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Discovery of Crustal Movements areas in Lebanon: A study of Geographical information systems

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ABSTRACT
The basic geomorphological techniques of studying the earth's crust movements are based on the fact that the Earth's crust, interacting with exogenous processes of the existing relief and the river networks. Geomorphological structural analysis method proposed by Russian scientist Filosofov (Filosofov, 1975). This method was not developed because of its complexity, but now with the use of GIS technologies it is possible to discover and predict areas of crustal movements. This method was translated in GIS by passing a series of spatial analysis steps applied on digital elevation model of shuttle radar topographic mission (SRTM) of the Lebanese territory. As a result, a predicted crustal movement map of Lebanon was built with selection of the most affected areas.
Keyword-*GIS, DEM, Stream analysis, Crust movements.*

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INTRODUCTION

Digital elevation models (DEMs) are generally used for visual and mathematical geomorphological analysis, as well as modeling of surface processes [1,2]. Also DEMs play an important role in earth crustal movement analysis.
Geographic Information Systems (GIS) and DEM together offer the most common method for extracting and modeling topographic information's.
In 1975 Filosofov a Russian scientist describe a method of mapping crustal movements, he used Strahler's stream order classification for building base maps from each stream order.
Then he calculated the difference between these base maps to extract a relative relief map in which high values express a higher probability of crustal movements.
Filosofov in his research used traditional methods of calculations based on paper maps; from here was the idea to run the same experiment with the application of the new applied technologies in geography.
Using GIS tools reduces the time of maps creation a hundreds of times, and it is possible to apply mathematical formulas and to study large areas that had previously been impossible because of the huge amount of manual works.
We choose as study area the Lebanese territory because of its complex geomorphological structure.
The aims and objectives of the project were carried out by the discovery and study of the spatial distribution of the newest areas of vertical crustal movements in the Lebanese region.
The results of the study are important for practical applications of geology, tectonic processes as the cause of formation and re-formation of different geological structures and formations.
The main methods of studying crust movements are geomorphological methods. They are based on the fact that the movements of the earth's crust, interacting with exogenous processes and interact with the river network.

Study area

The unique geomorphological structure of the Lebanese territory among all middle eastern countries expressed by his mountain chains, river basins and valleys.

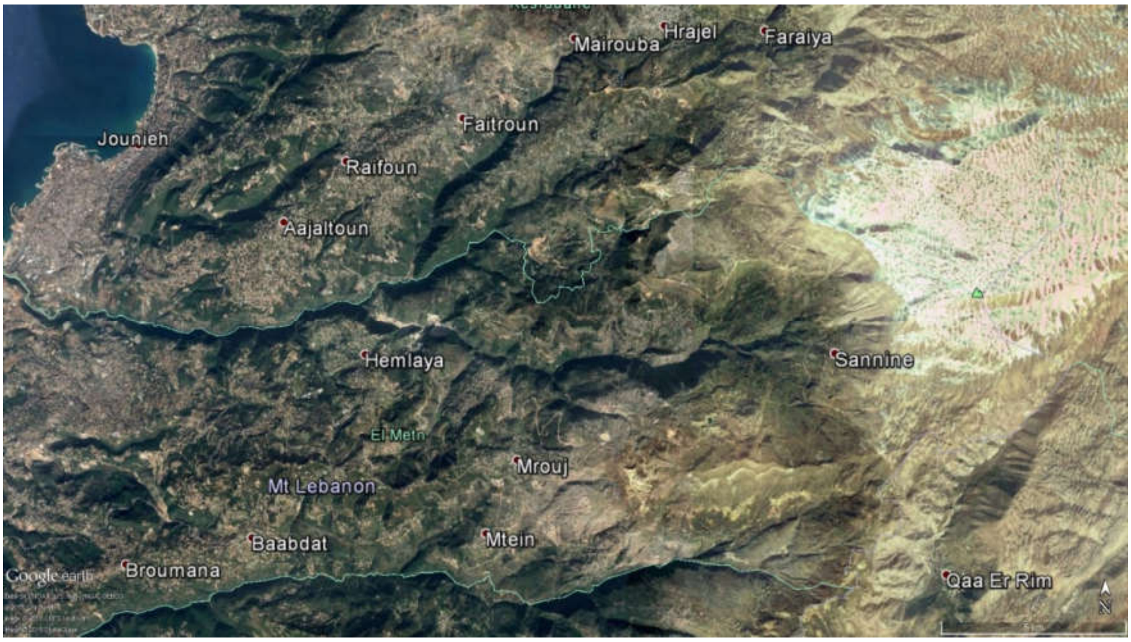

Fig 1: Google Earth Spatio-map of the study area

Gives us a specific study area with geological diversity beginning from the sea level to the highest point of Lebanon with 3088m above the sea level (Sannine mountain), the study area delineated from the North the Bai of Jounieh to Faraya mountains ending at Beirut river valley, constituted by two watershed basins of Nahr el Kalb and Nahr Beirut.

MATERIALS AND METHODS

The Digital Elevation models (DEM) used in our study for the preparation of the morphometric maps was the open source Shuttle Radar Topography Mission (SRTM), with a spatial resolution of 90 m, available at the Consortium for Spatial Information (CGIAR-CSI) [4].
Filosofov V. P. developed a method for the studying of neotectonic structures [5], this method is based on contour line and said that there is a direct relation between watersheds surfaces and the tectonic crustal blocks. These relations help to study the hierarchical crust block structure and its quantitative characteristics. Nonlinearity boundaries of the tectonic blocks appeared from the watershed surfaces a hydrological analysis for the extraction of stream network was done through DEM with standard hydrology GIS-module [3]. The hydrological steps in figure 2 was building a GIS algorithm to the preparation and correction of the digital elevation model (DEM) to be suitable for the hydrological analysis of stream network extractions by filling the sinks, then a raster model of flow direction followed by a flow accumulation matrix showing the concentration of flows, and a final raster operation of stream orders as per Strahler method. Streams without tributaries are assigned first order; a second-order stream is the segment downstream the confluence of any two first-order streams; a third-order segment is formed by the junction of any two second-order streams and so on [14].

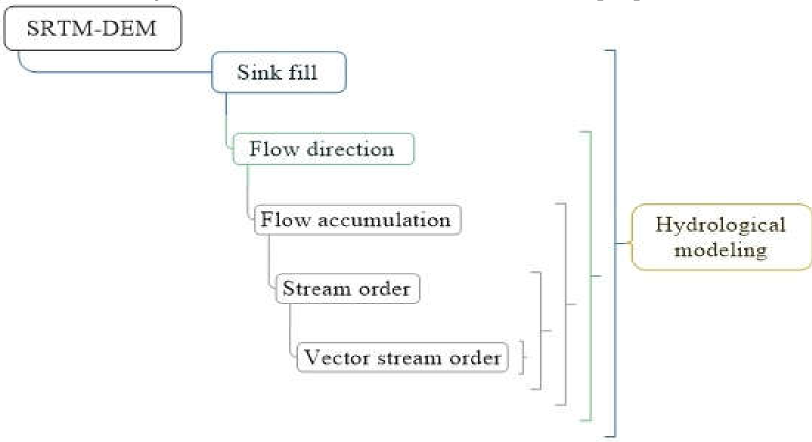

Fig. 2 a scheme showing the steps of the hydrological modeling

After building hydrological map of the region and the classification of streams, a conversion algorithm was lunched to change from raster mode to vector one figure 3.
The extracted stream orders as per Strahler figure 3, begins from the 3rd order till the 8th, we excluded from our calculations the first and the second order forming artifacts of straight lines.
Streams with the same orders are related to similar geological age, stream orders dynamics and terrain variations can be studied using an Isobase map [7,8,9,10]. Isobase lines represent erosional surfaces which have formed due to recent tectonic and erosional events [6].

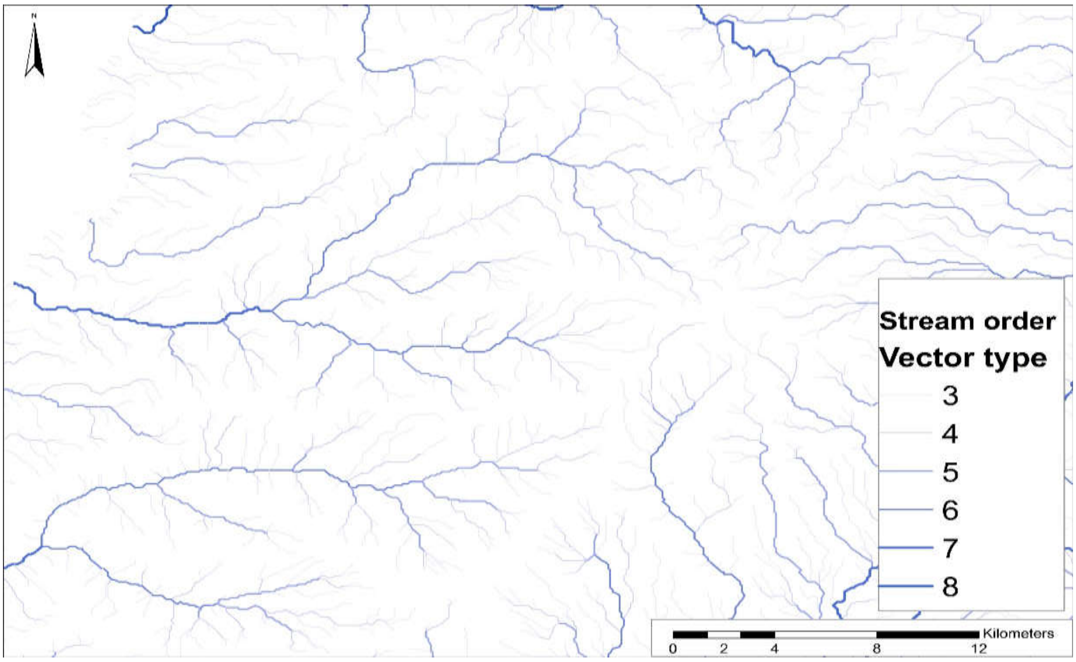

Fig.3: Stream order network as per Strahler for the study area.

Studies suggest that Isobase maps are prepared by interpolating the elevation at the location of 2nd and 3rd order streams [8,9].
In our study we used the 3rd and 4th which are acting as 2nd and 3rd, because GIS algorithms applied on DEMs could extract fine streams that was impossible to delineate from topographic maps.
The Isobase map is a topographic surface without the influence of the first stream orders [10,11] and the abrupt deviations in isobase values may reflect tectonic dislocations or severe lithological changes [8]. It was generated following the concept described by Filosofov, Golts and Rosenthal [6,8].
An interpolation of the stream orders elevations including the 3rd order was done to build the isobase map of the 3rd order and the same operation repeated excluding the 3rd order to build the second isobase map of the 4th order figure 4.

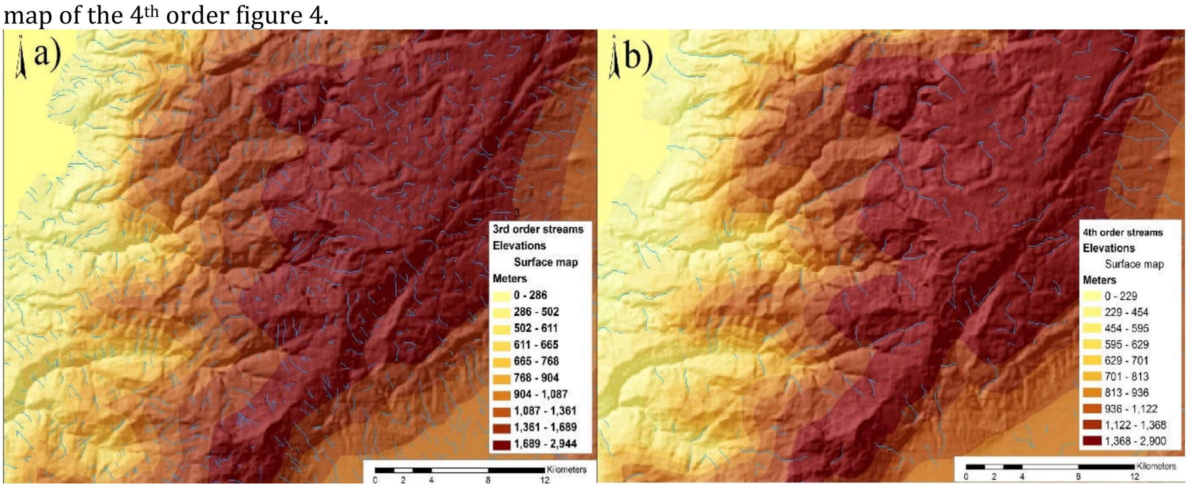

Fig.4: a) Isobase map of the 3rd order b) Isobase map of the 4th order.

The isobase maps in figure 4a and 4b are very similar with little difference in elevations, the 3rd order isomap is higher 44 meters at the maximum elevation.
The base maps of the tow first orders geologically the must younger 3 and 4 were subtracted from each other in raster calculator to obtain the final reference map.
The reference map is identified by the static relationship between morphometric surfaces and tectonic structures without regard to their development figure 5.
The difference between the base surfaces shows the algebraic sum of the vertical movements of the Earth's crust and erosion for certain periods of time.

RESULTS

The isobase map, constructed based on third and fourth stream order, allowed depiction of the features controlled by recent structures as an inflexion in the fault line area or a lineament.
The main morphological difference between the isobase map and the original topographic surface is the removed of the noise of the low order streams, we did it by excluding the first and second order from the account. The isobase level maps figure 4 generated from third and fourth order streams shows differential fluvial incision in the study area. The results from local base level map are consistent with the regional scale morpho-structures. The base level values are decreasing downstream where streams of low Strahler order have gentler slopes.
To quantify the amplitude of vertical movements, as well as identifying local active structures. The differences between the isobase maps of the third and the fourth orders show the algebraic sum of the vertical movements of the crust and erosion over time[6].

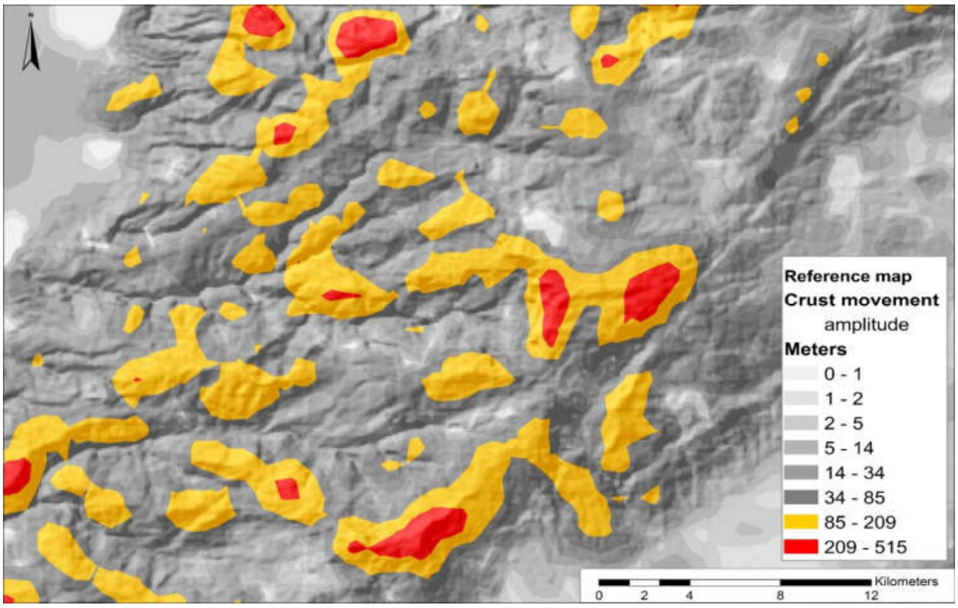

Fig.5: Reference map of crust movement.

As result of our study was the built of the hydrological model with Strahler stream orders of the study area and base on it we built the isobases digital models of the third and fourth orders, that leads to the reference map with the earth's crust movement's amplitude figure 5.
Figure 5 showing the reference map based on the third and fourth isobase maps, the crustal movements amplitude of the study area can vary from zero to 515 meters.
The light to dark gray areas with low values begins from calm to moderate crust movements, yellow to red are the extreme areas of high amplitude of crust movement.
The results of the study provide invaluable material to increase the representation of the laws of tectonic processes. They are also important for practical applications of geology.
The aims and objectives of the project were carried out by the discovery and study of the spatial distribution of the newest areas of vertical earth crust movements in the Lebanese territory.

CONCLUSION

The morphometric indices from GIS and DEM applications appear to be effective to detect tectonic activities and to understand the differential relative uplift.
The isobase level are capable of identifying younger, probably tectonic features.

Isobase analysis allowed discrimination of areas where the dominant geomorphic process is related to differential erosion from areas affected by tectonics. Drainage extraction from DEM presented satisfactory results when compared to topographic paper maps, SRTM-3 proved a good resource for geomorphological analysis at regional scale.

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