

STRUCTURAL INVESTIGATIONS IN THE MASSIF-CENTRAL - FRANCE -

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ABSTRACT

One survey we have achieved using ERTS imagery concerns the French "Massif-Central"—where cristallin and volcanic rocks outcrop—and its surrounding sedimentaries, "Bassin de Paris", Bassin d'Aquitaine" and Rhodanian valley.

The main purpose was the objective mapping of fracturing and the surveying of its relationship with known ore deposits. Then—eventually, to draw up a mineral research philosophy. During this survey we have shown the ability of ERTS imagery to outline lithology in some sedimentaries basins. On the other hand, in a basement area—under temperate climate conditions—lithology is rarely expressed. These observations can be related to the fact that band 5 gives excellent results above sedimentaries basins in France and generally band 7 is the most useful in a basement area.

Several examples show clearly the interest of ERTS imagery for mapping linear features and circular structures and confirm former ideas. All the main fractures are identified with the exception of a few—new ones are found both in sedimentaries and basement areas. Other interesting findings concern sun elevation which—stereoscopic effect not being possible—simulates relief in a better way under certain conditions. Then we have also found band 4, judged until now as not very useful by geologists can eliminate artificial details product by shadow of linear clouds (jet stream for instance, invisible on other bands).

At the least this paper aims to point out that ERTS images are a very useful tool but more time will be needed to prove its validity because details discovered have now to be carefully surveyed.

INTRODUCTION

The Massif-Central, located in the central part of France, is a fragment of the Hercynian chain peneplaned at the end of the Permian period.

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During the Westphalian it was divided by large fractures causing the formation of Stephanian coal basins (Saint-Etienne for example) over the whole area of the Massif.

The formation of graben during the Oligocene period (Limagnes, Aurillac, etc.) and of the high volcanic massifs (Mont Dore, Cantal, etc.) during the Neogene and Quaternary are the consequence of later evolution.

WHY THIS TEST SITE?

We have chosen this Massif to test the ability of ERTS images in the domain of tectonic geology because it is a very complex area where various geological phenomena are represented. Constituted by cristallin and volcanic rocks, showing exposures of Stephanian and Oligocene layers in more or less important graben, surrounded by sedimentaries basins (Parisian Basin, Aquitanian Basin, Rhodanian Valley), strongly affected by faulting, it is very interesting geological model.

Fracturing of different periods is very important all over the Massif-Central and metalliferous deposits, linked with it, have an economic interest: for instance the main lineament, called the "Sillon houiller" seems to be a boundary between two mineralized districts, the eastern one being the most important from a mining point of view. The study of the possible extent of this lineament toward the North (Sancerre fault), suggested by geophysical investigations is an interesting matter. Elsewhere we have seen that large fractures have permitted the formation of Stephanian coal basins but antimony, lead, gold, fluorite, baryte, zinc, silver and uranium appear in various districts. Some of them (fluorite) seem to be linked with coal basins and an accurate and objective mapping of fractures make it possible with ERTS images, could establish to research a good chronology and then become a useful guide for research of new deposits.

Let me point out, too, mineral springs, numerous in this country, are linked with fractures and here again the Sillon houiller seems to separate the Massif-Central into two districts, the eastern one only having the mineral springs: in France the economic value of thermal springs is certain.

Good maps exist for metalliferous deposits and mineral springs and a valid comparison is possible.

In another context, conscious of remote sensing ability in geology, the B.R.G.M. is involved, with other French geological societies, in experiments, mainly on the Massif-Central. Several investigations are being conducted in

cooperation with these companies—and with the national space agency—on four test sites (Villefranche, Meyrueis, Genolhac, Minervois) using colour and infra-red colour photographs, thermal infra-red imagery and multispectral scanning.

Finally for mineralized veins massive research is in progress over the Massif-Central and these surveys are very often conducted on the field with fractures maps interpreted by the B.R.G.M. photogeological team on 1/25 000 scale photographs. About twenty 1/50 000 scale fracture maps have been interpreted and checked in the field. Comparison between these photogeological fractures map and ERTS images interpretation demonstrates clearly the ability of orbital photographs and shows how many data they have registered.

Some of the surveys have been carried out at different scales (balloon photographs, 1/400 000, Mystere 20 photographs 1/100 000, classical photographs 1/25 000 and special cover 1/10 000) with different types of film while at the same time gravimetry and/or aero magnetism were used. Above the Villefranche test site these different scales aerial covers show, if some data exist on each one, some appear on ERTS image, for instance the circular structure we discuss in the "circular structure" part of this paper.

A fracture age map is scheduled and will be achieved in the next months.

Field mapping, drilling, geophysical surveys and remote sensing give us a very good control and make a valid interpretation of ERTS imagery possible on the Massif-Central. Several of these, in progress at the moment, will help us to obtain the necessary synthetic view of this complex area.

PROCESS OF SURVEYING

Each scene was carefully interpreted, using stereoscopic effect where possible, on the four bands at the beginning of the survey. However, it quickly appeared that only bands five and/or seven were useful and sometimes complementary for geological purposes. Band 6 generally is an image very similar to that obtained with band 7. Band 4 does not give any geological information; however, this band is necessary when the scene is apparently absolutely uncloudy. We have several examples where linear features, interpreted as possible fractures on bands 5, 6 and 7 are clearly related with the shadow of linear clouds with band 4.

One point is not clear. Why on some part of the test site band 5 is the best and on some others it is band 7? On the Massif-Central test site five scenes are interpreted on band five and nine scenes on band seven. For three of these

scenes the two bands present complementary features and for the others only one band can be exploited. Apparently, but this is not a rule, band 5 is better in sedimentaries formations, probably because vegetation is more contrasted there—and band 7 on basement areas. The Morvan scene illustrates this idea very well, but no conclusion can be drawn.

Another observation concerns sun elevation action. The Coiron volcanic massif is visible on two different scenes with two different sun elevations and only one shows the geological boundaries clearly; it is the one having a sun elevation of 35° (57° on the other).

Finally even if we have only one scene taken at two different seasons (March and September) we can assume the interest of multiseasonal images in geology by considering the results obtained on the eastern Parisian basin images. Comparison between the two images shows some differences which give a good idea of the geology of the "Bassin de Paris"; for instance, on band 7 taken in March, an important change appears towards North, in the Upper Cretaceous chalk, and also another one to the South. This change, not visible in September, corresponds to Quaternary argillaceous formations.

On the other hand, the extension of the Metz fault interpreted towards the West because the Seine river was seen without its alluvial terraces is not clearly observed in March these alluvium being not apparent.

All the interpretations we made on the test site were compared with existing documents:

- geological mapping at different scales,
- photogeological interpretation,
- geophysical exploration,
- drilling,
- various analysis,

and numerous results are confirmed by at least one of these methods. Such results in an area well known in the field are important and prove the validity of ERTS images.

RESULTS

We have not specially surveyed lithology but we can say that results are very irregular, and better in sediments than in the basement. Volcanic rocks were not generally observed. A fracture map at a 1 million scale is achieved and illustrates this paper. Some of the new results obtained from ERTS images are being checked at the moment or will be checked later. Features interpreted on ERTS images as possible fractures belong to four groups:

- fractures known in the field,
- extension of known fractures,
- fracture unknown in the field but corroborated by geophysical investigations, drilling and other methods,
- totally new fractures.

Notice that known fractures exist which are not visible on ERTS images but these represent only a small percentage.

Fractures we wish to discuss mainly correspond to group III and confirm that deep structural features under a thick cover are sometimes translated on the surface by indirect criteria.

The Aigueperse Fault

This fault was discovered by geophysical investigations and shows that the Limagne Basin is partitioned by North-East fractures. A field party is mapping this area at a 1/50 000 scale and if there is really a difference between the northern and the southern formations—sand and limestones to the North, marls to the South—there is no trace of fracturing on the ground except near Chatel-Guyon where thermo-mineral springs are known. However, on the ERTS image a linear feature we interpret as a fracture follows on the surface level the path of the fault found by gravimetry and confirmed by drillings, showing granite near the surface to the North and 1 800 meters deeper to the South.

The Toucy Fault

This fracture is known in the field at the jurassic level. An extension is found on ERTS images, towards the North, in the Cretaceous level and this ground trace corresponds quite exactly with a fault interpreted from drilling by petroleum geologists under 1 000 meters of Cretaceous chalk. We can assume this deep fault, probably not effecting Cretaceous levels is however visible on ERTS images through indirect criteria, difficult to interpret on the ground.

The Saint-Etienne Fault

The Saint-Etienne coal basin is strongly bounded on ERTS images on its southern limit. Another fracture, parallel to the North, is quite visible, but located in granites and migmatites, and shows the Westphalian graben is probably widest as indicated on the geological map even if there are no coal deposits in the northern part. These two faults extend across the Rhône Valley under thick fluvial sediments. We specially underline the southern extension because it follows quite exactly the basement high, known by drilling at 500 meters, which limits to the South the continuation, under the Rhône Valley of the Saint-Etienne coal deposit. This is a proof of the value of ERTS images in mineral research, a tool to explore ore deposit extensions.

ERTS images also show in this area a communication between the Roanne basin, filled with Oligocene sediments and the Saint-Etienne coal deposit and pose the problem of the ages of these two graben considered until now Oligocene for that of Roanne, Westphalian for the other.

The Bracieux - Gien and Cere - Romorantin Linear Features

These linear features are genuine ERTS discoveries. Geophysical and geological maps do not give a possible explanation of the phenomenon and unfortunately drillings are only a few there. It seems therefore that these two ERTS "fractures" each one hundred kilometers, or more, could reflect on the surface the Permian basin partly known by drilling and geophysics and named "the Cointre Fosse" by J. Lienhardt. These Permian sediments are at a thousand meters under the Jurassic and Cretaceous levels. Then on the "hypogeological" map of Weber the existence of a northern fault is confirmed near Villebourgeon, but very locally indeed.

Such a fault, trending north 80°, follows a direction that numerous authors have outlined in France (Guillemot, Duplan) and is parallel to the South with the extension of the Metz fault.

Then we can assert with Groslier and Letourneur, a displacement of nearly 70 kilometers along the main North-South trend (Sillon houiller - Sancerre Fault) because it is the distance between Gien and Montereau (see map). If we remember, we have shown on ERTS images the Metz fault follows westwards the Permian basin of Courgivaux - Trois Fontaines known under thousands of meters of sediments, we can assume that we begin to have a good knowledge of deep structures in the Parisian Basin, thanks to orbital imagery.

The Brive Fault

East of Rochechouart a 50 kilometers long fracture is visible on ERTS images, partly in Cristallin rocks, partly in Jurassic levels. This alignment is to be specially discussed because unknown until now on the geological map, it is partly described in a recent paper (J. Delfaud). This author shows that this fault, in its southern part, is the western margin of the "Occitan high", a paleo-relief he outlines with detailed sedimentology. Northwards we extend this fault across the Massif-Central in using the alignment interpreted on ERTS images.

Once again, with this example we demonstrate the interest of orbital imagery in tectonic research. On the other hand, and we specially want to underline this idea—we think it is absolutely necessary, checking in the field all the ERTS discoveries, to use not only the classical "hammer investigation" but also all other techniques available: geophysics, drilling, sedimentology . . . and others. Examples described in this paper, and in a recent one (ERTS-1 symposium) where we talk about the possible extension of the Metz fault, have been chosen to prove this idea and it is quite evident it will need some time to corroborate all the ERTS-1 discoveries in the geological tectonic domain.

Circular Structures

To end this paper we want to say a word about circular structures found on M.S.S. images and they are numerous.

The Rochechouart one is known from the time Raguin described it and demonstrated it was due to meteoritic impacts. B.R.G.M. and University of Paris Orsay are working on the topic (Lambert) and ERTS images are used, enlarged at a 1/200 000 scale. At the first glance a circular pattern is obviously visible, West of Rochechouart, and corresponds quite exactly to the breccia zone. Faults interpreted on ERTS images are partly known in the field and the North-South one, cutting the Vienne river West of Chabanais follows scattered microgranite veins and allows M. Lambert to draw up an interesting hypothesis we shall discuss in another paper. On the other hand a western extension of the meteoritic structure, found in the field but not evident is supported by M.S.S. images, even if not really obvious.

Other circular structures were found on ERTS images around Rochechouart. None is meteoritic structures; some are in relationship with oriented level in metamorphic rocks, some others are more interesting for this discovery, if confirmed by detailed surveying, could be important as it is in the vicinity of the already known circular structure of "Puy les Vignes" which is tungsten bearing.

South-East of Rochechouart, but East of the "Sillon houiller", another obvious circular structure appears on M. S. S. images near the town of Villefranche and located in granite. A field party mapping the area is checking it. This structure is in relationship with mineralized veins also visible on ERTS imagery. Notice this feature is visible on two different scenes and stereoscopic effect is allowed. However we have surveyed aerial photographs at a 1/25 000 scale—nothing appears—and balloon colour photographs at a 1/400 000 scale where the circular pattern is not obvious.

In the volcanic area circular structures are numerous and we cannot describe all of them; they are shown on the map and we will look for their validity later.

CONCLUSIONS

The map of linear structural features interpreted on the Massif-Central test site—and illustrating this paper—is one of the results we were expecting. This map is to be improved, in the next months but even in its genuine form it shows that numerous fractures visible on ERTS images are not only corroborated by field geology but also—and this point seems important to us—by other methods of investigation: geophysics, drilling, sedimentology. Also we can assume linear features seen on ERTS images, even if not visible to geologists in the field—very probably exist but do not affect the surface. We can conclude that these fractures cannot be sought by classical methods of surface geology.

On the other hand in the Massif-Central, where mineralized veins were recently discovered (Saint-Salvy for instance) by B.R.G.M. geologists it is important, for mineral research in the near future, to have a fracture map as obvious as possible. This map, compared with a large scale fractures map interpreted from the aerial photographs is to become a guide but it is evident that more time is necessary to prove its usefulness in mineral research.

To conclude we should say that B.R.G.M. geologists involved in mineral resources investigations all around the world, in view of the results obtained on the Massif-Central test site believe that ERTS imagery, or other orbital photographs, stereoscopic if possible, are a necessary tool for their research. For these reasons the B.R.G.M. has already bought several hundred ERTS images in the countries where we are working.

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