How to Find Buried and Inactive Seafloor Massive Sulfides using Transient Electromagnetics - A Case Study from the Palinuro Seamount in the Tyrrhenian Sea

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INTRODUCTION

Investigations of seafloor massive sulfides (SMS) are strongly limited by the currently available technology to the detection of actively forming sites. At present, the detection of SMS deposits mainly rely on plume detection of active hydrothermal venting in the water column and seafloor morphological observations. While these methods have proven to be valuable for actively forming SMS, they do not allow the detection of deposits which are no longer connected to hydrothermal activity and which are possibly covered by sediments. Therefore, to broaden the scope of investigations on SMS it is necessary to develop new technologies allowing for the detection of SMS deposits which have finished their active formation phase.

In land-based exploration it has been common practice for several decades to use electromagnetic methods to detect and characterize massive sulphide deposits. However, when turning to marine investigations only a few electromagnetic experiments have ever been conducted on SMS, e.g. by Cairns et al. (1997) on the TAG hydrothermal mound or by Kowalczyk (2008) on the Solwara SMS deposits. In a recent publication our workgroup has proposed to use the transient electromagnetic (TEM) method (Swidinsky et al., 2012). There, we have shown that the TEM method would in principle not only be useful for the detection of a deposit under a sediment cover, but could also yield valuable information about it's depth and potentially also it's thickness.

In our presentation we will give a proof of principle by showing results of the – to our knowledge – first successful experiment, which has used the TEM method to detect a buried SMS deposit at the Palinuro Seamount in the Tyrrhenian Sea.

Transient Electromagnetic Measurements at the Palinuro Seamount

Research cruise PO483 (on-board R/V Poseidon) was carried out in April 2015 to the Palinuro Seamount, which is located about 75km off the coast of Italy in the Tyrrhenian Sea. It was chosen as target because during previous investigations carried out in 2007 massive sulfides had been recovered in an area of about 45m x 27m (marked area in Fig.) at the NW corner of the seamount's central depression. For this area Petersen et al. (2014) report up to 5m of massive sulfides and barite in drillings and also show that the massive sulfides were in parts covered by several meters of sediments. Thus, the seamount was chosen as suitable target for the test of

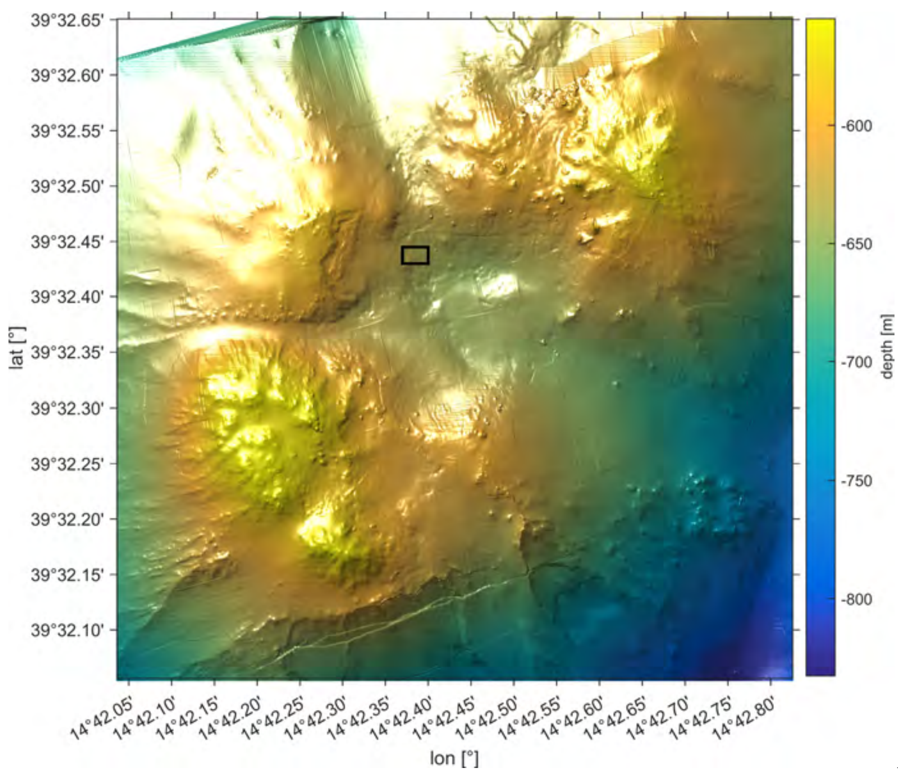


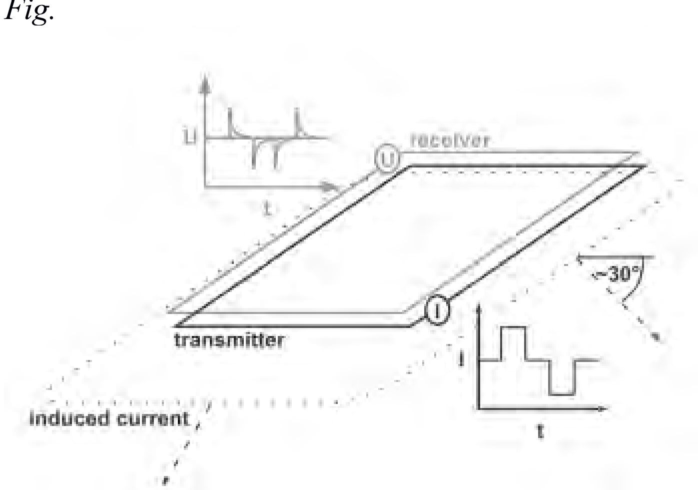
Fig. 1: Bathymetric map based on AUV measurements at the Palinuro seamount (Petersen 2013). In several drillings (marked rectangle) massive sulfides were recovered in 2007 (R/V Meteor, cruise M73/2).

existing and new electromagnetic instrumentation developed at Geomar, which in principle is capable of detecting electrically conductive targets such as massive sulfides. Here, we will report on the transient electromagnetics experiment.

Transient Electromagnetics (TEM)

Generally, the TEM method is used to investigate the distribution of the electrical conductivity. Since the method measures the secondary fields of actively induced current systems, it is inherently sensitive to good conductors like massive sulfides.

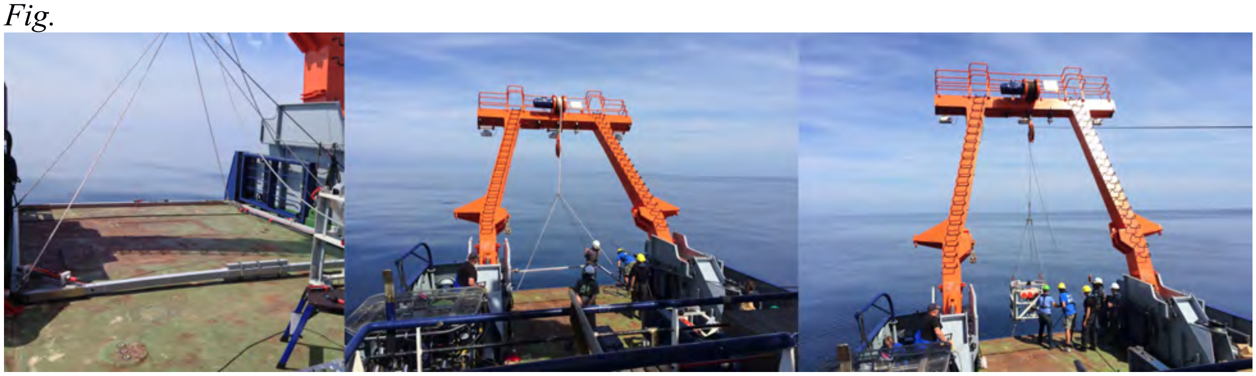
Fig.



2: Basic sketch of TEM method with transmitter

TEM systems usually use a bipolar waveform to generate a current in a transmitter loop (Fig., black symbols), which excites a quasi-static primary magnetic field while being turned on. Based on Farraday's law of induction, the current switch-off in the transmitter and, thus, the breakdown of the associated primary magnetic field, induces eddy-currents in the conductive materials (Fig., dotted line). The strength and geometry of these eddy-currents depends on the spatial distribution of the conductivity. Thus, the secondary magnetic field associated with the decaying eddy-

Fig.



3: TEM system with the 4.3m x 4.3m horizontal coil before deployment (left) and during deployment (middle) over the A-frame. After lowering of the coil into the water it was attached currents carries information about the conductivity distribution and is the measured quantity (Fig., gray symbols). The decay of the secondary field is measured with a receiver loop, which may coincide with the transmitter loop, in which case the configuration is called coincident loop configuration.

For TEM measurements at the Palinuro seamount we have used such a coincident loop configuration, in which the transmitter and the receiving loops were held by a 4.3m x 4.3m large rectangular loop frame, which was assembled on the aft of the ship (Fig., left). After assemblage, the loop frame was lowered into the water (Fig., middle) and attached at a vertical distance of 14m beneath a cage (Fig., right), which held the transmitter electronics and power units. The whole system was lowered towards the seafloor using the ship's winch cable and then “flown” across the seamount by moving the ship at a slow speed of 0.1 – 0.2 knots. By using an altimeter the position of the loop was kept at a close distance between 3-5m to the seafloor by

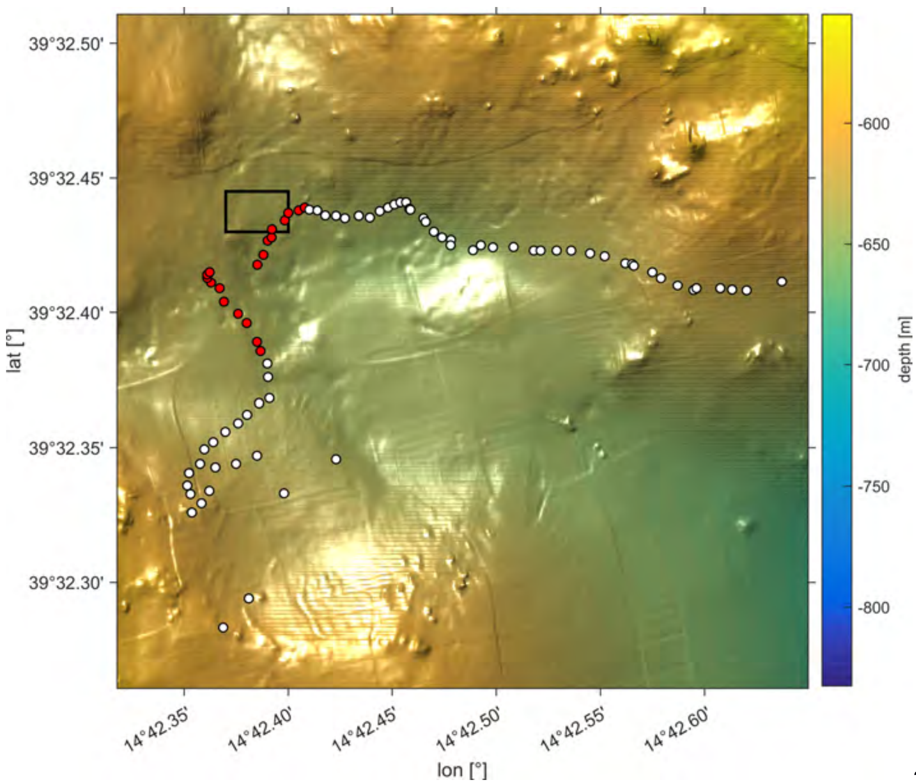


Fig. 4: Bathymetric map of the Palinuro seamount with locations of TEM measurements (circles). Measurements at some locations showed significantly increased amplitudes (see Fig. 5), which are a strong indicator for the presence of conductive massive sulfides.

constantly adjusting the length of the winch cable. Since the ship has no dynamic positioning and had some issues with the steering gear, it was not possible to measure along straight profile lines, but we managed to partially cross the area of interest. With the loop close to the seafloor, TEM measurements of 30s duration were taken once a minute. For each measurement we used a bipolar transmitter waveform with 50% duty-cycle (sim. Fig., lower right), a current amplitude of about 38A and a repetition frequency of 2.5Hz. The data was received with a 24bit data logger at a sampling frequency of 10kHz. The locations of measurements are depicted in Fig..

The processed data of all measurement locations is shown in Fig.. It is clearly evident that at some locations the measured amplitudes are significantly increased. According to Swidinsky et al. (2012) (s. inlay in Fig.) such an increase in amplitudes may be caused by an increased conductivity of the seafloor. We have marked the associated locations in Fig. (red markers) and find that they coincide and further extend the area where massive sulfides were found in

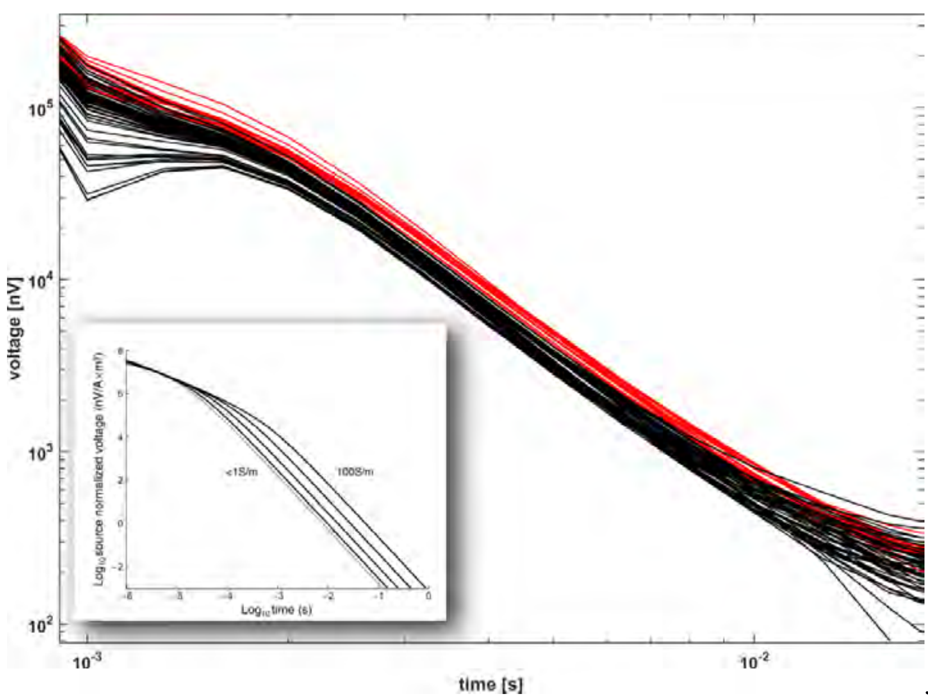


Fig. 5: Processed transient curves of 80 locations depicted in Fig.. At some locations increased amplitudes are evident (red curves) and the associated locations of these measurements are shown with red markers in Fig.. For comparison we have included Fig. 6 from Swidinsky et al. (2012) as inlay, which shows the theoretical response of a regular seafloor (gray curve) and responses of a more conductive seafloors (black curves).

drillings. Thus, it seems evident that the area of mineralization is much larger than previously detected.

Since we have just returned from the cruise four weeks ago our analysis of the data can only be qualitative at the time of writing this abstract. Currently, we are in the process of inverting the measured data, which will allow us to present a quantitative interpretation of the data in terms of a true earth model during the conference.

Acknowledgment

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Sebastian Hölz received his PhD from the Technical University of Berlin in 2007 for his work in land-based transient electromagnetics carried out in the Gobi desert in NW China. In the same year he joined the marine electromagnetic research group at the Helmholtz Centre for Ocean Research, GEOMAR in Kiel, Germany. His work deals with all aspects of marine controlled source electromagnetics like experiment and instrument design, planing and implementation of experiments, data processing and data interpretation.