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RESEARCH ARTICLE

FTIR, XRD, SEM-EDX, XPS AND MAGNETIC CHARACTERISTICS ON SEDIMENTARY ROCKS OF MANGALAMALAI HILLS, TAMIL NADU, INDIA

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ABSTRACT

Rocks are mainly divided in three types namely Sedimentary, Metamorphic and Igneous rocks depends upon their nature of forming. These rocks constitute many minerals and elements. Those are having much amount of applications in Agriculture, Medicines, Physico-Chemistry applications, Engineering, Mining, Cosmetics and Materials applications etc., The proper investigation by suitable spectroscopic techniques we could identify the Minerals and Elements presented in the Natural rock materials. The sedimentary rock samples are collected from Mangalamalai Hills which is part of Eastern Ghats located in Dindigul district, Tamil Nadu, India. Fifteen number of samples were collected the elevation wise from top to bottom of this hill. The collected samples have undergone the spectroscopic studies like FTIR, Mineral composition, because each mineral possess a unique pattern of absorption in middle range of infrared spectra. The X-Ray Diffraction analyses confirm the minerals along with their morphology. Here fifteen minerals were identified the availability, their extinction coefficient of dominant minerals such as Quartz, Calcite, Sepiolite, Organic Carbon and Kaolinite were calculated. The SEM-EDX observations revealed the presence of elements (C, O, Na, Mg, Al, Si, K, Ca, Ti, and Fe) with their percentage of atomic weight. XPS (X Ray Photoelectron Spectroscopy) method directly confirms the available minerals in the rock sediments. The magnetic properties of these powdered rock samples were studied by (VSM) Vibrating sample magnetometer instrument and it has found their susceptibility with their hysteresis curves.

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INTRODUCTION

Hills play a vital role in the natural resources of various ore minerals and elements. The development of industry and technological applications incorporates many metals and minerals. In Quartz processing, the knowledge of the mineral composition of rock sediments is essential. The sources of minerals are not uniformly distributed, in horizontal space and vertical depth. Their qualitative occurrences are also highly varied. The valuable products are fingerprints that could be used in modern exploration surveys to conceal the ore mineral system ^[1]. The Fourier Transform infrared [FT-IR] spectroscopic technique is the most commonly used for qualitative analysis. Careful examination of intensity peaks shows the identification of minerals and elements as well in rock sediments from available literature. The present study made an attempt to characterize the minerals and elements available in sedimentary rock samples in Mangalamalai Hills, which is located in Dindigul district, South India.

MATERIALS AND METHODS

Mangalamalai Hills are the part of Western Ghats and it is near Kodaikanal hills in Dindigul district with GPS location 10°19'16" N 77°75'90" E. It contains more medicinal plants and is suitable for agriculture land. This hill is located in Bathlagundu town from Dindigul 35 km away. It is notable hills in Bathlagundu town for more species. This hill has approximately 400 m elevation from the ground surface. The locations are divided in 10 different sites nearly 50 m different from each place to collect the samples. The path is divided into mean paths of hills from top to bottom. In order to check the availability of minerals and elements the samples were collected nearly 1 kg from each location.

Sample Collection and Preparation: Ten different locations were selected at various altitudes randomly with at least from 100 m to 500 away from each location of the mountain and the rock samples are collected around 1 kg from each location and stored in self lock thick polythene bags.



Fig. 1 Location of Mangalamalai Hill

The rock samples are numbered as 1 to 10. All the samples were brushed, cleaned with clear water and weathered on the surface for an hour in order to remove moisture. The samples were crushed into small stones. These stones were ground into fine powder, by taking 30-50 mg and grinding in an agate mortar for 15-20 minutes till to get expected size (near 10^{-6} m).

FTIR: Fourier Transform InfraRed Spectroscopy is an essential tool to identify the minerals with absorption wave number. The Nicolet-Avatar 330 series FTIR Spectrometer is used to analyse the samples in mid region infrared wavelengths of $4000 - 400 \text{ cm}^{-1}$ at room temperature. The selected powdered rock samples were crushed and ground KBr was mixed with a ratio of 1:40. In one minute it could scan the spectra 100 times with resolution of 0.001 cm^{-1} with accuracy of 4 cm^{-1} . The standard polystyrene film was used every time the calibration of instruments for their accuracy with the spectrum.

XRD: An X-ray diffractometer (XRD is an instrument that uses X-rays to determine the atomic structure of crystalline materials, identifying their phases, crystal structure, and properties by measuring how the X-rays are scattered by the atomic lattice. The process relies on Bragg's Law, where incident X-rays of a known wavelength are diffracted at specific angles (θ) by the crystalline planes, producing a unique diffraction pattern a "fingerprint" for each substance^[2]. The X Ray diffraction patterns were recorded in room temperature for selected four powdered rock samples using Seifert (JSO-DEBYEFLEX 2002). Each 0.5 mg sample was homogeneously dispersed in a cover glass which served as a sample holder in the X Ray diffractometer. This instrument has a curved graphite crystal diffracted monochromator, $\text{CuK}\alpha$ radiation as a source with $\alpha = 1.5406 \text{ \AA}$, the patterns were recorded in 2θ range from 20° to 80° and NaI (TI) scintillation detector

Relative Distribution of Major Minerals: The relative distribution of can be quantified by calculating the extinction coefficient formula.

$$K = \frac{DA}{m} \quad (1)$$

Where, K is the extinction coefficient, D is the optical density, A is the area of the pellet and m is the mass of the pellet^[3].

The optical density D can be calculated by using the formula

$$D = -\log_{10} \left(\frac{I}{I_0} \right) = \log_{10} \left(\frac{I_0}{I} \right) \quad (2)$$

Where, I_0 – initial intensity of incident radiation, I – intensity of transmitted radiation.

EDX with SEM: Energy Dispersive X Ray Spectrometer (EDX), the emission of X rays determined the elemental composition for elemental identification during Scanning Electron Microscopic (SEM) observations. The morphological investigations were done on JEOL, JSM 6390 scanning electron microscope with 20 V accelerating voltage and a beam current of 1-3 nA. The SEM images were revealed by either secondary electrons or back scattered electrons.

XPS: X Ray Photoelectron Spectroscopy (XPS) is a powerful tool to identify the elements present in the samples and also what other elements were bonded to. This technique could be used in line profiling of the elemental composition across the surface or in depth profiling when paired with ion etching. It provides the information about the oxidation and structural state parameters of the iron oxides and to determine the surface chemistry of the investigated ironstones to a depth less than 10 nm.

Magnetic Studies: Rocks are part of the earth's crust which has solid chemical compounds derived from magma consisting of 1 or more minerals which are formed naturally with different magnetic values. The magnetic minerals in rock can be identifying using several methods. The VSM studies of rock materials reveal the magnetic properties of them such as susceptibility through the hysteresis curve. The Magnetic susceptibility of a material is quantitative measure of the material to be magnetized when subject to the magnetic fields. Magnetic property can be divided into: Diamagnetic, Paramagnetic, Ferromagnetic and Ferrimagnetic materials

RESULTS AND DISCUSSION

FTIR - Determination and Characterization of Minerals: In the Mangalamalai Hill, ten different locations were selected for FTIR studies from top to bottom. After following the standard procedure, the collected samples were examined using an FTIR spectrometer. By comparing the obtained spectra with available literature, fourteen minerals were identified based on their characteristic band assignments and corresponding wave numbers. These minerals include Quartz, Kaolinite, Anorthite, Anorthoclase, Diopside, Gehlenite, Gypsum, Hematite, Illite, Magnetite, Muscovite, Nontronite, Organic Matter, Wollastonite and Gibbsite. The FTIR absorption spectra with their respective peak wave numbers are shown in Figure 2. A comparison of the FTIR spectra from site numbers 1 to 10 is presented in Figure 3, and the identified

minerals with their corresponding wave numbers are listed in Table 1.

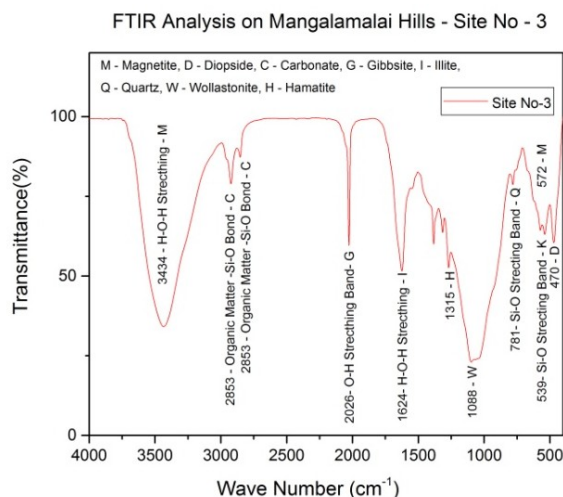


Fig. 2 FTIR Analysis of Mangalamalai Hills at location no 3

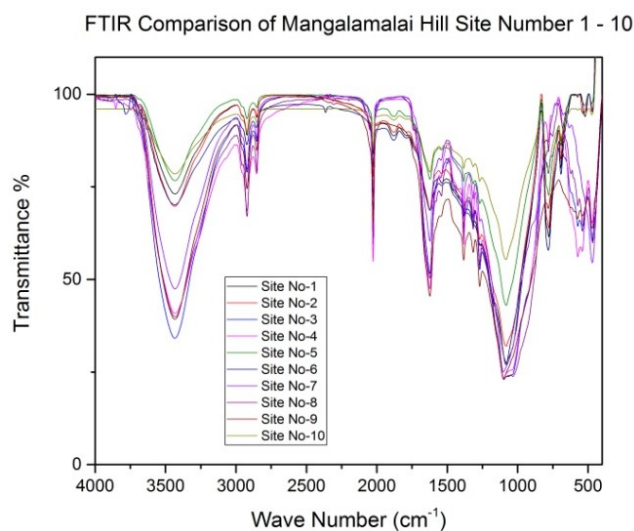


Fig. 3. Comparative Analysis of FTIR spectrum on Mangalamalai Hills

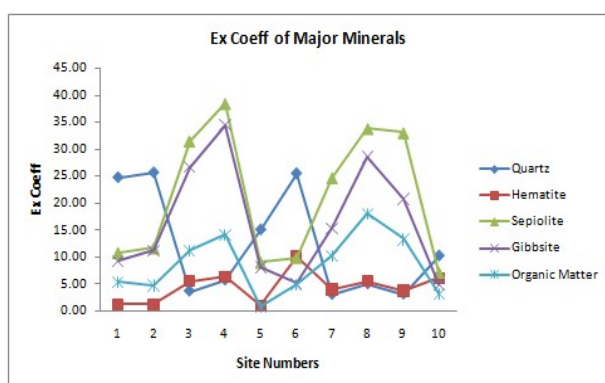


Fig. 4. Comparison of Extinction Coefficient of Major Minerals on Mangalamalai Hills

Quartz (SiO_2): Quartz is the one of the major mineral in rock samples, it presents in all site numbers. At the wave number 487 cm^{-1} Si-O stretching band shows the presents of Quartz at site number 8. At $522, 523 \text{ cm}^{-1}$ and 541 cm^{-1} with Si-O asymmetric bending vibration mode the Quartz mineral presents at the site number 4,5 and 10 [4].

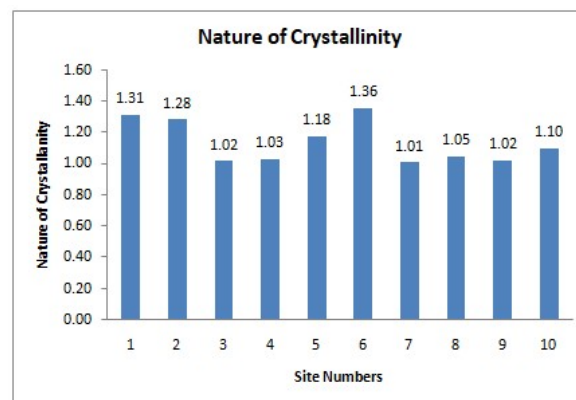


Fig. 5 Nature of Crystallinity of Mangalamalai Hills

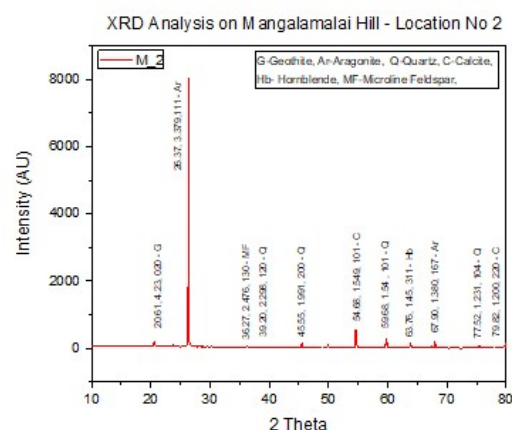


Fig. 6 XRD Spectrum on Mangalamalai Hills on site number 2

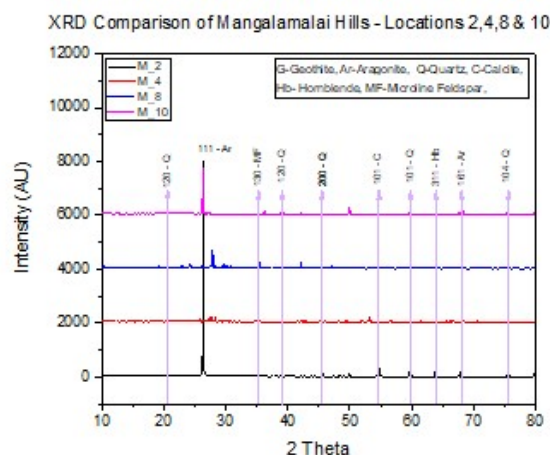


Fig. 7. Comparative Analysis of XRD spectrum in Mangalamalai Hills

Due to Si-O symmetrical bending vibration mode with the wave number region of $779\text{-}781 \text{ cm}^{-1}$ this mineral has shown their presence in all site locations. Similarly in the wave number region of $1079\text{-}1100 \text{ cm}^{-1}$ the Quartz mineral confirm their presence in all site numbers with Si-O-Si symmetric vibration mode [5-7]. Si-O band with the wave number region between 1877 and 1879 cm^{-1} has shown the availability of Quartz mineral at the location of 1,2,5,6 and 10.

Clay Minerals (Kaolinite, Montmorillonite, Illite): Kaolinite mineral is the unavoidable mineral in almost all the rock sediment samples. The wave number region of $468\text{-}471 \text{ cm}^{-1}$, $538,539 \text{ cm}^{-1}$ and 1032 cm^{-1} has shown the Si-O stretching vibration mode has revealed the presence of Kaolinite mineral in almost all the site locations [8].

S. No	Mineral	Wave Number	Band Assignment	Site No
1	Quartz	487	Si-O stretching	8
		522-523	Si-O asymmetric bending vibration	10,5
		541	asymmetric Si-O-Si vibration	4
		692-693	Si-O symmetrical bending vibration	2,5,6,10
		779-781	Si-O stretching	1 to 10
		1079-1100	Si-O-Si symmetrical stretching	1 to 10
		1877-1879	Si-O -band	1,2,5,6,10
2	Kaolinite	468-471		1,2,6
		538-539		3,8
		1032	Si-O stretching clay mineral	8
3	Anorthite	575		1
4	Anorthoclase	473		10
5	Diopside	470, 670		3, 7-9
6	Gehlenite	536, 633	Si-O-Al vibrational band	7, 9
7	Gypsum		SO4-2 asymmetrical stretching	6, 9
8	Hematite	474	stretching vibration of Si-O-Al	5
		520-534	stretching vibration of Si-O-Al	1,2,6
		1314-1316	stretching vibration of Si-O-Al	1 to 10
9	Illite	1622-1624	H-O-H Stretching	1 to 10
10	Magnetite	572-574		2-5, 8
11	Muscovite	753		8
12	Nontronite	676	Fe-O out-of-plane vibration	7
13	Organic matter	2851-2854	Si-O -band	1 to 10
		2923	Si-O -band	1 to 10
14	Wollastonite	1088		3
15	Gibbsite	2026	O-H bending vibrations	1 to 10

Site Number	Extinction Coefficient					Crystanillity Index	Nature of Crystanillity
	Quartz (778)	Hematite (1316)	Sepiolite (1622)	Gibbsite (2026)	Organic Matter (2923)		
S-1	24.77	1.12	10.71	9.30	5.38	0.762	1.313
S-2	25.69	1.08	11.59	11.16	4.75	0.781	1.280
S-3	3.67	5.51	31.49	26.68	11.16	0.984	1.016
S-4	5.74	6.31	38.45	34.40	14.16	0.971	1.030
S-5	15.08	0.95	8.90	8.15	0.80	0.851	1.175
S-6	25.52	10.16	9.81	5.10	4.95	0.738	1.356
S-7	3.08	3.99	24.64	15.31	10.22	0.993	1.007
S-8	5.03	5.51	33.79	28.51	17.99	0.957	1.045
S-9	3.12	3.73	33.03	20.72	13.29	0.982	1.019
S-10	10.22	6.09	7.01	4.95	3.21	0.912	1.097
Total	121.914	44.450	209.420	164.280	85.910	8.930	11.337
Average	8.128	2.963	13.961	10.952	5.727	0.595	0.756
Maximum	25.686	10.160	38.450	34.400	17.990	0.993	1.356
Minimum	3.080	0.950	7.010	4.950	0.800	0.738	1.007

S. NO	Quartz (778)	Hematite (1316)	$(x-\bar{x})$	$(y-\bar{y})$	$(x-\bar{x})(y-\bar{y})$	$(x-\bar{x})^2$	$(y-\bar{y})^2$	$(x-\bar{x})^2(y-\bar{y})^2$
1	24.77	1.12	12.58	-3.33	-41.82	158.21	11.06	1749.07
2	25.69	1.08	25.69	1.08	27.75	659.98	1.17	769.80
3	3.67	5.51	3.67	5.51	20.22	13.47	30.36	408.92
4	5.74	6.31	5.74	6.31	36.22	32.95	39.82	1311.84
5	15.08	0.95	15.08	0.95	14.33	227.41	0.90	205.23
6	25.52	10.16	25.52	10.16	259.28	651.27	103.23	67227.78
7	3.08	3.99	3.08	3.99	12.29	9.49	15.92	151.02
8	5.03	5.51	5.03	5.51	27.72	25.30	30.36	768.14
9	3.12	3.73	3.12	3.73	11.64	9.73	13.91	135.43
10	10.22	6.09	10.22	6.09	62.24	104.45	37.09	3873.79
Sum	121.92	44.45	109.73	40.01	429.86	1892.25	283.81	76601.03
Mean	12.19	4.45	10.97	4.00	42.99	189.22	28.38	7660.10
							SQRT	87.52
							R	0.49

Table 4. Pearson Correlation Coefficient of major minerals of Mangalamalai Hills

Pearson Correlation Coefficient	Ex. Quartz	Ex. Hematite	Ex. Sepiolite	Ex. Gibbsite	Ex. Organic Carbon
Ex. Quartz	1.00				
Ex. Hematite	0.49	1.00			
Ex. Sepiolite	0.76	0.80	1.00		
Ex. Gibbsite	0.74	0.76	0.72	1.00	
Ex. Organic Carbon	0.74	0.80	0.73	0.70	1.00

Table 5. XRD analysis on Mangalamalai Hills on site number 2

S. No	Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]	(hkl)	Mineral Name
1	26.3735	7982.28	0.0984	3.37944	100	111	Aragonite
2	36.2739	48.67	0.1476	2.47659	0.61	130	Microline Feldspar
3	39.2014	31.24	0.1476	2.29813	0.39	012	Quartz
4	42.1531	21.09	0.1476	2.14378	0.26	200	Quartz
5	45.5538	112.59	0.1968	1.99134	1.41	200	Quartz
6	49.8983	62.01	0.1968	1.82767	0.78	354	Magnetite
7	54.6231	493.89	0.2952	1.68023	6.19	112	Quartz
8	59.6841	299.82	0.246	1.54928	3.76	101	Calcite
9	63.7683	169.81	0.1476	1.45954	2.13	311	Hornblende
10	67.9089	210.72	0.1476	1.38029	2.64	167	Aragonite
11	75.4176	92.67	0.12	1.25938	1.16	220	Calcite
12	77.52	6.44	0.3936	1.23141	0.08	104	Quartz
13	79.5755	71.6	0.12	1.20369	0.9	220	Calcite
14	79.8292	167.27	0.12	1.20051	2.1	220	Calcite

Table 6. EDX Analysis of Mangalamalai Hills on Site numbers 6 & 8

Element	Site Number 06		Site Number 08	
	Weight%	Atomic%	Weight%	Atomic%
C	20.47	28.72	5.97	9.59
O	52.59	55.39	54.2	65.32
Na	0.25	0.19	1.21	1.01
Mg	-	-	2.9	2.3
Al	0.93	0.58	7.25	5.18
Si	24.38	14.63	17.37	11.93
K	0.5	0.22	0.24	0.12
Ca	0.16	0.07	5.88	2.83
Ti	-	-	0.19	0.08
Fe	0.72	0.22	4.8	1.66
Total	100	-	100	-

Table 7. Elements' electron state of Mangalamalai Hills

S. No	Name	Peak BE eV	FWHM eV	Area (P) CPS.eV	Atomic %
1	Si 2p	103.1	2.93	506315.89	18.99
2	Al 2s	119.34	3.25	174878.97	7.44
3	C 1s	285.01	2.5	542987.92	20.43
4	Ca 2s	441.45	3.36	85406.38	1.7
5	O 1s	532.28	3.24	3057763.14	47.62
6	Fe 2s	857.46	1.16	99413.66	1.86
7	Cu 2p	945.27	2.01	47265.4	0.12
8	Na 1s (~7% area is Ti LM2)	1072.31	2.31	141864.87	1.1
9	Mg 1s	1304.11	2.47	83336.83	0.76

Table 8. Magnetic analysis of Mangalamalai Hills

Site Numbers	Saturation Magnetization (Ms) 10 ⁻³ Am ² kg ⁻¹	Retentivity (Hr) 10 ⁻⁴ Am ² kg ⁻¹	Coercivity (Bc) mT	Susceptibility 10 ⁻⁸ m ³ kg ⁻¹	Classification
M – 2	136	44.4	4.2	274.90	Antiferro
M – 5	503	122.2	1.86	55.27	Antiferro
M – 8	291	37.5	1.3	58.71	Antiferro

Magnetic Minerals (Hematite (α -Fe₂O₃)): Hematite, Magnetite and Muscovite minerals are having the more magnetic property minerals. The Hematite mineral at 474 cm⁻¹ with Si-O-Al stretching vibration mode has shown the presence of it, similarly at the wave number region of 520-534 cm⁻¹ and 1314, 1316 cm⁻¹ the Hematite minerals has shown their presence at site number 1,2 and 6 with same vibration

assignment [9-11]. The Magnetite mineral with the wave number region of 572-574 cm⁻¹ vibration mode revealed the presence of it. 753 cm⁻¹ the Muscovite mineral revealed at the site number 8.

Other Minerals: Anorthite minerals revealed at 575 cm⁻¹ at the site number 1. Anorthite mineral has shown availability at site

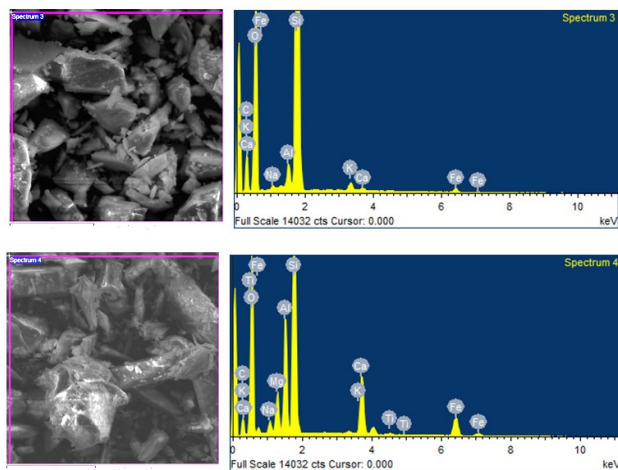


Fig. 8 SEM image and EDX spectra of Mangalamalai hills in site numbers 6 and 8

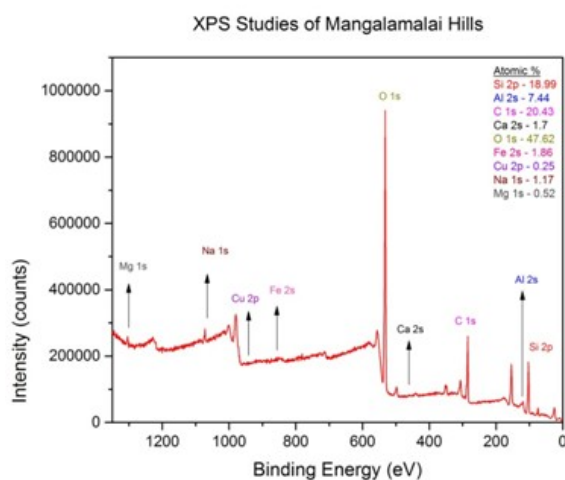


Fig. 9 XPS Spectrum of Mangalamalai Hills

number 10 with the wave number of 473 cm^{-1} . Diopside mineral 470 cm^{-1} and 670 cm^{-1} wave number has shown the presents at the site number 3, 7-9. Si-O-Al vibration band assignment 536 cm^{-1} , 633 cm^{-1} at the site number 3 and 7 and 9^[12], Gehlenite mineral at the site locations of 7 and 9. Anorthoclase mineral exhibited at frequency 575 cm^{-1} at site number 1. Illite mineral has shown with the wave number region of $1622\text{--}1624\text{ cm}^{-1}$ H-O-H Stretching mode at the site number 1 to 10. Nontronite minerals 676 cm^{-1} Fe-O out of plane vibration at the site number 7. The Wollastonite mineral has shown their presence at 1088 cm^{-1} at the site number 3.

Extinction Coefficient of Major Minerals: In Mangalamalai hills the Quartz, Hematite, Sepiolite, Gibbsite and Organic matter are major minerals available in all the locations. The extinction coefficient of the minerals has maximum value has Sepiolite (38.45) and minimum value is Hematite (10.16). The value of extinction coefficient of Mangalmali Hills has shown in Table 2 and its respective graph value at Fig. 4.

Crystallinity Index and Nature of Crystallinity: The nature of crystallinity of the minerals gives the information of order the crystalline nature. The samples were collected from top of the hill to bottom of the hill. The Nature of crystallinity has maximum at the site location number 6 (1.356) and minimum value of 1.007 at the number 7. This study confirmed the order of the crystallinity is placed in random manner

Pearson Correlation coefficient matrix among the parameters for sediment samples: The Pearson correlation coefficient measures that strength of direction of relationship of two variables. These values are lies between -1 to +1. Quartz, Hematite, Sepiolite, Gibbsite and Organic Matter are major minerals present in Mangalamalai Hill. The Correlation coefficient between the Quartz and Hematite is 0.49, Quartz and Sepiolite is 0.76, Quartz and Gibbsite is 0.74, Quartz and Organic Matter is 0.74, Hematite and Sepiolite is 0.80, Hematite and Gibbsite is 0.76, Hematite and Organic Matter is 0.80, Sepiolite and Gibbsite is 0.72 and finally Gibbsite and Organic Matter is 0.73. The Positive values are indicating they have high correlation between them, whereas the negative value represents their lower correlation value. Among this Sepiolite and Hematite and Organic Matter and Hematite shows higher value 0.80 and Quartz and Hematite shows lower value 0.49. The table 3.13 shows the Pearson correlation between the major minerals^[13].

X-Ray Diffraction Analysis: Qualitative mineralogy of the Mangalamalai hill samples is determined with the standard interpretation procedure of XRD. Major minerals in the studied samples are Quartz, Calcite, Aragonite. The mineral wise discussion is follows.

Quartz: Quartz is one of the major crystalline minerals present in all rock samples. The Quartz mineral in 2θ positions 39.20° , 42.15° , 45.55° , 54.62° and 77.52° have shown their presence with d-spacing of $2.29\text{ \AA}$, $2.14\text{ \AA}$, $1.99\text{ \AA}$, $1.68\text{ \AA}$ and $1.23\text{ \AA}$ with respective hkl Miller indices values are (012), (200), (200), (112) and (104) values at examined location M-2. At location M-4 the Quartz mineral occurred with 2θ reflection angle 41.6° , 42.3° , 53.23° , 68.32° along with the d-spacing value $2.16\text{ \AA}$, $2.13\text{ \AA}$, $1.72\text{ \AA}$, $1.37\text{ \AA}$ with suitable interplaner distances (110), (200), (112), (031) value confirm the presence of it. Similarly it has shown the presence in locations M-8 and M-10 with the 2θ positions 68.4° , 45.5° , 55.02° repective d-spacing values $1.37\text{ \AA}$, $1.99\text{ \AA}$, $1.66\text{ \AA}$ along with the miller indices values (031), (200) and (112)^[14-17].

Calcite: Calcite (CaCO_3) is an important carbonite mineral, which is identified in maximum site locations in Magnalamalai hills. The 2θ : 59.68° , 75.41° , 79.57° and 79.82° are the diffraction peaks with the d-spacing values are 1.54, 1.25, 1.203, 1.200 along with the Miller indices values are (101), (220), (220) and (220) confirm the presence of the Calcite mineral [24]. It exhibited the presence at 2θ position 59.6° , 29.6° , 42.8° , 29.6° , 59.6° with repective d-spacing values $1.54\text{ \AA}$, $3.01\text{ \AA}$, $2.11\text{ \AA}$, $3.01\text{ \AA}$, $1.54\text{ \AA}$ with the interplaner distances of (101), (104), (121), (104), (101) values.

Kyanite: Kaolinite is a clay mineral exhibited generally in soil and rock samples as well. Kyanite is keynote to kaolinite mineral has shown the presence at reflected angle 2θ positions 28.24° and 28.28° with suitable d-spacing values 3.159 and 3.154 along with the interplanar distance (211) and (0211) at locations of M-8 and M-10.

Aragonite: Aragonite mineral with the chemical composition is $\text{CaAl}_2\text{Si}_2\text{O}_8$ has two 2θ position values. 2θ : 26.37° , 67.90° with the d-spacing values $3.37\text{ \AA}$ and $1.38\text{ \AA}$ distance along with the hkl value (111) and (167) confirmed the presence of this mineral at examined location M-2.

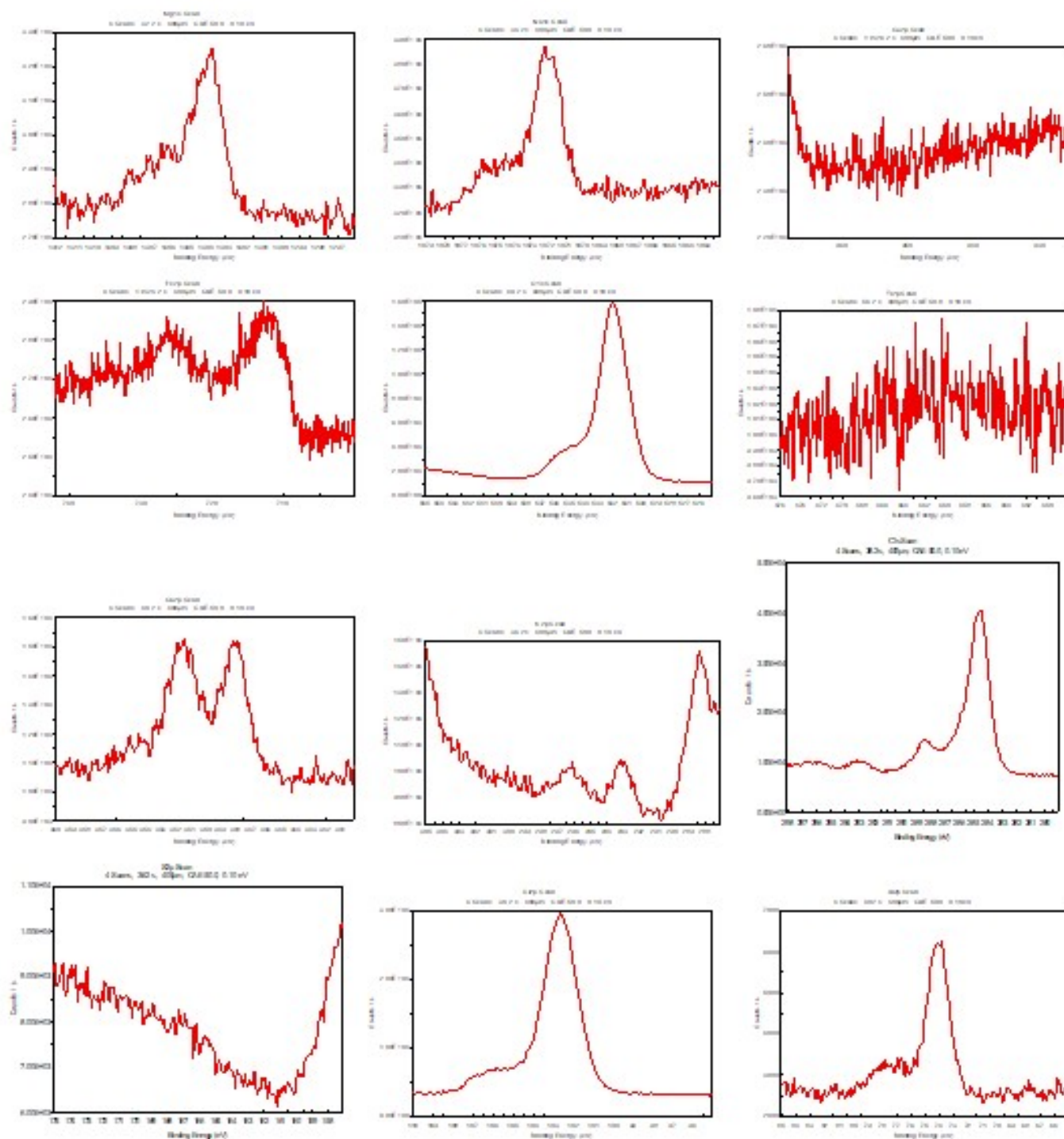


Fig. 10. XPS studies of Mangalamalai Hills – Elements Mg1s, Na1s, Cu2p, Fe2p, O1s, Ti2p, Ca2p, K2p, C1s, S2p, Si 2p, and Al2p

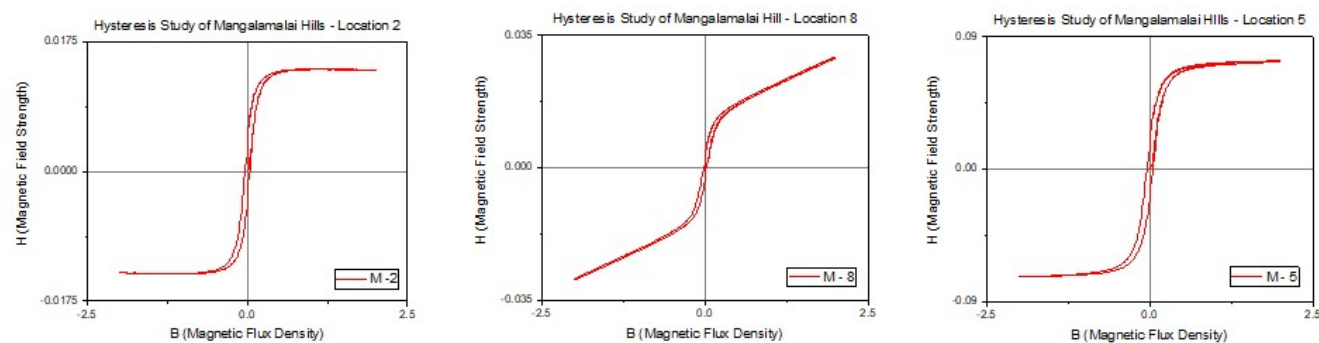


Fig. 11. Magnetic Analysis of Mangalamalai Hills – site number 2, 5 and 8

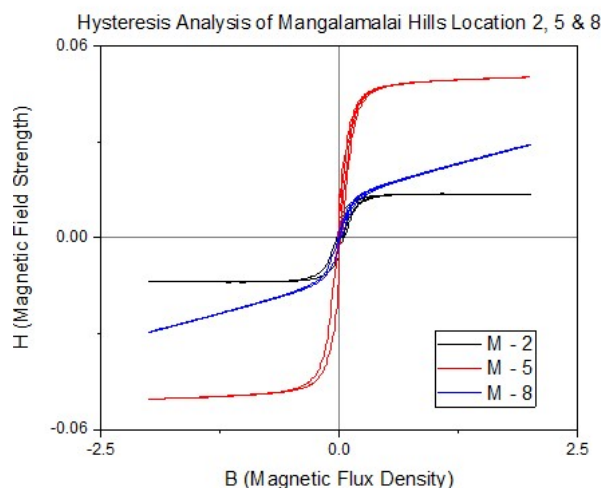


Fig. 11 Comparison of Hysteresis Curves of Mangalamalai Hills

Feldspar (Microcline, Orthoclase): Microcline Feldspar is an Iron constituent mineral showing their presence with 2θ position 36.27° and the d-spacing value of $2.47 \text{ \AA}$ along with the hkl value of (354). Orthoclase Feldspar revealed with reflection angle 2θ positions 27.56° , 27.82° , 60.44° , 27.87° with respective d-spacing values $3.23 \text{ \AA}$, $3.20 \text{ \AA}$, $1.53 \text{ \AA}$, $3.20 \text{ \AA}$ along with suitable interplanar distance values (002), (002), (510) and (002) at analysed location 8 and 10 [18].

Hornblende: Hornblende mineral is a silicate family dark green to black mineral shows the presence with 2θ position of 63.76° with the d-spacing value $1.459 \text{ \AA}$ along with hkl value of (311) at location M-2. Similarly, at location M-10 it occurred with 63.7° of reflected angle $1.459 \text{ \AA}$ d-spacing value and hkl value of (311).

Magnetic Minerals (Magnetite, Hematite, Goethite): Magnetite is an magnetic property mineral revealed in Mangalamalai hills, 2θ value of 49.89° and d-spacing value is $1.82 \text{ \AA}$ and the hkl Miller indices value is (354). Hematite plays a vital role of magnetic material in examined locations exhibited at locations 8 and 10 with reflected angles 42.12° and 42.21° with d-spacing values $2.145 \text{ \AA}$ and $2.140 \text{ \AA}$ with respective interplanar distance of (112) and (112). Goethite is an essential magnetic property mineral, it exhibits the narrow and weak hysteresis curve shows the weak ferro magnetic property. This mineral occurred in M-4 and M-8 locations at characteristic XRD peak 35.35° , 35.39° with suitable d-spacing values $2.538 \text{ \AA}$ and $2.355 \text{ \AA}$ with respective hkl values (001) (001).

EDX with SEM: The Energy dispersive spectrum is given Fig. 8, it shows the elemental composition of the site numbers 6 and 8. The minerals like Carbon, Oxygen, Sodium, Magnesium, Aluminium, Silicon, Potassium, Calcium, Titanium and Iron revealed in the site locations. Quartz mineral is one of the major constituents of the rock samples, in EDX analysis Silicon shows the atomic percentage 14.63%,

11.93% and Oxygen is 55.39%, 65.32% in the Mangalamalai rock samples. The presence of Silicon and Oxygen confirms more minerals in Si-O symmetric and asymmetric band vibration modes. Carbon element is 28.72% and 9.59% confirms presence of carbonate minerals like Calcium and Organic Carbon minerals. Sodium revealed in these two

locations 0.19% and 1.01% have shown the confirmation of mineral like Kaolinite which contains Aluminium minerals, Palygorskite etc., Magnesium is small portion of the minerals like Palygorskite and Sepiolite exhibits in 2.3% of atomic weight in site number 8. The presence of Potassium in atomic percentage of 0.22% and 0.12% are supporting the availability of minerals like Microcline and Orthoclase Feldspar minerals [19]. Iron element presents in two locations in atomic percentage of 0.22% and 1.66%, which are supporting occurrence of Iron contents magnetic minerals like Goethite, Hematite. The respective EDX spectrum with SEM images on the two locations given in Table 6.

X-ray Photoelectron Spectroscopy: The XPS survey scan in Mangalamalai hill sample indicates the presence of Si, Al, C, Ca, O, Fe, Cu, Na and Mg is shown in Fig. 9. Their individual spectrum is given in Fig. 10. The high resolution peak Fe 2s and O 1s with the binding energy peak at 857.46 eV and 532.28 eV corresponds to the Iron content minerals such as Hematite, Magnetite [14].

The shift of Ca 2p characteristic peak corresponds to Calcium minerals like CaCO_3 , the shift N 1s peak at 1072.31 eV with 1.1% atomic percentage shows the contribution of minerals. Si 2p could be inferred to correspond to crystalline Quartz mineral, with the atomic percentage of 18.99% at peak 103.1 eV binding energy. Al 2s binding energy peak at 119.34 eV indicates the presence with atomic percentage 7.44% Feldspar minerals. The presence of elements of Mangalamalai Hill at site number 1 is given in Table 7, and their respective XPS spectrum is shown in Fig. 9. XPS studies of Mangalamalai Hills, the separate Element spectrum of Mg1s, Na1s, Cu2p, Fe2p, O1s, Ti2p, Ca2p, K2p, Cl1s, S2p, Si 2p, and Al2p are shown in Fig. 10.

Magnetic Studies: Most of the minerals found in Mangalamalai hills belong to dia and paramagnetic materials. The high crystalline mineral quartz, kaolinite, calcite, cristobalite, gibbsite, halloysite, hectorite, Microcline Feldspar, carbonate minerals are in the classification of diamagnetic materials. Illite, Lepidocrocite, Montmorillonite, Nacrite, Palygorskite and Sepiolite minerals are in the domain of paramagnetic substances. The magnetic minerals like Goethite, Hematite, Magnetite and Siderite are under anti ferromagnetic materials. In Mangalamalai hills the samples number M-2, M-5 and M-8 were chosen to undergo the VSM studies. Through the VSM data the smooth and narrow hysteresis curve has been revealed using origin software. The coercivity and retentivity values of the above-mentioned samples are in the range of 0.0148 – 0.0420 and 0.0037 to 0.0123. The calculated susceptibility values are lying in the range of 80.46 to $564 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ [19-23]. The obtained region belongs to a antiferromagnetic substance. Even though the presence of magnetic minerals is revealed in FTIR studies, it is a feeble contribution of them.

CONCLUSION

In Mangalamalai hills 10 different locations powdered samples were analysed with FTIR and XRD methods. In this study from FTIR analysis identified the fifteen minerals namely Quartz, Kaolinite, Anorthite, Anorthoclase, Diopside, Gehlenite, Gypsum, Hematite, Illite, Magnetite, Muscovite, Nontronite, Organic matter, Wollastonite and Gibbsite. These minerals were confirmed by XRD analysis and six minerals

identified additionally, those are Aragonite and Hornblende. Some of the minerals could not confirmed by XRD due to their loss of crystalline nature. From calculated Extinction coefficient values the amount Kaolinite is higher than other major minerals. The order of extinction coefficient values are Sepiolite > Gibbsite > Quartz > Organic Carbon > Hematite, the average values are 13.961, 10.952, 8.128, 5.727 and 2.963 respectively. EDX with SEM analysis confirm the presence of elements like C, O, Na, Mg, Al, Si, K, Ca, Ti, and Fe. Apart from basic elements, the elements Fe, Al, Mg and Ti reveals in significant value. Aluminium elements reveal in good significant values from 0.93% to 7.25% along with other elements. XPS studies revealed the chemical composition of elements like Si, Al, C, Ca, O, Fe, Cu, Na and Mg with their binding energy associated with atomic percentage. O 1s and C 1s are in the range between 47.62% to 20.43% and the elements like Si 2p, Al 2s, Ca 2s and Fe 2s had shown the range between 1% to 18% Mg 1s and Cu 2p has shown the range nearby 1%. The magnetic properties of these rock samples revealed the susceptibilities range between (58.71×10^{-8} to 274.9×10^{-8}) has confirms the most of the minerals are belonging to Antiferro magnetic materials.

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