MAP REVISION USING SLAR IMAGERY

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Abstract

Imaging of Nigeria and Togo with SLAR provided the data required for the production of map-controlled radar mosaics at scales of 1:250,000 and 1:200,000 respectively with 95% of all control points at that scale within ±4.0 millimeters of true positions. The mosaics served as the base for the generation of new geologic and vegetation maps of Togo and parts of Nigeria. Aided by two looks, numerous geologic revisions resulted, not only with the addition of previously unknown structural features, a revision of age relationships and the refinement of unit boundaries but also with the repositioning of rock units and the reorientation of major faults. Vegetation mapping vividly demonstrated the need for sufficient overlap of lines of flight in order to provide for continuity of floral signatures throughout the map area.

Introduction

The publication of the geologic map of Darien Province, Panama (MacDonald, 1969) emphatically demonstrated the value of SLAR as a geologic mapping tool. Not to be overlooked, however, was the significant repositioning and rotation of up to 60° of a series of hills east of La Palma (Figure 1). The mosaic and the topographic map were constructed from interferometer data generated from imagery in the slant-range format and thus uncontrolled; however, the extent to which repositioning had been effected precludes a significant error in the radar map. Although the value of the synoptic view and low illumination angle in detecting geologic features has been clearly demonstrated by many other investigators, the value of a SLAR survey for rectifying the location and orientation of such features has not received sufficient attention.

It becomes immediately obvious that a geometrically accurate base on which topographic and geologic features can be identified and accurately delineated is necessary if SLAR or SAR imagery is to be used for such purposes. In both Nigeria and Togo, LANDSAT imagery was evaluated but because of both coarse resolution and extensive cloud cover (which, in fact, has prevented any coverage being acquired in some areas as of this writing), provided little significant contribution to the solution of these problems (Gelnett, Dellwig and Bare, 1978). However, SLAR imagery was generated without disruption or attenuation by conditions adverse to acquisition of imagery in the visible portion of the spectrum. Such imagery, when mosaicked, provided the necessary geometric fidelity and offered a synoptic view at scales of 1:200,000 (Togo) and 1:250,000 (Nigeria).

Generation of the Base

The flight plan used for both the Togo and Nigeria SLAR surveys provided sufficient sidelap between strips so that 60 percent of all control points were common to any two adjacent strips and 20 percent were common to any three adjacent strips. On strip negatives mutual positive control points were identified and scale differences, where present, were rectified and reconciled to a master UTM (Universal Transverse Mercator) Grid and a corrected topographic base map, i.e., 1° x 1°, 1:200,000 scale IGN topographic maps and 1° x 1.5°, 1:250,000 scale JOG topographic maps. A specially designed SLAR strip printer featuring a high resolution process lens is used to scale-rectify SLAR strips of approximately 10 x 100 cm format. The process insures (1) the best possible registration of SLAR strips-UTM-topographic base maps, and (2) that position errors of features on the maps can be easily identified and corrected in constructing the mosaic.

Accuracy of the Base

The resulting mosaic should not be construed to be a precise geodetic product. The accuracy of the radar mosaics is proportional to the accuracy of the existing topographic base map control and, as such, can only be stated in terms of discrepancies between the map and the radar mosaic. Positional errors in the topographic base maps were frequently detected by matching control points on sidelapping SLAR strips which had been registered to the corrected UTM grid. A statistical analysis of mosaics constructed in this manner for Nigeria indicated a degree of accuracy of location of control points as follows:

All Control Points	Error in mm	Error in Meters
68% are within	± 1.09	273
95% are within	± 2.18	546
99% are within	± 3.28	819

Since the same construction techniques were used in the preparation of the Togo mosaics, the degree of accuracy achieved in the Nigerian survey is assumed. Position errors may well have been a fraction of those stated above if all control points on the existing base-map series were absolutely correct. However, this is unlikely by virtue of how they are compiled and in view of practiced drafting standards (± 0.5 millimeters or ± 127 meters at a scale of 1:250,000). At the scale of mapping, positional errors identified far exceed maximum possible mosaic constructional error.

Map Modification

The utilization of controlled radar mosaics (1:250,000) in the identification of positional error on existing base maps was clearly demonstrated in the survey of Nigeria. Although only random comparisons were made, several rather prominent errors were detected. Among these, east of its confluence with the Niger, a 70 kilometer long segment of the Benue River between Umaisha and Loko is displaced approximately 4 kilometers to the southeast. This segment of the river is carved in bedrock and does not meander, thus precluding a shift in the channel during the interim between mapping and SLAR imaging.

Imaging of Togo, West Africa, provided data for the construction of Radar mosaics at a scale of 1:200,000. Interpretation of first generation prints and positive transparencies and transfer of the derived data to mosaics revealed significant errors in the existing geologic and topographic maps of Togo. Aided by two opposing radar look directions, numerous revisions resulted, including identification of previously unknown structural features, redefinition of age relationships, refinement of unit boundaries, and the repositioning of structural features and lithologic units. Positional errors in some cases were as much as 12 kilometers and orientation errors of major faults as much as 22 degrees.

Geologic mapping of Togo was initiated at least as early at 1905 by Koert (Mayer, 1910). Since that time, contributions to the geologic knowledge of the country have been made by geologists of diverse national origins, primarily Germans and French. Although modification of the earliest map has been a continually ongoing process in an effort to refine lithologic and structural relationships, a great diversity of opinion concerning major rock and structural relationships as well as a lack of geometric fidelity is frequently observed. Furthermore, geologic studies having been conducted in Togo by the French and in the Gold Coast by the British, contrasting structural style and facies changes eastward from the Gold Coast across the Togo Range and general poor accessibility to terrain in the border areas precluded the elimination of "state line faults."

Mapping Guidelines

In Togo, guidelines for geologic mapping were established as follows:

1. Unless a rock unit has a sufficiently unique chemical composition to enable the development of a unique vegetation community, tone-texture-topographic signature of that unit may not be sufficiently distinct to permit its isolation because of the reduction of large areas to near peneplaination and an apparent development of a thick soil cover. Thus, no unit on the existing geologic map would be incorporated unless it was clearly expressed on the radar image. This does not imply that the unit is not sufficiently unique in composition to be identified on the ground.

2. Age relationships among geologic units were initially assumed to be correct as previously mapped by Lawson (1973). Modifications were made (a) where there is a clear relationship between intrusives and host rocks; (b) in areas of sedimentary rocks in which bedding can be used to document an unconformity; (c) in areas where relative vertical movement along faults between units of different ages can be documented; and (d) in areas where fold patterns can be accurately defined or can be used to demonstrate relative ages.

3. Numerous discrepancies in the orientation and positioning of faults exist on published maps. Therefore, the only faults shown on the interpretation overlays were those identified from the radar imagery.

4. In the identification of lithologic units, particularly intrusives, if the tone-texture signature on the radar suggested a lithology which contrasted with published information the change was made to conform with the evidence interpreted from the radar.

Once these decisions were made, characteristic tone-texture signatures were selected from areas which appeared to accurately relate to mapped units. Allowing for variations due to topographic relief, facies variations within a unit, partial masking by transported mantle and structural variations within the unit, such signatures were used as guides for the determination of the areal extent of each unit. Other criteria were called upon as needed to define lithologic contacts which were not expressed by an apparent contrast in bedrock signatures. Farming patterns or densities were assumed to be indicative of soil composition and, if not determined to be related to alluvial deposits, were considered to suggest changes in bedrock composition. Abrupt changes in drainage patterns were also assumed to suggest changes in composition or structure of the underlying bedrock. These were mapped as lithologic contacts. Although in gross aspect, vegetation as a criterion for separation of geologic units proved valuable on mosaics on which the range of incidence angles across the mosaicked one third of individual flight lines was confined to less than 5 degrees, the range of incidence angles on individual strips of up to 16 degrees precluded the utilization of tone-texture signatures on a small scale (Figure 2). Thus, map units are essentially rock-stratigraphic in nature and their vertical extent may contrast to some degree with that as originally defined. Utilizing such guidelines resulted in several significant changes in age relationships (Figure 3).

Map Modifications

The original map of Koert is gross in aspect and has been the subject of considerable modification. One must realize that at the time of the mapping, 21 tribes speaking a variety of dialects occupied the area and the only major highway in what is now Togo extended north from Lome to Sodoke. This four-year study actually represented an oustanding scientific achievement. Although north of latitude 10°N (Figure 4) the map of 1973 shows subdivision of units and refinement of contacts, several contacts mapped by Koert have undergone only minor repositioning. However, a comparison of the 1978 map generated from radar data and the 1973 map suggests considerable error in drainage pattern and floodplain extent as well as in the extent of exposure of the Birrimien. Furthermore, judging from topographic expression, the western limit of the Togo Formation as defined by Lawson at the Togo-Benin border appears to be misplaced by approximately 45 kilometers.

Southward in the Togo Range, previously published maps contrast in many aspects with the map generated from radar imagery (Figure 5). Although the map of Grant (1969) is intentionally simple, the area indicated as being underlain by the Togo Formation shows only nominal correlation with the topographic expression of that unit between Atakpame and Palime, and, having been drawn from other sources, suggests an earlier error of position. Additionally, correlation north of Atakpame with the map of Lawson, as well as the map generated through analysis of radar imagery, is essentially nonexistent. Although the interpretation of structure and lithology southeast of the outcrop of the Togo Formation between Atakpame and Palime through radar imagery interpretation may be subject to question, the lack of correlation of rock-unit distribution as proposed by Lawson with tone-texture signatures and topography as expressed on the radar image at very least identifies areas in need of additional field evaluation.

The mapped faults are not all-inclusive; smaller features were eliminated to improve clarity of presentation at this published scale. However important the detection of numerous previously unidentified sutures, the reorientation aided by the synoptic view provides important data particularly if the potential for mineral exploration arises. Better definition of orientation can be realized with the synoptic view of SLAR as has long been understood (Wing, Overbey and Dellwig, 1970). Additionally, hogbacks or cuestas properly oriented with respect to the direction of illumination enable the identification of changes in dip and consequently shifting of the position of fold axes.

Conclusions

That numerous investigators with diverse interests have participated in geologic map revision without apparent rectification of major errors in position and orientation suggests that the refinement of the geologic map of Togo was effected on a base which was generated prior to the availability of precise geodetic data. That such is the case is emphasized by the lack of congruity of major topographically expressed rock units and structures in recently published small scale maps with their well-defined counterparts on the radar imagery. Furthermore, it suggests the seriousness of the error of geologic map revision utilizing a previously published map as a base without verification of its geometric fidelity and raises the question of potential error elsewhere, especially in those countries where cloud cover has prohibited the acquisition of conventional aerial photography. At a scale of 1:200,000, point displacement on radar imagery (except in instances of extreme layover or foreshortening) is of considerably less magnitude than the latitude normally encountered in defining rock unit contacts. This would be especially true in deeply weathered terrain such as that encountered in Togo. The well-known capabilities of the sensor (i.e., presentation of a synoptic view and selective and differential shadowing) along with the demonstrated attainment of geometric fidelity more than adequate for geologic mapping, define SLAR as a valuable tool for modification as well as original map generation and, in areas where tone-texture signatures conflict sharply with map data provided by field or other sensor study, identify a need for further study.

References

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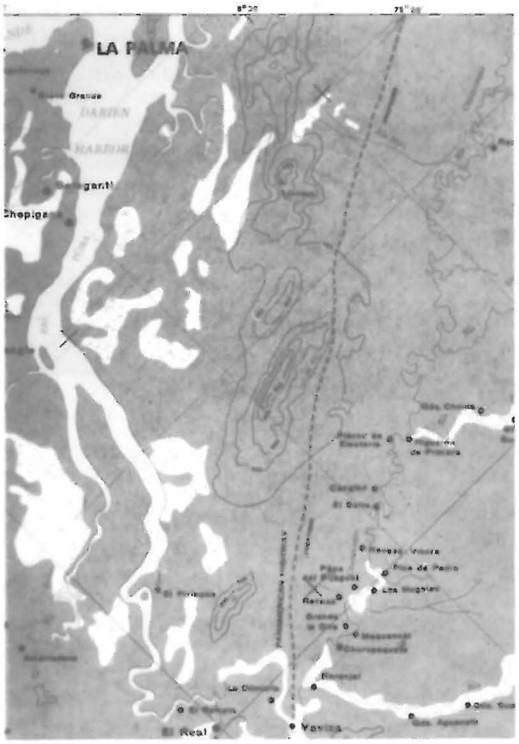
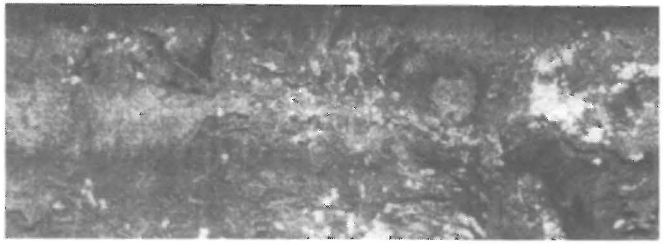
(a)



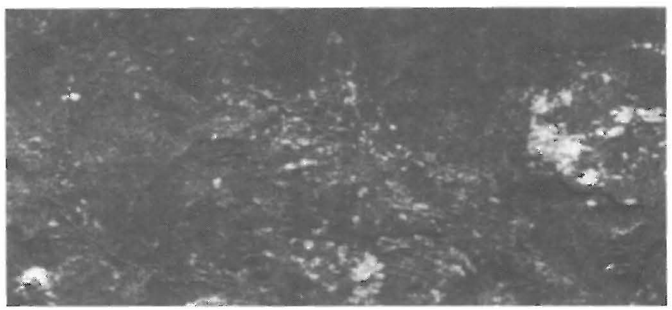
(b)

Figure 1. (a) Area east of La Palma, Republic of Panama, Special Map No. 2. Produced by USARCARIB. Undated (pre-1967). Because of problems of cloud cover control was at a minimum. Error in orientation of hills east of La Palma has been corrected in the map produced from radar imagery in 1968. (b) Topographic map east of La Palma constructed from interferometer data obtained during the SLAR (AN/APQ-97) survey of Panama.



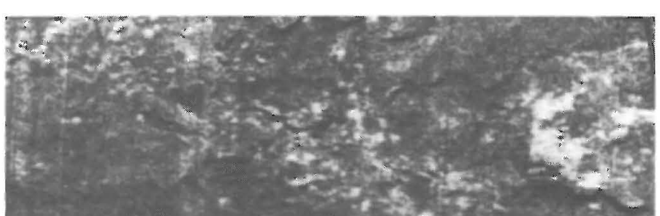
I

Near Range, S Look c.a. 17°



II

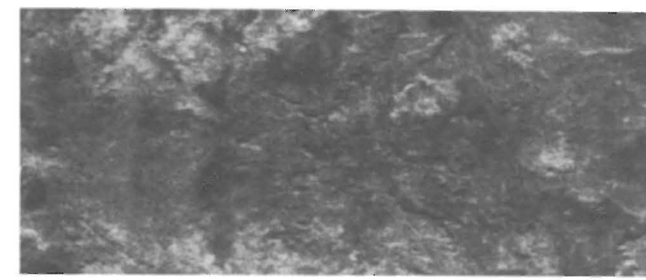
Intermediate Range, S Look c.a. 11°



III

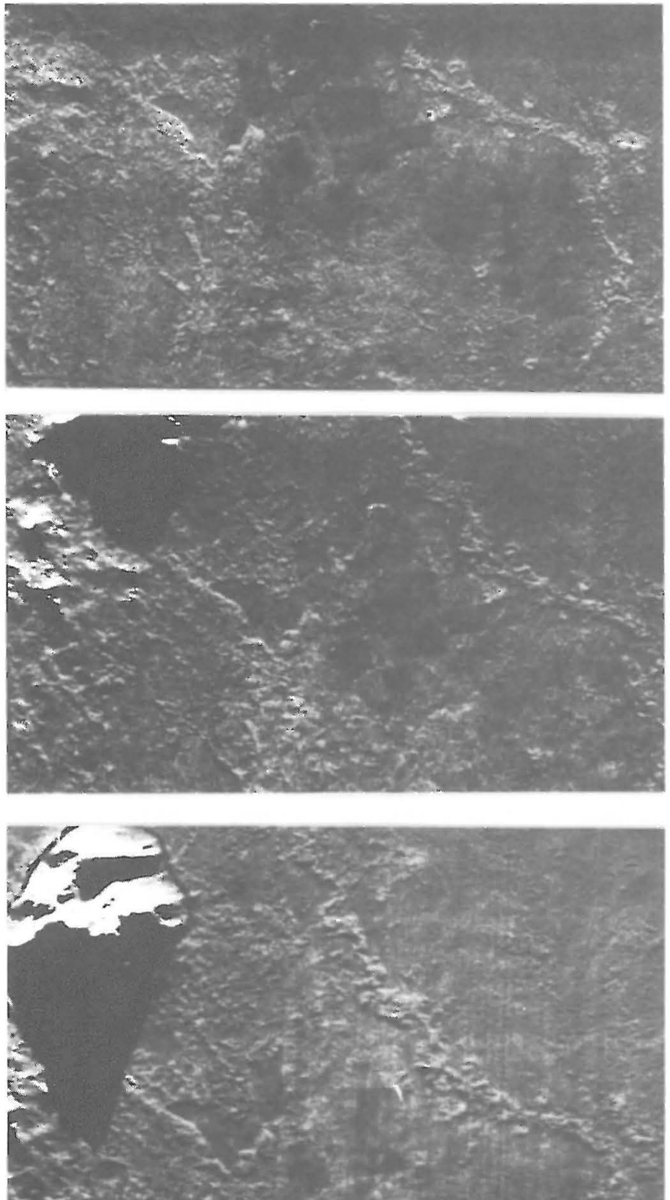
Far Range, S Look c.a. 5°

IV



Intermediate Range, N Look c.a. 9°

Figure 2A. Influence of depression angle on return signal, Togo, West Africa. Latitutde 10°53'N, Longitude 0°40'E.



I

Near Range, c.a. 17°

II

Intermediate Range, c.a. 11°

III

Far Range, c.a. 5°

0 KM 10

N

Figure 2B. Influence of depression angle on return signal, Togo, West Africa. Latitude 6°40'N, Longitude 0°50'E.

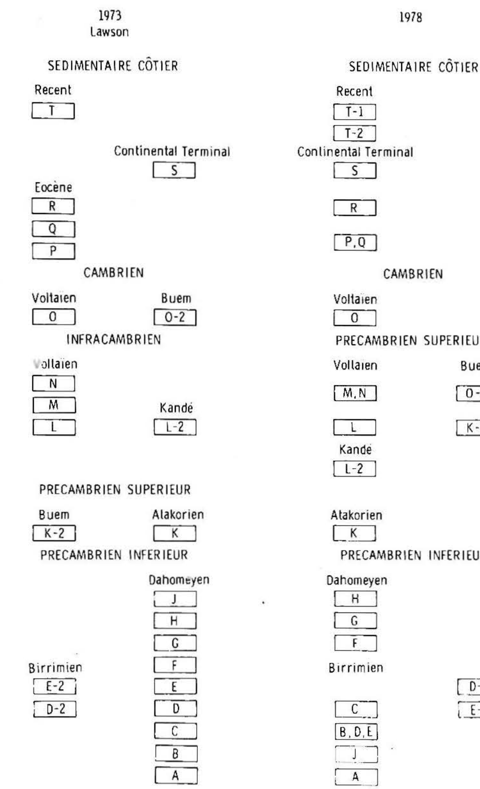


Figure 3. Geologic columns: 1973 map of Togo (Lawson) and map produced from radar imagery (1978)

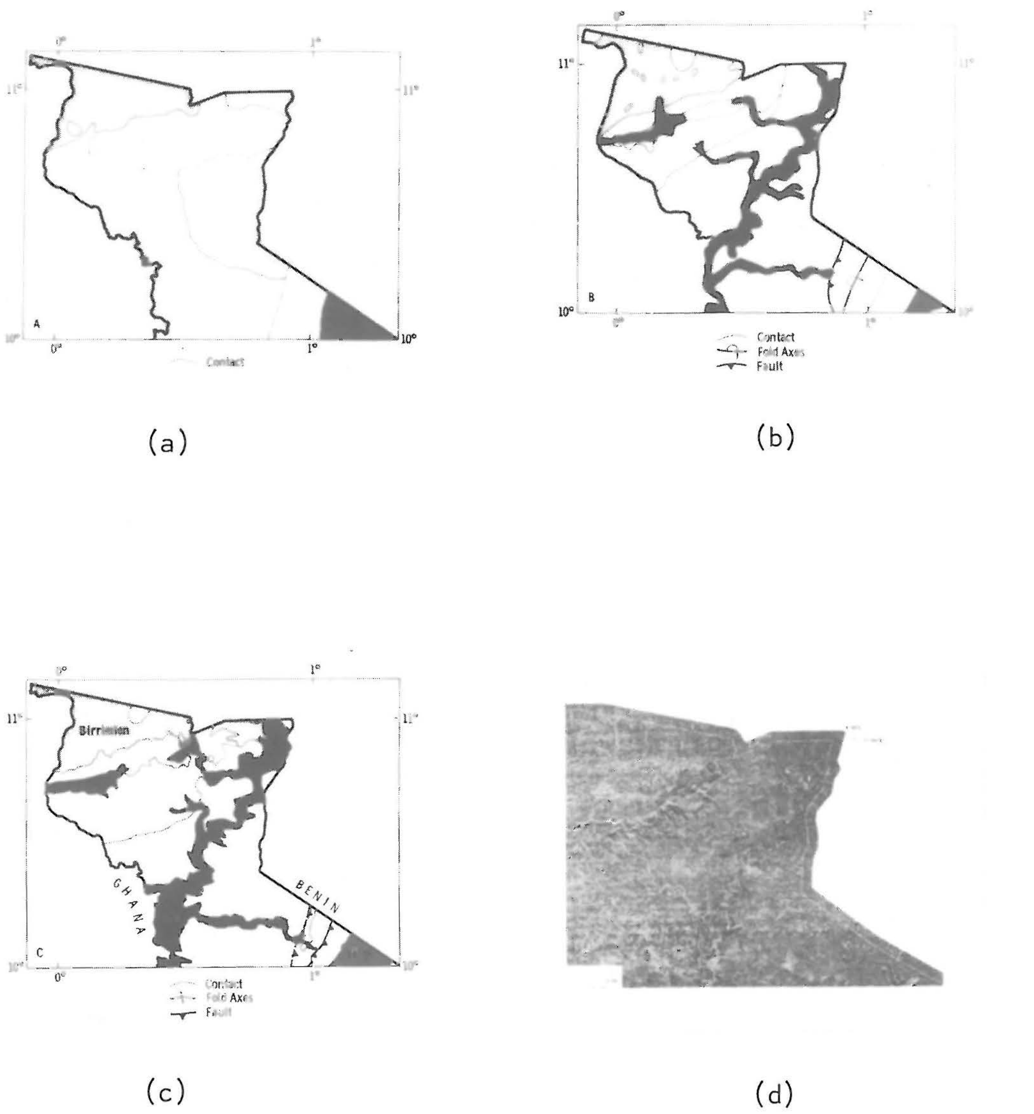
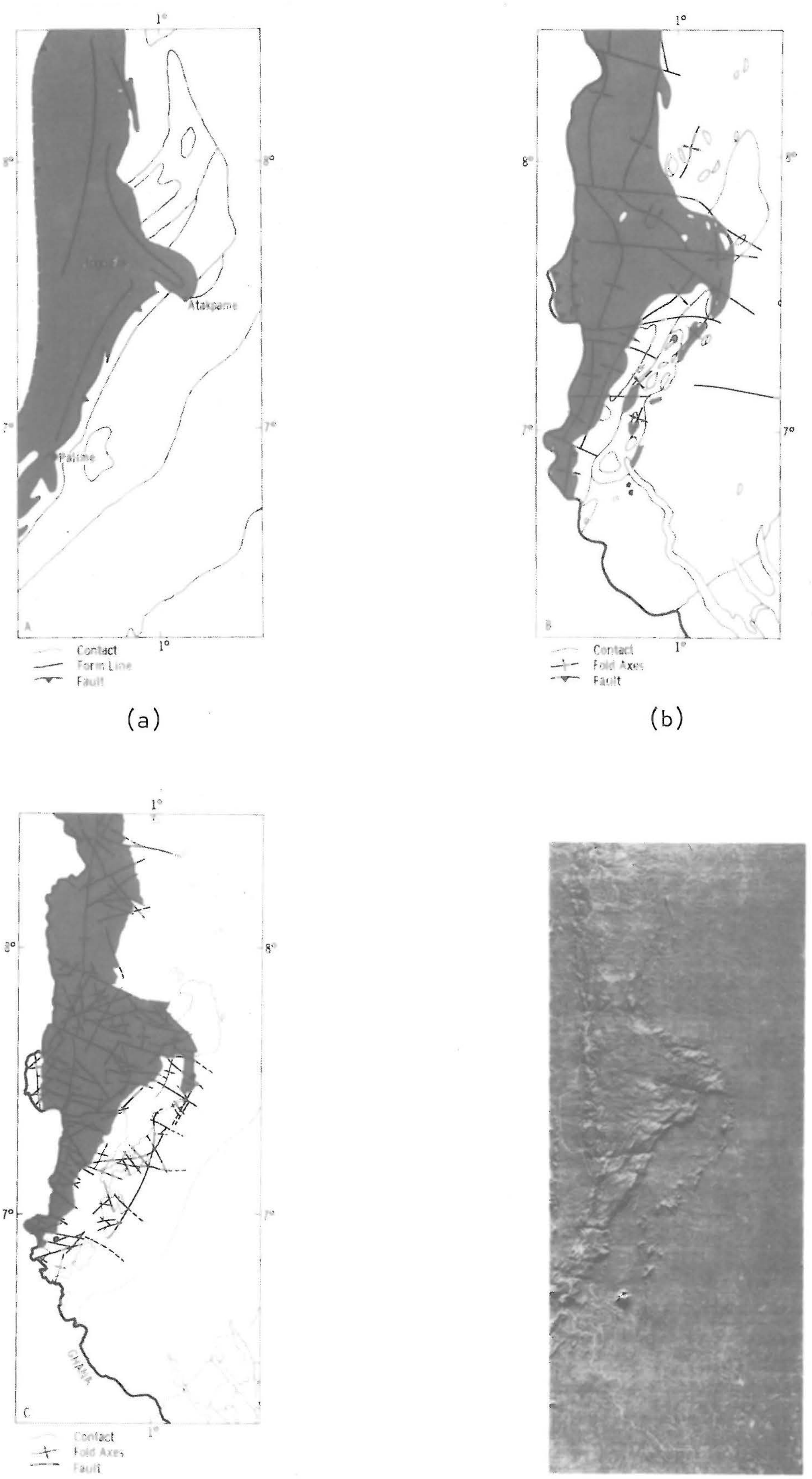


Figure 4. Comparison of distribution of selected geologic units north of Latitute 11°N, Togo, West Africa. (a) Koert, 1910; (b) Lawson, 1973; (c) MARS, 1978; and (d) radar imagery.



(a) (b)

(c) (d)

Figure 5. Comparison of distribution of Togo Formation in the Togo Range, Latitude 6-9°N. (a) Grant, 1969; (b) Lawson, 1973: (c) MARS, 1978; and (d) radar imagery.