BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

SERVICE GÉOLOGIQUE NATIONAL

E75 10228
CR-142414

GEOLOGICAL INVESTIGATION USING ERTS ORBITAL IMAGES IN THE PORTUGAL REPUBLIC AND WESTERN SPAIN

(E75-10228) GEOLOGICAL INVESTIGATION USING ERTS ORBITAL IMAGES IN THE PORTUGAL REPUBLIC AND WESTERN SPAIN Final Report, Jul. 1972 - Apr. 1974 (Bureau de Recherches Geologiques et Minieres) 40 p HC $3.75 CSCL 08G
N75-21753
Unclas
G3/43 00228

BRGM

Département carte géologique et géologie générale

003 D

7

B5190226

74 SGN 320 GEO

BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

SERVICE GÉOLOGIQUE NATIONAL
B.P. 6009 – 45018 Orléans Cédex – Tél.: (38) 66.06.60

Original photography may be purchased from
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

GEOLOGICAL INVESTIGATION USING ERTS ORBITAL IMAGES IN THE PORTUGAL REPUBLIC AND WESTERN SPAIN

by

J.-Y. SCANVIC – G. WEECKSTEEN

BRGM

Département carte géologique et géologie générale
B.P. 6009 – 45018 Orléans Cédex – Tél.: (38) 66.06.60

74 SGN 320 GEO

October 1974

SR N° 003 - 4

Title of investigation :	Geological investigation - using ERTS orbital images in the Portugal Republic and western Spain
Principal investigator :	Guy WEECKSTEEN
Name and address of principal investigator :	B.R.G.M., B.P. 6009, 45018 - Orléans cedex - France
Date :	April 1974
Type of report and period covered :	Type III report July 1972 - April 1974
Name and address of national sponsoring agency :	CENTRE NATIONAL D'ETUDES SPATIALES 129, Rue de l'Université 75 007 - PARIS - France.

TABLE OF CONTENTS

	Pages
1 - INTRODUCTION	1
1.1 - Reasons for this choice	1
1.2 - Planned objectives	3
1.3 - Data requirements	3
2 - SCOPE OF ACTIVITY	4
2.1 - Image received	4
2.2 - Quality of images and location	4
2.3 - Activities during the investigation period	5
2.4 - Procedure and methods	5
3 - TEST SITE DESCRIPTION	6
3.1 - Geological description	6
3.2 - Meteorology	8
4 - SIGNIFICANT RESULTS	8
4.1 - Analysis of the images	8
4.2 - Usefulness of ERTS data	23
5 - CONCLUSION	27
5.1 - Test site 1	27
5.2 - Test site 2	28
5.3 - Western Spain	29
5.4 - General utility of ERTS data	29
6 - APPENDIX	29
6.1 - Listing of presentation	29
6.2 - Images received	30
6.3 - Quality and localization of images	31
6.4 - References	32

I - INTRODUCTION

In 1971 we proposed to NASA, with the agreement of the "Servicos Geologicos de Portugal", two test sites in the Republic of Portugal to experiment the ability of the orbital images in various geological domains.

The first one, named Test A, is located in the northern part of this country (see fig. 1).

The second, named Test B, is located in the southern part of this country (see fig. 1).

1.1 - Reasons for this choice

1.1.1 - Northern region

Recent studies on the granitic rocks of this region show that two main groups exist :

- one, early Hercynian orogeny in age, is conformable with the main structures and is composed of acid alkaline granitic rocks,
- the other, post tectonic and composed of granodioritic rocks is unconformable.

Mineral occurrences are associated with the acid alkaline granites. The mapping is difficult because they are quite often poorly exposed and the petrographical variations are not evident.

1.1.2 - Southern region

In this area Carboniferous rocks, which are characterised by their tectonic, crop out : the units are tightly folded and overthrusted towards the South. On another side these formations present a flysh facies and with lithostratigraphy it is impossible to accurately separate the main tectonic domains.

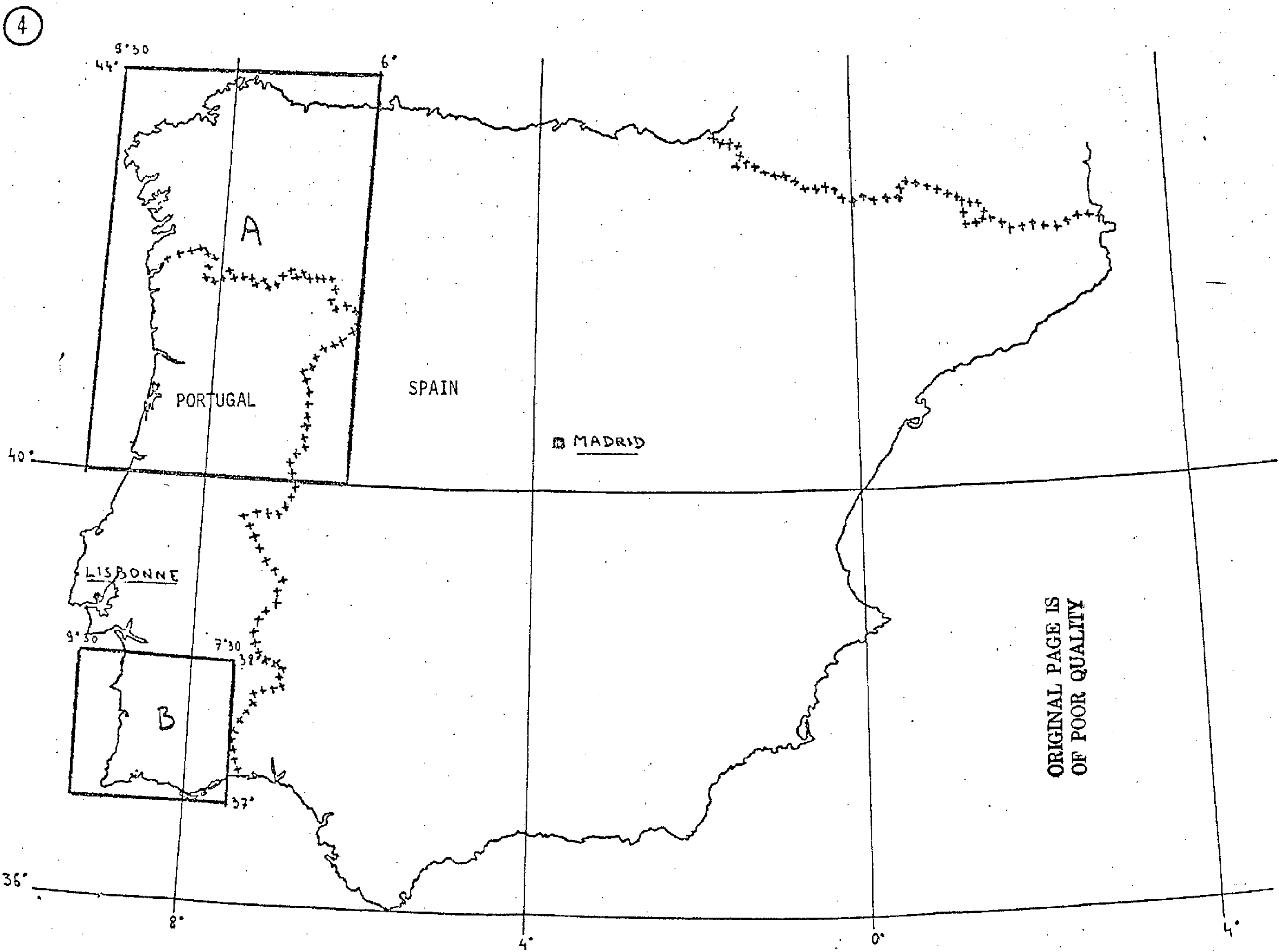

4
9°30
44°
6°
A
PORTUGAL
SPAIN
MADRID
40°
LISBONNE
9°30
7°30
38°
B
37°
36°
8°
4°
0°
4°

Fig. 1.

1.2 - Planned objectives

The two main purposes of the B.R.G.M. proposals concern:

- the geological mapping of the eruptive units in western Europe. This mapping is based on both petrographic and structural criteria (test site A).

- the ability of small scale orbital images or photographs to differentiate tectonic domains in a flysh facies (test site B).

The results of the analysis relating to these objectives are not very significant on the two test sites. All objectives are not met because an important percentage of the images received is partly or completely cloudy.

However, areas adjacent to the test sites (in Spain) were amenable to geologic analysis because they were not obscured by cloud cover. This report includes observations on these adjacent areas, some of them contributing to the achievement of our investigation objectives (test site B). The significant results are described in section 3.1.3.

1.3 - Data requirements

1.3.1 - Periods - Cloud cover

Only one set of images was required for the test sites, during the March - May period, the most interesting season to realize a coverage for a geological purpose.

We required the multispectral band 4 in positive print and 70 mm bulk negative transparency.

The percentage of cloud cover acceptable was estimed to 20 - 30% but this was not realistic.

1.3.2 - Comments on data requirements

An important percentage of the images received from NASA is partly or completely unusable because of the cloud cover quite often located on the land area of the scene, the sea being quite clear. Looking on the dates of coverage we conclude that the images taken during the period chosen in the proposals (March - May) are generally good in quality (1229-10 381, 1229-10 384, 1229-10 375) and the ones realized in August and September have a cloudy cover generally disturbing the interpretation.

This point validates the choice of the period proposed to NASA for this test site.

1.3.3 - Comments on data reception

We only received data in May and October 1973 and this delay in the delivery makes it impossible to include all the type I and II reports.

2 - SCOPE OF ACTIVITY

The first images we received in May 1973 were very cloudy. We hoped for better views of the test sites and for this reason we delayed the interpretation. Unfortunately the images NASA sent later on in October 1973 only covered Spain and sometiems a very narrow band in Portugal.

Finally, we have interpreted the first images but the cloud cover makes it impossible to achieve the proposed survey on test sites A and B. Then, in this final report, we intend to give an idea of the ERTS-1 ability only to solve the above mentioned problems.

2.1 - Image received

See Table 1 and map 5 (Appendix).

2.2 - Quality of images and location

See Table 2 and map 5 (Appendix).

2.3 - Activities during the investigation period

From the launch of ERTS-1 to October 1973 (reception of the first usable images) :

- Survey of the existing literature.

From October 1973 until now :

- Mailing of documents to the geological survey of Portugal,
- Surveying the images received,
- Group seminar with B.R.G.M. geologists,
- Synthesis of the scattered surveys and comparison with the existing geological maps,
- Discussion of the first results with Portuguese geologists,
- Preparation of the final report draft which we have submitted to the geological survey of the Republic of Portugal and to the technical NASA officer.

2.4 - Procedure and methods

Band 4 of the multispectral scanner was required in positive print. This requirement was not realistic, band 4 being generally unusable for geology but fortunately NASA sent us band 5 for 12 scenes, only 3 scenes being studied with band 4.

The survey of each image was made by direct ocular vision as there were few or no overlappings on these images. Nevertheless, it has been found practical to observe two copies of the same image with a stereoscope in spite of the lack of relief because the magnification due to the lenses make a better interpretation possible.

The survey has only been made with prints at a scale of 1/1,000,000 allowing the superposition with the published geological map. For this reason we cannot say what scales are the most efficient but the 1 millionth scale gives excellent results. The stereoscope used comes from Switzerland, Wild ST4 with mirror and 3 X magnifying lenses.

3 - TEST SITE DESCRIPTION

3.1 - Geological description

According to Professor DECIO THADEU, Ingenieur des Mines, I.S.T., the main geological units known on the test sites are :

1 - The "Massif Hesperique",

2 - The "Bordures mesocenozoiques",

3 - The "Bassins du Tage et du Sado".

The "Massif Hesperique is ante-mesozoic in age and constituted by granites and schists.

Test site A is located in the northern part of this "Massif Hesperique" where granitic rocks are mainly outcropping (crystallophyllian complex).

Test site B is located in the southern part of this "Massif Hesperique". In this region the known units are Cambrian to Carboniferous in age but near Beiras and Vila Boim this series is lying conformably on a "schisto-graywacke complex", azoic, probably infra-Cambrian. This complex is sometimes unconformable (Coimbra) on the "crystallophyllian complex".

From the upper Permian to the Trias there is a stratigraphic gap and the unit 2 begins with a fossiliferous sandstone, Rethian in age. The Lisboa basaltic complex seems to separate the units 2 and 3. Unit 3 is the youngest one, Oligocene to Holocene in age.

The geology of the adjacent area in Spain is in general an extension of the Portuguese one. Detailed description of the three areas covered is the following :

Oviedo area

The three images received correspond to the same area named Cantabrique (Asturian - Leonese), taken at different seasons of the year.

This Hercynian region is constituted by strongly curved Paleozoic sediments, convex towards the West: it is the Asturian area. In the central part of this Arc is located the Carboniferous Asturies basin.

The Mesozoic and Tertiary layers crop out on the eastern margin of the image - Santender basin - and on the western one - Gigou - Oviedo - Villarvicioza basin. They have been more tightly folded during the Alpine orogeny.

Numerous faults and fractures, Alpine in age, affect the geological formations and are responsible for the present morphology.

Finally, the southern part of these ERTS images covers the very linear geological boundary which separates the continental layers from the Duero basin.

Zamora area

The images received correspond to the western part of the Duero basin which is constituted with horizontal continental sediments (sand, clay and limestones) upper Tertiary and Quaternary in age. On the western margin of this basin, visible on the images, alternating quartzites and slates (Ordovician - Silurian) crop out towards the North and granito-gneiss towards the South.

Hervas area

The two images received correspond to the western part of central Cordillera which crosses along a E-W direction the "Castille" region, and separates the Duero basin from the Tajo basin. It is constituted by a complex granitic area dissected in blocks by fractures, the vertical displacement of which is responsible of the "germanic structure" characteristic of Cordillera.

This massif is surrounded by lower Paleozoic formations - quartzites, schists and slates - with a N.NW-E.SE direction of structures due to the Hercynian movements. These structures are sometimes deformed by the granitic batholithes which play a role of a resistant nucleus against the Alpine movements.

3.2 - Meteorology

The period chosen in the proposals (March to May) seems to be the best one, the images realized in August and September having an important cloudy cover disturbing the interpretation. In that the images taken above the adjacent area (in Spain) during the months of August and September are good in quality, we think, even if the first point validates the choice of the period proposed to NASA, meteorological conditions pose a problem which cannot be solved in advance.

4 - SIGNIFICANT RESULTS

4.1 - Analysis of the images

We briefly describe, in this section, each image received from NASA. This analysis is realised because of the experimental aspect of the survey, with a maximum objectivity: we have avoided all extrapolation in the interpretation.

4.1.1 - Test site A

Three images cover the test site :

- 1 - 1032 - 10 425,
- 2 - 1032 - 10 432,
- 3 - 1033 - 10 491.

The third image, very cloudy, is not usable for the earth sciences. The two others, even if they are partly cloudy, allow the following interpretation :

1 - 1032 - 10 425 (fig. 2)

This image covers both Portugal and Spain (2/3 - 1/3). The cloud cover (5%) makes the interpretation difficult, being mainly located above the Republic of Portugal :

- Point 1 corresponds to the trace of the Serra de Bornes fault,

- The tectonic complexity of the Breganca region appears clearly on the ERTS image, the interpretation only being restricted by the scale,

- In point 3 several linear features are recorded which outline the circular pattern of the sedimentary levels around the Morais basin. The boundary between the Silurian and the dolerites is very clear.

In general - and point 4 illustrates this - the boundary dolerite surrounding formations is generally well recorded on multispectral images.

In the Spanish area of this scene, points 5 and 8 follow the trace of already known fractures.

2 - 1032 - 10 432 (fig. 3)

This image covers both Portugal and Spain.

The cloud cover is very important on the Portuguese part of the scene. Some observations are possible and concern :

- two linear features, located southwards of Viseu, which follow the straight course of the Rio Daô and a subsidiary river along 50 kilometres,

- Point 1, an extension towards the North East, in Spain of the Aljustrel dyke,

- Point 2, an extension of the Castelo Branco fault,

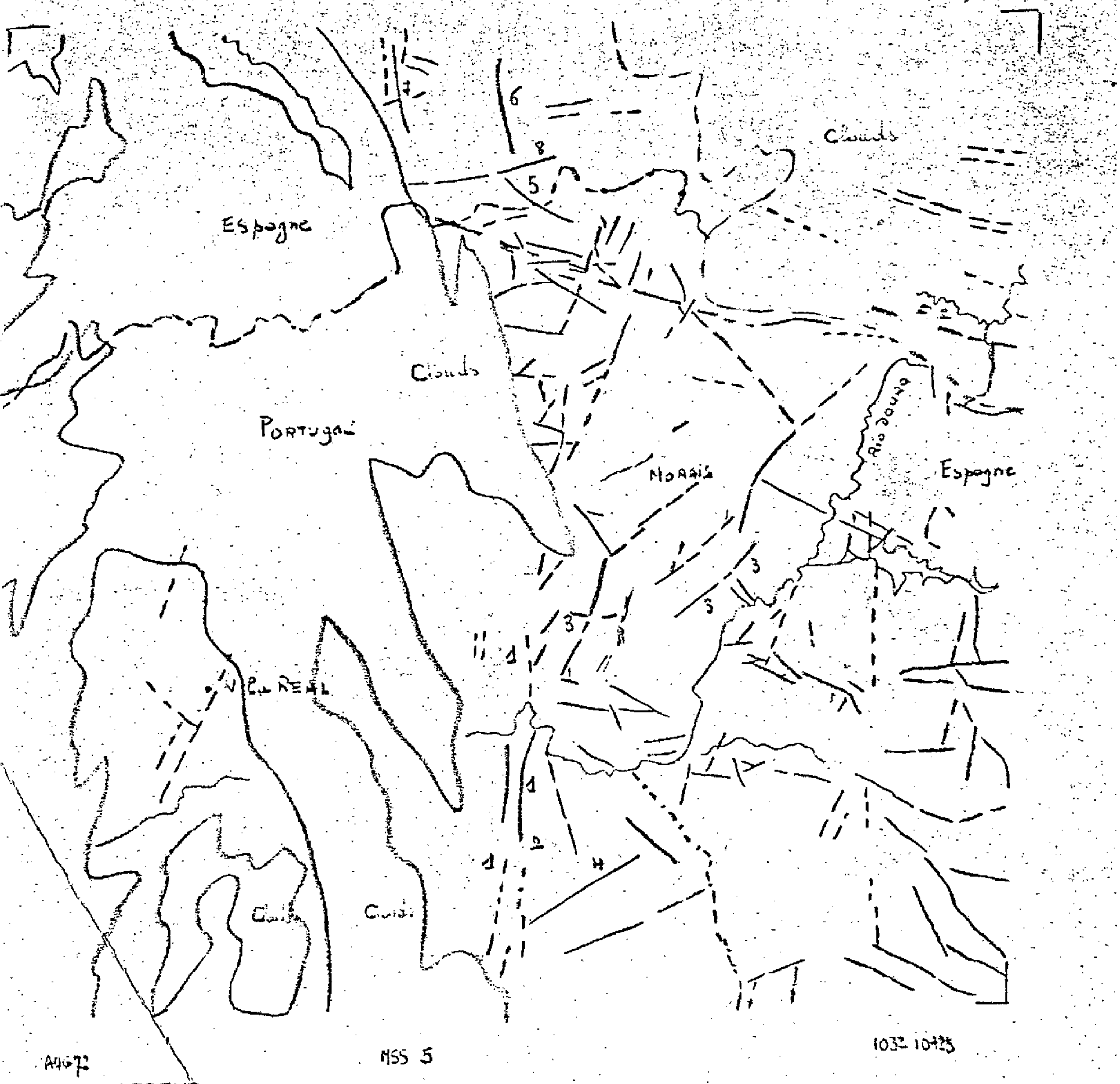
- Point 3, a dolorite massive, faulted on its northern limb,

- points 4, 5, 6, 7 and 8, interpreted as fractures because they are very linear lines, they correspond to boundaries between rocks of different types.

Fig: 2

REGION DE VILA REAL - PORTUGAL

ERTS 1



LEGEND

1,2, etc. references to the text

limit of clouds

rivers

geographical boundaries

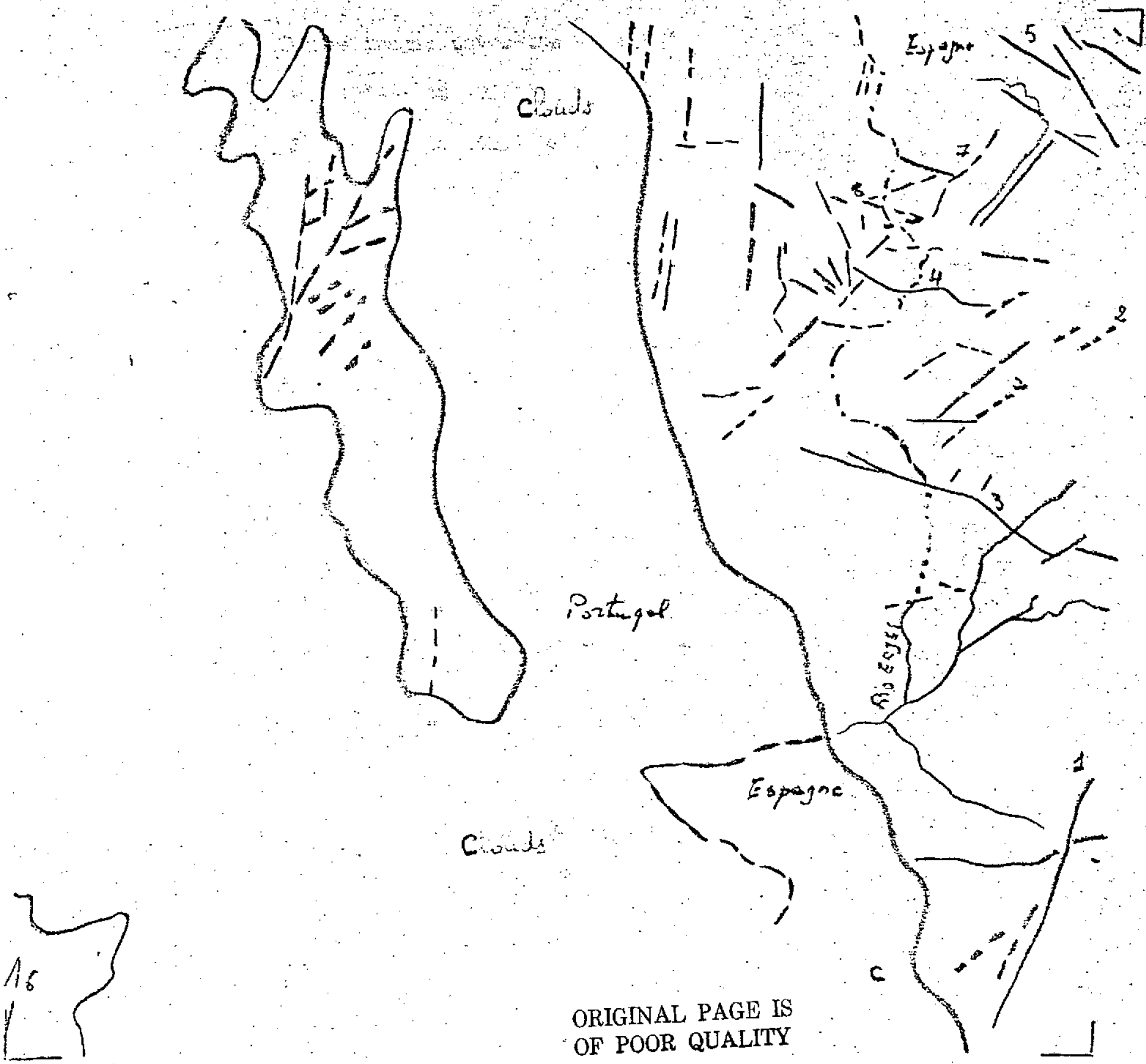
ORIGINAL PAGE IS OF POOR QUALITY

SCALE: 1/1.000.000

Fig. 5

REGION DE GUARDA - PORTUGAL -

ERTS 1



A4672 NS 5 1033 10932

LEGEND

1, 2, etc. references to the text

limit of clouds

rivers

SCALE : 1/1000.000

3 - 1033 - 10 491

This image is too cloudy to be used.

4.1.2 - Test site B

Three images cover the site :

1 - 1014 - 10 435,

2 - 1067 - 10 382,

3 - 1033 - 10 493.

The third image, very cloudy, is not usable for the earth sciences. The two others, even if they are partly cloudy, allow the following interpretations :

1 - 1014 - 10 435 (fig. 4)

Even with a 25% cloud cover this image is the most interesting to test the ability of orbital photographes on the proposed site. It covers nearly the entire zones of interest between Faro to the South and Setubal on the western coast. The main results concern fracturing and the following points must be mentioned :

a) Linear structures SW-NE

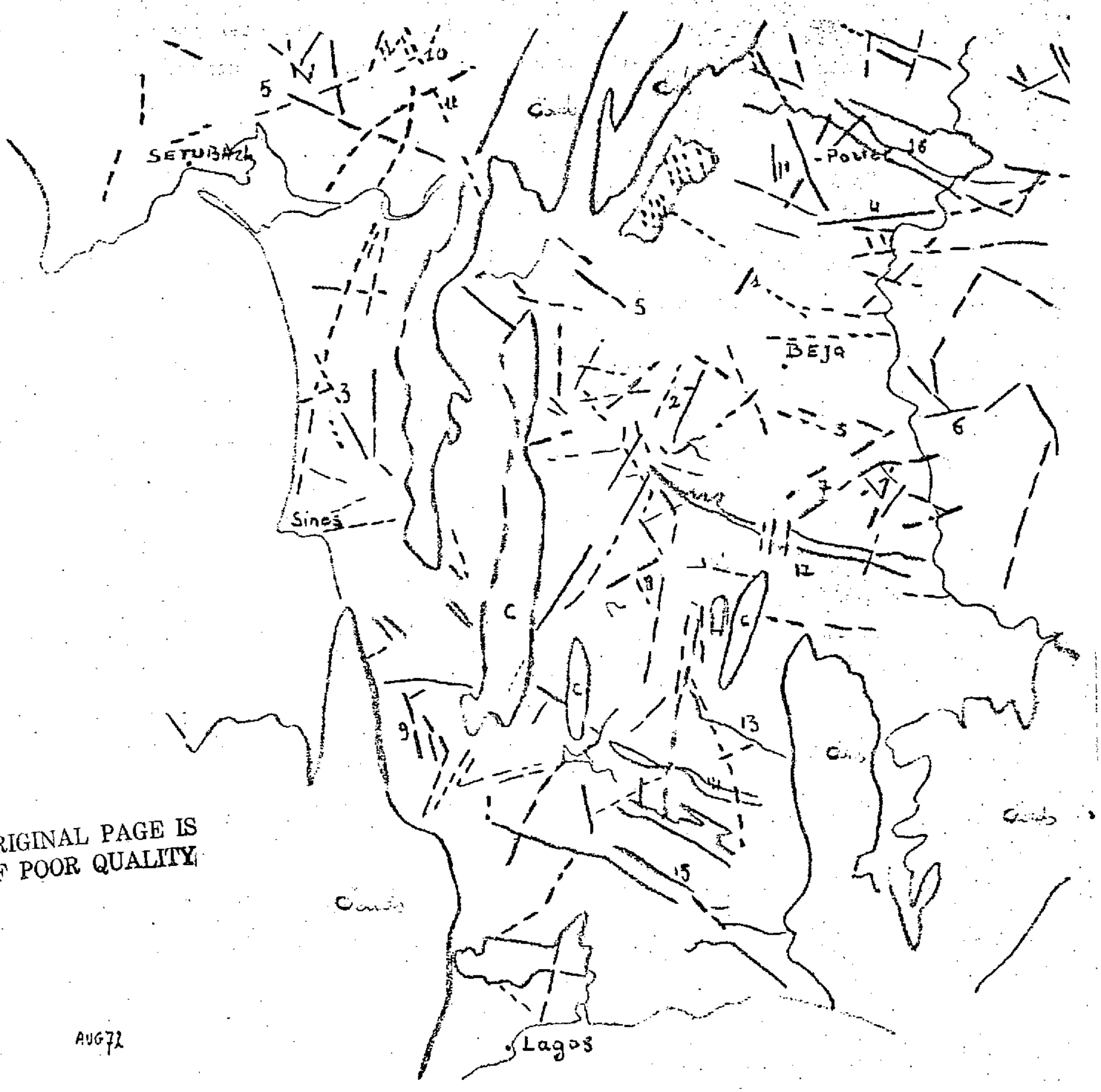
- The important dyke of dolerite passing through Aljustrel is recorded on ERTS images but its trace is not continued. It trends NE-SW along 100 kilometres. Towards the South it is hidden by the cloud cover.

The comparison with the existing maps indicates that the visible parts of the fracturing correspond to the zones where the fault is filled with dolerite. The fault itself, without volcanic rocks, on the surface, is only recorded in 1 - in the eruptive complex near Beja - and in 2 - in the Paleogene formations. In this region the linear feature observed on ERTS is not a single one but is composed of 2 traces parallel to a copper bearing structure.

Fig: 4

REGION DE BEJA - PORTUGAL -

ERTS 1



AUG72

LEGEND

2, etc. references to the text

limit of clouds

rivers

1014 10435

SCALE: 1/1000.000

- To the East of this dyke, scattered lineaments North 45° East in direction are visible on the image.

- To the West, from Cabo de Sines and towards the North-East there exists a fault trending along the same direction as the Aljustrel dyke and 80 kilometres long. This hypothetical accident does not find its counterpart on the geological map, even locally, but to the South of Melides, and parallel, a fault is known in the field and allows the tectonic origin of the ERTS trace to be assumed.

b) <u>Linear structure North 75° to 90° East</u>

This direction is not important. It is therefore observed in several places along the Guadiana river and mainly in point 6 where it follows pro parte the trace of the faulted basement - Silurian boundary, and also in point 4 where it corresponds with a known fault which the ERTS image allows to extend after a change of direction.

c) <u>Linear structure North 130° to 140° East</u>

The main structure observed in point 5 is not mentioned on the geological map. It extends discontinuously along 150 kilometres. It is interesting to point out that this ERTS trace is recorded on the Mio-Pliocene layers, crossing the subsidiary rivers of the Rio Sado (right bank) without disturbing their water courses. Once again this observation poses the problem of the nature of the phenomena which make the interpretation of fractures on ERTS imagery possible.

Finally, in the Carboniferous formations, which crop out in the southern part of the scene, an alternation of grey and dark tone parallel to the main accidents is visible : this is typical in points 13 and 15. This alternation is certainly enhanced by the vegetation but it very probably indicates a lithological phenomenon. Similar distinctions exist in point 12 in the Devonian and in point 16 in the Silurian.

d) To conclude this analysis the existence of a nearly North-South direction should be noticed, without any great extent but seen everywhere on the image. On point 8, in the Castro Verde area, this direction of faulting, known in the field in the volcanic and sedimentary Carboniferous formations, is recorded with a southern extension. On point 9 the linear structure following the Rio Mira corresponds to a northern extension of a known fracture.

e) Other noticeable data

The linear feature recorded in 3 corresponds in its southern part to the boundary between the Carboniferous and the formations of the Santiago de Cacem syncline.

The points mentioned in 10 and 11 follow the trace of the basement - Devonian boundary.

2 - 1067 - 10 382 (fig. 5)

This image covers Portugal, Spain and the sea. The Portuguese part is already interpreted on image 1014 - 10 435 and the new data concern the Spanish part. The main points of interest are :

- On point 1 the boundary between the Carboniferous and the Quaternary deposits filling the Gualdalquivir valley, the linear trace of which suggests an important fracture.

- The points 2, 3, 7, 8, 9 and 10 correspond to intra-Carboniferous limits. It is important to point out that these observations are in concordance with the ones made possible in the Republic of Portugal.

4.1.3 - One example of the multiseasonal interest of the ERTS images : The tectonical and geological survey of western Spain

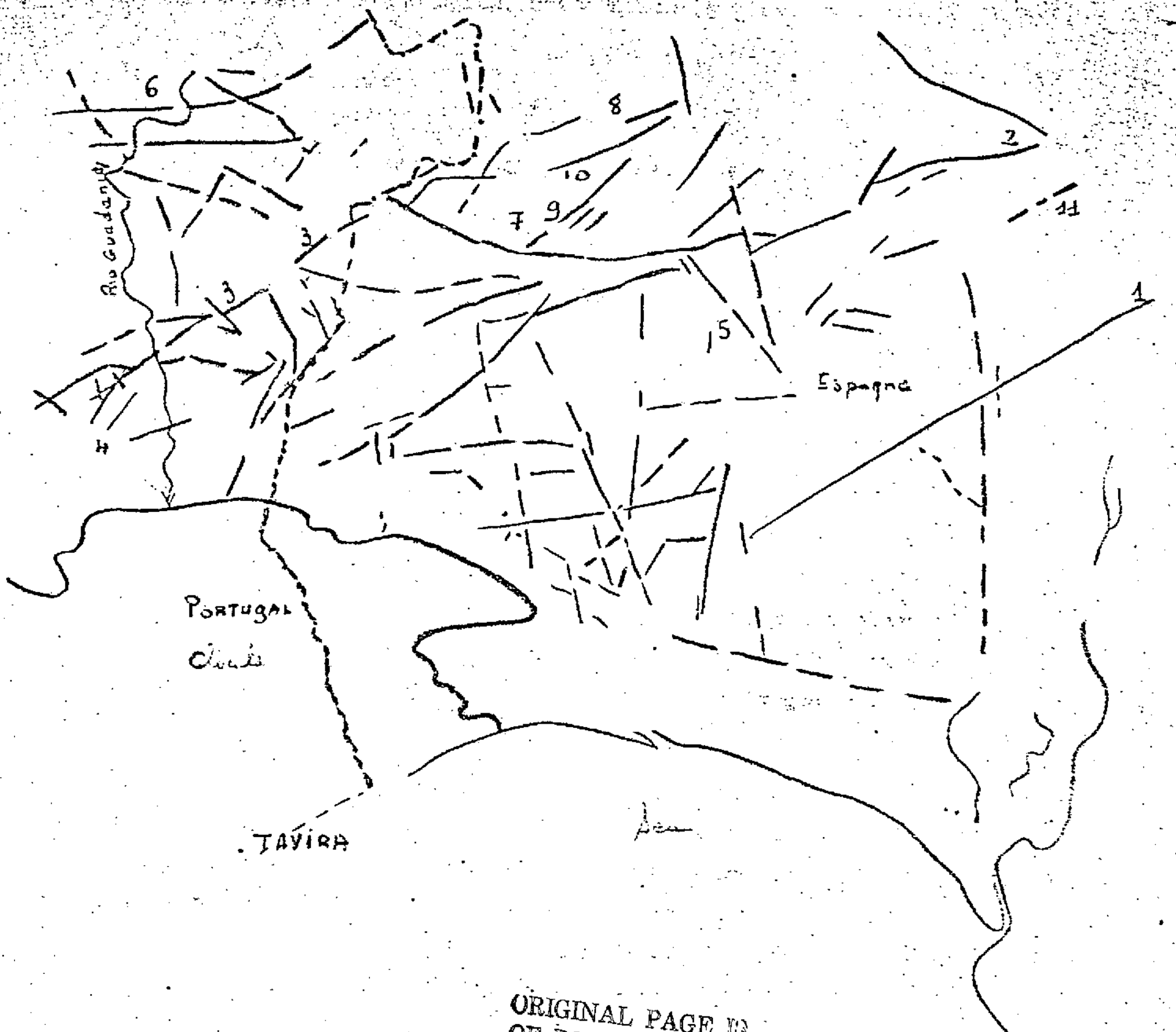
The ERTS images received cover a wide part of the western Spain, outside the two test sites we proposed to NASA. As we got two or three

Fig : 5

REGION DE RIO CHANGA

PORTUGAL - ESPAGNE

ERTS 1



sep72

MSS +

1067 10382

LEGEND

2, etc. references to the text

limit of clouds

rivers

SCALE: 1/1000.000

coverages for the same scene it appears that the results obtained from each image were different and complementary. Finally, the seasonal effect seems an important factor of change reflecting, in certain circumstances, geological and tectonic phenomena.

Three areas are scanned which we intend to study in this section from a tectonical point of view. Map number 4 is the cartographic result of this survey. A lithological description is given in section 4.2.3.

Oviedo area

The MSS images covering the region were scanned at three different periods :

1031 - 10 364 501	August 23, 1972	(Map n° 2)
1067 - 10 364 501	September 18, 1972	(Map n° 3)
1229 - 10 375 502	March 9, 1973	(Map n° 1)

ERTS images interpretation :

The ERTS images make possible the interpretation of linear features which correspond to tectonic mouvements. Numerous faults and fractures as well as overthrust and axes of folding are recorded. Precisely, the flexure of the Asturian Arc and the main faults cutting this formation are perfectly interpreted on the ERTS images. We specially outline :

- The fault number 1, already known on the field, crosses the Rouga overthrust running along a NW-SE direction. Some other important fractures, having a similar direction, are recorded on ERTS images on the points number 2, 3 and 4 : they very locally correspond in the field to fracture zones. On points 8 and 9 the linear features observed trend along a direction forming a 60° angle with the above mentioned one.

The East-West faults registered on points 5, 6 and 7 correspond to an already known fracturing, represented on the tectonic map at a

1/1,000,000 scale published by the "Instituto Geologico y Minero Espanol" but the ERTS images allow their extent to be defined. Notice that most parts of these linear features are partially observed on each of the three images and it is the integration of these scattered seasonal details which makes it possible to outline the phenomenon in its entirety.

We conclude this section by an important remark : the interpretation of a multiseasonal orbital coverage gives very good results in the tectonic domain.

Zamora area

The MSS images covering the region were scanned at three different periods :

1031 - 10 370 501 August 23, 1972 (Map N° 2),

1067 - 10 370 501 September 28, 1972 (Map N° 3),

1229 - 10 381 501 March 9, 1973 (Map N° 1).

ERTS images interpretation :

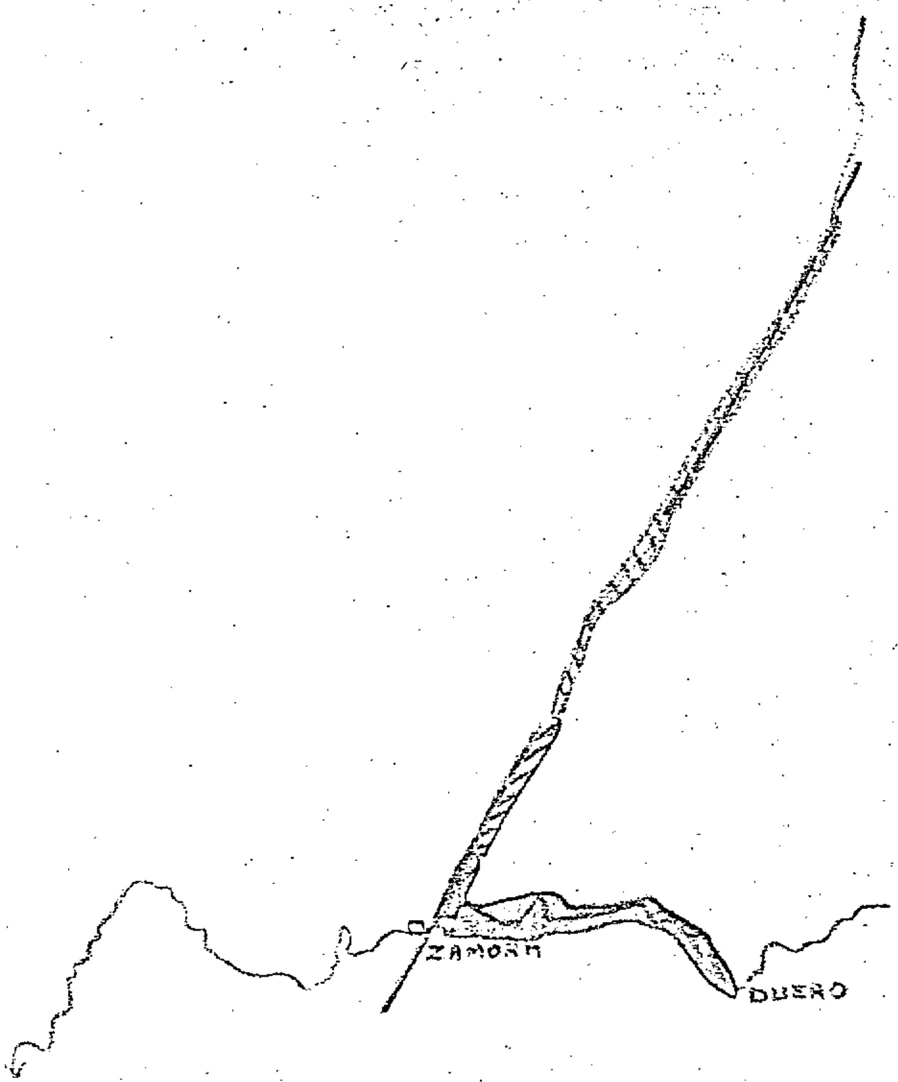
Different types of phenomena are recorded on these images outlining basement fractures not visible on the earth surface because they are buried under thick Tertiary formations. On the eastern part, fractures number 10 and 12, clearly visible on the September image, are also recorded on the two other images, taken at different periods, but with a lesser extent. These linear features are outlined by the hydrographic pattern and by the enhancement of the boundary between the abundant green vegetation of the wet zone and the surrounding dry soil where there is little vegetation.

The reasons why fracture 10 is clearly visible on the September image and not on some others can partly be found on the existing geological and vegetation map, (see figure 6).

a) The geological map indicates an important change towards the West, in the extent of the Rio Douro alluvial deposits which disappear in Zamora.

Fig 6

IMAGE ERTS 1 1067.10370



LEGEND

cultures irriguées

pâturages

alluvions

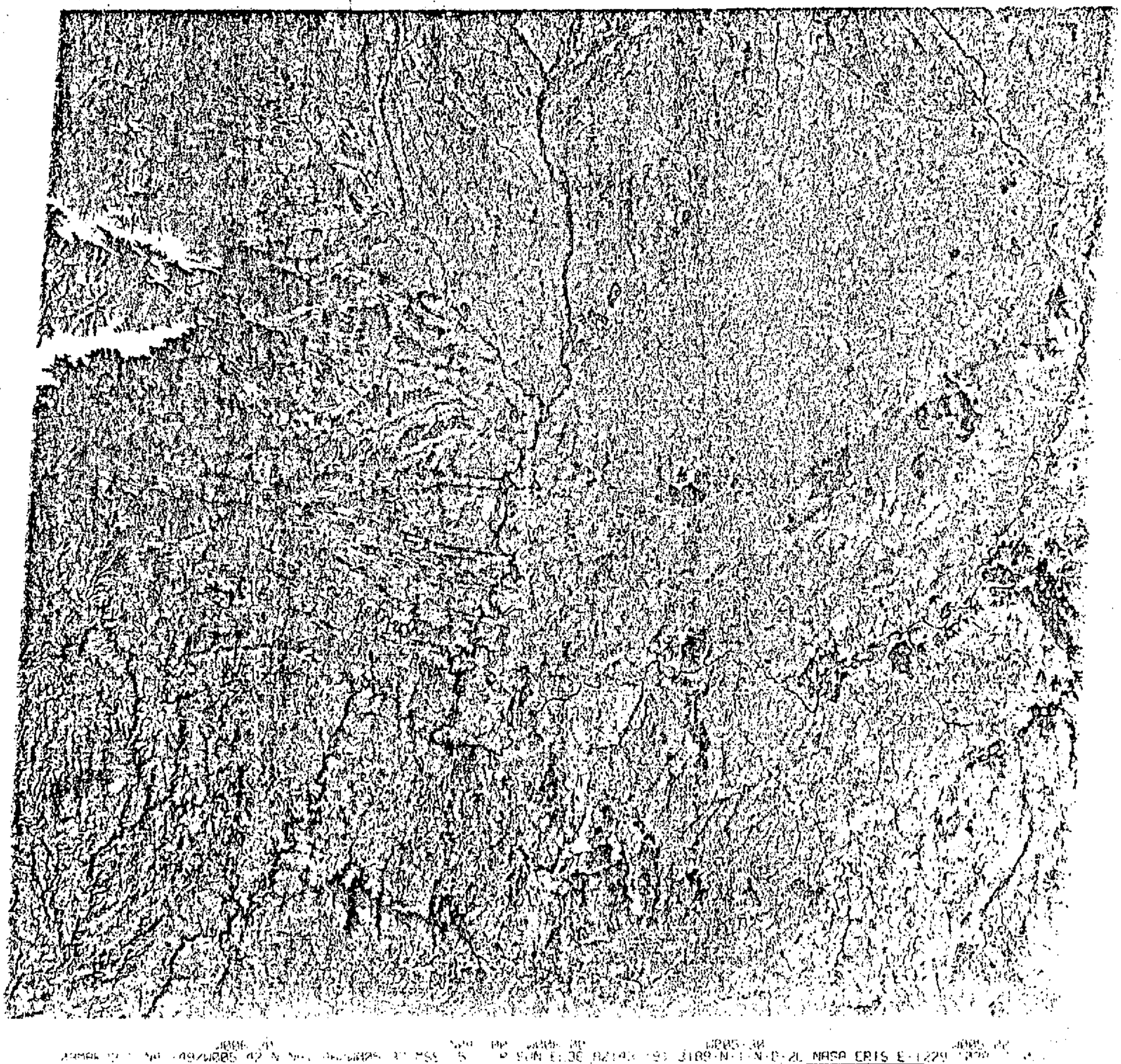
fractures

ORIGINAL PAGE IS
OF POOR QUALITY

SCALE: 1 / 1000.000.

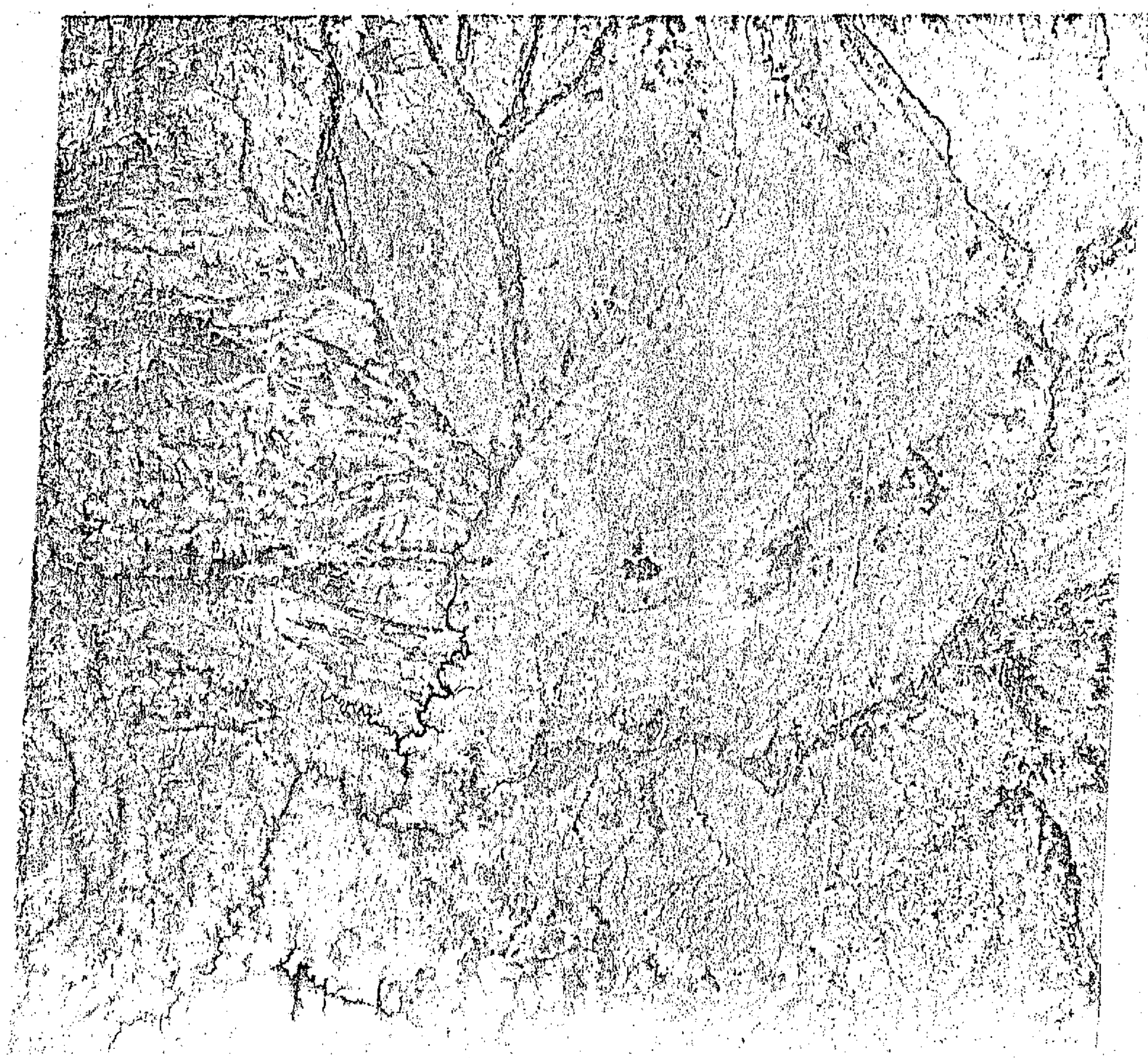
ORIGINAL PAGE IS
OF POOR QUALITY

042



ORIGINAL PAGE IS
OF POOR QUALITY

USU



W006-30 W006-00 W005-30 N041-00
23AUG72 C N41-53/W000-00 N N41-52/W005-25 MSS 5 R SUN EL51 AZ134 191-0428-A-1-N-D-2L NASA ERTS E-1031-10370-5 01

28SEP72 C N41-44/W005-29 N N41-42/W005-24 MSS 5 R SUN EL41 AZ147 191-0930-N-1-N-D-2L NASA ERTS E-1067-10370-5 01

b) As a consequence of the first rains in September, after a dry season the irrigation is vigourous. On the August image, taken during the dry season, and on the March one, realized during the heavy rain period, this fracture is not visible. This linear feature is outlined by a hydric phenomenon, but this phenomenon, to be perceptible, must succeed a dry period because after a long rainy season the contrast does not exist any more, the vegetation growing equally.

Fracture 11 is better recorded on the March image but the geological map indicates that it outlines a discreet lithological change :

- granite and detritic sediments (Arkosic) to the South,

- marls and marly limestones (Caliza de los Paramos) to the North.

In this example the vegetation is not an important factor, but we can assume that the differences in the rock permeability may play a role. Fractures 11 and 15 present a direction parallel to the Jerte Fracture and we shall talk about this in another section.

From these examples we can conclude that :

- If the earth surface observed corresponds to an area where the geological levels are constituted with rocks having few differences, the possible fractures are better recorded on the images taken after a wet season because the physical characteristics of the rocks - permeability, porosity - can then play an important role to enhance these small differences,

- if the area observed corresponds to a homogeneous formation wet and dry seasons level the differences in the distribution of the vegetation - then the only one perceptible - and the more convenient period corresponds with an abrupt change in the soil moisture content which enhances the singularities in the water distribution and consequently in the vigor of the vegetation, outlining in this way some important fracturing.

The western part of these images, where Hercynian formations crop out, is very complex from a tectonic point of view.

A system of fractures NW-SW in direction is well developed and we specially want to discuss some of them :

- Fracture 13 follows the trace of the linear boundary existing between granitic rocks towards the South and Ordovician-Silurian layers towards the North. This fracture is only visible on the March image.

- Fracture 14 also follows a boundary between alternating quartzites and slates and the porphyric gneiss named "Ollo de Sapo". From the observations recorded on ERTS image we can assume that this contact is a faulted one.

Fracture 16 is represented on the tectonic map at a 1/1,000,000 scale published by the I.G.M.E. as an overthrust. It is outlined by a change in the direction of schistosity of the Cambro-Silurian levels.

Some other alignments with a 60° angle, forming with the above mentioned direction, also exist.

Another direction of fracturing is N.NE-S.SW, parallel to the main faults cutting the Bragança massif, located further West, and quite clearly recorded on the ERTS image. Fracture 17 is one of these directions.

Notice, to end this interpretation, that the Cambro-Ordovician layers, because of the alternation of quartzites and slates, are quite clearly registered on the image.

Hervas area

The MSS images covering the region were scanned at two different periods :

1067 - 10 373 501   September 18, 1972   (Map N° 3),

1229 - 10 384 501   March 9, 1973   (Map N° 1).

The March image is the only one we have surveyed practically in this zone. In September the cloud cover is very important and makes the observation of the earth surface impossible.

In the central part of the ERTS image a spot darker than the surrounding can be observed. It corresponds to the mountainous zone of the region named "Sierra de gata", covered by heavy forest and having a very marked relief. We assume this strong difference could correspond to a lithological difference but there is no evidence of such hypothesis on the existing geological map. This point is also to be checked in the field as soon as possible.

4.2 - Usefulness of ERTS data

4.2.1 - ERTS data complement existing data in several places mentioned in the above 4.1. section, "analysis of the images".

points 1 and 2	(fig. 3),
point 4	(fig. 4),
point 9	(fig. 4),
points 5, 6, 7	(map N° 4).

Point 1 (fig. 3) is an extension towards the North East in Spain, of the Aljustrel dyke.

Point 2 (fig. 3) is an extension of the Castelo branco fault.

Point 4 (fig. 4) is near Portel and extends a known fault towards the East, after a change in direction.

Point 9, a linear structure following the Rio Miza, corresponds to a northern extension of a known fault.

Points 5, 6 and 7 (map N° 4) define the extent of already known East-West fractures, towards the North of Leon.

All these data are visible on ERTS images in the way of linear grey-tone anomalies generally due to a moisture change and/or density of vegetation.

4.2.2 - ERTS data make it possible to detect new faults.

Two systems of fractures trending E.NE-W.SW and W.NW-E.SE, forming between them an angle of nearly 60° are recorded on ERTS image.

Belonging to this system are recorded on ERTS image :

- the Jerte fracture (18),

- the Castello Branco fracture (19),

- the Alba de Tornes fracture (20),

- the Bejar fracture (23),

all of them having a E.NE-W.SW direction. Along this trend it is also possible to observe on the orbital images the linear features 21 and 22 which follow the trace of a geological boundary between the Paleozoic levels and the Tertiary layers filling the Duero basin.

Some other important fractures are also recorded in 24, 25 and 26, trending W.NE-E.SE, but they are without counterpart on the tectonic map at a 1/1,000,000 scale, published by I.G.M.E.. The fractures 24 and 25 therefore follow the boundary between the Cambrian formations and the Ordovician-Silurian levels along a short part of its extent towards the West.

Another important trend of linear features is recorded on ERTS images and is parallel to the main faults which cut the granitic rocks and the Paleozoic levels constituting the MORAIS and Bragança massives in the Republic of Portugal. Along this direction can be observed another group of fractures N.NE-S.SW in 27 and 28.

In the southern part of the image a very clear flexure developed into the Ordovician and Silurian layers is observed.

This tectonic feature is visible on ERTS images because a morphological contrast exists between the Cambrian slates and schists, and the quartzites forming the flexure.

The important fault named "Jerte" and the fracture recorded in 29 on ERTS images have a similar direction and, even if the latter linear feature is located further East they both affect the above mentioned flexure.

Several new faults detected on the ERTS imagery are not supported at the moment by field observations and are mentioned in the following section :

- from Cabo de Sines towards the North-East. This fracture parallel to the Aljustrel dyke, is 80 kilometres long (fig. 4),

- a linear structure North 130 to 140 East extends discontinuously along 150 kilometres from the North of Setubal to the South East of Beja. It crosses the Rio Sado without disturbing its water course but affects the Guadiana river (point D). Several changes in direction in A, B, and C along the Guadiana river are probably due to a parallel system of faults (fig. 4),

- in Spain (map N° 4) fractures number 10 and 12, located towards the North and the North East of Zamora, have important extensions (130 and 50 kilometres),

- fractures 24, 25 and 26 trending W.NW-E.SE are totally new. Each of them has a 100 kilometre extent.

Faults known in the field and not detected on ERTS data are very rare. The example of the dyke of dolerite passing through Aljustrel is interesting because, although it is continuous on the field its trace is observed discontinuously on ERTS images and the detected anomalies correspond to :

a) the zone where the fault is filled with dolerite,

b) the fractured zone in the eruptive complex and in the Paleocene.

As far as the volcanic rocks do not fill the fault and the fractured zone affects units other than the one mentioned in b), the trace is not recorded on ERTS.

4.2.3 - The comparison of ERTS data with an existing geological map makes the following remarks possible :

- numerous linear features detected on ERTS images and interpreted as faults correspond on the existing geological maps with geological boundaries. The main observations concern :

point 4 (fig. 2) : boundary dolerite - surrounding formations, points 4, 5, 6, 7 and 8 (fig. 3) boundaries between rocks of different types,

point 3 (fig. 4) boundary between Carboniferous and other formations.

points 10 and 22 (fig. 4) follow the trace of the basement and the Devonian boundary.

Point 1 (fig. 5) follows the boundary between the Carboniferous and the Quaternary deposits filling the Gualdequivir valley. Seismic activities and geophysical explorations confirm the tectonic origin of this contact,

point 11 (map N° 4) outlines a lithological change,

point 13 (map N° 4) follows the granite-Ordovician limit,

point 14 (map N° 4) follows the phorphyric gneiss - slates limit,

points 24 and 25, already mentioned in the "new faults" section, follow the Cambrian-Silurian boundary along a short part of its extent.

Geological boundaries are not always detected on ERTS imagery. The results obtained on the two Portugal test sites are not significant because of cloud cover, but the analysis realized in western Spain make it possible to assume that it is not easy to visually map the geological units on ERTS data. The following comments sum up our experience in this domain.

In general, if it is possible on ERTS images to observe a specific tectonic - i.e. fracturing, folding - it is possible to recognise and so to bound the geological units which are concerned with this tectonic event. In the following examples these characteristics are clearly enough expressed in the morphology and/or in the vegetation to allow a differentiation.

- Paleozoic formations (Cantabrique) on image 1056 - 10 366 501 and to the West of the Duero basin (image 1031 - 10 370 501),

- Mesozoic-Tertiary (upper) folded formations in the Santender and Oviedo basins (1067 - 10 364 501),

- Tertiary-Quaternary formations, unfolded and horizontal, filling the Duero basin (1031 - 10 370 501),

- Granitic massif of Gredos, to the West of central Cordillera (1229 - 10 384 501).

Some other lithological boundaries are locally recorded on ERTS images, sometimes with more details and more accuracy than the above mentioned ones, even without tectonical characteristics. Note that one of the best examples is : Ordovician-Silurian quartzites inside the southern flexure on image 1229 - 10 384 501.

This is therefore an exception but, if there is no special tectonic characteristic in one unit, a strong difference between the composition of the rocks quite often make it possible to delineate the units : for instance the Arc Asturian is quite differential because the rocks forming this unit are different enough from the surrounding ones.

To conclude this section it is necessary to mention the possibility to differentiate alluvia on ERTS images. They are only visible when the soil moisture content changes and affects the growth of the vegetation. For these reasons, and on the considered test site, the August and September images are the most useful ones because the alluvia, in this region, are suitable for irrigated cultivation : then, during the dry season there is a strong difference in tone between them and the surrounding soil where the vegetation is absent (1067 - 10 364 501 and 1067 - 10 370 501).

Finally, the vegetation is an important factor to delineate the lithology on orbital imagery, but the point is to know how far this vegetation is typical of some type of rocks. This is sometimes the case but it may be the consequence of a change in the altitude, or a preferential orientation of the slopes or even of human alteration. In this case it is evident that there is no relationship between lithology and vegetation and it is not possible to make a geological interpretation.

4.2.4 - ERTS data make possible a good understanding of the fracture pattern as far as the cloud cover allows interpretation.

- Test site A : important cloud cover,

- Test site B : a better observation makes it possible to classify the faults into four classes and to understand their relationship with the mineralised veins known in this district.

These classes are :

1) SW-NE,

2) North 75 to 90° East,

3) North 130 to 140° East,

4) North-South.

Classes 1 and 3 are parallel to the pyrite band. The copper mineralised veins seem to be associated with the SW-NE family of faults.

- Spain

The North to North-East class is the most important in this adjacent area (75° East).

In the northern and southern parts the North 130-140° East is also important.

The SW-NE class is represented everywhere.

Finally, the tectonic scheme over this region of Spain is similar to the one detected in Portugal.

4.2.5 - ERTS data obtained in Portugal and Spain have not been checked at the moment and we cannot say how ground survey plans were affected by this study. This survey is supported by the "Servicos Geologicos" of Portugal who plans to use it as a guide to detect possible mineralised structures.

Finally, we cannot mention important errors found in the existing geological map.

The western Spain survey was not included in our proposals but the results are promising and Miss CID BALLARIN, a Spanish geologist "fellow" CNES in France, plans to check the main discoveries during the coming months.

5 - CONCLUSION

5.1 - Test site 1

The main objective of this experiment concerns the differentiation between granitic mountain massifs ; one is conformable and the second unconformable, based upon petrographic and tectonic criteria.

The region chosen to test the ability of the spacecraft images is cloudy and makes it impossible to conclude on the mentioned objectives.

Therefore the survey of the images allows some observations :

- most of known fractures are identified and new observations are made in the field of linear features,

- some boundaries between geological units constituted by rocks showing a very differentiated lithology (dolerite - sedimentary levels for instance) can be mapped on ERTS images when they follow a linear trace.

5.2 - Test site 2

The objective of this second experiment is an attempt to map different tectonic domains in a flysh facies. It is impossible to draw entirely successful conclusions after one survey realized on only one image of medium quality but it is certain that ERTS imagery supplies some very interesting observations on the folding in the Carboniferous formations. This information is expressed by some alternations due to the vegetal cover - parallel to the main known tectonic structures, (faults, overthrusts), and very probably reflects lithological differentiations that the field survey might confirm. The lithological aspect of these observations is proved by image 1067 - 10 382 where the correlation with intra-Carboniferous boundaries is good.

A more important result is once again obtained in the tectonic domain. Particularly image 1014 - 10 435 which makes a precise fracture analysis possible and allows their chronology to be established locally.

Some of these fractures, unknown until now, have a great extent ; they are visible in recent Mio-Pliocene formations but do not disturb the hydrographic pattern : this observation makes possible the assumption that they probably correspond to ancient faults, without recent throw, and we suppose evidence in the field is not easy to find.

5.3 - Western Spain

This survey was not included in our proposals but represents the only one experiment we have really based upon the comparison of multi-seasonal images. The results are very promising in the tectonic domain and demonstrate, in a region where the seasons are quite differentiated, the interest of repetitive coverage but also the difficulty to find the accurate date to maximise a discreet and fugacious phenomenon. The interpretation mainly based upon differences in the growth of vegetal cover and moisture content reveals several examples of fracturing strongly enhanced under special meteorological circumstances and partly or completely cancelled under others.

5.4 - General utility of ERTS data

Pertinent conclusions on the general utility of ERTS data relating to the test site cannot be drawn because of excessive cloud cover over portions of the principal area of interest. However, the scattered results obtained in the tectonic domain improve the geological knowledge of these regions. The survey realized over Spain demonstrates the major interest of multiseasonal images in the tectonic domain.

The B.R.G.M. activities in both Portugal and Spain not being important at the moment, nothing has been forecast and plans have not been expanded, reduced or revised in the view of ERTS data.

The ERTS data technical impact on research projects, if evident, is not yet proved in this survey, disturbed by an important cloud cover.

6 - APPENDIX

6.1 - Listing of presentations

Only one paper has been prepared by Miss CID BALLARIN, but not published at the moment :

"One example of the multiseasonal interest of the ERTS images : the tectonical and geological survey of the western Spain".

6.2 - Images received

TABLE 1

Image number	Date	Received
1014-10435	August 1972	May 1973
1033-10493	" "	" "
1067-10382	September 1972	" "
1031-10364	August 1972	" "
1032-10423	" "	19/10/73
1032-10425	" "	" " "
1032-10432	" "	" " "
1033-10491	" "	" " "
1067-10370	September 1972	" " "
1067-10373	" "	" " "
1229-10381	March 1973	" " "
1229-10384	" "	" " "
1031-10370	August 1972	" " "
1067-10364	September 1972	" " "
1229-10375	March 1973	" " "

6.3 - Quality and localization of images

TABLE 2

Image number	Localization	MSS	Quality
1014-10435	Beja Setubal - Portugal	4	cloudy
1033-10493	Lisboa - Portugal	4	cloudy
1067-10382	Rio Changa - Tavira - P	4	cloudy
1031-10364	Oviedo (Spain)	5	cloudy
1032-10423	Luga (Spain)	5	cloudy
1032-10425	Vilareale (Spain)	5	cloudy
1032-10432	Guarda (Portugal)	5	cloudy
1033-10491	Santarem (Portugal)	5	cloudy
1067-10370	Zamora (Spain)	5	good
1067-10373	Hervas (Spain)	5	good
1229-10381	Zamora (Spain)	5	good
1229-10384	Hervas (Spain)	5	good
1031-10370	Zamora (Spain)	5	good
1067-10364	Oviedo (Spain)	5	cloudy
1229-10375	Oviedo (Spain)	5	good

6.4 - References

- Instituto geológico y Minero de Espana - Paranifo

  "Mapa geolsgico de Espana y Portugal 1/1,250,000" - 2e edition - 1965 - Madrid.

- Instituto geològico y Minero de Espana

  "Mapa tectònico de la Peninsula Ibèrica y Baleares 1/1,000,000" 1972 - Madrid.

- Instituto geològico y Minero de Espana

  S.G. del M.OP   C.S.I.C.

  "Mapa litològico de Espana" 1/500,000 - 1969 - Madrid-Zarasgora.

- Servicio del Mapa Agronòmico nacional del Ministerio de Agricultura

  "Mapa de cultivos y aprovechamicutos de Espana 1/1,000,000", 1962 - Madrid.

- Serviços geologicos de Portugal (1968)

  Carta geologica de Portugal, 1/1,000,000.

- Serviços geologicos de Portugal (1972)

  Carta geological de Portugal, 1/500,000.

Diffusion :

ERTS technical officer
ERTS scientific monitor
Technical information
Division
ERTS program manager
ERTS program scientist
Office of international
affairs
C.N.E.S.