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Dedicated to

the countless workers
died of asbestosis and other lung fibroses
in South African and other mines of the world especially
to Stur Gust of Belgium who died of this deadly disease on October 27, 1996

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ABSTRACT

Studies in environmental geology are limited in Pakistan. Asbestos has been mined since early 70s around Peshawar valley but environmental degradation was never regarded as concern untill 1983. This study has been carried out to map asbestos deposits of the Skhakot Qila Ultramafic Complex around Peshawar valley, describe their petrological characters and evironmental aspects. Dunite, peridotite, serpentinite, chromitite and mafic rocks are the main rock types of the complex and tremolite rock, talc-carbonate rock, carbonate-quartz rock, steatite and chlorite wall rock are found in the forms of irregular to pod-like, elongated or tabular masses and veins transacting the ultramafic rocks along shear zones. Deposits at Narai Obe, Newe Kili, Behram Dheri, Qila, Hero Shah and Bucha were mapped and sampled. In addition to asbestos sampling in situ and mines, samples were also collected from asbestos crushing grinding plants at Tangi, Berlin and Newe Kili to identify the type and fibregenesity of asbestos. Individuals related to asbestos business or living in the vicinities of crushing plants were also interviewed for noticing any abnormalities since their contact with asbestos dust or fibres.

Rocks were analysed using conventional wet chemical techniques and atomic absorption spectrophotometer, UV-spectrophotometer and flame photometer at the National Centre of Excellence in Geology, University of Peshawar. Asbestos samples were anlysed using XRD and Electron microprobe at the National Centre of Excellence in Geology. Fibrogenesity was determined under petrological microscope. The data indicate that rocks of the Skhakot Qila Ultramafic Complex represent an ophiolite segment of the Tithean oceanic crust and are classified as a partly metamorphosed mafic ultramafic complex. Igneous crystallization, fractionation and accumulation of olivine, pyroxenes (and chromite) has led to the development of mafic and ultramafic rocks. Tectonic emplacement has caused the

deformation and metamorphism of these rocks transforming dunite and peridotite into serpentinite. Local variation in P-T condition during tectonic deformation and metamorphism caused the crystallization of various minerals with serpentine as essential constituent and brucite, forsterite, magnetite, magnesite, talc and carbonate associated in variable proportions. On the bases of XRD and probe data serpentine is classified as chrysotile and along shear zones it is grown as fibrous asbestos. Asbestiform tremolite also occurs locally at Newe Kili, Hero Shah and Behram Dehri and has most probably grown from the deformation and alteration of pyroxenite. Chemical and physical classification of asbestos define these as highly carcinogenic and potentially hazardous for producing asbestosis and other lung diseases including cancers. The dust produced during the crushing and grinding of asbestos and related minerals in crushing plants is also a potential hazard for skin and eye allergies and asthma in the locals.

Being proved carcinogenic the asbestos of the Skhakot Qila Ultramafic Complex also passes hazard to the users of asbestos products manufactured in various industries in Pakistan. Of particular danger is the use of talcum powder produced from crushing talc together with asbestos in crushing plants at Newe Kili, Berlin and Tangi. Recommendations suggesting mitigation stratagies are given at the end.

Chapter 1

INTRODUCTION

Asbestos is the fibrous form of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals. The most significant types include chrysotile (white), crocidolite (blue) and amosite (brown or gray). As a naturally occurring rock fiber, asbestos is mined, then broken down from mineral clumps into groups of loose fibers. Asbestos has been used in more than 3000 products, including heat resistant textiles (cloth, padding), asbestos cement products (sheets, pipes), special filters for industrial chemicals, thermal insulation products (pipe and boiler insulation), friction material (clutch plates, brake linings), gaskets, floor tiles, roofing materials, packing materials, paints and protective paper etc. It has been used as sprayed insulation for buildings and other structures and in their repair. Exposure to airborne asbestos dust occurs particularly in the course of dust-forming operations such as handling, sawing, sanding, grinding, drilling, turning or general maintenance, renovations or similar operations upon materials containing asbestos. Inhalation of high concentration of asbestos may result in asbestosis, a progressive scarring of lung tissues. Further development of scar tissue (fibrosis) may occur after the cessation of exposure. The two main forms of cancer associated with the inhalation of asbestos are lung cancer and mesothelioma. Generally fibers $<3\mu m$ in diameter and $>8\mu m$ in length are potentially carcinogenic and the risk of cancer increases as fiber diameter decreases. The risk of cancer is also greater with increased exposure to asbestos, and vice versa. Cancer in the gastro-intestinal tract and other sites of the body has been noted in workers exposed to asbestos. In the early and middle eighties the death of majority of the workers in American, South African, European and Australian asbestos mines occurred due to asbestosis (Worksafe Code Australia, 1988).

Asbestos occurs in many parts of northern and north-Western Pakistan (Qaisar et al., 1967; Jehan & Khan, 1963; Qaisar & Khan, 1967). These occurrences are largely confined to the ultramafic rocks (dunite-peridotite, pyroxenite) of possible ophiolitic affinities associated with the Main Mantle Thrust (Asrarullah et al., 1979, Tahirkheli et al., 1979). Two of the major belts of such ultramafic rock occur in Malakand and Mohmand agencies and district Charsadda (Rafique et al., 1983). These are described as Skhakot Qila Ultramafic Complex (SQUC) with particular reference to the genesis of chromite (Ahmed, 1982). The Mohmand agency, ultramafic complex is a westren extension of the rocks in Malakand agency and district Charsadda. Hamidullah (1984) reported two new localities from Bucha, Prang Ghar area of Mohmand agency.

Previously little work has been done on the environmental impacts of asbestos. The present work has been carried out to map the geology of the asbestos-bearing rocks of the SQUC, describe their preliminary petrological feature and genetic characteristics, with special reference to the health-related environmental problems of this deadly fibrous mineral, generally in the world and especially here in northern Pakistan.

1.1 REGIONAL GEOLOGY

The geological and tectonic features developed in the northern part of Pakistan are the product of collision of Eurasian plate with Indian plate, 55 m.y. ago (Powell, 1979). This collision occurred due to northwards subduction of Tethys ocean floor under the Eurasian plate. The Kohistan island arc formed in response to this subduction during the Cretaceous and was sandwiched between the two mighty continents, (Eurasia and Indo-Pakistan) during early Tertiary. The northern and southern limits of Kohistan island arc are marked by two branches of the Indus suture zone which marks the collisional line of India and Eurasia in Tibet (Desio, 1964). The northern one, the Hini-Chalt-Yasin-Drosh fault is called Main Karakoram Thrust (MKT), (Tahirkheli et al., 1979). It separates the Kohistan arc from Eurasia. The southern one is traced along Babu Sar-Utla-Jijal-Shangla-Mingora and Khar, and has been named as Main Mantle Thrust (MMT) (Tahirkheli et al., 1979) along which the Kohistan island arc is wedged with Indo-Pakistan plate (Fig.1.1).

The rocks of the Main Mantle Thrust suture in the lower Swat are known as the Indus melange group (Kazmi et al., 1984) whereas in the Malakand and Mohmand agencies and district Charsadda they have been described as an ultramafic complex of Skhakot-Qila, Harichand and Dargai (Ahmad, 1982; Rafique et al., 1983). Here the sack name Skhakot Qila Ultramafic Complex (SQUC) has been used, instead. The rocks of the MMT suture comprise fragmented blocks derived from oceanic crust, volcanic arcs, trenches and continental margins ranging from Precambrian to Late Cretaceous in age. Figure 2 shows the distribution of ultramafic rocks in the study area in Malakand and Mohmand agencies and Charsadda district. This SQUC has an east-west strike with northward dip ranging from 60° to 90°, and is partly in contact with a series of low grade metasediments. The northern and southern boundaries of the complex are marked by north dipping thrusts. The main body of the ultramafic complex also contains shear zones. Dunite, peridotite, serpentinite and mafic rocks are the main rock types of the complex. Along shear zones, serpentinite asbestos, tremolite rock, talc-carbonate rock, carbonate-quartz rock, steatite and chlorite wall rock are found in the form of irregular to pod-like, elongated or tabular masses and veins transacting the ultramafic rocks.

1.2 LOCAL GEOLOGICAL SETTING

The Malakand Mohmand and Charsadda asbestos deposits are associated with a complex of dunite, harzbergite and chromite which extends from Skhakot Dargai to Mohmand agency for a linear belt of about 40 Km with a 2-5 Km width. The ultramafic complex has an east-west strike with a north-west dip ranging from 60 to 90 degrees and is partly in contact with a series of low grade (metasediments). Along the northern and western borders of the complex, the metasedimentary rocks are well exposed and consist mainly chlorite schist and phyllite, biotite muscovite- quartz schist and soapstone. A small elongated body of metagabbroic rock separates the ultramafic complex and schistose metasediments in west of Hero Shah. Another metagabbroic rock is exposed in the south of Usmankhel Garhi (Fig.1.2).

Nearly two third of the ultramafic mass is composed of harzbergite with small conformable but randomly spread outcrops of dunite rock. There are three dunite-harzbergite exposures which are partly or completely surrounded by peridotite (Fig.1.3). The peridotite is in turn surrounded by a narrow zone of serpentinite with asbestos occurring along the contact of ultramafic complex with metasediments and other enclosing rocks.

Most of the dunite outcrops are barren while at places chromite is concentrated to constitute chromitite rocks. The latter commonly exhibits layering but sometimes it occurs as compact bands and rarely as "a grape shot" ore. The entire ultramafic complex is sporadically traversed by thin pyroxenite dikes. At places veins of tremolite talc, tremolite, talc carbonate and quartz are abundant. (Rafique, 1984; Rafique et al., 1984; Uppal, 1972; Ahmed, 1978).

Fig. 1.1 Geological map of the Skhakot-Qila Ultramafic Complex, modified after Rafique (1984; map in side pocket).

Fig. 1.2 Geological map of the Skhakot-Qila Ultramafic Complex, modified after Shakirullah & Waleed Ahmed (1984; map in side pocket).

1.3 ASBESTOS OCCURRENCES

Asbestos mostly occur along the joints, shears and fractured planes (Fig.1.4). These deposits are being worked on hit and trial basis by the locals in the localities of Narai Obe, Behram Dheri, Qila, Hero Shah and Bucha. No detailed work has been done on the genesis, types and related health hazards of asbestos. The present work is aimed to map and classify all the asbestos deposit of the SQUC, define their petrogenesis and describe the health hazards associated with this mineral generally throughout the world and particularly here in northern Pakistan. Asbestos of variable quality occurs in the SQUC. During the present work asbestos have been collected from Behram Dheri, Qila, Narai Obe, Hero Shah, Newe Kili and Bucha.

Following is the description of the above occurrences:

1.3.1 Behram Dheri deposits

The mineralization near Behram Dheri is in District Charsadda. Asbestos is developed in shear zone and joints in dunites and serpentinite (Figs. 1.4a-c). These are light green to greenish white and having cross fiber. The mineralized veins are 2-5 cm to 11 cm thick with asbestos fiber attaining the size up to 20 cm. The mineralization has been noted in a zone which is about 700m long and 3-6m wide (Fig. 1.5). The shear zone trends N20°E and dip 65°NW.

Fig. 1.3. Contact between dunite and peridotite at Narai Obe.

a

b

c

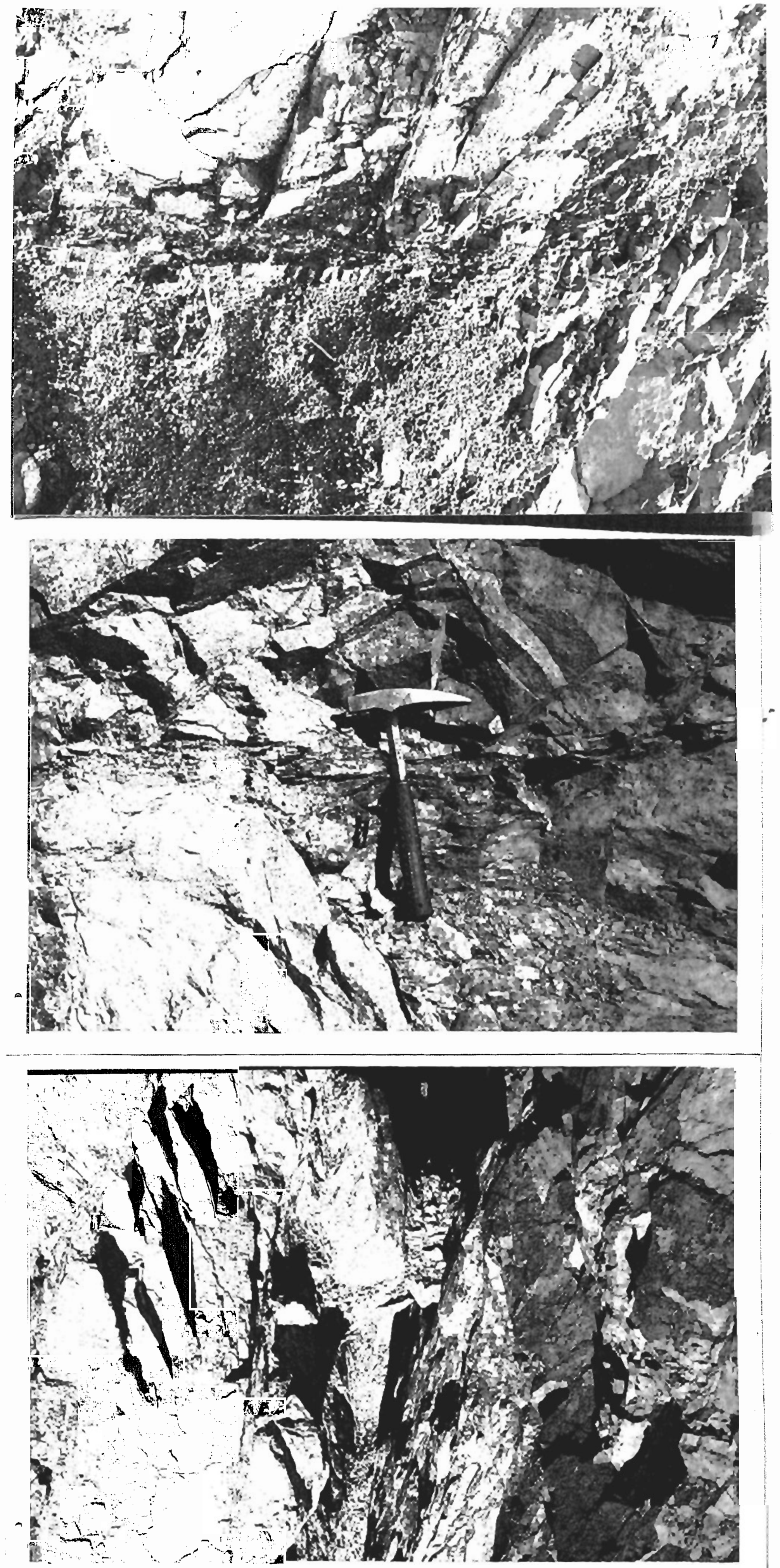


Fig. 1.4 (a-c) Asbestos along shear zones (a) and joints (b-c) at Behram Dheri, district Charsadda.

Fig 1.4d Asbestos mine at Behram Dheri, District Charsadda.

Fig. 1.5 Viewing from East to West, a 700 meters long asbestos-bearing shear zone (see arrows) at Behram Dheri.

1.3.2 Qila asbestos deposits

The mineralization is found near Qila, district Charsadda. The following two zones are noted.

a) The upper zone which is about 150m long and 3-6m wide with the asbestos veins ranging from 1-72 cm in thickness.

b) The lower zone, which is 300m long and 3-7m wide with asbestos veins in shear zones and joints (normally 1 cm in width). Asbestos from both zones are light yellowish green to greenish white having slip and cross fibers (Fig.1.6). The size of fiber is appreciable and the quality is good.

1.3.3 Narai Obe deposits

The Narai Obe deposits occur in Malakand Agency (Fig. 1.2). These deposits occur in an E-W extending zone of about 20-25m width. (Figs.1.7a-b). The asbestos is of grayish green in color and it is mostly cross fiber type. The country rock is harzbergite in contact with peridotite.

1.3.4 Hero Shah deposits

The mineralization is found near the village of Hero Shah in Malakand agency. Asbestos occurs at the contact of gabbro and serpentinite with schistose rocks (graphitic schist). The asbestos bearing zone is 62 meters long and 18-23 meters wide. It is extending east-west and dipping in north. The asbestos is white to brownish in colour and brittle, having cross fibers (Fig.1.8). The veins are 5-30 meters long and 5-8 cm wide.

1.3.5 Newe Kili deposits

Newi Kili deposits are the extension of the Prang Ghar deposits in Mohmand Agency. These deposits are in contact with gabbros and schistose rocks. The asbestos is of white, greenish and brown colours. The fibers are soft and are slip and cross types.

1.3.6 Bucha deposits

The Bucha deposits occur in dunites and serpentinites of Mohmand agency (Hamidullah, 19849. The asbestos is white in colour and is of cross and slip fiber types. The length of fiber varies from 1mm to 8 cm.

Beside the above localities, there are reports of more occurrences of asbestos in SQUC. Near Kuchian good quality deposits occur but are not easily accessible due to trible fueds. All the deposits are mined by the locals having no technical knowledge, and as a result the deposits are being wasted (cf. Fig. 1.4d). At Qila most of the mining is done through blasting. All the mines are now abandoned.

Another interesting and more dangerous aspect is that the locals are grinding flour and asbestos in the same grinding mill. They do not take any preventive measure to avoid inhaling the dust produced during crushing and grinding of asbestos.

Fig. 1.6. High quality fine fibers of asbestos from Qila, district Charsadda.

Fig. 1.7(a) Asbestos mines along shear zones and joints in ultramafic rocks, Narai Obe, Malakand agency.

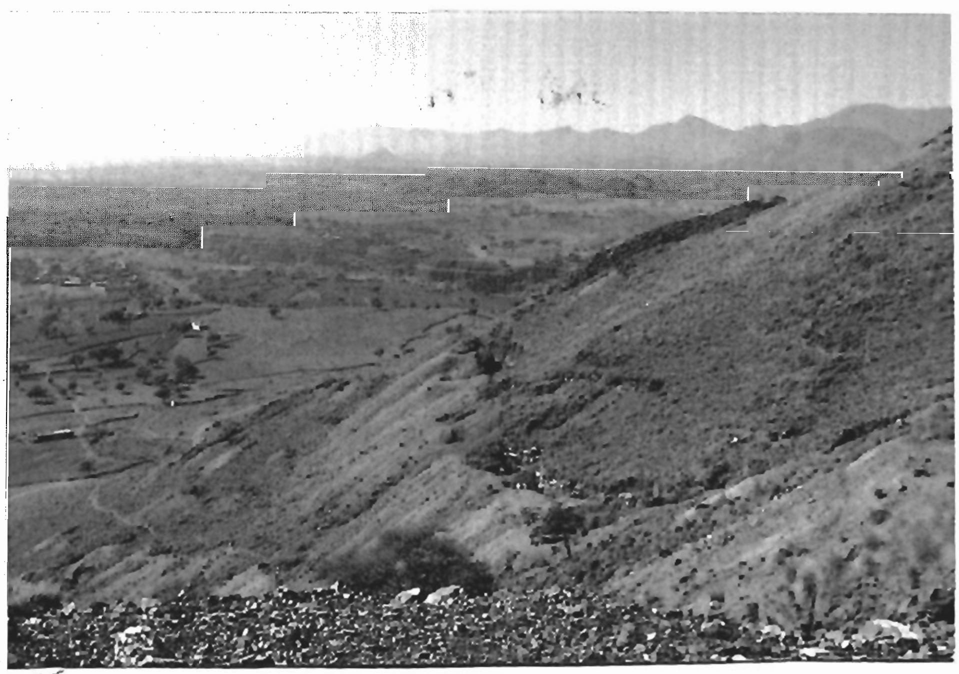


Fig. 1.7(b) A close up of the mines shown in Figure 1.7a.

Fig. 1.8 Asbestos veins along small joints and shears, at Hero Shah, Malakand agency.

Chapter 2

PETROGRAPHY

The petrography in conjunction with other aspects of rocks of the SQUC, with particular reference to the chromite-bearing ones, has been described by several workers, (Qaiser et al., 1970; Uppal, 1972; Ahmed, 1979; 1982). Mainly based on petrography, Rafique (1984) presented the geology of the ultramafic rocks from Utman Khel area - a western extension of the SQUC. In the recent studies samples were collected both from the main SQUC at Hero Shah, Narai Obe, Behram Dheri and Qila and from the Utman Khel extension, at Newe Kili and Bucha. The main concern of the current investigation was asbestos, therefore samples studied for petrography were collected mainly in the vicinities of asbestos mines. As mentioned by Uppal (1972), two third of the ultramafic rocks in the complex are dunite and peridotite. Other igneous and meta-igneous rocks are altered pyroxenite, serpentinite, chromitites, gabbroic rocks, certain meta-volcanics, steatite, talc-carbonate rock and carbonate-quartz rock.

Based on the current investigation and previous studies following are the major petrographic features of these rocks.

2.1 DUNITE

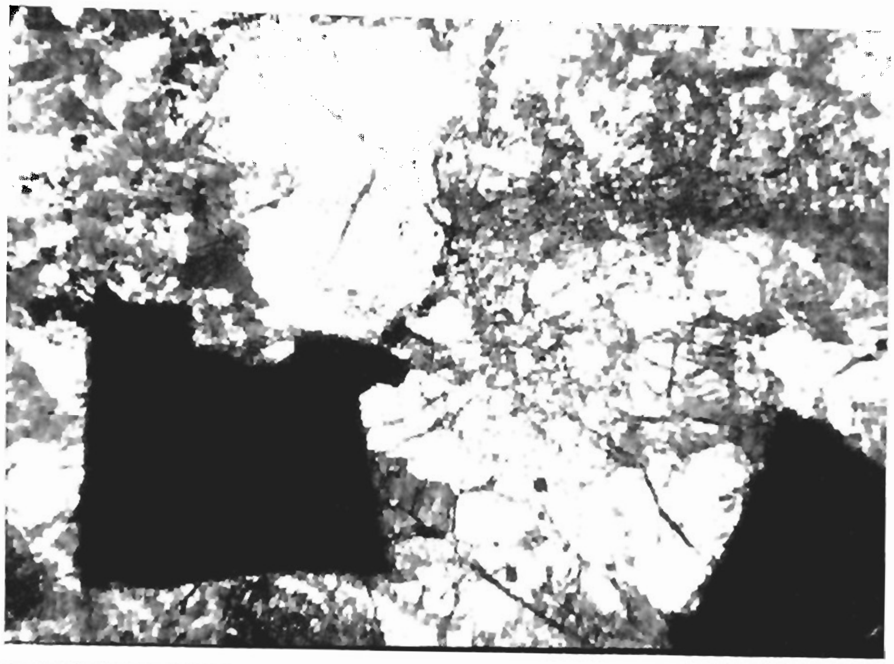
Dunite interlayered with peridotite is the dominant ultramafic member of the complex (Uppal, 1972). It is a medium to coarse-grained rock which contains >90% olivine (Fo_{88-92}), pyroxene 0-11% and opaque ore (mainly chromite) 0-5% (Fig. 2.1a-c) as primary constituents together with traces of serpentine, talc, chlorite and carbonate (see also Rafique, 1984). In relatively altered varieties 25-50% olivine has altered to serpentine and magnetite and rocks with >50 serpentine are rather classified as serpentinite than dunite (Table 2.1, samples NJ 11, 39, 43, 44). Olivine occurs in cores of chromate crystals which is again surrounded by olivine megacrysts, forming corona structure indicating that both these phases crystallized simultaneously. (Fig. 2.1b,c). Olivine, however, may have appeared on liquidous a little earlier than chromite.

Olivine alteration occurs in two ways. (a) To pseudomorphs of serpentine and magnetite perfectly retaining the original grain size and shape, with magnetite concentrating along cracks. In such cases alteration seems to be mainly due to addition of water with little involvement of directed pressure, as the pseudomorphs do not show any signs of deformation (Fig. 2.2a-c). At other places, i.e. closer to the vicinities of asbestos zones deformation becomes evident both in olivine and its pseudomorphs (Fig.2.3a-c). In such rocks alteration to fine-grained serpentine increase with crystals/ pseudomorphs slowly loosing their outlines (Fig.2.3c,d). (b) A second phase serpentinisation is also noticed along cracks, cross cutting both olivine and olivine pseudomorphs in the same rock. This phase seem to be associated with the addition of water related to the increasing directed pressure. Magnetite is generally associated with this serpentine too (plate 2.2a, b).

Dunite is also cross cut by quartzo-feldspathic veins and in certain instances the quartz crystals occur in deformed discontinuous patches along with olivine indicating that deformation occurred after the emplacement of these veins. Fibrous asbestos occurs in dunite (Fig.2.4) and its proportion increases towards the shear zones where these are mined.

2.2 SERPENTINITE

Rafique (1984) has classified serpentinites into massive and friable with the latter generally surrounding the former types. The former types contain relic olivine, olivine pseudomorphs, serpentine + magnetite, magnesite, chromite, brucite, chlorite and carbonate (Fig. 2.5a-d). In friable serpentinite serpentine occurs as very fine to large flakes (Fig. 2.5e). Chromite is associated in two different forms: patterned crystals initially associated with zoned olivine along zones, from which the olivine part has been completely serpentinized to large flaked serpentine (Fig 2.5a-c) and as small disseminated grains with relatively small flakes of serpentine (Fig. 2.5d-e). In the latter types the megacrysts of olivine pseudumorphs do not seem to have associated chromite crystallized in a similar fashion. Also the olivine pseudomorphs are indicating shearing due to directed stress. All possible gradations between dunite and serpentinite can be noticed (see Figs. 2-3; Table 2.1).



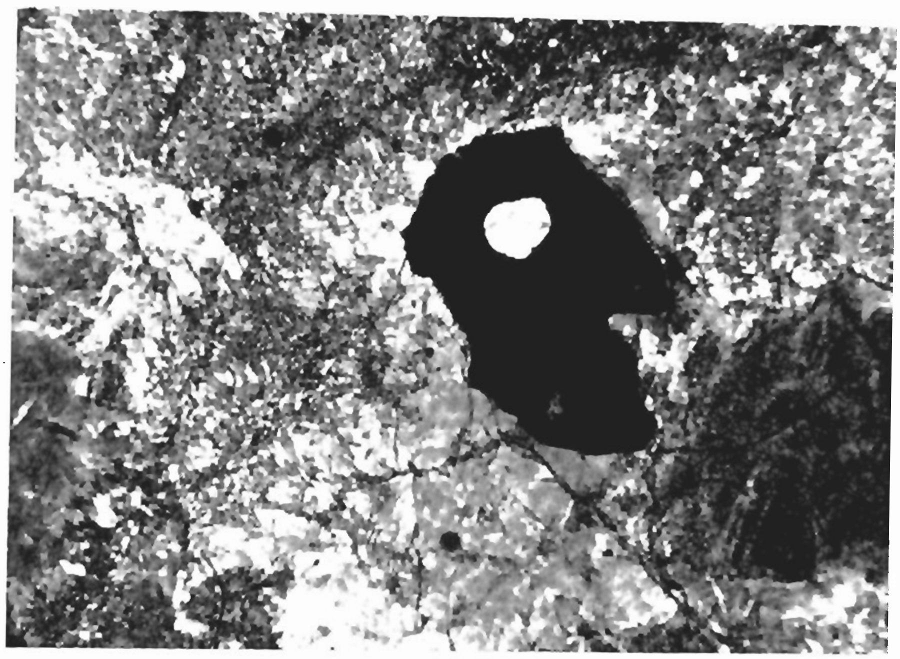


Fig. 2.1 (a-b) . Olivine and chromite cumulate crystals in dunites (NJ11 upper; NJ39 lower; from Behram Dheri and Narai Obe, respectively) . Olivine altering to serpentine and magnetite at (upper left corner) and occurring as core to chromite can be noticed in Figures 2.1b.(Fig. 2.1a-b: cross light x 2.5).

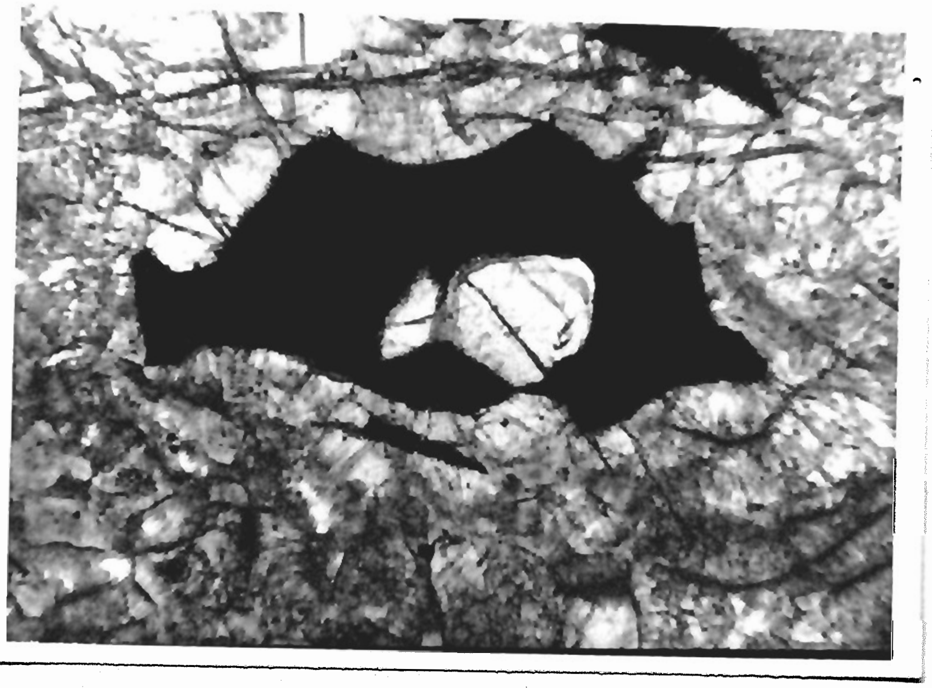


Fig. 2.1c. Olivine coronated by chromite which is again surrounded by olivine in dunite from Behram Dheri (Sample NJ 11, plain light x 2.5).

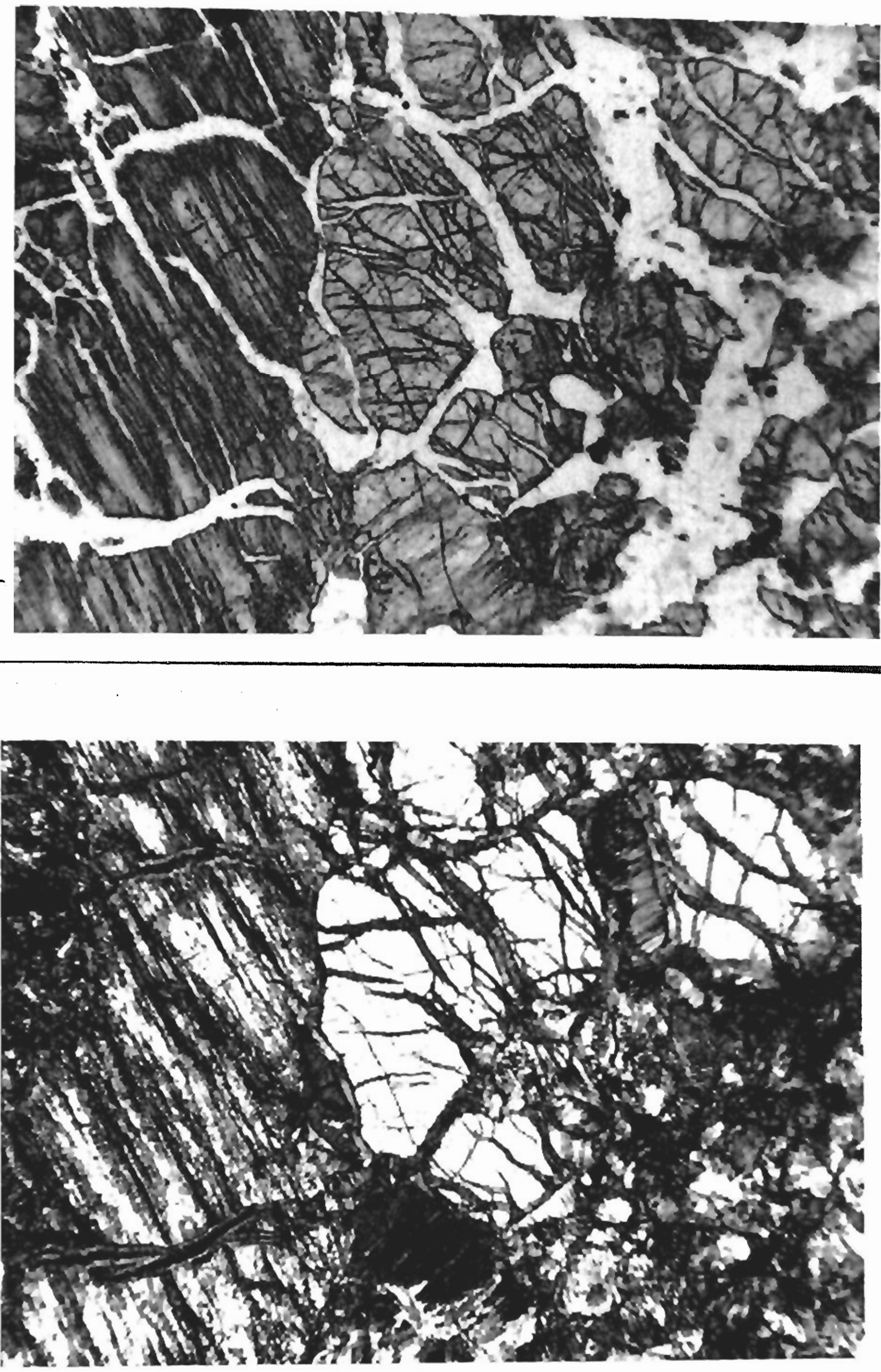


Fig 2.2 (a-b) Formation of pseudomorphs (left) after olivine (right) in dunite from Behram Dheri. A second stage of alteration along cracks both in olivine and their pseumorphs is visible both in plain (upper) and cross (lower) lights. (Sample NJ12).

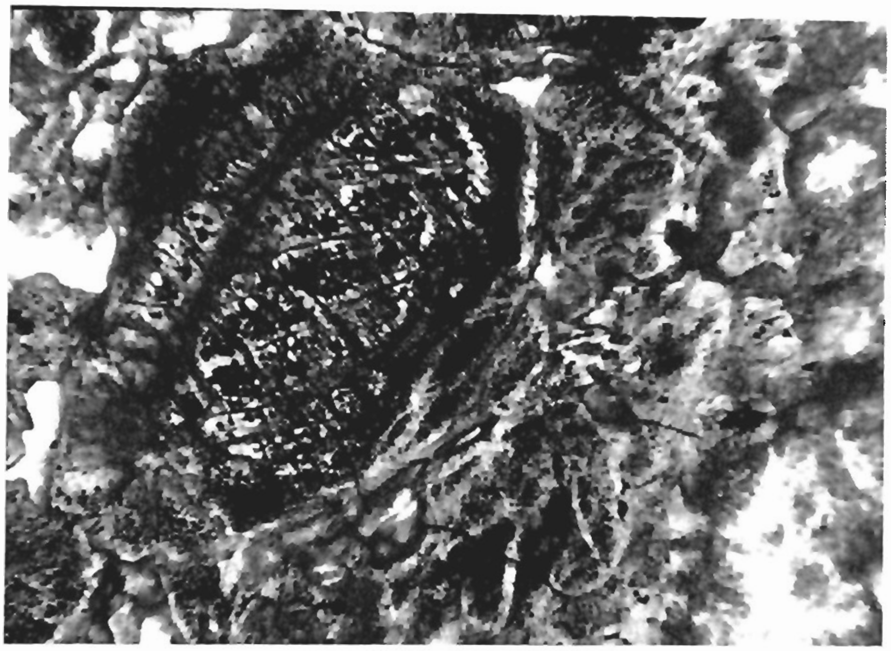


Fig. 2.2c. Complete obliteration of olivine in dunite from Behram Dheri. Olivine pseudomorphs indicating serpentinization and magnetization can be seen. The fine grained white stuff on the right is magnesite and talc, indicating a high degree of alteration and mylonization in shear zones (plain light x 2.5; Sample NJ 5).

Fig. 2.3. (a) Olivine, needles of serpentine and chromite in the ultramafic rocks of Bucha (B102). The white material is talc associated with magnesite. Locality, Bucha, Mohmand agency. Plain light x 2.5.

Fig. 2.3. (b) Banded pseudomorphs of olivine, indicating alteration due to deformation in the presence of water in serpentinite from Behram Dheri (plain light x 2.5; sample NJ 17).

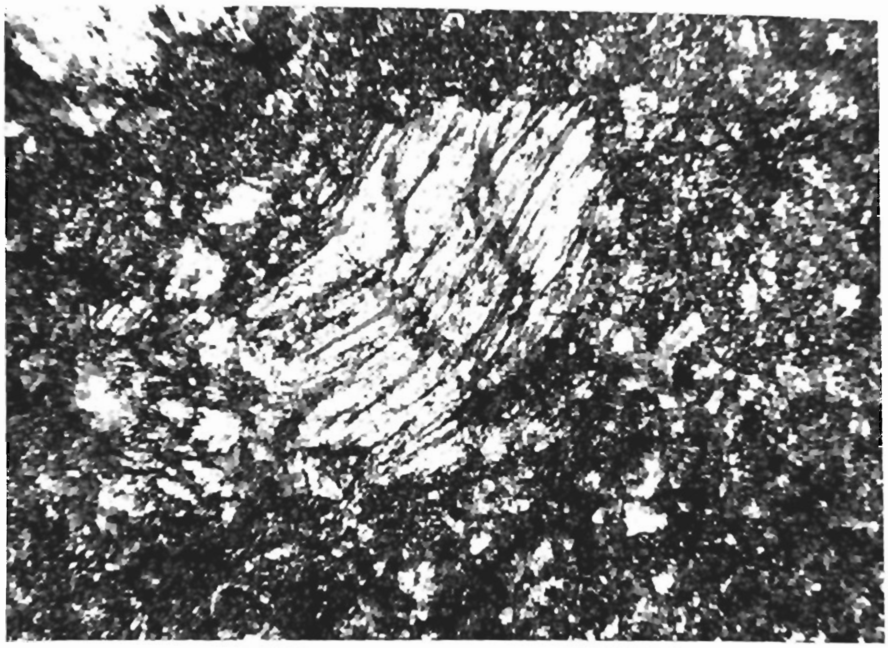


Fig. 2.3 (c) Sample NJ 12 from Behram Dheri indicating similar features as shown in Figure 2.3b, in cross light (x 2.5). Fine grained serpentine surrounding the pseudomorphs is visible.

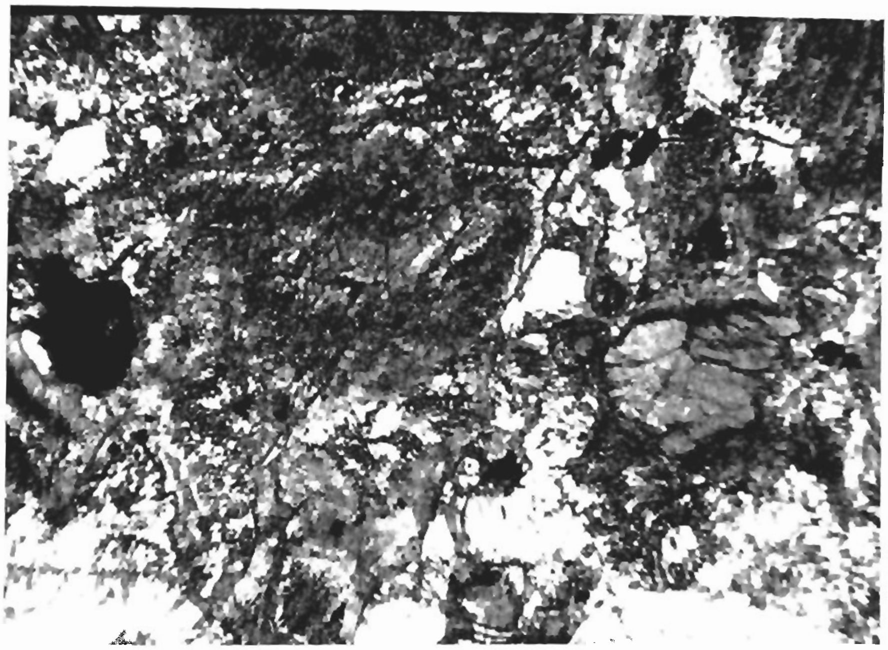


Fig. 2.3 (d) Fresh relic olivine (pink), olivine pseudomorphs (dark brown), chromite (black) and serpentine (gray and white) in serpentinite from Behram Dheri. (Cross light x 2.5; Sample NJ16).

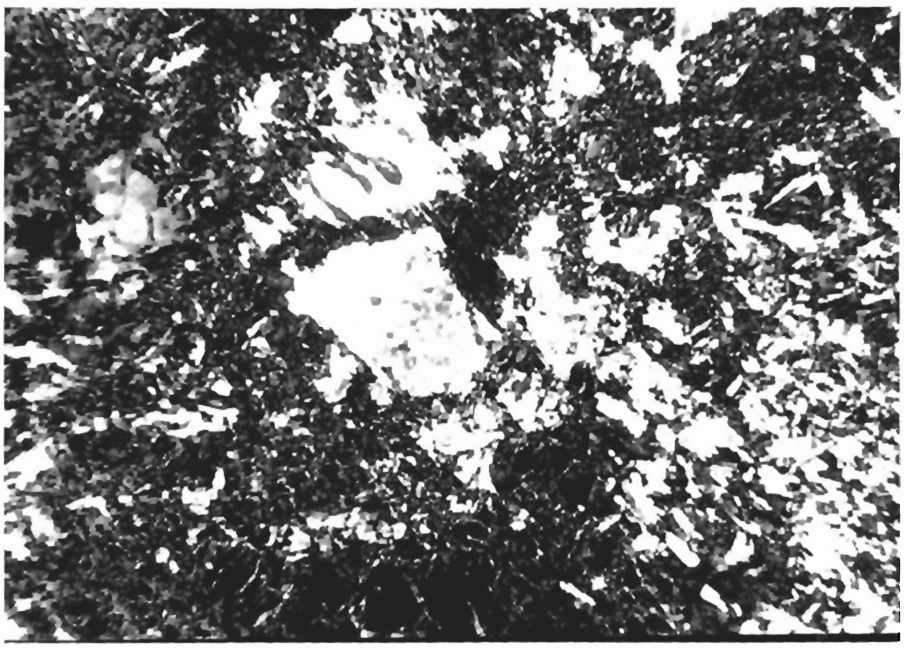


Fig. 2.4 Quartzo-feldspathic veins deformed along with olivine and serpentine in serpentinised peridotite from Qila (Cross light x 2.5; Sample NJ 35).

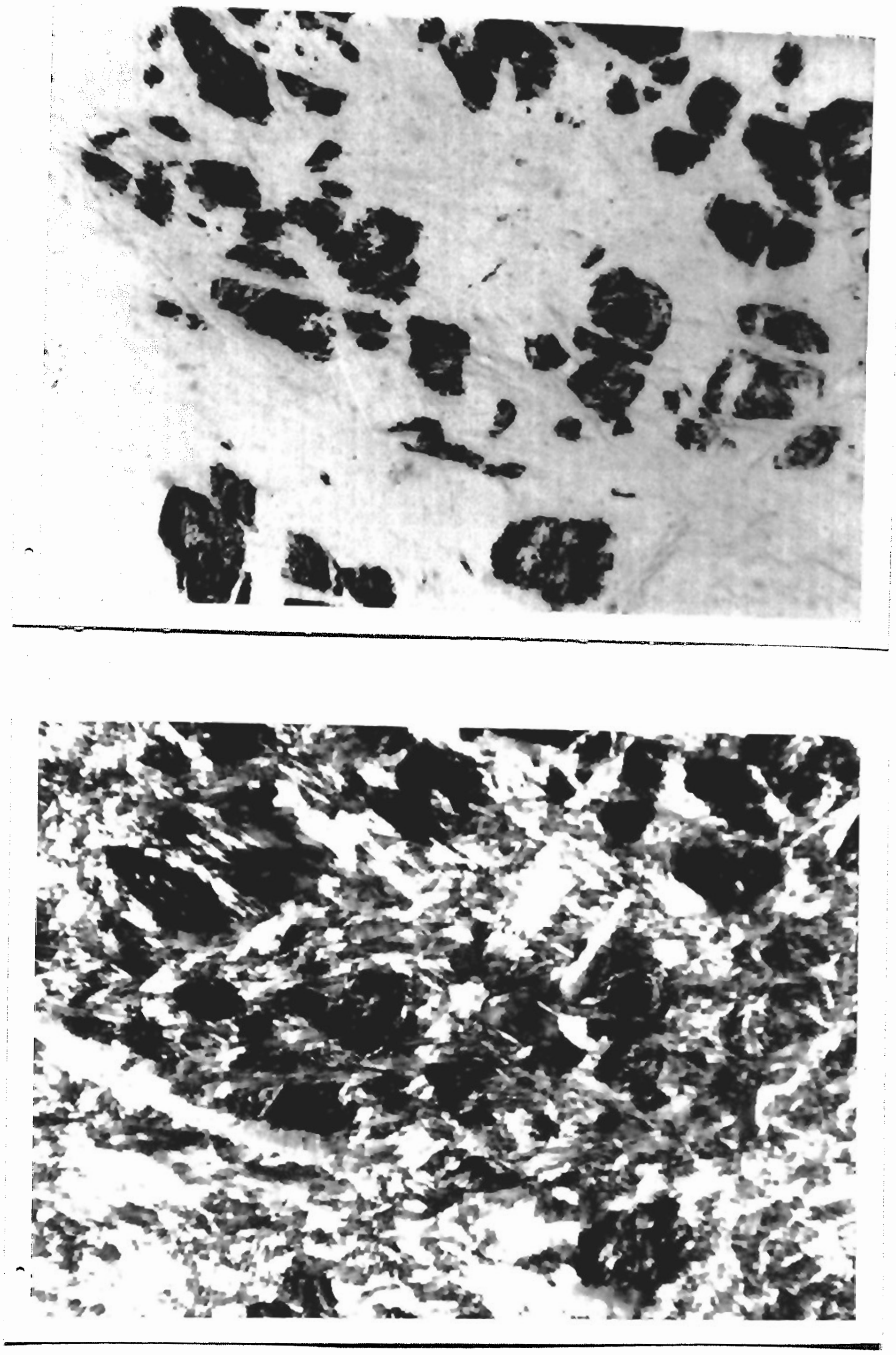


Fig 2.5 (a-b) Olivine completely altered to serpentine leaving behind unaltered chromite. The chromite grains indicate that these have crystallized along circular zones in olivine; serpentinite from Bucha; plain light (a) cross light (b); x 2.5; sample B92.

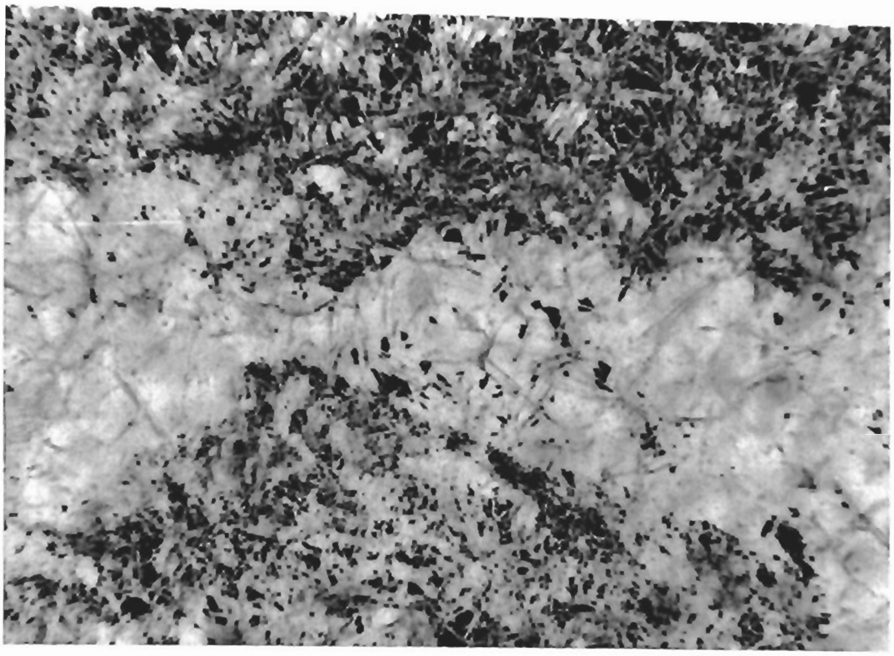


Fig 2.5 (c) Banded serpentinite from Bucha, Mohmand agency, indicating chromite-rich and poor bands. Other minerals presumed were olivine and pyroxene now all altered to serpentine. (plain light x 2.5; sample B104).

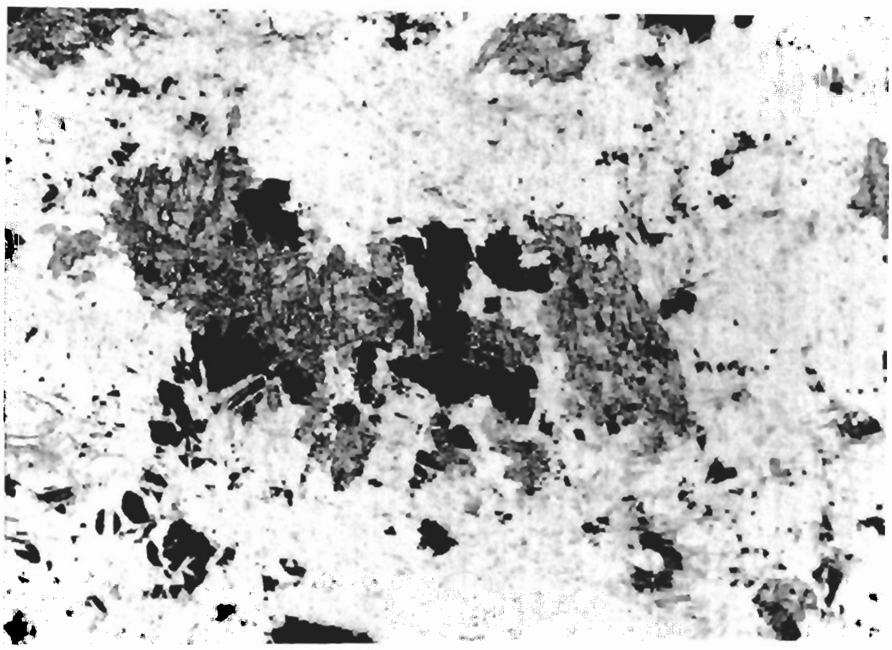


Fig 2.5 (d) Serpentine (light brown), chromite (black) and magnesite (dark brown, grainular) in serpentinite from Bucha, Mohmand Agency (plain light x 2.5; sample B108).

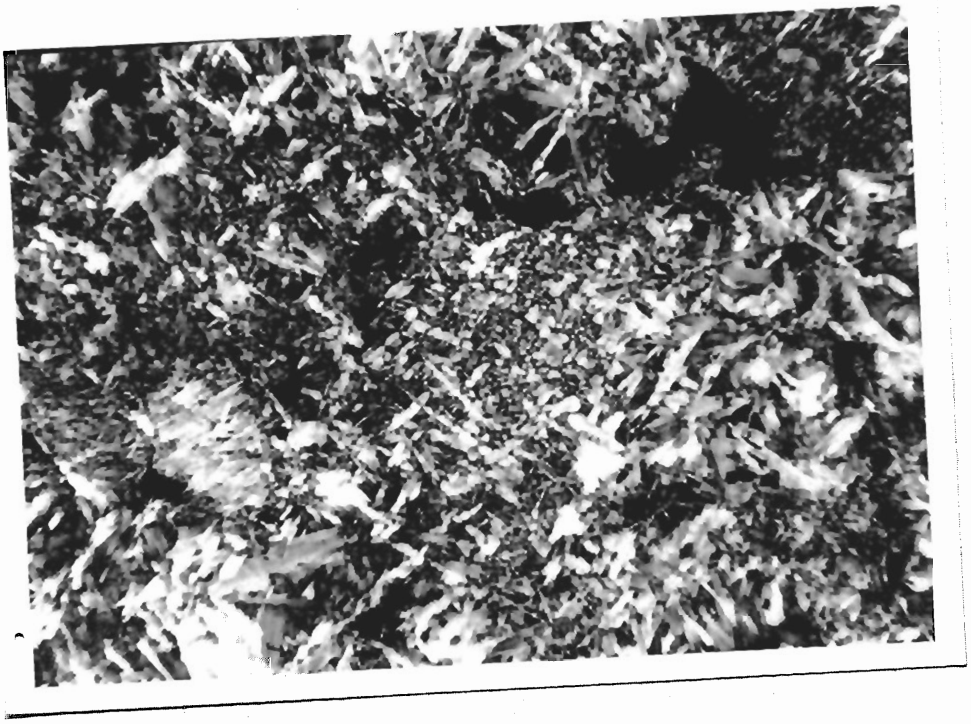


Fig 2.5 (e) Typical serpentinite from Bucha, Mohmand agency. Relics of olivine can be seen in the middle. Scattered chromite is also visible surrounding the olivine grain. (Cross ligh x 2.5; Sample B81).

2.3 PERIDOTITE

Samples from Behram Dheri containing 10-15% pyroxene, mostly clinopyroxene with dominant olivine or olivine pseudomorphs are classified as peridotite (Table 2.1; NJ 5,16). Other constituents in these type are chromite, magnetite, carbonate, talc and accessory plagioclase. Olivine is similar to that described in dunite and has partially or totally altered to serpentine (pseudomorphs and flaky both). On the basis of the presence of both clino- and ortho-pyroxenes, peridotites can be classified as wehrlite and harzburgite.

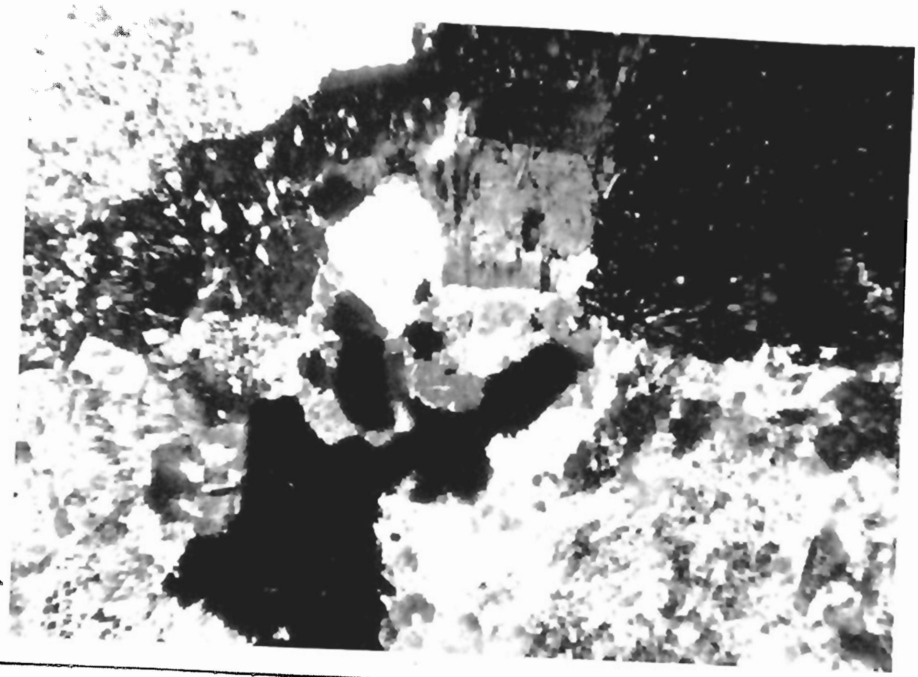
Pyroxene in peridotite is kinked and banded and also shows schiller structure providing evidences of cataclasis. The kinked pyroxene show wavy extinction (Figs.2.6a, b).

2.4 MAFIC ROCKS

Mafic rocks include meta-gabbros and meta-volcanics. The former are coarse grained rocks exposed at Rangmena, Kawal, Kotagai, Gumbatai and Lakarai, containing plagioclase $_{(An_{65-73})}$ (50-60%), clinopyroxene (15-20%), orthopyroxene (5-8%), biotite (1-4%) and opaque ore (2%). At Behram Dheri hornblende-gabbro occurs which consists hornblende (50%) and plagioclase (45%) with 5% opaque ore. Hornblende is partially chloritized and plagioclase has turned cloudy and epidotized. Opaque ore is both chromite and magnetite. The latter seems to be a by-product of the chloritization of hornblende

(Fig. 2.7a-c; Table 2.1-NJ47). Similar rocks are also exposed at Bucha at the southern extremity of the complex containing fresh hornblende crystals with plagioclase set in relatively finer grained matrix of plagioclase, hornblende and epidote (Fig. 2.8a-b; sample B101). Considering its porphyritic appearance this rock can be classified as porphyritic microgabbro. Associated with these microgabbros are more fine-grained rocks in which plagioclase phenocrysts containing clinopyroxene core are set in a highly chloritized ferromagnesian matrix. The texture of these mafic rocks seems to be mainly obliterated by chloritization with chlorite developed on plagioclase probably at the expense of plagioclase + magnetite or other ferromagnesian minerals like pyroxene sandwiched in the plagioclase crystals. Fresh pyroxene grains in the cores of plagioclase crystal indicate that the order of primary crystallization was pyroxene - plagioclase. In certain sections of these rocks plagioclase seem to be like micropillows lying over each other in a paste of magma having adopted ropy structure and now represented mostly by chloritic minerals (Fig.2.8c, d). Rutile is also noticed in these meta-volcanics (Fig.2.9a, b).

As mentioned earlier other significant rocks associated with ultramafic and mafic types are, steatite, talc-carbonate rocks and carbonate quartz rocks.



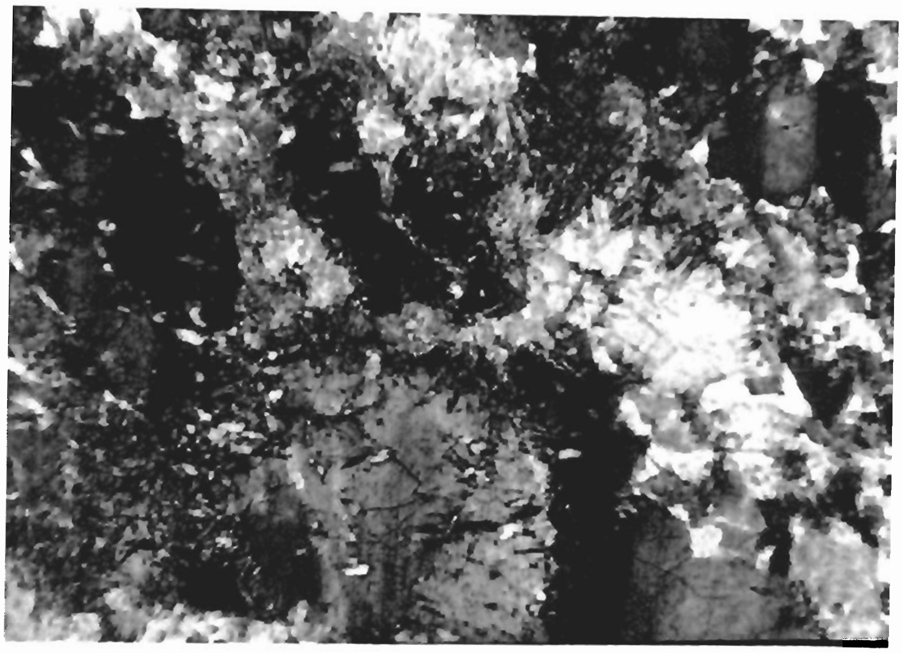


Fig 2.6. (a-b). Pyroxene and chromite in altered pyroxenite from Behram Dheri. Schiller structure and kinking can be notice in these rocks. Cross light x 2.5; Sample NJ5.

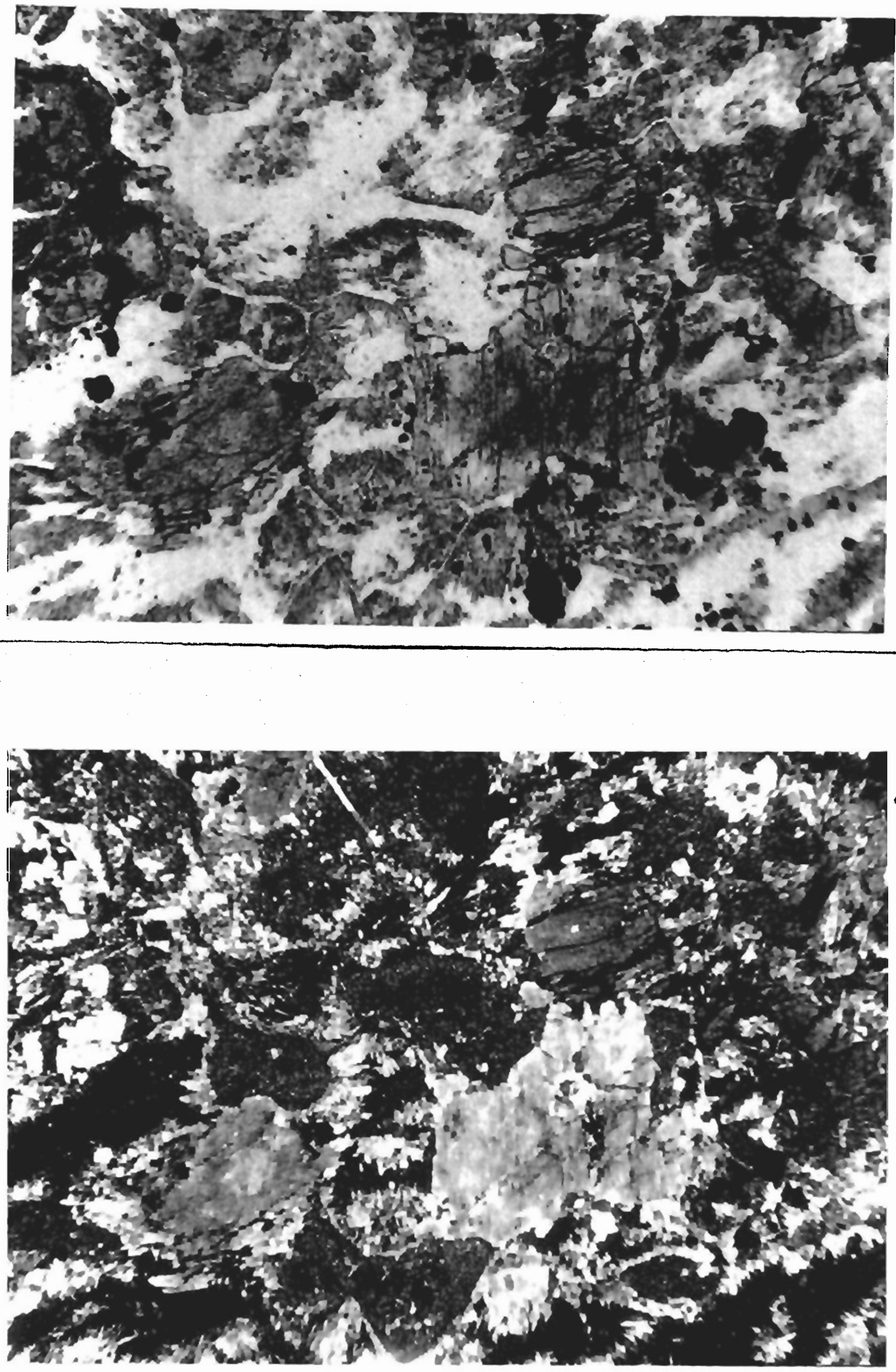


Fig. 2.7 (a-b). Pyroxene and plagioclase with chromite in metagabbro from Hero Shah. (upper-plain light; lower- coss light; both x 2.5; sample NJ 47).

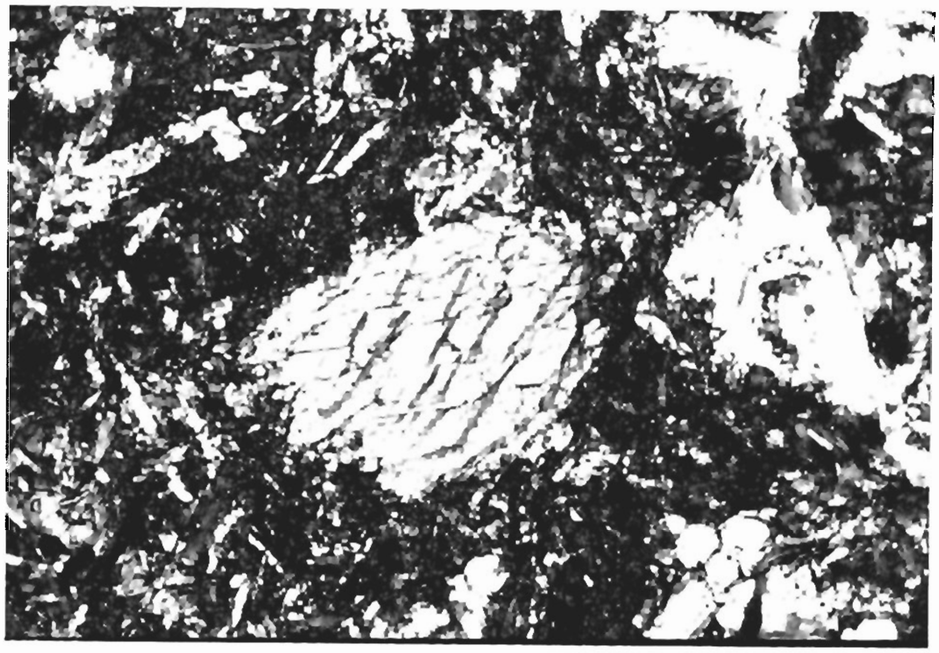
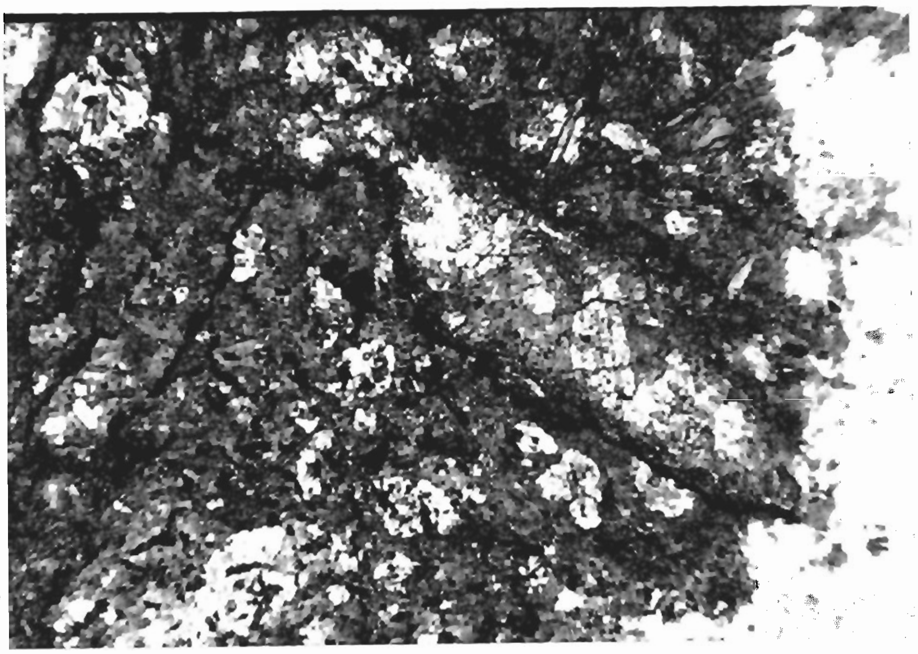


Fig. 2.7 (c) Hornblende phenocryst in microgabbro from Bucha (B101). cross light x 2.5.



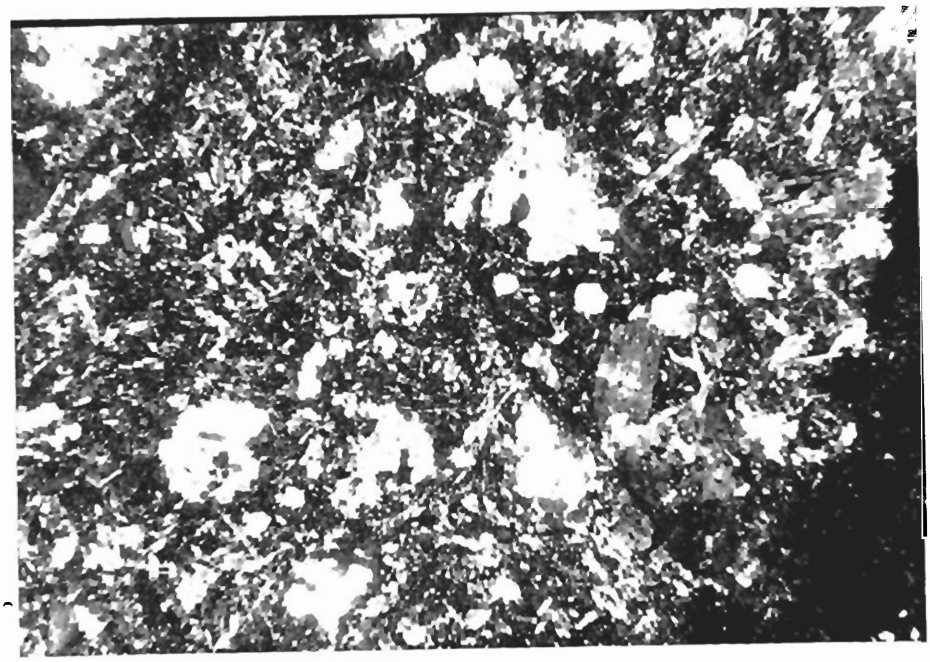
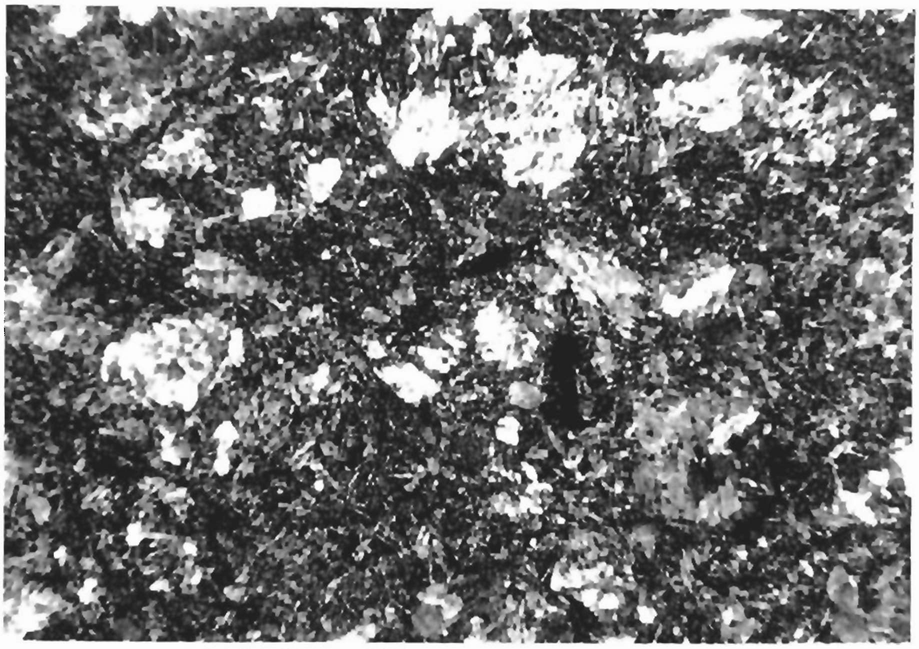


Fig. 2.8. (a-b) Epidotised plagioclase occrring as phenocryst and in the ground mass of microgabbro from Bucha (B101). Relic pyroxene can be noticed in the core of plagioclase phenocryst. Other minerals are quartz and chlorite after farromagnesium minerals in the groundmass . Plain light (a), Cross light (b); both x 2.5.



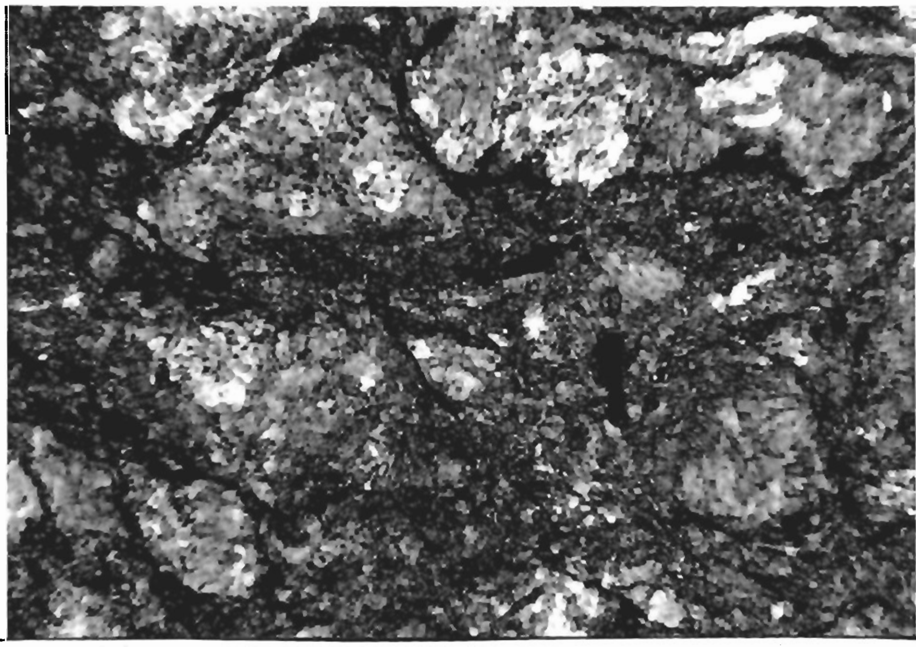
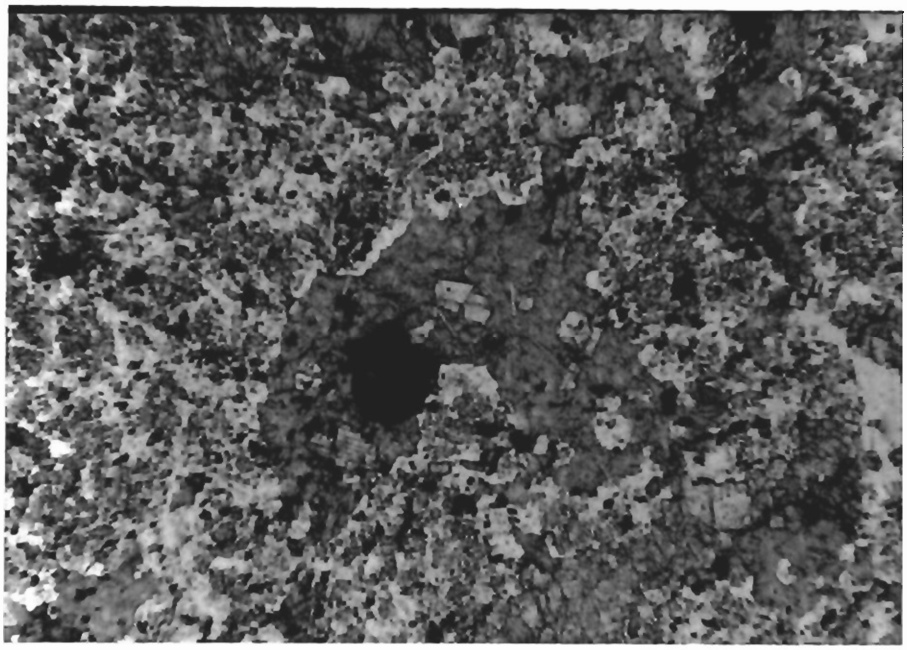


Fig. 2.8. (c-d). Texture of microgabbro from Bucha. Epidotized plagioclase and chloritised ferromagnesium mierals occur in this rock; (c-plain light; d- cross light; both x 2.5; sample B101).



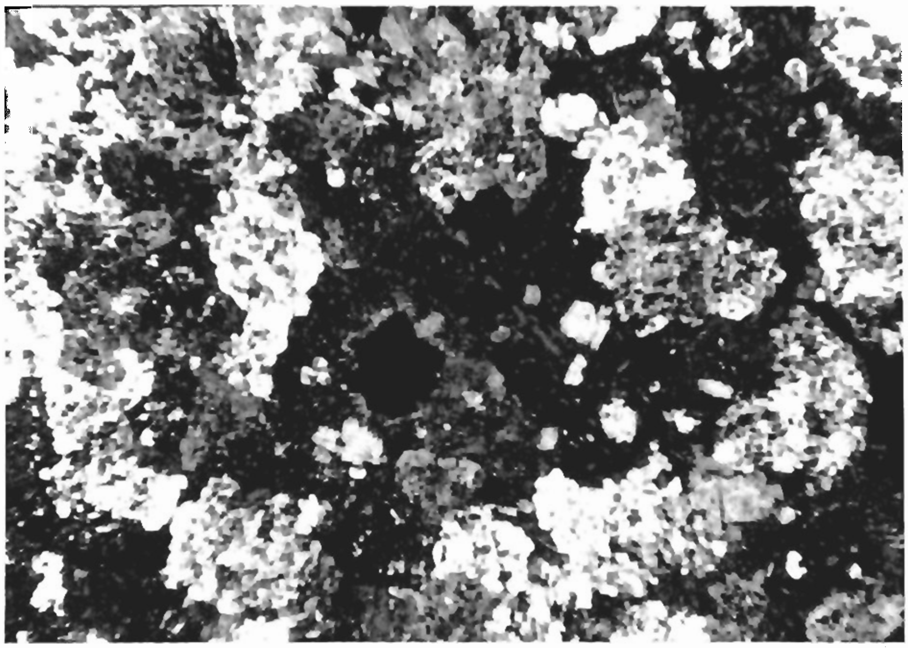


Fig 2.9 (a-b) Chloritised hornblende with rutile, cloudy plagioclase and epidote. The hornblende could be primary as in Figure 2.7c. (upper-plain light, lower-cross light; both x 2.5; sample B101).

Table 2.1 showing modal compositions of rocks from SQUC.

Sample No.→	B81	B92	B100	B101	B102	B104	B105	B106	B107,8,10,11,12,15,18,22,24	B123	P15	P22	P53	NJ5
Olivine					20									10
Pseudomorphs	5							5						10
Serpentine	90	93			70	93	95	90	92					65
Magnetite														5
Orthopyroxene					5									15
Clinopyroxene			15	20						25	20		20	
Opaque														
Chromite	5	7			5	7	5	5	8					
Plagioclase			65	60						60	55	50	60	
Crysotile														
Tremolite														
Antigorite														
Hornblende			10	10						5	5		5	
Chlorite			5	5						5	5	40	5	
Calcite														2
Epidote			5	5						5	5	10	5	1
Sphene			Tr	Tr						Tr	Tr	TR	Tr	

Localities of samples:
B = Bucha; P = Prang Ghar; NJ 1-23 from Behram Dheri; NJ 24-36 from Qila; NJ 37-44 from Narai Obe; NJ 46-59 from Hero Shah

Table 2.1 continued

Sample No.→	NJ11	NJ12	NJ15	NJ 16	NJ17 NJ 20	NJ 26	NJ32	NJ 35	NJ39	NJ 36	NJ43	NJ 44	NJ46	NJ47	NJ59
Olivine	70	55		2		25			85	20	50	75			
Pseudomorphs		35		60	50			35	15						
Serpentine	15			5	50	70		35		75	50	25			100
Magnetite	2							10							
Orthopyroxene	5			10			3	10							
Clinopyroxene				20			2	10							
Opaque														20	
Chromite	15		15			5	1	5		5			15		
Plagioclase				2										50	
Crysotile			85				45						85		
Tremolite															
Antigorite							45								
Hornblende														30	
Chlorite															
Calcite	2			1											
Epidote	1														
Sphene															

Chapter 3

PETROCHEMISTRY

3.1 AFFINITY DISCRIMINATION

The petrographic classification of the various rock types described in the last chapter is reflected in their chemical composition. Except the two serpentinite samples showing alkalis between 4-5 wt.% and SiO_2 between 35-52%, all the ultramafic rock plot below the boundaries defined for basaltic rocks on the alkali vs. SiO_2 classification plot of Cox et al. (1978), indicating their cumulate nature. On the other hand the gabbros, microgabbro and volcanic rocks (Table 3.1-B100, 118,123, P14a, 15, 22, 53, 57) plot in the fields defined for basalt, picric basalt and one in the field of andesitic basalt (Fig.3.1).

On an AFM plot dunites and peridotite plot in the ultramafic ophiolite field while the gabbros, microgabbro and basalt occur in fields of island arc cumulates and non-cumulates (Fig.3.2). On the MgO - FeO* - Al_2O_3 (Fig.3.3) plot most of the mafic ultramafic rocks stretch from the MgO-rich corner towards the field defined for ocean ridge basalts which is also occupied by the microgabbro and indicating their oceanic characters and evolution through fractionation.

On the CaO-Al_2O_3 - MgO (Fig.3.4) plot most of the ultramafic rocks occur in the fields of ultramafic cumulates and metamorphic ultramafic cumulates. The mafic rocks mostly occur within or close to the field of mafic cumulates.

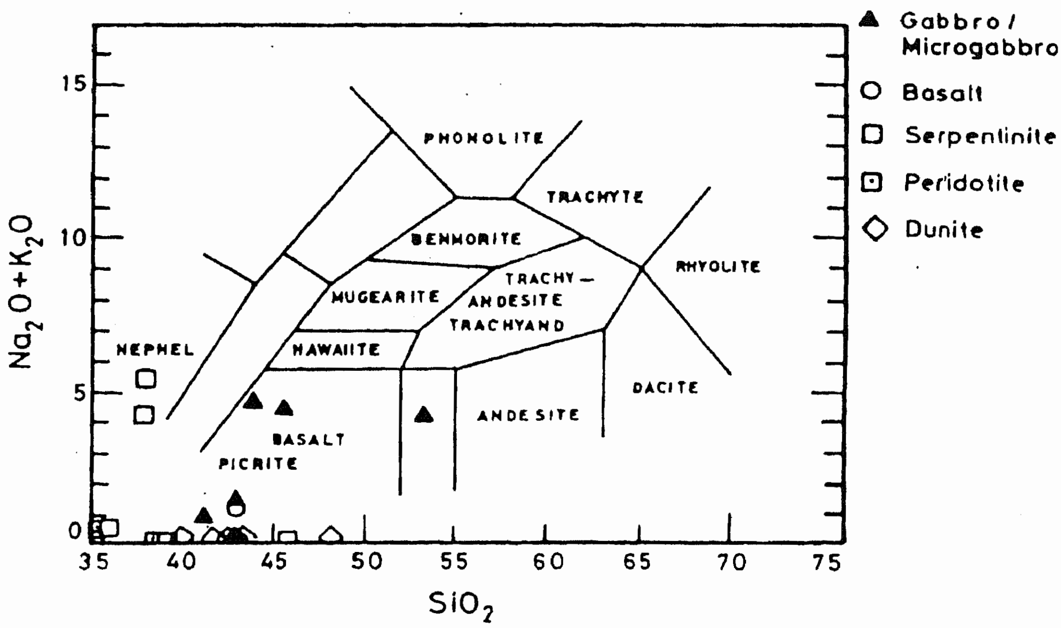


Fig. 3.1. Alkali vs. SiO_2 classification diagram of rocks from SQUC. Fields after Cox et al., (1979)

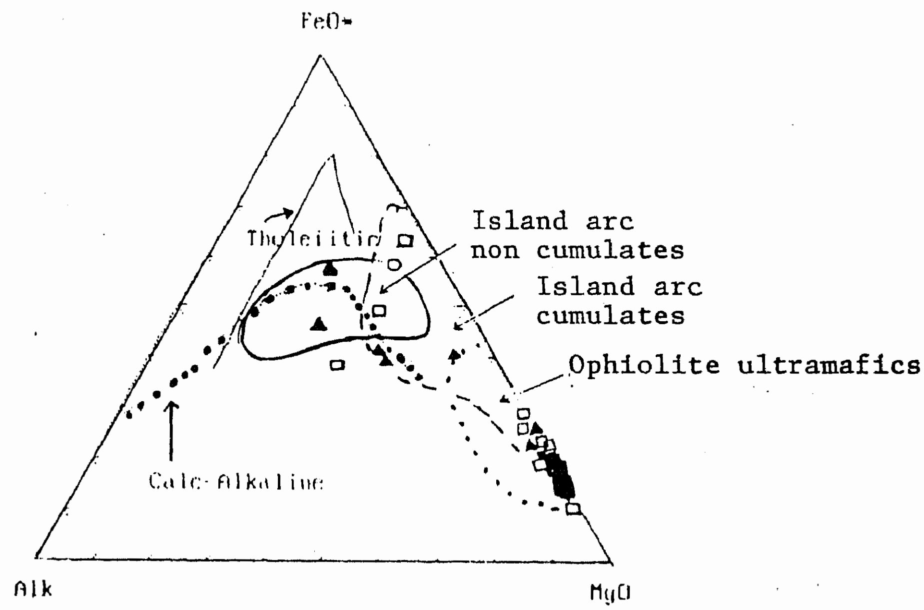


Fig. 3.2. AFM plot of rocks from SQUC. Fields after Irvine and Baragar (1971).

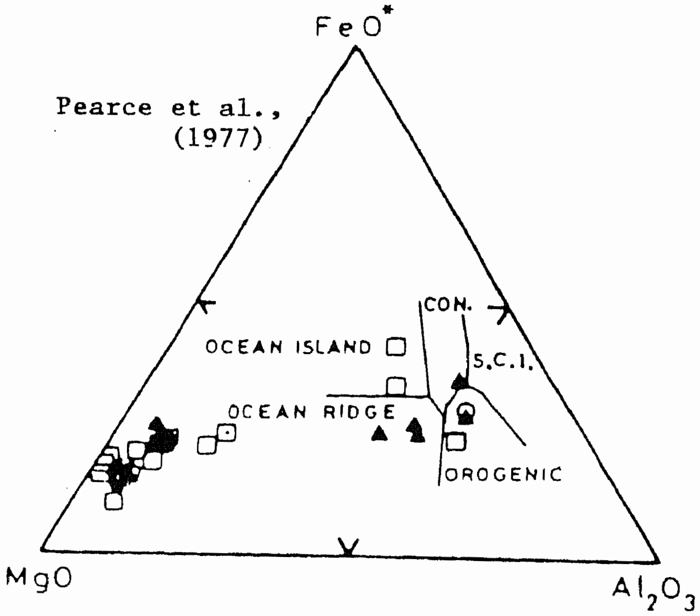


Fig. 3.3. Tectonic discrimination plot of the SQUC on the basis of MgO-FeO*-Al_2O_3. Fields after Pearce et al., (1977).

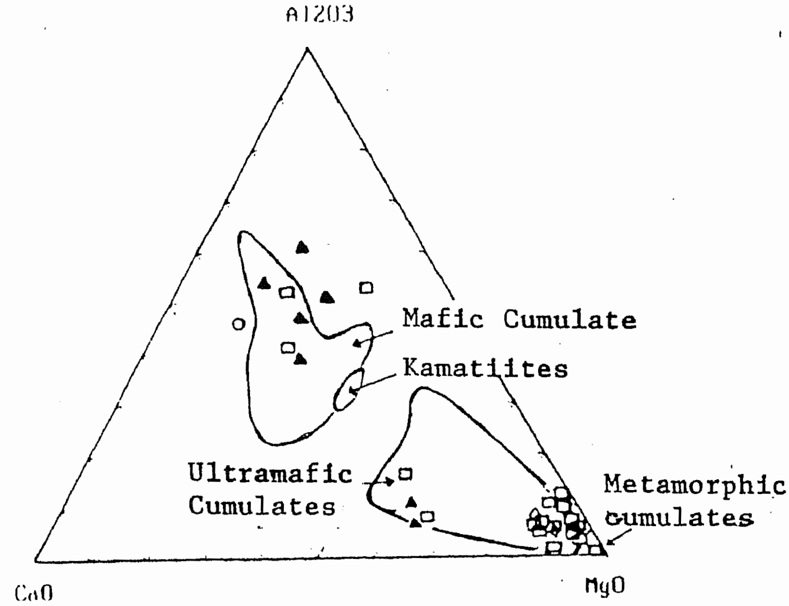


Fig. 3.4. Tectonic discrimination plot of the SQUC on the basis of CaO-Al_2O_3-MgO. Fields after Coleman (1983).

3.2. MAJOR ELEMENT CHEMISTRY

On the MgO vs. Oxide plots (Fig.3.5), the data though generally show scatter however SiO_2, CaO, Al_2O_3, TiO_2, MnO and K_2O have negative correlations with MgO. A gap between the mafic and ultramafic mafic rock exists which may be related to sampling gap or more typically to the appearance of plagioclase as one of the dominant minerals on liquidous in the former types. This gap may also be related to a partial genetic disconfirmity between the mafic and ultramafic rocks as would be expected from a collage of an ophiolitic melange zone. The Al_2O_3 vs MgO plot show a better correlation than the others with a R^2 0.8977 indicating the absence of plagioclase as a dominant phase on the liquidous. The CaO vs MgO plot has an R^2 0.5697 with a higher scatter than Al_2O_3 vs MgO, indicating the distribution of CaO both in calcic pyroxene and the residual liquid. The Al_2O_3 vs MgO plot is one evidence that the two sets of rocks are most probably related to each other either by partial melting and/or crystallization differentiation. The scatters in other plots reflects most probably contamination during serpentinization and other alteration processes related to tectonic events. The presence of carbonate and quartzofeldspathic veins confirms these transformations.

3.3. CMAS PLOTS

In a projection from Opx (MS) to Ol (M_2S)-Pl (CAS_2)-Di (CMS_2) most of the serpentinites, partially altered dunites and peridotite follow a linear trend perpendicular to the Ol- Pl join, close to the Ol corner and away from the triangle, indicating olivine fractionation and a systematic variation in the chemistry (Fig.3.6). The microgabbros follow a general trend from the Pl apex towards the Opx position and then turning towards the dunites trend (through a couple of serpentinites) indicating a continuation in chemistry of the two sets of rocks (at least the course gained facies). The mafic rocks indicate orthopyroxene + plagioclase fractionation as the dominant controlling phenomenon. Certain serpentinites, one partially altered dunite and one peridotite sample lie close to Pl corner. These samples may contain a large proportion of plagioclase but their extensive alteration does not let this to be confirmed petrographically. In addition these samples are also carbonated, some of them extensively, and their greater affinities towards Pl corner may be related to this phenomenon. It is worth noticing that the microgabbros and basalt samples plot close to the Pl apex indicating a high degree of plagioclase fractionation.

In a projection from Di to Ol-Pl-Qtz (S) the gap noticed between the mafic and ultramafic groups on oxide MgO plots is more visible (Fig.3.7); most of the ultramafic rocks lie close to the Ol corner and the basic ones close to the Pl corner along the Ol-Pl join. Both show limited affinities towards Di.

These observations indicate the data can be chemically divided into two groups, (i) ultramafic rocks with a dominant olivine fractionation and limited incorporation of Opx and/or Cpx, on the liquidous and (ii) the mafic rocks with dominant orthopyroxene and plagioclase fractionation. Considering petrographic characters this group can be further divided into two groups, (a) the microgabbros dominated by plagioclase + orthopyroxene fractionation and may be possibly termed micronorites rather than microgabbros, and (b) the microgabbros and basaltic member indicating the dominant plagioclase fractionation.

Similar conclusions can be drawn when those data were plotted on other projection of O'Hara (1976) and in CMAS projection devised by Cawthorn and O'Hara (1976) and Grove et al., (1982; Fig. 3.8, 3.9).

3.4 TRACE ELEMENT CHEMISTRY

It is difficult to utilize the meager trace element data for major conclusion, however, the available concentrations and their systematics support the conclusion drawn from major element data. The Ni content of 2000-3000 ppm in ultramafic and >1000 ppm in basic rock and a positive correlation between Ni and MgO (Fig. 3.10a) indicating olivine fractionation. Ni values >2000ppm in dunites and peridotite are typical of alpine type peridotite (see Scotford & William, 1983). Co also shows a positive correlation with MgO (Fig. 3.10d) and can be related to olivine fractionation (see Sato, 1977; Hamidullah & Bowes, 1987). Cr shows concentration between 1000-6000 ppm and higher concentration are expected in rocks rich in chromite. Any discrimination from layered complexes on an basis of Cr content may not be useful because of the accumulation of chromites found in both types of ultramafic complex. Cu vs. MgO plot shows a negative correlation which may suggest the concentration of Cu in residual liquids and its incompatible behaviour.

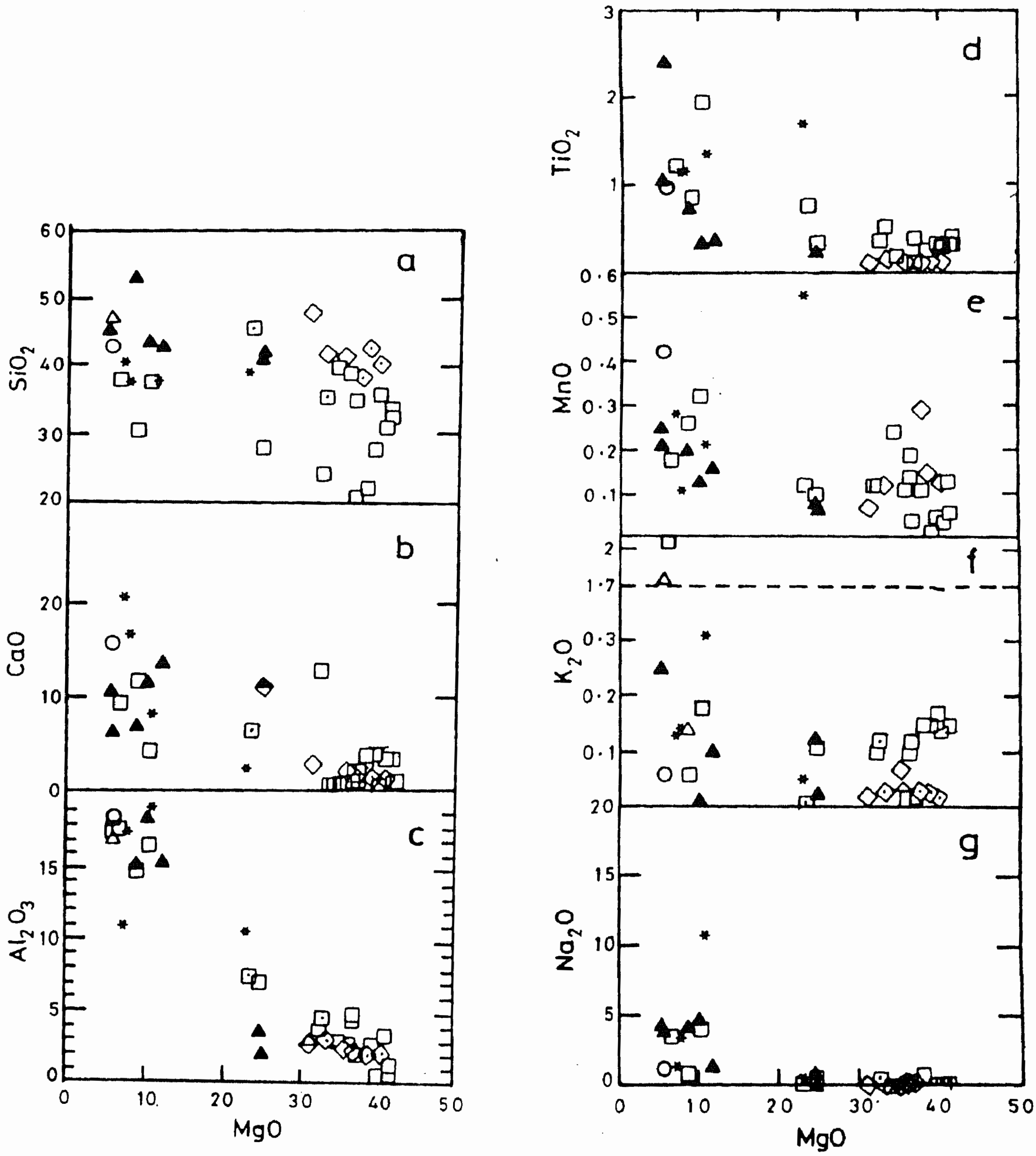


Fig. 3.5 (a-g). SiO_2, CaO, Al_2O_3, TiO_2, MnO, K_2O and Na_2O vs MgO plots of rocks from SQUC; symbols as in Figure 3.1.

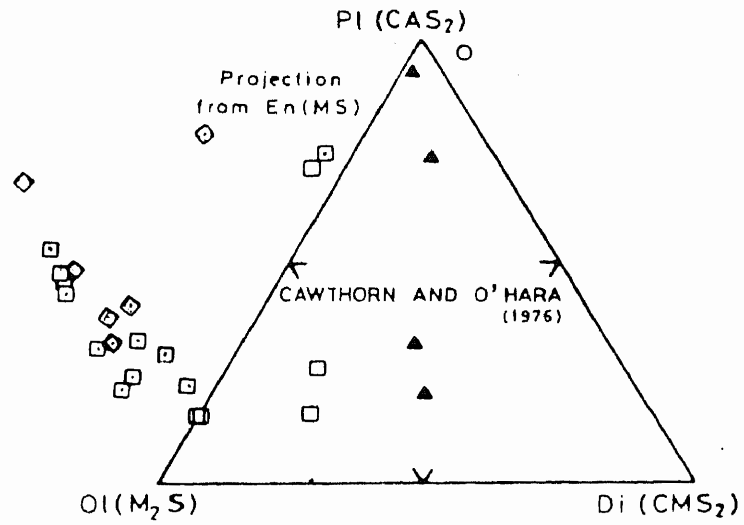


Fig. 3.6. Compositional variation of rocks from the SQUC shown in a projection from MS into M_2S-CAS_2-CMS_2 (En into Ol-Pl-Di) plane of the CMAS quadrilateral of O'Hara (1968)

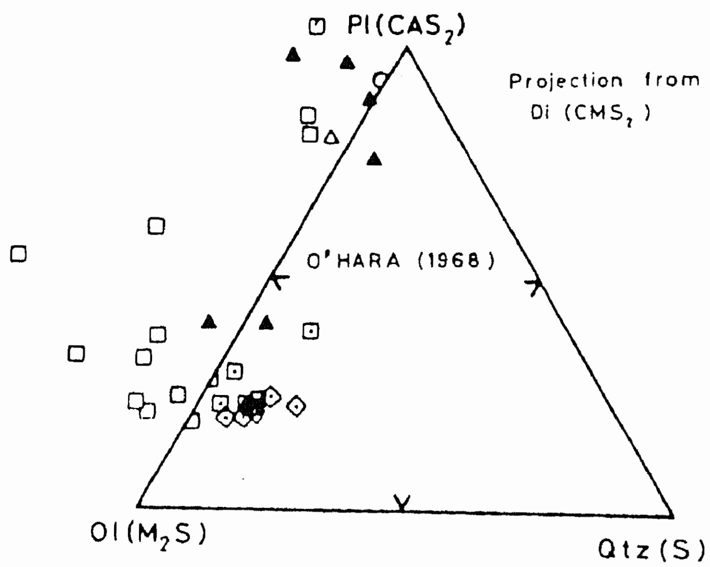


Fig. 3.7. Compositional variation of rocks from the SQUC shown in a projection from CMS_2 into M_2S-CAS_2-S (Di into Ol-Pl-Qtz) plane of the CMAS quadrilateral of O'Hara (1968).

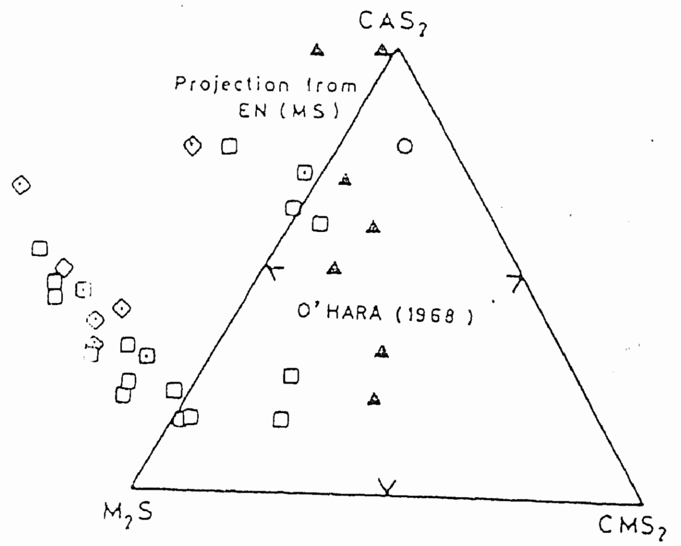


Fig. 3.8. Compositional variation of rocks from the SQUC shown in a projection from MS into M_2S-CAS_2- CMS_2 (En into Ol-Pl-Di) plane of the CMAS quadrilateral of Cawthorn and O'Hara (1983).

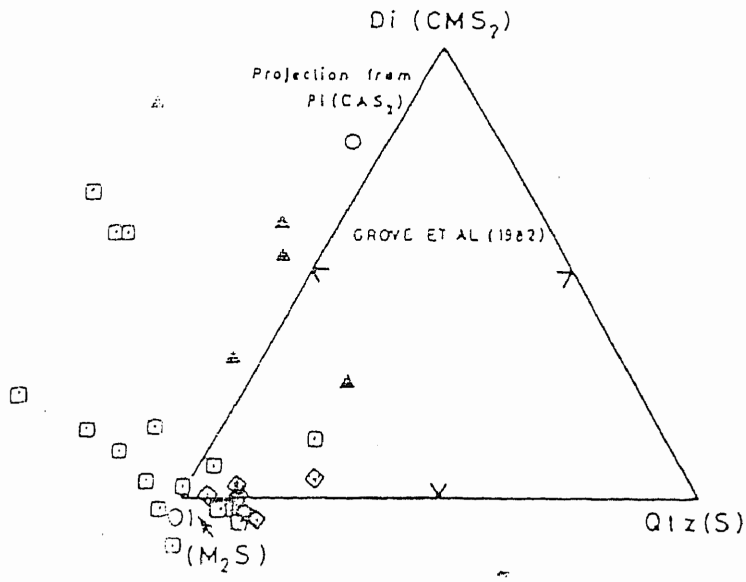


Fig. 3.9. Compositional variation of rocks from the SQUC shown in a projection from CAS_2 into M_2S-CMS_2-S (Pl into Ol-Di-Qtz) plane of the CMAS quadrilateral of Grove et al., (1982)

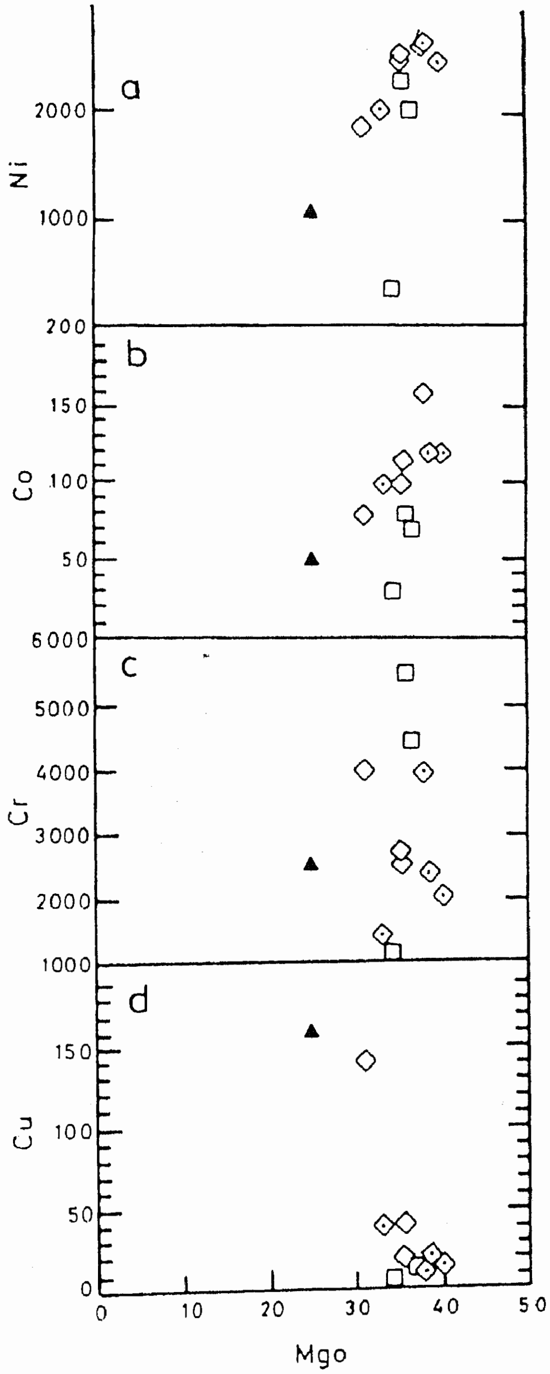


Fig. 3.10 (a-d). Ni, Co, Cr and Cu vs MgO plots of the rocks from SQUC.

Table 3.1. Chemical data of rocks from SQUC.

Sample No→	B100 gabbro/micro-gabbro	B102 serpentinite with relics of olivine and	B105 serpentinite with relics of olivine and	B106 serpentinite with relics of olivine and	B107 serpentinite with relics of olivine and	B108 serpentinite with relics of olivine and	B110 serpentinite with relics of olivine and	B111 serpentinite with relics of olivine and	B112 serpentinite with relics of olivine and
SiO_2	053.25	035.00	036.00	033.00	028.00	034.00	031.25	022.50	038.00
TiO_2	000.74	000.39	000.29	000.32	000.33	000.40	000.27	000.24	001.20
Al_2O_3	015.28	004.42	000.42	000.76	002.83	001.38	003.40	002.08	017.60
Fe_2O_3	006.57	007.05	007.40	007.38	009.96	009.20	003.46	007.29	004.94
FeO	002.62	002.78	002.06	001.49	001.68	001.68	001.90	002.06	003.19
MnO	000.20	000.14	000.05	000.06	000.01	000.13	000.04	000.11	000.18
MgO	008.62	036.75	039.99	041.51	039.39	041.51	040.78	038.26	006.69
CaO	006.97	001.80	000.44	003.45	004.03	001.17	003.33	003.90	009.54
Na_2O	004.10	000.16	000.33	000.17	000.23	000.33	000.34	000.80	003.38
K_2O	000.14	000.12	000.17	000.15	000.15	000.15	000.14	000.15	002.07
P_2O_5	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Ig. Loss	000.00	012.50	012.80	012.00	013.80	010.20	015.00	013.20	013.60
Total	098.49	101.11	099.95	100.29	100.41	100.15	099.91	090.59	100.39
Ni	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Co	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Cu	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Pb	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Zn	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
	B: Bucha	P: Prang Ghar	NJ 12- 20: Behram Dheri	NJ 26-36: Qila	NJ 43: Narai Obe	NJ47-59: Hero Shah			

Table 3.1

continued

Sample No→	B115 serpentinite with relics of olivine and	B118 microgabbro	B122 serpentinite with relics of olivine and	B123 Gabbro	B124 serpentinite with relics of olivine and	B130 ultramafic	P14a Gabbroic	P14b serpentinite with relics of olivine and	P15 Gabbro	P17 serpentinite with relics of olivine and
SiO_2	038.00	045.50	030.75	043.00	024.50	045.75	043.75	020.75	041.25	028.25
TiO_2	001.94	001.03	000.84	000.38	000.36	000.75	000.35	000.36	000.26	000.32
Al_2O_3	016.65	017.81	014.80	015.50	003.93	007.50	018.42	004.84	003.66	007.08
Fe_2O_3	008.70	008.34	012.49	007.09	008.62	006.76	002.80	010.49	004.15	007.03
FeO	006.40	005.10	005.74	002.62	002.43	003.66	006.50	002.62	003.85	002.73
MnO	000.32	000.25	000.26	000.16	000.12	000.12	000.13	000.19	000.08	000.10
MgO	010.43	005.28	008.85	012.00	032.36	023.48	010.18	036.61	024.60	024.83
CaO	004.37	010.81	011.89	013.75	012.95	006.50	011.66	000.50	011.31	011.21
Na_2O	004.15	004.23	000.84	001.41	000.14	000.10	004.72	000.35	000.80	000.53
K_2O	000.18	000.25	000.06	000.10	000.10	000.01	000.01	000.10	000.12	000.11
P_2O_5	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Ig. Loss	008.50	000.00	013.70	003.50	014.10	005.50	001.50	023.60	009.10	017.00
Total	099.64	098.60	100.22	099.51	099.61	100.13	100.02	100.41	099.18	099.19
Ni	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Co	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Cu	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Pb	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00
Zn	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00

Table 3.1

continued

Sample No→	P16 Ultramafic	P22 Basaltic	P43 Chlorite Schist	P53 Microgabbro	NJ12 partially serpentinised dunite	NJ20 partially serpentinised dunite	NJ26 partially serpentinised peridotite	NJ31 partially serpentinised peridotite	NJ36 partially serpentinised peridotite	NJ43 dunite
SiO_2	035.50	043.00	039.00	047.50	048.12	040.12	042.62	041.78	040.30	041.30
TiO_2	000.51	000.97	001.67	002.42	000.12	000.13	000.14	000.16	000.13	000.13
Al_2O_3	004.65	018.37	010.50	017.40	003.12	002.56	001.98	003.18	002.13	002.43
Fe_2O_3	007.26	009.75	008.97	008.40	006.47	007.83	008.10	008.79	007.92	008.38
FeO	003.85	001.02	007.44	001.49	000.00	000.00	000.00	000.00	000.00	000.00
MnO	000.12	000.42	000.55	000.21	000.07	000.10	000.15	000.12	000.13	000.13
MgO	032.82	005.66	023.08	005.54	031.22	035.50	038.82	033.36	040.27	035.70
CaO	000.34	015.73	002.47	006.42	002.88	001.94	001.24	000.82	001.14	000.89
Na_2O	000.43	001.20	000.41	003.91	000.03	000.08	000.04	000.04	000.04	000.04
K_2O	000.12	000.06	000.05	001.68	000.02	000.07	000.03	000.03	000.02	000.03
P_2O_5	000.00	000.00	000.00	000.00	000.28	000.34	000.27	000.33	000.29	000.24
Ig. Loss	013.80	003.50	005.70	005.50	008.49	010.19	006.18	011.11	006.40	009.72
Total	099.40	099.68	099.84	100.47	100.82	098.86	099.57	099.72	098.77	098.99
Ni	000.00	000.00	000.00	000.00	1700.00	1700.00	1800.00	1500.00	1900.00	1900.00
Co	000.00	000.00	000.00	000.00	080.00	100.00	120.00	100.00	120.00	115.00
Cu	000.00	000.00	000.00	000.00	140.00	020.00	020.00	040.00	015.00	040.00
Pb	000.00	000.00	000.00	000.00	004.00	004.00	004.00	004.00	004.00	004.00
Zn	000.00	000.00	000.00	000.00	023.00	030.00	040.00	036.00	040.00	080.00

Table 3.1

continued

Sample No→	NJ47 gabbro	NJ49 peridotite	NJ51 serpentinite	NJ59 serpentinite	NJ60 serpentinite
SiO_2	042.13	038.42	039.12	039.88	039.12
TiO_2	000.32	000.12	000.14	000.18	000.12
Al_2O_3	002.10	002.10	002.31	002.87	002.81
Fe_2O_3	010.33	007.90	008.10	008.07	007.72
FeO	000.00	000.00	000.00	000.00	000.00
MnO	000.07	000.29	000.04	000.24	000.11
MgO	024.96	037.99	036.80	034.59	035.97
CaO	011.38	002.62	000.63	000.63	000.80
Na_2O	000.08	000.03	000.04	000.03	000.03
K_2O	000.02	000.03	000.02	000.02	000.02
P_2O_5	000.31	000.30	000.32	000.25	000.37
Ig. Loss	007.48	010.66	011.67	012.73	013.92
Total	099.18	100.46	099.19	099.49	100.99
Ni	800.00	1800.00	1400.00	400.00	1700.00
Co	050.00	160.00	070.00	030.00	080.00
Cu	160.00	013.00	014.00	004.00	018.00
Pb	004.00	004.00	004.00	004.00	004.00
Zn	035.00	046.00	030.00	060.00	050.00

Chapter 4

ENVIRONMENTAL GEOLOGY

4.1 GENERAL

Environment is comprised of all features and conditions surrounding an organism. These features and conditions include rocks, soil, air, water and factors like light and temperatures as well as various types of other organisms. Considering geology as the study of earth which provides us the basic physical environment, all of the curriculum of geology may be in a sense regarded as environmental geology. By definition however, environmental geology is restricted to topics related directly to human activities. These topics may encompass studies which determine how geological processes and hazards influence human activities - and how human activities influence the geologic process. Environmental geology also extends to understanding the geologic aspects of pollution, and waste disposal problems. As biological life is ultimately influenced by these pollutants through air and food chain, particularly water, a major concern of an environmental scientists is the analytical study of water and air. An environmental geologist is particularly concerned with pollution imparted to water and air from geological sources, geological processes and industries based on mineral and mineral-cum-synthetic material. Mining and mineral processing activities have wide-spread environmental degradation impacts both on air and water systems. Mining process not only pose long lasting environment threats to the surrounding areas but also immediately to the miners, particularly in the underground mining processing. The most serious environmental impacts are from diesel emission, fumes from explosive, dust, radiation, noise, illumination, methane in coal mines, mine fires, spontaneous combustion of coal, heat and humidity, vibrations, and toxic and harmful chemicals used in processing. Among these, pollutant dust, both in surface and underground mining processes, has generally a geological source, i.e. the rock/ore being mined. Dust can be classified into:

- Fibrogenic dust harmful for respiratory system: This includes silica, silicates (including talc, asbestos and mica), beryllium ore, metal fumes, tin ore, iron ore and coal.
- Carcinogenic dust: This dust includes radon derivatives carried by dust particles, uranium and thorium ores, asbestos, arsenic and quartz (?).
- Toxic dust, poisonous to human organs: This dust may include arsenic, lead, uranium, nickel, tungsten, silver, and some beryllium minerals.
- Nuisance dust with few adverse effect: This dust is generated from limestone, gypsum and kaolin.

The harmfulness of the dust is determined by factors like chemical and mineralogical compositions, concentration, particle size, exposure time and individual susceptibility. The concentration is determined as either in terms of number of particles per unit volume of air or weight per unit volume of air. The particle size for respirable particle is smaller than 5 μm. Particle size in this context refers to equivalent diameter of a spherical particle of unit density having the same falling velocity as the particle in question. Exposure time means the average time for the development of a related air bond disease, e.g. 20-30 years for people working 8 hours a day, 40 hours/week for silicosis. Individual susceptibility depends on genetic factors but can be modified by environmental factors. For example, heavy smoker or workers exposed to chemical irritants are likely to develop lung diseases caused by dust at an earlier stage than non smokers. The most common lung diseases related to dust are pneumoconiosis, silicosis and asbestosis.

4.2 PNEUMOCONIOSIS

Pneumoconiosis is a diseases caused by the accumulation of fine-dust in the lungs tissues. Among coal miners the black lung diseases is a kind of pneumoconiosis in which coal mine dust is inhaled and retained in lungs.

4.3 SILICOSIS

In silicosis, scar tissue or fibrosis is formed progressively due to exposure to silicate dust and may continue growing even after exposure is ceased. The lung develop destroyed macrophage which try to ingest and seal off silica particles. After some time the silica particles set free and attack another macro-phage and the process continues. Dust measurement is an important part of the study and both dust concentration and particle size may be determined for diagnostic investigative and preventive studies.

This study is particularly concentrating on asbestos in the study area, therefore asbestosis are described in further details as below:

4.4 ASBESTOSIS

Asbestosis is defined as a diffused interstitial fibrosis and clinical and pathological features are unable to discriminate it from other types of fibrosis unless evidence of long term exposure to asbestos is provided or extraordinary number of asbestos fibers are detected in lungs. (Janet Epps, 1992).

The current study has been especially carried out to investigate the types of asbestos in SQUC, where it has developed in serpentinites along shear zones (Chapters 1-3). However to present a comprehensive account of previous work and the various accounts of the present study it is worthwhile to shed some light on the general aspects of asbestos and asbestosis. Following are the details about asbestos and its carcinogenic imprints.

4.5 ASBESTOS

4.5.1 Definition of asbestos

The term asbestos is used to describe the commercially useful fibrous form chain silicate minerals. The most commonly known commercial types are chrysotile, crocidolite and amosite, all being used since the beginning of the industrial era by the turn of century. Table 4.1 describes the physical and chemical characters of various type of asbestos.

4.5.2 Types of asbestos

The detailed description of the various types of asbestos is as follows:

Chrysotile: Chrysotile is the most important source of commercial asbestos. It belongs to the serpentine group of chain-silicates with an approximate composition of $Mg_6 (OH_4Si_2O_5)_2$ (Table 4.1). It occurs in white, yellow, gray and green colors and is colourless to pale green in thin sections. It has a density of < 2.55, hardness 2 and a fibrous cleavage parallel to x-axis. Chrysotile has greater tensile strength than that of amphibole fibers where as the latter ones has greater acid and heat resistant properties. Chrysotile mostly occurs in veins of silky fibers (Figs. 4.2b). The fibers of chrysotile mostly occur across the veins with lengths varying between <1cm - > 12cm. Slip fibers also occur. The structure of chrysotile is similar to all other serpentines, i.e. a trigonal analogue of the kaolinite structure. Chrysotile is one of the three principal polymorphs of serpentine (chrysotile, lizardite, antigorite) (Deer. et. al., 1966). Chrysotile mainly comes from Thetford in Quebec province, and Cassiar in British Colombia, Canada; Asbest near Sverdlovsk in Ex-USSR, Swaziland and Zimbabwe in southern Africa. Also small quantities are produced in Australia, Cyprus, Italy, Turkey and the United States. The Quebec province deposits of Canada is the largest in the world and`is mined since 1876. The one near Sverdlovsk in USSR is mined since 1885. Similarly deposits of south Africa have been mined vor the last 40 years. Fibers of asbestos varies in physical properties and the harshness of these fibers is mostly the determining factor for the type of utility. Chrysotile is generally the softest type of asbestos and is therefore used for spinning and weaving to produce asbestos clothes and tapes.

Amphibole asbestos: Five types of asbestiform amphibole occurs in nature. These include amosite, montesite, crocidolite, anthophyllite, tremolite and actinolite. The former three are of higher commercial value like chrysotile. Tremolite and actinolite are of relatively less commercial significance and are normally mixed with true talc to make commercial talc (e.g. Newe Kale, Mohmand Agency; cosmetic talc is generally assumed to be free of fibrous silicates).

Amosite and montesite amphiboles: Amosite and montesites are asbestiform varieties of cummingtonite - grunerite series (Mg, Fe), (Si_8O_{22}) $(OH)_2$. Amosite is harsher and more iron-rich where as montesite the softer and more magnesian. Amosite is generally gray to brown in color and is found only in NE Transvall, South Africa where it is mined since 1916. It is the longest type of fiber asbestos occurring in 30 cm wide seams. Due to its harshness it is very useful for spinning and when "opened" it produce a large bulk and thus excellent for heat insulation.

Crocidolite: Crocidolite or blue asbestos is the lavender blue highly fibrous variety of riebeckite (glaucophene - riebeckite series; $Na_2Mg_3Al_2[Si_8O_2]_2[OH]$ - $Na_2Fe^{2+}{}_3$ $Fe^{3+}{}_2$ $[Si_8O_{22}]$ $(OH)_2$ of amphibole. Crocidolite fibers have greater tensile strength but lower heat resistance than chrysotile. The major producing mines are in North-West Cape in South Africa. It is also found in western Australia and Bolivia. The harshness of crocidolite is intermediate between chrysotile and amosite. Like amosite, it also occurs in seams as banded ironstone (Table 4.2).

Anthophylite: Anthophyllite belongs to the anthophyllite-gedrite series (Mg, Fe), $Si_8O_{22}(OH, Fe)_2$ - $(MgFe)_5$ - Al_2 $[Si_6Al_2O_{22}]$ $(OH,F)_2$ of iron magnesian amphibole. It occurs in fibrous masses in which the fiber bundles are short. Its major production is from Pakkila area of north-east Finland where it is mined since 1918. Mining has been stopped now (Table 4.2).

4.5.3 Distinguishing features and methods

The quick physical method for identification of the various types asbestos in bulk is its colour, i.e. blue for crocidolite, gray-brown for amosite and white or greenish for chrysotile and Anthophyllite. Similarly hardness can be used as an affective physical tool for distinction. Chemical composition can be used as a supporting evidence (Table 4.1).

To investigate the proportion of various types of asbestos in a single specimen, particularly small samples like airborne dust or long residue, electron microscope attached with Energy Dispersive System is an excellent tool. Fibers with only 0.2 μm in diameter and a few μm long can be identified with electron microscope. XRD is useful and quick tool but sometime unable to distinguish chrysotile from other minerals in parent serpentine rock or some times the amphibole asbestos from each other. It is however, useful in discriminating chrysotile from amphibole asbestos.

Asbestos has been considered highly useful for industrial purposes because of the high tensile strength and flexibility of its fibers, their resistance to heat, abrasion and many chemicals. Bundles of fibers split parallel to c-axis as straight needles with amosite and crocidolite having an average length of 0.4μm and a diameter of 0.2 μm. Chrysotile fibers are finer than those of crocidolite and amosite and have a diameter of 0.16μm. Their larger fibers are curled. The fineness and length of fibers are directly proportional to their ability to be respired and take part in biological activity.

Recent studies have shown that the length and diameter rather than composition of fibers play a more vital role in causing mesothelioma and asbestosis. These studies have provided evidence that other fibrous minerals may take part in similar biological activity as asbestosis if taken in considerable amount for a longer time. Fibrous erionite, a type of zeolite has been proved to have caused mesothelioma in Turkey (Gilson, 1983).

4.5.4 Extraction and preparation

Various deposits contain various proportions of asbestos fibers varying between 30 - 3% in the richest and poorest, respectively. The mined asbestos is associated with a considerable parent rock. The ultimate separation of quality grade fibers is achieved through the following steps:

a) Preliminary sorting

b) Crushing

c) Passing though a rotary drying kiln or drying in sun to facilitate no (d).

d) Subsequent separation.

The subsequent separation is carried out by passing the crushed material over sloping vibrating sieving trays. The compact particles of parent rock fall quickly than fibers. Fibers are air lifted by suction. The process is repeatedly carried to improve the quality of fibers and sorts them by length. The final fibers are filled in hessain (burlap) sacks of 45 kg each. Now because of environmental considerations the hessain sacks are replaced by paper of plastic sacks or in sealed containers (Gilson, 1983). To separate the fibers, the asbestos textile industry uses several types of mills.

4.5.5 Uses

The world asbestos means inextinguishable or indestructible in Greek. For strengthening clay pots, asbestos has a history since 2500 B.C. in Finland. Historically the ashes of eminent people were preserved in the indestructible shrouds made of asbestos. For lamp wicks it has also been used since pre-historical time till this day.

In modern age, asbestos industry exists since 1830 when the large chrysotile deposits of Canada and USSR were first exploited. Cotton industry in England and France started using it for incombustible fabrics. Since the World War II the industry has expanded.

More than 1000 uses of asbestos can be described. Following are some of the major ones (also see Table 4.1-4).

a) More than 70% of asbestos goes to asbestos cement products: roofing sheets, wall boards, pipes, and pressure pipes.

b) It is used as filters for plastics for many purposes e.g. roof tiling.

c) When mixed with calcium silicate and magnesia, it is used as heat insulate for boilers.

d) It has been used for fire proofing bulkheads in ships, stanchions and girders in buildings.

e) It is widely used for improving fire resistance of cellulose and other material.

f) Using modified cotton industry machinery, chrysotile and crocidolite can be spin and woven.

g) Asbestos cloths can be used for fireproof clothing and curtains.

h) It is also used in breaks and clutch lining.

i) Can be used in filters and masks.

j) For insulation and fire protection of railway carriages, navel ships and storage buildings asbestos fibers is mixed with cement and sprayed.

k) After World War II it was used for encasing of structural steel in buildings to avoid bending during fire.

l) In 1960 the hazards of asbestos became limelighted and its use decreased in spraying mixed with cement.

m) Since 1972, the case of asbestos in many utilities has been reduced by the introduction of man-made mineral fibers and other similar products. For fraction material however, no such alternative has been found.

n) Despite the general trend of reducing the use of asbestos, in industrialized nations of the world, its use is still wide spread in Latin America, Asia and Africa. In Brazil it is used in the name of fiber cement in all sort of building material. The main culprits are the multinational companies (Gilson, 1983).

4.5.6 Health hazards related to asbestos

The inhalation of asbestos has described as causing specific diseases including asbestosis (a kind of lung fibrosis), cancers of bronchi, pleura and peritoneum and possibly of other organs too. Asbestos also causes asbestos corns of the skin. As asbestosis is the most common disease related to asbestos, it is worthwhile to describe this disease and other related diseases in some detail as follows:

4.6 ASBESTOSIS

Asbestosis is defined as a diffused interstitial fibrosis of the lungs as a result of exposure to asbestos dust (Berry et al., 1979; Gilson, 1983). The pathology and clinical feature reflect insufficient features to discriminate it from other interstitial fibroses. Therefore, evidence of significant exposure to asbestos dust is needed to confirm asbestosis. Practically the detection of asbestos fibers or bodies in the lung tissues, greatly in excess of that commonly seen in general population may prove a lung fibrosis as asbestosis.

4.6.1 Pathology

Fibers from 5 - 200 μm long and <3 μm in diameter may retain in alveolar. Some of the longer fibers particularly those of the amphibole group become coated with an iron protein complex producing drum-stick appearance of the asbestos bodies. All types of asbestos behave similarly in causing fibrosis - starting in the respiratory bronchioles with collection of microphage containing fibers and other lying free. These features produce collagen replacing the initial reticulin web affecting initially fewer bronchioles and latter on spread to the terminal bronchioles and through peripheries to acinus. The effected area progress slowly causing diffuse interstitial fibrosis with shrinkage. The lower part of the lungs is effected first and the disease move slowly upwards finally collapsing all the lungs once and for all. The distorted lung is then replaced by dense fibrosis, cysts and some areas of emphysema (too much inflation). The pleura is effected by fibrosis more than any other types of pneumoconiosis.

4.6.2 History of asbestosis

Montague Murray (1899) described for the first time fibrosis of the lung caused by asbestos. Cook (1927) used the world asbestosis. Recognizing it as a major hazard in mineral textile industry, research activated in 1930, with appearance of at least 10 papers/year and after 1960 the number rose to 200 papers/year. Introduction of optical and electron microscopy paved the way for detail study of parts of the lungs to measure the amount, size, distribution and types of fibers in the lungs. Oncogenic and fibrogenic action of the major types of asbestos in animals have been now largely understood. This study was difficult to be carried out in man who is normally exposed to different type of asbestos.

4.6.3 Types of fibrosis caused by asbestos

The major types of fibrosis caused by long term exposure to asbestos are (a) asbestosis and (b) pleural plaques (Table 4.5).

Asbestosis: Epidemiological research shows that the symptoms of asbestosis are similar to those caused by other types of diffused interstitial fibrosis of the lungs. The initial symptoms are shortness of breath on exertion occasionally associated by aching (i.e. transient sharp pain in the chest). The most diagnostic physical sign is the presence of high pitched fine creptations (crackles) at full inspiration and persisting after coughing. Cough may be associated only at final stages except if there is bronchitis. Clubbing of fingers and toes may occur. Its presence may be related to the rapidity of progression of diseases. Radiography can be utilized to easily identify the disease, together with a record of the pattern of lung function, lung volume and some features of restriotire syndrome. All diagnostic features may not exist together.

Pleural plaques: Pleural plagues occur as flat, often raised patches on the membrane surrounding the lung. Pleural plaques occurs alone or with asbestosis. Radiological diagnosis are the most reliable evidence as parietal pleural plague may not show any clinical symptoms.

4.6.4 Sources of exposure

The thousands of products in which asbestos is used can be the possible sources of exposure. Exposure is possible around mines and manufacturing areas. Families may expose to the dust brought home on clothing and those working in an area where logging is in progress. In localized areas pleural plague may occur in general population as happened in Finland, Czechoslovakia, Bulgaria and Turkey.

The following facts may be taken to consideration when the sources of exposure are needed to be determined:

Being occupational in origin, asbestosis may result from exposure to asbestos passing through mining, milling, manufacturing and applying, removing and transporting asbestos fibers. When asbestos is bound with other material like plastics, cement and paper, the danger of exposure decreases. Exposure threat in the past were greater than today. Asbestosis or pleural plague may be caused in families by clothes dust when there is no sufficient awareness, as occurred in the past in the west. Very limited exposure does not cause asbestosis. The use of asbestos varies from country to country. For instance dry wall filters (spackling) contain asbestos in USA but not in UK. On the other hand crocidolite was commonly sprayed on railway tracks in UK than in US, in 1940s. Pleural plaque can be caused by much lower levels of exposures than causing asbestosis. Also chrysotile fibers are considered to be possibly more related to pleural plaque and amphiboles (crocidolite, tremolite, amosite) to asbestosis because, the amphibole asbestos have normally longer fibers and thus stay for longer time in lungs as compared to chrysotile. In other word the amphiboles are more fibrogenetic than chrysotile.

4.6.5 The relation of asbestosis to doze of dust

Information is generally based on miners and millers in Canada, and textile worker in UK. Both these data indicate that concentration of ***fibers* x *exposure time*** are both directly proportional to the incidence or severity of diseases. It is however still impossible to determined a threshold values of these factors above which asbestosis will certainly occur. The North American studies show value above 100 million particles/ft3/yr, with a risk as low as 1%. The textile industry study in UK shows that the risk for possible asbestosis is not more than 1% of men after 40 years of exposure to concentrations of 0.3 - 1.1 fibers/cm3. Data collected for mid sixties including dust sampling, if related to the number of incidences, will reveal valuable information about a threshold value. Fig. 4.1 shows risk of lung cancer relative to accumulated dust exposure.

4.6.6 Asbestosis and other lung cancers

Studies have shown that people dying of asbestosis also show other lung cancers at post mortem in 50% cases. Thus the dust showing enough to discard asbestosis will also eliminate the risk of other bronchial cancers. This relation however does not extends to mesothelioma which is not so closely related to asbestosis. Also it has become evident that the smokers have high risk of asbestosis and other related lung cancers than non smokers (McDonald & McDonald, 1980).

Mesothelioma related to asbestos: Malignant mesothelioma is a rare tumor of the lining of the chest cavity or abdomen cavity and sometimes of pericardium. The symptoms are pain, effusion of fluid into the cavity and local growth. Being highly malignant it kills within months rather than years. No therapy has yet been considered effective. However, surgical removal, radiotherapy and chemotherapy may prolong life in certain instances. Smoking has no role in mesothelioma. Pulmonary fibrosis is not

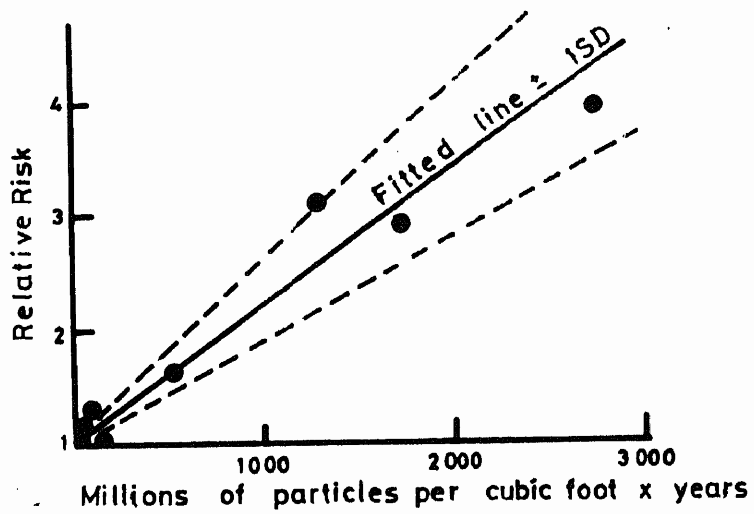


Fig. 4.1 Relative risk of lung cancer realted to accumulated dust exposure (McDonald & McDonald, 1980).

necessary in mesothelioma. Table 4.6 shows the record of malignant mesothelioma in N. America and Table 4.7 shows the death rate related to exposure time.

Some other cancers: Mucocilliary escalator removes most of the inhaled asbestos from the lungs and passes it on to the gastrointestinal passage. Cancers of the various parts of digestive system were thus suspected. To verify such probabilities, studies have been carried out but no solid conclusions have been drawn because such cancers have also other origins like nutritional circumstances and habits, both depending on climate, geographical location and ethnic origin of the population. Carcinoma of larynx has been however, noticed in workers exposed to asbestos. In this however, a stronger link has not been established (Pelnor, 1983).

4.7 ASBESTOS AROUND PESHAWAR VALLEY

On the north-western boarder of Peshawar valley the first occurrence of asbestos was described from Khyber Agency by Coulson (cf. Qaisar et al., 1966). Coulson mentioned small veins of slip fibers asbestos in limestone in contact with epidiorite from Char Bagh fort (latitude 34° 07', longitude 71°07'). Latter on asbestos was found to be present sporadically throughout the SQUC also known as the Dargai Clippe, extending from Khyber agency through Mohmand agency to district Charsadda and Malakand agency (see Fig. 1.2). The geology and petrology of these ultramafic rocks from Prang Ghar, Qila, Behram Dheri, Narai Obe, Bucha, Newe Kili, Behram Dheri and Hero Shah has been described in Chapters 1 and 2. Asbestos mostly occurs along joints and fracture planes along shear zones generally in dunite - serpentinite. The dunite to serpentine/asbestos transformation occur along strike slip faults. Several workers have described the composition and genesis of these asbestos deposits. Qaisar et al., (1966) presented the chemistry, X-Ray diffraction data and differential thermal analyses and thermogravimetric curve of three samples from Qila (Charsadda), Charbagh Fort (Khyber Agency) and New Dheri (Mohmand Agency). These data show that the Qila (Charsadda) asbestos has a chrysotile structure (serpentine). The results of asbestos from Charbagh (Khyber Agency) and New Dheri (Mohmand Agency) are somewhat complicated and have been tentatively grouped as tremolite-anthophyllite (amphibole). Khurshid and Khan (1973) described potato asbestos on the basis of chemical data and XRD patterns from Qila area and classified it as clino-chrysotile. According to these authors the formation of asbestos occurred as a result of hydrothermal phenomenon as spheroids latter on enveloped by the development of serpentine.

Arif (1994) analyzed 49 samples including 48 silicate ultramafic rocks and one chromite from SQUC. The serpentine from silicate ultramafic rock showed very limited variation of Mg# between 95 and 98 with principal chemical constituents as SiO_2, MgO and FeO*. On the basis of high SiO_2/MgO ratios (>1) he classified these serpentines as antigorite. He used 30 samples for XRD analyses and classified them as antigorite. Arif (1994) however did not mentioned of analyzing any typical asbestos and it seems that his studies were restricted generally to non-asbestiform serpentine. Hamidullah (1983) reporting asbestos occurrence at Bucha, Mohmand agency regarded its formation due to the transformation of dunite to asbestiform serpentinite along shear zones, according to the reaction: Olivine + $H2O \rightarrow$ Serpentine + brucite + magnetite

(Coleman & Keith, 1971; Moody, 1976a, b)

Hamidullah (1983) also described the local economics and the environmental hazards related to the mining and processing of this deposit at Bucha, Mohmand agency. This study also turned out to be a basis for inspiration to carry out the current investigation.

4.8 PRESENT STUDY OF ASBESTOS

Asbestos sample collected from from various localities of SQUC were collected along with sample of the associated ultramafic rocks. Field relationships petrography and rock chemistry of the silicate ultramafic rocks have been described in chapters 1 and 2. The selected asbestos samples were variously subjected to Electron Microprobe, and XRD analyses in order to determine the type of asbestos. In addition the length and diameter of the fibers from these samples were also determined under microscope in order to determine their fibrogenitic and inhalation properties. The details of these data are as follows:

4.8.1 Type of Asbestos

Asbestos from Behram Dheri were analyzed using electron microprobe. The data (Table 4.8) closely correspond with composition of chrysotile/antigorite having a SiO2/MgO value >1. As it is difficult to distinguish between the 3 polymorphs of serpentine (Arif, 1994), XRD data can be utilized as a tool to find out which serpentine is present.

The XRD data of the analyzed asbestos samples from the SQUC are shown in Table 4.9. The data show that asbestos from these localities is generally chrysotile with local occurrences of antigorite and tremolite.

4.8.2 Fibrogenicity of asbestos

As mentioned earlier fibers with length >8 μm and a diameter <3 μm are highly fibrogenic and be easily inhaled and thus can play a role in causing asbestosis or other lung cancers (Worksafe Code, Australia, 1988). The length over diameter ratio can be utilized as combined threshold value, provided the minimum length is 8 μm and maximum diameter is 3 μm. Any value of length/diameter (L/D) ratio > 2.66 may be thus considered as having sufficient inhalative character and thus carcinogenic.

Asbestos fibers from different localities and crushing machines (see Fig. 4.2a-f) under investigation were subjected to determination of length and diameter of thin and long fibers under microscope. The minimum L/D value obtained is 4. The maximum value is 4666 from Newe Kili Machine. All other values from other samples and other localities fall between these two minimum and maximum values (Table 4.10), indicating that all these localities contain asbestos fibers with considerable inhalation character and are thus carcinogenic.

4.8.3 Mining and industrial processing of asbestos

Hamidullah (1984) reported asbestos occurrence at Prang Ghar and Bucha area with special reference to health hazard related to asbestos mining and processing by the locals. He suspected the occurrence of lung disease at Bucha to be related to the fibrogenetic impacts of asbestos mined and processed by locals without any precautionary measures. Thirteen years latter during the current investigation the whole asbestos mining belt stretching from Mohmand Agency (Bucha, Prang Ghar, Newe Kale) through district Charsadda (Qila) to Malakand Agency (Hero Shah) was not only sampled for analytical investigation of asbestos but also surveyed for the procedures adopted for mining and processing of this fibrous minerals. The details are as follows:

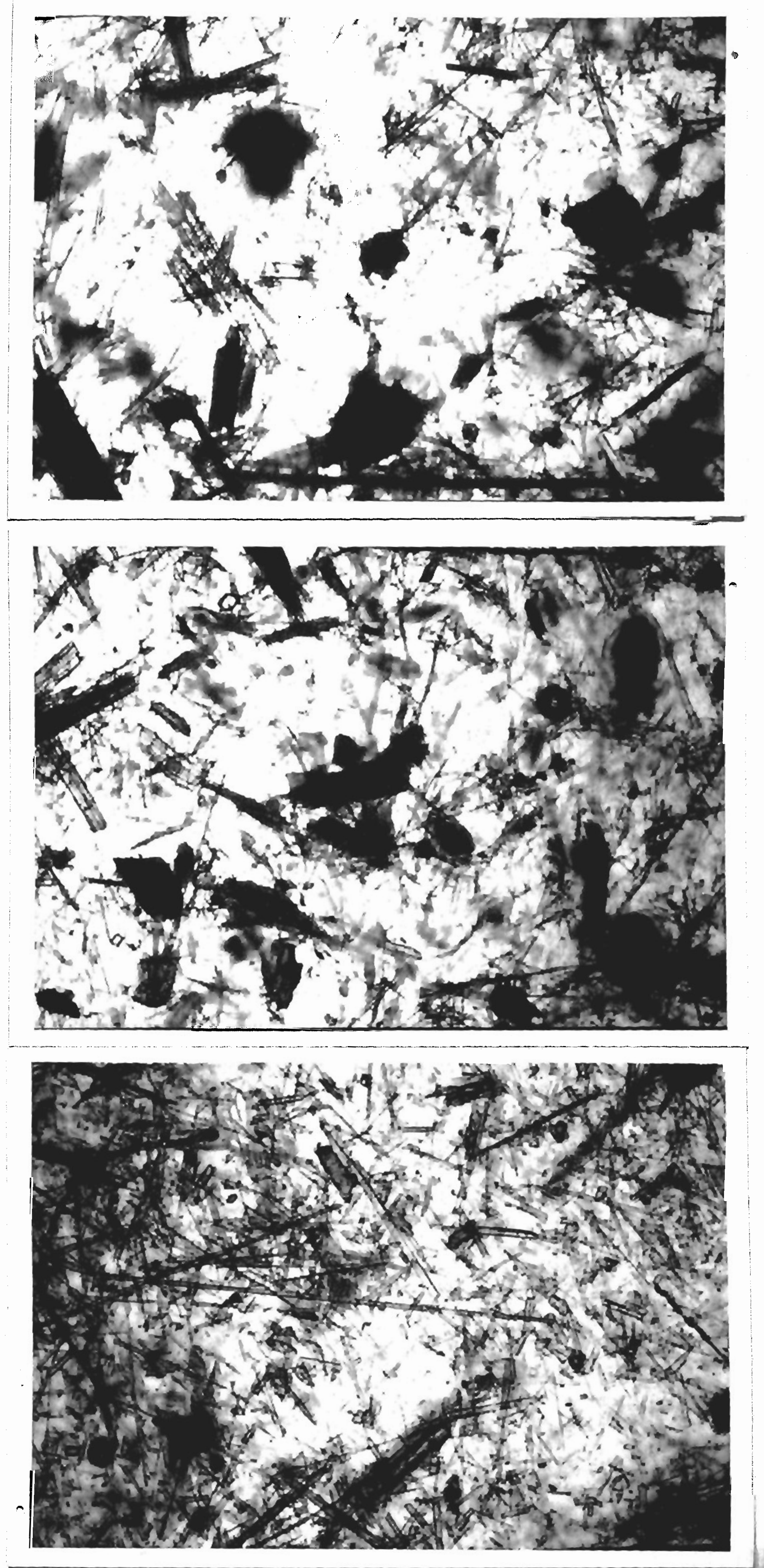
Asbestos is mined using conventional dynamite blasting along the asbestos bearing-shear zones in dunite-serpentinite (Fig.4.3a-b). Asbestos occurring along joints, is associated with magnetite and other minerals of the parent rock (Fig.4.3c-e). This raw stuff is then carried away to the local crushing plants. Initially there were a few primitive crushing machines but now several relatively modern plants have been installed at Newe Kili, Tangi, Berlin and other places (Fig. 4.4a-c; 4.5a-d; 4.6a-d).

Fig. 4.2 (a-f) 25 times magnified asbestos fibres from various mines of the SQUC.

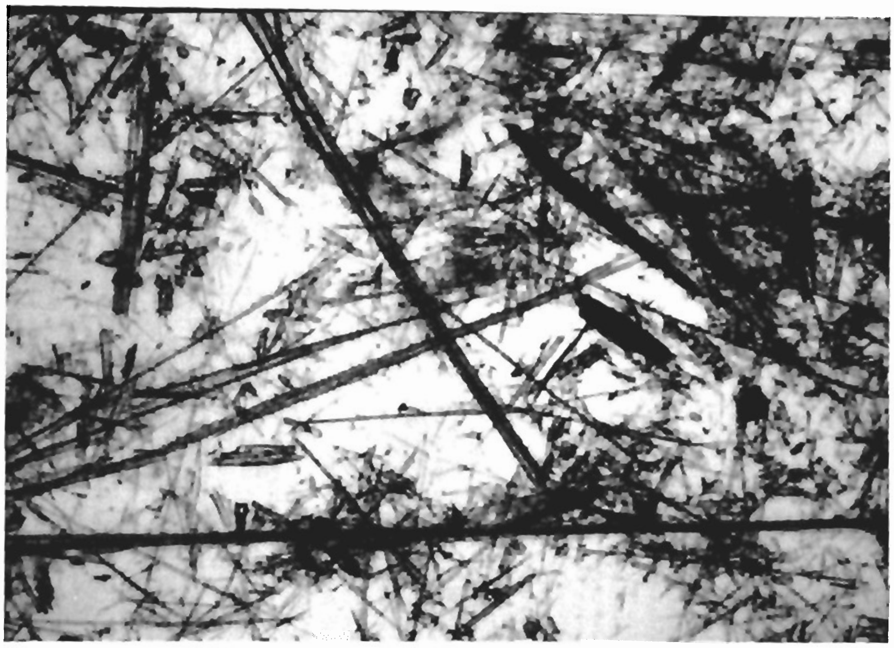
a

b

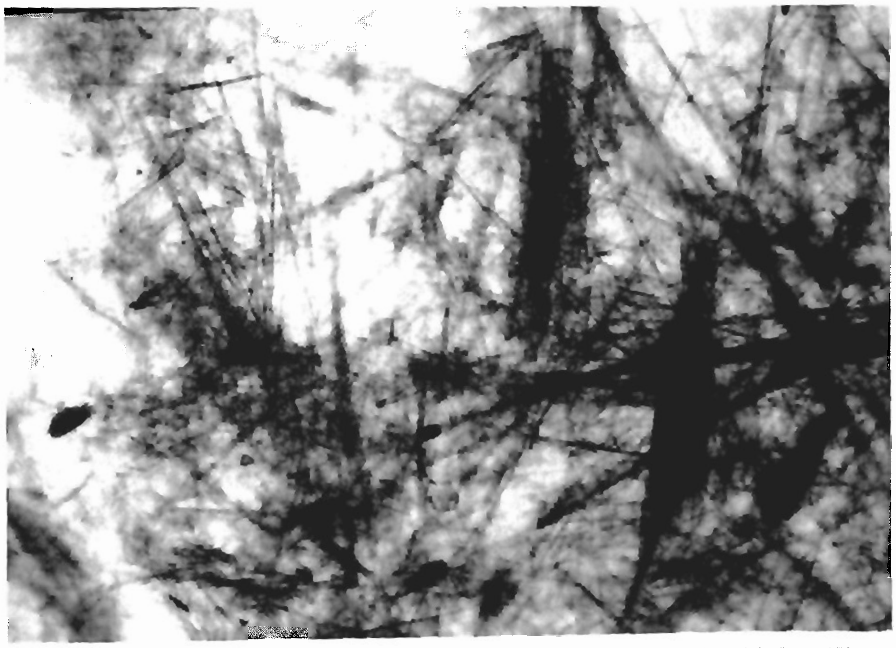
c



d



e



Figures 4.4a-c show the dumps of asbestos in a crushing machine at Berlin Inside the room is a flour mill and out side is asbestos crusher. The man in the view has worked for 8 years in this machine and was not convinced of any hazard related to asbestos inhalation or its mixing with flour produced inside the room. Asbestos dust is however visible on the walls and must be mixing with the flour on the ground inside the room. Figures 4.5a-d show another machine at Newe Kili with asbestos and grain feeders hardly at 4-5 feet distance from each other. Figure 4.5a was taken when the machine was quite and Figure 4.5b shows when the machine was run and fed with raw material. The dust produced is clearly visible in the picture. The man has hidden the nose with his chaddar but his eyes are open. Figure 4.5c and d are the close ups of the same views.

At Newe Kili there are at least 7 or 8 asbestos crushing plants together with one silica crusher. Here some of the crushing plants are operated in similar conditions as shown in Figure 4.5a-d. Both flour and asbestos are treated together on machines 3 feet apart from each other. Both the machines are sometime operated simultaneously. In the middle of Newe Kili several relatively modern machines have been installed (Fig. 4.6a-d, 7a-b). The Khan machine is equipped with modern exhausts and theoretically safe for the labor working. However, when the plant was visited during the operation, visibility was very low inside the plant due to fine dust as can be seen in Figure 4.6b. Other plants crushing quartzite, silica sand and feldspar in Newe Kili (Fig. 4.7a-b) pose similar threats to the environment. At Newa Kili several workers related to asbestos crushing plants and other locals were interviewed. A local Basic Health unit personnel was present to help in these interviews and also comment on the answers received from these individuals. The following data was collected:

Asbestos dust is blown into air from these crushing plants. Apart from affect on the labor inside the plant the dust dissipates into the surrounding atmosphere affecting the local population in the village. At machine shown in Figure 4.5a-d the operator who had been working since 3 years complained that after his association with the plant his flues/allergies are more frequent and coughs are more severe and prolonged. Young children and teen agers were complaining from eyes irritation. Their eyes were red and the allergy was mentioned to be present variably since 3 - 6 years. Women living in the vicinity of the crushing plant are normally more asthmatic because they stayed home longer than men and received persistent asbestos/rock dust from air.

4.9 ECONOMICS OF ASBESTOS

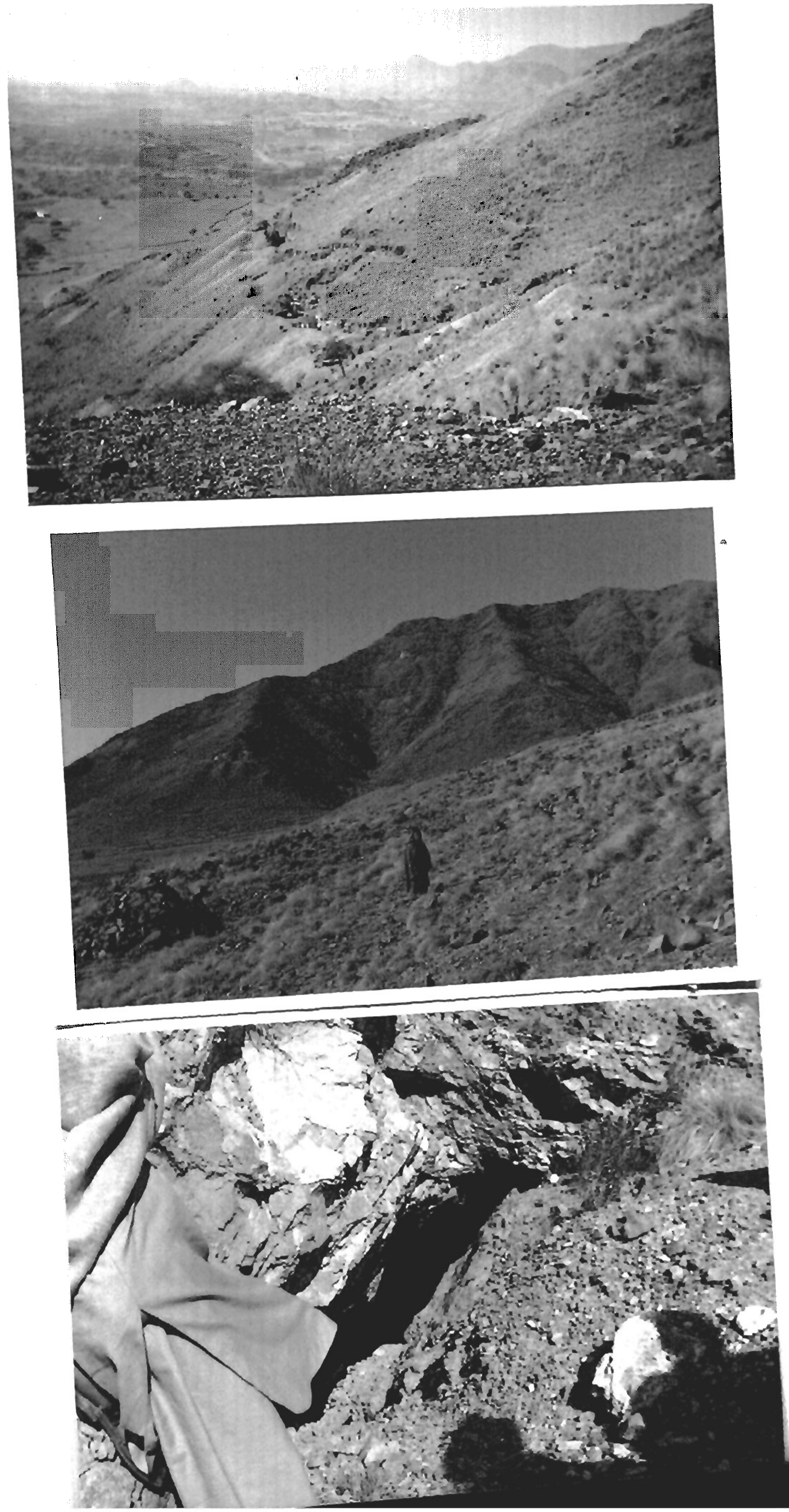
Unfortunately due to the occurrence of most of the mines in tribal territory and the lack of cooperation from the mine and machine owners, the collection of economic data was very difficult in the early stages. The mine and machine owners had been suspecting that the recommendations of this project would lead to the closure of their business. After several disccussions and sufficient awareness and education, however, many of these owners ultimately begun cooperation and provided rough and/or approximate information shown in Table 4.11. This data shows that asbestos and other allied minerals provide a total business of Rs.69000/- daily to the inhabitants of this area.

Fig. 4.3 (a-e). Various views of the asbestos mines at qila. Figure 4.3c shows mining along the shear zone and Figures 4.3d-e are close ups of the mineralized surface.

a

b

c



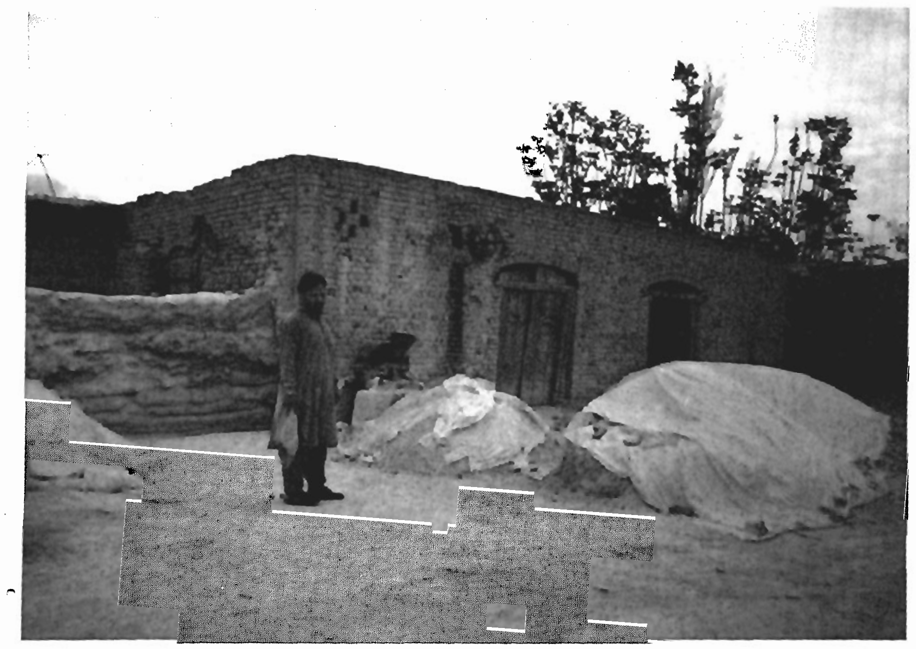
d

e

Fig. 4.4 (a-c). Asbestos dumped in the crushing plants/grinding mills at Newe Kili (a) and Berlin (b-c). At Berlin inside the room is a flour grinding mill while the feeder of raw asbestos can be seen in the middle of the snaps.

a

b



c

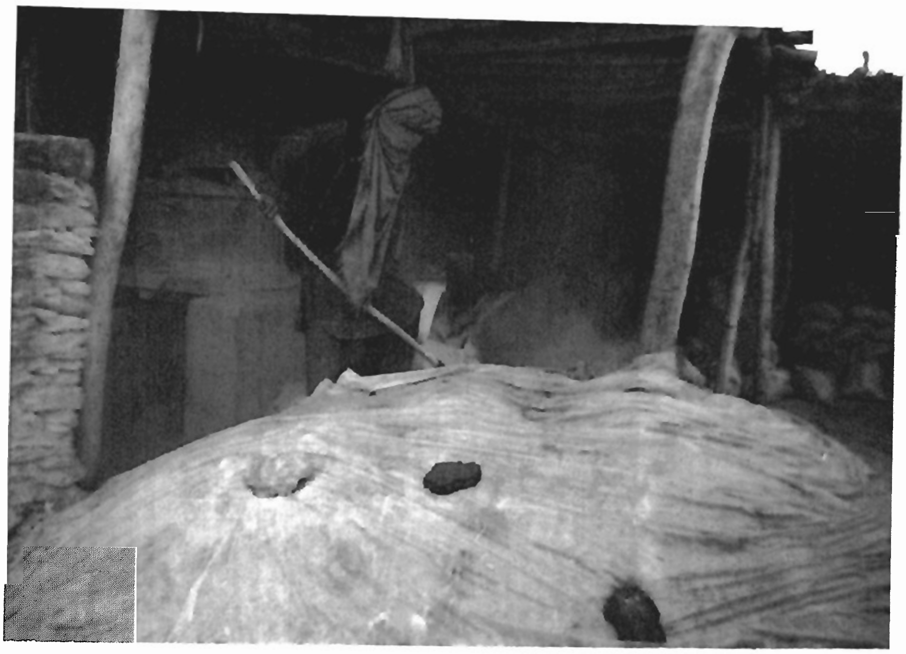


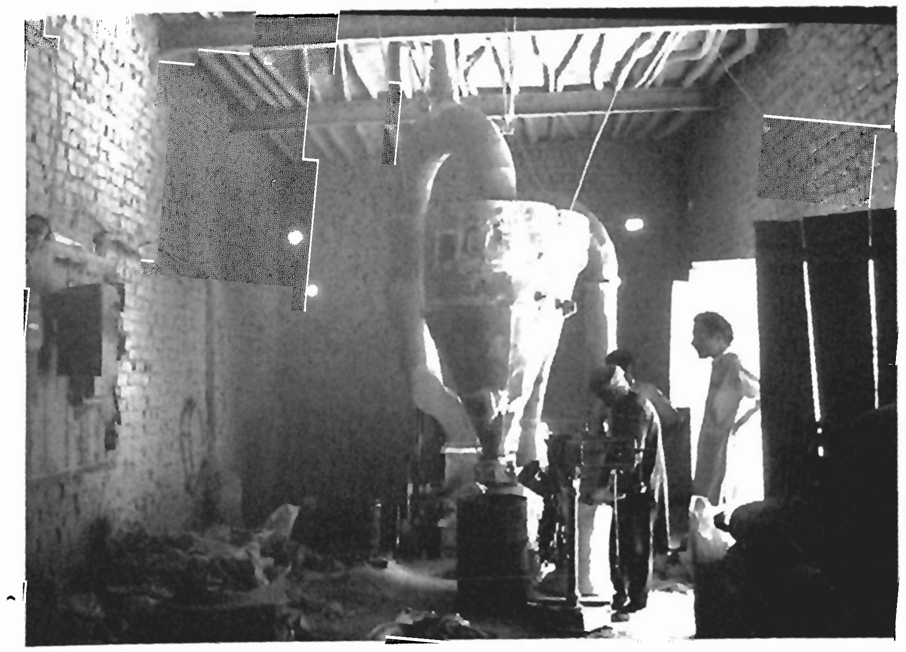
Fig. 4.5 (a-b). Asbestos being fed to the grinder at an older/very premitive grinding mill at Newe Kili, Mohmand agency. Blowing dust can be seen after grinding begins, in Figure 4.4b. The worker is hiding his nose with his chaddar but his eys are open to dust. Also he may carry home a lot of fibres in his cloths.

Fig. 4.5 (c-d) Close ups of the asbestos (front) and flour (back) feeders of the grinding mill shown in Figures 4.5a-b.

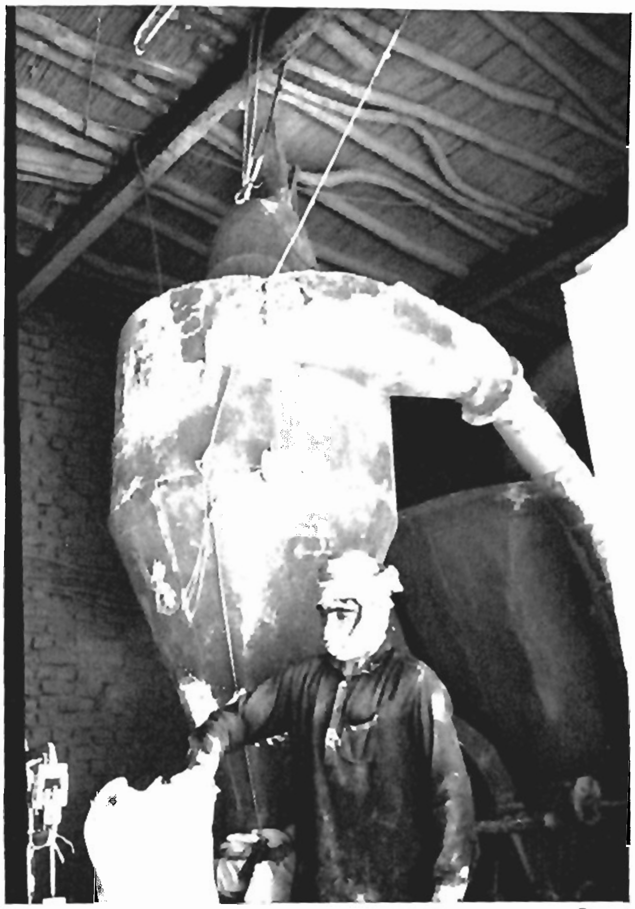
Fig. 4.6. Outer (a) and inside (b-d) views of the relatively modren asbestos crushing/grinding plants at Newe Kili. The haze in Figure 4.6b is because of asbestos dust.

a

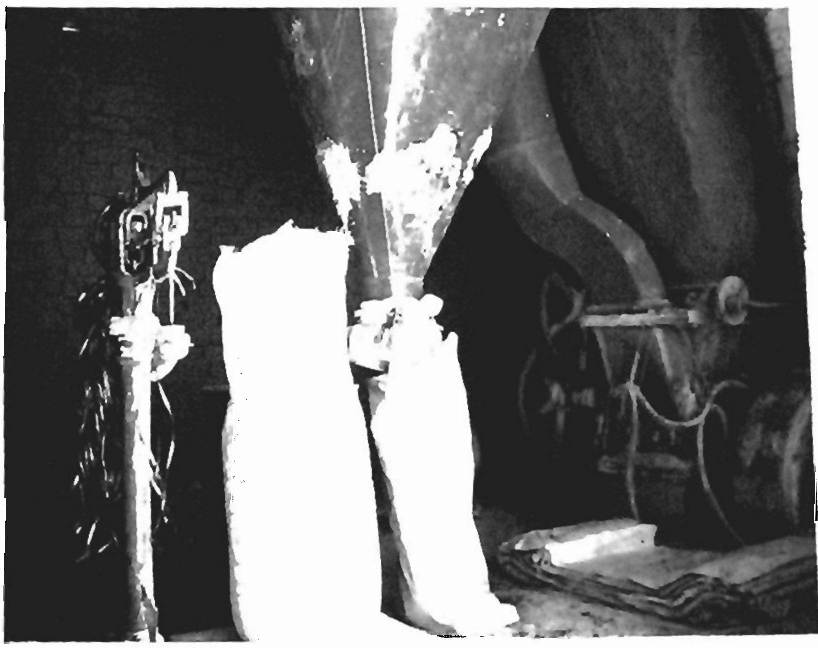
b

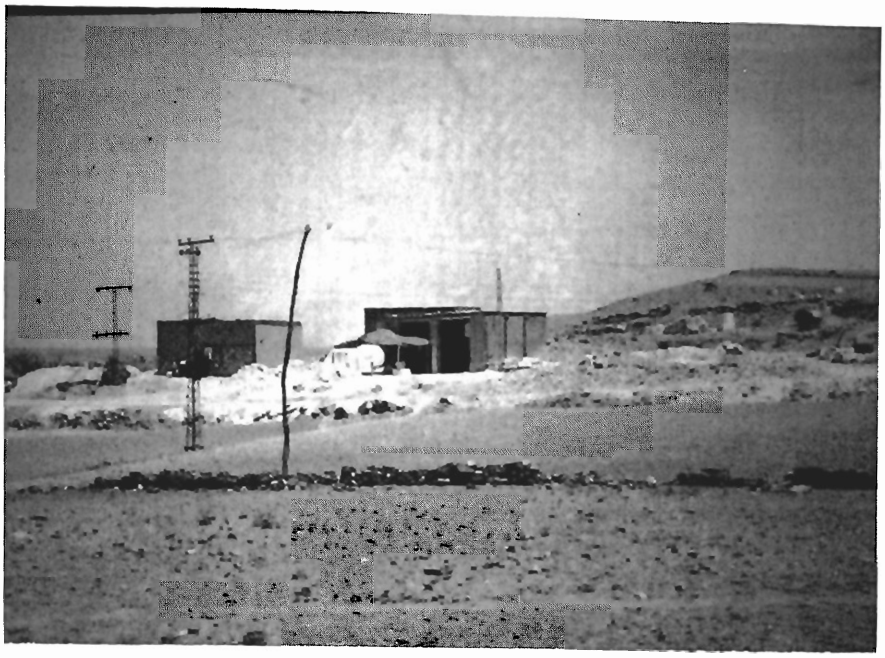


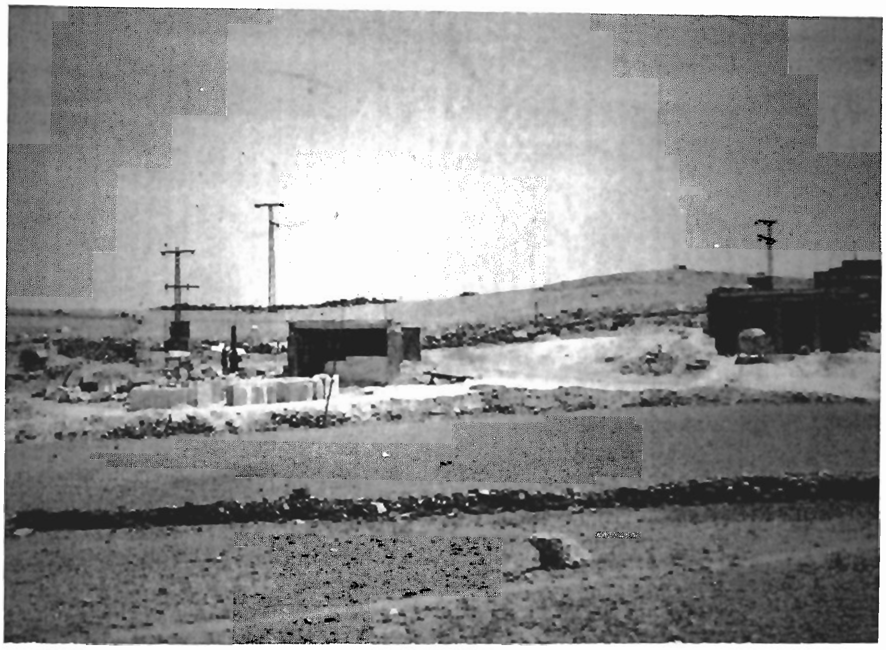
c



d







. Fig. 4.7 (a-b). Views of the various mineral crushing plants in Newe Kili. Silicate minerals other than asbesos like feldspars and free quartz are also crushed in these machines.

Table 4.1. CHARACTERISTICS OF MAIN TYPES OF ASBESTOS FIBRE

Chemical analysis (%)	Chrysotile[a]	Crocidolite[b]	Amosite[c]	Anthophyllite[d]
SiO_2	38-42	49-56	49-52	53-60
Al_2O_3	0-2	0-1	0-1	0-3
Fe_2O_3	0-5	13-18	0-5	0-5
FeO	0-3	3-21	35-40	3-20
MgO	38-42	0-13	5-7	17-31
CaO	0-2	0-2	0-2	0-3
Na_2O	0-1	4-8	0-1	0-1
H_2O^+	11.5-13	1.7-2.8	1.8-2.4	1.5-3.0
Colour	white to pale green, yellow or pink	blue	light grey to pale brown	white to gray or pale brown
Decomposition temperature(°C)	450-700	400-600	600-800	600-850
Fusion temperature of residual material (°C)	1500	1200	1400	1450
Density ($10^3 kg/m^3$)	2.55	3.3-3.4	3.4-3.5	2.85-3.1
Resistance to acids	rapidly attacked	good	attacked slowly	very good
Resistance to alkalis	very good	good	good	very good
Texture	flexible, silky and tough	flexible to brittle and tough	usually brittle	usually brittle
Producing countries (last 5 years	USSR, Canada China, Zimbabwe, USA, Italy, S. Africa, Swazilnad	S. Africa	S. Africa	Finland, USA, Mozambique

a. theoretical formula $Mg_6(OH_4Si_2O_5)_2$
b. theoretical formula $Na_2Fe_5(OHSi_4O_{11})_2$
c. theoretical formula $MgFe_6(OHSi_4O_{11})_2$
d. theoretical formula $(MgFe)_7(OH_4Si_4O_{11})_2$

Table 4.2. Frible Materials and Woven Products Containing Asbestos.

Subdivision	Genetic Name	Asbestos % by Weight	Dates of Use	Binder/Sizing
Friable Insulating Material	spray-applied insulation	1-95	1935-1970	Sodium silicate portland cement organic binders
Performed Thermal Insulating Products	batts, blocks & pipe covering			
	85% magnesia	15	1926-1949	magnesium carbonate
	calcium cilicate	6-15	1949-1971	calcium silicate
Textiles 2/	Cloth			
	blankets	100	1910-present	none
	felts	90-95	1920-present	cotton/wool
	blue strips	80	1920-present	cotton
	red strips	90	1920-present	cotton
	green strips	95	1920-present	cotton
	sheet	95-50	1920-present	cotton/wool
	cord/rope/yarn	80-100	1920-present	cotton/wool
	tubing	80-85	1920-present	cotton/wool
	tape/strip	90	1920-present	cotton/wool
	curtains (teacher, welding)	60-65	1945-present	cotton

Table. 4.3 Bibfruabke Natrux Bonded composite Products Containing Asbestos

Subdivision	Genetic Name	Asbestos % by Weight	Dates of Use	Binder/Sizing
Cementitious Products	extrusions	8	1965-1977	portland cement
	panels:			
	corrugated	20-45	1930-present	portland cement
	falt	40-50	1930-present	portland cement
	flexible	30-50	1930-present	portland cement
	flexible perforated	30-50	1930-present	portland cement
	laminated (outer surface)	35-50	1930-present	portland cement
	roof tiles	30-20	1930-present	portland cement
	clapboard & shigles			
	clapboard	12-25	1944-1945	portland cement
	siding shingles	12-14	unknown-present	portland cement
	roofing shingles	32-20	unknown-present	portland cement
	pipe	20-15	1935-present	portland cement
Paper Products	Corrugated:			
	high temperature	90	1935-present	sodium silicate
	moderate temperature	70-35	1910-present	starch
	indented	98	1935-present	cotton and organic binder
	millboard	85-85	1925-present	starch, lime clay
Roofing Felts	smooth surface	10-15	1910-present	asphalt
	mineral surface	10-15	1910-present	asphalt
	singles	1	1971-1974	asphalt
	pipeline	10	1920-present	asphalt
Asbestos-Containing Compounds	caulking putties	30	1930-present	linseed oil
	adhesive (cold applied)	5-25	1945-present	asphalt
	joint compound		1945-1975	asphalt
	roofing asphalt	5	unknown-present	asphalt y
	mastics	5-25	1920-present	asphalt
	asphalt tile cement	13-25	1959-present	asphalt
	roof putty	10-25	unknown-present	asphalt
	plaster/stuco	2-10	unknown-present	portland cement
	spackles	3-5	1930-1975	starch, casein, synthetic resins

	sealants fire/water	50-55	1935-present	caster oil or polyisobutylene
	cement, insulation	20-100	1900-1963	clay
	cement, finishing	55	1920-1973	clay
	cement,magnesia	15	1926-1950	magnesium carbonate
Asbestos Ebony Products		50	1930-present	portland cement
Flooring Tile and Sheet Goods	vinyl/asbestos tile	21	1950-present	poly (vinyl)-chloride
	asphalt/asbes-tos tile	26-33	1920-present	asphalt
	sheet goods/ resilient sheet	30	1950-present	dry oils
Wallcovering	vinyl wallpaper	6-8	unknown-present	--
Paints and Coatings	roof coating	4-7	1900-present	asphalt
	air tight	15	1940-present	asphalt

Table 4.4 TYPICAL PRODUCTS CONTAINING ASBESTOS

	Products	Typical Asbestos Content (% W/W)	Typical Asbestos Fibre Type
1.	Friction materials: brake and clutch linings, friction sheet	30-70	C
2.	Asbestos millboard	20-45	C, Cr
3.	Woven asbestos products: cloth, webbing and tapes, gloves	65-100	C
4.	Asbestos yarn and rope	65-100	C
5.	Asbestos-cement building materials: flat sheets, corrugated sheets, pipe, mounded products, high density floor sheets	10-16	C, A, Cr
6.	Fire doors		
7.	Electrical switchboards		
8.	Gaskets and asbestos paper	70-90	C, A, Cr
9.	Caulking compounds and filters, muffler putty		
10.	Clacium siliate/asbestos marine board, sheets, turned products	25-40	C, A
11.	Head tiles used in steelworks		
12.	Insulation blocks		
13.	Asbestos insulated cable		
14.	Floor tiles and tile adhesives	8-30	C
15.	Anti-friction materials		
16.	Abrasive papers		
17.	Moulded plastics and battery boxes	55-70	C, Cr
18.	Thermal insulation products. including sprays	12-100	C, A, Cr
19.	Paints	4	

a Data derived from HSC (1979a), NHMRC (1979b), CEC (1977) and Hodgson (1965)
b. A = Amosite
C = Chrysotile
Cr= Crocidolite

Table 4.5 Types of lung fibrosis caused by asbestos

Parachymal			Asbestosis
Pleural:			
	Visceral:	Acute	Asbestosis
		Chronic	Asbestosis
	Parietal:	Hyaline Calcified	Pleural plaques

Table 4.6. Employment in occupational groups ten or more years before death for 344 male cases and their matched controls (Canada, 1960-1972; United Sates, 1972)

Occupational group	Jobs		Men		Relative risk
	Cases	Controls	Cases	Controls	
A. Insulation	27	1	27	1	46.0
B. Asbestos production and manufacture			25	7	6.1
Mining and milling (chrysotile)	4	2			
Manufacture	14	2			
Asbestos cement products	3	2			
factory using asbestos	7	1			
C. Heating trades (excl. insulation)			70	27	4.4
Job necessitating heat-protective clothing	11	7			
Installing or repairing	28	9			
furnaces or boilers	5	2			
Streamfitter	2	1			
Boiler maker	23	8			
Plumbing and heating	14	8			
Welder					
D. Shipyards	49	17	21	13	2.8
E. Construction industry			45	30	2.6
Building trades	59	36			
Building demolition	3	2			
Painting	13	3			
Sheetrock spackling	1	0			
F. Other listed jobs			55	90)	
(excl. men in groups A-E)			101	176)	
G. None of the above			344	344	

From McDonald, A.D.; Mcdonald, J.C., "Malignant mesothelioma in North America", Cancer (Philadelphia), 1980, 46/7 (1650-1656).

Table 4.7 Mesothelioma death rates

Exposure category and duration (years)	Pleura	Peritoneum	S years	Rate per 100000 S years
Males				
Low to moderate				
< 2	3	1	12031	33
> 2	3	4	7500	93
Severe				
< 2	6	10	15428	104
> 2	7	12	7827	243
Laggers				
< 2	3	2	7893	63
> 2	1	4	2690	186
Females				
Low to moderate	1	0	2066	48
Severe				
< 2	8	5	9538	136
> 2				

Table 4.8. Electron miicroprob analyses of asbestos from Behram Dheri, Distriict Charsadda.

S.NO	NJASB1-1	NJASB1-2	NJASB1-3	NJASB1-4
SiO_2	51.690	51.020	50.580	51.950
Al_2O_3	01.330	01.320	01.400	01.450
FeO	01.910	02.780	02.940	01.970
MgO	45.000	44.570	44.690	44.630
CaO	00.060	00.040	00.040	00.000
Na_2O	00.000	00.000	00.020	00.000
CR_2O_3	00.000	00.270	00.320	00.000
Total	99.990	100.000	99.990	100.000
	Formulae on the basis of 23 oxygens			
Si	05.681	05.635	05.601	05.704
Al	00.173	00.173	00.184	00.188
Fe^{2+}	00.176	00.257	00.272	00.180
Mg	07.368	07.337	07.372	07.299
Ca	00.008	00.004	00.004	00.000
Na	00.000	00.000	00.004	00.000

Table 4.9	Showing XRD data of asbestos samples from localities under investigation.						
Sample No						Type	Locality
NJ 1	d	7.3	3.64	2.52	2.42	Antigorite 6M	Behram Dheri
	I	400	300	70	40		
NJ 15B	d	7.3	3.61	2.52	2.42	Antigorite 6M	Behram Dheri
	I	400	300	50	30		
NJ 9	d	7.3	3.64	4.54		Chrysotile 2M	Behram Dheri
	I	100	70	40			
NJ15A	d	7.3	3.64	4.57		Chrysotile	Behram Dheri
	I	100	70	40			
NJ 8	d	8.41	3.12	2.7	3.27	Tremolite	Behram Dheri
	I	100	100	42	70		
NJ 2	d	7.3	3.67	4.57		Chrysotile	Behram Dheri
	I	100	84	35			
NJ 50	d	7.36	3.63	2.52	2.45	Antigorite 6M	Hero Shah
	I	400	300	54	36		
NJ 55	d	8.41	3.12	2.71	3.27	Tremolite	Hero Shah
	I	83	81	57	40		
NJ 45	d	7.24	3.64	4.57		Chrysotile	Hero Shah
	I	90	67	43			
NJ 54B	d	7.3	3.64	4.54		Chrysotile	Hero Shah
	I	100	75	35			
NJ 66	d	8.41	3.12	2.71	3.27	Tremolite	Newe Kili
	I	100	100	50	55		
NJ 65 Mixtu	d	8.41	3.11	2.7	3.27	Tremolite	Newe Kili
	I	100	100	62	50		
NJ 65	d	weak peaks of chrysotile				Chrysotile	Newe Kili
	I						
NJ 63	d	3.12	2.71	3.27		Tremolite	Newe Kili
	I	100	55	56			
NJ 62	d	7.24	3.6	2.53	2.41	Antigorite 6M	Newe Kili
	I	400	300	52	35		
NJ 42	d	7.3	3.64	4.57		Chrysotile	Narai Obe
	I	100	93	38			
NJ 28	d	2.87	7.24	3.34	3.63	Unknown	Qila
	I	200	70	60	45		
NJ 22	d	7.24	3.61	4.52		Chrysotile	Qila
	I	100	72	40			

Table 4.10 Showing fibrogenisity characteristics of asbestos from various localities under investigation.

Locality	Readings —>	1	2	3	4	5	6	7	8
Behram Dheri	Fibre length in micrometer	3250	600	50	3000	1000	1250	900	30
Mine 6	Fibre diameter in micrometer	25	10	0.75	30	5	7	8	1
Sampe 15A	Length/Diameter	130	60	66.66667	100	200	178.5714	112.5	30
	Fibre length in micrometer	175	150	100	112.5	140	160	200	300
Hero Shah Mine no 1	Fibre diameter in micrometer	0.25	0.25	0.075	0.075	0.3	0.45	0.5	0.5
Sample 54A	Length/Diameter	700	600	1333.333	1500	466.6667	355.5556	400	600
Hero Shah Mine no 1	Fibre length in micrometer	30	250	150	175	175	300	350	700
Sample 55J	Fibre diameter in micrometer	1	2.5	1.25	1.25	1	5	2	0.5
	Length/Diameter	30	100	120	140	175	60	150	1400
Newe Kali Machine-1	Fibre length in micrometer	10	20	61	65	70	50	70	85
	Fibre diameter in micrometer	2.5	1.25	2	1	1	1	0.5	1.5
	Length/Diameter	4	16	30.5	65	70	50	140	56.66667
Newe Kili machine-2	Fibre length in micrometer	100	40	50	70	100	40	50	80
	Fibre diameter in micrometer	0.3	0.1	0.2	0.1	0.15	0.1	0.2	0.1
	Length/Diameter	333.3333	400	250	700	666.6667	400	250	800
Newe Kali machine-3	Fibre length in micrometer	30	50	60	70	40	70	40	90
	Fibre diameter in micrometer	0.01	0.02	0.02	0.015	0.02	0.03	0.03	0.02
	Length/Diameter	3000	2500	3000	4666.667	2000	2333.333	1333.333	4500
Qila Mine no 3	Fibre length in micrometer	1000	150	175	500	300	150	1200	150
Sample 24	Fibre diameter in micrometer	12.5	7	2.5	10	5	6	8	6
	Length/Diameter	80	21.42857	70	50	60	25	150	25

Table 4.11. Statistics of the economics of asbestos and the population of the area.

Number of mines visited = 35

Number of mines in production state = 15

Daily average number of trucks from each mine = 1

Weight of material per truck = 10 metric tonnes

Daily total number of trucks = 15

Daily total of all minerals including asbestos = 10 x15 = 150 mts

Cost per truck= Rs 3000/-

Total daily earning = 15 x 3000= Rs 45,000/-

Number of crushing and grinding machines

Newe Kili, Mohmand agency = 5

Tangi, District Charsadda = 3

Berlin, District Charsadda = 1

Total number of machines = 8

Number of days spent on crushing of one truck by each machine = 2 (average)

Number of trucks crushed by 8 machines daily = 4

Total crushed material each day = 4x10 = 40 metric tonnes

Cost of ground asbestos = Rs 6000/truck

Total daily earning on ground asbestos = 4x6000 = Rs. 24000/-

Pure threads of asbestos cost = Rs 60/kg

Approximate number of villages in asbestos bearing area = 15

Average population per village = 1500/-

Total population of the area = 15x 1500 = 22500 people

Chapter 5

DISCUSSION

The Skhakot Qila Ultramafic Complex has been described as an ophiolite segment of the Tithean oceanic crust (sandwiched between the Gondwanic continent and Kohistan arc - generally exposed along MMT), tectonically emplaced in the present location (see Ahmed & Hall, 1981; Tahirkheli et al., 1979). Ahmed (1982) has referred it to the harzburgite sub-type of Alpine type peridotite of Jackson and Tyre (1972).

The tectonic settings, field relationship, petrographic and chemical data of the ultramafic and related rocks (gabbros, microgabbro, metavolcanic) of this complex support the previous work. The ultramafic rock, dunite, pyroxenite and peridotite have major element characters typical of metamorphosed ultramafic cumulate. Similarly the limited data on the basic rocks also indicate oceanic characters. Therefore both the sets of rock can be tectonically classified as rocks of an oceanic mafic-ultramafic complex. The trace element support these evidence (Scotford & Williams, 1983). Major and trace element chemistry also indicate initially the role of igneous crystallization differentiation with olivine and pyroxene as dominant phases on the liquidous in ultramafic rocks (Chapter 3). In the chromite-bearing rocks chromite coronated with olivine indicate simultaneous crystallization of the two phases with the latter being appeared on liquidous a little earlier than the former. The role of plagioclase fractionation seems meager as no plagioclase-rich rocks occur in the complex and plagioclase if present, is interstitial and accessory. Petrography and chemical data also indicate pyroxene and plagioclase as the dominant crystallizing phases on liquidous in the mafic rocks. This is supported by the presence plagioclase pseudomorphs and epidote after pyroxene in these rocks (see Chapters 2-3).

The dominant post solidification transformation are serpentinization of dunite and peridotite, and the formation of chlorite and epidote in the mafic rocks (Figs 2.7-9). A variety of other secondary minerals associated with serpentine locally in dunites/serpentinite and peridotite/serpentinite are magnetite, asbestos (chrysotile, tremolite), magnesite, brucite carbonate and talc. Hamidullah (1984) working at Bucha, Mohmand Agency on the petrogenesis of asbestos referred the transformation of dunite/peridotite to serpentinite according to the reaction of Coleman and Keith (1971) and Moody (1976a, b) as following:

$$\text{Olivine} + \text{H2O} \rightarrow \text{Serpentine} + \text{Brucite} + \text{Magnetite}$$

He signified these transformation under high temperature and oxygen fugacity and referred the presence of talc at certain localities to the presence of CO_2. On the basis of asbestos associated typically with shear zones and the presence of slickensides and mylonite he attributed the formation of this fibrous mineral to increased directed pressure, locally during tectonic emplacements. On the other hand Jehan and Khan (1963) reporting spheroidal asbestos from Qila, attributed the origin of asbestos to (a) the transformation of olivine to serpentine under hydrothermal alteration, (b) the formation of a mixture of magnesium silicate and water constituting a binary system of immiscible liquid, (c) subsequent cooling resulting into spheroids of asbestos in water, (d) further cooling resulting into massive serpentine enveloping the spheroids. As both slip fiber and spheroidal asbestos are present at Qila, Bucha and all other localities, it is suggested that both the phenomenon were operative at different places and wherever P_{CO_2} increased 5 mole %, talc instead of chrysotile/asbestos formed, particularly under directed pressure (see Moody 1976a, b; Johannes & Metz, 1968). The overall petrographic and chemical data and previous studies indicate that the ultramafic rocks SQUC have undergone the following stages of evolution:

1. Emplacement of basic magma under oceanic environment in magma chamber under the Titheon oceanic crust.

2. Crystallization differentiation and accumulation of olivine, and/or pyroxene resulting into layered dunite, peridotite and pyroxenite as the ultramafic members of the complex.

3. Tectonic emplacement of the complex during Himalayan orogeny.

4. Metamorphic transformation due changes in P-T regimes resulted in the formation of serpentine after olivine and pyroxene, tremolite after pyroxene, in the ultramafic rocks and chlorite and epidote after pyroxene and plagioclase in the basic rocks; indicating at least green schist facies environment (Miyashiro, 1976).

5. Other minerals which developed during metamorphism and tectonic processes are asbestos, talc, brucite, various carbonates, magnetite and magnesite. Asbestos is represented by tremolite after pyroxene and by chrysotile after olivine and orthopyroxene. As mentioned earlier other phases associated with serpentine including talc, brucite magnetite etc. all indicate local variations in P-T conditions (i.e. brucite - low temperature serpentinization, talc-low P_{CO_2}, asbestos - high P_{CO_2}, talc + magnesite intermediate fO_2 and fS_2; see Moody 1976).

Moody (1976) has also defined pivotal as responsible for the formation of various phases during serpentinization as following:

Chrysotile + brucite + Forsterite - 6.5 Kb

Chrysotile + brucite + magnetite - 2 Kb

Chrysotile - talc - forsterite - 7 Kb

(see Johannes, 1968, Chernosky 1973; Moody, 1976; also see Coleman & Keith, 1971).

Further details study of the origin of these rocks and asbestos is beyond the scope of the present investigation.

The major aim of this study was to determine whether the asbestos from the northern Pakistan is environmentally safe or not? To answer this question several other question had to be answered, e.g. what type of asbestos occurs? what is its fibrogenesity? how it is mined? how it is processed? And if it is not the safe, are environmental safety procedures adopted during mining, milling, crushing and industrial utilization. The current study has answered several of these questions as follows:

Previous studies (references) and the current data including electron microprobe analyses and XRD results indicate that at Bucha, Prang Ghar, Newe Kala, Narai Obe, and Hero Shah the dominant variety of asbestos is chrysotile, associated by tremolite and antigorite; all considered highly carcinogenic if their fibber length exceed 8 mm and diameter is <3 mm. In this study a factor length/diameter has been determined using 8/3 = 2.333 as the threshold value and any fiber with a value higher than this factor may be considered fibrogenetic and thus carcinogenic. Asbestos collected from all the mining localities studied under microscope have fibers indicating values varying between 4 and 4666 (Table 4.10). Similarly asbestos fibers from crushing plants at Newe Kili also have values above the threshold value. No data has been collected on the amount of dust in air but photographs taken inside the crushing plants indicate very high proportion of dust.

Crushing plants which are covered and apparently use semi-modern machinery and thus considered relatively safe are rather more dangerous for the labor working inside because the dust/fibers mostly remain within the limited area, example is the machine at Newe Kale in which the intensity of dust inside the plant has lowered the visibility to a great extent (Fig. 5.6a-d)

Another dangerous aspect of these crushing machines in their multi-purpose use; i.e. at some places there are crushers/grinder for crushing asbestos and grinding grains to flours for the locals (Figs. 4.4b-c; 4.5a-d). In other places the same grinders are utilized both for grinding asbestos and wheat or maize. The carcinogenic impacts of asbestos on the digestive system are not clear because of the lack of data but several worker (e.g. Gilson 1979) have documented cases of cancers in digestive system where water polluted with asbestos has been utilized for drinking purposes.

The current study shows that the asbestos type, the fiber length and diameter, the exposure time and the amount of dust blown determine the limit of carcinogenicity in asbestos. It also shows that it is mined and milled without any precautionary measures so the miners and labor working in crushing plants are at risk. Also the dust dissipated from the crushing plants to the air of the surrounding areas (Newe Kili, Berline) has already intensified the cases of asthma in women leaving in the vicinity of the plants. Further in these areas children have developed skin and eye allergies. The labour working within the machine complain of high intensity of coughs and flue since they have started working in the machine. Therefore, considering all these facts it is concluded that the asbestos of

Mohmand agency, Malakand agency and Charsadda district are classified as carcinogenic on the basis of its type and fiber length and may cause asbestosis, pleural plaque mesothelioma, pneumoconiosis and other types of lung cancers in the miners, laborers in crushing and grinding plants, in population living in the immediate vicinity of the crushing plants, and in the population who are the ultimate users of the asbestos industrial products. The asbestos dust is also a potential danger for creating asthma, skin allergies in the population receiving asbestos dust. At Mohmand agency and Charsadda district apart from asbestos dust, dust of other silicate minerals including talc and quartz are also mined crushed and grinded in various crushing plants at Newe Kale and are permanent sources of the silicate dust. Therefore precautionary measure for controlling dust in general and for asbestos fibrous dust in particular, at various levels of processing, including mining, crushing and grinding, are needed. For general dust control the following precautions are need to be adopted.

5.1 GENERAL DUST CONTROL METHODS

Ventilation and water spraying are the two primary methods for dust control in underground mining. In addition, dust filter plants and scrubbers are used to clean very dusty air at permanent installations such as underground crushers, skip loading stations etc. Ventilation, primary and secondary, is by far the best method of dust control. The ventilation will both dilute the dust and transport it out of the mine. Water spraying can only supplement ventilation by hindering dust becoming airborne. Water spraying can be used to wet muck piles before and during loading, at transport transfer points such as chute dumping and draw points, conveyor transfer points, when dumping in the crusher etc. Spraying of the muck pile after blasting, will also bind some of the explosive gases which are trapped in the pile, and thus reduce the amount of gases being emitted into the atmosphere during loading. The efficiency of water spraying depends among other factors on the size of the water droplets. The wetting capability of water spraying can be enhanced by adding small amounts of a surface tension reducing agent. Similar precautionary measures are made to be adopted in the crushing plants. At Newe Kili only one plant has relatively modern equipment and claim to be controlling dust. However, as mentioned earlier, the amount of dust inside the plant and that dissipated in to the surroundings can be seen in Figure 4.6a-b and thus their control system seems to be totally ineffective. Therefore, the above mitigation methods must be followed in letter and spirit.

Other mining hazards mentioned earlier are radiation, noise, bad illumination, mine fires, heat and humidity, vibrations and the use of toxic and harmful chemicals used in processing.

The level of radiation can be controlled by the normal ventilation needed to dilute and disperse gases and dust. Noise can be reduced by designing means of avoiding noise (rubber lining of machines, ore chutes and grinding mills), using mufflers through the transmission paths, use of sound absorbing material in the control rooms, and use of earplugs, earmuffs and noise helmets by the worker. Illumination is needed to be improved which will reduce workers fatigue, improve safety and increase productivity. Mine fires can be prevented and controlled by good house keeping and training especially in connection with maintenance work. Detection and warning devices should be installed in permanent installations. Smoke and temperature detection devices can also be installed in some of the main airways of the mines and crushing plants.

Mine cooling can be achieved by ventilation at shallow level and by service water cooling at deeper level in mines. Vibration frequencies of 0.5 - 20 Hz are the most harmful. Exposure to vibration should be minimized through basic machinery design and development of good ergonometric (?) cabins, seats and handles for vibrators. To ensure the above mitigation practices and avoid accidents due to the use of toxic chemicals and explosive a thorough program of safety training of various levels is needed for the mine and plant workers. Some imported elements of training may include:

- Basic training of all new employees.
- Training of operators to use equipment safely both for themselves and their colleagues.
- First aid training of some personnel.
- Training of selected rescue teams.
- Training of fire fighters.
- Training of personnel for monitoring health and safety conditions.

Basic training should involve all new employees. The program will include topics as:

- health hazards such as dust, gases, and noise.
- use of personal safety equipment; helmet, life saver, car protection, safety boots, safety harness, safety glasses etc.
- procedures for accident report location of first aid equipment.
- location of escape routes and exits.

Operator training is of prime importance in modern, mechanized mining operations. The training program will seek to establish good housekeeping practices and working routines. The operators are supposed to have the responsibility to ensure that all safety equipment and devices are in working order at all times, if not, equipment should not be allowed to operate. In addition, it sh uld be mentioned that regular maintenance of all equipment is of great importance in order to ensure trouble-free and safe operation.

First aid training should be offered to interested and dedicated personnel. First aid personnel will also be doing ordinary jobs, and should be dispersed throughout the operation. Rescue teams are to be trained to handle rescue operations in case of mine fires and explosions, collapse of mine workings, flooding, and other catastrophic events. In some operations it can be advisable to train the team to handle plant fires, chemical spills etc. Fire fighting teams can increase safety and reduce damage by quick action in case of industrial fires, especially since the asbestos mining operations and mining towns are located far from any regular fire fighting forces or fire brigade

Health and safety monitoring personnel will often be mandatory. The Mining Act must be, demanding that certain health and safety risks, such as dust (and methane) should be monitored on a regular basis.

As with all other trainings, safety trainings are forgotten with time. Regular refresher courses are therefore an integral part of all comprehensive safety training programs.

It is also important to involve line supervision directly in all facets of the health and safety work in an operation. This can best be done by defining health and safety work as an integral part of the production work which supervisors are responsible for.

Health limit values for various gases and other parts of air borne dust may be taught as part of the training.

5.2 SAFETY AND HEALTH MEASURES FOR ASBESTOS

5.2.1 Protection from Dust

Prevention of dust production and its effective control at the site of production is the basis of technical control. Water spraying and ventilation have been described above to control dust in situ. Once the dust is airborne in the general atmosphere, its elimination and control become expensive and relatively ineffective. Thus, successful technical control starts with enclosing machines and applying local exhaust ventilation at points where the equipment has to be opened- for example where bags of fiber are fed into mixers or the fiber comes out of the machine at the bagging end of the mills. Damping of the fiber before mixing with other products and during spinning and weaving can greatly assist the elimination of dust production. In many circumstances, such as removing old insulation and spraying new material, personal protection is essential. A well fitting dust mask may be adequate for some jobs where exposure is intermittent and longer exposures occur in certain conditions. Where dust control is inadequate, such as the removal of old insulation in large amounts, full respiratory protective equipment should be used (see Fig. 5.1). It is now common practice to require complete insulation of the area where old insulation is being removed to protect those in the vicinity. Exhaust ventilation is required where asbestos-containing products are ground, swan, drilled, or turned, and the cleaning up should be done by vacuum cleaners rather than brushes.

As asbestos dust in clothing has been shown to be a possible hazard, a change of clothing at the job should be provided and its use made obligatory. Laundrying of the clothing will be needed. Asbestos-containing products are so widely used that complete control under all conditions is clearly impracticable. At present there is little evidence to show that occasional slight, intermittent exposure is harmful (see also Fibres, Natural Mineral; cf Worksafe Code Industrial).

5.2.2 Prevention of asbestosis and other cancers

The prevention of asbestosis depends on successful control of dust exposure and medical surveillance to protect the individual, as far as is possible, and for the detection of health trends in the group.

5.2.3 Engineering control

Replacement of asbestos by other materials believed to be safer has been widespread since the mid-1970s. Man-made mineral fibers and other insulating materials are rapidly replacing asbestos for heat insulation. But for other uses, for example asbestos cement, friction materials and some felts and gaskets, substitution is not practicable at the present.

Dust control has been gradually improved by partial or complete enclosure of plants and the wide use of well designed local exhaust ventilation. In the textile section a completely new wet process of forming the thread has greatly reduced dust level, previously difficult to control. During maintenance work an old insulation much stricter control of exposures is possible by isolation of the working areas, and by training in the use of good working practices to reduce the dust, for example damping of the insulation before removal, and the use of vacuum cleaning in place of sweeping. But removal of old insulation is likely to remain for many years a major potential source of high exposure (see also Dust Control, Industrial).

5.2.4 Medical surveillance

The insidious onset of asbestosis and the lack of highly specific features indicate the need for well recorded and systematic, initial, and periodic examinations of asbestos workers. This ensures the best chance of detecting the earliest signs. Physical examination of the chest, full - sized, high technical quality chest radiographs and tests of FVC and FEV1-0 are the minimum required. The interval will vary from annually up to four times yearly, with more frequent visits when there are clinical reasons. There is increasing evidence that the radiological features of asbestosis are in part cigarette-smoking dependent, which requires the recording of smoking histories. This and the multiplicative effects of asbestos dust and cigarette smoking on the risk of bronchial cancer provide the strongest possible grounds for stopping cigarette smoking in those potentially exposed to asbestos. Personal advice on the special dangers of smoking and limiting opportunities for smoking at work are essential steps in prevention. Full personal protective equipment will be required where dust levels cannot be lowered to the hygienic standard. The system of periodic examinations also provides, if properly analyzed, essential information about the effectiveness or failure of the engineering control of the dust. Tabulation, by age and years of exposure, of the results of classifying the chest films on the ILO 1980 scheme-preferably by independent readers-gives early evidence of trends in the prevailence of asbestosis. This valuable information will be missed if the group findings are not examined in detail.

5.2.5 Treatment

There is no specific treatment for asbestosis. Where the rate of progression appears unusually rapid further special investigations, including lung biopsy, may be justified if it is likely to assist in the differential diagnosis, and influence treatment - for example the use of steroids, but these are not of proved value. The severity of past exposure is the only factor known to influence progression rate. Thus, those with some evidence of asbestosis, if young or middle-aged, should be removed from further exposure. In cases where exposure has not been heavy and asbestosis is only detected late in life, progression may be very slow and the grounds for removal from work with asbestos, under good conditions, are less compelling.

The widespread and often misleading publicity given to the hazards of exposure to asbestos may cause much anxiety to those with asbestosis, both for their own health and for that of their family. Reassurance, and the putting of the likely prognosis in true perspective, are an important part of good treatment. The special risks of continuing cigarette smoking need emphasis. Mesotheliomas are a rare complication in those exposed only to chrysotile.

5.2.6 Compensation

The conventions on the awarding of compensation for asbestosis vary in different countries. Unusual breathlessness on exertion, as a cause of disability, may be required, even though it is not essential for a confident diagnosis of asbestosis. Compensation may be limited to those with evidence of parenchymal disease; pleural fibrosis-parietal or visceral-alone may not be accepted. Lung (bronchial) cancer is usually accepted as part of the disease provided there is at least some evidence or parenchymal fibrosis, but may be rejected if there is no radiological evidence of pleural or parenchymal fibrosis. There is plenty of opportunity for disagreement, especially when a factor for uncertainty of prognosis is included. It is now established that asbestos dust alone may cause lung cancer although the absolute risk is very small compared with that from the combined effects of cigarette smoking and asbestos dust. It has not been established that pleural plaques alone result in an increased risk of bronchial or mesothelial tumor, above that for similar exposures to asbestos dust without these pleural changes. The considerable uncertainty about the likely rate of progression of the fibrosis makes assessment on first diagnosis especially difficult. Lung biopsy is not justifiable solely for compensation assessment.

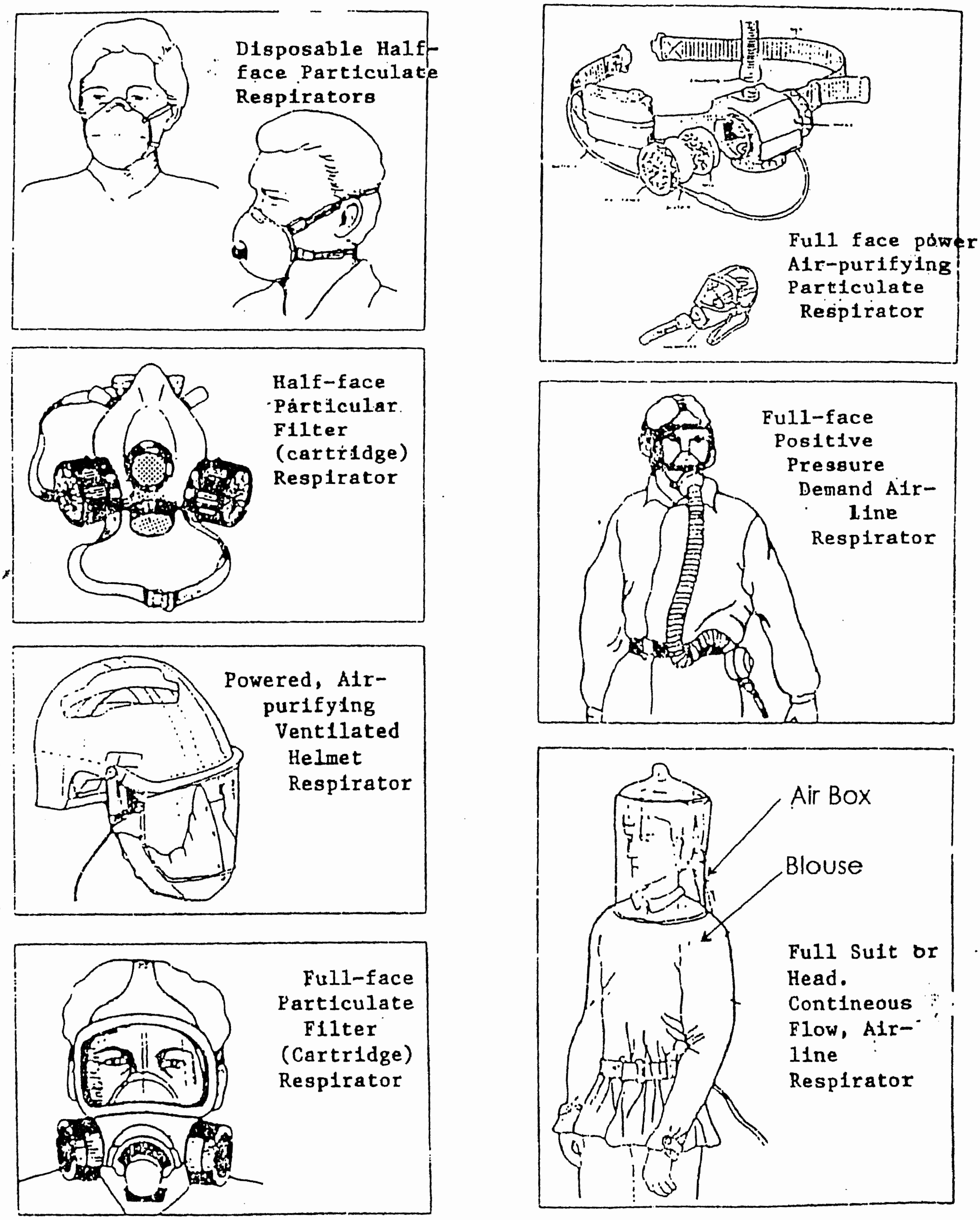


Fig. 5.1. Respirators for protection against exposures to asbestos (Worksafe Code Aus., 1988)

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. Rocks of the Skhakot Qila Ultramafic Complex represent an ophiolite segment of the Tithean oceanic crust and are classified as a metamorphosed mafic ultramafic complex.

2. Igneous crystallization, fractionation and accumulation of olivine, pyroxenes (and chromite) led to the development of dunite, harzbargite pyroxenite (and chromitite) and fractionation of pyroxene and plagioclase led to the development of gabbros, microgabbros and volcanic members of the suite (Bucha).

3. Tectonic emplacement led to deformation and metamorphism of these rocks transforming dunite and peridotite into serpentinite.

4. Local variation in P-T condition during tectonic deformation and metamorphism caused the crystallization of various minerals with serpentine as essential constituent and brucite, forsterite, magnetite, magnesite, talc and carbonate associated in variable proportions.

5. Serpentine is classified mostly as chrysotile and along shear zones it is grown as fibrous asbestos.

6. Asbestiform tremolite also occur locally at Hero Shah, Behram Dheri and Newe Kili and has most probably grown from the deformation of pyroxenite.

7. Chemical and physical classification of asbestos define these as highly carcinogenic and a potentially hazardous for producing asbestosis and other lung cancers. The dust produced during the crushing and grinding of asbestos and related minerals in crushing plants at Tangi , Berlin and Newe Kale is also a potential hazard of skin and eye allergies and of asthma in the locals.

8. Being proved carcinogenic the asbestos of the Skhakot Qila Ultramafic Complex also pass hazard to the users of asbestos products manufactured in various industries in Pakistan. Of particular danger is the use of talcum powder produced from crushing talc together with asbestos in crushing plants at Newe Kili, Berlin and Tangi.

6.2 RECOMMENDATIONS

1) Pakistan Environmental Act may be revised to emphasize on pollution control and hazard mitigation related to mineral and mineral based industry.

2) The mineral policies and mining acts of the central and provincial governments may be revised to include in-built measures and laws regarding environmental and health hazards from minerals and mineral industries.

3) Asbestos in particular may be emphasized as carcinogenic and may be allowed for mining under special licensee from the government and PEPA.

4) Asbestos mining and processing around Peshawar valley may be immediately taken in control of an agency which can implement the following mitigation procedure:

a) Ventilation and water spraying procedure mentioned in sections 5.1 and 5.2 are followed strictly at underground mining at Qila, Bucha, Newe Kele, Hero Shah etc. and other mining installation. In addition water spraying must be applied during loading, dumping at dumping points and dumping in crushers at Berlin, Newe Kele, Tangi and other crushing plants in the area.

b) All the machines must be enclosed and proper local exhaust ventilation may be applied.

c) Personal protection of labor and skilled worker has to made essential at all points, providing a well fitting dust mask, and where longer exposures are possible, a full respiratory protective equipment may be provided.

d.) Exhaust ventilation is required where asbestos-containing products are ground, swan, drilled, or turned, and the cleaning up should be done by vacuum cleaners rather than brushes.

e) A change of clothing and laundrying at the job should be provided and its use made obligatory.

f) The use of asbestos in the talcum powder must be abandoned.

g) All the employees of the mining, crushing transportation and other asbestos processing unites must be properly trained and made well aware of the general hazards of mineral industry and asbestos hazards in particular.

h) Health and safety monitoring, training and refresher courses must be made mandatory by The Mining Act.

i) Health and safety work may be made as an integral part of the production work well defined by the supervisors.

j) Health limit values for various gases and other parts of airborne dust may be taught as part of the training and displayed prominently at all units.

k) A well recorded and systematic, initial, and periodic medical examinations of asbestos workers has to be made mandatory. The minimum requirements of this examination are physical examination of the chest, full - sized, high technical quality chest radiographs and tests of FVC and FEV1-0 with 1 to 4 times a year.

l) Those with some evidence of asbestosis, if young or middle-aged, should be immediately removed from further exposure.

m) Compensation laws may be devised for those effected and be implemented.

5) Asbestos and asbestosis have remained and are still a hard core issue in Europe, north America, South Africa and Australia. Mining, medical and environmental expertise including environmental laws and safety codes of these countries may be consulted.

6) Man-made mineral fibers and other insulating materials replacing asbestos may be encouraged.

7) Further research in this area must be continued. This must be carried out by environmental scientists and medical experts in close coordination.

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