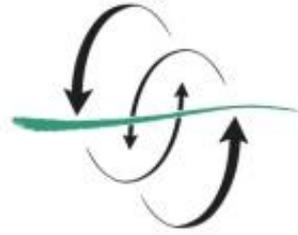


FACULTAD  
DE CIENCIAS  
DEL MAR



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# **Nutrient Concentration Determination in the Post-Eruptive Process of the Volcano of El Hierro.**

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Trabajo Fin de Título para la obtención  
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**TÍTULO**

**Nutrient Concentration Determination in the Post-Eruptive Process of the Volcano of El Hierro**

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### Abstract

This study shows the behavior of nutrients in the water column in the submarine volcanic area south of the island of El Hierro 3 years after its eruption. For this, silicates, nitrates and phosphates were analyzed and oxygen, fluorescence and pH were measured with sensors to help explain and identify the eruptive phenomenon and their effect on the distribution of nutrients. With this information it will be concluded if the pre-eruptive conditions of nutrients have been recovered or how are these important compounds seem to be reacting to the remaining volcanic activity.

## INTRODUCTION

In the oceanic context carbon, nitrogen and phosphorous are vital nutrients for life. They are essential for all organisms. However, also iron and silicon are elements that play really important roles in certain regions of the ocean and for certain phytoplanktonic species.

However, these are not the only elements necessary for life but the other elements have higher availability in the sea than demand by the organisms. The concentration of these main nutrients, either in excess or shortage, may limit or favour the development of certain primary producers and therefore regulate the whole ecosystem. Nutrients may come from outside of these ecosystems, from fluvial, atmospheric entrance or upwellings, which is denominated new production or from inside these ecosystems, from excretion, decomposition, remineralization or recycling by organisms; which is denominated regenerated production. Waters with a high concentration of nutrients are called eutrophic while waters with low concentration of nutrients are known as oligotrophic. It has been studied that phosphorous limits more the production in the North Atlantic Ocean than nitrogen due to nitrogen fixation related with iron presence (Wu et al., 2000). Nitrogen is abundant in the atmosphere while phosphorous enters through rivers, also the process that may generate bioavailable nitrogen are more frequent, therefore limiting the amount of phosphorous. (Falkowski et al., 1998) Silicon will depend more on the entrance through atmospheric dust.

Depending on their source and process they participate in, nutrients can be found in the sea in their inorganic and organic forms. This is the situation of nitrogen and phosphorous, they either can be part of organic compounds developed by organisms or

be in an inorganic state dissolved in water as nitrates and phosphates. Even silicon can either be found forming dissolved silicic acid or being part of planktonic structures. Some authors classify this speciation in the chemical functional families of non-living organic, living organic and inorganic (Vichi et al, 2007). This speciation controls the availability of nutrients for living organisms which have different preferences and have adapted to be able to absorb and incorporate nutrients in a certain form. For example, in the case of nitrogen it is mostly in its gaseous state  $N_2$  dissolved in the oceans but this form is biologically inaccessible except for a few microbes denominated nitrogen fixers; these nitrogen fixers change  $N_2$  into more biologically accessible specie such as  $NH_3$  or  $NH_4^+$ . These forms of nitrogen can now participate in lots of chemical reaction mediated by organisms in which they will be incorporated into organic compounds, changed into their inorganic forms or even back to their gaseous species (Liu, 1979; Libes, 2009).

However, the concentration and ratio of all these forms the nutrients can be controlled by biologically mediated reactions as well as other measureable oceanic parameters that may vary depending on the location and moment of the research.

For instance, pH will modify the acid-base equilibrium of some of the inorganic nutrients and hence the abundance of the different inorganic species. In acidic environments inorganic nutrients tend to gain protons and in basic environments inorganic nutrients will be forced to lose their protons. For example, phosphate is the conjugated base of a poliprotic acid, the number of hydrogen atoms it has will depend on the pH of the water it is in. Silicon species also vary with pH but the most common form is the ortosilicic acid for pH from 1 to 9. Even  $NH_3$  and  $NH_4^+$  are affected by pH due to the ability of loosing or gaining protons (Millero, 2006).

The concentration of oxygen also plays a really important role in the speciation of nutrients. On one hand, oxygen is needed for the decomposition of organic matter and hence the organic species will decrease in favour of the inorganic species. On the other hand, the absence of oxygen may trigger the reduction of nitrates by certain denitrifying bacteria in their search for another electron acceptor when oxygen is less available. For example, there is less  $NO_3^-$  than the expected in depths of minimum oxygen levels and there is an abnormal increase of more reduced forms such as  $NO_2^-$  or even  $N_2O$  or  $N_2$  due to bacterial denitrification in this conditions of low oxygen concentration (Codispoti et al, 2001).

The concentration of C can alter nutrient speciation in multiple ways. The entrance of high concentrations of CO<sub>2</sub> can acidify the water when dissolved and the effects of pH have already been commented (Millero, 2006). High levels of organic non-living matter, organic carbon, contributes to decrease the concentration of oxygen because it increases the decomposition of organic matter and the effects of oxygen concentration and organic matter decomposition have been described (Codispoti et al, 2001). However CO<sub>2</sub> also plays an important role in photosynthesis and therefore can encourage living organic matter production.

The presence of light also affects the concentration of nutrient species through its effect on living organisms. In the photic zone of the oceans photosynthesis is taking place and this implicates the presence of primary producers and their predators. This production and predation can reduce the concentration of inorganic nutrients that are being assimilated by organisms and increase the concentration of organic forms of nutrients from these organisms' deaths or excretions. Also organisms play key roles in important reactions already mentioned like decomposition, nitrogen fixation, denitrification and other processes that use or produce species of nitrogen and modify the concentration of its species.

High concentrations of iron can stimulate the uptake of nitrogen if nitrogen is in high concentration (eutrophic conditions) or nitrogen fixation in waters with low concentration of nutrients (oligotrophic conditions) ( Timmermans et al., 2004).

Temperature has an effect on the presence and absence of nutrients due to its effect on the thermoclines' depth and estratification. If the temperatures are low there is less estratification in the sea and hence better mixing and an easier resuspension of nutrients from deeper waters. If the temperature is high the water column estratifies and does not allow proper mixing which complicates nutrients from deeper waters to rise and retains nutrients in the upper waters which are probably consumed. However a deeper relation between temperature and nutrients has been studied for the surface waters (Switzer et al., 2003; Louanchi et Najjar, 2000).

Phenomena such as upwellings, atmospheric dust, river flows, hydrothermal sources and several others have important effects on nutrients but one of the most drastic events with a big impact on nutrient availability and their speciation are volcanic eruptions.

Volcanic underwater eruptions and their effects on water have not been profoundly discussed. It has been demonstrated that ashes and dust of volcanoes fertilize oceans

(Lin et al 2011) but few studies have taken place monitoring the effect of underwater volcanoes normally due to technical difficulties related with the depth of the volcano or the violence of its eruption. This is why the volcano of El Hierro (Canary Islands) was a great opportunity to describe its evolution and chemical consequences. The effects recently after the eruption have been described by Santana-Casiano et al, 2013 and Fraile-Nuez et al, 2012 and there are clear effects on nutrients. It influences directly the concentration of certain nutrients like Si and N in form of  $\text{SiO}_2$  and  $\text{NH}_3$  by direct injection from the volcano (Sedwick & Stüben, 1995, Valsami-Jones et al., 2005). The ammonia oxidizes to nitrite and nitrate (Kilias et al., 2013). Other elements present in the emissions may affect indirectly the concentration of the inorganic forms of nitrogen, silicon and phosphorus. For instance, the release of HCl,  $\text{CO}_2$  and  $\text{SO}_2$  during the eruption acidifies the water and the effects of altering the pH have been described. The entrance of reduced sulphur species during the eruption contributes to reduce the redox potential and depletes the water of oxygen and the oxygen concentration has an effect on nutrients (Mort, 2010). Volcanic eruptions produce a large increase on iron which enriches this area fertilizing the water for algal blooms when conditions are less extreme and has an effect of nitrogen uptake and fixation (Timmermans et al, 2004; Kilias et al., 1995).

This article will centre principally on studying nitrogen, phosphorous and silicon in an environment with particular conditions which may affect these nutrients, the underwater volcano of El Hierro.

The main objective of the VULCANO project was to study how the physico-chemical conditions have evolved over time and how the organisms have adapted to them. In this study, we explored the distribution of inorganic N, P and Si near the volcano three years after the eruption and how they have changed from the beginning of the eruption. The aims of this study was to verify if the area has recovered the conditions of its transitional location between the African upwelling and the subtropical gyre or if this condition is influenced in any way by the volcanic activity affecting its nutrient concentration. For this we compared the evolution of nutrients from previous moments of more volcanic activity to the actual state of the sea on top of the volcanic area.

The cruise took place from the 5<sup>th</sup> to the 24<sup>th</sup> of March in the south of the island of El Hierro just over the top of the volcanic cone. 10 stations were considered in the volcano area, sampling the principal and secondary cones and 2 stations out of the volcanic area which served as control. At each station there were samples taken at various depths depending on the varying sea floor between 100 and 1000 meters. (Fig. 1)

Normally, in this site, the inorganic forms of nutrients follow a typical nutrient vertical distribution in which there are low levels in the superficial waters due to their use by organism and increasing their concentration at deeper waters where the organic matter is being decomposed by other organisms using oxygen (Redfield, 1942; Barton et al, 1998). This is why older waters have higher concentration on nutrients and a lower concentration of oxygen than younger waters due to the accumulation of recycled nutrients.

In fact, the water near the island of El Hierro had an oligotrophic characteristic where nutrients are very scarce for the first 200m. This is because it is far from the upwelling region and it is only sometimes influenced by regional eddies (Gonzalez-Dávila et al, 2006). During the eruption there was a big entrance of nutrients and other compounds to its euphotic zone. In this cruise to study El Hierro's volcano, more than 2 years after the eruption, we will try to see if the nutrient distributions have recovered their original conditions or how they have been modified.

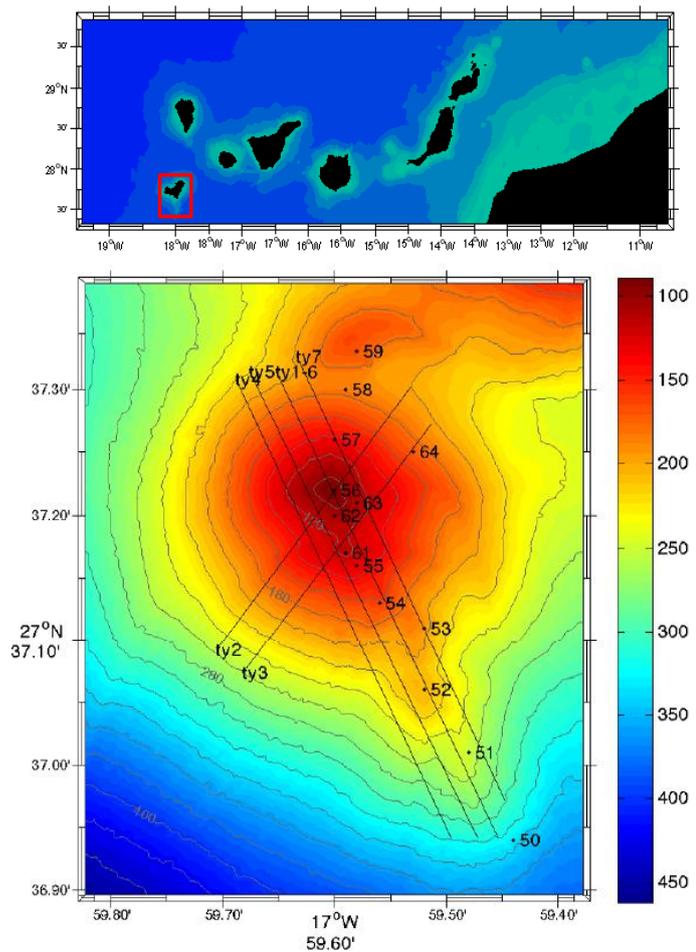


Figure 1. Situation of the stations of the transect along the volcano bathymetry.

## METHODOLOGY

In this study, at each station samples were obtained using Niskin bottles in a CTD-rosette at 5, 25, 50, 75, 100, 150 and 200 when possible. Nutrients were drawn from the Niskin bottle and stored as suggested in the Protocol for Continuous Flow Automated Analysis of Seawater Nutrients (Phosphate, Nitrate, Nitrite and Silicic Acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study (Gordon et al, 1993).

The sample containers were made of plastic, precisely, bottles of 250ml of polyethylene. Glass was not use because it could alter the measurements of silicate. These samples were stored frozen at -20°C because continuous flow analyser was not functioning on the boat. They were transported to the laboratory where the samples were analysed for nitrates, nitrites, phosphates and silicates.

The instrument used to analyse the samples was a Micromac 1000. It had already configured methods to measure nitrates, nitrites, phosphates and silicates automatically using spectrophotometry with previous calibration and reactant preparation. The measurement of each nutrient requires 25ml approximately and when done for multiple nutrient measurements around 100ml are needed, 250ml were sampled to have enough sample to repeat measurement in case of error or if a replicate was needed. Before analysis frozen samples were de-frozen at room temperature.

For this analytic purpose the Micromac 1000 had to be ready and therefore tested to know its limits and analytical capacities.

The linearity of each method was tested for concentrations according to their ranges found in the ocean (Kolterman et al, 2011) (Fig. 2). The linearity was also tested with mixed dilutions, i.e. with all nutrients, just in case the calibration varied and to test the multiparameter analysis system implemented in the method. For this second test the concentration excesses occurred during the eruption (Santana-Casiano et al, 2013) were taken into account for this verification to be prepared for possible persisting emissions of the volcano.

The micromac 1000 displays concentration in ppb ( $\mu\text{g/L}$ ) so we worked with this unit when operating with it, but graphs have been displayed in  $\mu\text{M}$ .

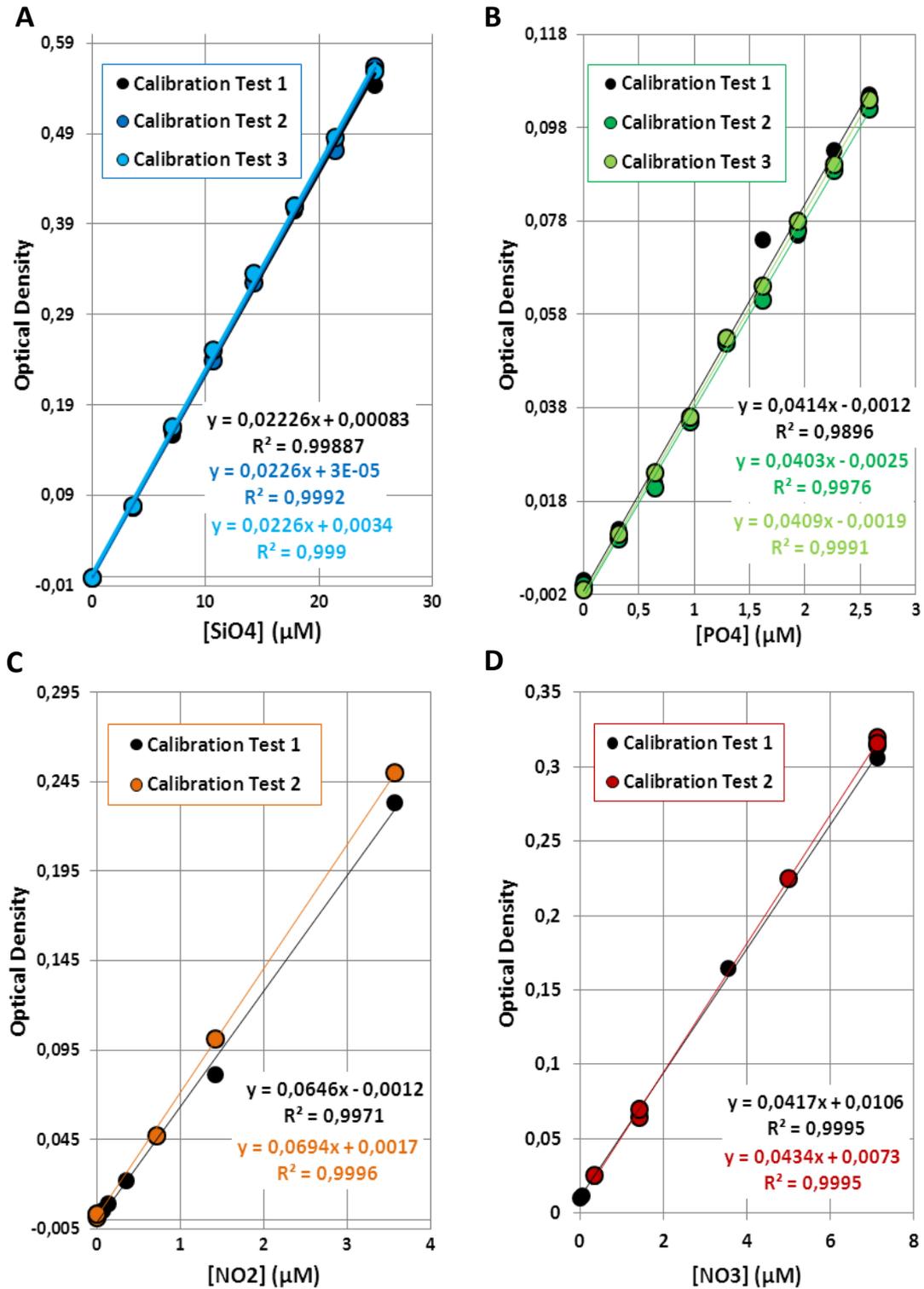


Figure 2. Calibration of the different methods to test linearity of the Micromac 1000.

Methods: A. Silicate, B. Phosphate, C. Nitrite, D. Nitrate

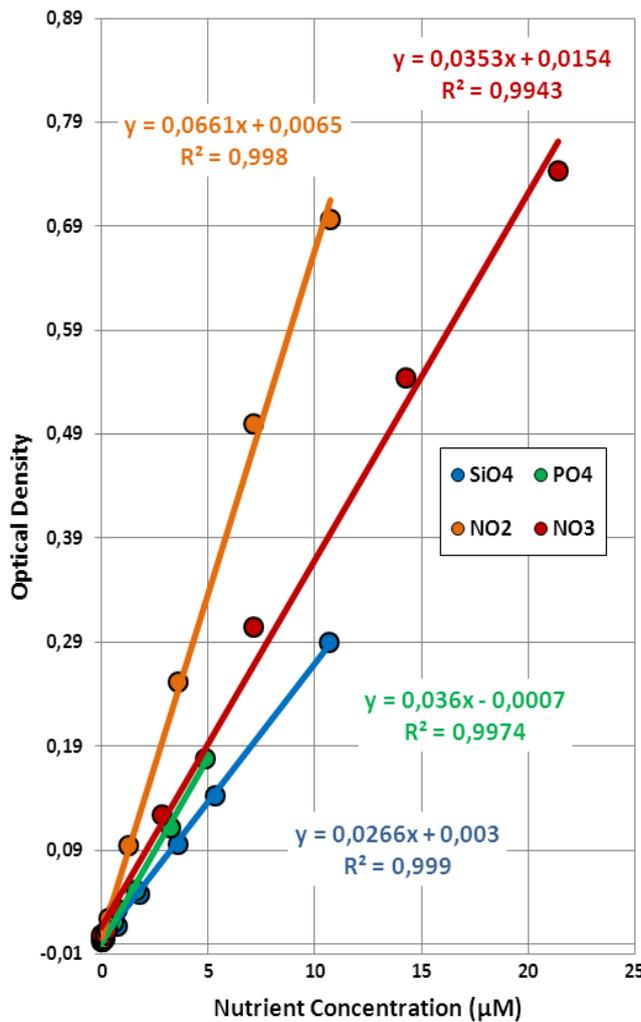


Figure 3. Calibration lines testing linearity with mixed nutrients dilutions. Each nutrient analyzed separately.

Apart from the information obtain from the samples of this research cruise, results are discussed with data from previous ones to the water surroundings of the volcano of El Hierro from Santana-Casiano et al, 2013 that provide data of nutrients during the eruption.

Data of oxygen, fluorescence and pH measured by the sensors in the CTD-rosette are used to explain their effect on the nutritional distribution along the water column and to confirm volcanic emissions.

To compare the results from this cruise and check if the original conditions of the area have been recovered, the data obtained during cruise across the archipelago inside the project BIOCAN (Gonzalez-Dávila et al, 2006) were also considered.

A calibration line equation was used and the resulting concentrations were calculated using the optical density evaluated by the instrument. The analyses were performed for each nutrient separately without using the multiparameter method provided by the equipment.

The detection limits defined as 3 times the standard deviation of the blank divided by the slope of the calibration curve ( $3\sigma_B/S$ ) (Analytical Methods Committee, 1987; Thomsen et al, 2003) were 0.255, 0.061, 0.068 and 0.111  $\mu\text{M}$  for the methods to measure silicate, phosphate, nitrite and nitrate respectively.

Apart from the information obtain from the samples of this research cruise, results are discussed with data from previous ones to the water surroundings of the volcano of El Hierro from Santana-Casiano et al, 2013 that provide data of nutrients during the eruption.

## RESULTS

A calibration equation was employed to calculate nutrient concentration ( $\mu\text{M}$ ) from the optical density measured by the Micromac 1000. This equation was estimated by measuring a series of standards of known concentration each time the reagents were replaced. The concentrations of these dilutions of all nutrients were prepared based on the concentrations expected to measure from data of other previous research cruise.

Figure 4 depicts the results of these calibrations:

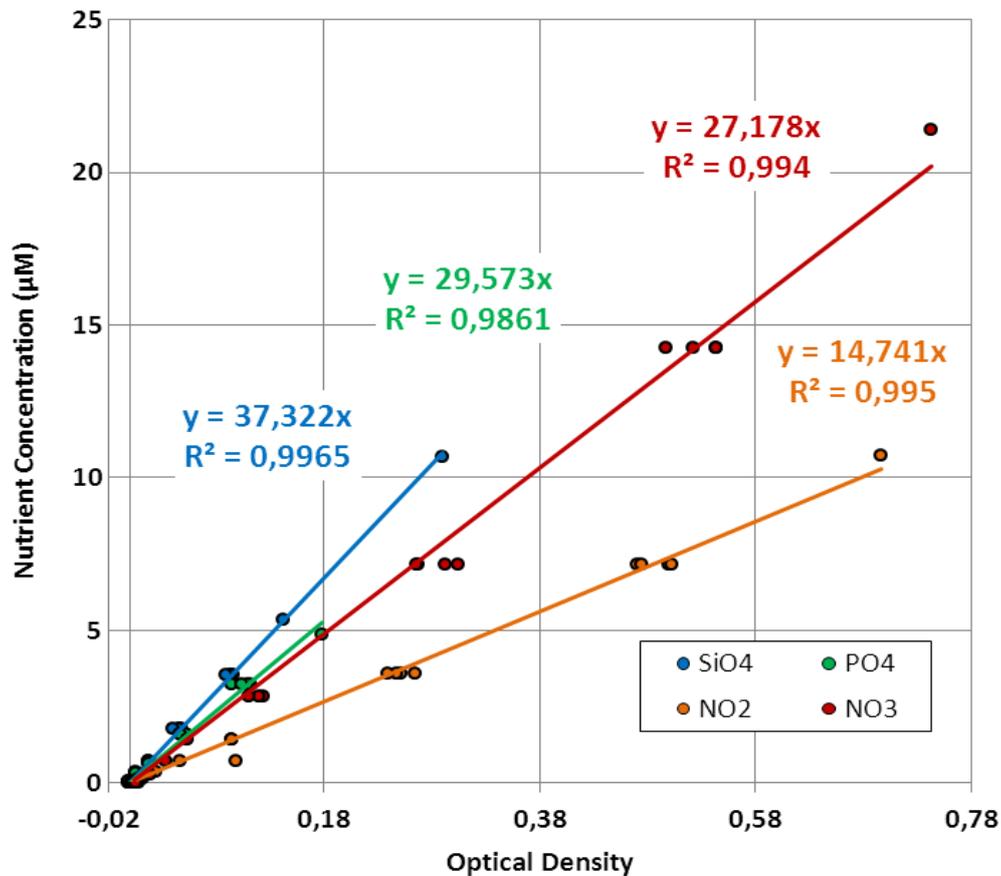


Figure 4. Calibration curve for the 4 nutrients.

In reality the Micromac 1000 displays the concentration in ppb units of the elemental nutrient (Si, P, N) this had to be taken into account. To change from ppb to  $\mu\text{M}$  concentration in ppb has to be divided by the atomic mass of the element.

Once the results were achieved the control station (13), out the volcanic transect, was used to compare with the results obtained by the Spanish Institute of Oceanography (IEO) during the BIOCAN project in similar coordinates in 1998 (station 85). (Fig.5)

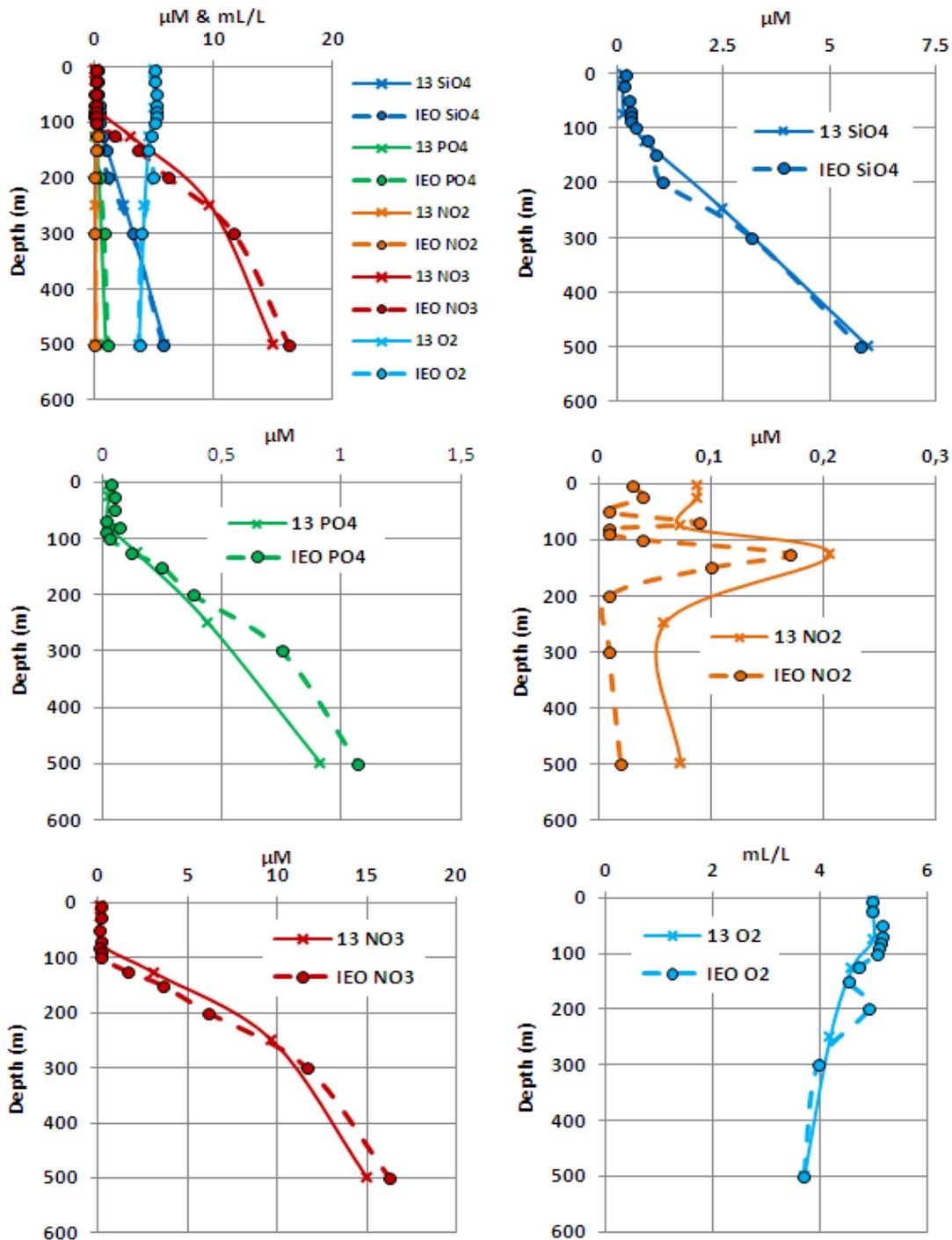


Figure 5. Comparison between control station 13 and station 85 from IEO research cruise in 1998. Vertical profiles of silicate, phosphate, nitrite, nitrate and oxygen.

After assuring the correct behavior of the analytical methods, the results of the high resolution study over the volcano were processed to spot significant deviations from the average distribution or to verify the recovery from the volcanic effect comparing it with the control station away from the volcano.

The information of the stations locate on the transect over the volcano will be displayed as vertical sections and profiles to explain in detail the process taking place at certain stations of interest to compare distributions when there were volcanic and when there were not.

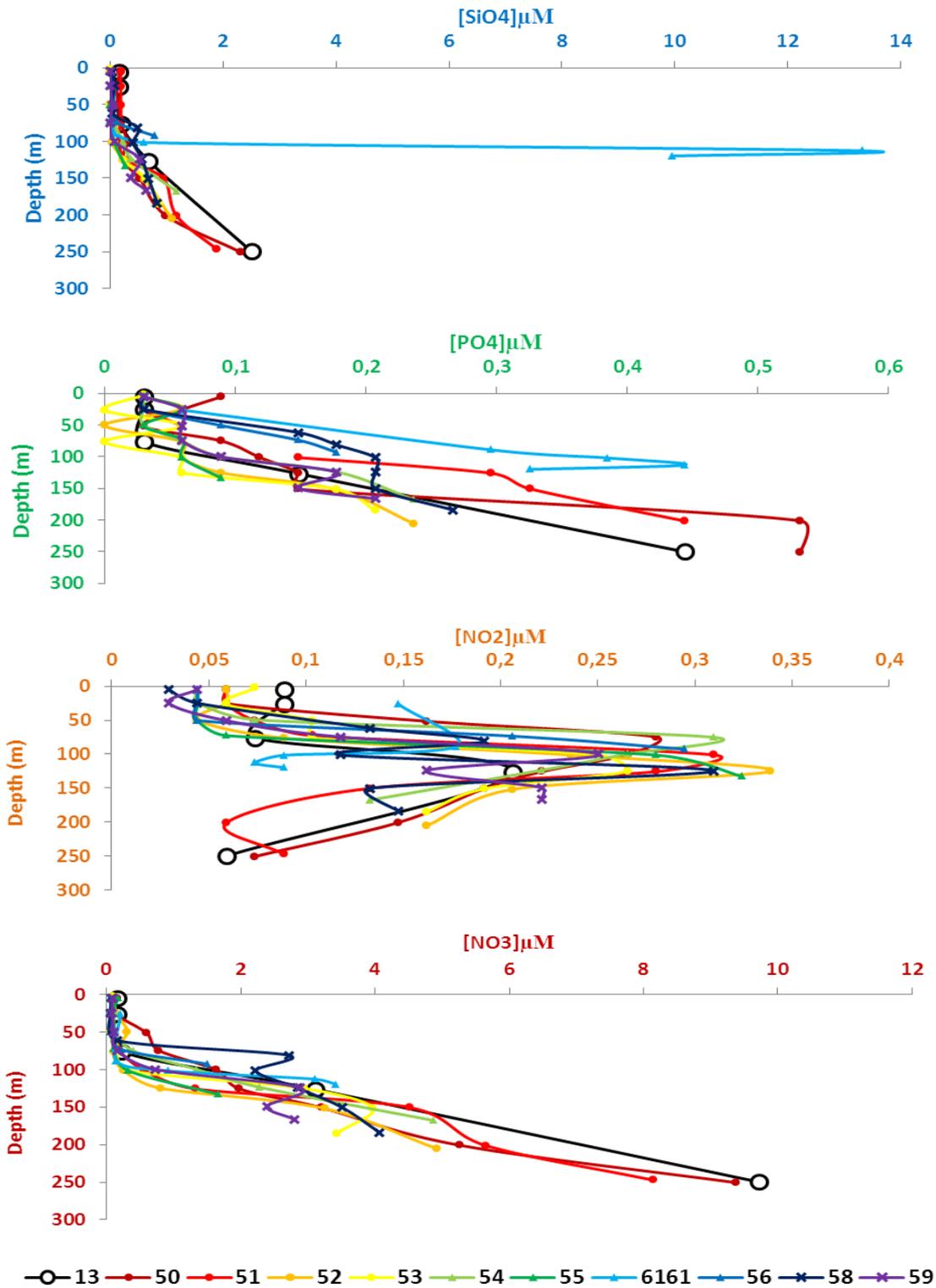


Figure 6. Vertical profiles of the 4 nutrients analyzed from the samples of each station of the research cruise.

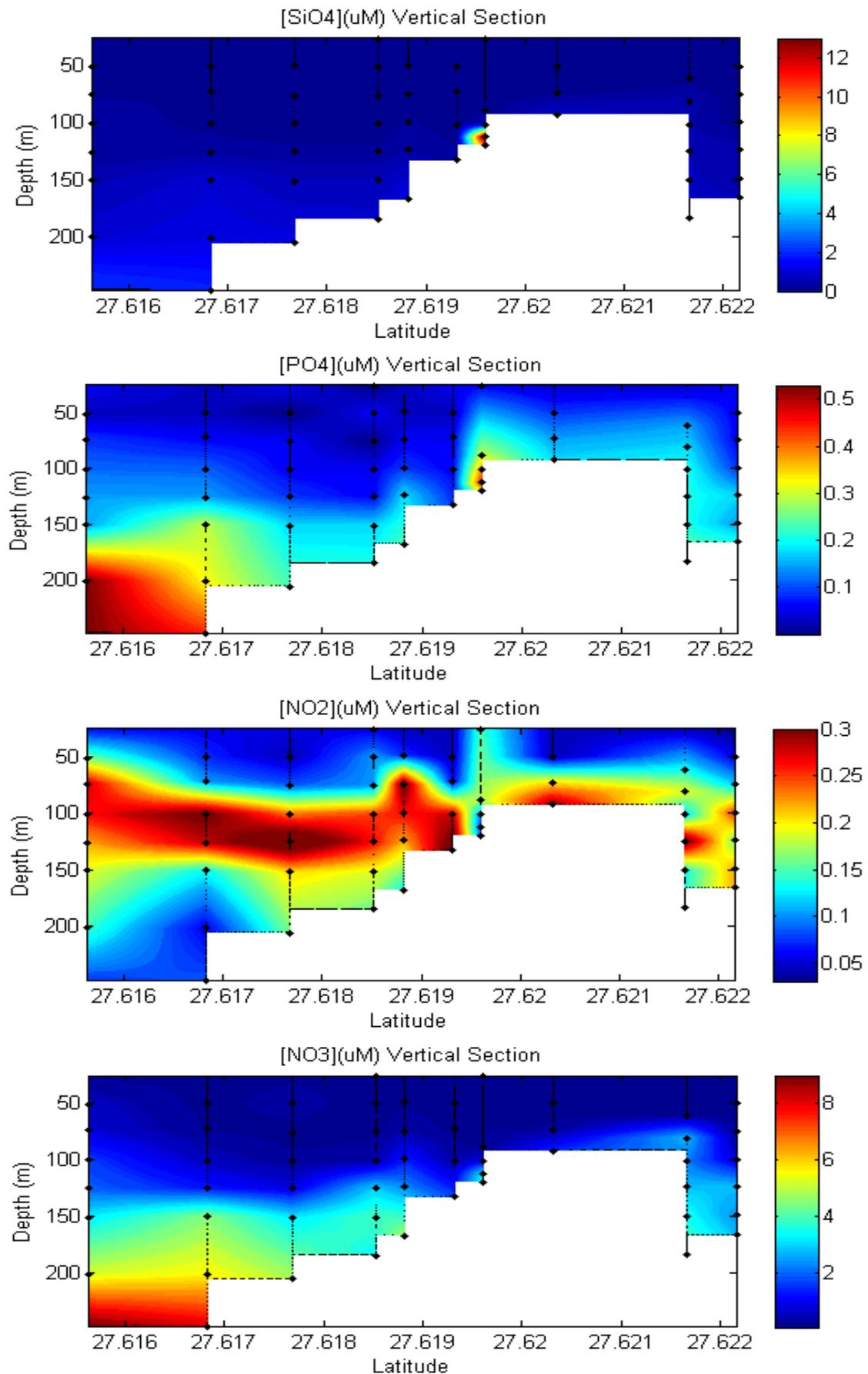


Figure 7. Latitudinal vertical sections between 25 and 250m of the principal nutrients analyzed over the volcanic cone. Dots represent sampling depths. St. 50-55, 61,56,58,59.

Parameters highly related with volcanic emissions and that may affect the nutrients' distribution are also displayed in both forms to identify volcanic activity and explain the effect of the condition setted by emissions.

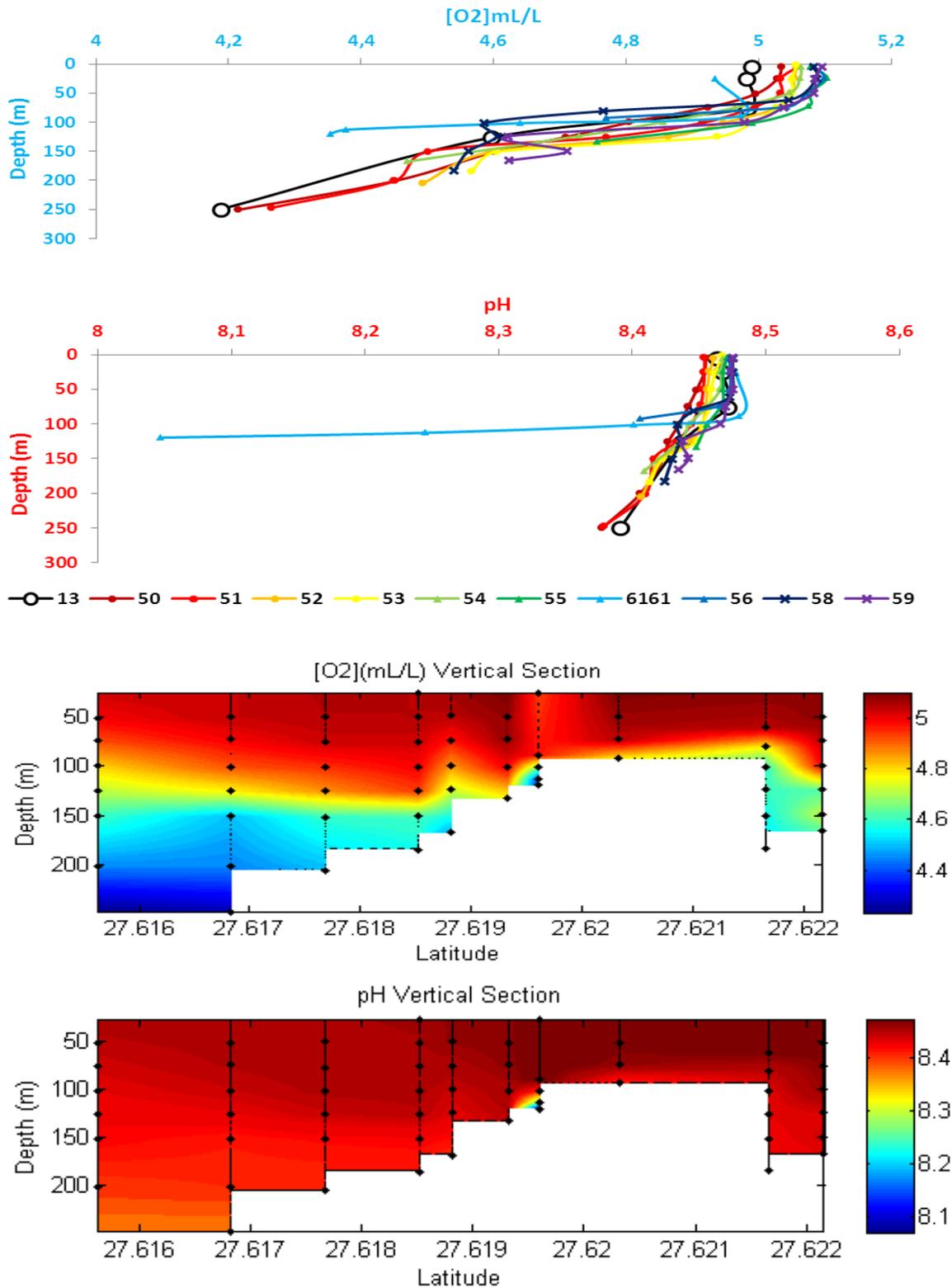


Figure 8. Vertical profiles and latitudinal vertical sections of oxygen and pH for the stations of the volcanic transect. St. 50-55,61,56,58,59

## DISCUSSION

The detection limits for each nutrient determined by the Micromac 1000 that used a 5 cm path-length were similar to those from other research cruises, with most of the data in the first 50-75 m inside the detection limit for the different nutrients.

The results show that the distributions of nutrients in the water column near the volcanic area have recovered their original behavior. This is shown by the similar behavior of the nutrients in station 13 of this recent research cruise and the station 85 of the cruise of 1998 when the volcanic emissions had not occurred and could not influence the nutrient concentration. (Fig.5)

The distributions of silicates, phosphates and nitrates, follow a positive relationship with depth and therefore increase their concentration as depth increases. Specifically, between 50 and 100m their concentrations start to increase but from there upwards their concentrations are very low. If the ranges of these nutrients are taken into account the nitrate experiences the greatest increase, then silicate and finally phosphate that does not increase much. This could be due to the nitrification processes taking place.

On the other hand nitrites follow a different path. Nitrite concentration is low throughout the water column but experiences a small increase between 50 and 100 meters and then a decrease between 100 and 150m approximately. This gives it a peak at approximately 100 meters.

Oxygen, however, decreases with depth. During the first 50 meters oxygen concentration is highest but experiences a sudden small drop at between 50 and 100 m and then decreases steadily.

These distributions can easily be related. Oxygen enters from the atmosphere and is generated during photosynthesis in the photic zone of the water column. But at 50 meters oxygen is utilized in processes of decomposition and remineralization that turn organic species into their inorganic forms. These include respiration, nitrification and organic phosphate and silicate remineralization which are less frequent and are less abundant elements in organisms which is the reason why they experience a smaller increase than the one of nitrates.

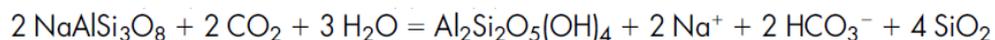
Nitrites are formed in the beginning but are quickly oxidized. Nitrate normally increases the moment nitrites started to decrease from their peak concentration. This can be explained by the order of steps in nitrification in which nitrogen or ammonia is oxidized once to form nitrites and then oxidized again forming nitrates.

The distribution of nutrients can also be explained with data of fluorescence (data not shown). It reaches maximum levels at between 25 and 100m where conditions are optimum for photosynthesis, hence oxygen production. At deeper depths less oxygen may be produced by photosynthesis and remineralization processes become more important which consume oxygen and less inorganic forms of nutrients are consumed. This is also sustained by the fact that during the highest fluorescence levels nutrient concentration is lowest due the absorption and assimilation of inorganic species by the high amount of organisms at those depths but the moment fluorescence decreases nutrient concentrations start to increase.

However, the stations close to the volcano showed a different profile. Most of the points displayed distributions similar to that of the station 13 as shown in the profiles. But there are clear deviations. (Fig.6)

All nutrient profiles experience a deviation of the standard behavior near the bottom on station 6161. This station was sampled because a gaseous emission event was identified with redox and pH sensors. The event was relatively strong as shown by the sudden decrease on pH and oxygen. (Fig. 8)

As expected, a volcanic emission had an effect on nutrients, precisely on silicates (Sedwick & Stüben, 1995). The emission of reactive minerals containing silicates that interact with water generates a strong increase on the silicate concentration that reaches at 120m approximately levels found at 1000m (Fig.6). This is shown by the following reaction:



(Sedwick and Stüben, 1995)

Phosphate also experienced a considerable positive deviation that could be favored by the speciation related redox reaction and dissolution of precipitates occurred with metals which free phosphate scavenged by these precipitates (Codispoti et al. 2001). Also it is considered that sudden emissions transport sediment precipitate and deep water with high concentration upwards, enriching components like phosphates (Fig. 6). Some

authors suggest that bacterial activity related with the sulfur injected by the volcano, that caused the reduced-less-oxic conditions, favor the production of phosphate species from organic matter (Mort, 2010).

The majority of nitrogen produced by the volcano is usually in the reduced  $\text{NH}_3$  form (Sedwick & Stüben, 1995). When the water of station 61 reaches higher waters nitrite concentration is higher at this depth than in other stations (Fig. 7). The ammonia is being oxidized to nitrite thanks to the higher oxygen levels and the time mixing which allow this increment but nitrate is being absorbed by organisms so it appears like it does not increase (Kilias et al. 2013).

Furthermore, the 6161 was not the only station. It was the one that suffered the severest effect of a volcanic gas emission of a secondary chimney but there were other stations that show some kind of similar nature to station 6161.

Volcanic effects are present on stations 56 and 58. They both suffered the respective decrease of oxygen and pH found with volcanic emissions (Fig. 8) and an abnormal increase of all nutrients at approximately 75 -100 meters (56 only reach up to 90 m). Moreover station 58 also shows a decrease of nitrite similar to that found on 6161 disrupting the peak that could start at lower depths (Fig. 6 and 7). At least these values are noticeably different at this depth, at least more than the ones of other transect stations without 61.

These evidences may sustain the possibility of a small volcanic plume that could be affecting these 2 and water between them where the plumes origin could be placed and was not sampled. Another possible cause is that the center cone station 56 is producing small emissions and that a plume near 58 is affecting this station. The origin is not in the bottom of station 58 because the deviation takes place at approximately 100m far up from the bottom (~180m) (Fig.6 and 7). This plume theory could also answer why there is such a remarkable peak of nitrates at 100m when at 61 there was not any increase of  $\text{NO}_3$ . This increment at 58 could be caused by the plume crossing this station at shallower waters and therefore higher oxygen levels at this depth allow to oxidized the ammonia enriched volcanic plume water, as well as the time taken to travel to 58, which allows oxidation to take place (Kilias et al, 2013).

This hypothesis explains that there is not such an increase of nitrates at station 56 because there is not enough distance from the source to have time and oxygen to oxidize the ammonia but there is enough distance and time from the source at station 58.

Likewise pH is highest at station 61, then at 56 and finally at 58 because at 58 the water closest from near the source has mixed with the surrounding water smoothing the effects of the emission (Fig. 6 and 7).

The increments of nutrients in this post-eruptive face during the volcanic events were already identified during emissions of the eruptive face (Santana-Casiano et al., 2013). But, as expected, the results almost three years later are not as high as those found when the volcano was active. These last results allow comparing the distribution of nutrients in moments of emissions and in their absence.

The measurements of these samples partially contradict Sedwick & Stüben, 1995 measurements of beach fumaroles because their results showed no correlation between the volcanic emission and phosphate or nitrate, only with the silicate, ammonia and metals enrichment.

But the difference may be in that their results are very close to the fumaroles' depths with very low redox potentials. This means it was not contemplate the hydrothermal influence on the water after dilution at other depths like Kiliyas et al, 2013 that observed an increment of  $\text{NO}_2$  and  $\text{NO}_3$  after time to oxidize while reaching shallower depths. Hence Sedwick & Stüben did not study the possibility of oxidation of the enriched ammonia after time. Another difference may be that the emissions at the volcanic site of El Hierro are punctual and quite aggressive and not always continuous so the enrichment of phosphate could be related with the ascension of sediment and deeper water that would not be as noticeable in the continuous fumaroles.

## CONCLUSIONS

From the observations done it can be concluded that the time passed from the eruption has been enough for the nutritional chemistry of the water surrounding the volcano to recover with a consequent recovery of life as shown by direct images. Nevertheless there are still punctual volcanic emissions which affect strongly the distribution of nutrients, especially silicon, and the effect of plumes can extend through the area, however these effects are limited to the deepest layers and travel while mixing to other depths meaning that reactions involving nutrients may be noticed at certain distance from the volcanic source. These perturbations after being lightly diluted can be beneficial. If the emission is not severe it can be really beneficial for primary production.

So unless volcanic emissions are vigorous enough the deviations caused are rapidly dissolved or smoothen by nature. Hence the time from the eruption has been enough to recover the condition in water near the volcano and over it but the deep water in areas of active emissions can still suffer considerable modifications.

The weak activity of the volcano and the multiple evidence of life recovery take to predict that nutrients are providing the conditions for the positive transformation of the area.

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## **TFT REPORT**

### **Detailed description of the activities performed for TFT**

To accomplish my degree project I had to learn how to operate with the Micromac 1000 which I then used to analyse the concentration of the nutrients silicon, phosphorus and nitrogen in their inorganic forms in the water column of the volcanic site.

For this purpose I had to prepare the reactants for each nutrient and get the method calibrated in order for it to display the correct concentration measured. I spend several weeks with each method, running tests to learn its analytical limits and understand its possible flaws, as well as, trying to prepare calibration standards and reactant as accurately as possible and observing their efficiency over time.

It took me especially long time to use properly the nitrate measuring method because it required the preparation of a cadmium reduction column which was a task difficult to achieve with enough precision so the reduction was sufficiently effective.

When all methods were ready I analysed prepared standards to test the instrument and myself for the analysis of real samples and also to see if results were different when nutrients were mixed.

All this tests and even during the analysis were done washing and taking proper care of the apparatus.

I also collaborated 10 days on a research cruise of the IEO to study the underwater volcano of the island of El Hierro for the VULCANO investigation. During the cruise the water samples for the nutrient analysis were obtained and then frozen and transported to the laboratory for the analysis using the Micromac 1000. All the sampling for my study took place in one day and it was carefully labelled and stored frozen for its transport days after.

When the samples were ready and stored and I felt confident with the methods of the Micromac 1000 I prepared reactants and started analysing all the samples that took me quite a while because there were quite a few samples that needed to be de-frozen.

Nevertheless, I spend long periods of time reading papers about nutrients, preparing the topic to understand parameters that may affect their concentration, understanding the conditions of the ocean surrounding the canary archipelago and search for the information on the effect of a volcanic eruption and hydrothermal events on the sea

composition. Likewise I got the degree project ready for its defence which involve the development of a program on Matlab to process the data and display it in the form of vertical sections.

### **Received training**

I was able to use the Micromac 1000 properly for my degree project because I was taught on how it functioned and how to work with it. To do so I was given a manual on the software and hardware that contained instructions for reactant preparation, for the analytical methods the Micromac had programmed.

I was taught, helped and supervised during the first cadmium reducing column preparations due to their difficulty.

I was helped and supervised during the preparation of this manuscript by my tutors.

### **Integration and involvement within de department and relationship with the staff**

The people I've been working with are very professional and thorough workers. Nevertheless, they have always time to help you and I have felt during all the development of my project their disposition to answer any of my questions. I consider not only to have known good colleagues but also to have made good friendships in this laboratory.

I felt integrated because I discuss my problems with the investigations my lab companions but also my results and they share their own with me making me sometimes participant of the solution.

### **Most significant negative and positive aspects of the TFT development**

This has been a complete experience of an oceanographical investigation. I've been able to experience laboratory work and also an oceanographical cruise to investigate a phenomenon of such topicality as a recently erupted underwater volcano.

However I think that workers of the laboratory would benefit of larger spaces to store all the oceanographical material when not in use. The space was enough and I was really comfortable but it is an issue that I feel could be improved.

### **Personal assessment of the learning achievement throughout the TFT fulfillment**

I have been able to improve skills I learned during the degree related with lab work like reactant and standard preparation, and incorporate new abilities like reducing column preparation and the use of an analytical instrument. I've deepened my knowledge on nutrients which I already had some notions on from the degree. I trained other skills I worked on during the degree such as Matlab programming for data processing and displaying, as well as, English writing, reading and speaking which are vital in the scientific field.

After working on the TFT I feel more confident to work on an oceanographical ship because I could train sampling and other activities performed during the research cruise.

I feel completely satisfied with my time working on this Project. It has been a great experience I would gladly repeat.

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