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ORIGINAL RESEARCH PAPER

# Physio-chemical and mineralogical analysis of gas hydrate bearing sediments of Andaman Basin

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## Abstract

The hydrate reservoir of Andaman Basin in the Bay of Bengal is huge reserves of hydrates in India. In this study, we studied the mineralogical behavior of gas hydrate bearing sediments of Andaman Basin by X-ray Diffraction, Raman Spectroscopy and Scanning Electron Microscopy. We also determined the physical properties such as pH, TDS, TOC, salinity, conductivity, water content, density and porosity of the hydrate bearing sediments. This work aims to analyze the physio-chemical and mineralogical properties of hydrate occupying sediments of Andaman Basin. The physio-chemical and mineralogical analysis of hydrate bearing sediments can provide the useful data for the methane production from Andaman Basin reservoir by adjusting the natural sediment properties and can help in designing a viable technology for the commercial production of gas from the hydrates.

**Keywords** Gas hydrate · Sediments · Physio-chemical · Mineralogical · Andaman basin

## Abbreviations

| | |
|---|---|
| $D_{10}$ | The diameter of 10% portion of sediment particles is smaller than this value |
| $D_{50}$ | The diameter of 50% portion of sediment particles is smaller and larger than this value |
| $D_{90}$ | The diameter of 90% portion of sediment particles is smaller than this value |

## Introduction

Gas hydrates are a non-stoichiometric solid type crystal which is formed when a suitable sized and shaped guest molecule is encaged inside the cage of host molecules by the Vander Waals forces. These solid crystals are stable at low temperature and high pressure and contains 180 $m^3$ of gas within 1 $m^3$ of hydrate (Sagidullin and Stoporev 2019). The guest molecules for the hydrate formation are $CH_4$, $C_2H_6$,$C_3H_8$,$H_2S$, $CO_2$ and $N_2$ and natural gas and these guests are hosted by the cages of water molecules (Yin et al. 2018; Kumari et al. 2020). The huge deposits of gas hydrates formed in the offshore and permafrost has the potential to fulfill the future energy requirement in the world. Naturally, Gas Hydrates are deposited after the natural gas diffusion in the pores/fractures of silts, clays and fine grained muds (Liu et al. 2018). The size of the pores and chemical composition of sediments can affect the thermodynamic properties of natural gas hydrates (Kumari et al. 2020). A sharp elastic contrast has been observed between the hydrate bearing sediments and the underlying sediments. This contrast can form the Bottom Simulating Reflectors (BSR) for the detection of gas hydrates. This BSRs are parallel to the seafloor at a sub bottom depth of some depth (Ecker et al. 1996; Kvenvolden 1998). In marine sediments, the gas hydrates are formed by two ways such as pore filling in sand and grain displacing in hydrate nodules or veins in mud based on the

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observation of infrared and X-ray images of conventional and pressure cores (Bahk et al. 2013). During the dissociation process, the hydrate bearing sediments include physical, chemical and mechanical interactions and this can create various challenges for the development of safe and economic methods for the dissociation of gas hydrates. Hence, the analysis of physical properties of the sediments can help in the effective method for the dissociation of gas hydrates (Li et al. 2020). For the numerical simulation of gas hydrates, the essential parameters required are compressibility, permeability, undrained shear strength and index properties. Various studies are in progress for the analysis of properties of natural sediments with or without gas hydrates for the identification of the effect of formation of hydrate on the properties of the sediments (Kwon et al. 2011). Winters et al. (2014) compared the properties of sediments of Krishna-Godavari, Kerala-Konkan, Mahanadi and Andaman Basin and it was concluded that the properties of sediments affect the morphology, distribution and formation of hydrates in sediments. Winters et al. (2014) showed that the production potential of natural hydrate reservoir can be affected by the porosity, rate of sedimentation and permeability. They also gave the relationships between physical properties and morphology of natural hydrate deposits with respect to the location. The natural hydrate deposits require the assessment of production rate, well bore stability and flow assurance for the recognition of cautious and productive hydrate dissociation methods. The basic standard for the characterization of physical behavior of sediments is the observation of physical properties such as density, porosity and grain size (Lee et al. 2013).

Seo et al. (2009) concluded that the mineralogy and rheology of the sediments can influenced the gas production efficiency of gas hydrates formed in marine sediments. During National Gas Hydrate Program (NGHP-01) an increase in the electrical resistivity of hydrate occupying sediments of Krishna-Godavari (KG) basin was observed. This observation was used to determine the effectiveness of insitu electro thermal heating upon the dissociation process of hydrates (Chandrasekharan Nair et al. 2019). The hydrate bearing sediments has much higher seismic velocity and lower porosity than the continental nearby seafloor sediments. The velocity in hydrate occupied sediments is higher than the sediments without hydrates. If hydrate filled 15% of the pore space then a 10–15% increase in observed in the seismic velocity (Gabitto and Tsouris 2010). Santamarina and Ruppel (2010) performed various experiments for the analysis of the thermal, electrical, mechanical and electromagnetic properties of hydrate occupying sediments by standardized test protocols and geotechnical devices. Stoll and Bryan (1979) concluded that the thermal conductivity of sediments decreases after the hydrate formation (Gabitto and Tsouris 2010). Stoll (1974) observed that the thermal conductivity of hydrate occupying sediments tends to decrease rather than increase after the hydrate formation in sediments. For a given sediment and heat source, the change in thermal conductivity would tend to change the expected thermal gradient for a hydrate bearing sediment column. The particle size of the sediments will disturb the growth and induction rate of hydrate formation. The sediments with clay and silt will show the change from shear thinning to thickening after the enhancement of particle size of the sediments. The strength of sediments increases as the hydrate saturation increases. The hydrate stability can be affected by the pore water salinity and water quantity in the clays. Uchida et al. (2004) concluded that an increase in water content will increase the accumulation of hydrates in sediments.

The mineral present in the hydrate bearing sediments can also affect the formation of hydrates because the minerals can disturb the rheological properties of the sediments. The diversity in the genesis of the clays and their physical and chemical properties can inhibit or promote or have no effect on the stability of hydrate. The strength of hydrate bearing sediments will be high after the formation of hydrates. The shear strength of sediments can increase and effective tress can decrease after the hydrate formation in sediments. The instability in seafloor will occur after the decrease in effective stress and leads to geohazards such as subsea landslides, slope failure and subsea subsidence and also influence the production of methane gas (Chandrasekharan Nair et al. 2019). The difference in physical properties of the sediments can be observed by downhole logs and field measurements. Hence the physical properties analysis is required for the geophysical data gathered in the field settings and slope stability analyses, borehole and simulation and dissociation methods of natural reservoir. The physical properties of the bulk hydrate are unusually close to the pure ice and the physical properties of hydrate bearing sediments are similar to the ice baring sediments. The hydrate bearing sediments are stiffer than the water occupying sediments. The hydrate formation can exclude the salt form pore fluid hence the electrical resistivity of hydrate bearing sediments are higher than the pure sediments (Jang et al. 2019).

In this work, we have analyzed the several physio-chemical properties of hydrate occupying sediments of Andaman Basin. These properties can disturb the formation of hydrate in clayey reservoirs of hydrate. We have observed the properties of sediments such as conductivity, pH, salinity, Total Dissolved Solids, Water Content, Density, Porosity and Total Organic Carbon of real natural reservoir sediments samples. The mineralogical behavior of hydrate bearing sediments was also observed and which can help in designing a viable commercial technology for the dissociation of gas hydrates and hence can help in utilizing this potential resource of future generation fuel.

## Geographical overview

The source of sediments in Andaman Basin is the silt and clay contained Irrawaddy Rivers. The lithology of sediment core from the Andaman Sea is impacted by terrigenous nannofossil carbonate and muddy clay (Kamesh Raju et al. 2004). The sediments from Andaman basin are homogeneous type of silty clays which contains only small amount of sand (Rodolfo 1968; Kumar et al. 2014). The locations of gas hydrate rersvoirs located in India is shown in Fig. 1.

## Material and methods

### Preparation of sample

The sediment sample was obtained from Andaman Basin at site location NGHP-01-17 and depth 619.3 mbsf by Gas Hydrate Research and Technology Center (GHRTC), Panvel, Mumbai, INDIA. The samples were dried and converted into powder form by mortar (Fig. 2).

## Physical properties of sediment samples

A Multi Parameter-Measuring Device (Model No.-KI-266A) has been used to estimate the Conductivity, pH, Salinity, TDS and TOC of 50wt% concentration of sediment solution. Water content, Density and Porosity of sediment sample was calculated by American Society for Testing and Materials (ASTM) Standard D2216 (ASTM 2006) by Gas Pycnometer (Ultrapyc 5000,Anton Paar, Austria) (Winters et al. 2007).

### Inductively coupled plasma mass spectrometry (ICPMS)

For chemical analysis, the sediment sample were digested with 10 ml of Nitric Acid ($HNO_3$) using Fume Hood. Then samples were washed with ethanol and then ICPMS analysis was performed by Perkin Elmer, ELAN DRC-e-2004, USA.

### Particle size analyzer (PSA)

The Particle Size Analysis of sediments containing hydrate was performed by Particle Size Analyzer (HORIBA Scientific, Nano Partica, Nano, Particle Analyzer, SZ-100, JAPAN). The samples were converted to powder form by mortar and dried to remove moisture.

**Fig. 1** Geological setting of natural gas hydrate reservoirs in Andaman, India (Ayyadurai et al. 2015)

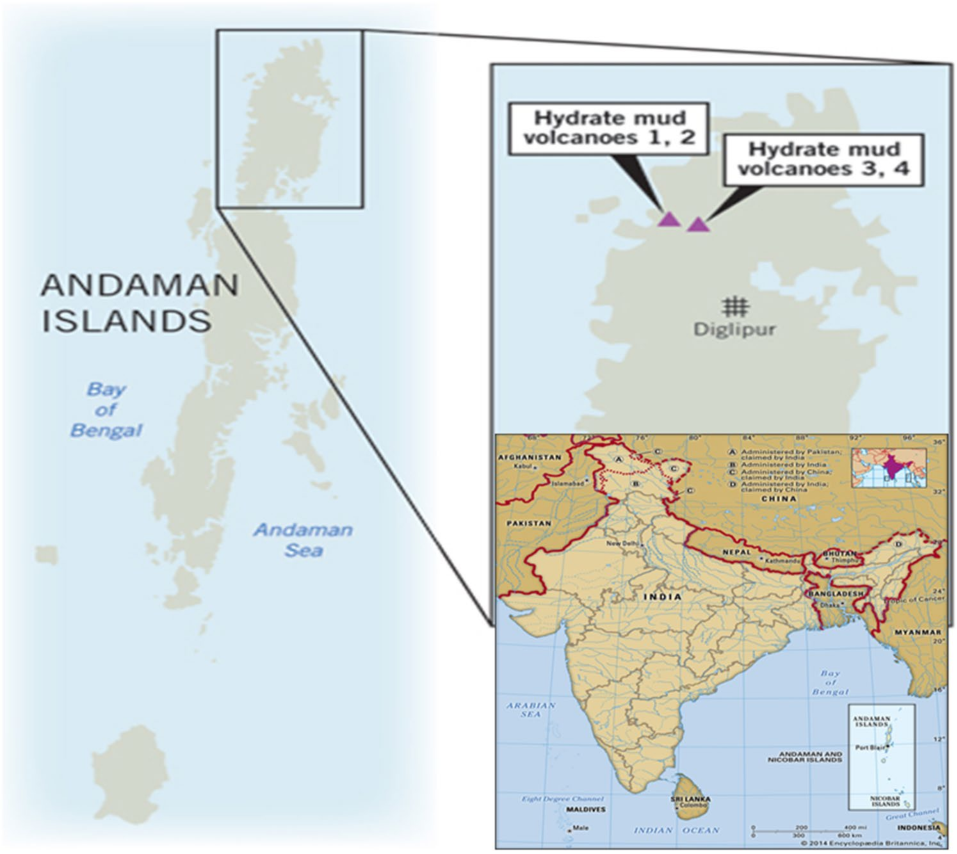


**Fig. 2** Samples in aggregated form and powder form

### Pore size distribution and specific surface areas

Pore Size Distribution and Specific Surface Area was performed by BET Surface Area Analyzer (Micromeritics Asap 2060, USA) at a temperature of 77 K.

### Cation exchange capacities

Cation Exchange Capacities (CEC) was performed by the Copper Ethylenediamine $(EDA)_2$ $CuCl_2$ complex method (Bergaya and Vayer 1997).

### Scanning electron microscopy (SEM)

For SEM analysis, a thin layered coating of gold was applied on the sediments in vacuum on the rotating stage. This coating has no effect on the SEM analysis of the sediment sample but it gives the conductive nature to the sediments. SEM analysis was performed by TESCAN MIRA3 FEG-SEM, Czech Republic.

### X-ray diffraction (XRD)

The powdered XRD analysis has been performed using Cu- Radiation at wavelength of 0.15 nm and at room temperature by Bruker, D8-Advance,2008.

### Fourier transform infrared spectroscopy

FTIR of the sediment sample was performed by JASCO, FTIR-6700 FT-IR Spectrometer, JAPAN. Sediment sample was mixed with potassium bromide (KBr) and then formed in the KBr pellet.

### Raman spectroscopy

Raman Spectra were performed by the Renishaw Invia Raman Microscope instrument (United Kingdom) with a confocal microscope and a 50 × lens. 1 µm sample was placed at the specimen for the analysis. Some particles from each sediment sample were deposited on the aluminum slide and kept below the lens. The laser excitation was performed by an argon ion laser which provides radiation of 514.5 nm wavelength to ensure the representative signals from heterogeneous specimens. The spectral accumulations times was in the multiple of 100 s.

## Results and discussion

### Sediment classification

The adequate description of sediments is based on the sand-silt–clay ratios. Shepard (1954) gave the definitions of sand, silt and clay based on median diameter at 3.9 microns between clay and silt and at 62.5 microns between silt and sand. The mixture of sand-silt–clay is represented by one central large area which is used for the description of uniform mixtures of three grades of sediment. The rest of the divisions are uniform in size (Shepard 1954). The sediments found in the Andaman Islands were found to be predominantly clayey silt to silty clay in size with fine skewness based on the ternary grain size plots [14]. The sediments

**Table 1** Physical properties of sediment samples

| Conductivity (mS/cm) | pH | Salinity(ppt) | TDS (ppt) | TOC (ppm) | Water Content (%) | Density (g/cm$^3$) | Porosity (%) |
|---|---|---|---|---|---|---|---|
| 18.76 | 7.98 | 16.60 | 14.47 | 327.68 | 70.13 | 1.69 | 65.01 |

**Table 2** Chemical analysis of sediment sample

| Zn Ppm | Mg Ppm | Fe ppm | Cu ppm | K ppm | Mn ppm | Al ppm | Si ppm | Ti Ppm |
|---|---|---|---|---|---|---|---|---|
| 62.6836 | 370.7612 | 1651.423 | 9.4752 | 405.8036 | 135.4228 | 768.5828 | 7.8468 | 0.192 |

from Andaman basin contains cay/silt with nanno fossil ooze and volcanic ash (Kumar et al. 2014).

## Physical properties of sediment samples

The physical properties of the hydrate containing sediment samples are listedin Table 1. The hydrate formation in natural sediments depends upon these physical properties. TDS and Salinty repersents the disolved salts and ions in the sediment solution. It is already revealed in the literature that salt acts as a inhibitor during the formation of hydrate. Hence, TDS and salinity can the alter the formation conditions of hydrate in natural sediments. Various studies are going on for the identification of inhibitors and promoters which can be any material with acidic, base or neutral nature. pH is the representation of acidic and basic nature of the sediments and the presence of acid or base materials in sediments can disturb the hydrate formation in sediments. The physcical properties such as Water Content, Density and Porosity can also become helpful for the formation of hydrates in the sediments. Highly porous sediments can occupy more gas in its cage like structure. Water Content and Density of the sediments can help in the formation of cage like structure around the guest molecules. The water content of the sample was observed to be 0.7013 which is much lower value. This lower value will indicate the higher strngth of the sediments (Wang et al. 2020). Total Organic Carbon can be used to distinguish organic matter present in the sediment sample and the soil quality. The porosity as shown in Table 1 is 65.01% which determines the prodction potential of hydrate bearing reserviors. All these physical properties are very hepful in designing the production strategy.

## Inductively coupled plasma mass spectrometry (ICPMS)

As shown in Table 2, the sediments from Andaman Basin contains Iron, Potassium, Aluminum and Magnesium in higher concentration as compares to other metals. The sediments contain lower concentration of Copper, Silicon and Titanium. The cementation effect of the sediment particles can increase with the presence of Al, Mg, Si, K, and Ti. The presence of kaolinite mineral can also be identified through the presence of Fe, K and Si. High concentration of Al, Mg and K represent the higher cementation effect of sediments and higher cementation properties can influence the formation of hydrate in natural sediments. The presence of these elements can also represent the minerals present in the sediments sample. The chemical proportions of the sediment sample indicate the origination of the particulate matter, the reaction linking with them and the dissolved phase throughout the transport and displacement and the later depositional changes. The presence of Al indicates the supply of detrital and organic minerals in the sediments sample. The existence of K indicates the presence of feldspar. The presence of Si, Fe, Mg and Cu confirm the existence of Quartz, Hematite, Illite and Bornite respectively.

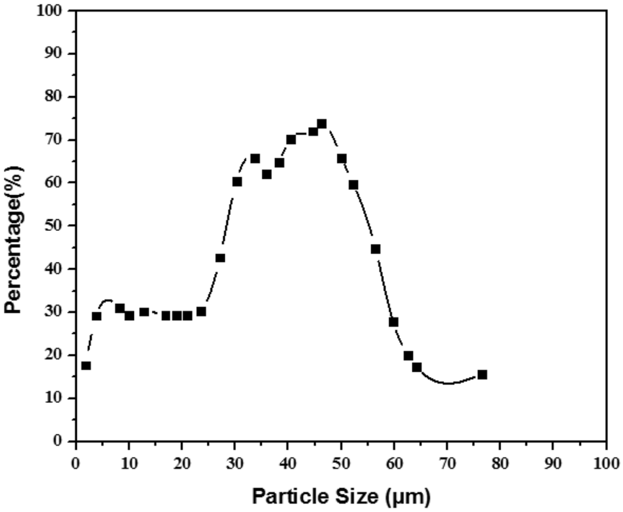


**Fig. 3** Particle size analysis of sediments

## Particle size analyzer (PSA)

The Particle Size Analysis of the sediment sample of different hydrate deposits is shown in Fig. 3. As per the results from NGHP, the gas hydrate bearing sediment samples are mainly silt and clay. The sediments samples from Andaman Basin are of clay/silt with volcanic ash beds type. From the observation of data from Particle Size Analyzer, it is confirmed that the sediment sample contains silt, sand and clay. The rate of induction and growth of hydrate in sediments is affected by the particle size of the sediments. The particle size of the sediment is one of the major properties that may disturb the stability conditions of gas hydrates formed in sediments. It has an essential role in formation and dissociation of gas hydrates formed in sediment. Hydrate will form with higher rate in small sized particles than the large sized particles. The equilibrium conditions of gas hydrate formed in sediments can be disturbed by the irregular particle size of natural sediments. As the particle size decreases, the relaxation time of water decreases. The water in the porous material has less numbers of hydrogen bond, less dynamics than the bulk water (Lu et al. 2011). Hills et al. (1996) estimated that the average water activity decreases with the reduction in the size of the particle or increase in the specific surface area. The activity of bound or surface water is less than the bulk water. Gallo et al. (2002) concluded that the stability temperature of hydrate formed in porous material is higher than the hydrate formed in bulk water. Hence the effect of particle size of sediments can be explained by the effect of proportion of bulk water. Water restricted in porous sediments has dissimilar chemical and physical properties than bulk water (Lu et al. 2011). The minimum and maximum particle size diameter of the sediment sample is given in Table 3.

**Table 3** Distribution width of sediment particles

| | $D_{10}$ | $D_{50}$ | $D_{90}$ (μm) |
|---|---|---|---|
| Min | 0.69 | 1.59 | 4.19 |
| Max | 2.86 | 45.01 | 282.9 |

Lu et al. (2011) studied the change in the saturation of $CH_4$ hydrate in sediments due to the change in the particle size. It was revealed in this study that the particle size has a remarkable effect on the saturation of hydrate. The approximate value of hydrate saturation between the particle size range 0–100 μm is 80% (Lu et al. 2011). Hence, this size range of sediment has supported the formation of hydrates in sediments as shown in Table 3.

## Pore size distribution and specific surface areas

As shown in Fig. 4, the pore size of the sediments sample from Andaman Basin is lies in between 50 and 250 Å and the Specific Surface Area of the sediments is 20.1116 $m^2/g$. The nucleation of hydrate in sediments is affected by the pore size of the sediments. The hysteric loop of the isothermal adsorption–desorption curve if of Type H3, which represents that the particle of sediments are of plate shape and the pores of sediments are of silt configuration mostly (Sing et al. 1985; Wang et al. 2019). The pore diameter (50–200 Å) of the methane hydrate formed inside the nanoscale pores leads to the nucleation of hydrates in sediments (Handa and Stupin 1992; Wan et al. 2019). The pore volume of the sediment was found to be $2.305 \times 10^{-3} cm^3/g$ representing the porous nature of materials.

## Cation exchange capacities (CEC)

The CEC of fine sand are higher than the coarse sand depending upon grain size. The minerals present in the sediement

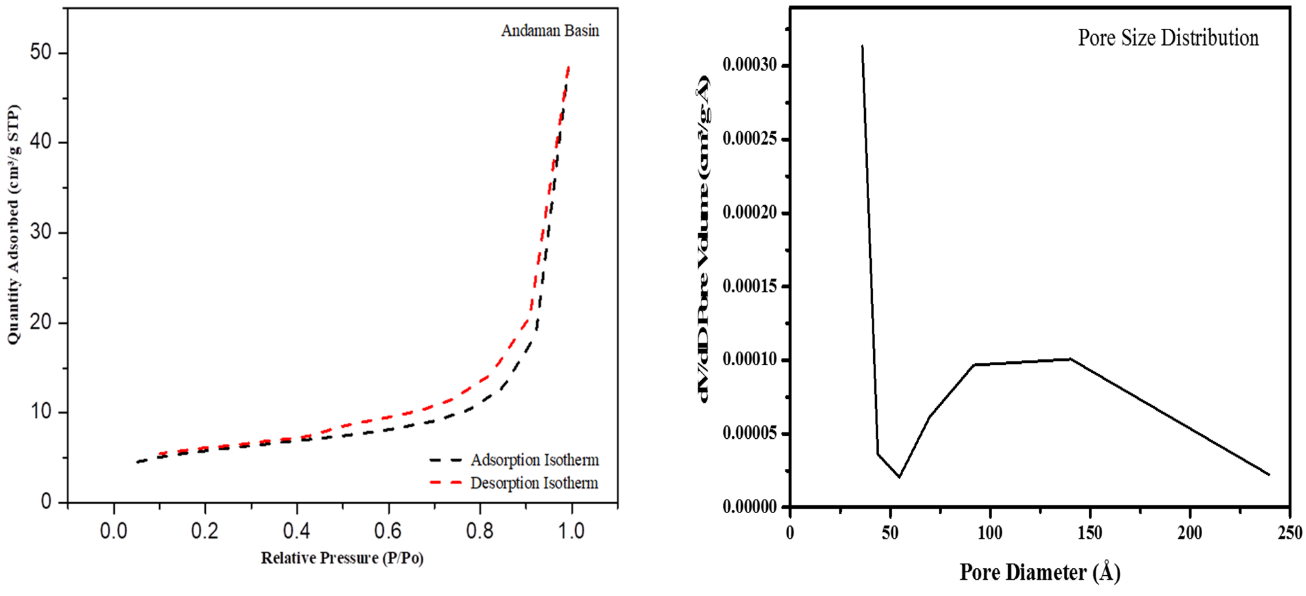


**Fig. 4** Adsorption/desorption isotherms and particle size distribution of sediment

sample can be idetified by the CEC values. The presnece of Kaolinite and Quartz in the hydrate bearing sediments is obesrved by the CEC values between 3 and 15 meq. Surface area of the sediment sample represents the adsorption of organic matter onto the sediments minerals and the organic matter contributes in the hydrocarbon adsorption in the pore space or the surface of the sediment's samples. Specific surface area is apredominant physical property of hydrate bearing sediments (Santamarina et al. 2004) which can represent the mineralogical components in sediments and help in the determination of mechanical and elastic properties of the sediments which influence the formation as well as dissociation of hydrates. The specific surface Area designate the degree of dissipation of the sediments and this is also inversely related to the size of particle. Smaller the size, higher the specific surface area and higher the dispersion degree of sediment. For hydrate occupied sediments, specific surface area is 20.1116 $m^2/g$. The specific surface areas of kaolinite is 10–20 $m^2/g$ and the obtained value for sediments represents the presence of kaolinite in the sediments sample (Santamarina et al. 2004). The values of specific surface areas and cation exchange capacities of Sediments is given in Table 4.

## Scanning electron microscopy (SEM)

The surface texture and shape of sediment particles can influence the mechanical properties of the hydrate bearing sediments. Figure 5 shows the SEM analysis images (at 10–20 µm resolution) and Energy Dispersive Spectroscopy (EDS) analysis of sediment samples from different basin. SEM of sediments helped in visualizing the morphological changes induced upon hydrate formation. The sediment sample have weak vanderwaals forces and hence the SEM image of this sample shows the dispersed like structure. More over the SEM images of sediments is showing the swallowing effects because of the larger inter-particle separation justifying the formation of hydrate formation and dissociation. Kwon et al 2011 concluded that the surface texture and geometry of sediments can disturb the mechanical properties of hydrate occupied sediments. These sediments are angular and enveloped with flaky fine silt and clay (Kwon et al. 2011).

The EDS analysis of sediment sample confirmed the existence of O, Na, Si, Al, Cl, K, Ca and Fe. Table 5 shows the wt% of different elements observed in sediment sample. The cementation properties between the particles of clay will be enhanced by the presence of elements such as Al, K, Si and Fe. The cementation properties of the sediment particles can increase after the presence of Al, Mg, Si, K, Ca, O and Ti. The presence of kaolinite mineral can also be identified by the presence of Fe, K and Si. High concentration of Al, Mg and K represents the higher cementation effect of sediments and higher cementation properties can affect the formation of hydrate in natural sediments. The presence of these elements can also represent the minerals present in the sediments sample. More over the insight of cementing will assist in the dissociation as it needs to be removed while dissociation.

**Table 4** Specific surface areas and cation exchange capacities of Sediments

| Specific surface area ($m^2/g$) | Cation exchange capacities (meq/100 g) |
|---|---|
| 20.1116 | 7.415224 |

## X-ray diffraction (XRD)

The pattern for X-ray diffraction has been shown in Fig. 6. The origin software to identify the peaks analyzed the data for XRD and those identified peaks were confirmed with the Joint Committee on Powder Diffraction Standards (JCPD) database. The XRD analysis confirms the presence of minerals Quartz(Q), Sepiolite (S), Kaolinite (K), Magnetite (M), Calcite (C) and Halite Syn (H) in sediments. The behavior of the nucleation and agglomeration behavior hydrate gets changed by the type of minerals. From the figure, the strong and weak peaks at 26.65, 28.443 29.406, 33.115, 46.945 and 47.005 angle confirms the presence of minerals Quartz, Silicon, Calcite, Hematite, Bornite and Fluorite, hence the formation of hydrate in the sediments under study is justified as all these are having good pore volumes and promote the formation of hydrates as they promote the gas and water contact in their pores.

## Fourier transform infrared spectroscopy

The mineralogical behavior of sediment can be identified with reference to infrared spectroscopy. Figure 7 shows the infrared spectra of sediment samples from different natural deposits of gas hydrate. In sediment sample from Andaman basin, the peaks are detected at 3447–3623, 1636–1638, 1416–1424, 795–798, 691.8–694 and 526–565 $cm^{-1}$ and these peaks confirm the presence of Kaolinite, Smectite, Silica, Carbonate, Quartz and Silicate (Farmer 1968) respectively as all these materials are having suitable pore size and pore volumes promoting the hydrate formation as it leads to better gas and water contact.

## Raman spectroscopy

Raman Spectra for gas hydrate bearing sediment sample Andaman Basin is shown in Fig. 8. The specific minerals were observed in the Raman Spectra and compared with Renishaw's Inorganic Material and Minerals Database. The sediment sample from Andaman basin does not detect the strong peaks for quartz or other minerals. In sediment sample from Andaman basin, the peaks are detected at 190–200,

**Fig. 5** SEM and EDS analysis of sediment sample

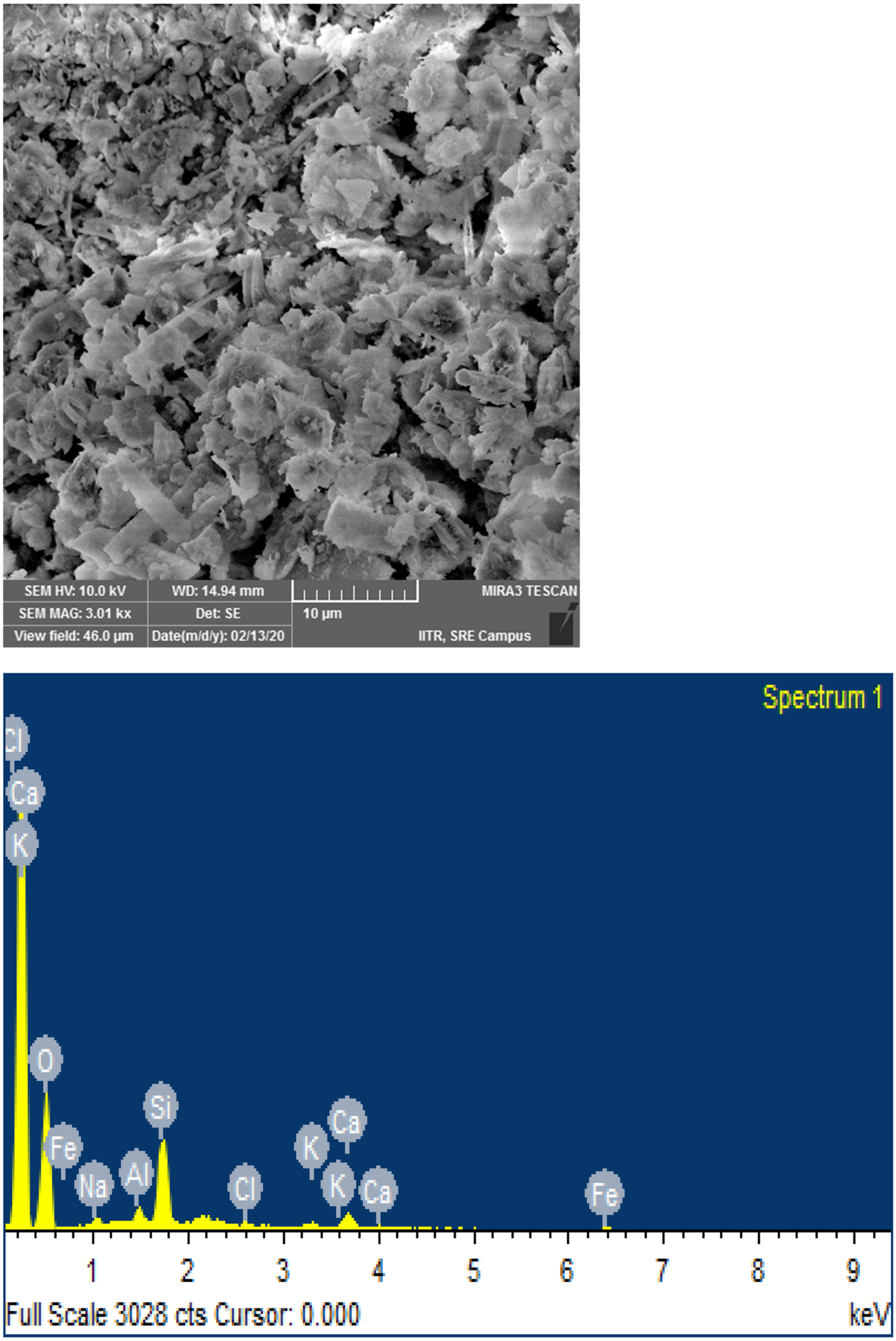


**Table 5** Elemental analysis of sediment sample

| Elements | O | Na | Al | Cl | K | Ca | Si | Fe |
|---|---|---|---|---|---|---|---|---|
| wt (%) | 71.71 | 1.98 | 2.56 | 1.07 | 0.86 | 4.45 | 16.15 | 1.22 |

394, 409, 472, 520, 712 and 1300 $\text{cm}^{-1}$ and these peaks confirm the presence of Halite, Kaolinite, Hematite, Bornite, Silicon, Calcite and Quartz respectively (Bishop et al. 2003). The minerological component present in sediments can affect the flow behavior of pore size sediments and formation of gas hydrates in sediments. The above components found in the sediments has justified the hydrate formation in the sediments because all these components are porous and facilitates the gas and water contact and hence promote hydrate formation.

The particle size distribution and surface area analyzer show the unequal distribution of clay and silt in hydrate bearing sediment samples. The mineral composition of sediment samples has been examined by performing the X-ray Diffraction, Raman Spectroscopy, ICPMS and EDS. The hydrate bearing sediment samples contains quartz, hematite, silicon mainly. The morphological features of sediment sample have been analyzed the Scanning Electron Microscopy. The sediments samples of Andaman Basin contain higher concentration of Iron, potassium, Aluminum and Magnesium and lower concentration of Copper, Silicon and Titanium as compared to other metals.

All of these physical and chemical properties can be used for the improvement of currently available methods for the dissociation of hydrates. For example, the knowledge of these properties can enhance the mechanical stability of hydrate reservoir. The currently available dissociation methods are Depressurization, Thermal Stimulation, Inhibitor Inhibition and $CH_4$-$CO_2$ exchange (Bhattacharjee et al. 2019). There are some drawbacks in currently available hydrate dissociation methods. Depressurization is favorable for widespread gas hydrate deposits and thermal stimulation provide poor recovery efficiency of gas from hydrate deposits because the temperature increase can disturb the hydraulic stability of the hydrate reservoirs. Hence, knowledge of above properties of hydrae bearing sediments can help in improving the production efficiency by controlling the hydraulic failures. The prediction of hydraulic failures can also help in the production efficiency of gas from gas

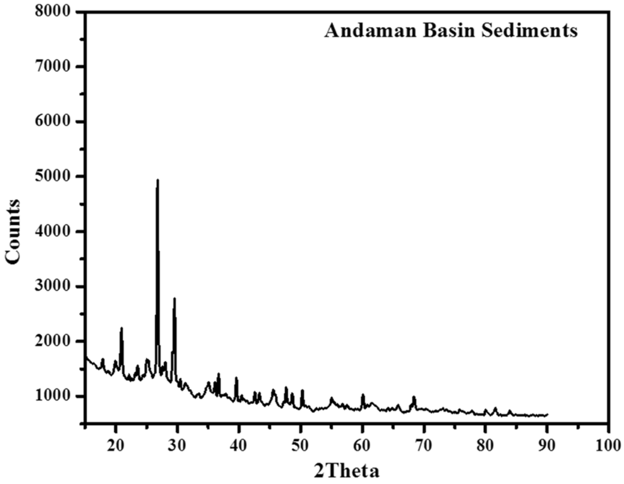


**Fig. 6** XRD diffractrogram

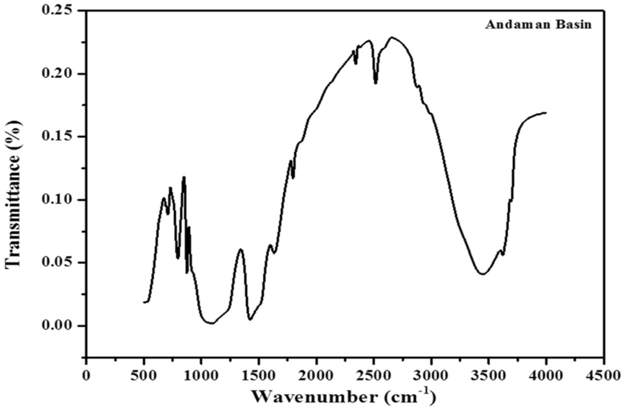
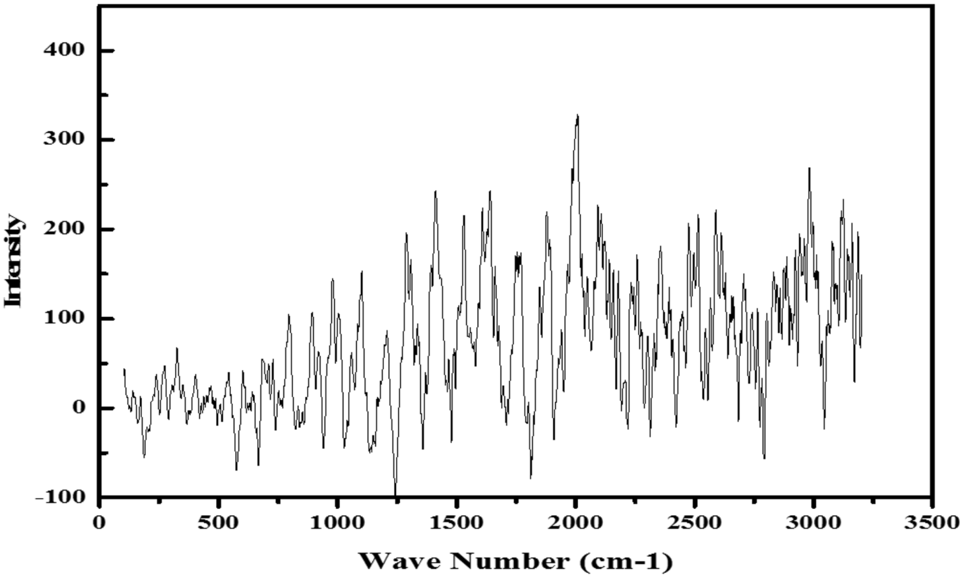


**Fig. 7** FTIR analysis

**Fig. 8** Raman spectra of sediment sample



hydrates by the $CO_2$sequestration method. These types of comprehensive studies can help in the production of gas from gas hydrates by avoiding many unwanted events during production.

As we have seen above the physic-chemical properties influence the type of hydrate which will be formed as well as its distribution also so its understanding can be utilized for determining the dissociation techniques for the production of gas from the hydrate and moreover it can also predict the kinds of problems which will be faced while production clogging etc. The above data of physio-chemical and mineralogical analysis of hydrate bearing sediments is quite useful as its better understanding can be utilized for the methane production from Andaman Basin reservoir by adjusting the natural sediment properties.

## Conclusion

This study has revealed the Physio-Chemical and mineralogical behavior of gas hydrate occupied sediments retrieved from Andaman Basin. We have analyzed the physical properties such as pH, TDS, TOC, Salinity, Conductivity, Water Content, Density and Porosity of hydrate bearing sediments sample of 50 wt% concentration. The water trapped in the porous structure of hydrates have different chemical and physical properties. Hence, it is very important to understand these properties of hydrate bearing sediment samples before designing any hydrate dissociation methods such as thermal stimulation, depressurization, Inhibitor injection, $CO_2$ sequestration etc. These properties have very important role in depicting the saturation of gas hydrates and moreover the fluid or thermal agent which will be applied on the sediments for the dissociation of gas hydrates. These properties can help in selecting the thermal and chemical agent for the future behavior of hydrate dissociation. Hence, these properties will be helpful tool for the designing an economic and viable dissociation technology of gas hydrates. These properties can also help in the improvement of the production efficiency of currently available hydrate dissociation methods. The shortcomings and limitations can also be improved by the knowledge of these properties. Physio-chemical and mineralogical analysis of hydrate bearing sediments also supported the hydrate formation and will be a useful tool for the methane production from Andaman Basin. By adjusting the properties of natural sediments can help in designing a viable technology for the commercial production of gas from the natural deposits of gas hydrates.

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