# Vermiculite in the Gopalpura Area, Karnataka – A Mineralogical Study

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Abstract: Vermiculite mineralization in the Gopalpura area, Karnataka in the Archean supracrustal rocks of the Sargur Group occurs as discontinuous lenses and pockets within the ultramafic rock and at the contact with acid intrusives Detailed mineralogy as studied using microscopy, X-ray diffraction, infrared spectroscopy, differential thermal analyses, and electron microprobe analyses are presented. The probable origin of the vermiculite from biotite through hydrobiotite is discussed.

Keywords: Vermiculite, Sargurs, Gopalpura, Mysore district, Karnataka

### Introduction

Vermiculite is a general term for a group of platy, mica-like, hydrated silicate minerals with the general formula (Mg,Fe,Al)<sub>3</sub>(Al,S1)<sub>4</sub>O<sub>10</sub>(OH)<sub>2</sub>•4H<sub>2</sub>O Most of the vermiculite group minerals are the products of aqueous alteration, whereby typically biotite alters to hydrobiotite or chlorite, and then to vermiculite Based on the host rock lithology, vermiculite deposits are categorized into three broad groups (1) deposits within large ultramafic intrusions, such as pyroxenite, many of which are zoned and are cut by syenite, alkalic granite, carbonatitic rock or pegmatite, (2) deposits associated with small to large ultramafic intrusions, such as dunite and unzoned pyroxenite and peridotite, cut by pegmatite and syenitic or granitic rocks, and (3) deposits in metamorphosed ultramafic or mafic rocks (Bush, 1976) Vermiculite is often found associated with carbonatites and may also form in the border zones of contact-metamorphosed carbonates Vermiculite occurrences have been described from several parts of the woild, such as Pavagada in Karnataka state, India (Radhakrishna, 1948), the Palamau district, Bihar (Chattopadhyay and Bhattacharyay, 1994), Nagasaki Prefecture, Japan (Nakamuta, 1981), in the Malaguide Complex, Spain (Ruiz Cruz, 2003, Ruiz Cruz and Novak, 2003), near Hafafit, Egypt (El Shazly et al 1975), and in several areas of the United States (Bassett, 1959, Bush, 1976; Van Gosen et al 2002)

South of the Mysore city in Karnataka state, a prominent suite of supracrustal rocks of 3400-3100 Ma, designated as

the Sargur schist complex, is exposed. It forms a zone of high-grade metamorphic assemblages scattered within a migmatite gneissic complex, extending over a length of 70 km with a width of about 10 km (Fig 1) They are mainly composed of diverse igneous and sedimentary lithologies, such as ultramafic-mafic intrusive bodies, pelites, quartzites, impure carbonates, Iron formations and enclaves of anorthosites The ultramafic bodies occur as enclaves within the gneissic complex, obscuring the original relationship The contact of the supracrustals with the gneissic complex is generally concordant and marked by intense migmatization (Radhakrishna and Vaidyanadhan, 1997) The ultramafic lithounits are cut by late acidic (felsic) intrusions The present study characterizes the vermiculite deposits hosted by ultramafic rocks of the Sargur Group in the Gopalpura area and probes the process of their formation

## **Geological Setup**

Vermiculite mineralization in the Gopalpura area  $(12^{\circ} 14'N, 76^{\circ}33' E)$  occurs within the ultramafic rock and also at the contact zones between felsic intrusive rocks and ultramafic bodies. It occur as clots within the ultramafic body and as narrow belts in the marginal portions of fractured and altered ultramafic rocks, in contact with acid intrusive Veins of vermiculite at the acid intrusive contact trend in N 15-20° W and have variable widths of <10 cm to ~2.5 m Pods of vermiculite mineralization extend for nearly 30 m in length (Fig 2)



Fig.1. Simplified geological map of Sargur area showing vermiculite mineralization.

## Petrography

The host ultramafic rocks consist of olivine + clinopyroxene + orthopyroxene + opaques + carbonates. The olivine grains show different degrees of alteration, mainly to tale and serpentine. The orthopyroxene alters to biotite and the clinopyroxene to hornblende and tremolite. In turn, hornblende alters to biotite. Biotite grains show imprints of deformation, such as kink bands and swerving of the grains. In contrast, the clinopyroxene and hornblende grains show the least signs of deformation, indicating that the alteration resulted from the acid intrusion into the ultramafic body. Both ortho- and clinopyroxenes show exsolution of opaques along grain boundaries and cleavage planes.

Hydro-biotite shows alteration along cleavage planes and grain boundaries to vermiculite and is interwoven with the biotite grains (Fig.3). The vermiculite is brownish black in hand specimen and yellowish in thin section. It is pleochroic from light brown to brown, often contains inclusions of altered olivine, and shows deformed lamellae and kink bands. The acid intrusives are mainly pegmatitic in composition, consisting of K-feldspar, quartz and biotite in variable proportions. The K-feldspar shows alteration to sericite, while biotite has altered to vermiculite. Petrographic observations indicate that growth of vermiculite observed in both the ultramafic and pegmatite samples occurred after the formation of biotite through an intermediate stage of hydrobiotite, in agreement with studies of vermiculite deposits elsewhere (Prasad and Majumdar, 1966; Nettleton et al. 1973; Tarzi and Protz, 1979; Ghabru et al. 1987).

X-ray diffraction studies on vermiculite samples were carriedout using a Scintag X-1 automated diffractometer with a Cu target. The XRD pattern of the raw vermiculite corresponds well with the standard (ICDD pattern PDF: 16-0613). Other phases present include hydrobiotite and quartz. The hydrobiotite peaks in the XRD pattern of the raw sample correlate well with the standard hydrobiotite data (ICDD pattern PDF: 13-0233) and quartz peaks in the XRD pattern correspond well with the standard quartz data (ICDD pattern PDF: 78-1252). In all of the samples studied, vermiculite is a major phase, invariably associated with hydrobiotite, which indicates the formation of vermiculite from hydrobiotite (Chattopadhyay and Bhattacharyay, 1994). Exfoliated

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**Fig.2.** Vermiculite mineralization in the form of vein (N 15-20 W) and also as clots within the Ultramafic body, Gopalpura area.



Fig.3. Photomicrograph showing the alteration of biotite to vermiculite.

vermiculite, created by heating the raw sample to  $\sim 270^{\circ}$  C, shows a partial shift of the 14.7 Å basal reflection (raw vermiculite) to 12.6 Å, while the 17 Å reflection decreases in intensity compared to raw vermiculite. This behaviour indicates the presence of randomly ordered vermiculite layers during the removal of water from its structure.

Fourier transfer infrared spectroscopy (FTIR) studies were carried out with a NEXUS FTIR spectrometer from Thermo-Nicolet. The FTIR spectra of vermiculites closely resemble those of biotite and phlogopite. However, certain differences in the OH stretching band region are prominent. The fundamental OH stretching region due to water molecules (held in the vermiculite layers) occurs around 3400 cm<sup>-1</sup> ( $v_{OH}$ ) and the corresponding bending vibration is clearly observed at 1643 cm<sup>-1</sup> ( $\delta_{OH}$ ). The shoulder peak at around 3572 cm<sup>-1</sup> indicates the presence of OH groups coordinated with other cations. Spectral features observed in these vermiculites are broadly comparable to those reported earlier by Cariati et al. (1983). The combination modes due to  $(v_{OH} + 2\delta_{OH})$  are observed around 6990 cm<sup>-1</sup>. The asymmetry of this band is attributed to variations in the strength of hydrogen bonding schemes of water molecules. Similar band structure is found for the mode due to  $(v_{OH} + \delta_{OH})$ , which has been observed around 5210 cm<sup>-1</sup>. Corresponding modes reported by Cariati et al. (1983) for vermiculites from Libby, Montana, occur at 7052 cm<sup>-1</sup> (1418 nm) and 5202 cm<sup>-1</sup> (1922 nm) respectively.

### **Thermal Analyses**

Differential thermal analyses (DTA) of the vermiculite

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Fig.4. DTA curve for vermiculite of Gopalpura area

samples were performed using a Perkin Elimei DTA1700 model having range of 100 to 1200°C, applying a heating rate of 10°C per minute The effects of heating vermiculite have been summarized by Baishad (1948) and Grim (1968) The differential thermal curve for the Gopalpura vermiculites is shown in Fig 4 The DTA curve shows a rhythmic dehydration of vermiculite, characterized by an endothermic peak at 148° C and 267° C indicating loss of hygioscopic (surface) water (Gillott, 1968) The intensity of the peak in the low temperature region reflects the amount of absorbed water within vermiculite Endothermic peak at 998°C represents loss of hydroxyl (OH) water indicating slow rate of water loss (Mackenzie, 1970) The dehydroxylation is followed by the sharp exothermic effect at 1022°C, indicating the incipient stage of high temperature phase transition Further heating resulted in the endothermic peak at 1103° C that indicates melting

## **Electron Microprobe Analyses**

Electron probe microanalysis was performed using a JOEL 8900 microprobe equipped with wavelength dispersive spectrometer. The operating conditions of the instrument are 15 kV, 20 nA (cup), and 5 mm beam diameter. A total of 21 analyses were made on each sample, measuring 3 spots from 7 different grains within each sample. Selected analytical results are shown in Table 1.

Analyses of hydrobiotite grains show SiO<sub>2</sub> values of 36 6 to 37 7 wt%, MgO values ranging from 18 1 to 19 9 wt%, and CaO values varying from 0.54 to 0.70 wt% The hydriobiotite grains contain a high percentage of K (1.76 to 2.59 wt% K<sub>2</sub>O) SiO<sub>2</sub> values in the vermiculite grains vary from 34.5 to 38.4 wt% The vermiculite compared to the hydrobiotite shows only subtle differences in CaO and MgO contents with distinct contrast in K<sub>2</sub>O and Na<sub>2</sub>O contents (0.02 - 0.33 wt% K<sub>2</sub>O) and < 0.01 wt% Na<sub>2</sub>O as against

Table 1. Mineral chemistry of representative Gopalpura Hydrobiotite and Vermiculite grains

	Hydrobiotite			Vermiculite			
SIO2	37 7	37	36 6	38 4	37 2	34 5	35 9
T1O2	32	196	23	2 38	2 74	219	216
$Al_2O_3$	13 1	13 1	12 9	13 7	13 2	13	129
FeO	12 6	125	11 29	114	118	128	117
MnO	0 05	0 09	0 04	0 04	0 04	0 04	0 06
MgO	181	192	199	20 2	193	20 3	20 7
CaO	07	0 62	0 54	0 84	05	0 65	0 73
Na <sub>2</sub> O	01	0 04	0 09	0 01	0 01	0 01	<0 01
K <sub>2</sub> O	1 76	2 59	218	0 02	012	0 02	0 33
F	0 25	0 28	02	0 42	0 11	0 28	0 44
Cl	0 01	<0 01	0 01	0 01	0 02	0 03	0 01
Total	87.5	87 3	86.05	87 42	85.04	83.82	84.94
Cations							
S1	58	57	57	58	58	55	56
Tì	0 37	0 23	0 27	0 27	0 32	0 26	0 25
Al	24	24	24	24	24	24	24
Fe	16	16	15	14	15	17	15
Mn	0 01	0 01	0 01	0 01	0 01	0 01	0 01
Mg	41	44	46	4 5	45	48	48
Ca	011	01	0 09	0 14	0 08	0 11	012
Na	0 03	0 01	0 03	0	0	0	0
к	0 34	0 5 1	0 43	0	0 02	0 01	0 07
F	012	014	01	0 2	0 05	014	0 22
Cl	0	0	0 004	0	0	0 01	0
Iotal	14 9	15.1	15.1	14.8	14.7	15	15

1 76-2 59 wt%  $K_2O$  and 0 04 -0 10 wt%  $Na_2O$  in hydrobiotite) This demonstrates that the Gopalpura vermiculite has undergone nearly complete transformation from mica to vermiculite.

### **Discussion and Conclusions**

Field, textural and physico-chemical characteristics of the vermiculite of Gopalpura area indicate that it formed from a combination of hypogene and epigene processes similar to many other vermiculite deposits reported worldwide The localized, complete alteration of ultramafic rock bodies in the Gopalpura resulted from fluid reactions during acidic (pegmatite) intrusion. This hypogene process formed secondary phases, such as talc and serpentine from olivine, amphibole and biotite from pyroxenes, and further alteration of amphibole to biotite. The alteration of biotite to vermiculite through an intermediate stage of hydrobiotite is interpreted as a later supergene event caused by the circulation of groundwater, which leached potassium from biotite/hydrobiotite, ultimately forming vermiculite. The general geologic setting and conditions that formed vermiculite deposits in the Gopalpura are similar to those reported for several vermiculite deposits elsewhere vermiculite bodies found along ultramafic rock-felsic intrusive contacts—such as examples in Egypt (El Shazly and others, 1975), and in Wyoming and North Carolina in the USA (Hagner, 1944, Kulp and Brobst, 1954) Acknowledgements The authors are grateful to USGS for XRD and Microprobe data We thank Prof C Srikantappa, Chairman and Prof A Balasubramanian, Dept of Geology, Univ of Mysore, Manasagangotri, Mysore for their constant encouragement and help The author's extend sincere thanks to the anonymous reviewer for constructive suggestions to improve the manuscript

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