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TITANIUM CONTENT OF A CHLORITOID-QUARTZ-ILMENITE BAND IN OPHIOLITIC MELANGE NEAR PRANG GHAR, NW PAKISTAN

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ABSTRACT

Titanium is a valuable engineering metal and has many uses. In the greenstone of the Indus suture melange near Prang Ghar, a 200 m long and 1 to 3.5 m thick band consists essentially of chloritoid (31 to 59 vol.%), quartz (10 to 27 %), and ilmenite + Fe-oxide (8 to 25 %). The rocks contain very high Al_2O_3, total Fe_2O_3 and TiO_2, and low SiO_2, CaO, MgO and alkalis. The unusual composition may have formed from basaltic precursors of the greenstone by weathering (laterization) or alteration, followed by greenschist facies metamorphism. Chemical analyses of three samples, containing 5 to 10 wt. % TiO_2, warrent further investigation of the area.

INTRODUCTION

Titanium is the ninth most abundant element in crustal rocks (making 0.63 % by weight), and second of the transition elements.It has a low specific gravity (4.5), high melting point (1750^{0}C), high mechanical strength and resistance to corrosion. When used with small quantities of metals such as Al and Sn, it has the highest strength : weight ratio of the engineering metals (Greenwood and Earnshaw, 1984). By 1950, a considerable demand developed for Ti in the manufacture of gas turbine engines, aircraft and spacecraft industry, marine equipment and chemical processing. Titanium dioxide is used as a pigment in paints and plastics because of its whiteness, opacity and chemical inertness. Titanium has several other uses, e.g., in mineral fiber, ceramics, paper, etc.

The minerals ilmenite ($FeTiO_3$) and rutile (TiO_2) are the most important sources of titanium. Economically exploitable concentrates of these minerals (and their alteration products) occur in a variety of geological environments: igneous, metamorphic, placer deposits, and residual concentrates associated with laterite and bauxite (Rankama & Sahama, 1950; Bateman, 1967; Borisenko, 1969). Because of scarcity of high grade ores and increasing demand, low grade ores are mined in several areas. In the case of hard rocks, crude ores containing 8 to 10 % TiO_2, which can be upgraded to 45 % TiO_2, can be profitably mined. Gravel deposits containing 10 to 15 kg of ilmenite per ton can be economical, and reserves up to a few million tons of Ti-ores are considered large (Borisenko, 1969). The ores may contain valuable amounts of vanadium, cobalt and nickle by-products.

The major producers of titanium include Canada, USA, South Africa, India, Scandinavia, Australia, Malayisia and former USSR. To date, economic deposits of titanium have not been found in Pakistan. Here we report preliminary data on a chloritoid-rich rock from Prang Ghar, some 60 km to the north of Peshawar. There is sufficient amount of ilmenite+magnetite (up to 25 vol. %) in this rock to warrent further field and laboratory investigations from commercial point of view.

FIELD AND PETROGRAPHIC ASPECTS

During exploration for chromite, emerald, asbestos and talc, a 1 to 3.5 m thick band of chloritoid-rich rock, hosted by greenstone, was found by one of us (M. Rafiq). It occurs 1 km south-east of Prang Ghar : 34^0 25'N, 71^0 37' 3" E. The greenstone forms up to a 500 m broad zone along the southernmost margin of the Skhakot-Qila ophiolite melange which has been emplaced onto the Indian plate (Hussain et al., 1984). Associated with the greenstone are metapelites, blocks of limestone , pockets and lenses of talc, tremolite/actinolite, and talc-carbonate rocks locally containing green beryl (Hamidullah, 1984; Rafiq, 1984; Rafiq & Jan, 1985).

The chloritoid-rich rock forms an irregularly lenticular body traversed by minor faults. It is 1 to 3.5 m thick, 200 m long, and made up of 31 to 59 vol. % chloritoid, 10-25 % quartz, and 8-25 % ilmenite + subordinate oxidized/hydroxidized Fe-sulfide. White mica (in some sections brown-stained) occurs in variable amounts (Table 1). Locally associated with these rocks are greenstones containing abundant chlorite, ore, epidote and/or white mica, with or without chloritoid (no. X4, X10 and X11). In the marginal parts of the body the rocks are medium-grained and they may display megascopic lineation, foliation/schistosity, and local banding. Towards the interior, the rocks become coarser grained and devoid of megascopic foliation. However, under the microscope, ilmenite, which occurs typically in tiny granules dusting the entire thin section, shows a strong alignment (Fig. 1a). In some rocks, quartz and mica may also be aligned.

The chloritoid is mostly medium- to coarse-grained (up to 2 cm long in the central part of the body), euhedral to subhedral, multiply twinned , and full of matrix

TABLE 1. MODAL COMPOSITION OF CHLORITOID-RICH AND ASSOCIATED ROCKS FROM PRANG GHAR AREA.

Sp. No.	X1	X2	X6	X7	X9	X12	S1	S2	S3	S4	X10	X11	X4
Chloritoid	56	58	55	59	50	47	45	31	59	49	8	Tr	-
Ore(il+pyr)	17	15	17	19	25	20	22	12	16	18	14	28	6
Quartz	11	22	26	8	12	12	23	10	20	27	10	9	5
White mica	14	3	1	3	Tr	6	Tr	16	2	2	40	27	Tr
Chlorite	-	-	Tr	7	12	15	9	30	3	1	27	35	40
Epidote	Tr	-	-	Tr	-	-	Tr	1	Tr	-	-	Tr	38
Biotite	-	1	-	3	1	Tr	Tr	-	-	Tr	Tr	Tr	-
Plagioclase	-	-	-	-	-	-	-	-	-	-	-	-	10
Others	2	Tr	Tr	Tr	Tr	Tr	1	-	Tr	3	1	Tr	Tr

Ore = ilmenite and oxidized/hyroxidized pyrite. Tr= < 0.5 %
Others include apatite, tourmaline and rutile.

ilmenite and quartz. There are two generations of chloritoid: an earlier one parallel to ilmenite foliation, and a later one across it. The second generation chloritoid forms distinctly larger grains, often in bow-tie and radial disposition (Fig. 1b), but the ilmenite inclusions still retaining their initial foliation. The sulfide (probably pyrite rather than pyrrhotite) commonly occurs in clusters of euhedral grains in quartz matrix. It is mostly oxidised/hydroxidised and may locally impart orangy brown colouration to the rock.

GEOCHEMISTRY AND PARAGENESIS

Major element analyses of three representative samples, together with some trace elements for one, are presented in Table 2. Samples X12 and S1 were analysed by automatic XRF and PG X1 by wet chemistry. The principal minerals were analysed by electron microprobe. Representative analyses of the ilmenite are also listed in Table 2.

The ilmenite analyses are not unusual, but the total absence of MnO, MgO and CaO is worth noting. The whole-rock analyses are characterised by high quantities of TiO_2, Al_2O_3 and Fe_2O_3 which, together with SiO_2, make up 97% of the rocks. There is a systematic variation in the chemistry of the three samples: with increase in SiO_2, Fe_2O_3 (total) increases and the remaining oxides decrease. This variation is an artifact of bulk mineralogical variation. The amounts of quartz and oxidized pyrite/magnetite increase and those of chloritoid, ilmenite, white mica+chlorite, and apatite decrease from sample X1 to S1.

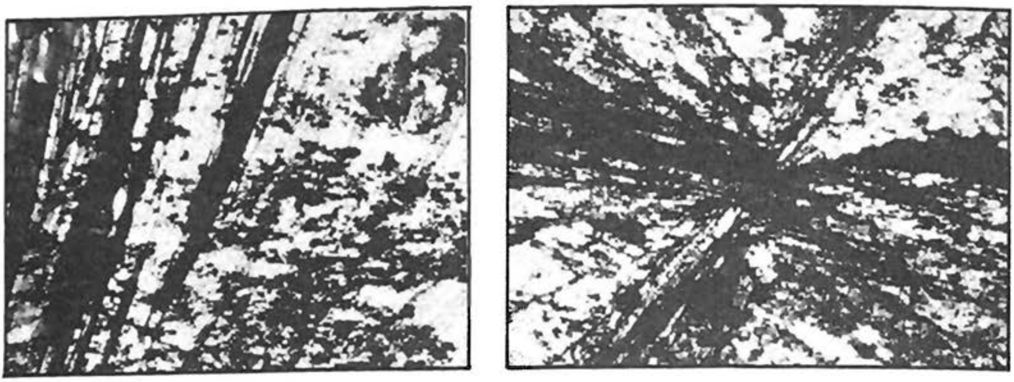

Fig. 1. A(Left) - Twinned crystals of chloritoid containing many ilmenite inclusions which display parallel alignment. Length of photograph is 2mm. B(Right) - Radiating crystals of 2nd generation chloritoid cutting those (lower left) of the first generation. Length of the photograph is 2 mm.

The bulk compositions are unusual for both igneous and sedimentary rocks. Indeed the mineral assemblage and chemical composition of the Prang Ghar rocks are quite unique. In our knowledge, this is only the second occurence of its type so far reported. The other, described from Taiwan (Yen,1959; Chen,1963; Liou and Chen,1978), also occurs in the form of lenses of chloritoid (up to 90 vol. %) + ilmenite in a thick sequence of marbles and chlorite schists. Some of the greenstone samples from Prang Ghar contain a lot of ilmenite and a few, as in Taiwan, contain chloritoid (Table.1, no. 10). This raises the possibility that the chloritoid-rich rock may be related to the greenstone.

Laterization of basaltic rocks can lead to concentration of Al_2O_3, Fe_2O_3, TiO_2, and removal of SiO_2, CaO, MgO and alkalis (cf. Pickering, 1962; Singer, 1973,1975). Thus Liou & Chen (1978) proposed that the chloritoid-ilmenite assemblage of Taiwan represents metamorphosed lateritic soil derived from basaltic rocks. Despite that such an origin can explain the peculiar chemistry and mineral paragenesis of the Prang Ghar rocks, there are serious hurdles in applying this model here. We regard that the melange zone rocks may be of oceanic affinity (Ahmed, 1988 ; Hussain et al.,1984), which were metamorphosed during collision-related tectonics. It is hard to suggest that they were first uplifted and weathered, and subsequently metamorphosed during thrusting onto the Indian plate. Lateritic soils, metamorphosed or otherwise, have not been thus far reported from the Indus suture melange anywhere else. As an alternative, we propose that the chloritoid-rich band of Prang Ghar may initially represent a shear zone within the volcanic rocks. Fluid (mainly water) migration in the shear zone may have led to the development of the peculiar chemical composition, followed by greenschist facies metamorphism during collision.

TABLE 2. WHOLE ROCK AND ILMENITE ANALYSES.

S.No.	X1	X12	S1	X1 il-1	X1 il-2
SiO_2	38.56	40.77	44.24	0.15	0.18
TiO_2	10.28	7.18	4.81	50.85	51.89
Al_2O_3	22.98	21.59	17.87	0.14	0.08
Fe^*	23.50	27.27	30.63	51.00	49.79
MnO	0.28	0.07	0.12	-	-
MgO	1.02	0.77	0.47	-	-
CaO	0.69	0.36	0.25	-	-
Na_2O	0.52	0.13	0.00	-	-
K_2O	0.20	0.00	0.00	-	-
P_2O_5	0.54	0.20	0.04	-	-
Total	98.51	98.14	98.43	102.14	101.94

* Fe = Fe_2O_3 in whole-rock analyses and FeO in ilmenite . X1, X12, S1 are whole-rock analyses and X1 il-1, X1 il-2 are ilmenite analyses from sample X1. X1 analysed by wet chemistry and X12 and S1 by XRF. S1 also contains Co 83, V 330, Cu 100, Zn 52, Ni 28, Cr 221, Rb 1, Sr 5, Ba 19, Nb 37, Y 43, Zr 208 (all in ppm).

CONCLUSIONS

The chloritoid-quartz-ilmenite band in the greenstone of the Indus Suture melange near Prang Ghar is unique in mineral composition and highly unusual in bulk chemistry . It appears to have developed from the basaltic precursor of the greenstone either by weathering (laterization) or, more likely, alteration, followed by greenschist facies metamorphism during collision. In addition to chloritoid, the presence of rutile and, elsewhere in the melange zone, glaucophane suggests that operating pressures were high. The TiO_2 content (5 to 10 wt %) of three samples is promising and justifies further field and labortory studies of the melange zone in the area and elsewhere.

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