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STRUCTURAL GEOLOGY INVESTIGATION
IN THE REPUBLICS OF DAHOMEY AND TOGOLAND,
AFRICA, USING ERTS
1. MULTI-SPECTRAL IMAGES

(E75-10237) STRUCTURAL GEOLOGY
INVESTIGATION IN THE REPUBLICS OF DAHOMEY
AND TOGOLAND, AFRICA, USING ERTS-1
MULTI-SPECTRAL IMAGES Final Report, Jul.
1973 - (Bureau de Recherches Geologiques et

N75-21762

Unclas
63/43 00237



Departement carte geologique et geologia generale

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BUREAU DE RECHERCHES GÉOLOGIQUES ET MINIÈRES

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STRUCTURAL GEOLOGY INVESTIGATION
IN THE REPUBLICS OF DAHOMEY AND TOGOLAND,
AFRICA, USING ERTS
1 MULTI-SPECTRAL IMAGES

by

G. WEECKSTEEN

Original photography may be purchased from:
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October 1974

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REFERENCES

Title of investigation :

Structural geology investigation in
the Republics of Dahomey and Togoland,
Africa, using ERTS-1 multispectral
images.

Principal investigator :

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principal investigator's
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Bureau de recherches géologiques et
minières, B.P. 6009 - 45018 - Orléans
cedex - France

Date :

April 1974

Type of report
and period covered :

Type III report

Name and address of
national sponsoring
agency :

CENTRE NATIONAL D'ETUDES SPATIALES
129, Rue de l'Université
75 007 - PARIS - France.

1. SR N°. 003 - 3	2. Type of report Type III	3. Recipient catalog n°.
4. Title Structural geology investigation in the Republics of Dahomey and Togoland Africa, using ERTS-1 multispectral images		5. Report date April 1974
7. Principal investigator Guy WEECKSTEEN		6. Period covered July 1973 - April 1974
9. Name and address of principal investigator's organization Bureau de recherches géologiques et minières, B.P. 6009, 45 018 - ORLEANS - Cedex - France		8. Number of pages
12. Sponsoring agency, name and address CENTRE NATIONAL D'ETUDES SPATIALES 129, Rue de l'Université, 75 007 - Paris France		10. Principal investigator report N°. 1.
14. Supplementary note This report has been prepared by G. WEECKSTEEN		11. G.S.F.C. Technical monitor C. BRODERICK
15. Abstract Recent geological studies in the Republics of Dahomey and Togoland put in light a new chronology and propose a schema indicating that the structural geology of this region is very complicated : this is the basis of our proposals. The new observations made possible by the ERTS images concern the main orientations, the folded units and the lithology. The correlation between different types of laterite and the petrology of the basement seems possible, and is the most significant result of this investigation but unfortunately conducted with poor quality images because of the atmospheric haze.		13. Key words (selected by the principal investigator) Remote sensing. Geology - Tectonic. Multispectral - Laterite. Haze effect

I - HISTORY OF THE RESEARCH PROJECT

In 1971 we proposed to NASA, using ERTS 1 imagery, a survey of Togoland and Dahomey in western Africa.

1.1 - Reasons for this choice

We have chosen this region to test the ability of spacecraft photographs because the considered climatic zone - i.e. tropical and sahelian - is very important all over the world, but also because the geological units which crop out in this country are various. The following formations are mapped :

<i>Tertiary</i>	(continental terminal sandstones)
<i>Upper Cretaceous</i>	(Kandi sandstones)
<i>Cambro-Ordovician</i>	(Oti schists, Bambuaka sandstones)
<i>Infracambrian</i>	Buem (sandstones - quartzites - jaspes) Birrimien (schists, amphibolites) in the upper Volta Republic
<i>Precambrian</i>	Atacorien (micaschists and quartzites) Dahomeyan (micaschists, gneiss, embrechites, quartzites).

The orogens - in the crystallophylian series - are characterised by isoclinal foldings dipping towards the East where it is impossible to observe anticlines and/or synclines. Finally, granitic batholits having various chemical compositions intrude these formations.

1.2 - Objectives

Recent geological studies put in light a new chronology and propose a schema indicating that the structural geology of this region is very complicated.

The main object of the proposals was to bring out new observations in agreement or not with the present conception of western Africa's structural geology.

Another objective was to look on the interest of ERTS images under tropical or sahelian climates and on lateritic cover.

1.3 - Data requirements

1.3.1 - Periods

Only one set of images was required for the test site during the February-April period, a long time after bush-fires and before the first rainfall.

1.3.2 - Cloud cover

We required the best possible coverage during the mentioned period, but as NASA thought this was not precise enough, we asked for less than 20-30% cloud cover.

2 - SCOPE OF ACTIVITIES

We explain in our conclusions that the image quality is poor because of the haze effect : the first images received being very hazy, we delayed the interpretation until the arrival of new documents. Unfortunately, the quality was no better and this is the reason why we are late in writing this final report. To conclude, note that all the images were received in July 1973.

2.1 - Images received

I.D. Number	Date	Received
1272-09433	April 21, 1973	July 16, 1973
1272-09435	"	"
1272-09442	"	"
1273-09491	April 22, 1973	July 06, 1973
1273-09494	"	"
1273-09500	"	"
1274-09550	April 23, 1973	"
1288-09324	May 07, 1973	July 16, 1973
1289-09374	May 08, 1973	"
1289-09330	"	"
1289-09383	"	"
1289-09385	"	"
1289-09392	"	"
1291-09490	May 10, 1973	July 06, 1973
1291-09493	"	"
1291-09495	"	"

2.2 - Quality of the images

I.D. Number	Quality
1272-09433	good
1272-09435	good
1272-09442	good
1273-09491	hazy
1273-09494	hazy
1273-09500	hazy
1274-09550	cloudy
1288-09324	hazy and cloudy
1289-09374	cloudy
1289-09380	good and cloudy
1289-09385	very cloudy
1289-09392	cloudy
1291-09490	cloudy
1291-09493	hazy and cloudy
1291-09495	cloudy

3 - SIGNIFICANT RESULTS

3.1 - Analysis of the images

The points mentioned in this section (1 to 29) refer to the map.

1289-09383

The main orientation in the gneissic formations of the basement is recorded by ERTS as linear features due to talwegs or to crest lines. This orientation - North to North North-East - is similar to the one measured in the field.

Some parts of structures are locally observed which cannot be more precisely interpreted (point 1).

Fracturing

This fracturing is oblique on the general orientation and is reflected on the earth surface by the linearity of the drainage pattern. Note that this is invisible on the 1/200,000 scale geological maps. The main SW-NE direction of fracturing is not known in the field at the moment.

Lithology

The quartzites forming the Badagba group are characterised by their morphology and their grey tone.

A light tone area in point 2 could represent - accuracy being a function of the scale - mylonitic schists outcropping in this area.

1272-09442

This image is located on a geological key point and its analysis is very useful. We also intend to completely describe the recorded units.

The Bambouaka sandstones (point 3) are recorded on ERTS in a typical dark tone facies. In the field they outcrop into tablelands forming relics.

The Oti schists (point 4) outcrop poorly and present a lateritic weathering. On the images they are recorded in a typical facies, very homogeneous and having a changing tone.

The Buem quartzites and sandstones (point 5). They are recorded on the central part of the image in a light tone facies very characteristic and probably related with a sandy soil. The boundary between the Oti and the Buem formations is outlined by quartzitic beds. Towards the North these beds disappear suddenly and the boundary becomes less accurate.

The Atacorien quartzites (point 6). They form a mountainous ridge named the Atacora range, bounded to the West by a 200 metres high scarpment, the trace of which is accurately recorded on ERTS image. This trace, very linear locally, suggests an anomalous or faulted contact, a hypothesis which is in agreement with field observations.

The quartzitic structures are clearly visible and seem more complicated than the field mapping indicates. Particularly wide syncline structures exist in quartzitic beds, considered until now as isocline.

The lack of structures in the central part, on point 7, indicates that Quaternary formations are present.

The eastern limit of the quartzites, within the gneissic basement (point 8), is not as clear as the western contact. The ending of the quartzitic structures and the arrangement of the drainage pattern make it possible to trace this boundary but without accuracy.

The Mount Kébré ultrabasites (point 9). The amphibolites and pyroxenites form a 200 metres high mountain mass, very characteristic on the image as it is recorded in a dark tone. The boundaries are very accurate, and towards the South the image makes it possible to precise a contact invisible on the 1/50,000 scale photographs interpreted during another

survey. Note that this southern contact is not clear in the field.

1272-09435

The sedimentary formations already described are present on this image. Some interesting points concern :

- the regularity of the Oti schists (point 10) exhibiting several annular structures, the origin of which is unknown,

- the extent and the regularity of the Bambouaka sandstone facies (point 11),

- the very detailed structures visible in the Atacorian quartzites and not mapped in the field, by reference to the 1/500,000 scale geological map,

- the granito-gneissic basement where a discreet orientation conformable with the main directions already known in this region is recorded by ERTS,

- a marked structure (point 12) 25 kilometres wide, unknown until now, and outlined by ERTS imagery probably because it is formed by a basic rock formation, showing a dark tone facies and also because of the arrangement of the drainage pattern, point 6. - Fig. 1 -.

- in general basic formations, some of them known in the field, (point 13) are interpreted on ERTS images because they have a dark tone facies,

- the laterite which is mapped presents a dark tone facies and its southern limit is accurately traced because of this characteristic facies (point 14),

- the fracturing is interesting in point 15 where the trace of the Kondio fault is visible. but, this is not due to the drainage pattern as it is generally. The Oti schists, the Bambouka sandstones and the basement are disturbed by this fault but not the Atacorian quartzites.

LITHOLOGY

The important lateritic cover masks the outcrops but, even in the field the rocks are invisible and rare.

STRUCTURES

In the laterite the more eroded valleys allow the observation of a schistosity which corresponds to the directions already known in the field.

LATERITE

Two types of laterites are distinct on the image :

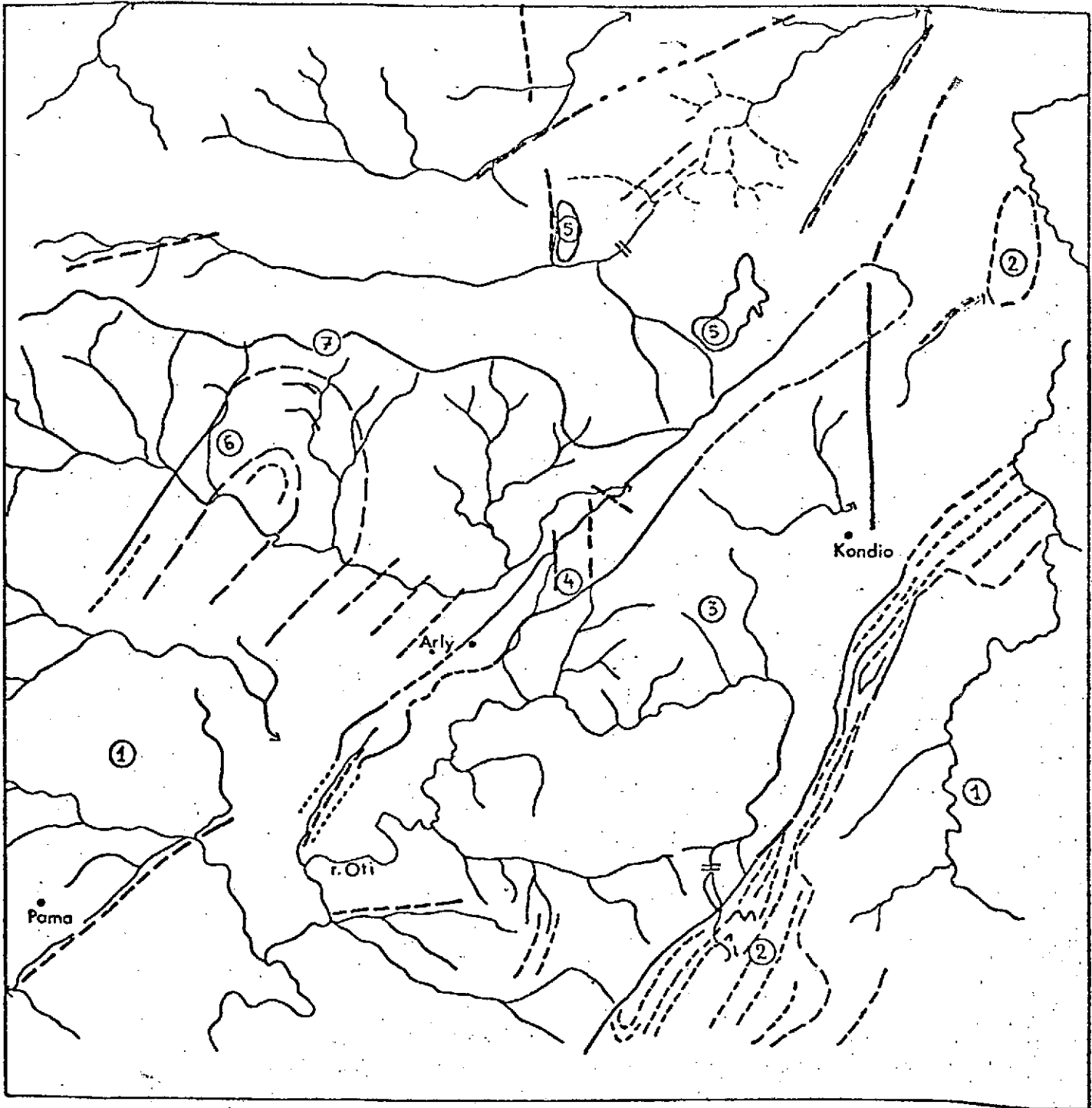
- the laterite covering the "continental terminal" formation (point 16), forming dark tone tablelands - this is due to ferruginous oxydes - and limited by a sandy soil,
- the laterite covering the basement (point 17) cannot be accurately limited because its grey tone facies gradually changes.

HYDROGRAPHY

Spectral band 5 is a better tool to interpretate the hydrography when the water courses are outlined by a forest gallery, but spectral band 7 gives better results to map the Niger river, making it possible to bound minor from major river beds and fossil meanders.

On this image ancient fossil affluents of the Niger river are recorded. The central flat, with a thick vegetation, and the major sandy bed, free of vegetation can be distinguished.

The laterites forming the tablelands covering the "continental terminal" are clearly delineated. Circular depressions are visible on point 18 as far as they have a certain extent.



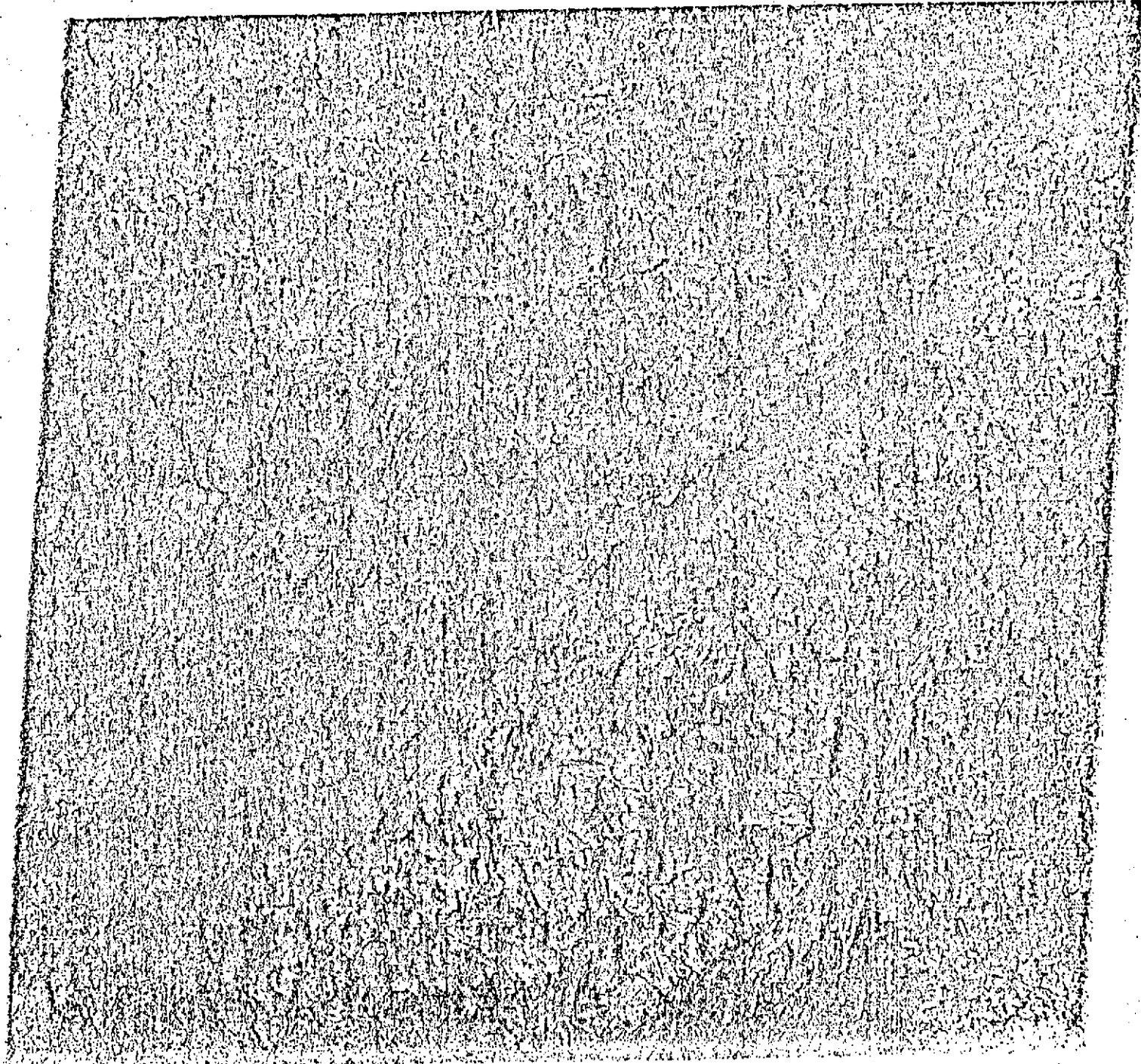
- | | | | |
|---|-----------------------|-----|----------------------------------|
| ① | Socle indifférencié | ⑥ | Structure |
| ② | Quartzites atacoriens | ⑦ | Limite des plateaux latéritiques |
| ③ | Schistes | /// | Fractures, failles |
| ④ | Grès de Bambouaka | --- | Limites lithologiques |
| ⑤ | Roches basiques | | |

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1289-09380

Observations already described can be made on this image. They concern :

- the extent of laterites covering the "continental terminal" (point 19). The ERTS image interpretation makes it possible to delineate some surfaces of laterites unknown until now,

- the Bambouaka sandstones, visible on point 20,
- the Atacorlian quartzites, recorded on point 21.

The genuine observations concern :

- the gneissic basement where the muscovite gneiss and amphibole-biotite gneiss seem to present a different facies (point 23). This difference is probably due to the lateritic weathering,

- the "Guene" fault (point 24) and its nearly one hundred kilometres extent, is visible and accurately mapped on ERTS image : it bounds towards the East the hills where the basal conglomerate of the Kandi sandstones (point 25), upper Cretaceous in age, crops out.

1291-09490

The oriented zones correspond to bands of schists, lavas and tufs, Birrimian in age.

The laterites which cover the Birrimian amphibolites are recorded in dark tone facies in point 26.

The gabbroic rocks present a dark tone facies very characteristic on point 27.

1273-09494

The basement is locally visible in the zones when the laterite is eroded : point 28. Other observations are :

- indications concerning structures,

- area showing a dark tone facies which probably corresponds to basic rocks (point 29),

- two types of laterites which have a certain extent :

. the first one, located at the NE, is recorded in a dark tone facies and seems to overlap the schists and the amphibolites Birrimian in age,

. the second one, located at the South presents a lighter tone facies and covers the basement.

1273-09599

Only the North-eastern part of the image covers Togoland. The Bambouaka and Dapango sandstones form delineated tablelands, but their chronology cannot be deduced from the ERTS images interpretation.

3.2 - Synthesis of the results

A) The multispectral images covering the zone located at the South of 10° North parallel are not usable because the cloud cover is too important. At the North of this parallel, the clouds are rare, but the atmospheric haze levels the contrasts.

On the cloudy zone, spectral band seven is slightly superior to spectral band 5. The strong reflectance of the vegetation makes several observations in the tectonic domain possible, and the beams absorption by water outlines the linear parts of the rivers which are under the dependance of the fracturing.

B) The usable part of the images allows the following observations :

- *the main orientation* in the basement is outlined by linear features parallel to the ridges - sometimes not higher than 10 metres - or by the main talweg direction.

- *the folded structures* are only visible when they concern a marker bed, wide enough to be recorded on the image. The arrangement of the drainage pattern sometimes confirms the structure,

- *in the lithological domain* the criteria used to identify the formations are various and indirect as the lateritic cover is thick.

They are :

- . the morphology when there is a differential erosion : for instance, the quartzitic beds; or the tablelands of sandstones,

- . the vegetal cover which presents some differences in its growth and texture,

- . the degree of weathering in the geological formations : in sandstones for instance, detailed structures are recorded, but in the basement, masked by a lateritic cover, the stratification and the schistosity are very discreetly recorded,

- . the type of drainage which changes when the lithology changes.

C) A comparison between the ERTS images interpretation and the geological maps at a 1/500,000 and a 1/200,000 scale allows, even without a field check, to point out the following observations :

- in the indifferetiated basement a discreet orientation is recorded on ERTS image in agreement with the field observations. In one example a new structure, 25 kilometres wide, is registered, outlined by a dark tone facies which could be related with basic rocks. The drainage pattern plays a role in this interpretation. The lithological differentiations are rarely possible, but when the basic rocks have a certain extent - for instance, in the Kabre mountain mass - ERTS image makes it possible to map it accurately. Exceptionally biotite-amphibolite gneisses are distinct from muscovite gneisses, the two facies being slightly different on the ERTS images,

- the Atacorian quartzites are quite distinct from the basement and the Buem schists. They present a dark tone facies and are characterised by detailed tight structures not mentioned on the present geological map. These structures not visible proves that the formation is concealed under a quaternary cover,

- the Oti schists, a very important formation relaying towards the West the Atacorion quartzites, ~~are~~^x recorded on the ERTS images with a characteristic "moire" facies. As bed-markers are present in this series differentiations are possible,

- the Bambouaka sandstones bound the Oti schists to the West and present on the ERTS images a facies very similar to the Atacorion quartzites one, but they are horizontal and any structures are indeed visible. Recent geological observations allow to assume that Bambouka sandstones are an unfolded equivalent of the Atacorion quartzites.

The possibility to map and to differentiate laterites was also an objective of this survey. The following observations can be mentioned :

- the laterite basement boundary is well recorded on the ERTS images. If this limit is different from the one mentioned on the geological maps it is because this one represents a schema extrapolated from scattered field observations : we assume that ERTS images give a true boundary,

- certain lateritic facies seem to be affected by the nature of the underlying basement :

. the laterites covering the continental terminal sandstones present a dark tone facies outlined on its limbs by a sandy soil and it is possible to map them with an accuracy comparable to the one of the 1/200,000 geological map,

. the laterites above the basement are not very contrasted and the changes in the tone are gradual,

. locally, the laterites overlapping the Birrimian schists have a grey toness darker than the one in the basement.

This possibility of differentiation must be checked in other climate conditions.

In the domain of fracturing, the ERTS images are a very important tool. The interpretation of the fractures oblique to the main orientation is very easy, but the faults parallel to this one are only differentiated if they have a certain extent.

x "Moire" facies is a changing tone facies.

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Linear features extending on more than one hundred kilometres are observed on the ERTS images, particularly the one having SW-NE and W-E directions. These fractures sometimes pose some problems : for instance in the "Gaya" region, 250 kilometres SE of Niamey, an important basement fracture also disturbs the Kandi cretaceous sandstones.

In the domain of the chronology, the observations realized in structural geology and the lithological differentiations recorded, make it impossible to give advice on this controverted topic. Such an objective is not realistic without stereoscopic effect.

D) Finally, spectral band five seems more usable in the geological domain. But locally, spectral band seven gives some complementary details.

Furthermore, the proposed period, February to April, is not the most favourable. The images taken some months later, during the rainy season, are better because the atmospheric haze effect is not so important.

4 - CONCLUSIONS

Referring to the objectives explained in the proposals, the experiment demonstrates the ability of space imagery to recognize geological units and structural features under tropical climate. Unfortunately the poor quality of the images does not allow new observations to be brought out in the domain of the chronology.

Therefore the correlation between different types of laterite and the petrology of the basement, which seems possible with these orbital images, is a significant result.

It is important, to conclude this section, to mention meteorology because it seems that the equatorial zones during the season chosen for coverages are not favourable to multispectral remote sensing : the haze effect in the dry season is very important and the images are not contrasted enough. The same scenes, taken during the rainy season are better, but notice that the usable periods are very short and very aleatory. Then, along the costal zone, meteorology is always very poor and images are not good.

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