

**SATELLITE REMOTE SENSING DATA APPLIED
FOR SEISMIC RISK ASSESSMENT OF VRANCEA REGION**

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ABSTRACT

The aim of this study is to present the results of the application of remote sensing techniques for seismic risk analysis, which estimate the geographic distribution, frequency, and intensity of seismic activity, without attempting to predict specific events.

This method is based on the recognition of the active faults, which are defined as breaks along which movement has occurred in Holocene time (past 11,000 years).

Remote sensing analysis and field studies of active faults can provide a geologic history that overcomes many of the shortcomings of instrumental and historic records.

The majority of strong Romanian earthquakes has the origin in Vrancea region, a distinctive active zone of the Alpine orogenic belt placed at the Eastern Carpathians Arc Bend with extensive macroseismic area.

Many seismological researches revealed two kinds of mechanisms involved in the occurrence of intermediate earthquakes having a Vrancea focus: one has a NW-SE oriented compression axis (the fault plane direction is NE-SW) while the other has a NE-SW orientated compression axis (the fault plane direction is NW-SE). Subduction of the Black Sea Sub-Plate under the Pannonian Plate produces faulting processes. The fault plane is oriented approximately parallel to the Carpathian Bend, i.e. NE-SW. The Black Sea Sub-Plate would have a NW displacement along "the markers" formed by the Moesian and Eurasian Sub-Plates admitting of another fault plane, oriented NW-SE, approximately perpendicular to the first.

Landsat images are excellent for recognising the continuity and regional relationships of faults, but the spatial resolution is not so good to distinguish topographic features indicative of active faults.

SAR ERS-1 data are more useful for this purpose.

This also allows a more precise characterization of lineament structures, especially in cloud and soil covered areas, where the lack of data reduces the tectonic analysis. An on-going evaluation of all data will lead to a better understanding of the stress field which controlled the tectonic movements.

The results obtained from the remotely sensed data have shown a good concordance with the available "in-situ" data implying that remote sensing techniques provide a means for locating, identifying and mapping certain terrain features and aspects of geologic structures.

Further methodical work on Landsat TM and ERS-1 and ERS-2 SAR data will be useful to elaborate even physical parameters for the discrimination of different lithological units.

Keywords: seismic risk assessment, Vrancea, Landsat TM, ERS-1 SAR, methodology, remote sensing.

1. INTRODUCTION

Romania's territory, placed at the border of the great East-European Platform, is a region of a complex geological structure dominated by the presence of the Alpine Orogenic Belt of the Carpathian Mountains. This mountains arc has a spectacular change of direction just above the well-known Vrancea seismic region, very important seismic area of Europe, remarkable by the uncommon energy of earthquakes¹.

The Vrancea earthquakes are produced by the release of stress that has built up in the earth's crust. Some zones of maximum earthquake intensity and frequency occur at the boundaries between the moving plates that form the crust of the earth.

Subjection of the Black Sea Sub-Plate under the Pannonian Plate produces faulting processes. The fault plane that results is oriented approximately parallel to the Carpathian Bend, i.e. NE-SW. The Black Sea Sub-Plate would have a NW

displacement along the “markers” formed by the Moesian and Eurasian Sub-Plates only provided that we admit of another fault plane, oriented NW-SE, approximately perpendicular to the first².

The Variance earthquakes are produced by the release of stresses that is accumulating in time along some fracture lines belonging to one of the first or second fault-planes.

From depth distribution point of view, Variance earthquakes foci are classified in three distinct zones: a zone of crust earthquakes with focal depth not exceeding 40-45 km; an aseismic zone up to 7-80 km; and a zone of intermediate earthquakes with focal depth between 70-80 km and approximately 200 km.

This finding suggested a new seismotectonic model of the Variance region, a model that implied, among others, the hypothesis that the subducted plate was torn in this region long time ago and the intermediate earthquakes were connected with the lithospheric “slab” (torn off the plate) remained in the mantle, the spatial distribution of Variance earthquakes’ hypocentres being in a relationship with structural tectonic systems involved in continental and oceanic crust, subcrustal lithosphere and asthenosphere³.

Remote sensing techniques are very useful for seismic risk analysis, which estimates the geographic distribution, frequency, and intensity of seismic activity without attempting to predict specific events⁴.

Such analysis are essential for locating and designing dams, electric and nuclear-electric powerplants as well as different other projects in seismic areas.

Seismic risk analysis based on satellite remote sensing methods is based on the recognition of tectonic active faults, which are defined as breaks along which movement has occurred in Holocene time (past 11,000 years).

remote sensing analysis and “in situ” studies of active faults are able to provide a geologic history better than instrumental and historical records.

ERS-1 SAR is an active remote sensing system which has his own source of illumination in the microwave region of the electromagnetic spectrum. Due to the used range of wavelengths radar has advantages compared with optical systems (Landsat TM, SPOT). Radar is independent of sun light, therefore data acquisition is possible 24 hours a day. It has an all-weather capability, since there is only few scattering through clouds and precipitation. Finally radar data shows only minimal atmospheric absorption. The C-band frequency, the VV polarization and the small incidence angle qualify ERS-1 SAR data especially for the mapping of tectonic structural features. The intensity of the radar backscatter is a complex function of the interaction between terrain and radar pulse. Especially in semiarid and arid areas the penetration depth of the radar can be half of the wavelength. Therefore covered morphological features, which can not be discerned by optical systems are detectable by microwave. The radar signal depends mainly on three factors: surface roughness, topography (slope effect on the backscattering) and moisture. These factors make radar indispensable for a wide range of geological applications, such as to discriminate different surface lithologies as well as to discern the structural inventory of certain areas.

Our studies have been centered on estimating of geologic features and environmental parameters from multispectral data supplied by satellite sensors. As there is a great variety of sampling strategies, digital image processing techniques, and procedures for finding the relationship between the images and environmental parameters, we have found it necessary to develop a methodology best suited for our case study.

We have also investigated the potential of merging satellite Synthetic Aperture Radar (SAR) data with optical data, to get complementary information.

Remote sensing studies based on color analysis and supervised classification, vegetation stress and vegetation cover, have been performed to obtain a processing methodology suitable for seismic risk assessment analysis. Thematic maps have been produced to control the parameters under consideration during the study periods.

2. TEST SITE DESCRIPTION AND SATELLITE DATA USED

It was analyzed Vrancea - Focsani seismic region. This area is structurally and seismically complex area, bounded by latitudes 45.6 °N and 46.0 °N and longitudes 26.5 °E and 27.5 °E (Fig.1).

The Peceneaga -Camena Fault, a deep crustal fracture with dextral slip, is considered to be North-Eastern boundary of the Mason Platform. The Eastern unit of the Moesian Sub-Plate is characterized by a series of principal faults with a North-Western orientation and by a secondary system of faults orientated NE-SW. NW trending crustal fractures are also evidenced East of the Peceneaga-Camena Fault, within our test area.

An ERS-1 SAR image and a multispectral Landsat TM data set was used.

Their characteristics are the following:

Landsat TM
 Acquisition date : 10. 14. 1989
 Path/ Row : 182 / 28
 Processed scene center
 latitude 46,0333406
 Processed scene center
 longitude 27,4253400

ERS-1 SAR
 Acquisition date : 11. 06. 1992
 Orbit/Frame : 6851 / 2691
 Frequency : 5.3 GHz
 Track : 193

All image enhancement steps were performed on a TITAN 3000 station , using a EASI/PACE image processing software package as well as own developed algorithms.

ERS-1 SAR data were acquired in PRI format and Landsat TM data at "system corrected" level. We used too topographic maps over the selected area.

In order to better manage all the informations available on the study area, data acquired have been integrated in an unique data base. This information consists of thematic maps from cartography, land use map from classification of remotely sensed data .

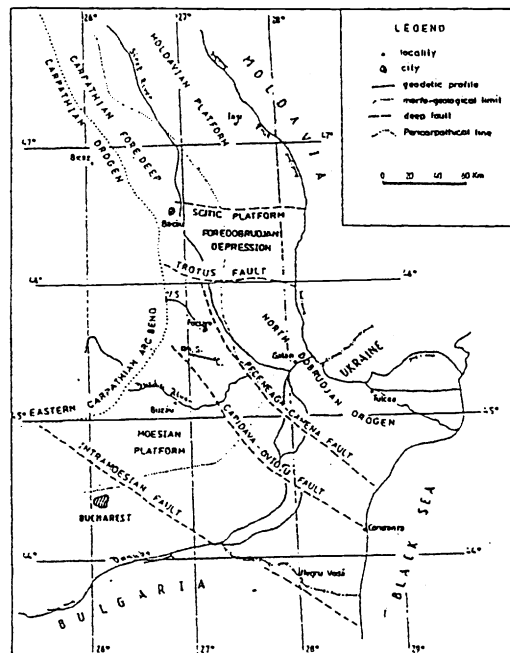


Fig.1. Tectonic faults for seismic region Vrancea

3. METHODOLOGY

The methodology used consists in the following steps :

- Reading the satellite data from the CCT magnetic tapes and including these in PCIDSK databases .

- Applying of atmospheric corrections.

- "De-speckling " of the SAR ERS-1 images was performed by using a 7x7 Frost filter, and a Lee filter too.

Reducing the speckle makes the discrimination of different lithological units easier and highlights more efficient textural features in radar images. This requires that the applied filters reduce the speckle without lowering thematic information. Comparing the best algorithms it appears that Lee filters reduce speckle most operative and run the procedure in the shortest computing time. Whereas the use of Frost filters highlights better textural features and there seems to be more efficient when a merge will be done in a further step. The slight structures are better emphasized as by Lee filter.

- Data conversion from 16 bits radar data to 8 bits images using AVS (Application Visualization System) from EASI/PACE software.

- To geometrically correct and geocode the images we have use a 1 : 100000 scale topographic map . 20 ground control points have been selected and second order polynomials were used to perform the image -map registration (the total RMS error was of 0,535 pixels).

- The registration-synergism between the Landsat TM geocoded image and SAR ERS-1 image was subsequently performed.

- Analysis of Landsat TM image processing :

The use of Landsat TM5 visible bands 1, 2, 3 , (0,452 - 0,518 μm ; 0,528- 0,609 μm ; 0,626 - 0,693 μm allows to represent with good correlation , the chromatic components of the observed area ⁷.

Analogously to the possibility to emphasize spatial and linear structures by filtering in the spatial domain, spectral characteristics of multispectral data can be enhanced by the adaptation of the adequate filters as linear transformation. Two different approaches were used : Principal Component Analysis and Relative Channel Analysis. By comparing the two processing procedures it can be stated that Principal Component Analysis as well as "Spectral Mean Value" show the same thematic information content concerning tectonic structures. Supplementary , the TM relative band 3 was taken for lineation mapping because a maximum of linear structures was emphasized in this channel.

- Data analysis:

Landsat TM and SAR ERS-1 data were use to identify linear features by visual interpretation (Fig. 2 and Fig. 3). Lithological units were differentiated By several Landsat TM RGB- processing. Finally the lineaments were digitized separating different stratigraphical units , in order to distinguish the tectonic structures in time and space.

4.RESULTS

The comparative analysis of ERS-1 SAR and Landsat TM data shows that linear features in TM images appear shorter and denser distributed , whereas ERS-1 images are dominated by the principal structures. In certain cases they complete the lineaments and lineament patterns derived from TM data .

Radar enables the interpretation of partly clouded zones for which Landsat TM are not available.

The method of seismic risk analysis and assessment is based on the recognition of the active faults . Comparison of the Landsat and SAR ERS-1 images of Vrancea- Focsani region with the topographic map and the map of faults indicates that the most of these faults are evident on the Landsat Tm and SAR ERS-1 images.

A fault zone includes the entire belt of active and inactive faults that may be hundreds of kilometers in length and several kilometers in width. The fault trace is the surface expression of the individual active faults.

Landast and SAR ERS-1 images are excellent for recognizing the continuity and regional relationships of faults, but the spatial resolution is too low to recognize any but the largest topographic features indicative of active faulting. The higher resolution of Skylab and aircraft photographs as well as SAR ERS-2 interferometric data are ideal for mapping of these features.

The most promising data are SAR ERS-1 and ERS-2 interferometric to measure tiny movements in the Earth's surface caused by shifting geological faults or volcanic activity.

Radar interferometry relies on taking two images on the same area from slightly different orbits of the satellite. The phase difference from one image is then superimposed by computer onto the phase information of the other. The phase values for

each corresponding picture element, or pixel, of the two images are subtracted, leaving an image, known as an interferogramme, that records only the differences in phase between the two.

These phase differences give the variations in altitude of each pixel. The effect is identical in principle like stereo vision.

The result is a computer relief map known as a digital elevation model, very useful for inaccessible parts of the world.

Differential radar interferometry is based on taking three images of the same area. The first two are subtracted to form an interferogramme, then the second and third are subtracted to form another interferogramme. The two interferogrammes are then subtracted from each other to make a final one which shows up with great accuracy and changes between the original three images.

Such researches will be very useful too for seismic risk assessment of Romanian Vrancea area.

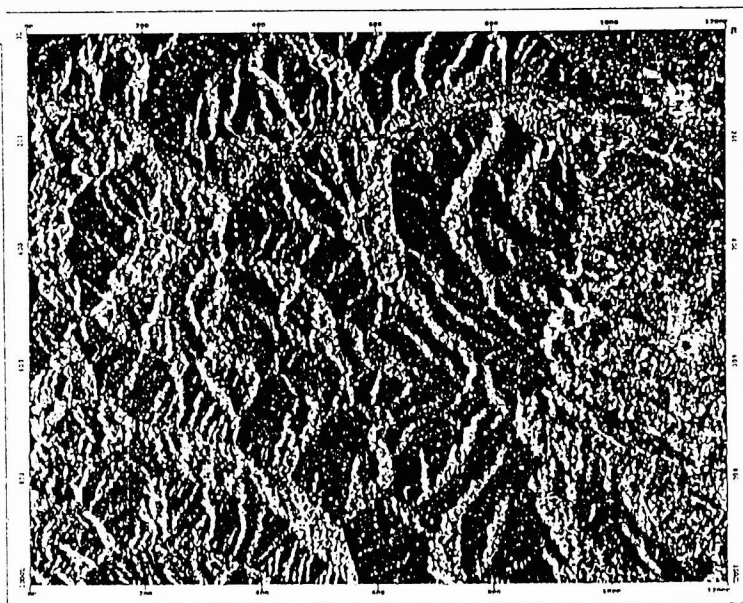
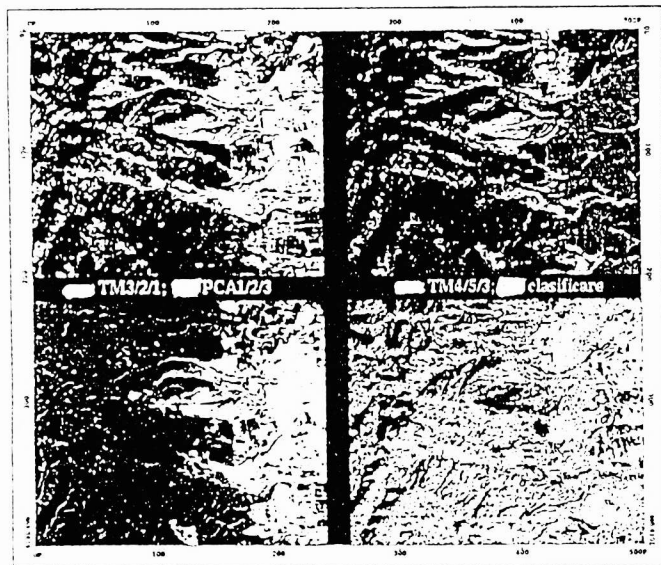


Fig.2 Landsat TM images for Vrancea region Fig.3 SAR ERS-1 image for Vrancea area

REFERENCES

1. V.Mocanu et al., Litospheric structure of Romania and recent crustal movements-Geodynamic Coconnections, Rev.Roum.Geophysique, Bucharest, 35, p 3-13, 1991.
2. D.Zugravescu et al., Romanian territory geodinamics, Rev.Roum.Gcol., Geophys., Geogr.-Geophysique, 29, p 3-8, Bucharest, 1985.
3. D.Enescu et al., Tectonics and geodinamical evolution of the romanian territory, Rev.Roum.Geol., Geophys., Geogr. - Geophysique, 26, p 29-36, Bucharest, 1982.
4. F. Sabins, "Remote Sensing Principles and Interpretation", cd. Freeman, San Francisco, p. 363, 1978.
5. C.Braescu, M.Zoran, F.Serban, et. al, An investigation of the potential of merging SAR ERS data with optical data, "Progress in Environmental Remote Sensing Research and Applications", Parlow (ed), Balkema, Rotterdam, ISBN 90 5410 5984, p.277-285, 1996.
6. F.Serban, C.Braescu, M.Zoran, et al., Black Sea coastal study by use of Landsat and ERS-1 data, "Progress in Environmental Remote Sensing Research and Applications", Parlow(ed), Balkema, Rotterdam, ISBN90 5410 5984, p. 291-301.
7. M.Ippoliti, U.Poli, Use of Landsat and ERS-1 data for mediteranean coast, Remote Sensing 96, Spiteri(ed), Balkema, Rotterdam, ISBN 90 54 10 855X, p.141-144, 1997.