	3.13	2.92	5.04
K_2O	5.43	4.87	6.05	5.99	5.68	4.68	3.87
Total	99.45	97.99	98.33	99.73	99.43	99.60	101.42

The data shows that the sediments were mostly graywackes to subgraywackes; with a fair MgO content. Pettijohn (1975,P.228) has given the chemical composition of representative graywackes (Table VII.8) from which it will be seen that the composition of the metasediments of the study area also point to their graywacke affinity.

The Al_2O_3:SiO_2 variation diagram (Fig. VII.4) based on the molecular percentages (Table VII.9) shows that the chemical composition of the pelitic schists as well as biotite gneisses is identical to that of graywackes - subgraywackes,

TABLE VII.8

CHEMICAL COMPOSITION OF REPRESENTATIVE GRAYWACKES

(After Pettijohn, 1975)

Constituent	A	B	C	D	E	F	G	H	I	J
SiO_2	60.51	66.24	76.84	69.11	68.85	74.43	70.60	71.10	68.84	65.05
TiO_2	00.87	00.64	-	00.60	00.74	00.83	00.70	00.50	00.25	00.46
Al_2O_3	15.36	15.28	11.76	11.38	12.05	11.32	13.50	13.90	14.54	13.89
Fe_2O_3	00.76	00.70	00.55	1.41	2.72	00.81	2.20	Trace	00.62	00.74
FeO	7.63	4.53	2.88	4.64	2.03	3.88	1.60	2.70	2.47	2.60
MnO	00.16	00.06	Trace	00.17	00.05	00.04	00.10	00.05	Nil	00.11
MgO	3.39	2.74	1.39	2.06	2.96	1.30	1.60	1.30	1.94	1.22
CaO	2.14	1.70	00.70	1.15	00.50	1.17	1.30	1.80	2.23	5.62
Na_2O	2.50	3.12	2.57	3.20	4.87	1.63	2.90	3.70	3.88	3.13
K_2O	1.69	1.91	1.62	1.76	1.81	1.74	1.60	2.30	2.68	1.41
H_2O^+	3.38	2.49	1.87*	4.13	2.30	2.15	2.80	1.90	1.60	2.30
H_2O^-	0.15	00.08	-	00.05	00.77	00.20	00.30	00.26	00.35	00.28
P_2O_5	00.27	00.12	-	00.03	00.06	00.18	00.20	00.10	00.15	00.08
ZrO_2	-	-	-	-	-	-	-	-	00.05	-
CO_2	1.01	00.30	-	-	00.08	00.48	00.60	00.12	00.14	2.83
SO_3	-	-	-	-	-	-	-	-	00.15	-
S	00.42	-	-	-	00.08	00.12	-	Trace	-	00.05
BaO	-	-	-	-	Trace	-	-	-	00.04	-
C	-	-	-	-	00.07	00.17	-	00.09	-	-
Total	100.24	99.99	100.18	99.69	99.94	100.45	100.00	99.80	99.93	99.77

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* Loss on igniton

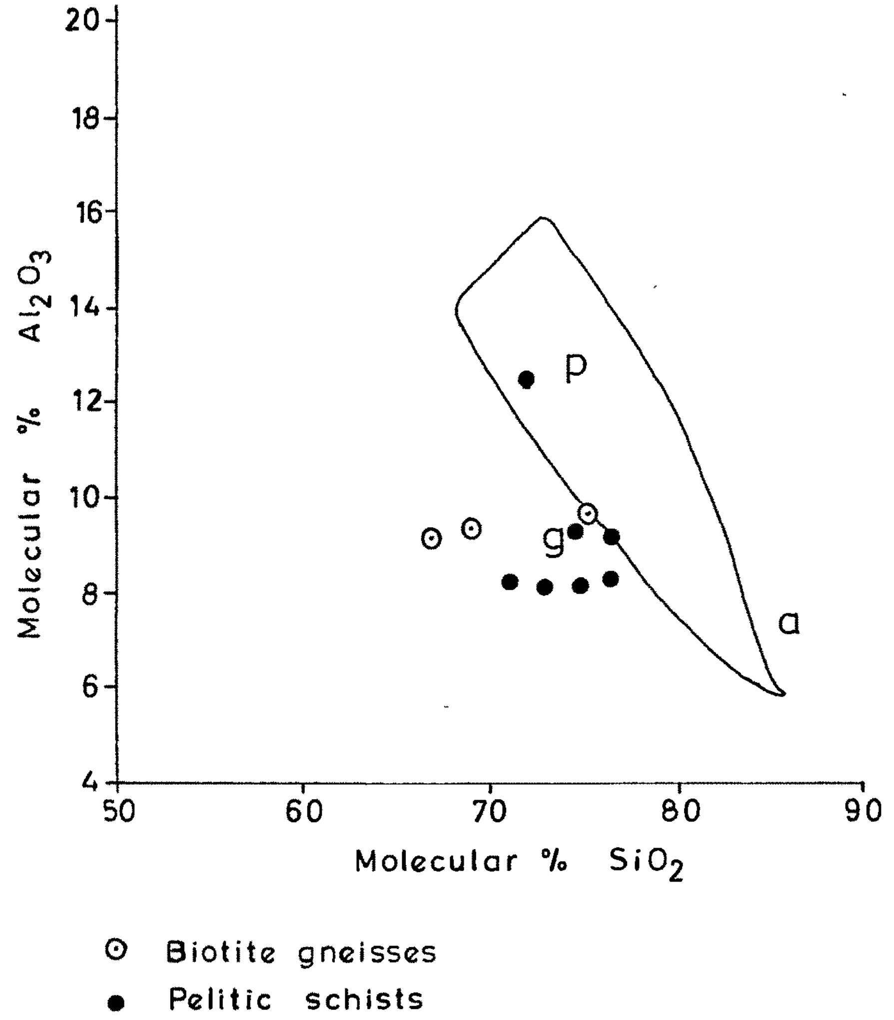
Contd....

Table VII.8 Contd.

A	Archean, Manitou Lake, Ontario. B. Brunn, analyst (Pettijohn, 1949, p. 250)
B.	Average of three Burwash Formation graywackes (Archean), Yellowknife Bay, Northwest Territories, Canada. L. Seymour, analyst (Henderson, 1972, p. 890)
C	Tyler Slate (Animikean), Hurley, Wisconsin. H.N. Stokes, analyst (Diller, 1898, p. 87)
D	(?) Ordovician, Rensselaer, near Spencertown, New York, H.B. Wiik, analyst (Balk, 1953, p. 824).
E	Tanner Graywacke (Upper Devonian - Lower Carboniferous), Scharzfeld Germanry, R. Helmblod, analyst (Helmbold, 1952, p. 256).
F	Carboniferous graywacke from Stanley Shale, near Mena, Arkansas. B. Brunn, analyst (Pettijohn, 1957, p. 319)
G	Average of six Kulm graywackes from Oberharz, Germany (Mattiat, 1960, Table 14)
H	Lower Mesozoic composite sample prepared by using equal parts of 20 graywackes exposed along shoreline between Palmer Head and Hue-Te-Taka, Wellington, New Zealand. J.A. Richie, analyst (Reed, 1957, p. 16).
I	Franciscan (? Jurassic) Quarry. Oakland Paving Co., Piedmont, California. J.W. Howson, analyst (Davis, 1918, p. 22)
J	Eocene, near Solduc, Olympic Mountains, Washington. B. Brunn, analyst (Pettijohn, 1949, p. 250).

Fig.VII.4.

$Al_2O_3 : SiO_2$ VARIATION DIAGRAM



Points p,g and a represent the compositions of average pelite, greywacke and arkose respectively (after Pettijhon, 1957) mostly all plotted points falling within the graywacke field of Pettijohn (1957). The rocks thus plotted, also include the so called 'Schistose quartz porphyries' of Sharma (1931) and obviously they do not represent a eruptive rock.

TABLE VII.9

MOLECULAR PERCENTAGES OF SiO_2 and Al_2O_3 (BIOTITE GNEISSES AND PELITIC SCHISTS)

Sample No	10	11	12	13	14	15	16	17	18	19
SiO_2	69.02	68.29	76.68	77.36	73.03	75.23	74.42	75.93	79.26	71.45
Al_2O_3	9.41	9.10	9.51	7.99	8.23	8.34	11.94	9.06	9.12	7.87

In this connection, the diagram (Fig. VII.5) showing Kohler Raaz values for pelitic schists (Table VII.10) clearly demonstrates the sedimentary parentage of these rocks.

META-DOLERITES AND ALKALI BASALTS

The dolerite sills intruded into the metasediments prior to the coarsegrained Erinpura granite, as also the narrow basaltic Post-Erinpura dykes, reveal alkaline nature in their chemical composition (Table VII.11). It is most likely that they have been intruded by the remobilization of the oceanic crust during successive deformational events related to the upheaval.

Fig .VII.5.

KÖHLER-RAAZ DIAGRAM

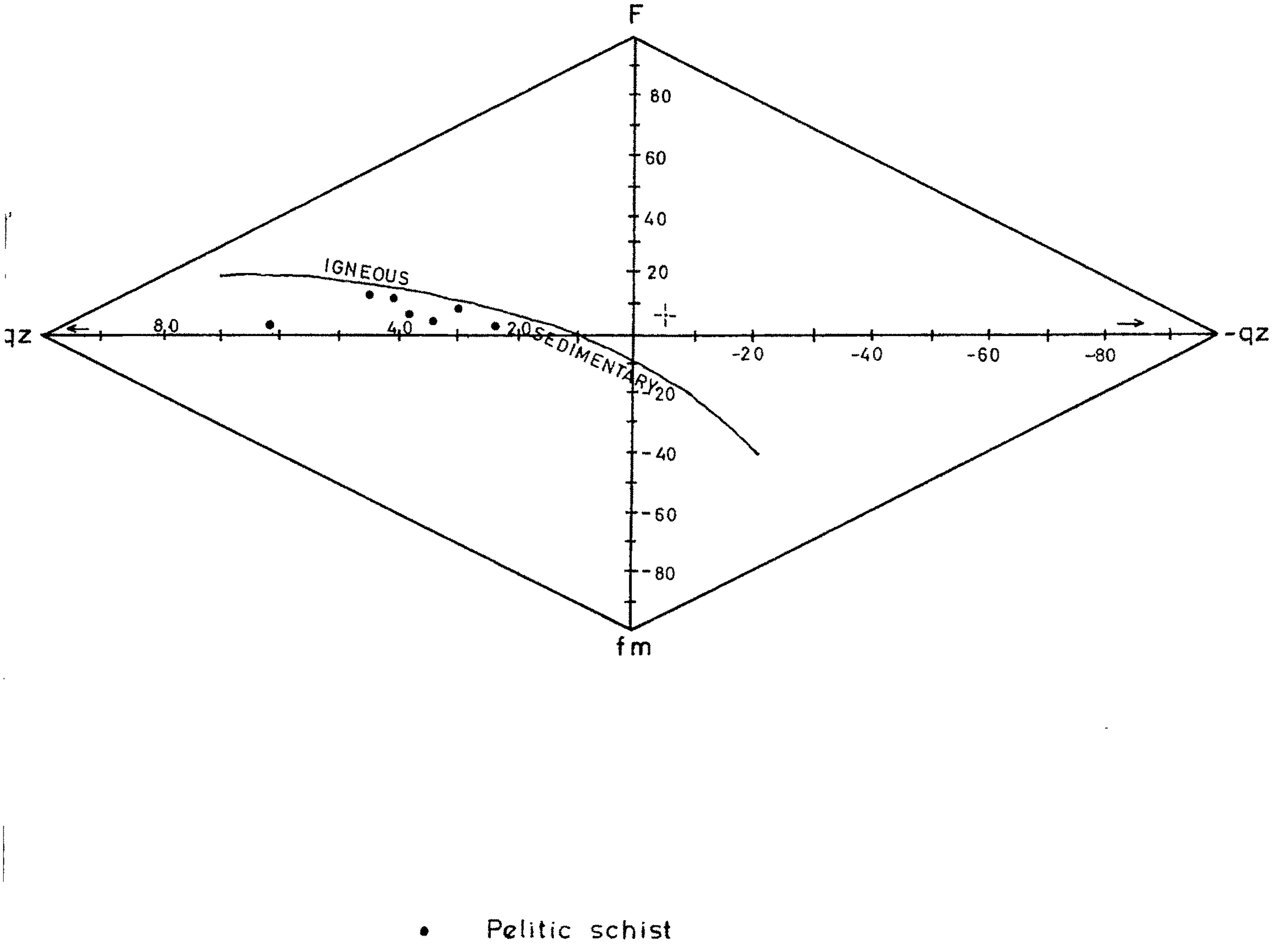


TABLE VII.10

KOHLER RAAZ VALUES FOR PELITIC SCHISTS

Sample No.	Case	Kohler Raaz Values		
		qZ	F	fm
13	II	46.07	35.39	18.54
14	I	39.17	34.51	26.31
15	II	29.89	39.71	30.40
16	III	34.38	36.29	29.33
17	III	41.22	36.77	22.01
18	III	60.15	20.07	19.77
19.	I	24.82	39.20	35.98

TABLE VII.11

CHEMICAL ANALYSES OF BASIC ROCKS

	20+	21+	22+	23+	24*
SiO_2	53.04	50.36	51.00	52.00	48.70
Al_2O_3	18.02	18.42	18.28	16.37	19.50
Fe_2O_3	3.28	4.12	3.96	2.76	3.45
FeO	8.53	9.00	9.38	9.83	9.24
MgO	6.10	6.80	6.82	6.36	6.49
CaO	8.80	6.24	6.66	7.43	7.38
Na_2O	3.14	3.46	3.09	3.45	3.29
K_2O	0.95	1.01	0.81	0.91	0.80
Total	101.86	99.41	100.00	99.11	98.85

+ Post-Delhi (Pre-Erinpura) * Post-Erinpura.

TABLE VII.12

CHEMICAL ANALYSES OF GRANITES

	25	26	27	28	29	30
SiO_2	66.89	72.47	72.13	71.66	64.29	70.42
Al_2O_3	16.41	13.21	13.26	14.22	17.76	13.56
Fe_2O_3	1.81	0.61	0.55	0.29	1.70	1.39
FeO	3.24	3.24	2.12	1.80	3.80	2.16
MgO	0.29	0.92	0.59	0.50	0.36	0.34
CaO	2.21	2.60	2.63	2.08	2.63	2.49
Na_2O	3.34	2.61	2.71	2.60	2.60	2.87
K_2O	5.93	5.31	5.56	5.12	5.24	5.37
Total	100.12	100.97	99.55	98.27	98.38	98.60

The chemical analyses of Calcareous rocks in Table VII.13 and 14 have been given to ascertain the composition of the original sediments and to calculate the A, C, & F values plotted in Fig. VII.1.

TABLE VII.13

CHEMICAL ANALYSES OF MARBLES

Sample No.	31	32	33	34	35
SiO_2	0.7	4.8	1.0	1.0	9.3
Al_2O_3	0.3	2.8	0.2	0.6	1.9
Fe_2O_3	0.4	0.2	-	0.4	1.6
FeO	-	-	-	-	-
MgO	0.7	3.3	0.7	0.8	0.4
CaO	54.9	50.2	55.2	54.9	50.2
Na_2O	-	-	-	-	-
K_2O	-	-	-	-	-
Loss on ignition	42.6	38.9	42.7	42.6	35.6
Total	99.6	100.2	99.8	100.3	99.0

TABLE VII.14

CHEMICAL ANALYSES OF CALC-SCHIST AND PARA-AMPHIBOLITES

Sample No.	36@	37*	38*
SiO_2	48.81	47.50	57.78
Al_2O_3	19.13	18.13	21.51
Fe_2O_3	6.29	13.79	0.62
FeO	5.12	1.96	3.40
MgO	5.60	5.00	2.15
CaO	4.91	3.22	2.10
Na_2O	5.25	4.72	3.18
K_2O	0.56	2.75	4.37
Total	95.67	97.07	95.11

@ Calc-schist * Para-amphibolite