ERTS Satellite Photography as a Tool for Tectonic Investigations in the Mediterranean Basin

by

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Introduction and Objective

This is a progress report of a research program involving the study and interpretation of terrain features observed on images of the northern Mediterranean Basin derived from the Earth Resources Technology Satellite (ERTS).

The objective of this research is threefold :

(1) To prepare a more accurate map of major tectonic features, particularly of linear elements, within a distance of 100-150 km of the shoreline;

(2) To display more precisely the full extent (length) of the tectonic elements and their relationship to each other — thereby better showing regional relationships;

(3) To clarify the genetic character of the tectonic elements, thereby providing understanding of both :

(a) The *mechanisms of crustal deformation* that have been involved in the tectonic evolution of the area.

(b) The *Timing of Tectonic events* which were the cause of the observed tectonic elements.

Background

Since the launching of NASA's ERTS in 1972 many thousands of images have provided repetitive coverage of most parts of the world. The images are of high quality, they gave essentially no radial distortion, and they display an area of approximately 170 km on a side.

A multispectral scanning system provides simultaneous imagery at four spectral wavelengths (Bands). These are :

Band 4 : 500-600 nanometers (5,000 - 6,000 Å) - Green
Band 5 : 600-700 nanometers (6,000 - 7,000 Å) - Red
Band 6 : 700-800 nanometers (7,000 - 8,000 Å) - near Infra-Red
Band 7 : 800-1100 nanometers (8,000 - 11,000 Å) - near Infra-Red

Each of the images provides valuable information about the terrain and its vegetative cover because of differences in reflectivity, tonal quality, etc. By experience Band 5 and Band 7 images reveal most clearly the structural features of an area.

Two major problems exist. Images may have extensive cloud cover, necessitating the examination of many repeated images to find one that is acceptable. The sun angle at the time of imagery is critical. If the sun angle is too high the image appears " washed-out ", showing very few details. However, subtle

Rapp. Comm. int. Mer Médit., **23**, 4a, pp. 91-94 (1975).

changes in tonal character sometimes are revealed under conditions of high sun angle. If the sun angle is too low, there is too much shadow. A sun angle of 20-35 degrees usually provides optimum conditions for identifying and interpreting structural elements.

Features that are best displayed on ERTS images are :

Circular features — such as craters, volcanic cones, and domed structures.

Linear features — such as faults, fault zones, rifts, major joint systems, major fold axes, mountain crests, valleys, and also such man-made features as roads and transmission lines with their " rights-of-way ".

Areal features — such as bodies of water and sediment-filled basins (which are revealed by distinct tonal changes on the image).

The resolution of structural features on ERTS imagery depends upon such things as associated soil or vegetative changes, on the topography and the character of erosion, and on the shape and length of the feature itself. For example, circular features of small diameter are more easily defined than a linear element of greater length. With optimum conditions, resolution of structural features within a range of 100-250 meters is possible.

Methods

Study of ERTS imagery is similar to that of conventional aerial photography except that stereoscopic examination is not feasible because there is less than 10 per cent overlap of adjacent images.

Individual images are examined visually from vertical, high-angle oblique and low-angle oblique positions, and from different directions in order to " find " linear elements. Simple optical magnification may be helpful as well as variation in the intensity of lighting during the examination. More complex optical instrumentation may also be used — but has not been applied in this study.

Similar study of photo mosaics, constructed from the individual images, is hepful in revealing large regional features.

Linear, circular, and areal features are drawn on a tracing overlay. These may be compared to published geologic and tectonic maps of the region.

Application of ERTS study to Tectonic Interpretations

The possible improvement in mapping accuracy, both of location and extent, of structural elements in a large region, and the establishment of more precise regional relationships among tectonic features by study of ERTS images is easy to understand. But how can study of ERTS imagery clarify the *genetic character of tectonic elements?*

On a regional scale three major categories of linear tectonic elements would be expected to result from three different generic situations. These are :

1. *Tensional conditions* within a large region create normal faults that are revealed as sharply defined, very straight, narrow (thin) linears. These sometimes bound wider (15-30 km) linear zones — *grabens* and sediment-filled grabens or valleys (revealed by sharp tonal changes).

2. *Compressional conditions* within a large region create *some* (but not many) long fold axes that are definable. Such conditions may also create thrust faults and large imbricate thrust slices whose bounding edges reveal a regional linearity. These linear features have local geometric sinuosity and crenulations typical of all eroded upper crustal plates that have been moved over large horizontal distances either by crustal compression or gravitational gliding subsequent to detachment. These linears are not as sharp or as thin as those created under tensional conditions. There is an absence of grabens and sediment-filled basins.

3. *Shear conditions* within a large region cause the crust to be displaced transcurrently for large distances along strike-slip faults. Such conditions of shear, or coupling, produce very long regional linears — in most cases longer than those created solely due to tension. They also produce wider linear zones as a consequence of multiple parallel faulting.

Such regional shear zones and/or rifts may be accompanied by, or be followed sequentially by, normal faulting with the consequent later development of grabens or sediment-filled valleys — both of which are linear.

In addition to being able to distinguish between three major categories of tectonic elements and of understanding what has been the major mechanism of crustal deformation — that is, tensional, compressional (including gravitational gliding), and shear — it should be possible also to determine the *relative timing of tectonic events.* This should be true especially for the Neogene and Holocene, in as much as there has been much less time for erosion to have destroyed the prominence of terrain features created by the structural elements.

Another factor of considerable importance in terms of understanding the tectonic evolution of a region involves the possible recognition of reactivation " of older structural features (such as Mesozoic, Paleozoic, or even Precambrian). This should be recognizable in two ways :

1. By examination of ERTS photo mosaics of a sufficiently large region that would include both ancient (Mesozoic or older) and young (Paleogene or younger) geologic terrains and identification of the tectonic patterns in each.

2. A more subtle method of recognition — as yet untested — may be reflected by the creation of sharper, more precisely defined linear elements in those cases where they are formed in the younger rocks by " reactivation " of existing structures in the older rocks beneath.

Although this study has not yet fully established the feasibility of determining the relative timing of tectonic events by interpretation of ERTS images, there is considerable promise that it may. The importance of being able to do so is obvious !

Application to the Mediterranean Basin

Two major concepts regarding the Tertiary tectonic evolution of the Mediterranean Basin have been hotly debated in the literature and at professional meetings such as the C.I.E.S.M. These are :

1. That large horizontal movements of lithospheric plates of varying size have occurred in the Mediterranean Basin during the Tertiary, resulting in large-scale rotational motions, crustal subduction, and the creation of new crust at centers of sea floor spreading.

2. That large-scale vertical movements (both uplift and subsidence) of the crust have occurred in the Mediterranean Basin and throughout southern Europe, particularly during the Neogene. This has involved major subsidence of the Black Sea, Pannonian Basin, Balearic (and Alboran) Sea, Tyrrhenian Sea, Ionian Sea, and more recently the Aegean Sea.

The status of research involving the identification of structural features on ERTS imagery of the Mediterranean Basin and the interpretation of these features both with regard to generic type (tensional, compressional, or shear) anf to timing of the tectonic events, suggests this may be a powerful tool in helping to understand the tectonic evolution of this region during Tertiary and Holocene time.

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Discussion

Remarques de ***M. Biju-Duval :***

Très intéressé par la communication du Professeur Foose, je dois signaler que notre groupe de travail de l'I.F.P. prépare un document d'ensemble établi à partir des images ERTS que nous présenterons au prochain colloque méditerranéen. Deux types de remarques complémentaires peuvent être apportées :

1. Du point de vue *technique*, je pense que l'heure matinale de prise de vue des images est telle que les orientations tectoniques orthogonales (NE-SW) sont beaucoup plus apparentes que les autres. Ensuite l'étude simultanée d'images dans les différentes longueurs d'onde et l'utilisation des fausses couleurs apportent des renseignements complémentaires.

2. Du point de vue *interprétatif*, nous sommes en présence de difficultés car la reconnaissance d'accidents distensifs ou compressifs n'est pas toujours évidente. En particulier la chronicité des événements observés n'est pas évidente. La plupart des éléments observés sont des figures jeunes parfois décelables sur les cartes bathymétriques; mais il est indispensable de confronter les observations avec les cartes géologiques détaillées et surtout d'effectuer des *vérifications sur le terrain*.

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