

STUDY OF CONTACT ZONE IN CHIDIYATTAPU AREA, SOUTH ANDAMAN USING TRANSIENT ELECTROMAGNETIC TECHNIQUE

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ABSTRACT

Two contact zones were found in the study area. The first one exists between Ophiolite and Mithakhari sediment group. The second one exists in between Mithakhari and Andaman Flysch sediment group. Both of these contact zones were found to be vertical and smooth. The present study has clearly shown that TEM profiling is highly instrumental in providing data about geological structures where no details are available, especially those with a high number of lateral boundaries. Though this is a very small scale study, it is surprising that two contact zones have been located in the same area, in 65 m distance from each other. This suggests that this area may have some unique features which may be interesting to potential researchers. This type of deep geological mapping is highly preferred, especially when there are many zones with little geological information in a given area. Since the Andaman Nicobar Islands are geologically very active and the seismic activities are highly pronounced, it is suggested that more studies are to be done with TEM profiling and other such deep geological mapping techniques for gathering more information on the geology of this group of islands. This will help us to predict better tectonic movements, and hence the seismic activities in this area.

KEYWORDS

Transient Electromagnetic Method, Contact Zone, Andaman Island, Subduction Zone

INTRODUCTION

Andaman and Nicobar Islands are located between 6° N and 14° N Latitudes in the northeast Indian Ocean. The “Ten Degree Channel”, separates Andaman and Nicobar groups of Islands. These group of Islands are part of an accretionary prism or wedge which forms the outer arc ridge of the Andaman subduction zone (northernmost section of the Sunda-Banda subduction zone). This accretionary wedge was a result of northward oblique subduction of Indian plate below the Burmese micro plate along the Andaman-Java Trench (Curry, 2005). This chain of Islands, extends from the Myanmar Arakan-Yoma coast in the north down to Sumatra and Java in the south. Sewell (1925) suggested that the Andaman–Nicobar Ridge had drifted toward the West away from the South-East Asian mainland, and had thus formed a pronounced curve with its apex in the region of ‘Little Andaman’ Island.

IMPORTANCE OF STUDY

The inimitable characters of the Andaman Islands are the presence of Ophiolitic rock strata which having a North-South orientation and having an extension of around 25 kilometres from Carbin cove to Chidiyattapu. These rocks are existed along with sedimentary formations such as Andaman Flysch and Mithakhari groups. Existence of these two sections with a considerable distance of occurrence having lot of significance importance. Hence it needs more geophysical studies to find out the exact characters and tectonic significance of these two sections. This area was formed by the thinning of ocean floor due to sea floor spreading which allowed the mantle rocks to come out of the seafloor, which was obducted by the tectonic force to the sea surface. While the movement from the sea bottom to the surface it carries the deep sea sediments with it. The deep sea sediment such as Flysch and Mithakhari are come out with the Ophiolite to the surface. Hence the contact zone was created between these two sections of rocks. The aim of this study is to demark the characters of contact zones and its tectonic implications. The study of the tectonics will give a path to study the origin and evolution of the earth. A contact zone is one in which originated by the direct influence of the tectonic action. Hence the study of contact zone will give a chance to study the tectonic implications and it's after effects. Andaman Islands are famous for its seismological and tectonic activities, so the main importance of this work is to exposes the mystery of tectonics through the contact zone studies.

OBJECTIVES

1. To identify the contact zone between the ophiolite and sedimentary formations in the given study area by using the geophysical method.
2. To identify the type of contact that existing between the rocks.
3. To study the resistivity changes between the contact zones, hence to explain the physical characters of the rocks.
4. To identify and extending the potentiality of the geophysical instrument, ie transient electromagnet (TEM) in the tectonic studies.

STUDY AREA

The study areas are situated along the northern side of South Andaman .This area is just 28 kilometre away from the Port Blair, which is the capital city of Andaman Nicobar Islands. “Chidiyattapu” is the local name of the study area. Geophysical Survey was carried out along the area near Chidiyattappu. The location of surveyed areas in Chidiyattapu is $92^{\circ} 70' 29''$ E $11^{\circ} 50' 94''$ N. The study area is a hilly area followed by a plane land mass. Geologically the hilly area is a vertical steep valley of having hard rock's with fault and fractures followed by the plane area of loose sediment. (Figure 1)

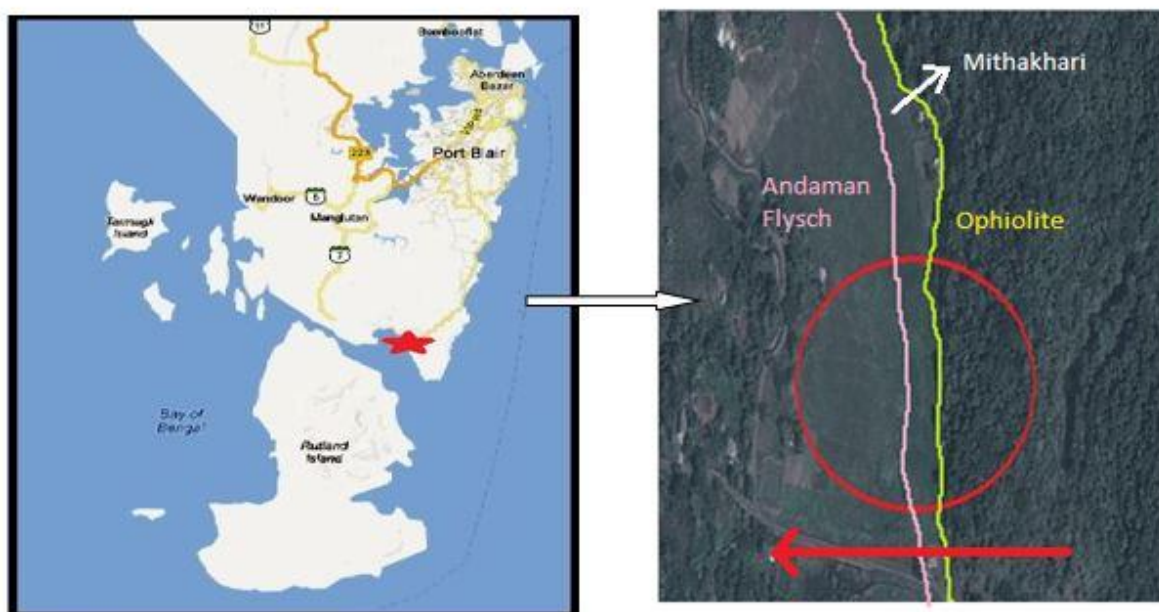


Figure 1: showing the study area map of South Andaman Island

Geologically, the rock types occurring in this area can be broadly divided into two major groups: (i) *Sedimentary rocks*, consisting mainly of the interbedded Flysch sequence (dominant greywacke – siltstone – shale) of the Palaeogene Port Blair Group and fossiliferous Neogene Archipelago Group (chalk – limestone) and Mithakhari group, the main contents are shale, siltstone and fine sandstone (ii) *Magmatic rocks* group, comprising mainly ultramafic to mafic plutonites and predominant basic volcanic. The major magmatic rocks of ultramafic plutonites (dominant serpentinite with lesser and variously serpentinized dunite and harzburgite plus rare pyroxenite) and basalt, together with minor radiolarian chert (Steinman trinity), constitute the ‘**Andaman ophiolite suite**’. This ophiolite rocks are more predominant in the island of **South Andaman** (Carbyn’s Cove to Chidiyatapu) and occupy a small area toward north. (Figure 2)

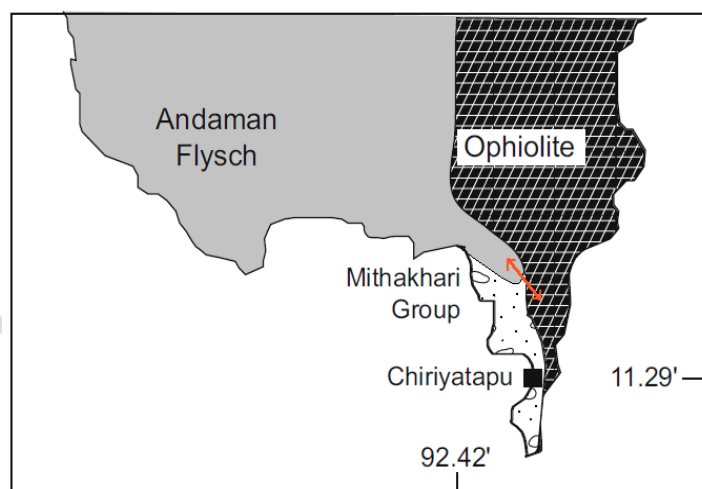


Figure 2: Geological cross section view of Southern part of South Andaman

GEOLOGICAL SETTING

The tectonic evolution of Andaman and Nicobar Islands has been modelled on the basis upon three components such as i) tectonic features recorded from the Sea floor (Curry and Moore, et al., 1982). ii) seismic records (Dasgupta and Mukhopadhyay, 1993) and iii) regional correlation of tectonic elements of the eastern part of the Himalaya (Sengupta et al., 1990). The temporal history of subduction in this part (central part of Sunda arc) has been a matter of debate. There exist two schools of thoughts. The first school (Acharyya et al., 1990; Sengupta et al., 1990) argues that the present subduction began, all around the western Sunda arc, during Miocene times and emplacement of Ophiolites on land took place

during terminal collision in Oligocene period. In that model the existence, a second trench was located further East of the present trench with a proto continent was presumed. Also, Cretaceous Ophiolites and Eocene sediments were considered as a part of this accretionary prism related to second subduction margin and believed to have subsequently emplaced as allochthonous nappe sheets propagating E to W on the present subduction margin. Thought of the second school is based on the presence of melange and the highly deformed sediments. These authors suggest that the onset of subduction took place during Late Cretaceous times, after the early break-up of the Gondwanaland during Cretaceous (Curry and Moore, 1979; Karig et al., 1979) or from Late Palaeozoic period (Hamilton, 1979; McCourt et al., 1996).

The stratigraphy of the Andaman and Nicobar Islands are classified into four lithostratigraphic groups: (a) Ophiolite Group, (b) Mithakhari Group, (c) Andaman Flysch Group and (d) Archipelago Group (Table 1)

Ophiolite Group

The Ophiolite group forms the basement of the Andaman Islands, a part of the Indo – Burma accretionary complex. It contains numerous N-S trending slices of Cretaceous – Palaeocene. Although the occurrence of Ophiolites in every part of Andaman group of Island, but large volume of mantle sequences are exposed in South, Middle and North Andaman (Pal et al., 2003). The age of Ophiolites is younger than ~ 95Ma (Srinivasa Sarma et al., 2010, Pederson et al., 2010). The similarity in age between the Troodos, Oman and Andaman Ophiolites seems best explained by a supra subduction zone origin (Pal, 2011). The Ophiolite sequence comprising tectonite (ultramafic)-cumulate (layered mafic and ultramafic) plagiogranite-diorite suite-basalt-pelagic sediments, is identified as fossilized oceanic crust (Gass, 1990). The Cretaceous age of the Ophiolite succession is indicated by the foraminiferal assemblage of pelagic sediments (Roy et al., 1988). The metasediment and metabasalt units associated with Ophiolites (either at their sole or as caught-up patches) are related to the emplacement history of the thrust slices (Pal et al., 2003).

The Ophiolites are present as dismembered slices and interleaved with Ophiolite-derived clastic sediments.

2.2.2 Mithakhari Group

The thickness of this sedimentary unit is ~1.4 Km, and is divided into three formation (Ray, 1982): i) the Lipa Black Shale, ii) the Hope town Conglomerates and iii) the Namunagarh Grit. The Lipa black shale is a minor unit with very limited exposures. The Mithakhari Group, represented by lensoid conglomerate and sandstone beds with dominantly shale facies, are interpreted as trench sediments (Chakraborty *et al.*, 1999). The Mithakhari group exposed in the Andaman Islands particularly in North and Middle Andaman. A number of mud volcanoes occur in the Middle and North Andaman Islands in shale facies of the Mithakhari group.

Table 1: Generalized stratigraphy of Andaman Islands (Allen etal 2007, Pal, 2003)

Tectonic setting	Age	Stratigraphic unit	Lithocharacter s	Palaeocurrent direction
Forearc	Pliocene (cf. ray, 1982) Miocene (Chatterjee, 1964)	Archipelago group (400 m thick)	Interbedded sequence of tuff, limestone, sandstone and clay (limestone is biothermal and biostromal)	East, west and majority in southwest
	Upper Eocene-Oligocene (Pawde & Ray, 1963) Oligocene-lower Miocene (Present work)	Andaman Flysch Group (300 m Thick)	Interbedded sequence of sandstone, siltstone and shale	Northeast, southwest and majority in southeast
Trench – slope	Middle to late Eocene (Karunakaran Ray & Saha, 1967)	Mithakhari Group (1400 m thick)	Conglomerate, sandstone and shale	Northwest; a few show northeast – southeast trend
Accretionary slices	Cretaceous to Paleocene (Roy <i>et al.</i> 1988)	Ophiolite Group	Metamorphic, tectonites, cumulates, plagiogranite-diorite-andesite suite, basalt and pelagic sediments	
	Early Cretaceous (Jafri, 1986)			

Andaman Flysch

A thick sedimentary pile of sandstone and shale representing clastic turbidites forms the Andaman Flysch Group. The Andaman flysch group along with the Archipelago group are deposited in a forearc environment. The Andaman flysch group overlies the Mithakhari group and underlies the Archipelago groups. The Andaman flysch group is a siliciclastic turbidite sequence which is completely exposed in South Andaman. The total thickness is only 250 – 300m.

Archipelago Group

The sedimentary sequence of the Archipelago Group comprises a thick pile of pyroclastic deposits, limestone, sandstone and shale. Archipelago group represents the topmost stratigraphic unit of the Andaman accretionary prism. These sedimentary rocks covered most of the Andaman group of Islands. Due to uplift and erosion, these sedimentary deposits were eroded associated smaller islands, east to South Andaman, these sediments are exposed. The age of this group in the range of 18.3 – 15.6 Ma (Early – Middle Miocene).

METHODOLOGY

The survey was done along the area in a linear manner. The total area was divided in to three. The first section was a hilly area having steep slope. The second and third section was plane in topography. The area of the loop is measured by a tape. The loops where keeps on overlapping with each other. The loop configuration used in this survey method is the coincident loop method which is applicable for the high depth studies like tectonic implications. (Figure 3)

SECTION-I

The loop was laid along the vertical sloppy area of the valley having a dip of 45° to the ground. The area of the loop was measured by a tape and laid the wire in a predefined manner. The area of the loop was 65m x 65m. The connections are made; the acquisition parameters for the soundings are as follows.

The co-ordinates where the instrument placed: 92° 70' 29" E 11° 50' 94" N

i) Run Mode : Normal

- ii) Time series : TerraTEM High resolution
- iii) Windows : 10 ms (17 windows)
- iv) Stacks : 100
- v) Stacking option : Standard
- vi) Transmitter loop : Coincident loop
- vii) Loop width : 65m X 65m
- viii) Transmitter current : Internal automatic
- ix) Base frequency : 50 Hz
- x) Receiver configuration : coincident Loop
- xi) Channel gain : 32
- xii) Nquist filter : On



Figure 3: Satellite image showing the section wise divisions of the study area

SECTION II

The loop was laid in continues and linear format from the first section. The loop was maintained an area of 65m X 65m. The area was very dry in condition and it has plane topography with loose sediments in the top surface and having very moderate vegetation content. The acquisition parameters for the soundings are as follows,

The co-ordinates where the instrument placed: 92° 70' 28" 11° 50' 94" N

- i) Run Mode : Normal
- ii) Time series : Terra TEM High resolution
- iii) Windows : 10 ms (17 windows)
- iv) Stacks : 100
- v) Stacking option : Standard
- vi) Transmitter loop : Coincident loop
- vii) Loop width : 65m X 65m
- viii) Transmitter current : Internal automatic
- ix) Base frequency : 50 Hz
- x) Receiver configuration : Loop
- xi) Channel gain : 32
- xii) Nquist filter : On

SECTION-III

The loop was laid in continues format which overlap the second section. The loop was maintained at an area of 65m x 65m. The area also was dry in condition and it has plane topography with loose sediments in the top surface and having very low vegetation content. The acquisition parameters for the soundings are as follows,

The co-ordinates where the instrument placed: Easting: 92° 70' 12" E 11° 51' 73" N

- i) Run Mode : Normal
- ii) Time series : TerraTEM High resolution
- iii) Windows : 10 ms (17 windows)
- iv) Stacks : 100
- v) Stacking option : Standard
- vi) Transmitter loop : Coincident loop
- vii) Loop width : 65m X 65m
- viii) Transmitter current : Internal automatic
- ix) Base frequency : 50 Hz
- x) Receiver configuration : Loop

- xi) Channel gain : 32
xii) Nquist filter : On

DATA ANALYSIS

Each time the output data was saved in the instrument memory. The row data had been transferred in to a portable memory stick. Then the row data is processed with the aid of “Tem plotting program-version 2.0.0” of Monash Geoscope Company. For processing the raw data, open the file location using the software command and transfer the data format. Then go to the option in the plotting menu, plot the data as pseudo section. Double click on the output image obtained, then convert it into, the suitable format (ex: Rainbow, i Rainbow etc.). For the study of Resistivity variation with depth, inversion software named Origin-pro lab is used. The input values are given to the data analysis by the aid of Microsoft office-Excel. The output is a clear cut image of the resistivity variation against depth.

RESULT AND INTERPERTATION

The result of the study is obtained is a 2-D pseudo section having depth and stations on sides, which is showing the conductivity values (in Siemens') of different underlying subsurface rocks at each depth sections. The conductivity values are converted in to resistivity (in ohm-m) values by a factor: $1/\text{conductivity} \times 1000$.

The resistivity value is inversely proportional to the conductivity value. And the resistivity value implies the physical characters of the rocks. The whole output image is divided into three section and carry out the interpretation.

SECTION-1

From the output image, section-1 extent up to 66 meter from the starting point. Topologically this section is a steep, hilly area. It is observed that the section-1 contain geological disturbance and other features. From the figure it is clear that the overall conductivity is low (below 6 Ms/m), which indicating the very high resistivity (200 ohm-m) of this section hence the presence of hard rocks. (Figure 4)

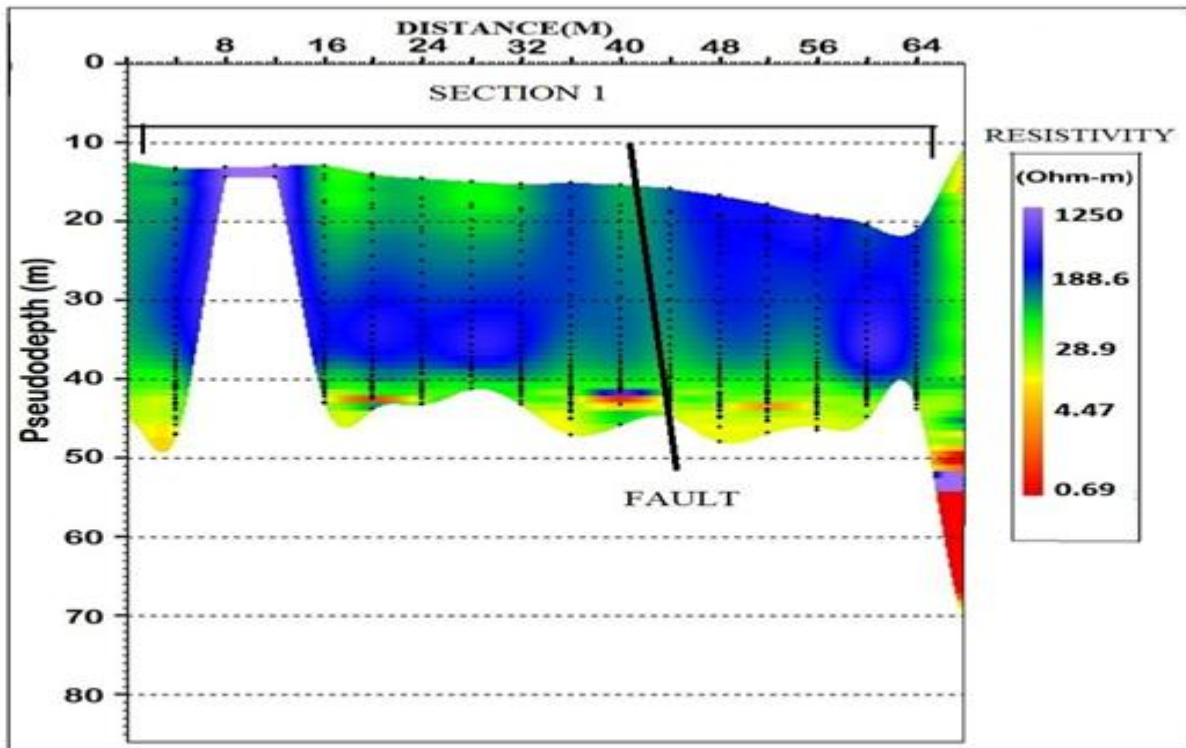
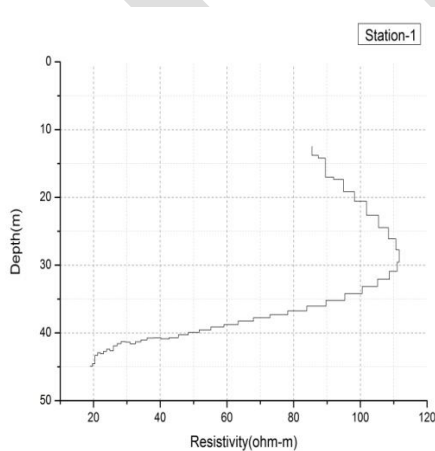
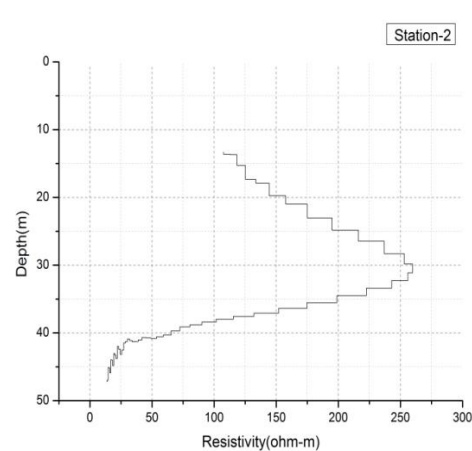


Figure 4: Showing section-1

By the close observation, it is identified that up to 4meter distance there is a change in resistivity as compared with the area from 4meter to 8meter. The resistivity value suddenly changed from 110 ohm-m to 270 ohm-m. The resistivity change with depth is shown in the graph-1 and graph-2.



Graph-1 (0-4m)

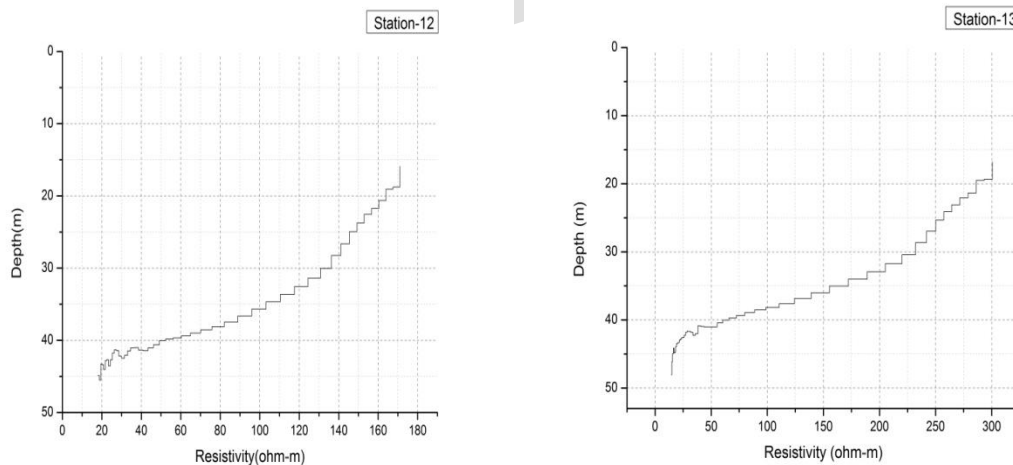


Graph-2 (4m-8m)

This change in resistivity indicates the presence of loose sediments and high water percolation in first 4meter area. Due to weak signal transmission, the image was not clear from 8meter to 12meter. But it can observe the presence of high resistive materials at these areas at a depth of 12meter to 15meter. So it indicates the presence of hard rock at that certain region of depth.

When it's coming to 15th to 16th meter, it is observed that the upper portion of this area having average high conductivity value hence low resistivity value around 100 ohm-m, as compare with lower part of that section which have a resistivity of around 375 ohm-m. This indicates that, the water and sediment content in this upper area is high. Due to erosion and other physio-chemical activities, the upper cover of the hard rock is altered and that area further filled with moisture and unconsolidated sediments of low resistivity.

There is some change observable in the area in between 44meter and 47meter. In this area it is observed that the value of resistivity has changed suddenly as compare with next 1meter that is at 48th meter. This is clearly visible in the graph-3 and graph-4.



Graph-3 (40m-44m) Graph-4 (44m-48m)

This type of unusual change in the resistivity indicates the change in medium or any geological disturbances. But visually it is clear that this change in resistivity is due to faulting of a depth of 50meter. This is an inclined fault having an inclination of around 25 degree. This fault may be formed due to any tectonic movements or any other geological activities occurred in the past time. In the field area also, this fault is clearly visible. Because of this fault, water entered

through the rocks and percolated up to a depth of around 45meters. Due to this action, the materials present in that area were altered. The gourse formed at the time of faulting was chalked with this water lead to change the resistivity value. The materials were formed which is having moisture content. These types of chemical reactions are occurred because of the presence of water, which is a good agent of chemical reactions.

It is observed that, these strata are extended up to the 64meter length. Here the material having an average high resistivity value around 350 ohm-m. Hence from all this observations indicating that these sections contain hard rocks of high resistivity, with some faulting in it.

SECTION-II

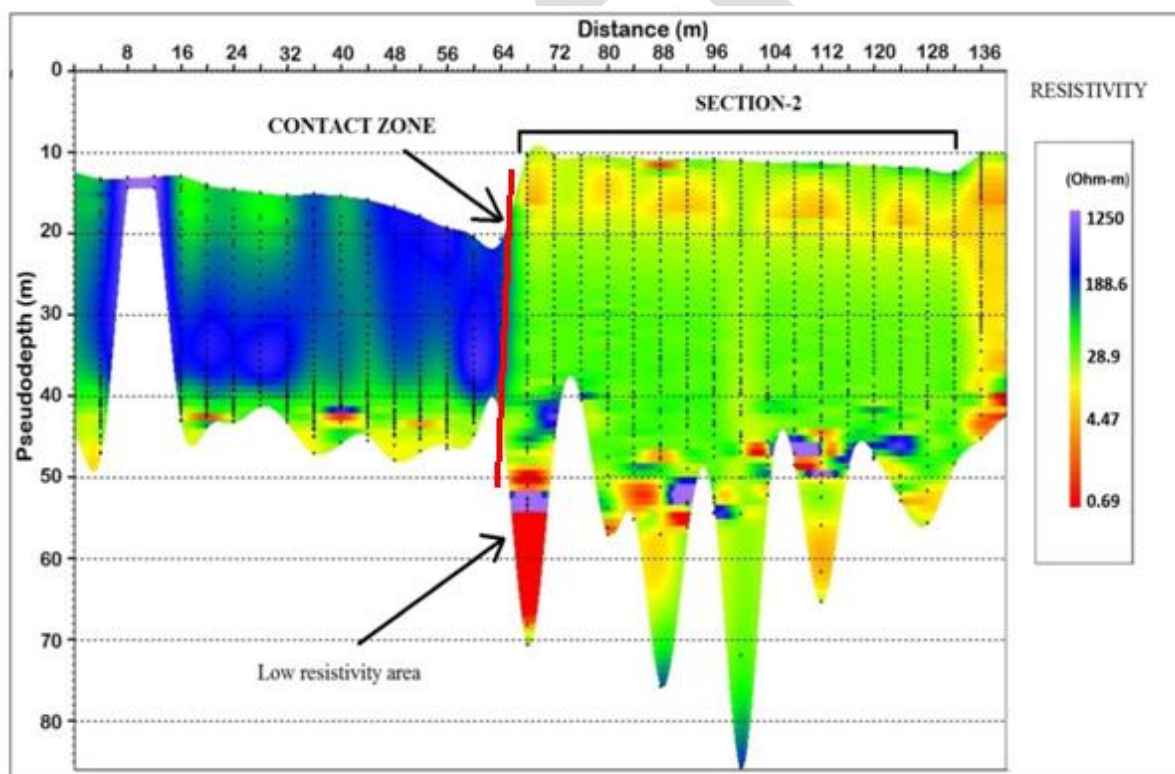
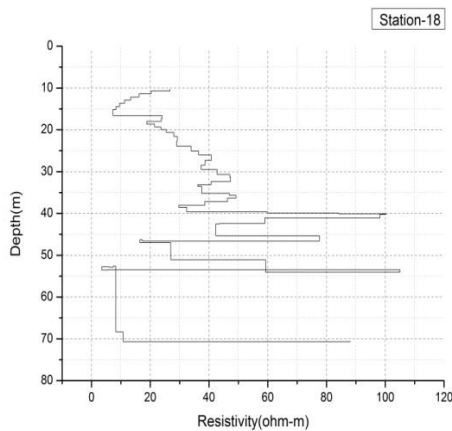


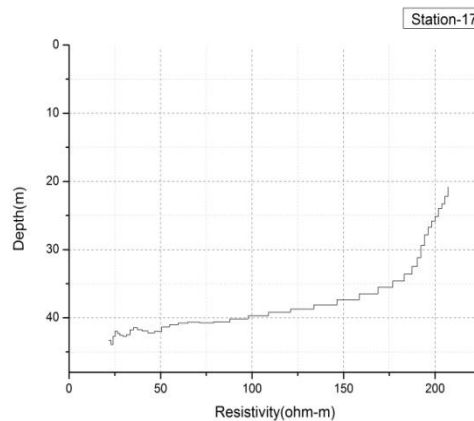
Figure 5: Showing the second - 2

The section-2 starts from 66meter to 132meter. The topology of section-2 is plane area followed by a hilly region of section-1. The profile started from the place where the section 1's loop ends. As compared to the 64th meter, the 66th meter is having a sudden increase of conductivity hence a decrease in resistivity, having an average value of 30 ohm-m in the upper

portion (up to 49 meter). This is clearly visible in the graph-5 and graph-6. This unusual change in resistivity from very high value to a low value shows the change in the medium or the different mineral composition or physiochemical characters of that rock type. This area having sudden change in resistivity is known as CONTACT ZONE. That is a zone of contact in between high resistivity hard rocks and low resistivity sedimentary rocks. By observing the resistivity value it is identified that the contact zone is exists in between Ophiolite and Mithakhari group of sediments. Here the contact zone is vertical and smooth. (Figure 5)



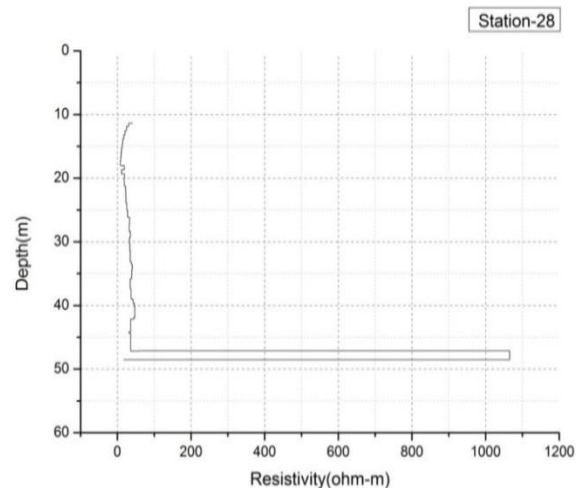
Graph-5 (64th meter)



Graph-6 (66th meter)

At a depth of 50 meter it is observed that a sudden increase in resistivity having an average value of 150 ohm-m. Just below this zone, there is a high conductivity zone is observed. It has a resistivity value of around 9 ohm-m. This abrupt change in resistivity may be because of the presence of salt water intrusions in small amount, because of the weak boundary which is existing near to the sea, which allow the easy passage of salt water into it.

There is some low resistivity area like small packets are present in the upper part of this section from 13 meter to 17 meter depth. It is because of the presence of some other types of sediments which is having very low resistivity as compared to the entire second section. At a distance of 108 meter, there is a sudden increase of resistivity at a depth of 47 meter as compared with the upper part of this area. The value of resistivity is around 1066 ohm-m. It is shown in the graph-7.



Graph-7 (108th meter)

This sudden change in the resistivity is because of the presence of small amount of some hard rock accumulation in that depth. Hence from the above observations, it is clear that a contact zone is existing between this high resistivity hard rock and low resistivity sedimentary rock. From the output image it is clear that the contact zone having a vertical dipping towards the ground hence it is a vertical contact zone. Here the contact between the hard rocks and sedimentary rock is smooth.

SECTION-III

This section starts from 132meter to 200meter. The topology of this area is plane and flat. It has a salt water inlet which is passing through its boundary. It is observed a decrease in the resistivity of the entire section as compare with the second section. It may be because of the presence some other types of sediments in that area. It is observed that, the average value of resistivity in the area is 20 ohm-m. (Figure 6)

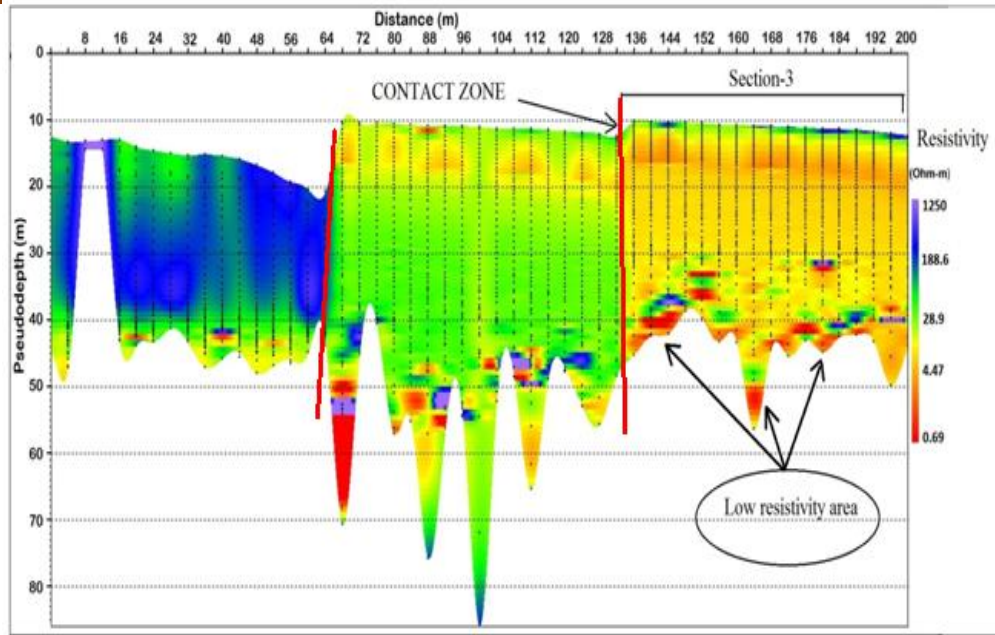
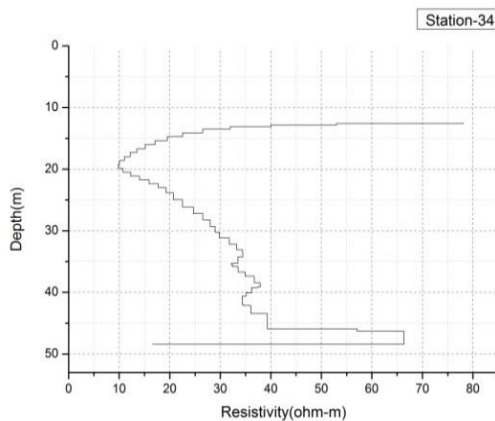
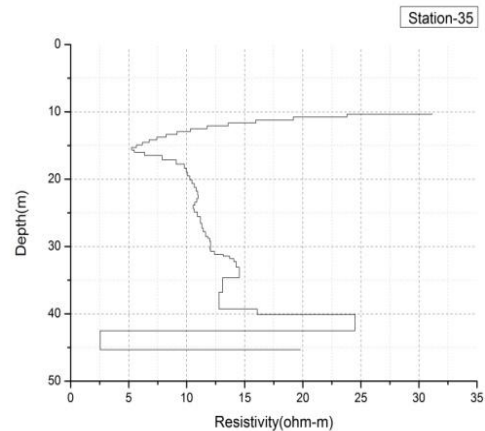


Figure 6: Showing section-3

It is observed that, in the 136th meter there is a sudden increase in conductivity hence decreases in resistivity as compare to the 132nd meter. This variation is shown in the graph- 8 and graph-9



Graph-8(132nd m)



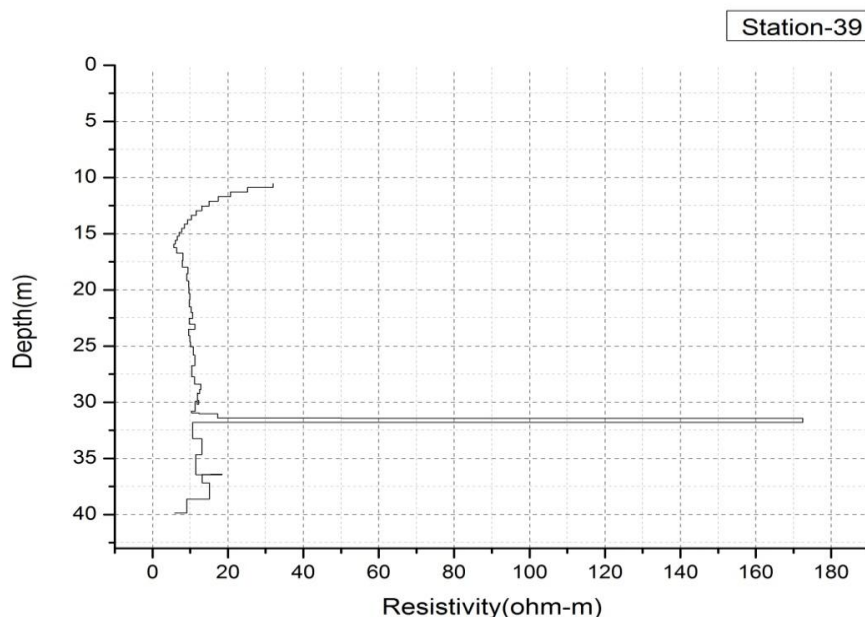
Graph-9(136th m)

This unusual change in resistivity from relatively high value to a low value shows the change in the medium or the different mineral composition or physiochemical characters of that rock type. This area having sudden change in resistivity is known as CONTACT ZONE. That is

a zone of contact in between relatively high resistivity rocks and low resistivity rocks. By observing the resistivity value, it is clear that this contact zone is existing in between two sedimentary rocks of Mithakhari group of sediments and Andaman Flysch sediments. Here the contact zone is vertical.

In this section the entire upper portion has almost unique physical property up to a depth of 30 meter. It is observed that after a depth of 30 meter to 50 meter, there are some differences in resistivity. These variations are because of the presence of some high resistivity hard rock materials and low resistivity salt water content. This high conductivity zones are marked in the Figure 5.3.

At 152nd meter, it is observed that the resistivity increased to 170 ohm-m after a certain depth of 33 meter. This change may be due to the accumulation of some hard rock substances. This change in the resistivity with depth is shown in graph-10.



Graph-10(152nd m)

Hence from the above observations, it is clear that a contact zone is existing between relatively high resistivity Mithakhari group of sediments in the second section and low resistivity Andaman Flysch sediments in the third section. From the output image it is clear that the contact

zone having a vertical dipping towards the ground hence it is a vertical contact zone. Here the contact between the hard rocks and sedimentary rock is smooth.

CONCLUSION AND DISCUSSION

From this overall studies it is clear that the contact zone is formed by the past tectonic action. The thinning of ocean floor have taken place due to sea floor spreading allowed the mantle rocks to come out of the seafloor, which is obducted by the tectonic force to the sea surface. While the movement from the sea bottom to the surface it carries the deep sea sediments with it. The deep sea sediment such as Flysch and Mithakhari are come out with the ophiolite to the surface. This is the origin of the contact zone in the study area. The Ophiolitic suite is extended from Carbin cove up to the Chidiyatapu, with a varying sedimentary contact zone. From the result and observations, it is clear that the contact zones are existing between the study areas that used for the survey. The study area has two contact zones along the transect.

The first contact zone is existing in between the hard rock of high resistivity ophiolite group of rocks (layered ultra mafics-mafics rocks) and the sedimentary rocks are Mithakhari group (which having shale, chert pillow lava, silt stone, grid sand stone and conglomerate) of low resistivity. The high resistivity hard rocks having an average resistivity value around 150 ohm-m, and the sedimentary rock having an average value of 30 ohm-m. There is one inclined fault in the first section which formed due to the past tectonic action. The contact zone is vertical and smooth in nature, which clearly indicating its origin is from tectonic movements.

The second contact zone is existing in the study area in between two low resistivity sedimentary rock sections. One section having relatively high resistivity value as compared to the other. The relatively high resistivity rocks are Mithakhari sedimentary group (which having shale, chert pillow lava, silt stone, grid sand stone and conglomerate). And the low resistivity rocks are Andaman Flysch sediments (contain inter bedded sequence of sand stone, black shale, silt stone and shale with locally developed conglomerate). It is very rare in case that 2 contact zones are situated in an area of low distance range. In the study area, the Mithakhari group of sediments are very thin in width. It have only around 65 meter width, which reveals the potential importance of the study area and the Andaman Islands. This contact zone is also vertical and smooth in nature. Small amount of salt water intrusions are present in the

second and third section which is identified by their high conductivity. Specifically in the contact between the Ophiolite and Mithakhari rocks a high amount of intrusions can be observed because of the weak boundary which is existing near to the sea, which allow the easy passage of salt water into it. The instrumental results shows that the TEM profile method is useful for deep geological mapping, especially for the detection of lateral boundaries, such as contact and fault, where no detailed geological information is available. The instrument is giving exact conductivity value of each and every point in its survey area. This geophysical signature is a direct measure of the state and its material characters of the study area. Such techniques will be helpful in the area of complicated structures frequently met in Quaternary geology near earthquake belts.

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