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P8

OPTICAL ANALYSIS OF SHALLOW WATERS IN THE LAKE ENVIRONMENT

ANALYSE OPTIQUE D'EAUX SUPERFICIELLES EN MILIEU LACUSTRE

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ABSTRACT

First results of an application project in the field of the optical remote sensing from satellite platform to monitoring the lacustrine coastal environment are here presented. Landsat Thematic Mapper imagery have been considered, on the basis of their good performances in the bands of visible, particularly useful for studies in water quality, although narrower wavelength intervals would be more suitable to the problem.

The case-study deals with the analysis of reflectance variations occurring in the shallow waters of the lake Garda (Northern Italy) depending mainly on the suspended materials and chlorophyll-a production, beyond the effects brought by the massive increase of tourists, with particular concern to the summer season respect to the other periods of the year. In this manner the residual optical anomaly which is detected can be seen as a transducer, or an indicator, of acting modifications due to the organic pollution, when the other remaining sedimentological influences could be separately identified.

Image handling has been carried out on the consideration of simple concepts about optical properties of water as commonly employed in remote sensing. No particular care has been paid to the atmospheric corrections or other algorithms since quantitative evaluations have not been done. The information acquainted results to be good enough for mapping some patterns of turbidity and chlorophyll-a distribution in agreement with the recent historical records from drilling logs realized into the sediments on the bottom of the lake.

RESUME

Les premiers résultats d'un projet d'application dans le domaine de la télédétection optique dans le but de contrôler l'environnement côtier en milieu lacustre à partir de données satellites sont présentés ci-dessous. Le système Landsat Thematic Mapper a été considéré, compte tenu de la bonne performance de ses bandes dans le visible, particulièrement utiles pour étudier la qualité de l'eau, bien que des intervalles de longueur d'onde plus étroits permettraient de mieux traiter le problème.

Le cas étudié traite de l'analyse des variations de réflectance se présentant dans les eaux superficielles du lac de Garde (Nord de l'Italie) et dépendantes en grande partie des matières en suspension ainsi que de la production de chlorophylle-a, avec un effet accru en période estivale par rapport aux autres saisons. De cette façon, l'anomalie optique résiduelle qui est détectée peut être percue comme un indicateur de nouvelles modifications dues à une pollution organique, alors que les influences sédimentologiques subsistantes peuvent être identifiées séparément.

Le traitement de l'image a été excuté sur la base de simples concepts s'appliquant aux propriétés optiques de l'eau, concepts aussi bien utilisés en télédétection. Aucun soin particulier n'a été apporté à des corrections atmosphériques ou autres alogrithmes tant que des évalutations quantitatives n'ont pas été faites. L'information acquise se révèle être assez bonne pour cartographier quelques modèles de turbidité et distribution de chlorophylle-a, en accord avec les données récentes et historiquee provenant de forages réalisés dans les sédiments du fond du lac.

INTRODUCTION

Remote sensing applications to water quality analysis are a consolidated method for marine and lacustrine environmental observations, although several cautions must be forwarded before embarking in these kind of experiences.

In particular we here refer to the behaviour of the water in relation to its reflectance amount in the optical bands of the electromagnetic spectrum, where it shows a much lower value respect to the other terrestrial natural features, as tested by Morel and Prieur (1977). This value is furtherly attenuated by the selective absorption operated by the atmospheric path.

So, the entity of the electrical signal which succeeds to reaching at the remote sensor results to be quite low, almost comparable to the noise's one, so that the resulting effect is so high to be the greatest problem in the remote sensing application to water studies, beyond other uncertainties for a quantitative evaluation which always requires in situ references for calibrations.

Secondarily, the problem of monitoring the water implies to take into account the great spectral variability of the water conditions due to the different interaction mechanisms with the oncoming electromagnetic energy, whereas the main reflectance effects are due to the sun light glittering and local meteorological situations. The other reflectance properties are governed by the different concentrations of suspended materials (both organic and inorganic) and to the presence of phytoplancton (chlorophyll-a and carotenoids) and floating macroalgae.

With particular concern to the coastal zones, the depth of waters and the bottom reflectivity properties are finally the last influences onto the measured radiance collected by the remote instrument. The transition zone between coastal and open waters is usually considered of great importance as the representative zone where man's influence is quite remarkable and evident, either by direct pollutant action from his large settlements or by indirect impact suffered by degradating actions coming from the inlands under the form of runoff and drainage, either at surface or at the subsurface level.

The case-study here presented deals with the first results of recent research activities carried out in the field of the remote sensing applications to monitoring of the coastal environment of the lakes.

So far, few works have been attempted on the lake waters ; that's been mainly for the low ground resolution of previous satellite sensors respect to the mean sizes of lakes in the world. In particular, we here refer to the colour analysis conducted by Bukhata et al., (1983) and by Jaquet and Zand (1989).

The site concerns with the southern basin of the lake Garda, is located in Northern Italy.

OUTLINES OF THE LAKE GARDA

The lake Garda is the largest in Italy, with a surface of 368km2 and a 133 meters of mean depth. Upon the conclusions by Bonomi et al., (1979) about the recent evolution of its environment, it can be classified as an oligotrophic lake with a good oxigenation of the waters. The relatively low rate of rainfalls, the limited extension of the hydrographic basin respect to the lake area and the noticeable volume of its water (about 50km3) fixes the theoretic cycle for water rechanging at about 27 years ; that's the principal reason because it appears to be much healthier than other sub-alpine lakes: the concentration of pollutants is very low, since the volume of waters is big ; however, pollution is mainly due to domestic and urban activities with particular intensity in summer due to the heavy tourism impact.

Analysis of records in the sediments

A campaign was performed in 1986 to realize drillings into the first 100 centimeters of the bottom of the lake (Parise et al., 1987). Analysis of sediments concerned different reference stations ; among them, here are presented the two of interest, namely Desenzano and Peschiera, centered in the middle of the two sub-basins, in the southern part of the lake (see fig. 1 for location) to be as representative as possible of the water masses involved.

Studies on recent sediments layered onto the bottom of the lake show their great importance in the acknowledgment of ecological variations occurred in the past and to check the quantity and the quality of pollutants interesting the whole basin, not only of autochthonous origin. Analysis of cores collected gives information about chemical and biological aspects of the sediments. Particular attention has been paid to the following factors which mostly are linked to the eutrophication:

- the concentration of phosphorus P and iron Fe ;
- the concentration of chlorophyll-a and carotenoids ;
- the concentration of organic matter ;
- the concentration of remain of Cladocera, a small planctonic organism that is a good indicator of active trophication.

Their distribution columns are shown in fig. 2, related to the sub-basin of Desenzano (a) and Peschiera (b).

Some remarks are possible :

Ø The sedimentation is quite slow and accumulative, far from perturbation of continental origin with a low sedimentation rate : 0,086 g/cm2 at Desenzano and 0,062 g/cm2 at Peschiera, according to the observation made by Parise and Premazzi (1986).

Ø The P and chlorophyll-a increments in the superior layers state the close relation between nutrients and primary production and show that productivity has been increasing after a diminuishing concentration of ipolimnic oxigen, starting from 1970.

Ø Concentration of organic matter and remains of Cladocera clearly increase during the same period only at the Desenzano station.

Ø All diagrams of Peschiera show high variability ; that can be explained by the numerous periodic fluctuations in the sub-basin, more exposed than the Desenzano's to the influences of an appreciable water circulation and mixing, perhaps due to the outlet vicinity.

LANDSAT THEMATIC MAPPER IMAGE ANALYSIS AND INTERPRETATION

Landsat Thematic Mapper (TM) images were acquired concerning the scene studied, within the frame 193-28, at two different dates: 7 April and 13 August 1985, which correspond to very representative seasonal moments for sub-alpine lacustrine environment.

No atmospheric corrections nor de-striping techniques have been applied; only the haze correction by the histogram equalization of the short wavelength bands referenced to the near infrared was performed.

The images analyzed have been processed through the steps hereby described as follows :

- generation of a blanked mask in order to consider only the pixels surely belonging to the water category and to avoid influences by terrestrial features in the successive image analysis;

- analysis of histograms of first four TM optical bands (from 450nm through to 900nm) ;

- application of linear contrast stretching of DN's (Digital Numbers).

Image handling has produced some interesting products here described.

Ø True Colour Composites (TCC) as shown in colour figs. P8A1-2, by the RGB composition of the bands TM3, TM2 and TM1, respectively. The distribution of the sediments and chlorophyll-a appear quite different in the two considered seasons, with precise geometric patterns more evident in summer than in springtime when they appear almost flattened. Of course the plumes appear to be mostly linked to the shallow waters, less than 10 meters deep, and comparable to the coastal bathymetry of fig. 1.

Ø Colour density slicing of band TM1 (450-520nm) on the basis of the equal DN's difference. The resulting elaborations, presented in colour figs. P8B1-2, clearly show the different levels of the blue radiant absorption. Starting from the lowest value to the highest value, they can be summarized and interpreted as follows :

Depth Zone	Colour Code	Descriptor
Coastal, 2 m	Yellow	Bottom reflectance
Coastal, 5 m	Red-orange	Suspended sediments
Coastal, 10 m	Green	Chlorophyll-a
Pelagic, > 10 m	Blue	Deep water

The difference of the two situations is enhanced by the expansion of the green and the red-orange levels, passing from April to August. In effect, the yellow level, confined to the first 2 meters of depth does not change to much ; on the contrary, the turbidity spreads a lot, with particular intensity in the sub-basin of Peschiera. The distribution of the green level appears to be more uniform in the western sub-basin of Desenzano, interesting also the pelagic zone up to about the surficial limit of 120 meters of depth. The red-orange and green levels seem to be not dependent on the bathymetry; that might be slightly seen into the Peschiera sub-basin, especially for the red-orange level.

Ø TM2 and TM1 band ratioing in order to describe the chlorophyll-a distribution. This elaboration (see colour figs. P8C1-2) has not produced the expected results for the great noise's effect resulting on the image. That should depend upon the small quantities ratioed whose values are comparable to the noise equivalent reflectance differences of the instrument.

Ø The presence of eventual tributes in the region of the infrared reflectance have been explored by the colour density slicing of band TM4, on the basis of equal DN's difference. They are imaged in colour figs. P8D 1-2, where striking differences are remarkable, passing from April, where high and uniform absorption is outlined, to August where different colour levels are presented. The most logical interpretation also in this case is due to the turbidity and chlorophyll-a influences on the reflected irradiance. It also seems that the uncomplete absorption by waters in this

electromagnetic region can be caused by the presence onto the surface of some gas, produced by anomalous situations either of productivity of nutrients or other organic concentrations, so that the radiance collected is consequently influenced. Another explanation could be found in possible skin-layer effects due to the presence of oil thin layers and organic bio-chemical pollutants.

CONCLUSIONS AND FUTURE WORK

The comparison of the images available and their elaborations show a general agreement with the historical records represented by the sediments and analysed by the drilling campaign. This result is of great meaning, since two kinds of data of quite different origin have been compared and utilized: the long-term variation records in the eutrophication evolution and the very short-term data taking represented by the instantaneous satellite imagery whose great advantage is the knowledge about the spatial distribution of the parameters studied and their spectral discrimination.

The main result is the noticeable difference of surficial components of turbidity and chlorophyll-a production during the summer season respect to the springtime which greatly helps in the assessment of different levels of eutrophication spatially distributed.

Future work needs the colour analysis of the two separate sub-basins in the first three TM bands by the methods of chromacity space through the reflectance computations, as suggested by Bukhata et al., (1983) and recently tested by Jacquet and Zand (1989) over more than 50 samples of subalpine french and swiss lakes. So far, remote sensing technology has permitted modest success in the examination of inland waters. Future improvements of sensors on polar platforms, like HIRIS and MODIS, promise better opportunities.

REFERENCES

BONOMI G., A. CALDERONI, R. MOSELLO, 1979. Some remarks on the recent evolution of the deep italian subalpine lakes. *Proceed. Symp. Biol. Hung.* 19, 87-111, Budapest.

BRIVIO P. A., P. COSTA, E. ZILIOLI, 1987. Il monitoraggio della qualità delle acque del lago di Garda mediante telerilevamento da satellite. *ECO-Ecosistemi n. 10,* pp. 9-12, Brescia.

BUKHATA R.P., J.E. BRUTON, J.H. JEROME, 1983. Use of chromaticity in remote measurements of water quality. *Remote Sensing of Environment. 13* : 161-177.

JAQUET J.M., B. ZAND, 1989. Colour analysis of inland waters using Landsat TM data. *Monitoring the Earth's environment*, pp. 57-67, ESTEC, Noordwijk.

MOREL A., L. PRIEUR, 1977. Analysis of variations in ocean colour. *Limnol. Oceanogr., vol 22*, pp. 709-722.

PARISE G., G. PREMAZZI, 1986. I fenomeni di compattazione nella geocronologia dei sedimenti lacustri. *Acqua e Aria, 8*, 783-790.

PARISE G., A. RIVA, L. SUPERCHI, 1987. I sedimenti del lago di Garda: registrazione della recente evoluzione trofica del bacino. *ECO-Ecosistemi, n. 10*, pp. 3-8, Brescia.

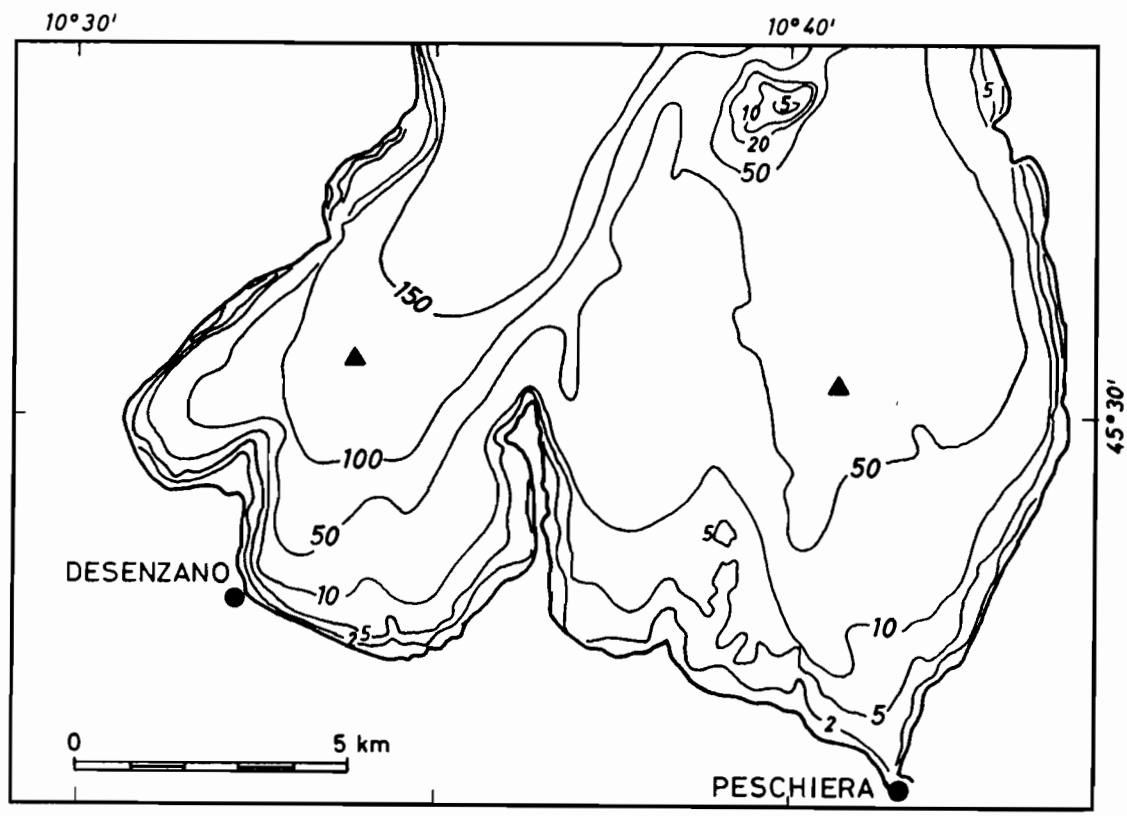


Figure 1 - Bathymetry of the southern part of lake Garda (Northern Italy). Coastal limit of 10 meters depth and drilling sites (s) are outlined.

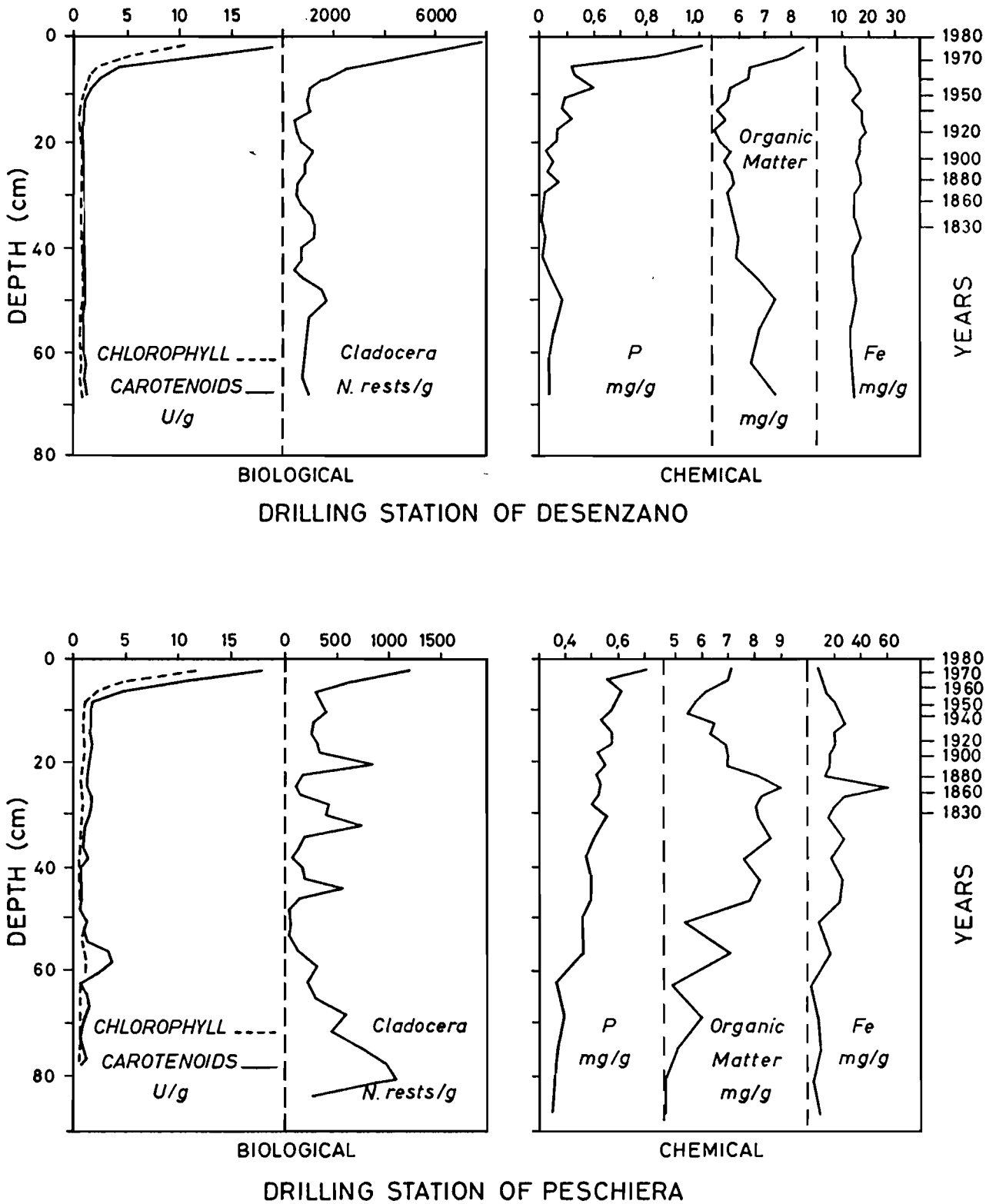
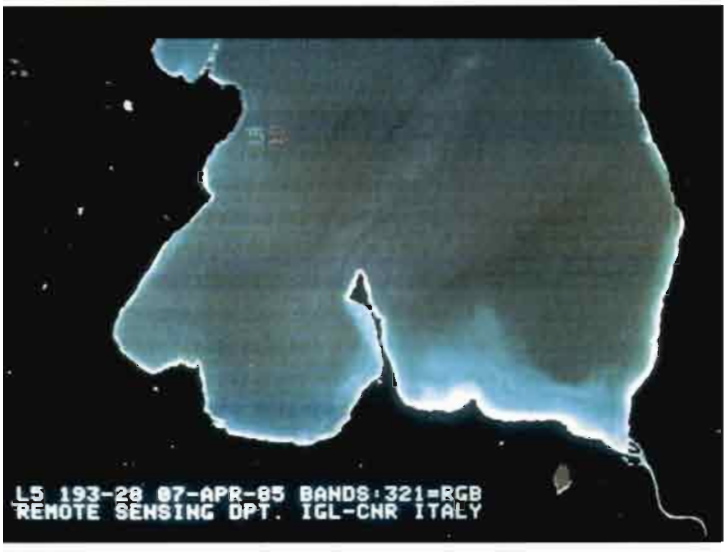
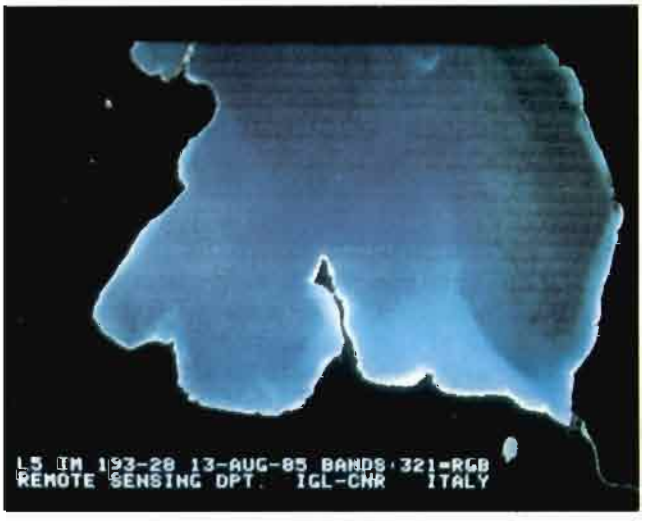


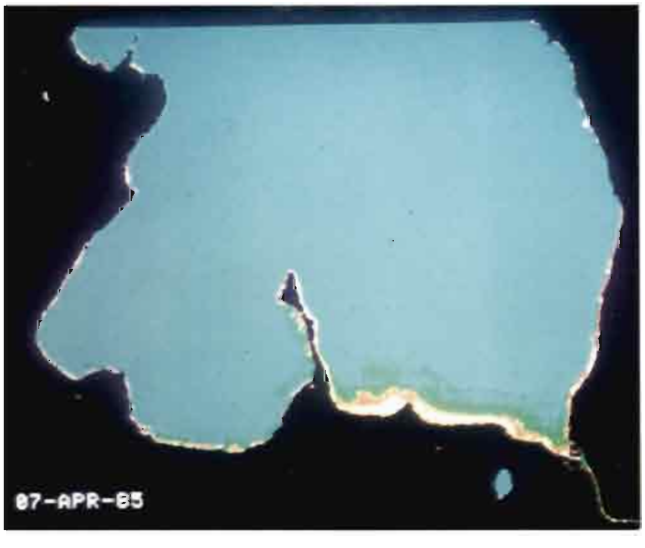
Figure 2 - Chemical and biological logs from the analysis of the cores drilled in the first 100cm of the bottom sediment in the middle of the sub-basins of Desenzano (a) and Peschiera (b). Chronological scale is also shown.

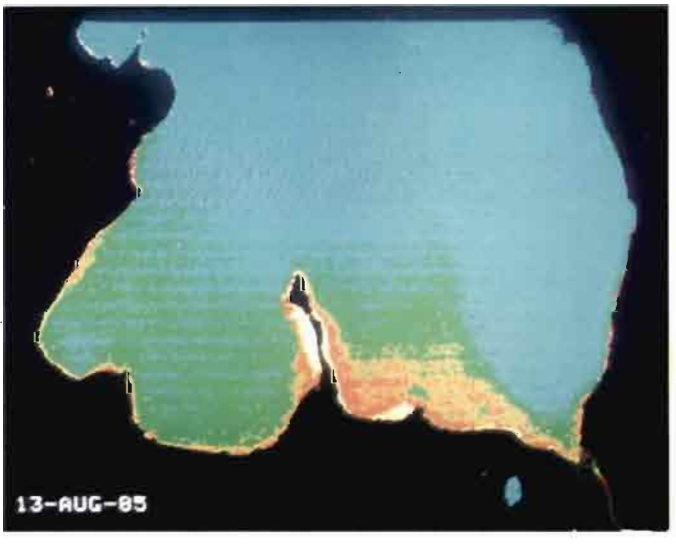




1 2

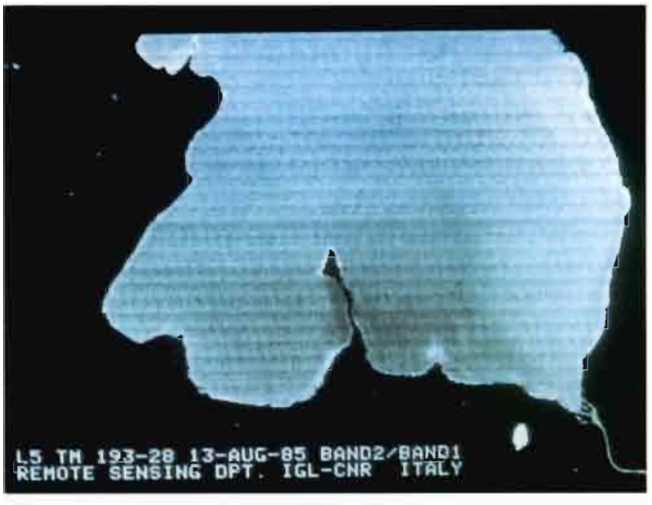
P8A - True Colour Composite RGB : 321.
1 : 07 April 1985 2 : 13 August 1985





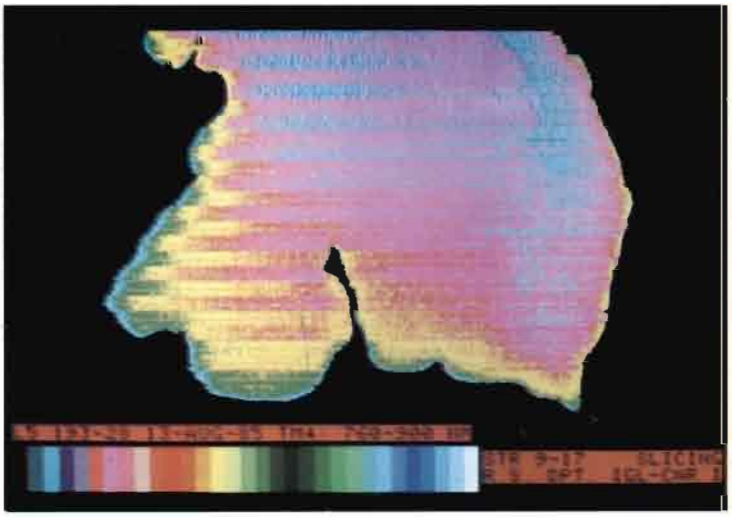
1 2

P8B : Colour Level Slicing of the blue band TM 1 (450-520 nm).
1 : 07 April 1985 2 : 13 August 1985



1 2

P8C : Ratio of bands TM2/TM1 for chlorophyll description.
1 : 07 April 1985 2 : 13 August 1985



1 2

P8D - Colour Level Slicing of the near infrared band TM 4 (760-900nm)

1 : 07 April 1985 2 : 13 August 1985

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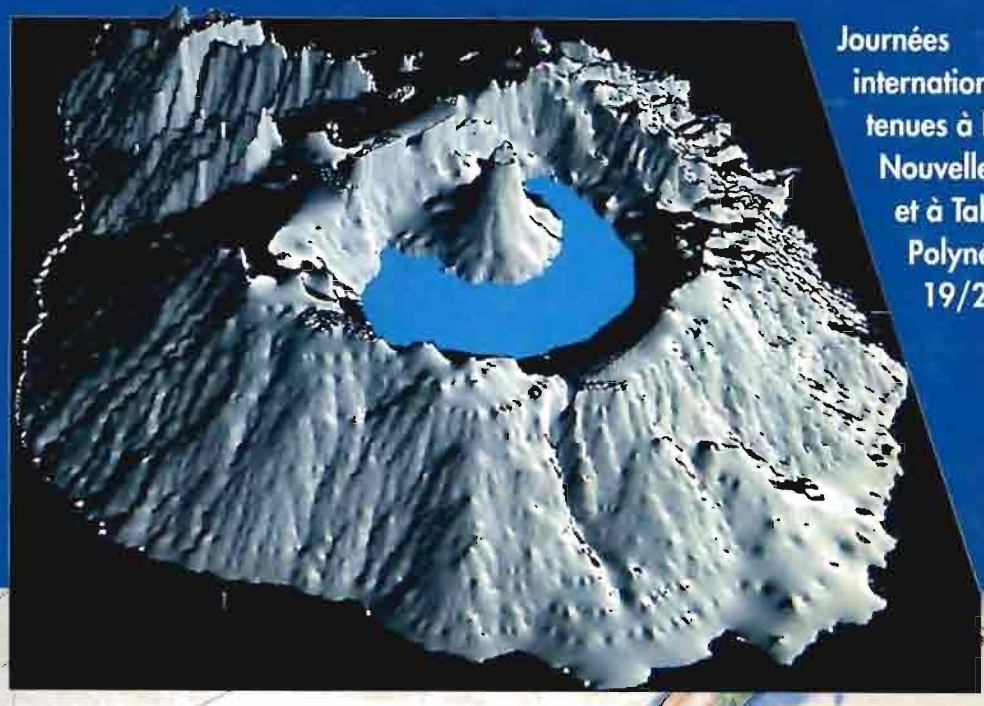

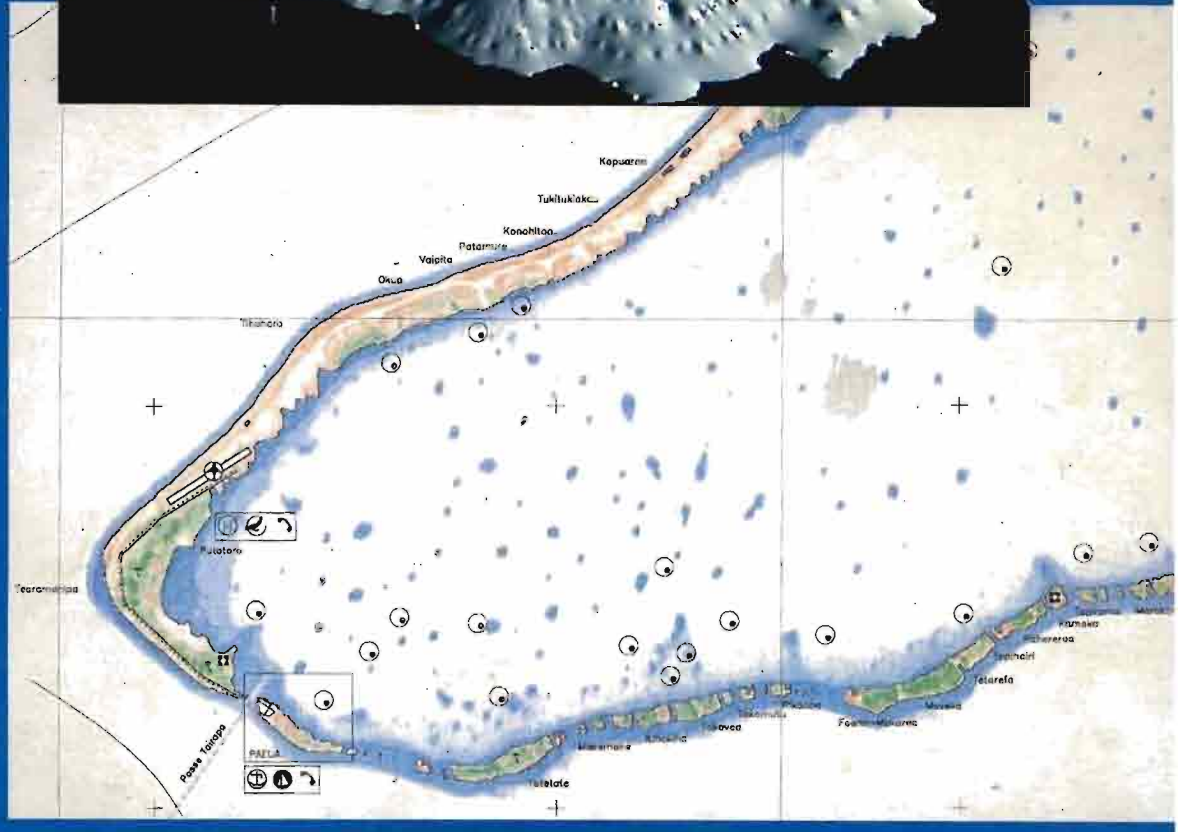

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