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Paper R 6

FIRST ERTS-1 RESULTS IN SOUTHEASTERN FRANCE: GEOLOGY, SEDIMENTOLOGY, POLLUTION AT SEA

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ABSTRACT

This paper summarizes the results obtained by four ERTS projects in Southeastern France (MMC 009.01, 009.02, 009.03, 009.04). With regard to geology, ERTS photos of Western Alps are very useful for tectonic interpretation because large features are clearly visible on these photographs even though they are often hidden by small complicated structures if studied on large-scale documents. The 18-day repetition coverage was not obtained, and time-varying sedimentological surveys were impossible. Nevertheless, we were able to delineate the variations of the shorelines in the Rhone Delta for a period covering the last 8,000 years. Some instances of industries discharging pollutant products at sea were detected, as well as very large "anomalies" of unknown origin. Some examples of coherent optical processing have been made in order to bring out tectonic features in the Alps mountains.

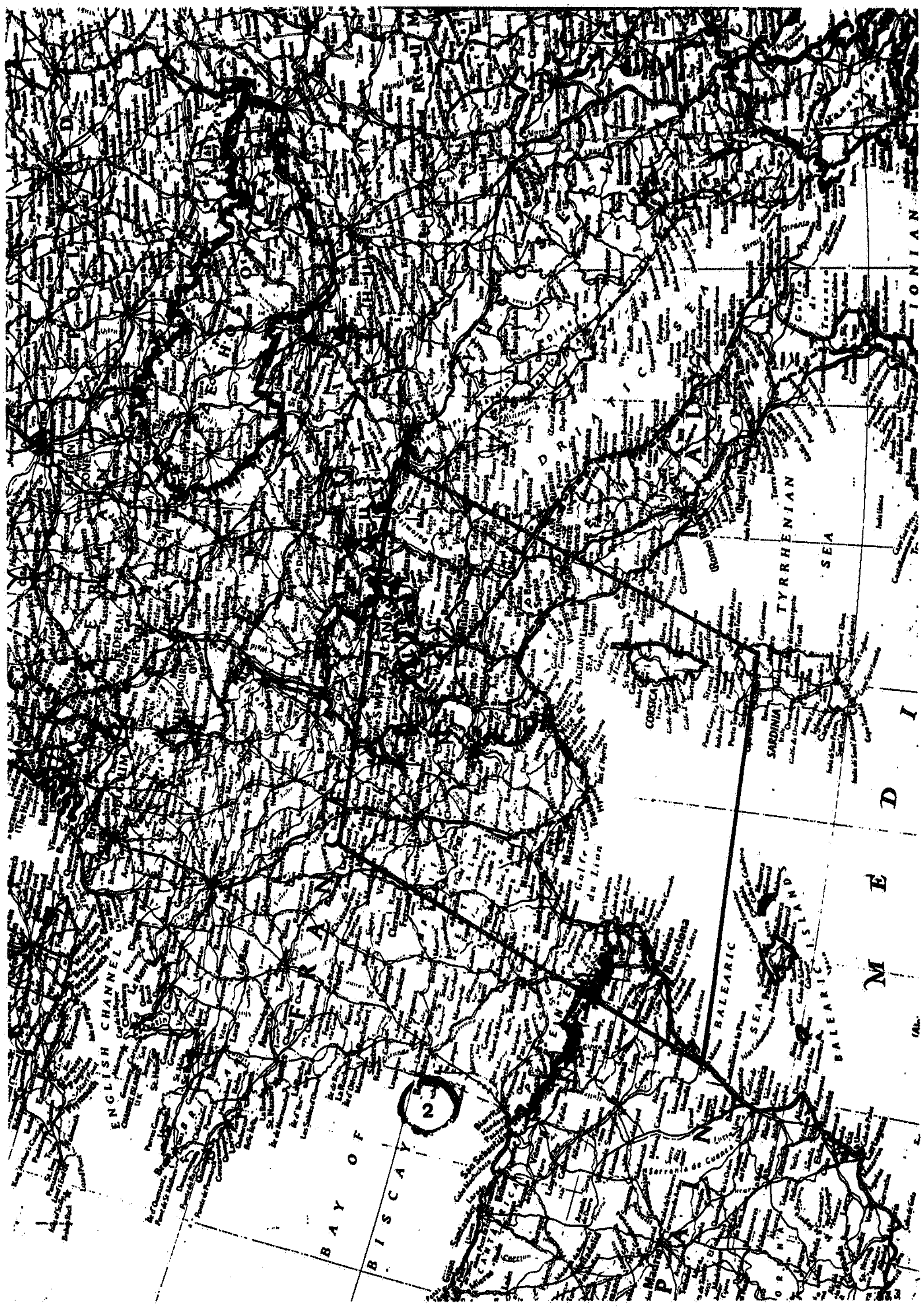
I - LINEAR TRENDS OBSERVED IN THE WESTERN FRENCH ALPS

(P.I. J. Guillemot) MMC 009.03

1. INTRODUCTION

The aim of the project PYRALP (009.03) was to study the tectonic relationships between the Alps and the Pyrenees and to make a survey of the fault network which separates these two mountain ranges and which is supposed to be related to the western Mediterranean collapse. Bad weather during autumn does not permit any image of the eastern Pyrenees to be obtained. Cloud cover was always much too heavy so it was impossible to carry out the main objective of the project.

But several very good photos of the Alps were delivered. They permit the improvement of ERTS 1 data in a structurally very complicated region. Indeed, one ERTS photo of this area shows a whole section of the Alpine chain in which rocks are intensively folded


ENGLISH CHANNEL
BAY OF BISCAY
2
Golfe du Lion
Barcelona
BALEARIC SEA
BALEARIC ISLANDS
LIGURIAN SEA
CORSICA
SARDINIA
TYRRHENIAN SEA
IONIAN
M E D I

and faulted. For the most part, each of the structures is less than 5 km wide and they are often hardly discernible from the photo.

However, through the various trends of the numerous small structures due to the folding of the sedimentary cover, linear features showing few preferential trends can be separated. These features, which are mainly visible when observed in a mosaic of several photos, are presented here on only one photo taken as an example.

2. GEOLOGICAL SKETCH OF THE AREA DESCRIBED

The area described in this paper, as an example of the information that the ERTS images can add to geological knowledge, is undoubtedly among one of the areas in the world more visited by geologists during the last century. The number of published papers about the geology of the western Alps is very great. It could be more than one thousand.

The selected example is part of the area shown by photo No. 1078-09562 of Oct. 9, 1972. This photo represents the valley of the lower Rhone, south of the city of Lyons and north of its Delta. There the Rhone runs from north to south and its valley, partially filled by alluvial deposits, separates the Massif Central in the west and the Alps in the east.

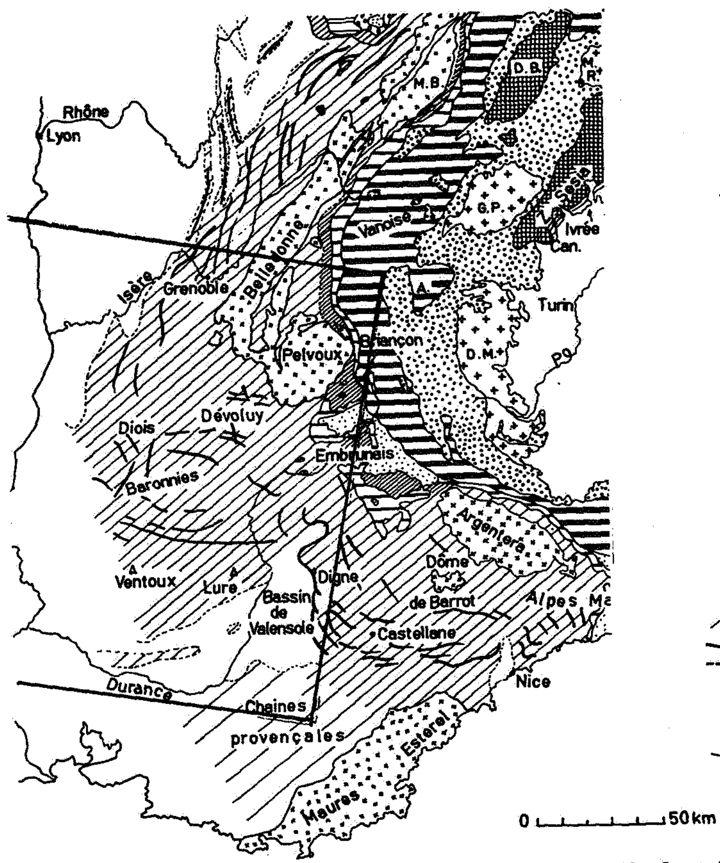
The Massif Central is a large uplift of metamorphosed rocks, mainly of Hercynian age, covered by a thin, deeply dissected layer of sedimentary rocks of Mesozoic age. The rise of the uplift was contemporaneous to the Alpine folding and accompanied by volcanism (Chaine des Puys) and formation of meridian troughs (Limagne). On its eastern border, the sedimentary rocks gently dip southeast although cut by numerous faults.

The Alps differ from the Massif Central by a thick severely-folded sedimentary sequence of Mesozoic and Cenozoic ages.

Several provinces have been separated by Alpine geologists, and, as can be seen in Figure 1, the westernmost part of the French Alps, represented by ERTS photo 1078-09562, is in the outer province (domaine externe) where are distinguished a "zone dauphinoise" in the north and a "zone provençale" in the south.

One of the outer crystalline massifs (Pelvoux, Belledonne) lies in the northeastern corner of the photo.

The "zone dauphinoise" is characterized by folds trending north-south in opposition to the "zone provençale" where the axis of the fold is east-west.



(After J. Debelmas and M. Lemoine)

Fig. 1

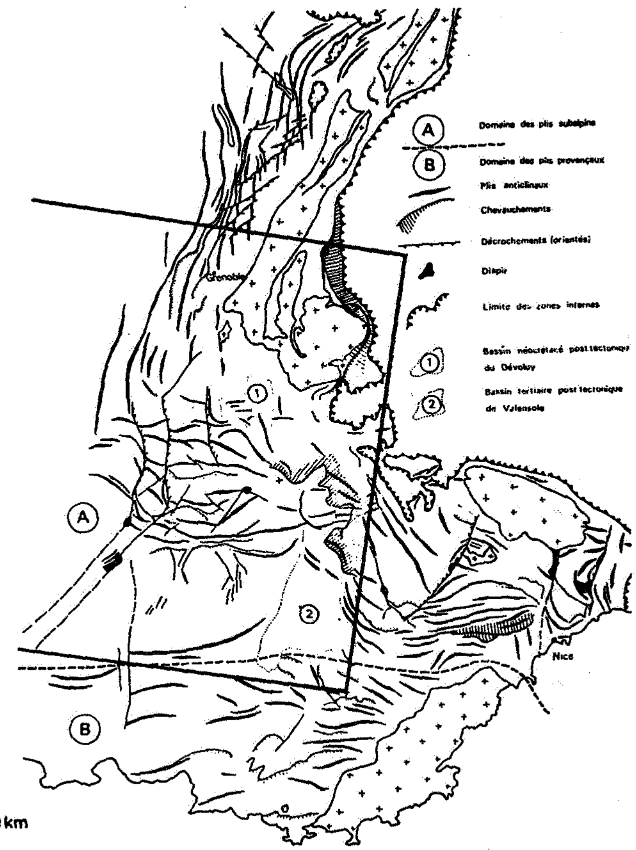


Fig. 2

Figure 1 is a structural sketch map of the western Alps published a few years ago (J. Debelmas and M. Lemoine*). On this map the area studied can easily be replaced in the general context of the Franco-Italian Alps. The sketch does not reveal any linear fracture, but several of them are drawn on Figure 2 published later by the same two geologists. The limits of ERTS photo No. 1078-09562 are drawn on both Figures 1 and 2.

DESCRIPTION OF THE AREA REPRESENTED BY ERTS PHOTO No. 1078-09562 (figs. 3 and 4)

An attentive study of the ERTS photo selected for this paper has been made. The features observed are not new features. They can be found on published geological maps (this is not very surprising in an area where so many geological surveys have been carried out). However several linear features can be pointed out more accurately than can be done from field surveys and geological maps.

West of the Rhone valley to the north of the Ardeche River are sedimentary unfolded Mesozoic series of the east flank of the Massif Central. Metamorphic rocks outcrop northwest of the Rhone-Isere junction. Dominant features are fracture lines trending mainly N 50° E to N 60° E with a few directions N 30° E to N 40° E. These faults are present both in the sedimentary and metamorphic rocks.

Southward, in the southwestern corner of the photo are gentle folds trending eastwest, cut by faults trending N 50° E to N 60° E. Some fractures trending north-south can be observed in the westward adjoining ERTS photo (1061-10015). They are only present in metamorphic rocks.

35 km north of the Ardeche River is a remnant of a quaternary basalt flow, the "Plateau des Coirons."

In the area east of the Rhone Valley the relief appears more intricate. However the two main directions of folding (dauphinoise and provençale) are quite clear from the photo (Fig. 3), i.e. N-S in the north, E-W in the south. Most structures are asymmetric, the anticline often overthrusting its syncline. On the photo some of the synclines are easily discerned owing to the reversal of relief in the Mesozoic series where thick limestone and shale formations alternate, but drawing the axis of the anticlines is almost impossible.

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* J. Debelmas, M. Lemoine, 1964, L'Information Scientifique, Edit. Baillière et fils, Paris, p. 1-33.

Fig.3
Photo ERTS 1078 - 09562 - 6 -
Scale : 1/1 000 000
(A strip 5cm large has been cut off in the right side of the original photo)

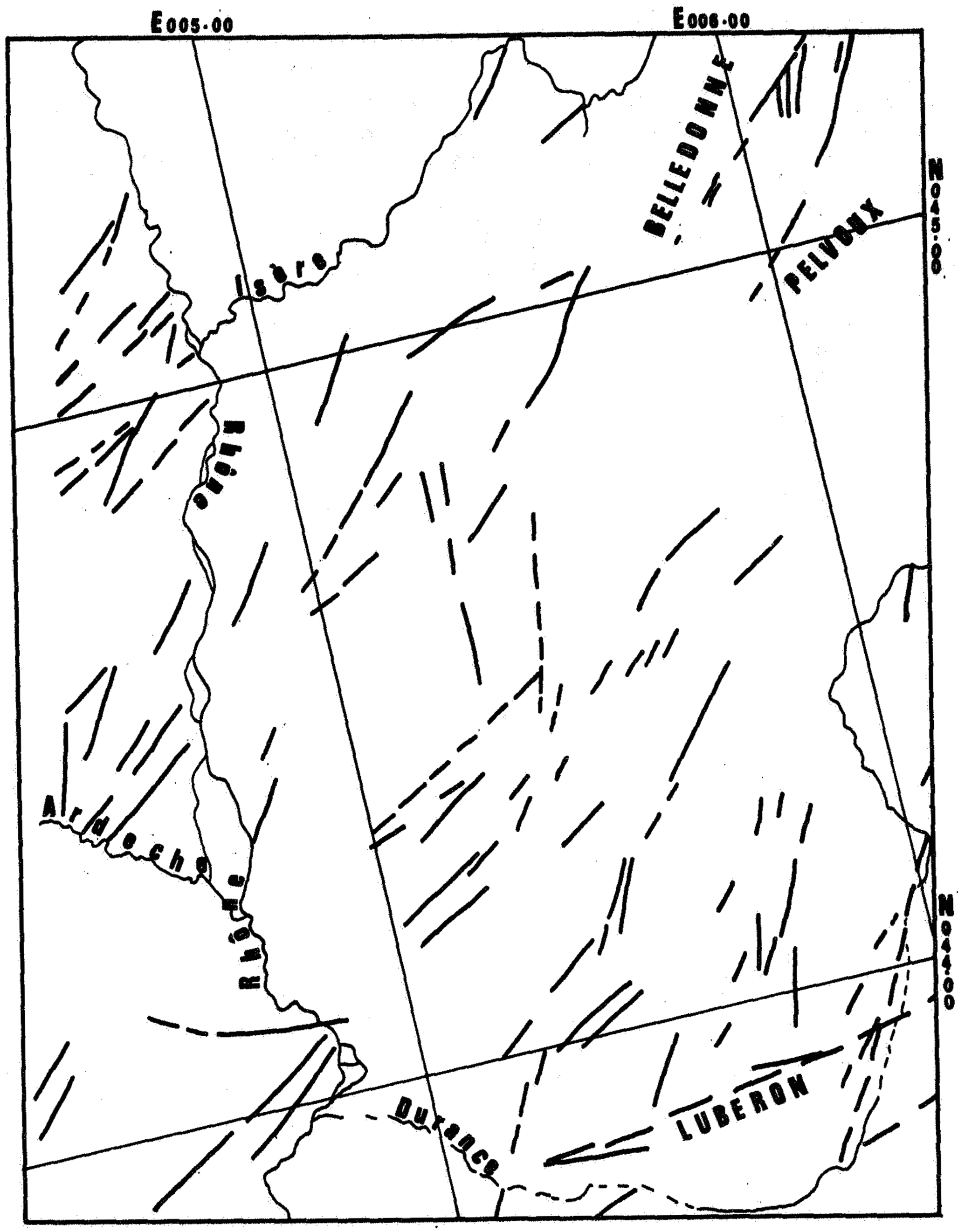

Fig. 4
Overlay of the photo fig. 3, showing the linear features pointed out.
Scale : 1/1 000 000.
Explanation in the text.

As in the border of the Massif Central, west of the Rhone, and in spite of a much more complicated tectonics it is possible to point out numerous linear features (Fig. 4). Their trends are identical, mainly N 50° E to N 60° E, and directions between N 30° E and N 40° E are also present. They are mainly traces of faults but in some places they are also flexures or geomorphological lines.

In the southeastern part of the photo a linear feature more than 100 km long trends N 80° E. This trend is also represented southward in Provence. It is not a fault line but the axis of a narrow anticline slightly faulted (Luberon anticline) prolonged by a straight line valley (Asse River) beyond a large valley (Durance) trending N 30° E.

The north-south faults (strike slip faults) which are near the center of the photo quadrangle in Figure 2 can hardly be spotted on the photo, probably because they run in a soft sedimentary formation (Upper Jurassic black shale). Likewise, the western borders of the Digne overthrusts near the central eastern limit of the photo are not visible.

COMPARISON WITH FIELD DATA

The whole area is covered by published geological maps on a 1:80,000th scale. Some of them have been revised four times, and more than half of the area is covered by published geological maps at the 1:50,000th scale. Field surveys were completed at various scales up to 1:10,000th.

A point by point comparison of field data and ERTS 1 data is beyond the scope of this report. But a simple comparison with Figure 2 which is a very interpretative tectonic sketch map is sufficient to give a fair idea of the help brought by ERTS imagery to the geological surveying of a tectonically complicated region.

The main fact which appears is the homogeneity and parallelism of trends of the linear features in the metamorphic massif as in the sedimentary folded zone. From detailed geological maps, the fault network is much more complicated. Besides SW-NE fractures, numerous faults trend SE-NW. They are hardly visible or not visible in the ERTS photos.

This leads us to think that most of the linear features trending SW-NE visible in the ERTS photos are reflections of deep-seated faults in the basement, while the SE-NW faults shown by field data are only in the sedimentary cover separated from the basement by a "decollement" in the Triassic series.

According to these features from ERTS data, the SW-NE trend is greatest in the western Alpine tectonics. It might be related to wrench faults in the basement. This idea has to be verified by a larger survey of the ERTS imagery and by a more accurate comparison with the field data.

3. CONCLUSION

Carrying on a project whose objective was to study the relationships between the Alps and the Pyrenees (Southern France), ERTS photos of the western French Alps have been carefully examined for tectonic interpretation. From this survey it appears that ERTS photos obviously show up some large features which in the field are often hidden by small complicated structures. In the example, these features trending SW-NE (N 30° E to N 60° E) are tentatively interpreted as reflections of deep-seated wrench faults in the basement of the folded sedimentary series.

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II - SOME RESULTS FROM THE STUDY OF THE DYNAMIC BEHAVIOR OF COASTAL SEDIMENTATION IN THE GULF OF LIONS

MMC 009.01 (P.I. M. Guy)

1. INTRODUCTION

The Gulf of Lions is a preferential area to study sedimentation problems on account of the complexity of the phenomena and of previous work.

The objectives of the project "GOLION" proposed for investigation of ERTS I data are:

i) A correlative study of the deformations in the patterns of sediment discharges at sea under various meteorological conditions.

ii) The precise mapping of the Holocene shorelines and a study of the chronology of the sediment bodies.

The short-term behavior of the coast is related to the meteorological conditions, and its study requires repeated coverage. Its long-term behavior is related to epeirogenic movements and eustatic sealevel changes, so a very small scale would be useful.

This paper relates some results obtained in the first phase of operations. Some good photographs were obtained ; but, due to very bad weather conditions, repeated coverage was not made and the coverage of the shoreline was limited to the Rhone Delta in the eastern part of the Gulf of Lions.

Nevertheless two important results were attained :

i) MSS bands 6 and 7 very clearly show the former shorelines of the Rhone Delta and enable them to be mapped directly.

ii) Recent changes in the morphology were clearly related to structural control (MSS 5).

2. MAPPING AND DATING THE FORMER SHORELINES

Figure 5 is an enlargement of part of photo 1078-09564 band 6 to a scale of 1:500,000th. Figure 6 is a sketch of the main coastal ridges or beaches and of the natural levees of the former beds of the Rhone.

They clearly show the southward accretion of the delta by numerous beaches which form an impressive beach pattern.

Fig. 5
Enlargement of the northwestern quadrangle of photo 1078-09564, Mss 6, showing the Rhône delta.

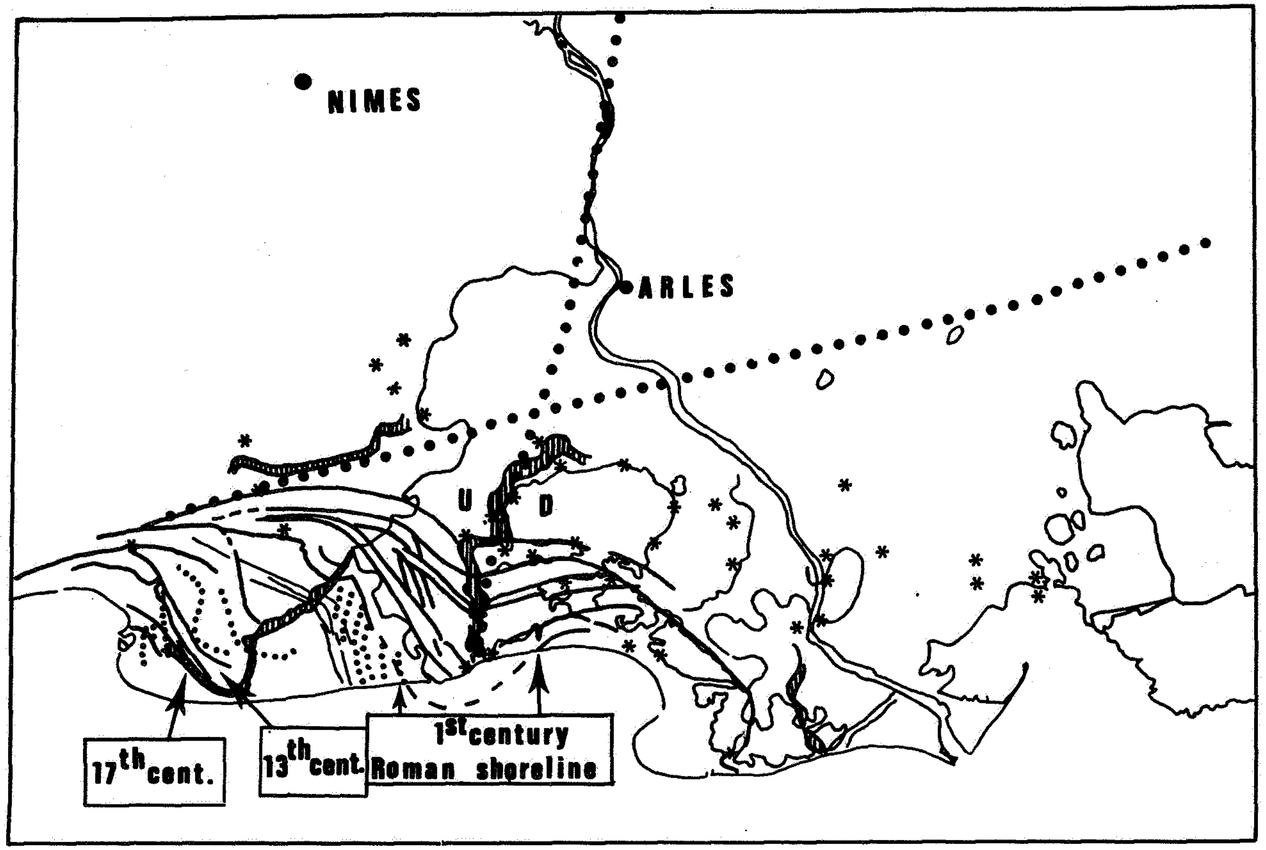

Fig. 6

* Roman built ruins

Levees of former beds of the Rhône

Already Known } Beach ridges
New

Faults controlling Holocene Movements

Up Down

These alluvial beaches and levees were recognized to exist in general before the ERTS I photo (Kruit*). However, it was difficult to link the ridge elements among one another so as to reconstruct the former shorelines, and so this had not been done in detail (cf. Fig. 9). In addition, unconformities between beach lines show that the accretion of the delta in the Holocene did not take place continuously. Variations in the sealevel or local tectonic phenomena are the probable causes of this jerkiness.

By using the positions of archaeological vestiges on the drawing of the ridges, the different phases can be dated with great accuracy. For example, Figure 6 shows that all the Roman vestiges are located behind a well-defined ridge line. Such a detailed analysis is now being made.

The eastern part of the delta shows a less clear-cut outline on the first ERTS I photos, although the phenomena are just as clear on the airphotos. The pictures taken in spring, and then in summer with different water levels, could be used to complete the layout of this area.

3. STRUCTURAL CONTROL OF SOME ANOMALIES

Fault control has been demonstrated by ERTS I photographs of the Rhone Delta.

On the MSS 5 and 6 photographs (Fig. 5), the eastern part of the Camargue region shows the outline of its former levees softened by the present overburden as the result of a slight downward movement. The western part is sharpened and eroded, and the clear lines of the beaches appear very detailed.

On the MSS 5 band, where slight changes in vegetation are emphasized, the boundary between these two zones is a very straight line, probably a fault trending N 30 E (Fig. 7).

Wells for petroleum exploration drilled some years ago have shown great changes in the thickness of the Tertiary sediments when crossing through this zone. But the exact position of the fault and its recent activity was not known.

The northernmost line of beaches forms, in its western end, a serie of curves asymptotic to a morphological alignments trending

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* C. Kruit, 1955, Sediments of the Rhone Delta, Mouton, The Hague.

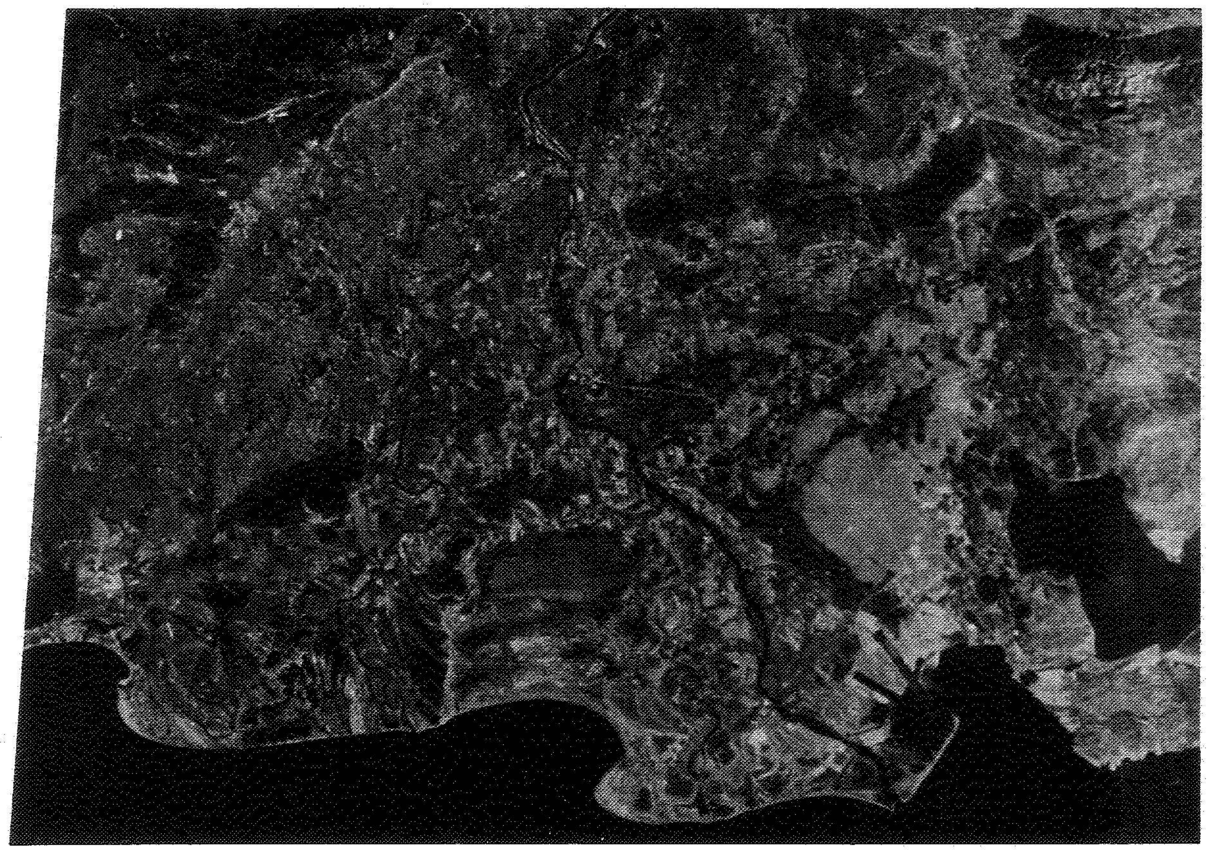

Fig. 7
Enlargement of the northwestern quadrangle of photo 1078-09564, Mss 5, where fault-alignments are perceptible by changes in the vegetation.

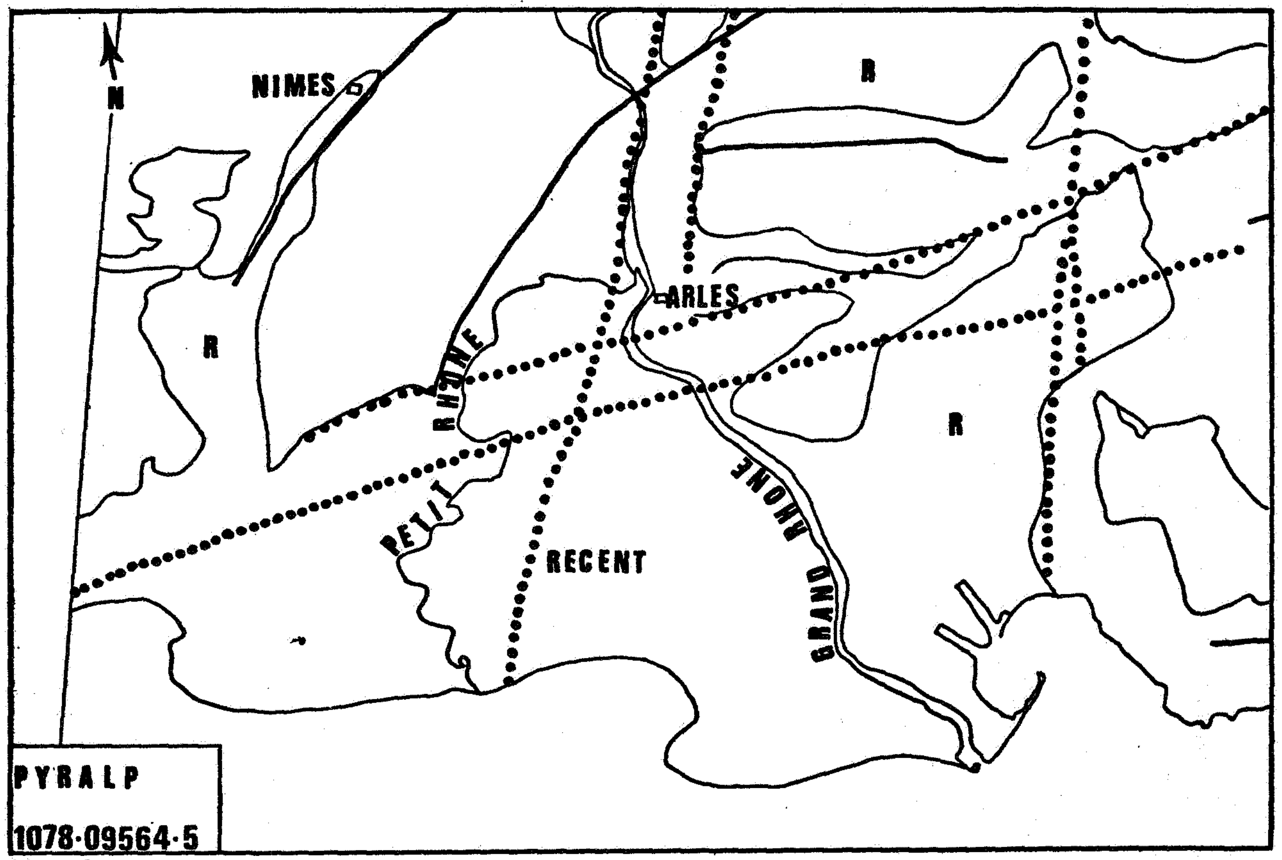

Fig. 8
These alignments are parallel to a network of faults studied by the PYRALP project.

approximatily E-W (N 70 E).

This alignment is known, in its eastern part from Secondary outcrops, as a large fault.

Study of the Alpine structure by the PYRALP project has shown the homogeneity of such a network of faults.

4. CONCLUSION

With these first observations on ERTS I photographs, a detailed study can be made of dynamic processes of the Gulf of Lions in the Holocene period.

The respective contributions of eustatic movements, climatic changes (increase in discharge) and structural control may be separated from one another by a precise study of the interrelationships of the geomorphic features, completed by ground surveys of archaeological and sedimentological remains.

Unfortunately, bad weather conditions have limited this study to the Rhone Delta, but the western part of the Gulf of Lions will probably be photographed in spring so that this study can be completed.

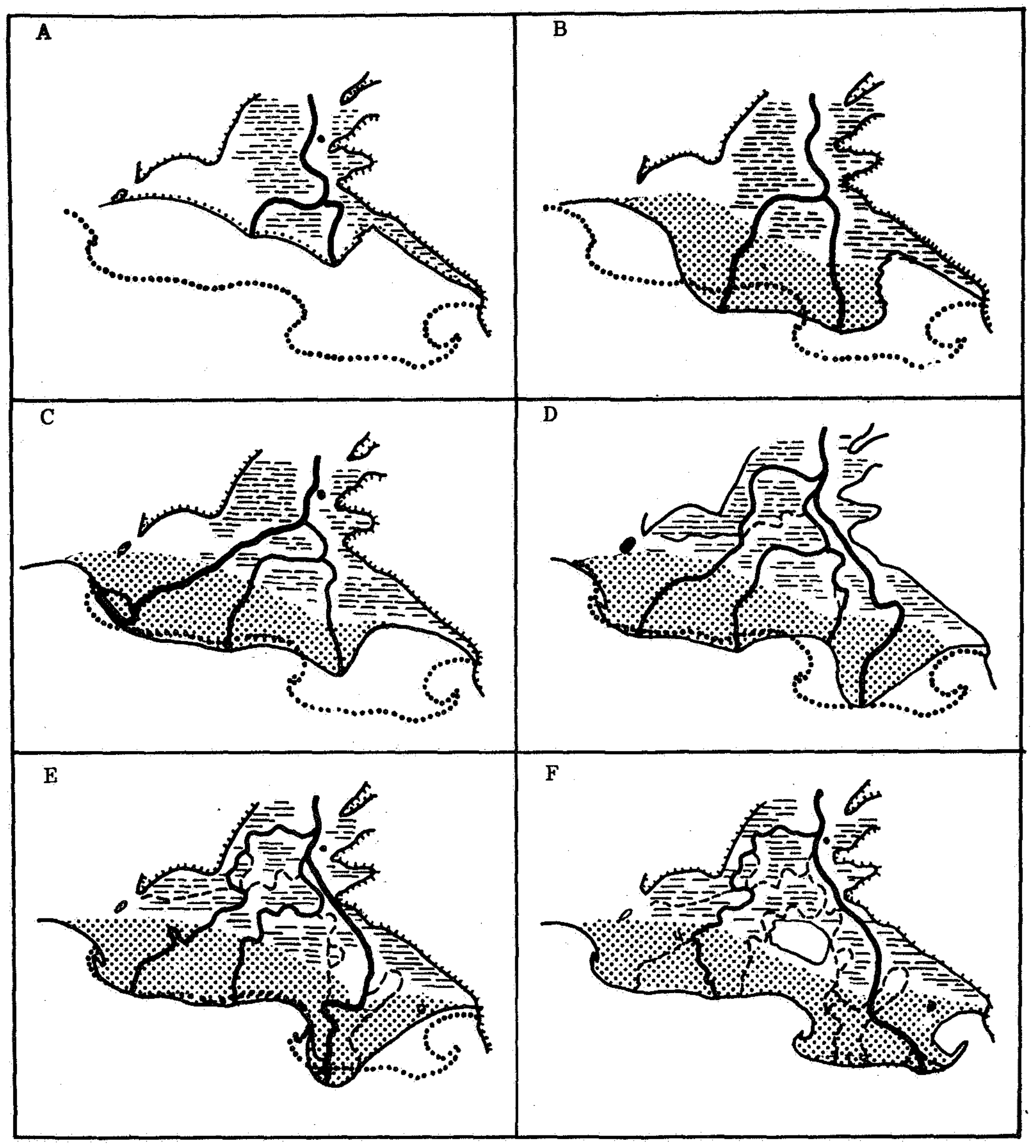

Fig. 9

Previous knowledge of the successive stages of Rhone delta advance during the last 5,500 years - (From KRUIT - 1955)

A - CLIMATIC OPTIMUM
B - PERIOD OF MAXIMAL ACCRETION
C - GREEK and ROMAN PERIOD
D - LATE ROMAN PERIOD
E - EARLY MIDDLE AGES
F - PRESENT SITUATION

Marsh
Beach and coastal lake deposits
Active channels
Abandoned channels

III - STUDY OF POLLUTION AT SEA IN THE WESTERN MEDITERRANEAN
MMC 009.02

(P.I. A. Fontanel)

1. INTRODUCTION

Our aim is to study the usefulness of ERTS imagery, associated with airborne records, to detect and perhaps identify various pollutants at sea and on coastal lakes in the southeastern part of France. Indeed the Mediterranean is almost a closed sea and pollution is a serious problem (Fig. 10).

2. RESULTS

A joint experiment was scheduled on September 19, 20 and 21 by I.F.P. (P.I. organization) and CNEXO (Co.I organization) under three different ERTS I tracks.

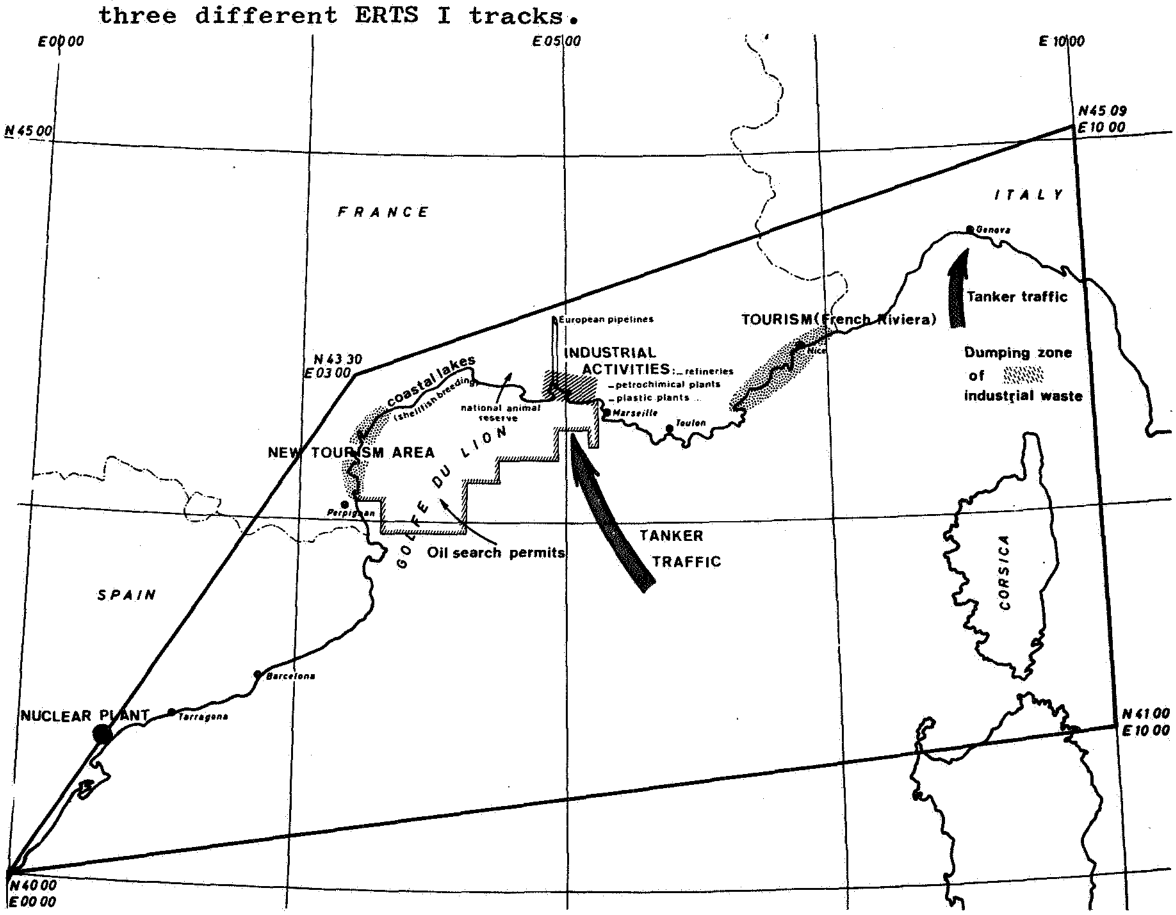

Fig. 10 Pollution problems encountered in the investigation zone

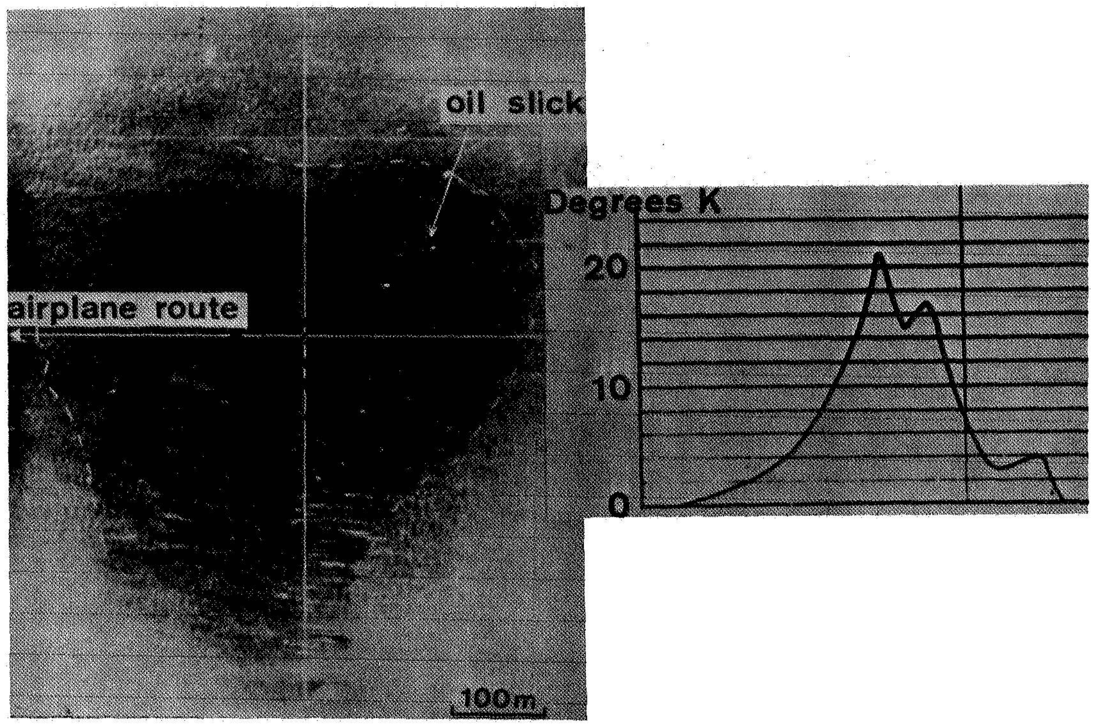

Fig. 11 Oil slick detection with a 32 GHz radiometer

Our aim was to pour various products at sea on parallel 42°30' (colza oil, crude oil, fuel oil, fresh water), to take samples of these products at different times in order to study their chemical variations, and also to track the slicks during daytime and nighttime with various airborne sensors including:

- color and infrared color photography (RC 10, Wild cameras)
- television camera for nighttime observation
- infrared scanner in the 3 to 5 micron band
- " " 8 to 14 " "
- microwave diffractometer at 32 GHz

Because of rough seas, we were only able to pour colza oil (6 m^3) at sea. Unfortunately, we did not receive ERTS imagery corresponding to the pouring point, quite certainly because cloud coverage was too great for ERTS. Furthermore, with regard to airborne records, results were obtained only with a T.V. camera, the 8-12 micron scanner and the 32 GHz diffractometer. The colza oil slick was clearly detected with these three devices, but we will give only the microwave results here. The left part of Figure 11 shows an image of the slick obtained with a vertical 35 mm camera (used solely to locate the airplane route). The right part shows the

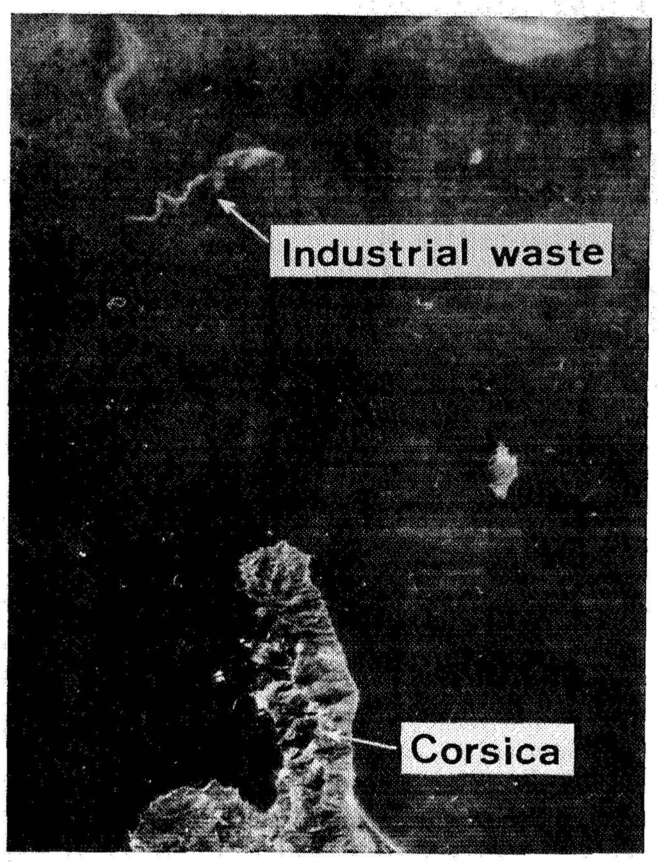

Fig. 12 Photo ERTS I - 1075-09393 - 4
scale 1:1,000,000
The arrow shows a patch of industrial waste containing ferrous oxides and sulfuric acid.

difference in brightness temperature between the slick and the surrounding water as recorded during the pass over the slick. The antenna is 0.70 m long. The beam width is about one degree. Its axis is directed behind the airplane route and is tilted 5 or 10 degrees with regard to the vertical. The temperature sensitivity is about 2° K. Fourteen passes were made after the oil was poured, from 9 a.m. to 12 a.m. The altitude was 250 m (800 feet) and the speed 75 m/sec. The polarization was horizontal at one time and vertical at another time. No noticeable difference was observed between the two polarizations. The brightness temperature differences between the oil and the surrounding water varied in the range of 10° K up to 34° K between the different passes.

Many remote sensing results have already been obtained by the P.I. and Co.I organizations in the visible and infrared bands, concerning coastal lakes and industrial zones on the southeastern coast of France, but they will not be presented here because they are not related to ERTS passes.

Up to now we have not received a complete ERTS coverage of the area (Fig. 10), and the 18-day repetition was not obtained, except with one photograph.

Nevertheless, several interesting features appeared on some ERTS photographs, but we will limit our discussion to two main examples.

Some industries have decided to dump their waste at sea off Corsica. These dumpings are not regular in time and occur at various locations. A certain concern can be felt among Corsicans about this waste which could be dangerous for the ecological balance of the region. Recently, a French oceanographic vessel went out to take samples of the polluted water in order to determine its noxiousness for marine life. This waste (called "red mud") contains ferrous oxides, other oxides such as titanium oxides, and sulfuric acid. Fig. 12 shows a patch of red mud 25 km long and two or three kilometers wide. This example proves that, under good weather conditions, satellite monitoring is possible and very useful for detecting and locating this type of dumping.

Figure 13 shows a very extensive "anomaly" in the northern part of the Ebro Delta, running for about 180 km along the Spanish shoreline and about 180 km off the coast.

Its origin is still unknown, but it is obvious that small-scale ERTS imagery is well suited for detecting such large phenomena.

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* This photo has been received by Pr. Rey (ARNICA project).

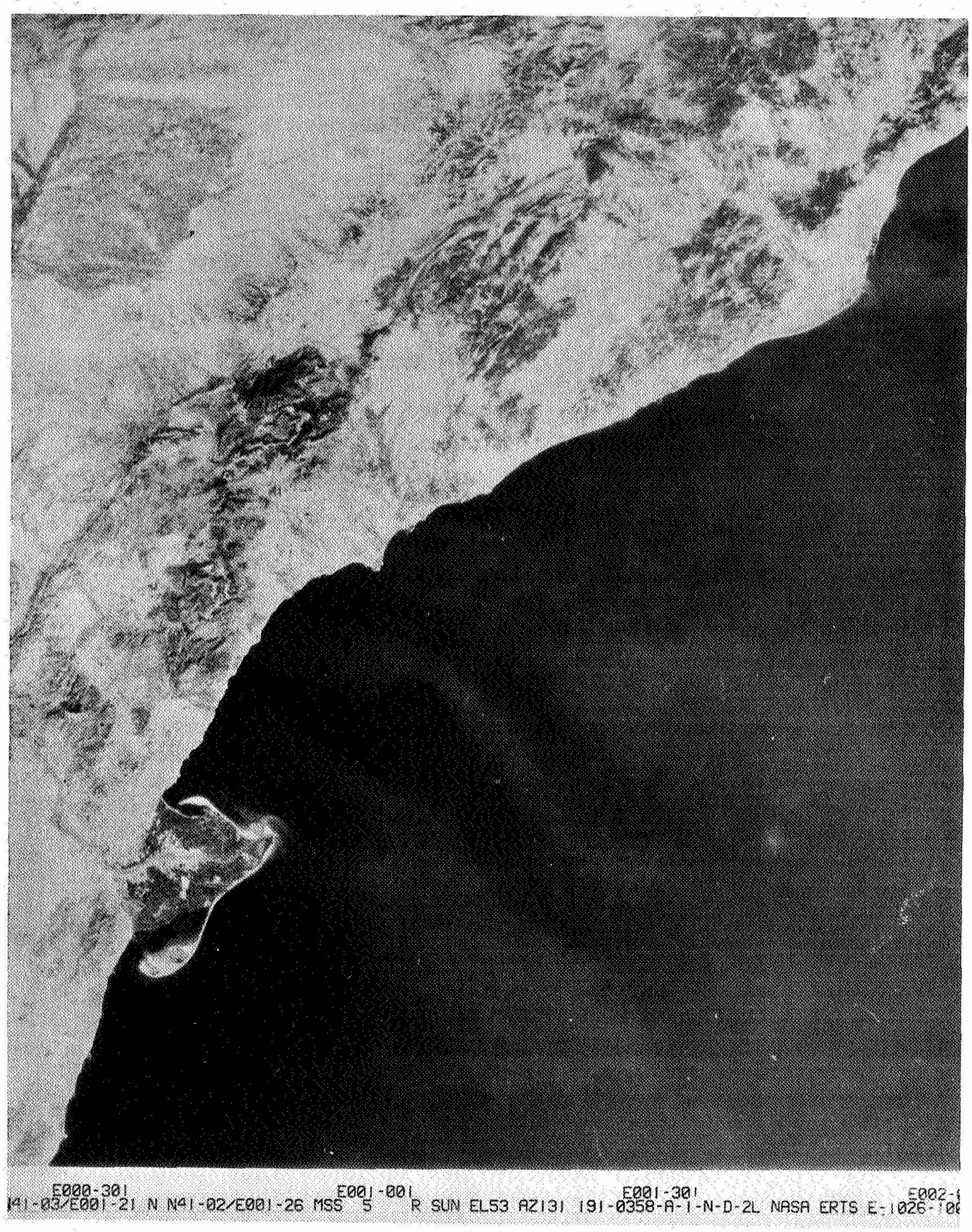


Fig. 13 · Large anomaly of unknown origin at sea

Experiments are scheduled in June 1973 to explain this "anomaly" which is, in part, situated offshore from a nuclear power plant.

3. CONCLUSION

It is obvious, from these examples, that small-scale ERTS imagery is well suited to detect such large phenomena.

IV - PROCESSING OF ERTS IMAGERY

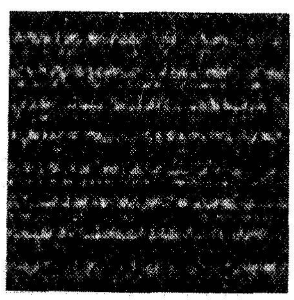
(P.I. A. Fontanel) MMC 009.04

1. INTRODUCTION

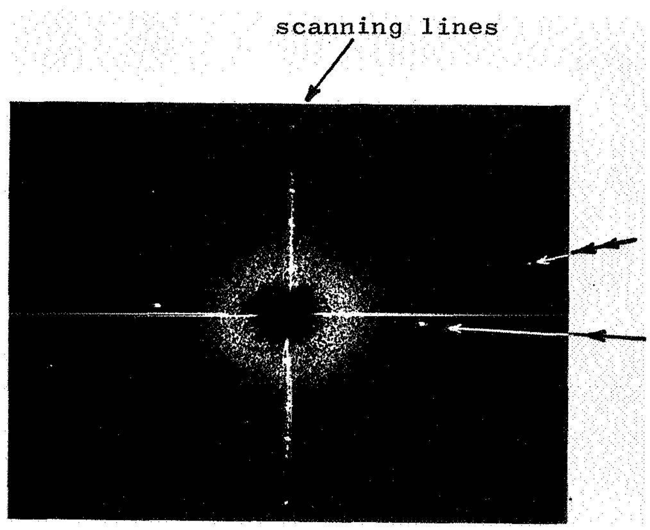
The aim of this project was to improve the quality of photographs, in order to make geological, geophysical, etc. interpretation easier and to automate some parts of this interpretation. We used optical and digital filtering techniques.

2. TWO-DIMENSIONAL SPECTRA OF MSS PHOTOGRAPHS

The optical Fourier transform of all MSS photos received shows two series of luminous dots positioned 92° and 77° with regard to the scanning lines. The spacing between these dots corresponds to a distance of 160 m and 85 m in the field. Fig. 14 shows an enlargement (approximately x 12 with respect to 1:1,000,000th scale) of an MSS photo taken at sea with its two dimensional spectrum. This phenomenon appears on each MSS spectrum but is very strong in areas with low contrast. It can hinder various kinds of studies of the MSS spectra. For example, we found this difficulty in trying to bring out the ancient Roman land partition in northern Italy.



a. Enlargement of an MSS photo



b. Two dimensional spectrum of a. The arrows (on the right side) show the directions of spurious points.

Fig. 14

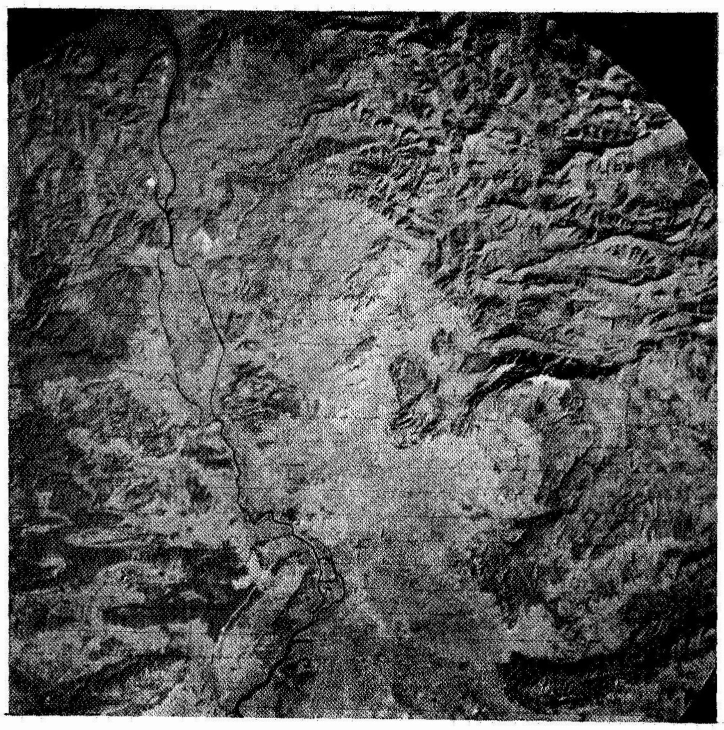


Fig. 15 a

Part of an image of an original MSS photo thru the coherent optical system
(1078-9562-6)
(scale 1:1,000,000)

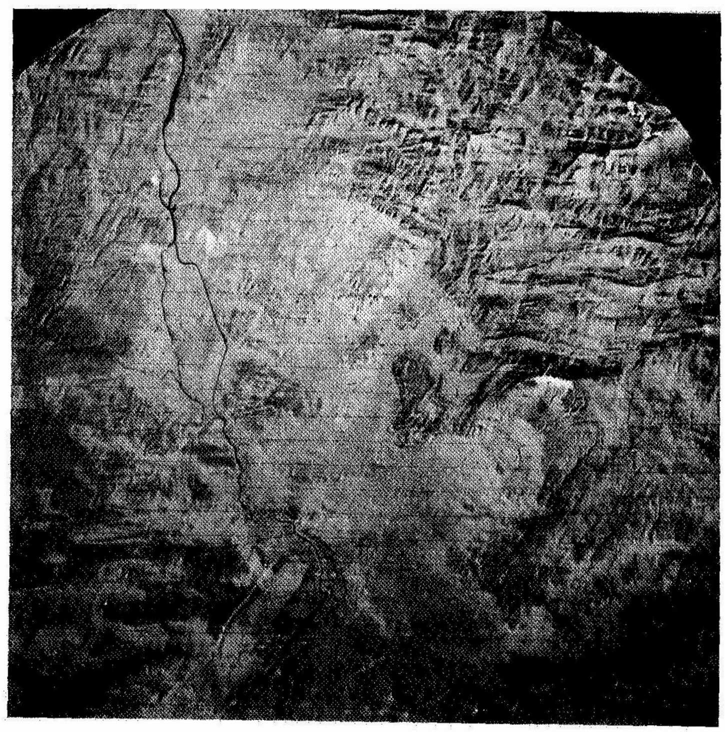


Fig. 15 b

Optical directional filtering of 15 a in order to bring out the NE-SW tectonic features

Fig. 16 a   Digitized original aerial photograph (taken on test-site)

Fig. 16 b Contrast enhancement of Fig. 16 a

3. COHERENT OPTICAL FILTERING

The photos in Fig. 15 b represent the southwestern corner of an ERTS image taken as an example of the use of coherent optical filtering in order to bring out tectonic features in a complicated area (ERTS I - 1078-09562). The main trends are underlined after directional filtering (Pincus, Dobrin*, Fontanel et al. 1967**). These underlined features correspond to the main tectonic fractures described in the first part of this paper (P.I. J. Guillemot).

4. DIGITAL PROCESSING

We did not receive magnetic tapes from NASA, so we only processes digitized aerial photographs taken on test sites. Fig.16a shows a digitized original aerial photo, and Fig. 16b shows the same photograph after contrast enhancement.

We also applied numerical directional filtering techniques to aerial photographs. Some examples will be given in later reports.

GENERAL CONCLUSION

In this report we have presented the findings of four ERTS projects. However we want to point out that these different researches were carried out in close collaboration between the P.Is. even though the objectives would appear to be different at the first glance.

For example, the faults spotted in the Camargue region, and which provided an explanation for various sedimentological phenomena (GOLION project), were situated in a much wider setting, thanks to structural geology surveys carried out farther north (PYRALP project). Likewise, there is no point in emphasying the links which

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* M.J. Pincus, M.B. Dobrin, 1966. "Geological Application of Optical Data Processing", J. Geophys. Res., 71(20), p. 4861-4869.

** A. Fontanel, G. Grau, J. Laurent, J. Montadert, 1967, Etude des photographies aériennes par diffraction de la lumière cohérente. Actes Symp. Intern. Photo-interpretation, Edit. Technip, Paris, III, p. 13-22.

exist between sedimentology and offshore pollution problems. Concerning the TRONU project which has to do with optical and numerical processing, it is being done on photos covering all four of the projects described.