TIARA-NET: TERAHERTZ IMAGING APPLIED RECOGNITION OF ANCIENT ROCKS

A PROJECT REPORT

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ABSTRACT

Investigations into the history of tectonic evolution, the paleoenvironment, and the paleogeography rely heavily on the depositional constituents of sedimentary rocks. The procedures for detecting geological evolution are still quite difficult, and it is unclear how to integrate geological age plus geological evolution. In order to determine the geological age of sedimentary rocks, a THz dating method was developed based on the sensitivity of terahertz vibrations to organic matter. The geological accumulation in this area is influenced by marine cover, as may be deduced from the close relationship between organic matter concentration and sedimentary environment.

These findings suggest that an area's sedimentary environment slowly transformed from continental to deep-water marine accumulation, and that the sea water gradually receded because of the movement of the crust. This transition from deep-water to continental nearshore ocean facies deposition was caused by the sea water's gradual retreat. These results are remarkably compatible with the research area's geological past. It is possible to divide sedimentary rocks' relative geological ages using principle component analysis (PCA) technology. Our research supported the accuracy of this THz dating method, which offers a useful method for examining the geological modification record of sedimentary rocks.

Keywords: Terahertz dating, geologic age, Refractive index, Adsorption Coefficient, Sedimentary Rocks

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LIST OF ABBREVIATIONS

ABBREVIATION	EXPANSION
THz	TeraHertz
TDS	Time-Domain Spectroscopy
RI	Refractive Index
ML	Machine Learning
ITU	International Telecommunication Union
THF	Tremendously High Frequency

CHAPTER 1

1. INTRODUCTION

Terahertz (THz) dating of sedimentary rocks is a relatively new technique that uses terahertz spectroscopy to determine the age of sedimentary rocks. Sedimentary rocks are formed from layers of sediment that accumulate over time, and the age of these layers can provide important information about the Earth's history. Traditional dating methods such as radiometric dating and stratigraphy have limitations, and terahertz dating offers a promising new approach. Terahertz radiation lies between the infrared and microwave regions of the electromagnetic spectrum, and has unique properties that make it useful for dating sedimentary rocks. Terahertz radiation can penetrate through many materials, including rocks, and is sensitive to changes in the molecular structure of these materials. As sedimentary rocks accumulate over time, their molecular structure changes, and terahertz spectroscopy can detect these changes.

The terahertz dating technique involves analysing the terahertz absorption spectra of a sedimentary rock sample and comparing it to a reference library of spectra from rocks of known ages. By matching the sample's spectrum to the closest reference spectrum, the age of the sample can be determined. This method has the potential to provide more precise and accurate dating of sedimentary rocks, particularly for those that are difficult to date using traditional methods.

The application of terahertz dating has the potential to revolutionize our understanding of the Earth's history, particularly in areas such as paleoclimatology, where accurate dating of sedimentary rocks is essential.

However, further research is needed to refine the technique and establish a more comprehensive library of reference spectra.

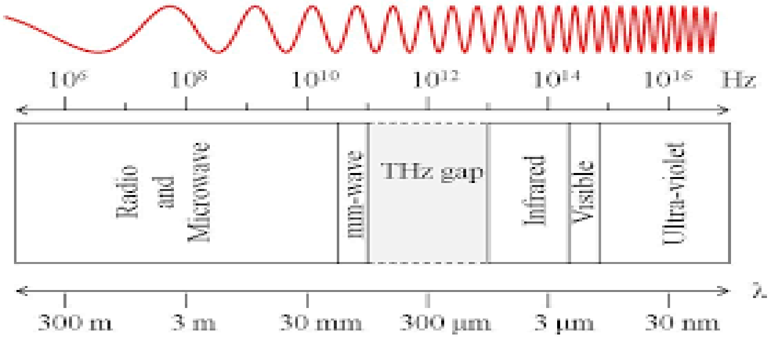

Figure 1.1 Electromagnetic Spectrum

Sedimentary strata are natural records of geologic history, and determining their sequence and age accurately is required for researching their pale environment, paleogeography, and tectonic development history. The essential components utilised to investigate geological processes and environmental change are time, space, materials, and movement; therefore, time is the foundation for analysing geological problems.

The THz spectroscopy was used to study sedimentary rock samples from nine areas with six different geological ages. The evolution of the strata was deduced using the changes in the absorption coefficient and the Refractive Index (RI) with geologic age. Then, principal component analysis (PCA) was employed to classify the geologic ages.

1.2 Terahertz spectroscopy

There are a great variety of techniques to generate THz radiation and to detect THz fields. One can, e.g., use an antenna, a quantum-cascade laser, a free-electron laser, or optical rectification to produce well-defined THz sources. The resulting THz field can be characterized via its electric field $E_{\mathrm{THz}}(t)$. Present-day experiments can already output $E_{\mathrm{THz}}(t)$ that has a peak value in the range of MV/cm (megavolts per centimeter).[1] To estimate how strong such fields are, one can compute the level of energy change such fields induce to an electron over microscopic distance of one nanometer (nm), i.e., $L = 1$ nm. One simply multiplies the peak $E_{\mathrm{THz}}(t)$ with elementary charge e and L to obtain $e\, E_{\mathrm{THz}}(t)\, L = 100$ meV. In other words, such fields have a major effect on electronic systems because the mere field strength of $E_{\mathrm{THz}}(t)$ can induce electronic transitions over microscopic scales. One possibility is to use such THz fields to study Bloch oscillations[2][3] where semiconductor electrons move through the Brillouin zone, just to return to where they started, giving rise to the Bloch oscillations.

The THz sources can be also extremely short, down to single cycle of THz field's oscillation. For one THz, that means duration in the range of one picosecond (ps). Consequently, one can use THz fields to monitor and control ultrafast processes in semiconductors or to produce ultrafast switching in semiconductor components. Obviously, the combination of ultrafast duration and strong peak $E_{\mathrm{THz}}(t)$ provides vast new possibilities to systematic studies in semiconductors.

Besides the strength and duration of $E_{\mathrm{THz}}(t)$, the THz field's photon energy plays a vital role in semiconductor investigations because it can be made resonant with several intriguing many-body transitions. For example, electrons in conduction band and holes, i.e., electronic vacancies, in valence band attract each other via the Coulomb interaction. Under suitable conditions, electrons and holes can be bound to excitons that are hydrogen-like states of matter. At the same time, the exciton binding energy is few to hundreds of meV that can be matched energetically with a THz photon. Therefore, the presence of excitons can be uniquely detected based on the absorption spectrum of a weak THz field.[7][8] Also simple states, such as plasma and correlated electron–hole plasma[9] can be monitored or modified by THz fields.

Terahertz spectroscopy detects and controls properties of matter with electromagnetic fields that are in the frequency range between a few hundred gigahertz and several terahertz (abbreviated as THz). In many-body systems, several of the relevant states have an energy difference that matches with the energy of a THz photon. Therefore, THz spectroscopy provides a particularly powerful method in resolving and controlling individual transitions between different many-body states. By doing this, one gains new insights about many-body quantum kinetics and how that can be utilized in developing new technologies that are optimized up to the elementary quantum level.

Different electronic excitations within semiconductors are already widely used in lasers, electronic components and computers. At the same time, they constitute an interesting many-body system whose quantum properties can be modified, e.g., via a nanostructure design. Consequently, THz spectroscopy on semiconductors is relevant in revealing both new technological potentials of nanostructures as well as in exploring the fundamental properties of many-body systems in a controlled fashion. For example, electrons in conduction band and holes, i.e., electronic vacancies, in valence band attract each other via the Coulomb interaction. Under suitable conditions, electrons and holes can be bound to excitons that are hydrogen-like states of matter. At the same time, the exciton binding energy is few to hundreds of meV that can be matched energetically with a THz photon.

1.3 Terahertz radiation

Also known as submillimeter radiation, terahertz waves, tremendously high frequency[1] (THF), T-rays, T-waves, T-light, T-lux or THz –

consistof electromagnetic waves within the ITU-designated band of frequencies from 0.3 to 3 terahertz (THz),[2] although the upper boundary is somewhat arbitrary and is considered by some sources as 30 THz.[3] One terahertz is 10^{12} Hz or 1000 GHz. Wavelengths of radiation in the terahertz band correspondingly range from 1 mm to 0.1 mm = 100 µm. Because terahertz radiation begins at a wavelength of around 1 millimeter and proceeds into shorter wavelengths, it is sometimes known as the submillimeter band, and its radiation as submillimeter *waves*, especially in astronomy. This band of electromagnetic radiation lies within the transition region between microwave and far infrared, and can be regarded as either.

Terahertz radiation is strongly absorbed by the gases of the atmosphere, and in air is attenuated to zero within a few meters, so it is not practical for terrestrial radio communication. It can penetrate thin layers of materials but is blocked by thicker objects. THz beams transmitted through materials can be used for material characterization, layer inspection, relief measurement,[6] and as a lower-energy alternative to X-rays for producing high resolution images of the interior of solid objects.

Terahertz radiation occupies a middle ground where the ranges of microwaves and infrared light waves overlap, known as the “terahertz gap”; it is called a “gap” because the technology for its generation and manipulation is still in its infancy. The generation and modulation of electromagnetic waves in this frequency range ceases to be possible by the conventional electronic devices used to generate radio waves and microwaves, requiring the development of new devices and techniques.Terahertz radiation falls in between infrared radiation and microwave radiation in the electromagnetic spectrum, and it shares some properties with each of these. Terahertz radiation travels in a line of sight and is non-ionizing. Like microwaves, terahertz radiation can penetrate a wide variety of non-conducting materials; clothing, paper, cardboard, wood, masonry, plastic and ceramics. The penetration depth is typically less than that of microwave radiation. Like infrared, terahertz radiation has limited penetration through fog and clouds and cannot penetrate liquid water or metal.[9] Terahertz radiation can penetrate some distance through body tissue like x-rays, but unlike them is non-ionizing, so it is of interest as a replacement for medical X-rays. Due to its longer wavelength, images made using terahertz waves have lower resolution than X-rays and need to be enhanced (see figure at right).

The earth's atmosphere is a strong absorber of terahertz radiation, so the range of terahertz radiation in air is limited to tens of meters, making it unsuitable for long-distance communications. However, at distances of ~10 meters the band may still allow many useful applications in imaging and construction of high bandwidth wireless networking systems, especially indoor systems. In addition, producing and detecting coherent terahertz radiation remains technically challenging, though inexpensive commercial sources now exist in the 0.3–1.0 THz range (the lower part of the spectrum), including gyrotrons, backward wave oscillators, and resonant-tunneling diodes. Due to the small energy of THz photons, current THz devices require low temperature during operation to suppress environmental noise. Tremendous efforts thus have been put into THz research to improve the operation temperature, using different strategies such as optomechanical meta-devices.

Many possible uses of terahertz sensing and imaging are proposed in manufacturing, quality control, and process monitoring. These in general exploit the traits of plastics and cardboard being transparent to terahertz radiation, making it possible to inspect packaged goods. The first imaging system based on optoelectronic terahertz time-domain spectroscopy were developed in 1995 by researchers from AT&T Bell Laboratories and was used for producing a transmission image of a packaged electronic chip. This system used pulsed laser beams with duration in range of picoseconds. Since then commonly used commercial/ research terahertz imaging systems have used pulsed lasers to generate terahertz images. The image can be developed based on either the attenuation or phase delay of the transmitted terahertz pulse.[68]

Since the beam is scattered more at the edges and also different materials have different absorption coefficients, the images based on attenuation indicates edges and different materials inside of objects. This approach is similar to X-ray transmission imaging, where images are developed based on attenuation of the transmitted beam.[69]

In the second approach, terahertz images are developed based on the time delay of the received pulse. In this approach, thicker parts of the objects are well recognized as the thicker parts cause more time delay of the pulse. Energy of the laser spots are distributed by a Gaussian function. The geometry and behavior of Gaussian beam in the Fraunhofer region imply that the electromagnetic beams diverge more as the frequencies of the beams decrease and thus the resolution decreases. This implies that terahertz imaging systems have higher resolution than scanning acoustic microscope (SAM) but lower resolution than X-ray imaging systems. Although terahertz can be used for inspection of packaged objects, it suffers from low resolution for fine inspections. X-ray image and terahertz images of an electronic chip are brought in the figure on the right. Obviously the resolution of X-ray is higher than terahertz image, but X-ray is ionizing and can be impose harmful effects on certain objects such as semiconductors and live tissues.

To overcome low resolution of the terahertz systems near-field terahertz imaging systems are under development.In nearfield imaging the detector needs to be located very close to the surface of the plane and thus imaging of the thick packaged objects may not be feasible. In another attempt to increase the resolution, laser beams with frequencies higher than terahertz are used to excite the p-n junctions in semiconductor objects, the excited junctions generate terahertz radiation as a result as long as their contacts are unbroken and in this way damaged devices can be detected.[74] In this approach, since the absorption increases exponentially with the frequency, again inspection of the thick packaged semiconductors may not be doable.

Consequently, a tradeoff between the achievable resolution and the thickness of the penetration of the beam in the packaging material should be considered.New types of particle accelerators that could achieve multi Giga-electron volts per metre (GeV/m) accelerating gradients are of utmost importance to reduce the size and cost of future generations of high energy colliders as well as provide a widespread availability of compact accelerator technology to smaller laboratories around the world. Gradients in the order of 100 MeV/m have been achieved by conventional techniques and are limited by RF-induced plasma breakdown. Beam driven dielectric wakefield accelerators (DWAs) typically operate in the Terahertz frequency range, which pushes the plasma breakdown threshold for surface electric fields into the multi-GV/m range.[55] DWA technique allows to accommodate a significant amount of charge per bunch, and gives an access to conventional fabrication techniques for the accelerating structures. To date 0.3 GeV/m accelerating and 1.3 GeV/m decelerating gradientshave been achieved using a dielectric lined waveguide with sub-millimetre transverse aperture.

An accelerating gradient larger than 1 GeV/m, can potentially be produced by the Cherenkov Smith-Purcell radiative mechanism in a dielectric capillary with a variable inner radius. When an electron bunch propagates through the capillary, its self-field interacts with the dielectric material and produces wakefields that propagate inside the material at the Cherenkov angle. The wakefields are slowed down below the speed of light, as the relative dielectric permittivity of the material is larger than 1. The radiation is then reflected from the capillary's metallic boundary and diffracted back into the vacuum region, producing high accelerating fields on the capillary axis with a distinct frequency signature. In presence of a periodic boundary the Smith-Purcell radiation imposes frequency dispersion.

CHAPTER 2

2.1 LITERATURE SURVEY

[1] TITLE: Terahertz Microfluidics for attomole- and picoliter-level sensing

AUTHOR: Kazunori Serita; Masayoshi Tonouchi

YEAR:2022

DESCRIPTION: We present a compact terahertz (THz) microfluidic chip based on a nonlinear optical crystal with a small number of meta-atoms for accelerating the research on THz microfluidics. The chip operates based on near-field interactions among a solution sample that flows in a micro channel, meta-atoms, and a highly dense point THz source that occurs in the process of optical rectification at the irradiation spots of femtosecond pulse laser beam. To date, we have achieved attomole-level sensing using a picoliter-order volume of various solutions in a sub-wavelength effective sensing area. Details of the chip, sensing examples, and future THz microfluidics are discussed.

[2] TITLE: A Deterministic Terahertz Channel Model for Inter-Satellite Communication Link

AUTHOR: Xing Hu; Kai-Xuan Guo

YEAR: 2021

DESCRIPTION: Owing to the revolutions in satellite constellation networking and the development of microelectronics, the terahertz band has become an attractive solution for inter-satellite communication links for its promising high date rate. For the accurate estimation of propagation characteristics of THz signals in space, this letter presents a deterministic channel estimation approach. Due to the existence of thermal multilayer insulation (MLI) blankets covering the satellite, the scattering mechanism from the satellite platform at the THz band is complicated and difficult to estimate. In this work, a simplified procedure to model the MLI surface and the physical optics approximation to calculate its scattering are presented. Mento-Carlo simulations are performed to evaluate the impact of the rough MLI surface in channel impulse response and other propagation characteristics.

[3] TITLE: Terahertz-Frequency Signal Source Based on an Array of Antiferromagnetic Spin Hall Oscillators

AUTHOR: Oleh Shtanko Oleksandr Prokopenko

YEAR:2020

DESCRIPTION: Terahertz-frequency (TF) signals have many promising applications in applied physics and technology. However, to date, there are no rather large-power (> 100 μW) compact and reliable sources of coherent TF radiation. One of the prospective approaches to develop such TF signal sources is based on the utilization of magnetic dynamics in the spin Hall oscillators (SHOs) based on antiferromagnets (AFMs). While a single antiferromagnetic SHO can typically emit output TF signal power ~ 10 μW or less, this power can be substantially improved if an array of synchronized SHOs is used. In this paper, we evaluate the output power of a TF signal source based on an array of antiferromagnetic SHOs embedded in a high-Q dielectric resonator and consider two limiting cases: the case of independent SHOs and the case of ideal phase-locked SHOs. Our calculations show that even a small number (≤ 10) of synchronized SHOs embedded in a high-Q dielectric resonator can provide output TF signal power of ~ 100-1000 μW (depending on their operation frequency), which might be sufficient for the majority of practical applications.

[4] TITLE: Roundness Estimation of Sedimentary Rocks Using Eliptic Fourier and Deep Neural Networks

AUTHOR: Erik Mejía Hernández; Gamaliel Moreno Chavez

YEAR: 2020

DESCRIPTION: Sedimentary rocks analysis is useful in geological science, economic sector, and risk evaluation. Roundness is a morphological parameter that provide information to characterize and classify sedimentary material. Roundness degrees is estimated from the contour of the particle. Waddell (1932) proposed a remarkable method based on the measurement of particle's curvature. This method is accurate; nevertheless, it is not invariant to scale and rotation. This problem can be solved by mapping the contour to the frequency-domain, however, spectral analysis is a difficult task. Based on these two approaches, we propose to use a deep neural network whose input is the elliptical Fourier spectrum and target is roundness proposed by Wadell. The training database consists of 623 real-rocks images from some geological phenomena. We have found the neural networks perform very well on the 88.8% of rocks.

[5]TITLE: Reliability of palaeomagnetic poles from sedimentary rocks

AUTHOR: Bram Vaes Shihu Li

YEAR: 2020

DESCRIPTION: Palaeomagnetic poles form the building blocks of apparent polar wander paths and are used as primary input for quantitative palaeogeographic reconstructions. The calculation of such poles requires that the short-term, palaeosecular variation (PSV) of the geomagnetic field is adequately sampled and averaged by a palaeomagnetic data set. Assessing to what extent PSV is recorded is relatively straightforward for rocks that are known to provide spot readings of the geomagnetic field, such as lavas. But it is unknown whether and when palaeomagnetic directions derived from sedimentary rocks represent spot readings of the geomagnetic field and sediments are moreover suffering from inclination shallowing, making it challenging to assess the reliability of poles derived from these rocks. Here, we explore whether a widely used technique to correct for inclination shallowing, known as the elongation–inclination (E/I) method, allows us to formulate a set of quality criteria for (inclination shallowing-corrected) palaeomagnetic poles from sedimentary rocks. The E/I method explicitly assumes that a sediment-derived data set provides, besides flattening, an accurate representation of PSV. We evaluate the effect of perceived pitfalls for this assumption using a recently published data set of 1275 individual palaeomagnetic directions of a >3-km-thick succession of ∼69–41.5 Ma red beds from the Gonjo Basin (eastern Tibet), as well as synthetic data generated with the TK03.GAD field model.

[6] TITLE: Underground Sedimentary Rock Moisture Permeation Damage Assessment Based on AE Mutual Information

AUTHOR: Kai Tao Qiang Wang

YEAR:2022

DESCRIPTION: Moisture permeation would lead to damage accidents. It is of great significance to measure and monitor the moisture states of underground sedimentary rock engineering in real time. In this research, a reliability assessment method for underground rock based on acoustic emission (AE) mutual information was proposed. First, the mutual relationship between multiple AE parameters and moisture permeation damage was analyzed. Then the mechanical parameters were fit by the probabilistic method, so that moisture permeation damage could be assessed with a data-driven approach. The experiment showed that this method could identify samples with different moisture permeation damage levels. The moisture permeation damage could be predicted in the early stage. Moreover, this method could reduce sensor error through probabilistic analysis.

2.2 INFERENCE FROM THE SURVEY

- The beam is scattered more at the edges and also different materials have different absorption coefficients, the images based on attenuation indicates edges and different materials inside of objects.
- This approach is similar to X-ray transmission imaging, where images are developed based on attenuation of the transmitted beam.
- Terahertz dating is primarily applicable to sedimentary rocks, and may not be suitable for other types of rocks or materials.
- Terahertz dating requires specific conditions for accurate measurements, such as low levels of moisture and temperature stability. This can make the method more difficult to apply in field settings

CHAPTER 3

EXISTING SYSTEM

There is currently no system for terahertz dating of sedimentary rocks. Terahertz radiation is a relatively new technology that has only been used in dating organic materials such as wood and bone, as well as for imaging and spectroscopy in various fields including chemistry, biology, and physics.

Traditional dating methods for sedimentary rocks include relative dating techniques such as stratigraphy and biostratigraphy, which can determine the relative age of rocks based on their position in the geological record and the fossils they contain. Absolute dating techniques such as radiometric dating can provide numerical ages for rocks by measuring the decay of radioactive isotopes, but these methods typically require the presence of certain minerals in the rock, which may not always be present in sedimentary rocks.

It is possible that terahertz radiation could be used in the future for dating sedimentary rocks, but more research would be needed to develop a reliable and accurate method.

3.1 C-14 CARBON DATING PROCESS

Carbon-14, C-14, ^{14}C or radiocarbon, is a radioactive isotope of carbon with an atomic nucleus containing 6 protons and 8 neutrons. Its presence in organic materials is the basis of the radiocarbon dating method pioneered by Willard Libby and colleagues (1949) to date archaeological, geological and hydrogeological samples. Carbon-14 was discovered on February 27, 1940, by Martin Kamen and Sam Ruben at the University of California Radiation Laboratory in Berkeley, California. Its existence had been suggested by Franz Kurie in 1934.[2]There are three naturally occurring isotopes of carbon on Earth: carbon-12 (^{12}C), which makes up 99% of all carbon on Earth; carbon-

13 (^{13}C), which makes up 1%; and carbon-14 (^{14}C), which occurs in trace amounts, making up about 1 or 1.5 atoms per 10^{12} atoms of carbon in the atmosphere. Carbon-12 and carbon-13 are both stable, while carbon-14 is unstable and has a half-life of 5700±30 years.[3] Carbon-14 has a maximum specific activity of 62.5 mCi/mmol (2.31 GBq/mmol),or164.9 GBq/g.[4] Carbon-14 decays into nitrogen-14 (^{14}N) through beta decay.[5] A gram of carbon containing 1 atom of carbon-14 per 10^{12} atoms will emit ~0.2[6] beta particles per second. The primary natural source of carbon-14 on Earth is cosmic ray action on nitrogen in the atmosphere, and it is therefore a cosmogenic nuclide. However, open-air nuclear testing between 1955 and 1980 contributed to this pool.

The different isotopes of carbon do not differ appreciably in their chemical properties. This resemblance is used in chemical and biological research, in a technique called carbon labeling: carbon-14 atoms can be used to replace nonradioactive carbon, in order to trace chemical and biochemical reactions involving carbon atoms from any given organic compound.

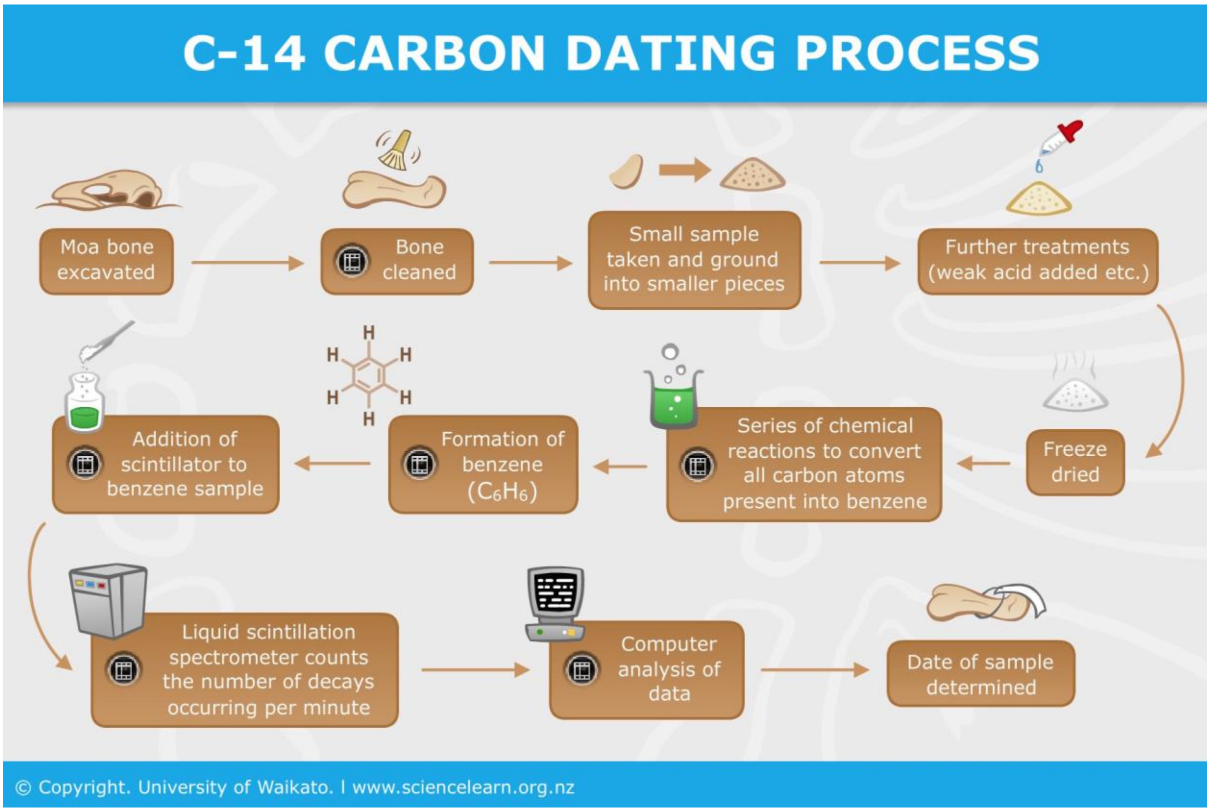

Figure 3.1 Steps involved in C^{14} dating process

Radiocarbon dating is a radiometric dating method that uses (^{14}C) to determine the age of carbonaceous materials up to about 60,000 years old. The technique was developed by Willard Libby and his colleagues in 1949[10] during his tenure as a professor at the University of Chicago. Libby estimated that the radioactivity of exchangeable carbon-14 would be about 14 disintegrations per minute (dpm) per gram of pure carbon, and this is still used as the activity of the *modern radiocarbon standard*. In 1960, Libby was awarded the Nobel Prize in chemistry for this work.One of the frequent uses of the technique is to date organic remains from archaeological sites. Plants fix atmospheric carbon during photosynthesis, so the level of C^{14} in plants and animals when they die approximately equals the level of C^{14} in the atmosphere at that time. However, it decreases thereafter from radioactive decay, allowing the date of death or fixation to be estimated. The initial C^{14} level for the calculation can either be estimated, or else directly compared with known year-by-year data from tree-ring data (dendrochronology) up to 10,000 years ago (using overlapping data from live and dead trees in a given area), or else from cave deposits (speleothems), back to about 45,000 years before the present. A calculation or (more accurately) a direct comparison of carbon-14 levels in a sample, with tree ring or cave-deposit carbon-14 levels of a known age, then gives the wood or animal sample age-since-formation. Radiocarbon is also used to detect disturbance in natural ecosystems; for example, in peatland landscapes, radiocarbon can indicate that carbon which was previously stored in organic soils is being released due to land clearance or climate change.[13][14] Cosmogenic nuclides are also used as proxy data to characterize cosmic particle and solar activity of the distant past.The above-ground nuclear tests that occurred in several countries between 1955 and 1980 (see nuclear test list) dramatically increased the amount of carbon-14 in the atmosphere and subsequently in the biosphere; after the tests ended, the atmospheric concentration of the isotope began to decrease, as radioactive CO_2 was fixed into plant and animal tissue, and dissolved in the oceans.

One side-effect of the change in atmospheric carbon-14 is that this has enabled some options for determining the birth year of an individual, in particular, the amount of carbon-14 in tooth enamel,or the carbon-14 concentration in the lens of the eyeIn 2019, Scientific American reported that carbon-14 from nuclear bomb testing has been found in the bodies of aquatic animals found in one of the most inaccessible regions of the earth, the Mariana Trench in the Pacific Ocean

Many man-made chemicals are derived from fossil fuels (such as petroleum or coal) in which C^{14} is greatly depleted because the age of fossils far exceeds the half-life of C^{14}. The relative absence of $^{14}CO_2$ is therefore used to determine the relative contribution (or mixing ratio) of fossil fuel oxidation to the total carbon dioxide in a given region of the Earth's atmosphere.

Dating a specific sample of fossilized carbonaceous material is more complicated. Such deposits often contain trace amounts of carbon-14. These amounts can vary significantly between samples, ranging up to 1% of the ratio found in living organisms, a concentration comparable to an apparent age of 40,000 years.This may indicate possible contamination by small amounts of bacteria, underground sources of radiation causing the $^{14}N(n,p)^{14}C$ reaction, direct uranium decay (although reported measured ratios of $^{14}C/U$ in uranium-bearing ores would imply roughly 1 uranium atom for every two carbon atoms in order to cause the $^{14}C/^{12}C$ ratio, measured to be on the order of 10^{-15}), or other unknown secondary sources of carbon-14 production. The presence of carbon-14 in the isotopic signature of a sample of carbonaceous material possibly indicates its contamination by biogenic sources or the decay of radioactive material in surrounding geologic strata. In connection with building the Borexino solar neutrino observatory, petroleum feedstock (for synthesizing the primaryscintillant) was obtained withlow ^{14}C content. Inthe Borexino Counting Test Facility, a $^{14}C/^{12}C$ ratio of 1.94×10^{-18} was determined;[47] probable reactions responsible for varied levels of ^{14}C in different petroleum reservoirs, and the lower ^{14}C levels in methane, have been discussed by Bonvicini et al.Since many sources of human food are ultimately derived from terrestrial plants, the relative concentration of carbon-14 in our bodies is nearly identical to the relative concentration in the atmosphere.

3.2DRAWBACKS OF EXISITING SYSTEM

- Terahertz dating is primarily applicable to sedimentary rocks, and may not be suitable for other types of rocks or materials.

- Terahertz dating requires specific conditions for accurate measurements, such as low levels of moisture and temperature stability. This can make the method more difficult to apply in field settings.

CHAPTER 4

PROPOSED SYSTEM

Terahertz dating of sedimentary rocks involves using terahertz radiation to measure the amount of time that has passed since the sedimentary rock was last exposed to sunlight. This dating method relies on the fact that minerals in sedimentary rocks can trap electrons when exposed to sunlight, which then become trapped within the mineral structure.

Sample collection: Sedimentary rock samples would be collected from the field, ideally from locations that are well exposed to sunlight.

Sample preparation: The rock samples would need to be cleaned and prepared for analysis, which may involve removing any surface contaminants or coatings.

Terahertz imaging: The prepared samples would be imaged using terahertz radiation, which would allow the researchers to visualize the distribution of trapped electrons within the sample.

Terahertz dating: The amount of time that has passed since the sample was last exposed to sunlight can be estimated by measuring the rate of electron release from the mineral structure using terahertz radiation.

Analysis and interpretation: The data obtained from terahertz imaging and dating would be analysed and interpreted to determine the age of the sedimentary rock sample. This analysis may involve comparison with other dating methods or geological data to validate the results.

Refinement and calibration: As terahertz dating is a relatively new technique, ongoing refinement and calibration will be necessary to improve the accuracy and reliability of the method. This may involve developing calibration standards, refining sample preparation methods, and conducting further research on the underlying mechanisms of terahertz dating.

Terahertz dating of sedimentary rocks has the potential to provide valuable insights into the history of the Earth's surface and the processes that shape it. However, further research and refinement of the method will be necessary before it can become a widely accepted dating method in the geosciences.

ADVANTAGE

Terahertz dating has the potential to achieve high precision dating, with a resolution of a few hundred years. This is particularly useful for studying recent geological events or short-term changes in the environment.

Terahertz dating has a wide range of applicability, from dating relatively young rocks that are a few thousand years old to much older rocks that are millions of years old.

4.1TERAHERTZ DATING

Terahertz dating is a technique used to determine the age of sedimentary rocks based on the time elapsed since their last exposure to sunlight. This technique relies on the fact that minerals in sedimentary rocks, such as quartz and feldspar, accumulate radiation damage from cosmic rays over time. When the rock is exposed to sunlight, the accumulated radiation damage is erased and the clock is reset. By measuring the amount of accumulated radiation damage, scientists can estimate the amount of time that has passed since the rock was last exposed to sunlight, and thus determine the rock's age.

Terahertz radiation is a form of electromagnetic radiation with a frequency range between 0.1 and 10 THz. This type of radiation is particularly useful for terahertz dating because it can penetrate deep into rocks and detect the accumulated radiation damage in minerals. Terahertz radiation can also be used to generate a "fingerprint" of the mineral structure, which can be compared to a database of known mineral structures to determine the age of the rock.

Terahertz dating has the potential to be a valuable tool for studying the history of Earth's geology, particularly for rocks that are too old for traditional radiocarbon dating methods. However, more research is needed to fully validate the accuracy and reliability of terahertz dating, and to develop more precise techniques for measuring the accumulated radiation damage in minerals.

4.2 TERAHERTZ TIME DOMAIN SPECTROSCOPY

Terahertz spectroscopy is a tool for collecting spectral measurements in the far infrared (approximately 3 – 100 wavenumbers). Data collection in this frequency range has many advantages; biological samples do not ionize from terahertz radiation, and many compounds, like explosives and pharmaceuticals, have unique fingerprints in this region. Terahertz time-domain spectroscopy, THz-TDS, is a spectroscopic technique for determining the properties of a sample probed by short pulses of terahertz radiation.

In order to create THz pulses, a diode-pumped CW laser at 532 nm pumps a mode-locked Ti: sapphire crystal to create ultra-short (100 fs or shorter) optical pulses at 800 nm at a repetition rate of 80 MHz. The optical pulses are sent through a prism pair to compensate for dispersion1 and then split into two parts: one used for detection and the other for generation. Photoconductive antennas are used for both generation and detection.2 A series of parabolic mirrors are used to guide the terahertz pulses from the emitter to the sample and then to the detector. A delay stage is used in the generation arm in order to vary the arrival time of the signal with respect to the optical pulse used for detection. By scanning the delay line, the electric field amplitude and phase of the THz waveform can be mapped out as a function of time. A LabVIEW program collects the electric field amplitude as a function of time from a digital lock-in amplifier that measures the signal from the detector.

4.3 TERAHERTZ RADIATION

THz radiation provides numerous specific benefits for spectroscopic applications. Many materials are transparent at terahertz wavelengths, and this radiation is non-ionizing, making it safe for biological tissue (as opposed to X-rays). Several intriguing materials have distinct terahertz spectral fingerprints that may be used to identify them. Several types of explosives, dynamic fingerprinting of DNA and protein molecules using polarisation varying anisotropic terahertz micro spectroscopy, polymorphic forms of many compounds used as active pharmaceutical ingredients (API) in commercial medications, and several illegal narcotic substances have all been demonstrated. Several materials are permeable to THz radiation, allowing access to underlying materials via apparently opaque intervening layers.

4.4 IMAGE PROCESSOR

An image processor does the functions of image acquisition, storage, pre-processing, segmentation, representation, recognition and interpretation and finally displays or records the resulting image as detailed in the diagram; the first step in the process is image acquisition by an imaging sensor in conjunction with a digitizer to digitize the image.

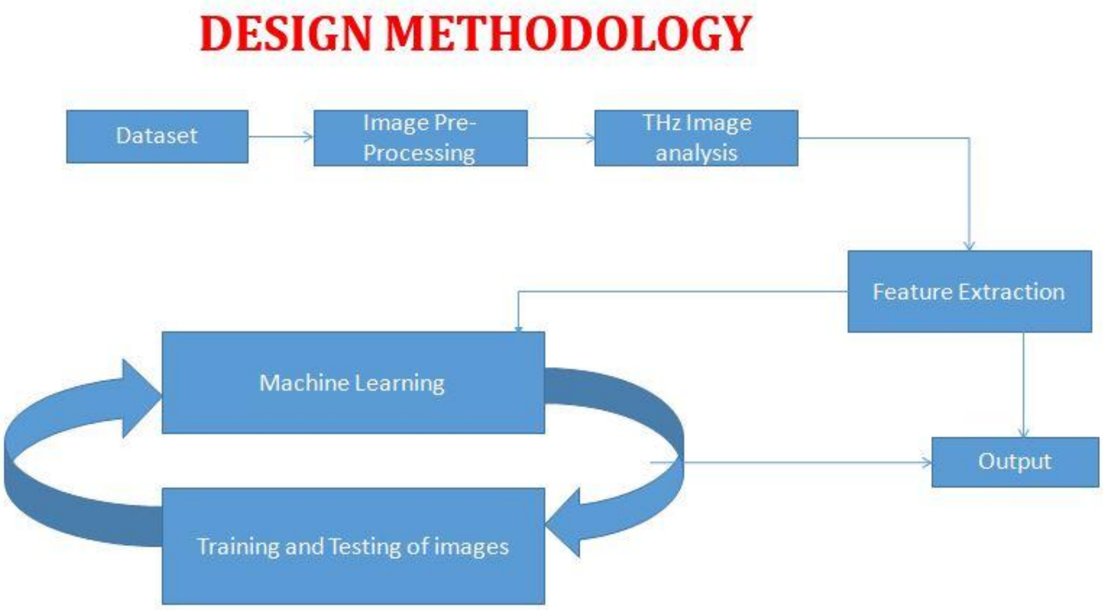

Figure 4.1 Block diagram of the Proposed methodology

The next step is the pre-processing step where the image is improved being fed as an input to the other processes. Pre-processing typically deals with enhancing, removing noise, isolating regions, etc. Segmentation partitions an image into its constituent parts or objects. The output of segmentation is usually raw pixel data, which consists of either the boundary of the region or the pixels in the region themselves. Representation is the process of transforming the raw pixel data into a form useful for subsequent processing by the computer. Description deals with extracting features that are basic in differentiating one class of objects from another. Recognition assigns a label to an object based on the information provided by its descriptors. Interpretation involves assigning meaning to an ensemble of recognized objects. The knowledge about a problem domain is incorporated into the knowledge base. The knowledge base guides the operation of each processing module and also controls the interaction between the modules. Not all modules need be necessarily present for a specific function. The composition of the image processing system depends on its application. The frame rate of the image processor is normally around 25 frames per second.

The images collected were primarily segregated into two different types. The first one includes the images directly obtained by Terahertz imaging technology and the other includes normal images which been analyzed in the THz frequency domain. Both the types are compiled as dataset. This flow is explained in the figure 4.

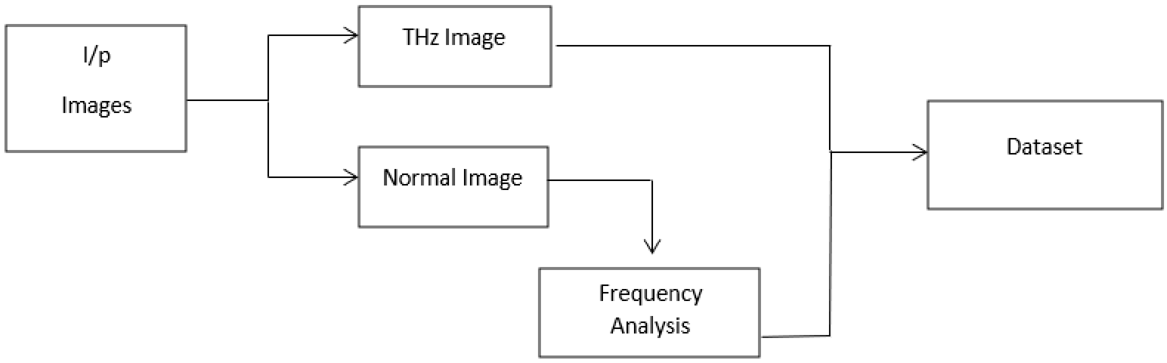

Figure 4.2 Flow Diagram_Compilation of the data set

The dataset compiled has been pre-processed to remove noise and unnecessary background data. The major features in determining the age of the given sample includes refractive index, major axis, minor axis and the secondary features those have been worked includes absorption co-efficient, electrical conductivity of the sample under diagnosis. But the secondary features are not taken into consideration as it needs more images for training and also its complicated in such a way that it stands similar for different types of objects which makes the classification process a tedious one. The flow diagram of the concept is shown in the figure 4.2.

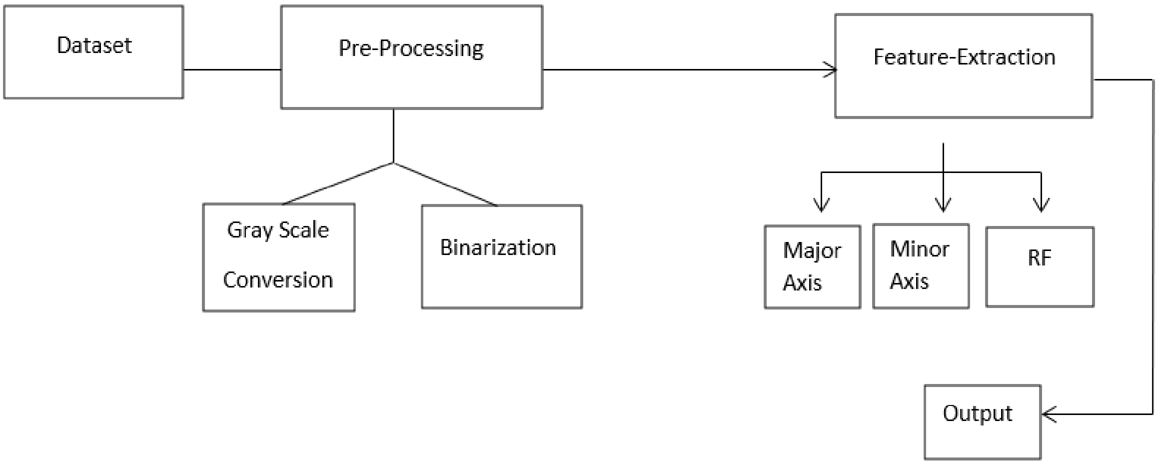

Figure 4.3 Flow Diagram TIARA NET

CHAPTER 5

SYSTEM SPECIFICATION

H/W SYSTEM CONFIGURATION: -

- processor - Pentium – IV
- RAM - 4 GB (min)
- Hard Disk - 20 GB

S/W SYSTEM CONFIGURATION: -

- Operating System: Windows 7 or 8
- Software : Matlab

SOFTWARE ENVIRONMENT

- MATLAB Version R2017a

5.1 MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics.
- Application development, including Graphical User Interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN

5.2 INTRODUCTION TO MATLAB

MATLAB (matrix laboratory)is a numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPADsymbolic engine, allowing access to symbolic computing capabilities.

An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

CHAPTER 6

RESULT AND DISCUSSION

The THz dielectric characteristics of the rocks with distinct geologic eras were first simply characterised. It can be shown that the samples' relative delay times and THz signal peaks can be used to distinguish between different physical attributes. The sedimentary rocks had the lowest peak intensities, while compared with rocks. Additionally, there were notable variations in the sedimentary strata' time delays. Therefore, the THz frequency domain spectra were obtained using the fast Fourier transform (FFT), and the THz absorption coefficient spectra and refractive index spectra were computed.

The refractive indexes and absorption coefficients of the sedimentary rock samples are shown in Figure 6.5. As the geological age increases, the absorption coefficient and refractive index initially increase and then decrease. The THz tests were carried out on a large number.

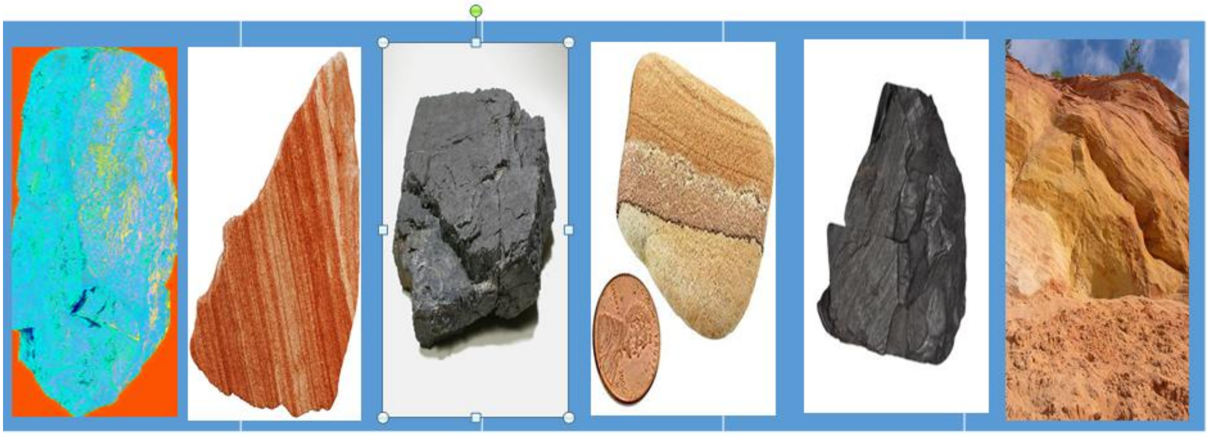

Figure 6.1 Sample images of stones from dataset

The samples had larger absorption coefficients than other geologic ages. The levels were lowest in the samples. Its other four geologic ages' variances in absorption coefficients were also not very different from one another, thus made qualitative recognition and determination challenging .

The current spectra are insufficient to clearly show how the components relate to the THz spectra. The evolution of all the samples' refractive indices over geologic time is shown in the Figure . These refractive indices of a sedimentary rock samples from different geological eras generally show slight variations. Yet, it was found that by using the average value from each age group, the refractive index risen and subsequently decreased even as geological age grew.

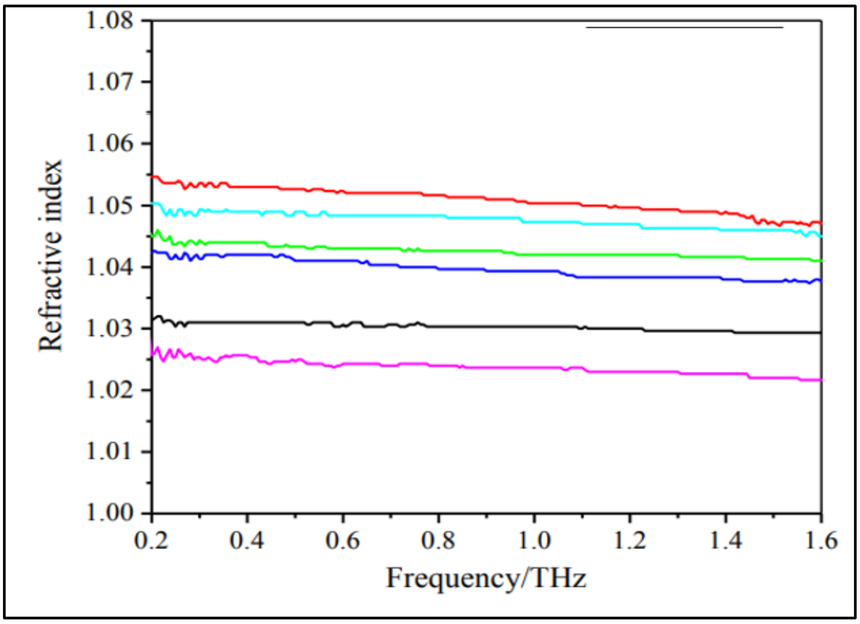

Figure 6.2 The evolution of all the samples' refractive indices over geologic time

Types	Refractive Index	Average
TYPE 1	0.0015515	1.05
TYPE 2	0.0012764	1.04
TYPE 3	0.0014249	1.05

Table 6.1 Average refractive indices of the datasets

also depicts how the refractive indices of all the samples have 25 changed over geologic time. Generally, there are subtle changes between the refractive indices of the ancient rock samples with various geological eras. Yet, it was discovered that when the geological levels increase, this refractive index initially climbed and then declined by utilising the overall average of each age group. Based upon their refractive indices. samples of ancient rocks. Overall era of rock samples could be determined by dividing them based on their mineral composition, which is essentially the same for all rock samples.

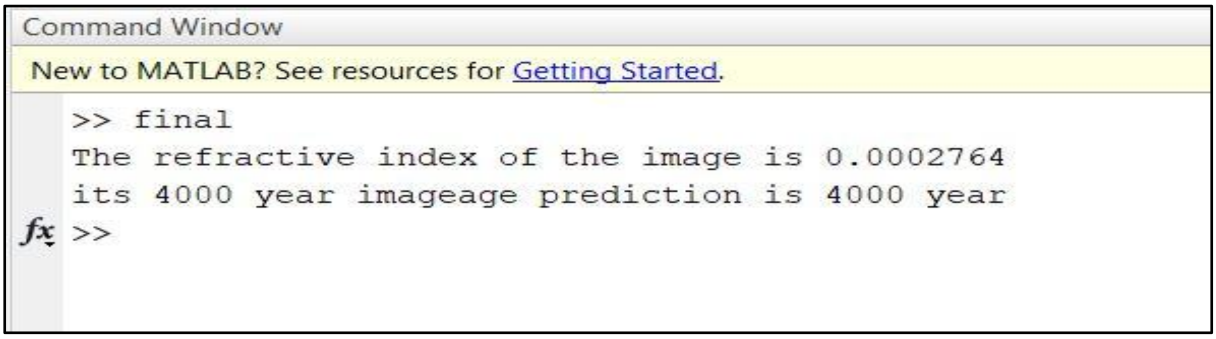

Figure 6.3 Command window of the output

The historical environment can be based primarily on the varied organic matter contents.It may be deduced from the THz wave's sensitivity to organic matter that the presence of organic matter and various composition types significantly affect the conversion of samples with in Terahertz band. As a result, the amount of organic layer formed in same environment will typically rise as the diversity of biological organisms increases. Consequently, it can be concluded that is responsible for the fluctuation in absorption coefficient of ancient rock samples with age. Aquatic organisms are the principal type of material that is deposited in the ocean. The deposited organic material often contains a lot of oils, proteins, and other nutrients, as well as relatively high levels of oxygen and nitrogen. The majority of the organic material deposited during continental sedimentation is made up of higher plants, which are typically rich in oxygen and poor in hydrogen and nitrogen. The absorb coefficient & refractive index would be higher for organic stuff with a higher C/H ratio. As a result, the ancient rocks will have greater absorption coefficients and refractive indices. The world was filled by a deep sea as a result of the Earth's crust moving, and the pattern of deposition switched from continent to neritic.Because of the abundance of marine life, organic material started to accumulate in the sediments of this time period. Because there are now no live organisms present, sediments nearly entirely lack organic stuff. This agrees with absorption coefficients discovered using the THz technique. Because there was more organic materials present during the initial stage, the absorption increased.

The geological evolution is in good accord with the absorption coefficient associated with the key turning point. This suggests that the geological history of ancient rocks can be studied using the THz approach.

The other research part includes, marine deposition and continental deposition are two different deposition modes, and the organic matter types deposited in these modes are also different. By analyzing the absorption coefficients and refractive indexes of the samples with different ages, the evolution of the marine and continental sediments can be roughly determined.

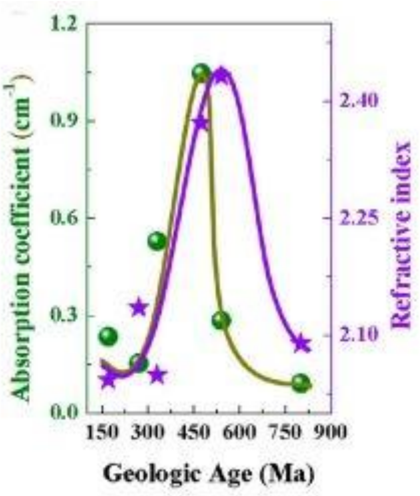

Figure 6.4 Absorption coefficients and refractive indexes of the rocks with different geological ages.

However, it is difficult to distinguish between similar continental sediments using the absorption coefficient and refractive index. To construct a more precise model of the relationship between the rocks' parameters and THz spectra, deposition (P_1 and P_2) in the rocks was used with V_p/d as the input. P_1, the variance of which was maximized, contains the most information according to the largest contribution rate, so it can be used to describe the importance of the PCs to the samples. P_2 contains the second most abundant information. By plotting the scores of the early PCs against each other, a two or three-dimensional score space can be obtained, in which samples that are closely related cluster together and unrelated samples plot as outliers. the two-dimensional space displays the two principal components (P_1 and P_2) and their contribution rates.

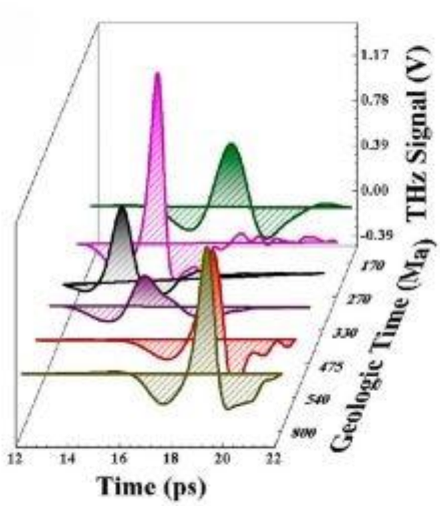

Figure 6.5 THz-TDS results for the rocks with different geological ages

Specifically, the first two points in the data set were found to describe 90% and 10% of the variance within the data, with a total contribution rate of 99% to all of the deviations. As deposition increases, the samples are significantly different from those of the other eras. Due to its large contribution, PC1 is of great importance to analyzing the components and absorption effect. Secondarythe rock samples of these geological ages can be used for the sample division.

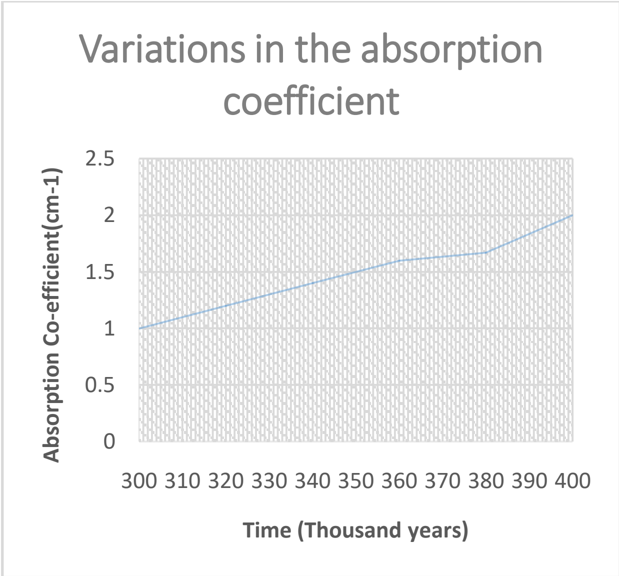

Figure 6.6 Variations in the absorption coefficient with geologic age

The first two points in the data set were found to describe 91.37 and 7.09% of the variance within the data, with a total contribution rate of 98.46% to all of the deviations. Consequently, the P_1 score is an effective parameter that reflects the geologic age, and the THz method is a promising supplementary tool for determining the geological ages of sedimentary rocks. In terms of the geologic ages of the sedimentary rocks, the PC1 scores based on the V_p/d can directly identify coals. The absorption coefficient can be used as an important reference for determining the geologic ages of sedimentary rocks in future research. In order to further confirm that THz technology combined with deposition analysis method can realize the recognition of rock geological age, this methodology has been carried out THz test on another batch of samples and got the results.

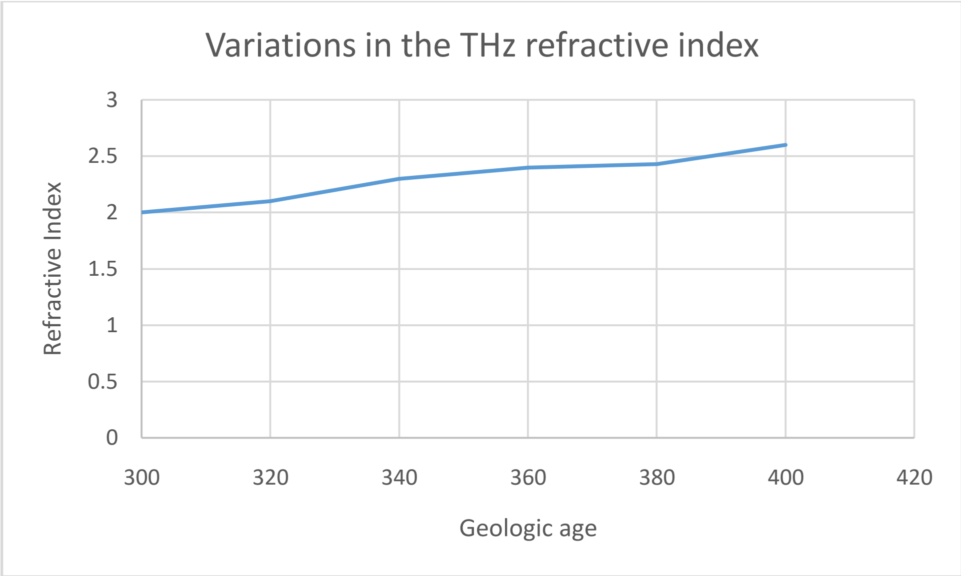

Figure 6.7 Variations in the THz refractive index with geo-logic age.

Mapping the change of THz response relative time delay (the time difference between sample peak time and reference peak time) of each test sample can realize geological age division of some rocks. Consequently, the testing of samples with other geological ages Figure 6.5 further demonstrates that the THz method can be used to determine the geological ages of sedimentary rocks. The more sedimentary rocks, especially the common types, are analyzed using this method, the more models can be constructed and the higher the accuracy of the models developed, which will improve the prediction of unknown strata.

Based on the results in this research, more and more rocks can be measured using the THz method, and then, the results can be combined with PCA to obtain a large database, which can be used as an important reference standard to judge sedimentary environment of sedimentary rocks.

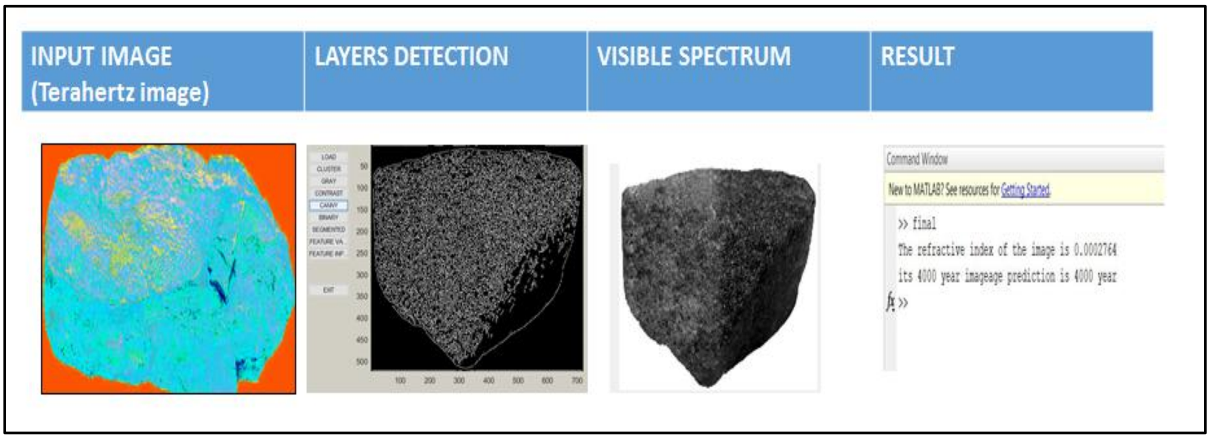

Figure 6.8 Sample Result

CHAPTER 7

CONCLUSION AND FUTURE WORK

In this study, sedimentary rocks with different geologic ages from the same area were investigated using THz time domain spectroscopy. The research focused on identifying that the relative geological ages of the sedimentary rocks and revealing the geological evolution of the area can be characterized using a combination of THz-TDS and PCA. Moreover, the THz absorption coefficients and refractive indexes of the rocks initially in-creased and then decreased with increasing geological age. Terahertz dating of sedimentary rocks is a promising technique that has the potential to revolutionize our understanding of Earth's geological history. By measuring the amount of time that has passed since minerals in a rock were last exposed to sunlight, terahertz dating can provide precise estimates of the age of sedimentary rocks.

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