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LE BASSIN DE TIKI (PACIFIQUE SUD CENTRAL) : RELATIONS ENTRE COMPOSITION-DISTRIBUTION DES NODULES ET LA MORPHOLOGIE DU FOND

Guy PAUTOT (*), Michel HOFFERT (**), Anne Marie KARPOFF (**), André SCHAAF (**)

ABSTRACT. The Tiki basin is in the south central Pacific, south of the Marquesas Islands and east of the Tuamotu archipelago. It is bounded northwards by the Marquesas Fracture Zone and divided in two parts by the topographic heights constituting the end to the Tuamotu Fracture Zone. One hundred stations with nodule sampling were occupied by the Group CNEXO-SLN in this area (scale 10 × 10 degrees). The nodule abundance at each station is determined from the weight of nodules brought back by free fall grabs. Chemical analysis were made on each sample (three by station) and the values presented here are the mean values. The parameters : abundance, Ni grade, Cu grade and Mn grade, are compared with water depth and topographic features of the area. The main results are :

- no nodules or very few between 0 and 3900 meters water depth;
- the maximum abundance of nodules (up to 4 kg/m^2) is found at or close an average water depth of 4240 meters;
- the abundance classes between 0.1 and 4 kg/m^2 show that abundance increases with depth in the range 3900 to 4300 meters;
- the Mn maximum grade is represented by a swarm of values near 4230 meters water depth;
- the highest Ni values are situated near 4200 meters, Ni grade also increases with depth;
- a comparable evolution is shown by Cu : most of the higher values occur close to 4245 meters.

In this area, there is thus a noteworthy convergence between abundance and high grade between 4200 and 4250 meters water depth.

Classes of nodule concentration and grade are reported on a detailed map of the area and correlations with the topographic framework are discussed.

RÉSUMÉ. Le bassin de Tiki est situé dans le Pacifique sud central au sud des îles Marquises et à l'est des Touamotou. Il est limité au nord par la zone de fracture des Marquises et séparé en deux parties par des reliefs constituant la terminaison de la zone de fracture des Touamotou. Une centaine de stations de prélèvements de nodules ont été disposées régulièrement dans cette zone par l'association CNEXO-SLN. La densité des nodules sur le fond (échelle 10 × 10 degrés) a été déterminée d'après la moyenne pondérale de trois préleveurs lâchés à chaque station. Les analyses chimiques permettent d'établir une moyenne par station des teneurs en manganese, nickel et cuivre. Ces différentes valeurs sont comparées à la bathymétrie de la zone. Des classes d'abondance et de teneurs sont définies et des profondeurs moyennes déduites pour chaque classe. Les résultats principaux sont les suivants :

- entre zéro et 3900 m il n'y a pas ou très peu de nodules;
- la profondeur moyenne correspondant à la plus forte population de nodules (supérieure à 4 kg/m^2) est disposée autour de 4.240 m;
- les teneurs maximales en manganèse forment un essaim de valeurs autour de 4200 mètres de profondeur;
- les teneurs en nickel croissent également avec la profondeur, les teneurs les plus élevées en nickel se trouvent à une profoneur moyenne de 4200 mètres;
- les teneurs en cuivre montrent une évolution semblable : la profondeur moyenne des teneurs les plus élevées en cuivre est 4245 mètres.

On trouve donc dans cette zone une convergence assez remarquable des fortes densités et hautes teneurs en éléments de transition et manganèse autour de 4200 et 4250 mètres.

Les classes de densité sur le fond et les teneurs sont reportées sur le fond topographique détaillé et les corrélations discutées.

INTRODUCTION

In recent studies (Pautot and Melguen, 1974; 1975 and 1976) on the general environment of nodules in the South Pacific ocean, a schematic model was presented showing the areas favorable to polymetallic nodules. Some factors were important in this model : carbonate dissolution, presence of deep antarctic water, general depth, bottom topography. This model is applied here at the scale of a specific structure, comparing the structural environment with the characteristics of nodules.

Nodules were sampled systematically in a south Pacific reference area which seemed fairly homogenous. This area has approximately a surface of 10 × 10 degrees, with a sampling interval of approximately one degree, totaling one hundred sampling stations. Three free fall samplers were operated at each station. The abundance was determined by dividing the average weight of nodules sampled by the three samplers by the surface of sampling. In the same way, the geochemical parameters (major and transition elements) were determined for each sample and the value used here is the average value for the station.

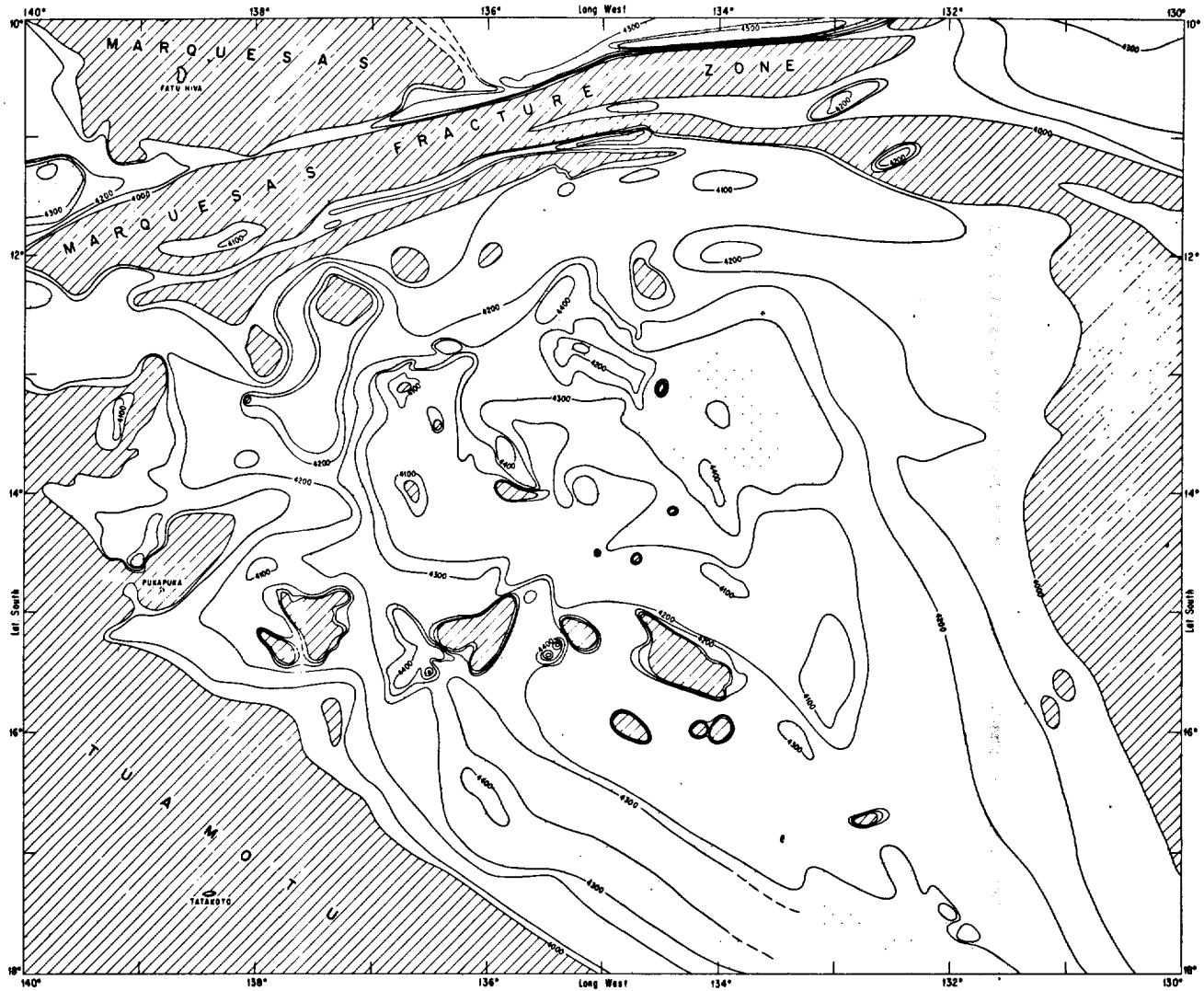
MARQUESAS
FRACTURE
ZONE
MARQUESAS
FATU HIVA
PUKAPUKA
TATAKOTO
PACIFIC
OCEAN
Long West
Lat South
140°
138°
136°
134°
132°
130°
10°
12°
14°
16°
18°

FIG. 1.

The area studied is a rather monotonous area, situated between the eastern border of Tuamotu archipelago and the base of the flank of the East Pacific Rise (Figure 1). This basin, called Tiki basin, is bordered northwards by the Marquesas fracture zone and southwards by the Australes fracture zone. We have used here a bathymetric map on the scale of 1/ 1 000 000, drawn by Monti and Pautot (1974).

ABUNDANCE OF NODULES

It is difficult and even pointless to apply methods of statistical analysis to one hundred samples. A diagram of abundance as a function of absolute depths enables us to find out simply some characteristic families (Figure 2). As an example, the family of samples presenting an abundance higher than 4 kg/m² is situated around 4,100 and 4,300 meters depth. The mean (arithmethic) depth of this family can be determined and is 4,240 m. The limits of abundance of these families have been chosen arbitrarily in order to have a sufficient number of samples, and to get classes comparable to other areas.

Stations with a density of 1.5 kg/m² to 4 kg/m² have a mean depth of 4,200 m; from 0.5 kg/m² to 1.5 kg/ m² : 4,170 m; from 0.1 kg/m² to 0.5 kg/m² : 4,120 m.

Least square straight line probably emphasizes the fact that average abundance increases with depth between 4,100 and 4,250 m.

A second important observation is that no, or very few nodules (less than 0.1 kg/m²) were sampled shallower than 3,950 m. This is not really surprising as most of these stations were made on the flank of the Tuamotu or in Marquesas fracture zone, but some other stations were made on seamounts inside the basin, and there again, no nodules were sampled.

At depths greater than 4,250 m, nodules appear to be less abundant; however, the small number of samples taken at these depths does not allow us to confirm this tendency.

The stations where no nodules were sampled are shown on the morphological map in order to better understand this phenomenon, and to determine the influence of the topography. The absence of nodules is confirmed in the Marquesas fracture zone, in the Tuamotu archipelago, at the convergence point between these two structures, east of this zone and on central heights which seem to be related to an intermediate

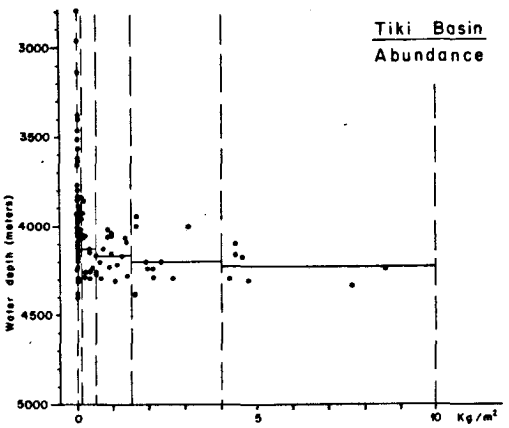

FIG. 2.

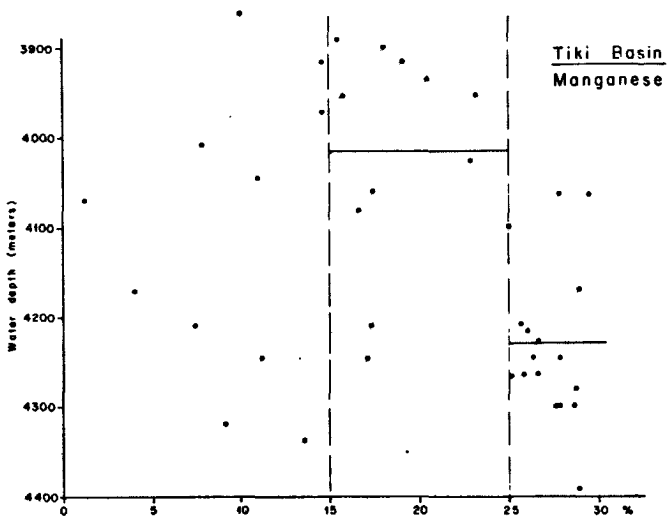

FIG. 3.

fracture zone (Tuamotu fracture zone) (Mammerickx et al., 1974).

In contrast, the stations which show a high abundance of nodules (more than 4 kg/m²) are on the periphery and flanks of two troughs inside the basin : the northern round basin (Tiki basin s.s.) and the southern elongated basin. The mean abundance stations (1.5 kg/m² to 4 kg/m²) are found in troughs.

There are not enough samples to define an abundance rate according to increasing depth in one trough of this area.

MANGANESE CONTENT

The same graphs were established for manganese content as function of depth (Figure 3).

- High manganese content (more than 25 %) are grouped between 4,200 and 4,300 m depth, with an average depth of 4,230 m.
- Average manganese content (between 15 and 25 %) are located at depth varying from 3,900 to 4,100 m, with a mean depth of 4,020 m.
- Manganese contents lower than 15 % are too scattered to permit to relate them to depth.

If we choose as a limit the 20 % content, values less than 20 % are very scattered, while values higher than 20 % show a rapid increase with depth.

Illustrating these values on the map shows that high manganese concentrations in nodules are regional. High values are concentrated in the northern trough and in the southern one. Intermediate values are located near the Marquesas and Tuamotu fracture zones.

NICKEL CONTENT

Two families of nickel-rich nodules were determined : values higher than 1.5 %, values between 1 and 1.5 %, (Figure 4). These two families could in fact be combined, as their characteristics are very similar : most of the values are situated between 4,200 and 4,300 m, though some values are scattered between 4,200 and 3,900 m. We can again deduce a mean depth of 4,200 to 4,220 m for high nickel content.

Medium nickel contents (from 0.5 to 1 %) are found in a wide range of depths and the arithmetic mean is at 4,040 m.

Average depths favorable to high concentrations of manganese and nickel are concordant (4,230 m), as well as medium-rich concentrations (4,030 m). As the values are obtained from the same samples, one can suppose that nickel and manganese are closely related and that their contents vary accordingly.

The morphological map shows some agreement between the location of high manganese and nickel content in the general trough area. However, there are no high or medium nickel contents in the Marquesas and Tuamotu fracture zones. This difference is essential when studying the origin of nodules composition. Finally, nickel contents are higher in Tiki basin s.s. than on its northern side, contrary to manganese values.

COPPER CONTENT

Copper content (Figure 5) is lower in absolute value : the highest value reaches only 1 %.

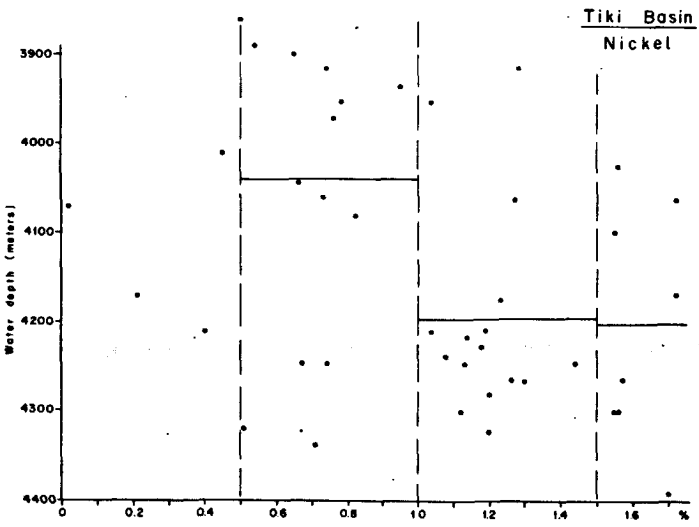

FIG. 4.

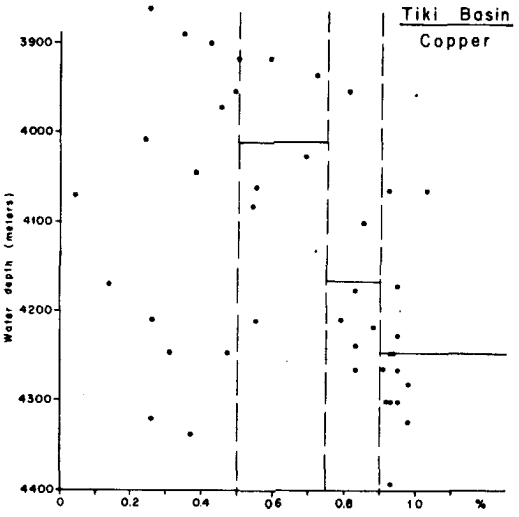

FIG. 5.

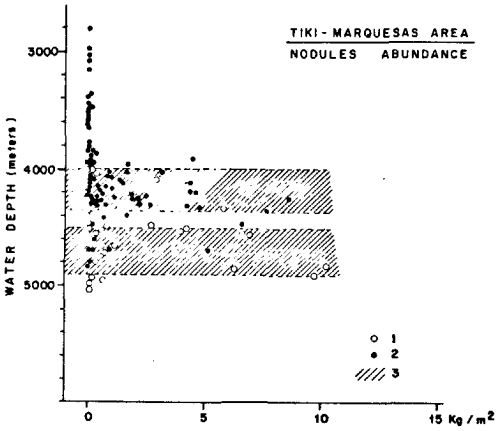

FIG. 6.

We can determine two main families of copper content as a function of depth, higher and lower than 0.75 %. High contents are found between 4,100 and 4,300 m, while lower contents are widely scattered in depth.

Highest contents (more than 0.9 %) are found at an average depth of 4,245 m. If we study all the samples having a content lower than 0.75 %, we find an average depth of 4,200 m; for the medium content samples, the depth is around 4,000 m. This character is common to the three main geochemical parameters of nodules in this area : manganese, nickel, copper.

High copper contents are preferably found in the northern trough area. They are not found in the southern trench. The fracture zone areas are favorable neither to copper nor to nickel.

CONCLUSION OF THIS ANALYSIS

A close link is found between the evolution of manganese, nickel and copper contents with respect to general depth. High contents are located between 4,200 and 4,250 m and medium contents between 4,000 and 4,050 m. However, when reporting these data on a morphological map, differences are noted between these geochemical parameters and the morphology, which are probably linked to the structural and sedimentary environment.

A good convergence is seen between the abundance and the manganese, nickel and copper contents in the studied area. The convergence zone is between 4,200 and 4,250 m depth.

EXTENT OF THE STUDY

Results of analyses of Tiki basin samples leave us with two unanswered questions :

- Is there a decrease in the studied parameters below the average preferential depth ?
- Does this preferential average depth vary according to the structural framework ?

An abundance diagram, covering an area wider than the whole Tiki basin can give us a tentative answer (Figure 6). Samples locations are reported on the diagram on both sides of the Marquesas fracture zone. We notice a difference in high-abundance depths between north and south Marquesas fracture zone areas. The high abundance depth is about 4,200 m in the south of the Marquesas fracture zone (as already shown in Tiki basin), while it is about 4,900 m to the north.

Depths favorable to high densities of nodules are comparable in both places, and are within a 300 m fringe : between 4,000 and 4,300 m in the southern area, and between 4,600 and 4,900 m in the northern area. Inbetween these 300 m, the highest values are found at the deeper depths.

This wider range of sampling shows that under preferential depth for high nodules densities, a fast decrease occurs. This phenomenon is visible in both areas. If verified, this is a very important fact for exploration.

DISCUSSION

These elements suggest a relationship between nodule abundance and carbonate dissolution. We know that the carbonate compensation depth (CCD) increases

near the Equator because of increasing productivity (Berger, 1976). The graph of nodule abundance follows the CCD graph. However the study of associated sediments (Hoffert et al. this volume) shows that maximum abundance depths do not correspond to CCD but are higher. In the Tiki basin, for example, the highest abundance is found at 4,200 m depth and the CCD would be at 4,500 m depth. Maximum abundance is located at a level which has a more or less high carbonate dissolution rate, between lysocline and CCD (Pautot and Melguen, 1978). We have called this the N facies. The content in transition elements is thought to increase from top to bottom of this N facies until the CCD is reached. The best economic agreement between abundance and content would be determined when highest abundance depth is near the CCD.

ACKNOWLEDGMENTS

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DISCUSSION

G. ARRHENIUS : You reported a large number of stations from all depths, where nodules are absent or at least not sampled. What is the nature of the sediment and the sea floor at these stations ?

G. PAUTOT : Stations without nodules are present at all depths on the Tiki Basin. But, the important fact is the total absence of nodules up to 3900 meters water depth. In this fringe associated sediments with nodules are dominantly calcareous. Below 3900 meters water depth, stations without nodules are often situated on topographic heights (top or flanks) But in some stations around 4200 meters water depth with red clay and smooth topography no nodules were also recovered.

P. BONTE : Do you observe some morphological, structural or mineralogical differences between the nodules from Marquisas Fracture zone (at 3900 m-4000 meters depth) and the Mn, Ni, Cu-rich nodules from the 4200 meters depth zone ?

G. PAUTOT : In this paper we did not present data on the morphological and structural facies of nodules. In a next paper we shall give information on the nodules of the Tiki Basin in comparison with other areas in the South Pacific Ocean.

J. GREENSLATE : Do you know the efficiency for nodule recovery by the CNEXO grabs ? How might this efficiency question affect the reported convergence between nodule abundance and Cu, Ni content ?

G. PAUTOT : It is very difficult to determine the efficiency of a grab. We can compare the weight of nodules in a grab, the porportion of nodules size classes, with an estimation from associated sea-floor photographs. Precision of such an estimation is about 50 %. Generally, by comparison with our sea-floor photographs and other samplings (in literature) our abundance values seem underestimated. I don't believe this pessimistic determination of abundance affects the observed general phenomenon of convergence between abundance and Ni, Cu content in the Tiki Basin.

R.K. SOREM : Were the sea floor photographs you mentioned taken by cameras *on* the grab samplers or by cameras lowered at a different time (and therefore at different site). The purpose of the question is to learn the basis for your statement that grabs show fewer nodules than photographs.

G. PAUTOT : Sea-floor photographs were taken, in the Tiki basin, with free cameras launched at the same time as free-fall grabs, but cameras were *not on* the grab samplers. Difference between weight of nodules in grabs and estimation on photographs are due principally to the covered surface by grabs (0.18 m^2) and photographs (1.0 m^2) on heterogeneous areas.

M. SCHVOERER : Dans la zone de prelèvement des nodules, des mesures precises de temperature de l'eau, entre 4000 et 4200 metres ont-elles ete effectuees, et si oui, que montrent-elles ?

G. PAUTOT : Nous avons peu de données hydrologiques dans le bassin de Tiki et c'est la raison pour laquelle nous ne presentons que comme hypothese l'avancee d'eau profonde d'origine antarctique dans cette zone.

Cependant, nos données suggèrent un passage d'eau profonde dans la zone de fracture des Marquises : temperature potentielle de 1,68ºC à 3800 metres de profondeur sur des fonds de 5000 metres, alors que l'eau de fond sur la crête de la dorsale Est Pacifique presente des valeurs de 1,82º à 1,96ºC et des valeurs de 1,79ºC sur les flancs (mesures realisees durant la campagne TRANSPAC II).