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SPATIAL ANALYSIS OF RIVER LONGITUDINAL PROFILS TO CARTOGRAPHY TECTONIC ACTIVITY IN KASSERINE PLAIN TUNISIA

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ABSTRACT:
The aim of this research is to detect the neotectonic activity and to map the seismic risk potential in the plain of Kasserine using the longitudinal profile of the Htab River and its tributaries. The adapted methodological approach is based on the extraction of the longitudinal profile and knickpoints, which are the main source of seismicity information in a plain filled up with more than 1000 m of silty deposit. In such a plain, compact structures are absent and thus we cannot detect the ordinary tectonic indices. The selected longitudinal profiles of the tributaries of the Htab River, extracted along the plain, show normal forms like river 1, 12 and 14 and abnormal ones such as 3, 5 and 7. The knickpoints distribution shows two main alignments trending NW-SE. The first one is in Semmama Mountain and it is represented in the structural map of Kasserine whereas, the second one is located in the plain of Kasserine and we think that it is caused by neotectonic activity. To confirm this hypothesis we use seismic records of the National Meteorology Institute since 2000. These data show seismic activity in the plain which is also a witness of a NW-SE alignment. Moreover, in situ investigations are performed and results pinpoint normal fault activity in the plain. Knickpoints, seismic records, and in situ investigation emphasize significant neotectonic activity affecting the thick quaternary plain of Kasserine.

***Key-words**: Longitudinal profile, Knickpoint, Seismic interpretation, Quaternary, Kasserine plain.*

1. INTRODUCTION

Tectonic indices are rarely detected in the sedimentary series of the Quaternary where there are no compact terrain structures. It would be better to deduce them from the analysis of morphometric parameters such as drainage density, hypsometric integral or drainage anomaly as well as longitudinal profile. Those parameters are found near the hydrographic network and its tributaries and this is the role of longitudinal profile interpretation (Schumm, 1986; Holbrook & Schumm, 1999; Peters & Van Balen, 2007; Kamberis et al, 2012).

The analysis of river longitudinal profiles is becoming a widely used concept to evaluate and assume neotectonic deformation (Peters & Van Balen, 2007; Gloaguen et al, 2008; Ambili & Narayana, 2014). The existence of river longitudinal profiles is related to the river equilibrium. In fact, a river in equilibrium shows a concave-convex shape of its longitudinal profile, however a desequilibrated river has a concave form (Snow &

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Slingerland, 1987; Whipple & Tucker, 1999; Whipple, 2001; Figueroa & Knott, 2010). This convexity represents an abnormal drainage which is a very important parameter to be considered in this study (Ritter et al, 2002; Phillips & Lutz, 2008; Larue, 2011). Generally, it is an indicator of lithology variation or pressure or tectonic activity.

The Kasserine plain is filled with more than 1000 m of silty Quaternary deposits (Chihi, 1995; Boukadi et al, 1992; Bkhairi & Karray, 2008) and, having a very dense hydrographic network, offers a useful case study to analyze longitudinal profile, to evaluate and assume neotectonic deformations, and finally to assess and predict seismic hazard.

In this research, we will use the relationship between river longitudinal profile and knickzones as a significant indicator of neotectonic deformation (Lewis, 1945; Goldrick & Bishop, 2007; Harmar & Clifford, 2007; Phillips et al, 2010) in the plain of Kasserine. A complementary study is provided by infield observations. The relationship between neotectonic and recent seismic activity interpreted through seismic records recently established in the plain and this may help predicting natural seismic hazards in central western Tunisia where the plain of Kasserine is located.

2. STUDY AREA

The study area 'Kasserine region' is situated in the western part of Tunisian central Atlas. It is characterized by the presence of NE-SW dissymmetric structures which have a developed hydrographic network because of several major faults oriented essentially NW-SE and E-W. Then, we note the existence of NE-SW faults that activated since Mesozoic time (Ben Ayed, 1986; Dlala, 1984; Philip et al, 1986; Chihi, 1995). The study area is also marked by the presence of a NW-SE trending basin where major hydrographic streams flow in.

Grabens of the Tunisian Atlas are generated by the geodynamic evolution of the country before the alpine chain which is situated at the eastern end of the Maghreb and Pelagian Sea. A slip movement generally turning into continental rift is associated with these NW-SE and E-W trending structures. The evolution of the grabens of the Tunisian Atlas began from the Aquitanian to Quaternary.

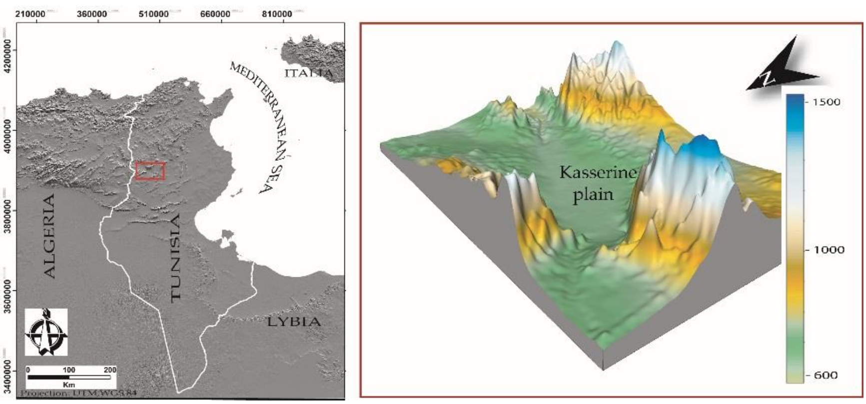


Fig. 1. Study domain showing the Kasserine plain.

The structural history of the graben of Kasserine is characterized, from the Mesozoic, by alternating periods of expansion from at least Neogene, with compressive periods. The result is a folded and faulted string sometimes seemingly simple but complex in detail by following the polyphase (Chihi, 1995).

3. METHODOLOGY

3.1 Data Processing

Studying the morphotectonic pattern of a Quaternary plain is related to the main features of the hydrographic network and its longitudinal profile. This latter is among the most important morphometric parameters derived from the hydrographic network and is also used to establish a coherent tectonic framework (Ambili & Narayana, 2014; Jacques et al, 2014). This tectonic framework will integrate all the components of the terrain (topography, geomorphology, hydrology and tectonic) and we will analyze them using a Geographic Information System (GIS) environment which give us the opportunity to study different types of data with different scales and formats for a better interpretation.

Data used consist of SRTM DTM with resolution of 30 m, the geological map of Kasserine (1/50 000 scale) and the seismic records. To superimpose data and interpret them we transform all these data into a common coordinate system (UTM projection WGS 84).From the DTM scenes of SRTM version 4.1 (Shuttle Radar Topography Mission) provided by the U.S. National Geospatial-Intelligence Agency (NGA) and the U.S. National Aeronautics and Space Administration (NASA) we extracted of the hydrographic network of Kasserine.

This product was converted from a raster to a vector format so we get the hydrographic network with six orders according to the classification of Strahler (1952). The lowest orders are located in the top of the mountains and the highest ones are in the plain. Only the highest orders (3, 4, 5 and 6) are considered to perform their longitudinal profiles relative to the plain of Kasserine where the SRTM is more accurate (Mukherjee et al, 2013; Chaieb et al, 2016).

3.2 Process of Longitudinal Profile generation

Based on the hydrographic network and the DTM SRTM we have generated the hydrographic network with its elevation value. From this network, we carried out the longitudinal profiles of the 12 rivers of the Kasserine plain. The identification of the anomalic points was identified by locating the points where the flow is against slope.

4. RESULTS

4.1 Tectonic cartography

Rose diagrams, plotted using Rose free software, show that this sector is very fractured and these faults are mapped only in the Cretaceous outcrop of the Chaambi, Semmama and Salloum mountains. The major directions of these faults are NW-SE (**Fig. 2**).

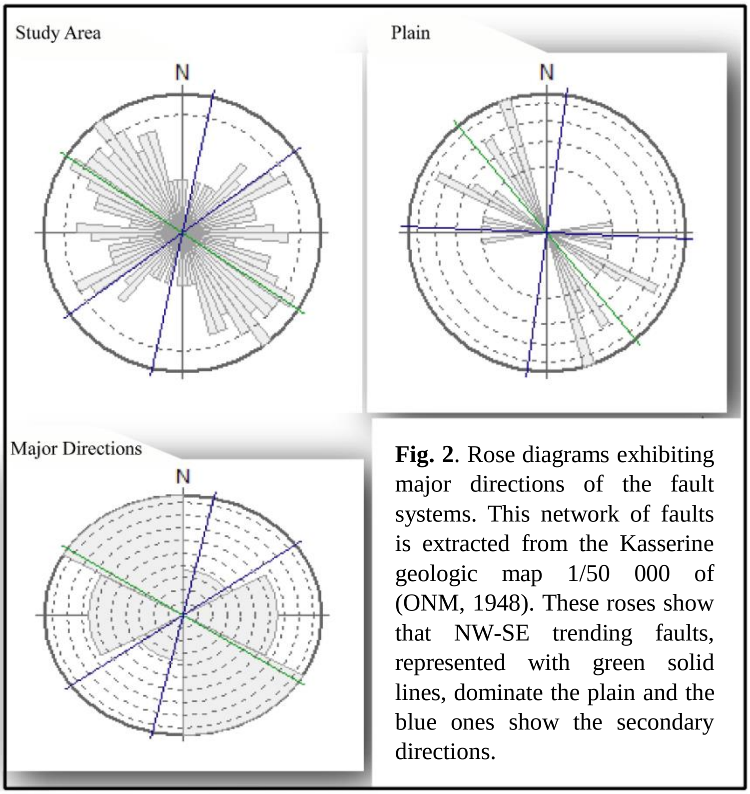


Fig. 2. Rose diagrams exhibiting major directions of the fault systems. This network of faults is extracted from the Kasserine geologic map 1/50 000 of (ONM, 1948). These roses show that NW-SE trending faults, represented with green solid lines, dominate the plain and the blue ones show the secondary directions.

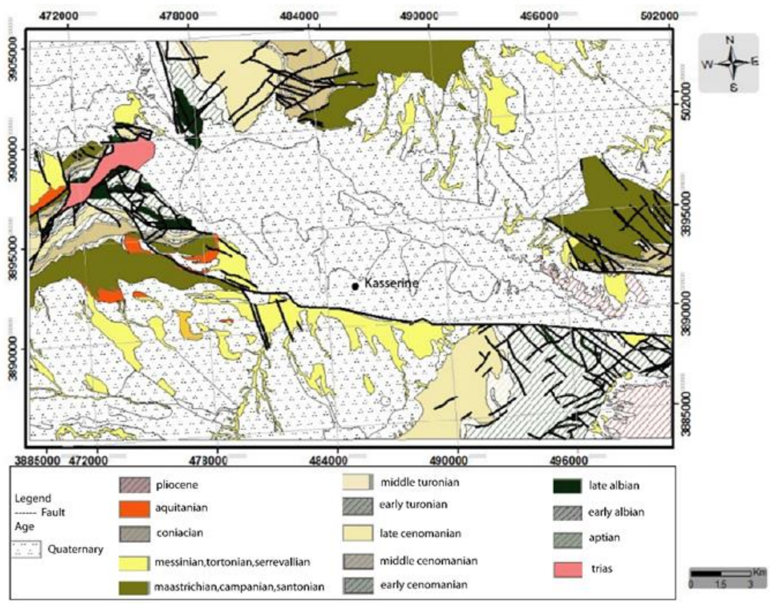


Fig. 3. Map showing the domination of the quaternary terrain in the Kasserine area.

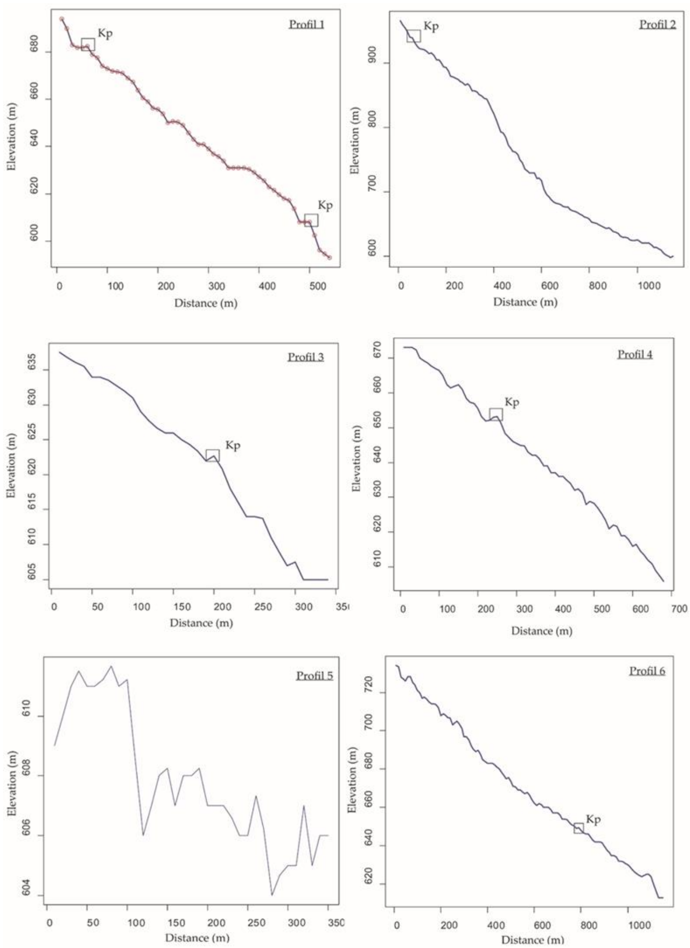
Tectonic index (faults, strike, pitch) are less frequent in Quaternary sedimentary deposits. To overpass this problem we use seismic records provided by the Tunisian National Meteorological Institute (NMI, 2011).

4.2 Seismic records cartography

The cartography of seismic records given by the National Meteorological Institute (NMI, 2011) shows the existence of tectonic activity in the plain of Kasserine, in Selloum Mountain as well as in Semmama Mountain during the 20th century. The spatial distribution of these tectonic activities dictates NW-SE alignment of the seismic epicenter.

4.3 Longitudinal Profile and Knickpoints

Many studies (Ambili & Narayana, 2014; Seeber & Gornitz, 1983; Bridgland & Westaway, 2007), shed light on the relationship between tectonic activities and stream longitudinal profile shape. The equilibrium stream profile on a single lithology is a straight line when plotted semi-logarithmically (Hack, 1973; Tucker & Whipple, 2002). Rivers in tectonically active regions show higher concavity indexes, whereas equilibrium river profiles show lower concavity index (Figueroa & Knott, 2010).



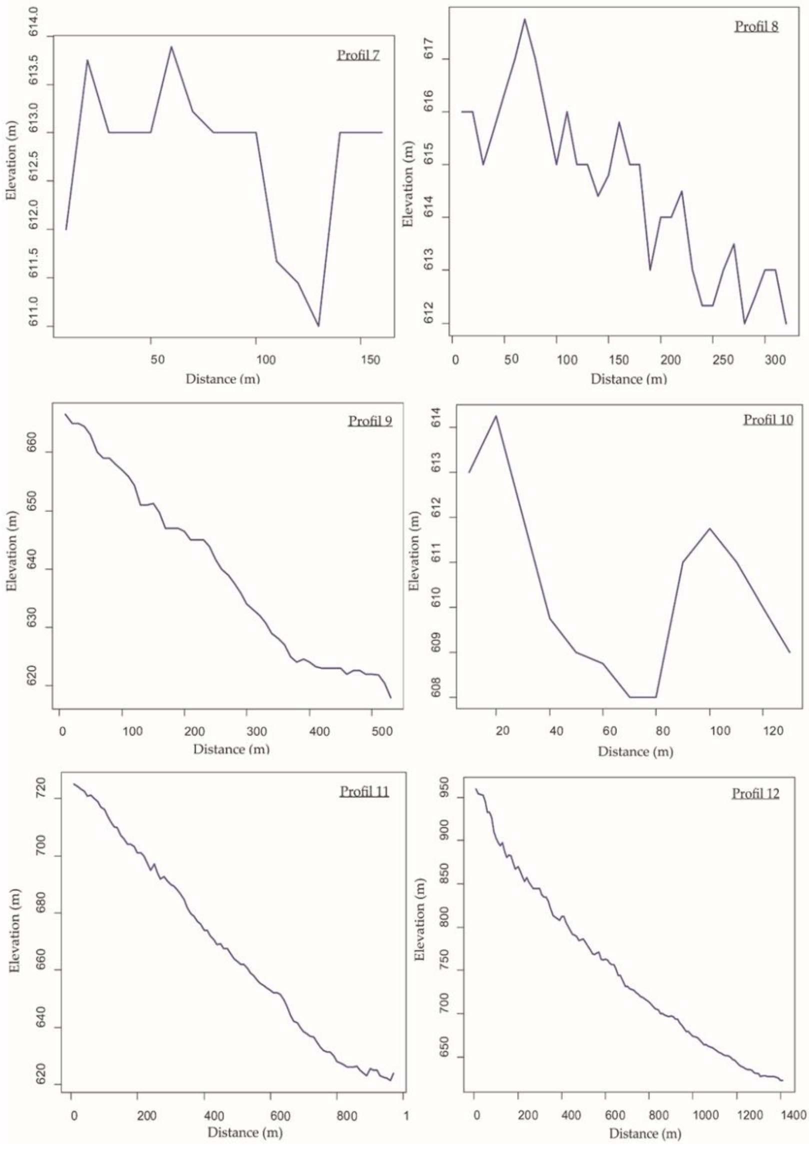


Fig. 4. 12 longitudinal Profiles relative to tributaries of Htab River.

The result of longitudinal profiles process (**Fig. 4**) shows normal profiles (2, 4 and 12) and anomalic ones (7, 8, and 11). These latter profiles define Knickpoints or Knickzones. An anomalic flow (Knickpoint) can be explained by either a variation of lithology or a tectonic accident (Bishop et al, 2005; Goldrick & Bishop, 2007). Based on the Kasserine geological map (**Fig. 3**) and the terrain investigations, we may confirm that a unique silty deposit fills up all the plain.

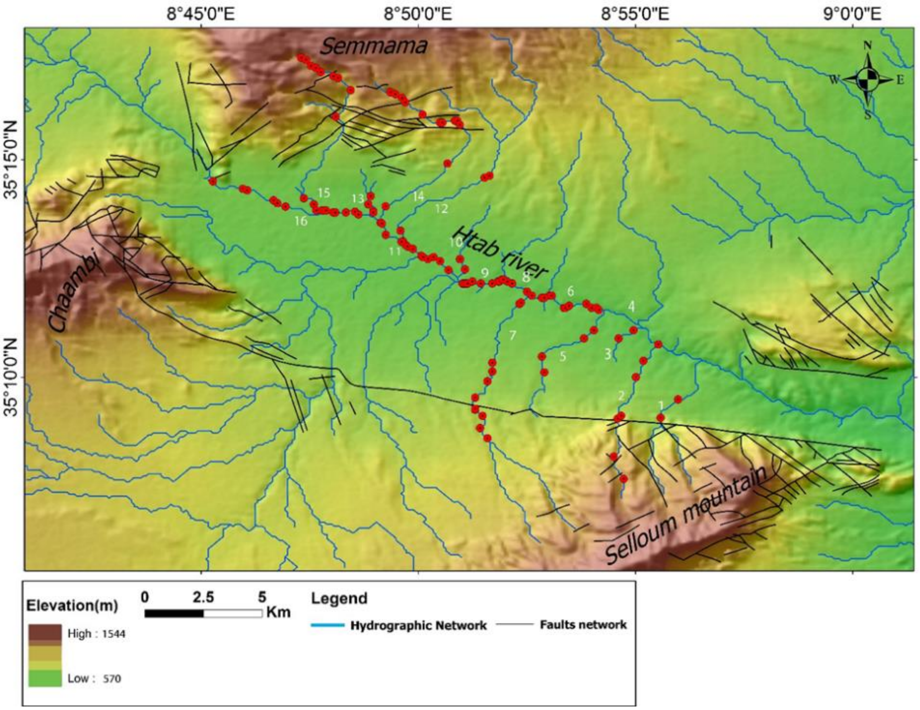


Fig. 5. Knickpoints distribution of all tributaries of Htab River in the plain of Kasserine illustrating a NW-SE alignment.

5. DISCUSSION

5.1 Longitudinal profile shape analysis

Htab master stream drains from surrounding mountains especially Chaambi Mountain into the plain of Kasserine. It has a very dense net of tributaries. Twelve tributaries have been characterized in terms of their longitudinal profiles.

Longitudinal profiles relative to tributaries of Htab River in the plain of Kasserine have been established (**Fig.4**). There are twelve longitudinal profiles (1-12) with a homogeneous spatial distribution over the plain of Kasserine.

Longitudinal profiles exhibit a wide range of shapes. They vary from smoothly concave shapes (1, 2, and 6) to concavo-convex ones (3, 7 and 10). Shape variability reflects either fluvial base level changes (interplay between deposition and incision process) or a dynamic equilibrium between fluvial process and tectonic activity. Concavo-convex shape implies the existence of knickpoints.

5.2 Knickpoints analysis

Recorded along longitudinal profiles of Htab River and its network tributaries (**Fig. 5**), knickpoints have been identified in two main sites. The first is Salloum Mountain, the second locality corresponds to the Htab master stream flowing through the plain of Kasserine.

These anomalies are often triggered by either resistant lithology or tectonic activity. The geological setting of the studied area discussed above shows that the plain of Kasserine is filled up by silty deposits which means an absence of an important lithology change.

Hence, identified knickpoints along longitudinal profiles indicate an increasing influence of tectonic activity in the two previously mentioned sites, Salloum Mountain and the plain of Kasserine. This tectonic activity in the plain of Kasserine is detected here for the first time and is proved by seismic records with field work observations.

Moreover, infield investigations documented normal faults with directions varying from N30 to N110 affecting Htab river terraces (**Fig. 7**). Furthermore, seismic records provided by the Tunisian Institute of Meteorology testify to recent tectonic activity near Salloum Mountain and in the Oued El Htab master stream (**Fig.6 B**). Two seismic records of 3.4 and 3.5 magnitude, have been recorded respectively in Salloum Mountain and in Htab River. Chihi (1995) and Khemiri (2014) prove the existence of tectonic activity with NW-SE direction as shown by the alignment of Knickpoint.

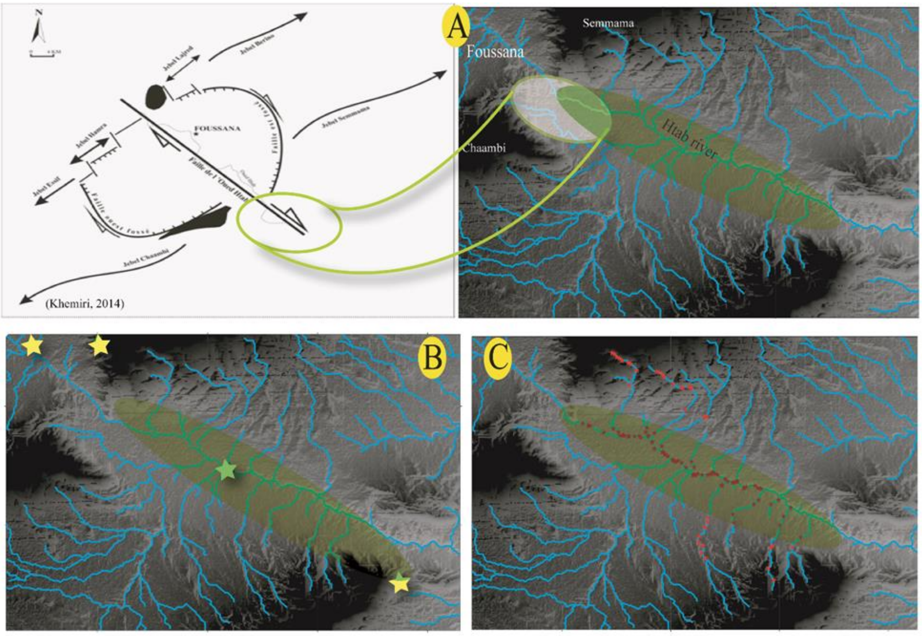


Fig. 6. Map showing the NW-SE direction of tectonic activity: (A) a part of the fault mapped by (Khemiri, 2014) in the plain of Kasserine, (B) seismic focal alignment, (C) Knickpoints alignment.

Consequently, we consider the plain of Kasserine filled with thick quaternary silty deposits is subject of recent tectonic activity as enhanced from knickpoints analysis and confirmed by infield observations and seismic records.

Knickpoint propagation exhibits a NW-SE direction compatible with the fault network identified in the structural map of Htab River and also with the main active fault of Kasserine (**Fig. 6**).

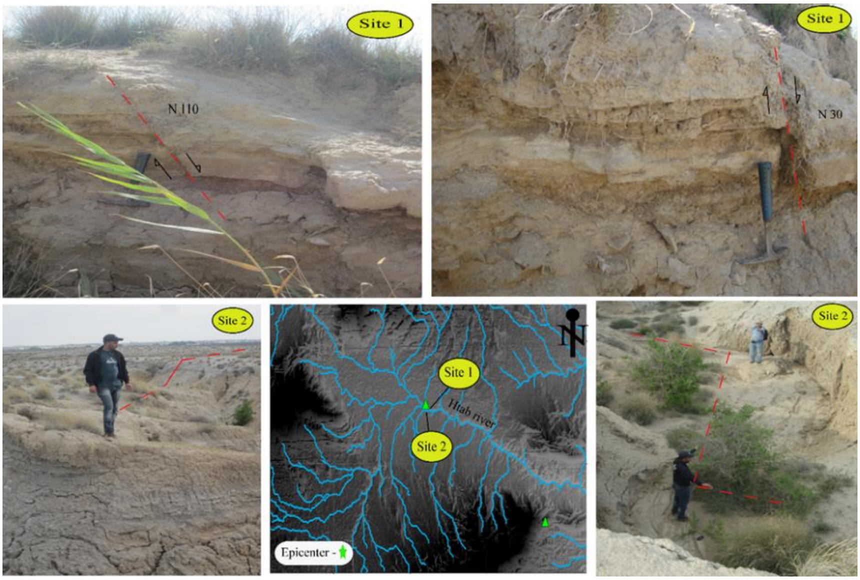


Fig. 7. Field observations showing in site 1 (right bank of Htab river) a normal faults N30 – N110 and site 2 (left bank of Htab River) strike slips affecting Htab river and its tributaries manifesting in the meandering forms.

6. CONCLUSION

The longitudinal profile is a good index to detect the neotectonic activity especially when ordinary methods are not applicable. From the longitudinal profile, we extract and localize the Knickzones. Results show a NW-SE alignment of knickpoints crossing the silty deposit of Kasserine plain. We think that this alignment originated from neotectonic activity even not being mapped in the geological map of Kasserine.

Some authors report tectonic activity in the eastern and western part of the plain (Castany, 1951; Chihi, 1995), but it is the first time to describe this event in the plain, which is probably related to recent seismic activity near the studied area.

To confirm the results of our study we used infield data where many normal faults have been detected and reported. In addition, seismic records of NMI plead for such seismic activity.

The approach based on hydrographic network and longitudinal profile interpretation shows significant efficiency to evaluate neotectonic deformation and to estimate the seismic risk in such domain where ordinary data are not accessible.

The study of longitudinal profile and determination of knickpoints can be improved and provide more accurate results by choosing the adequate scale and resolution of inputs.

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