# Scientific Research Outcome Report

*Reservoir Characterization of Cambay Shale Cambay Basin, India in Reference to Shale Gas Exploration and Exploitation*

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2. **Branch / Department :** School of Petroleum Technology, PDPU

3. **Researcher's Name along with designation :**

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   Rajshree Saini (M.Tech, P.E.)

   Kiran Bhatreja (M.Tech, P.E.)

4. **Research Title :** Reservoir characterization of Cambay shale Cambay basin, India in reference to shale gas exploration and exploitation

5. **Major Goal of this Scientific Research Project :**

   Understanding Reservoir Architecture of Cambay Shale

   India has strategic compulsion to explore and develop shale gas due to rising energy consumption and economic development. This widening gap between demand and supply coupled with volatility of oil prices can be reduced through unconventional gas production. In this context, Government of India has initiated the process of shale gas exploration by undertaking initiatives through Directorate General of Hydrocarbon (DGH) and Petroleum Ministry to have international multi task ventures to assess shale gas basins. An agreement is in place between DGH and United States Geological Survey to evaluate shale gas basins and their resource potential by acquisition of geological and engineering data through pilot wells and laboratory investigations which has aided in identifying thick shale sequences with proven source rock characteristics in many sedimentary basinal areas. This calls for a road map to be adumbrated for exploring shale gas in Cambay Basin. The primary aim is to understand the reservoir architecture of shale gas

Cambay basin unconventional energy exploitation requires understanding of architecture of reservoirs within shale anisotropy which plays an important role in defining the migration pathways within shales. Stress-strain designs, compressional and shear wave velocity study is already researched and documented in the literature to prepare a complete roadmap for exploitation and augment previous studies. The present study focuses on textural and mineralogical characterization of Cambay shale that will help us to understand the fracture and micro cracks within the reservoirs.

## 6. Major Activities:

- To prepare a road map for Shale gas exploration and exploitation in Cambay Basin
- To carry out mineralogy and textural studies for identifying the bulk minerals in the shale samples.
- To understand the elemental chemistry of the samples
- XRD analysis of various samples at different depths
- To carry out CT scan and SEM studies of the rock samples for shale characterization
- To analyze the mineral variation with depth
- To prepare a flow chart for rock typing characterization

## 7. Specific Objectives & Research Hypothesis:

**Mineralogy and Textural Study**

Shales due to mineral and textural heterogeneity, low porosity and permeability bring to the fore many problems, usually not encountered in conventional reservoirs. It makes determination of fluid and reservoir properties difficult as well as lowers the degree of accuracy of such estimations. Also the objective of formation evaluation is more biased towards identifying ideal spots for hydraulic fracturing rather than a static reservoir evaluation.

Mineralogical evaluation by X ray diffraction studies by which the bulk minerals presnt in shale samples are identified. Along with it, XRF is carried out to determine elements and compounds present in clay in shale samples. WD-XRF is fast, accurate, non-destructive and usually requires minimum sample preparation. WD-XRF can analyze elements from Beryllium to Uranium and from trace levels to 100% levels.

**Textural studies**

Shale characterization problems can be resolved to a considerable extent by studies of mineralogy and texture using standard petrographic techniques coupled with newly enhanced and emerging technologies. Rock based investigations using conventional cores and rotary side wall cores taken in pilot holes form the basis of these characterizations. Some of the techniques used to capture the textural and compositional variability of shale sections are given below

**CT Scans**

CT scans provide a non destructive method that can be used to describe the rock in high resolution 3D views. Movies created by compiling density scans can be reviewed through the horizontal and vertical planes of the core providing three dimensional views of important parameters. These include organic rich intervals, pyrite and barite, cement filled and open fractures, fracture orientation and density, bedding and bedset contacts, sedimentary structures, lithofacies, micro and trace fossils etc.

Micro Ctscan by SCANCO medical has been performed on two samples. This is done to identify micro fractures and obtain 2D slices and 3D orientations.

## 8. Material and Methods along with necessary diagrams

XRD Panalaytical Xpert-Pro, Panalytical Axios MAX, Mercury porosimeter, Philips SEM EDS.


*Figure 1: XRD set-up*

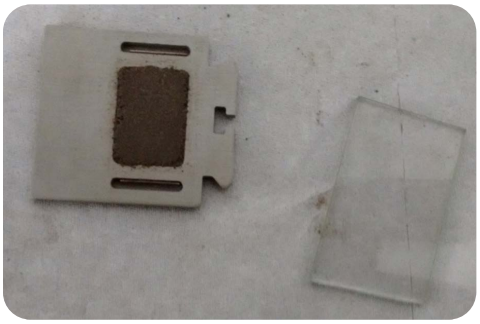


*Figure 2: XRD SAMPLE PREPARATION*

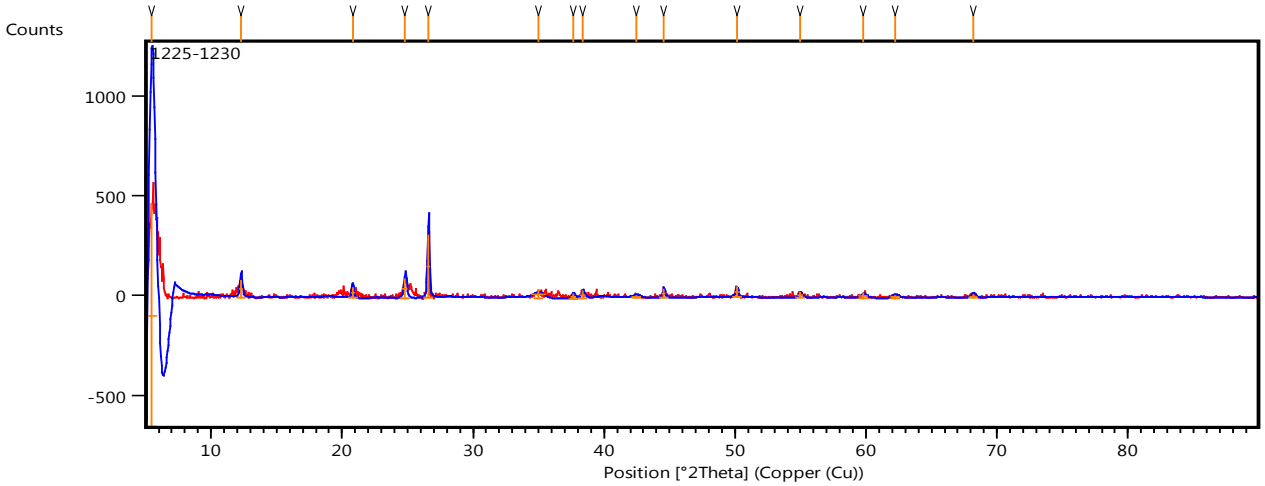
**9. List of equipment, technical facilities/resources used from PDPU for the above mentioned research activity :**

XRD Panalytical-Pro

**10. Significant Results/key outcomes/achievements along with necessary pictures / diagrams / images.**

Exploration of shale gas in Cambay basin is in nascent stage. However to understand the architecture in detail the present study aims at understanding mineralogy and texture, rock type, dynamics of porosity.

Identification of minerals present has already been done. XRF studies have been done on some samples. SEM and Mercury Porosity-meter studies are to be done and results to be interpreted.




| Score | Compound Name | Chemical Formula | Scale Factor |
|---|---|---|---|
| 38 | Silicon Oxide | Si O2 | 0.166 |
| 37 | Silicon Oxide | Si O2 | 0.167 |
| 4 | Chromium Oxide | Cr2 O3 | 0.013 |
| 1 | Aluminum Oxide | Al2 O3 | 0.005 |
| 1 | Iron Oxide | Fe2 O3 | 0.000 |
| 1 | Calcium Carbonate | Ca C O3 | 0.069 |
| 1 | Silicon | Si | 0.000 |
| 0 | Iron Oxide | Fe2 O3 | 0.003 |

*Figure 3: XRD of sample at depth of 1225 – 1230 m*

The XRD analysis of various samples at different depths shows that Quartz and Clinochlore are the most abundant minerals found at the depth range 1225-1240 m. Quartz content is an

important factor affecting the fracture development, thus the quartz-rich shale section is more brittle and easy to fracture.

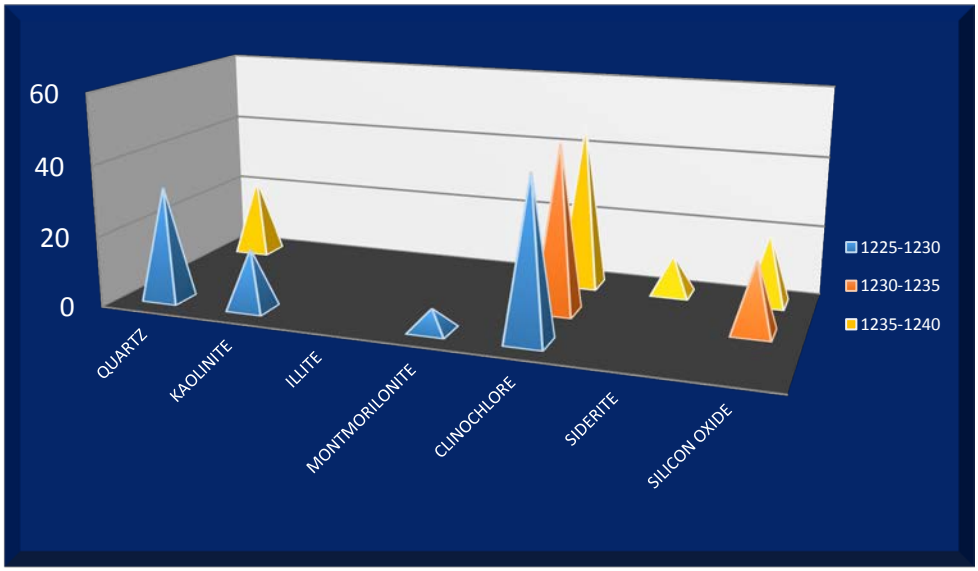



*Figure 4: Mineral variation with depth*

**11. Impact of the research outcomes or findings that address the intellectual merit and broader impacts of the research work**

Across the world, shale gas has become an increasingly important source of natural gas. As the energy demand and supply gap is widening, the need of the hour is to increase the supply. It is being believed that shale gas will greatly expand worldwide energy supply. Also shale gas development might help reduce greenhouse gas emissions.

In India, researchers are gradually moving towards greener initiatives and are trying to come up with innovative solutions for harnessing unconventional sources of energy. The present study is aimed at understanding the textural and mineralogical characterization of Cambay shale that will help to understand the fracture and micro cracks within the reservoirs. Though there is a geological risk of not finding gas in the resource plays, a detailed study of the shale samples will prove to be beneficial for better understanding of the Cambay Shale with reference to shale gas.

**12. How the results have been shared/ disseminated, you can list any of following, please specify**.

Results would be shared through journals and dissertation report.

***Papers under preparation:***

- Anto, R., Saini, R., Bhatreja, K., Sahajpal, S., Sircar, A., Understanding reservoir arcitechture of Cambay Shale, Cambay Basin, India using geoscientific data.
- Anto, R., Saini, R., Bhatreja, K., Sahajpal, S., Sircar, A., Study on Cracks and Micro-Cracks of Cambay Shale under a dynamic stress-strain regime.

***PhD (ongoing):***

Mr. Anshul Gupta is doing his PhD on Reservoir Characterization of Cambay Shale

**13. Give also name of other PDPU individuals involved in the research.**

Ms. Shreya Sahajpal, Faculty, SPT, PDPU

**14. Which organizations have been involved as partners?**

NIL

**15. Have other collaborators been involved?**

Sophisticated Instrumentation Centre for Applied Research and Testing – SICART

**16. Mention if any infrastructure got added out of research outcome to PDPU institutional resources.**

**17. Includes up to six images (images are optional)**

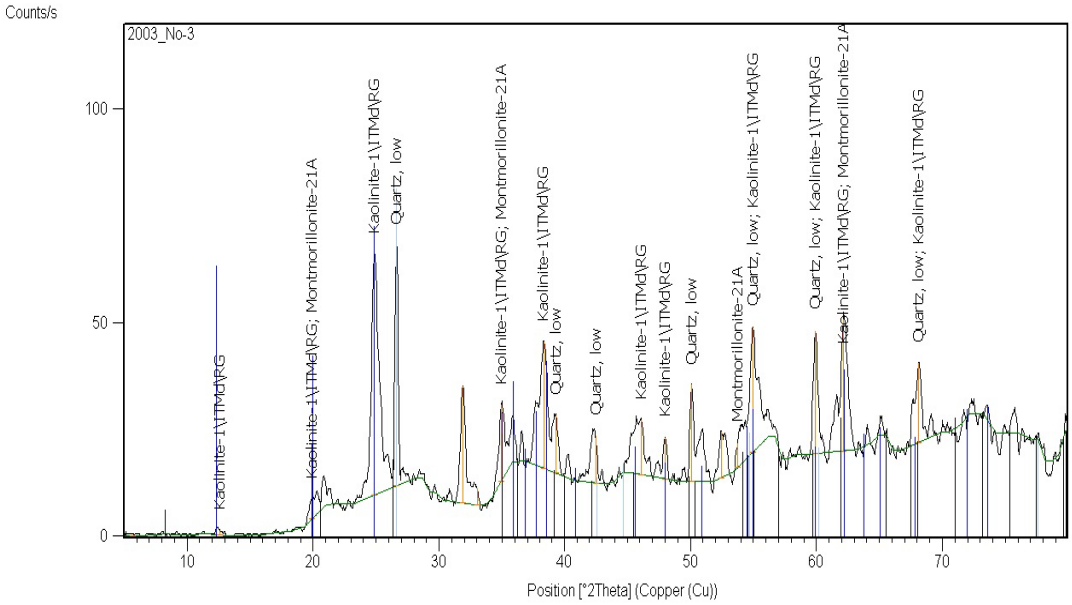



*Figure 5: XRD of shale sample indicating presence major minerals –quartz,kaolinite and montmorillonite*

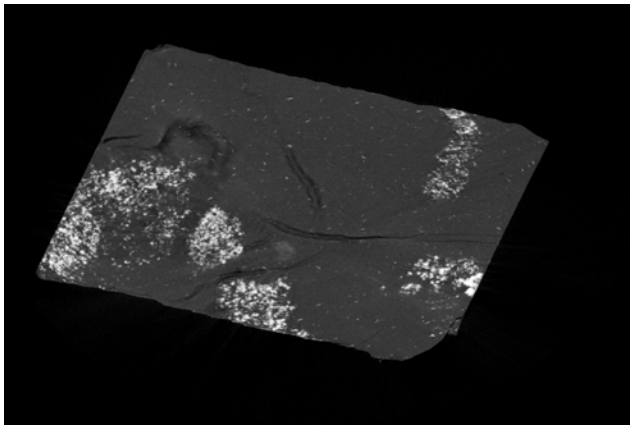


*Figure 6: 2D Micro CTSCAN*

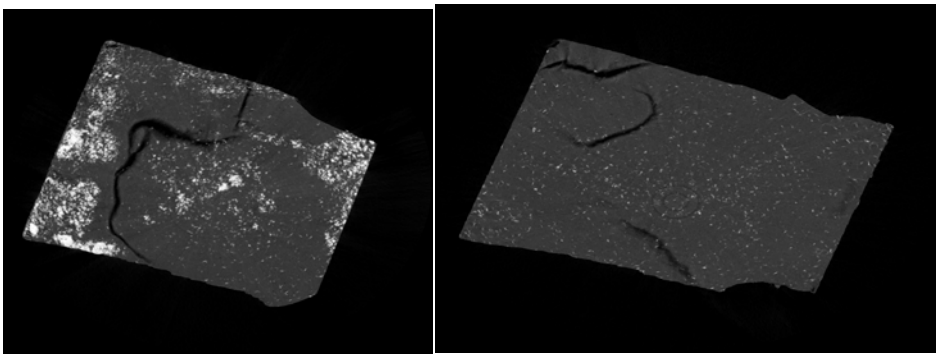


*Figure 7: 2D micro ctscsan images showing micro fractures in shale sample*

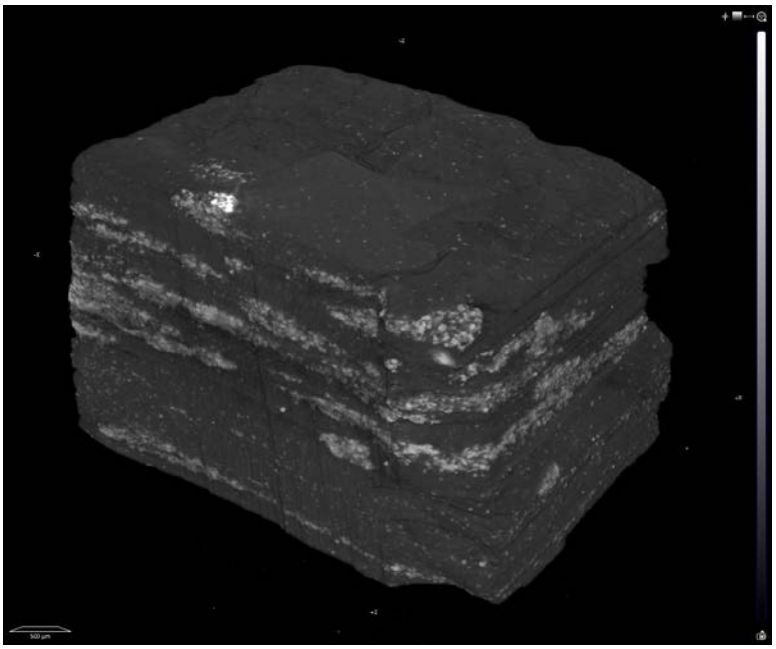


*Figure 8: 3D orientation through micro CT-scan*

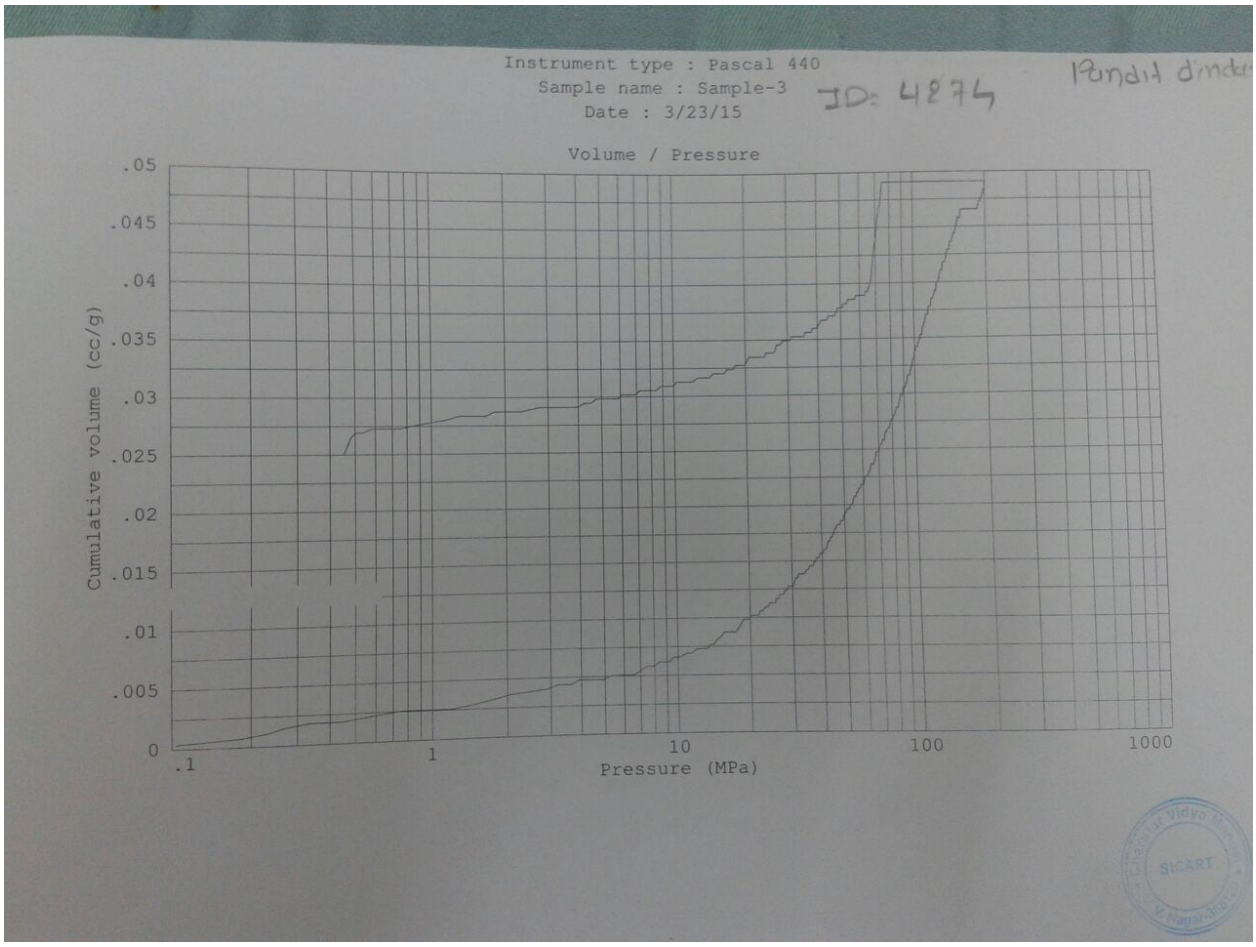



*Figure 9:* Pressure vs volume realtion obtained through mercury porosimeter

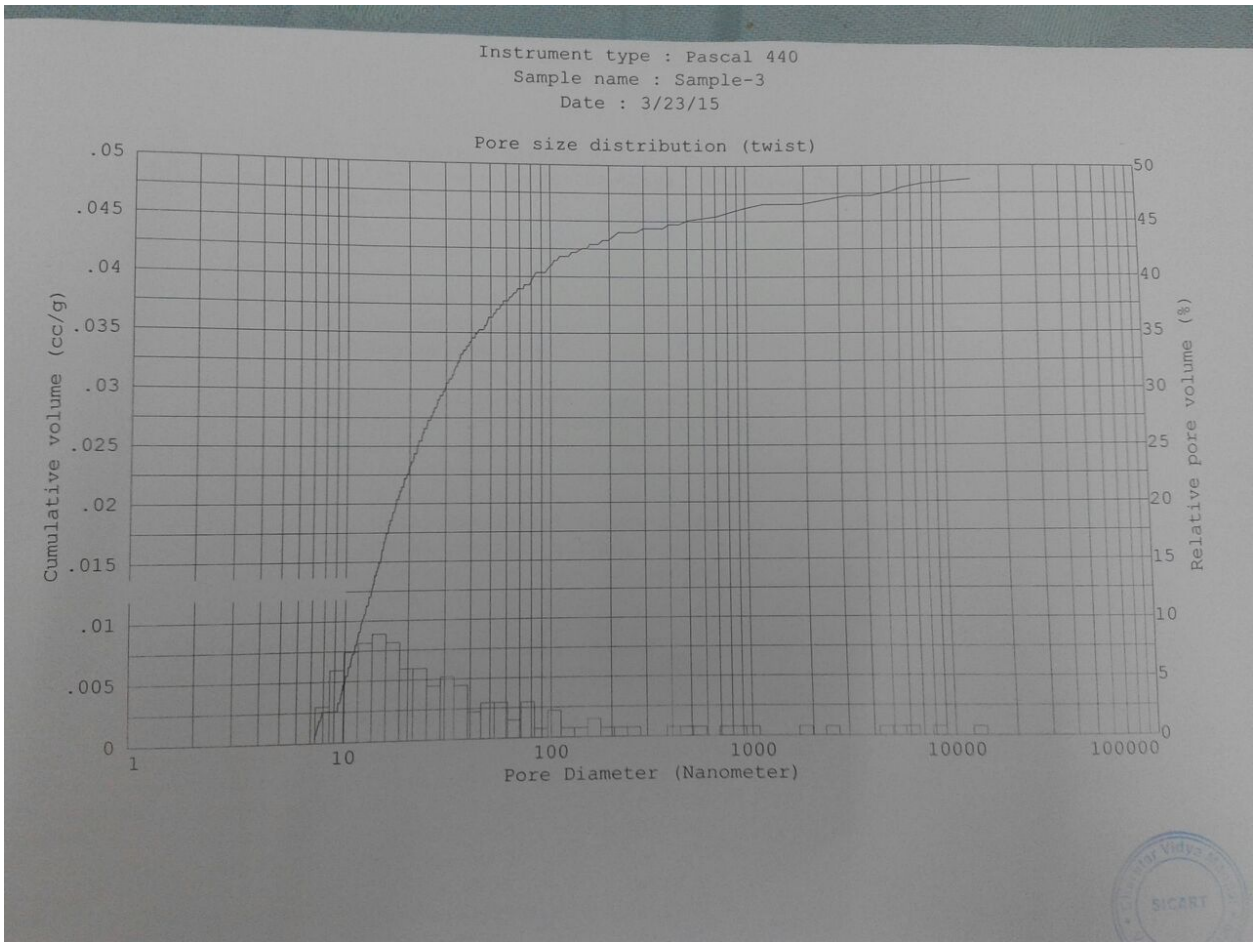



*Figure 10: indicating pore size distribution of particles in shale sample*