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Research article

# Seismic activity of Sidi Salem dam, NW Tunisia

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**Abstract**
The Sidi Salem dam was built in Beja, a semi-arid region in Northwestern Tunisia, to protect the lower valley against floods, for irrigation, for water supply, and for power generation. It is the biggest artificial water reservoir in Tunisia. It is a compacted-earth dam with 73 m of high and 814 $Mm^3$ water capacity. The seismic events in the studied area have been monitored by seismic network operated by the National Institut of Meteorology. The main aims of this study is to construe the correlation between water level in the reservoir and the induced seismicity. The first earthquake susceptible to be induced event was found out in 1987 with magnitude of 5 after complete filling of the dam. Shortly afterwards, an increase in the number of seismic events happened, and many seisms were noted. We suggest that this induced seismicity took place after the reservoir loading effect and also the postponed effect of the diffusion of pore pressure. The comparison between the seismic data and reservoir water level indicates that there is a correlation between the changes in the water level and the seismic activity.

***Key words:*** Dam, seismic activity, induced seismicity, correlation, water level, Tunisia.


## 1. Introduction

The studies of induced seismicity by human activities are becoming more common because of its high probability to destroy constructions and to cause human loss (Gough and Gough 1970; Beck 1976; Talwani 1976). In addition with field studies, other factors who play an important role in RIS are identified, as like as: ambient stress, the appearence of fractures, properties of subsurface rocks of the reservoir (Zoback and Hickman 1982; Talwani 1997; do Nascimento et al. 2004, 2005). Observational and theoritical models (Bell and Nur 1978; Roeloffs 1988; Talwani 1997) highlighted that there are two impacts when a dam is filled by water. The first one is due of the water load and it is manifested by the variation of the condition of local stress, which causes weakness and the second effect is the increase of pore pressure into the rocks and on fracture and faults of the reservoir. This effect is due to the pore pressure diffusion into fractures and it can also due to the saturated rock compaction by water because of the over weight of the reservoir.

North Tunisia is one of important seismic region in the country. It is one of the most earthquake prone areas. The Sidi Salem reservoir was built in Beja, a semi-arid region in Northwestern Tunisia. The studied articifial lake is an embankment dam with height of 73 m and volume of 814 $Mm^3$. It was built to protect the lower valley against floods, for water supply, for irrigation, and for power generation. The seismicity in the studied region has been controled by seismic network operated by INM (National Institut of Meteorology). This dam is considered to have the potential of occurrence of reservoir induced seismicity with its structures. The construction of the dam finished in 1981. The first identified reservoir-induced events occurred in 1987 with magnitude of 5 after complete filling of the reservoir. The seismicity around the dam became increasingly frequent from the year 2003.

## 2. Material and methods

The data of water level of the dam and the characteristics of the reservoir were collected from the direction of large dams (Ministry of Agriculture, Water Resources and Fisheries). The seismic events were collected from the INM (National Institut of Metheorology) seismic catalog (412-2011).

The maps in this study were georeferenced and digitized using ARCGIS 10.1 software. The data of water level of the dam and the seismic activity were analyzed by MATLAB (matrix laboratory) which is a programming language used for numerical calculation purposes.

## 3. Results and discussion

### *3.1. Cases of reservoir induced seismicity*

Induced seismicity by artificial water reservoirs was for the first time pointed out by Carder (1945) at Lake Mead in the United States of America. Damaging seismic events exceeding M 6 occurred at Hsinfengkiang, China in 1962; Kariba, Zambia–Zimbabwe Border in 1963; Kremasta, Greece in 1966; and Koyna, India in 1967 (Gupta 2002). In 10 December 1967, an earthquake of M 6.3 occured at Koyna, it is the largest and most damaging reservoir triggered earthquake. It causes about 200 human loss, injured about 1500 and rendered thousands homeless (Gupta 2002). The earthquakes in Hsinfengkiang and Koyna caused damage to dams themselves. Other reservoir triggered earthquakes like Aswan, Egypt; Kremasta, Greece; Oroville, united States of America; Kariba, Zambia and Srinagarind, Thailand caused damage in their surrounding area. The Hsinfengkiang Dam in the People’s Republic of China was enhanced two times before the triggered earthquake of magnitude 6,1 in March 1962 (Shen et al. 1974). The injection of waste fluid in the ground at Rocky Mountain Arsenal had to be discontinued due to induced seismicity (Evans 1966).

### *3.2. Mechanism of occurrence of induced seismicity*

Talwani and Rastogi (1978) and Talwani (1981 a) suggested after the evaluation of the world wide data that the diffusion of pore pressure is the preferred mechanism of reservoir induced seismicity. This suggestion was been the base on the observation of the linear growth of the epicentral area with time at Jocasse lake. The field data of Monticelllo reservoir was analysed by Talwani and Steve Acree (1985). The results showed that the diffusion of pore pressure has an important rôle in induced seismicity by decreasing of the friction coefficient of the rocks that enclose fractures and the clays between the preexisting fractures and also by the increasing of the weakness in rock masses. Hence the effect of fluids is clear in the occurrence of earthquakes (Zoback 1997 ; Shapiro 2010).

Simpson at al. 1988, suggested two types of seismic response after the filling of the reservoirs. These types are the result of two different mechanisms. The first response is related to rapid increase in the elasticity of the stress due to the load of the reservoir. The delayed seismicity (the second type of response) as is the case at Koyna, was related to an increase in pore pressure which resulted from the diffusion of these to hypocentral depths. The increase in pore pressure may play an important rôle in cases of reservoirs where there is a delay between the fillling of the lake and the triggering seismicity. In these cases, faults intersecting the reservoir serves as channel to transport the flow away from the reservoir. Hence, the extension of water diffusion far away from the lake which affects many other faults. The analysed strength changes at Monticelllo reservoir showed that the predominant mechanism of triggering earthquakes is the diffusion (Talwani 2000). Talwani in his interested paper (Talwani 1997) divided the temporal pattern of reservoir induced seismicity into two categories :

Initial seismicity: This category is widely observed, it is associated with the first filling of the dam or with major changes in the water level in the reservoir as is the case in Monticello Dam (South Carolina). This seismicity results from the instant effect of the loading or unloading of the water in the artificial lake and on the other hand from the delayed effect of the distribution of pore pressure. Hence the frequency of events increases and also their magnitude.

Prolonged seismicity : This category is induced when the cause of occurrence of reservoir induced seismicity is the increase in pore pressure, which is related to the fequency and amplitude changes of the water level in the dam (Roeloffs 1988). The increase of pore pressure occurs directly beneath the artificial lake and it decreases with distance. In this category of seismicity, the events are associated with big and/or fast variations of the water level in long time periods (lower frequency). Seismicity is recorded beneath the biggest depth and it surrounding. The seismic activity lasts for many years and does not appear to cease.

To illustrate, the review of different cases of reservoir induced seismicity allow to conclude that this phenomenon does not consider the geological and morphological conditions of the site. There is an only common circumstance for all cases: the filling of the reservoir with water, which increases the hydraulic pressure in the rock masses.

The filling of the reservoir varies the water level of the underground in the wider area. The water of the dam will fill all the existing cavities and pores and will lead the saturation water of the underground reservoir. After saturation, the changements in the water level of the reservoir will cause the appearence of a water course with different pressure in the direction of the underground reservoir. This water course suggests the increse of pore pressure with also the presence of specific geologial and morphological conditions in the site. Hence, the increased stress causes the reduction of permeability into the rocks and on fracture of the reservoir. The high concentration of this presure in the rock mass can induce rock damage.

Overweight dam causes changements in stress due to increased pore pressure. Consequently, the resistance of rocks can be exceeded at some points which can lead the failure of the rock mass and can also lead the release of the potential energy accumulated with deformations. These steps are suggested to be generating source of microseismic activity. In the case of Açu reservoir in Brazil, El Hariri et al. 2010 observed a clear migration of the seismic activity with depth on a fault after the relocation of microseismicity of the dam. The rate of microseismicity migration to the depth was varying between 15.5 and 17.5m/d, which is conistant with pore pressure diffusion on a fault zone.

*3.3. Seismicity in Sidi Salem dam*

The reservoir Sidi Salem dam on Medjerda valley (Fig 1) is the centerpiece of water mobilization of northern Tunisia in an interconnected system ensuring the security and sustainability of the country's economic infrastructure. The construction of the dam finished in 1981. The Sidi Salem dam is an embankment dam with height of 73 m and volume of 814 Mm3. It was built to protect the lower valley against floods, for water supply, for irrigation, and for power generation. The seismicity in the area has been monitored by seismic network operated by INM (National Institute of Meteorology). This dam is considered to have the potential of occurrence of reservoir induced seismicity with its structures. The first identified reservoir-induced events occurred in 1987 with magnitude of 5 after complete filling of the reservoir. The seismicity around the dam became increasingly frequent from the year 2003.

*3.3.1. Seismotectonic context of the studied area*

The Sidi Salem reservoir was built in the state of Beja, a semi-arid region in Northwestern Tunisia. In order to understand the seismotectonic context of the studied site, we refered to Soumaya et al (2015),Gharbi et al (2014), Gharbi et al (2015), Gaieb et al (2017). The reservoir is located in northern Tunisia, this region is characterized by fold-and-thrust series. It is a collision front which is part of the Maghrebides chain. This front is dominated by a NE-SW thrust faults (Rouvier 1977). The Trias of the NE trending Diapirs zone indicates the front of the thrust sheet zone. It is composed of diapiric folds aged upper Tortonian and which have been accentuated during the Quaternary compressive phase (Rouvier 1977, Ben Ayed 1993, Meghraoui and Pondrelli 2012).

According to Gueddiche et al (1992, 1998), the reflection seismic campaigns in the Tell and Diapirs zones showed that the current deformations mainly occur along thrust faults with direction NE-SW. In this regions the active faults are sometimes associated in dextral strike slip systems with direction E-W and sinistral strike slip system with direction N-S (Rouvier 1977, Ben Ayed 1993). In this box, these directions are the directions of the two nodal planes of the majority of focal mechanisms.

Upstream of the Sidi Salem dam site Mejerda flows in a direction E-W, through the Triassic diapir extrusions of Jebel el Melah with predominantly NE-SW direction over a length of about 8 km. At the confluence with the river Zarga, a tributary of the left bank Mejerda the direction of the river becomes N-S to Testour. The Sidi Salem dam site is located on the last topographic tightening Mejerda Valley at a synclinal structure inter Diapiric River el Melah. The tectonic contacts through the retaining sides upstream and downstream of the dam, some of which are dotted with Trias, suggest that the full pressure of the reservoir stood at these tectonic contacts, Added to this is an extensive to extensive wrench seismotectonic context which had a predominant effect to cause the seismicity induced by the reservoir (Fig.2).

*3.3.2. Stratigraphy of the main terrains outcropping in the study area*

- Trias

Characterized by the presence of transparent white gypsum or sometimes intensely colored in black or red with clays, sandstones, dolomites corroded on the surface. It is a physically and chemically heterogeneous field which has been intensely crumpled and its plasticity properties have allowed it to inject the host rocks (Fig.3).

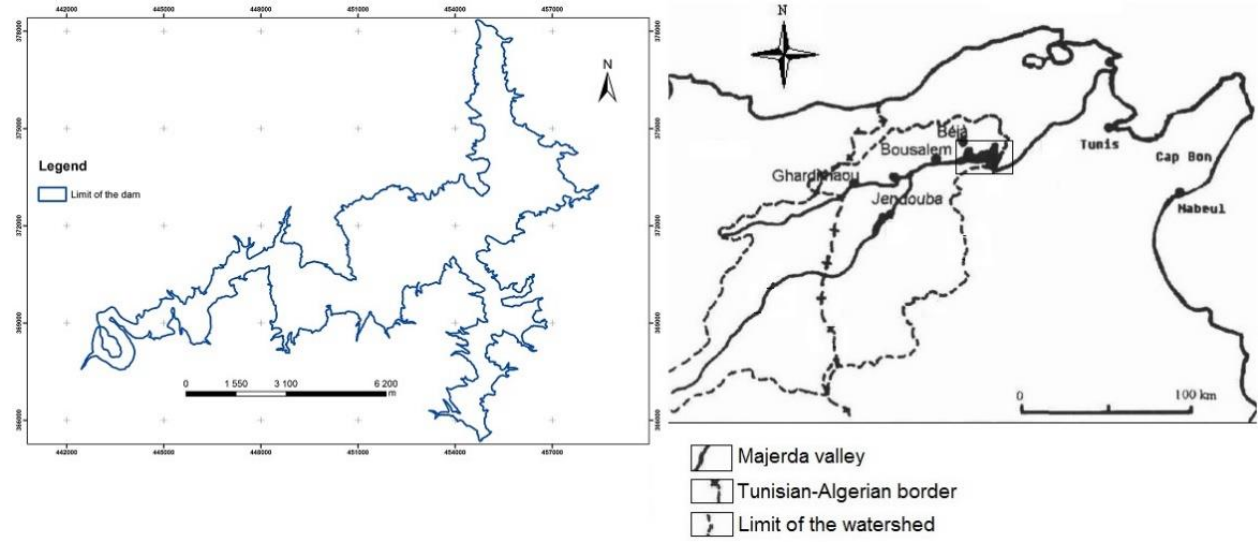


**Fig. 1.** Location of the Sidi Salem dam

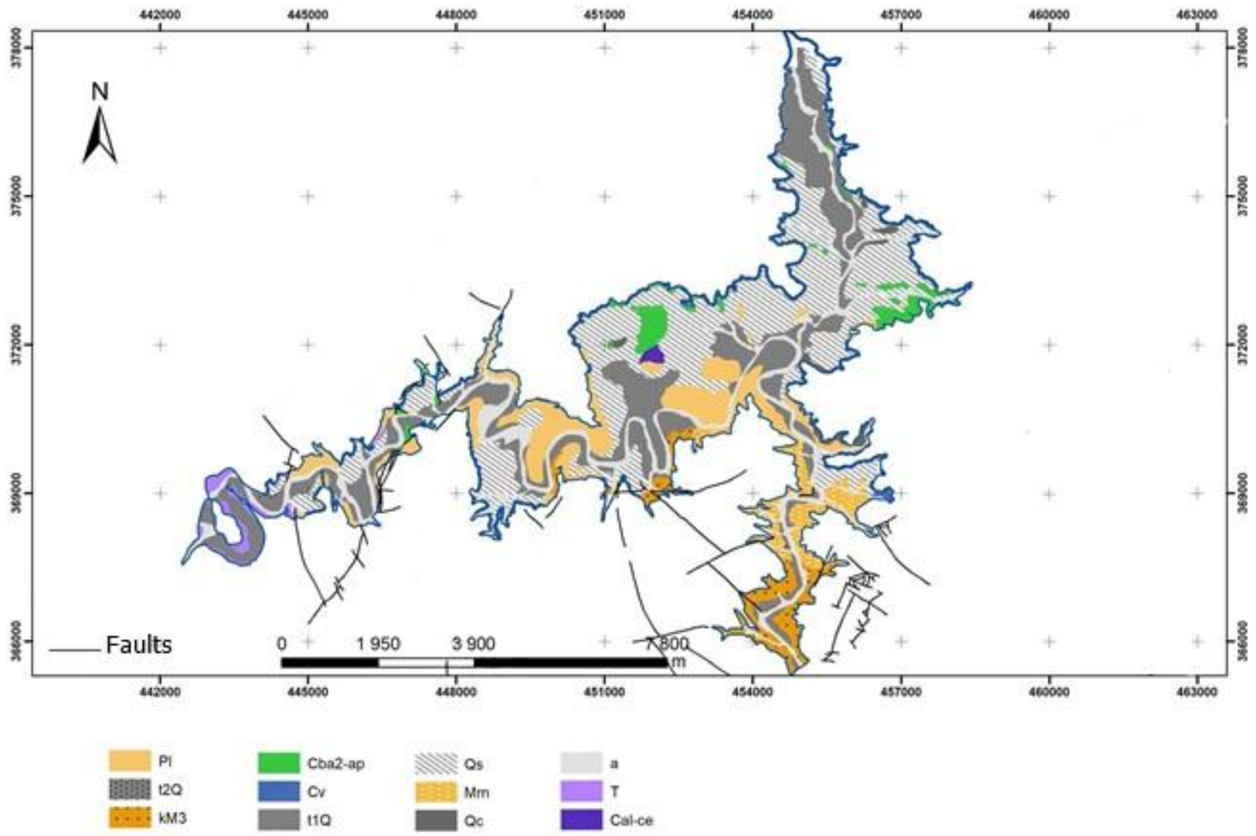


**Fig. 2.** Geological context of the Sidi Salem dam (geological map Oued Zarga NE, 1/25000)

With : P : Pliocene, t2Q : Quaternary (high terraces), kM3 : Upper Miocene (Kechabta formation), Cba2-ap : Upper Barremian-Aptian, Cv : Valanginian, t1Q : Quaternary (low terraces), Qs : Quaternary (soils), Mm : Messinian (Oued el Khedim formation), Qc : Quaternary (crusts and encrustation), a : Quaternary (alluvium), T : Trias, Cal-ce : Albian- Cenomanian

- Upper Cretaceous

It is a slightly chalky whitish marl limestone alternating with gray or whitish marls. These outcrops are in thick layers (500 m according to the notice of the geological map of Oued Zerga) (Stranik, Biely, Salaj 1994) and they are associated with the Triassic scarves (Fig.3).

- Miocene (Hakima formation)

These are reddish or brown indurated clays alternating with beds of black limestone. Besides, there are sandstone banks at the top. This formation forms the heart of the anticline, which is situated immediately in the downstream of the dam. It is found at the entrance to the tunnel of the Trajan's Bridge railway (Fig.3) in abnormal contact with the Tibar diapir (jbel Mlouka).

-Miocene (Oued El Melah formation)

Presented by gray clays containing gypsum in thin beds, rich in dissolved salt giving white efflorescences on the surface, with rare sandstone banks on the upper part. These clays give forms of semi-fluid slides. They are flush with the entrance to Trajan's Bridge the tunnel.

- Miocene (Kechabta formation)

It is a thick sandstone-marly series (1000 m) (notice of the geological map of Oued Zerga) (Stranik, Biely, Salaj 1994). This series is the result of cyclic sedimentation (flysh facies). This flysh begins with a transition zone where the clays and marls have a dominant brownish or yellowish color. The rest of the flysh consists of sandstone beds and layers of gray marl, bluish with concoidal breaks, locally conglomeratic. The proportion of sandstone is almost equal to that of marl. We find this formation at jbel el Malia. This formation forms the basis of the dam.

- Pliocene

These are red clays with variegated red gravel, friable sandstone encasing limestone pebbles, lacustrine limestone, conglomerates...

It outcrops in unconformity on the upper Cretaceous in the tectonic pit of Mzougha.

- Quaternary

These are fluvial soils and terraces, conglomerates (Fig.3).

### *3.3.3. Seismicity around the dam*

The seismicity in the study area is monitored by the network of seismic stations of the INM (National Institute of Metheorology). The events used for this work are the events of the period from 1976 until the year 2010. This period of time was chosen because the network became more refined from the year 1976 by the installation of an important number of seismic recording stations. The magnitude of all events used in this study is greater than 2. The seismicity around the artificial lake is far from be negligible.

Around 100 km from the dam, the number of events recorded before the impoundment, i.e. from the year 1976 to the year 1981, is 248 events (Fig.4).

The figure 4 shows that the seismicity is not very important, moreover, the most numerous earthquakes are of low magnitude ($M \le 2$). The number of events is greater to the east of the dam than to the west. East of the Sidi Salem dam, the seismic events are associated with the major accident at Teboursouk, the active fault of Sidi Thabet, the Utique fault. In addition, during the 1980s, the Mejez el Bab region recorded several earthquakes at Jbel Bou Mousse.

During the period 1982-2010, the number of events increased to 684 seismic events. Therefore, the seismicity increased after the impoundment. The events that are close to the dam within a radius of 10 km around the reservoir have a magnitude that varies between 2 and 4 (Fig.5).

The seismicity after the impoundment increased, the number of events during this period is important to the west and east of the dam. The increase in seismicity west of the reservoir after the impoundment shows that the Sidi Salem dam caused seismicity. We also notice the presence of two earthquakes of magnitude 3 and 4 less than 5 km from the dam (Fig.5).

These results are not directly comparable because the period chosen for this study extends from the year 1976 to the year 2010. So from 1976 to 1982 which is the date of the impoundment of the dam, the recorded seismicity is the seismicity which took place 6 years before the impoundment. On the other hand, the events after the impoundment are events of 28 years (1982-2010). To have comparable results, we normalized the number of events.

### *3.3.4. Normalization of the number of events*

For the period chosen in our study (1976-2010), we notice that the number of years before the impoundment (1976-1982) is lower than the number of years after the impoundment of the dam (1982-2010). Hence, to confirm that the seismicity increased after impoundment, the time factor must be neglected. This is done by normalizing by dividing the number of events per month for the period (1976-2010) by the maximum number of events per month at different magnitudes (Fig.6). This figure shows that the number of events at different magnitudes is more frequent after the impoundment of the dam.

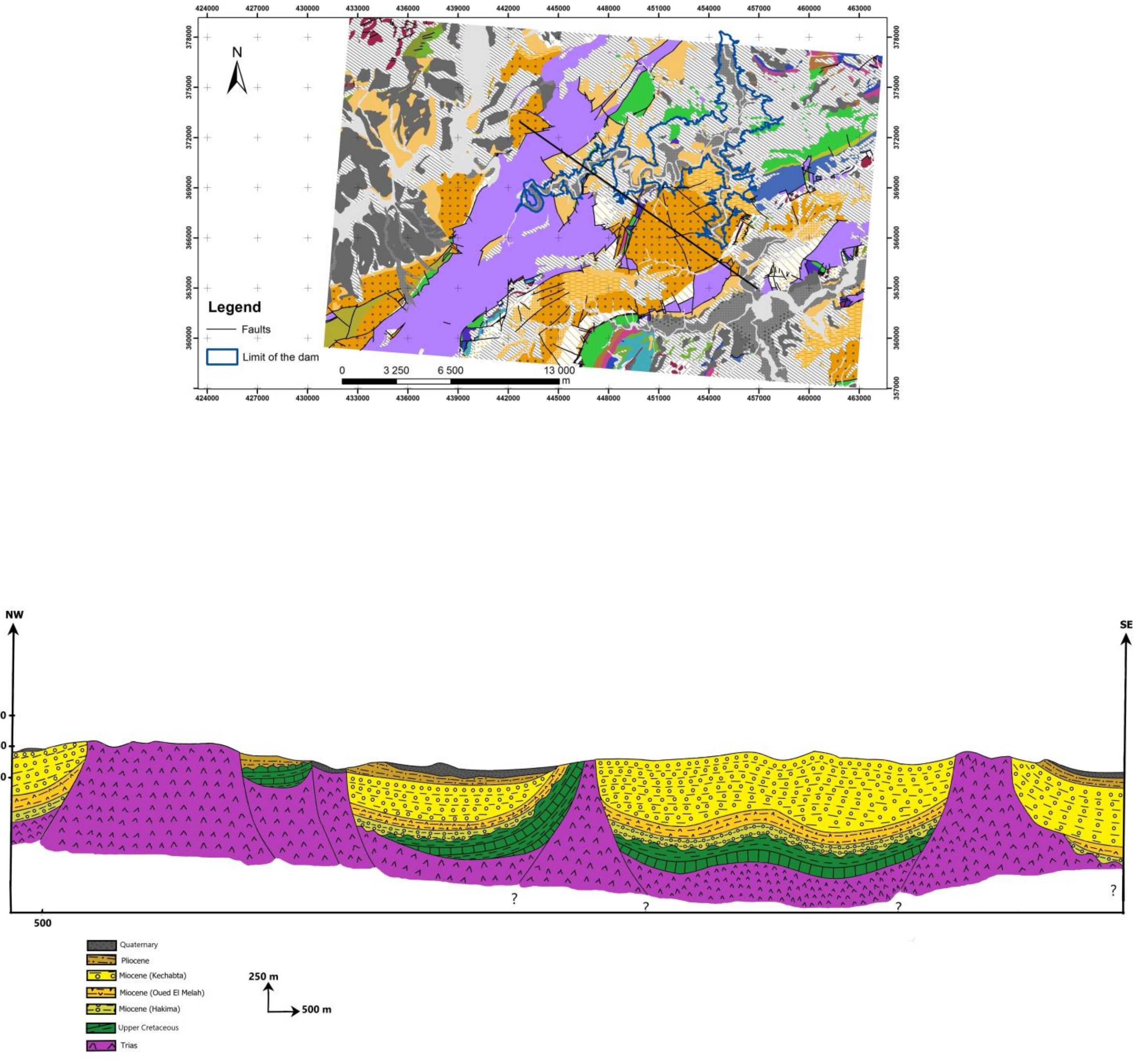


**Fig. 3.** General structure of the Sidi Salem dam site

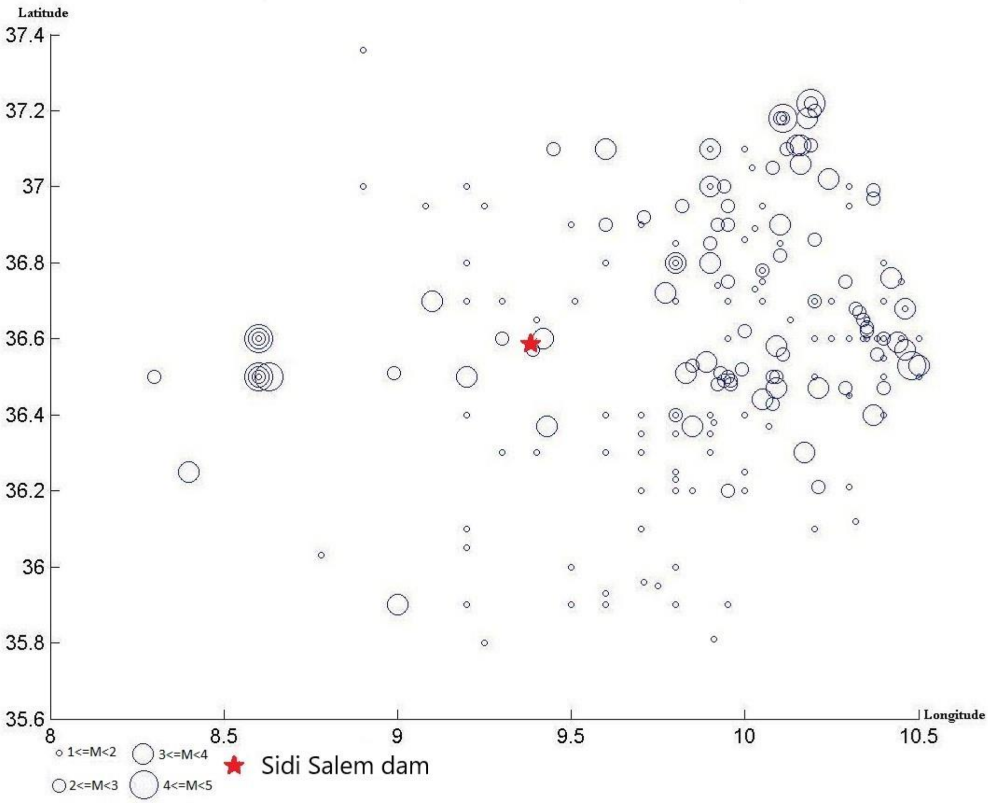


**Fig. 4.** Seismicity map before impoundment with different magnitudes within a radius of 100 km around the dam

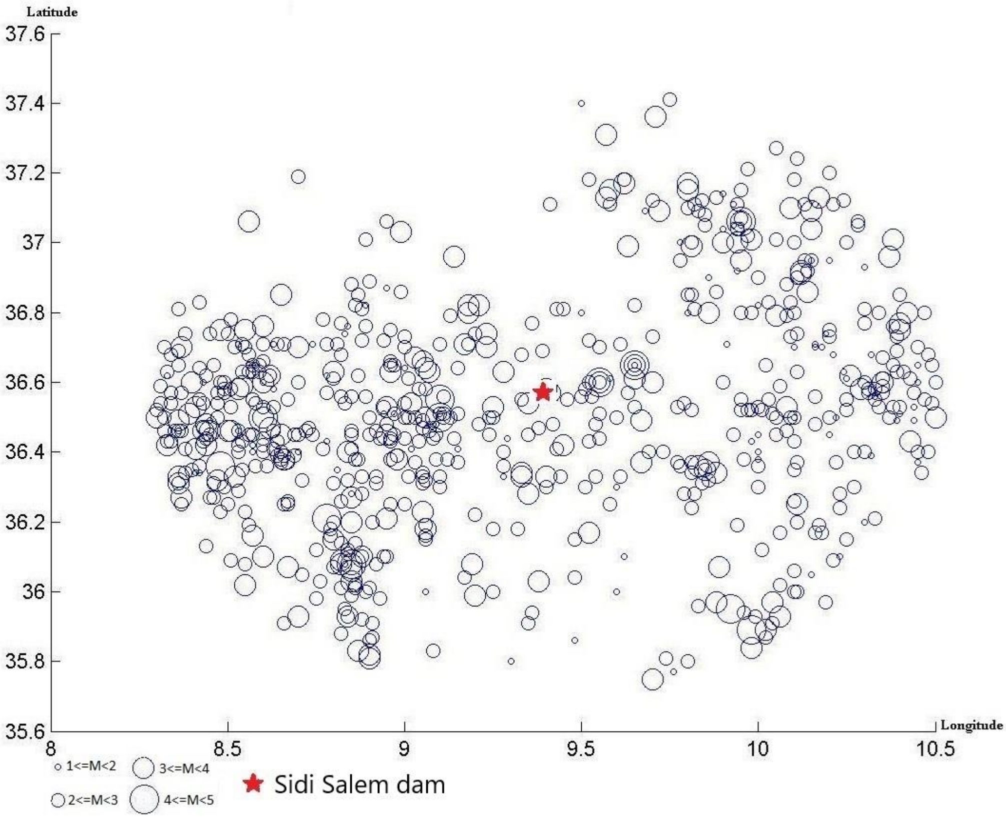


**Fig. 5.** Seismicity map after impoundment with different magnitudes within a radius of 100 km around the dam

For figures 6 (a, b and d), we notice the presence of a peak in 1999, which is explained by the fact that in this year there were several seismic events. The magnitude of the earthquakes that took place after the impoundment of the Sidi Salem dam is M $\geq$ 2 and M $\geq$ 4.

*3.3.5. Seismicity within a radius of 15 km around the dam*

It is observed that after the filling of the reservoir, 30 seismic shocks occurred within a radius of 15 km around the dam. Among these events, there are 5 seismic events that are very close to the dam (Fig.7). The last earthquake recorded in the period chosen for this study, an event that occurred in July 2009, and its magnitude was 3.3 on the Richter scale. The depth of this earthquake was 5 km. This event took place 1 km from the Sidi Salem dam.

*3.3.6. Seismicity and water level*

As mentionned in the previous paragraph, the magnitude of all the events is upper than 2 on the Richter scale. The Fig 7 shows the relationship between the water level in the reservoir and the seismicity since 1982. Within a radius of 10 Km of the dam, the seismicity appears to be related to the complete filling of the reservoir. A seismic shock occurred mainly in 1987 with a magnitude of 5.0 after a complete filling of the reservoir (Total net input to Sidi Salem for the hydrological year 1986-1987 more than 725 hm3 with a water level 109 m exceeded during 4 months: February, March, April, May). Concerning the September 1991 earthquake of magnitude 3.3, the epicentre was located at the level of the Trajan Bridge at the Sidi Salem retaining tail, this event follows a particularly wet hydrological year 1990-1991 (Water level of the dam was varying between 109.96 m in April 1991 and 108.24 m in August 1991).

The frequency of seismicity is increasingly important from the year 2003 (Magnitude 3.5). For the record, the normal water level of the dam reservoir (110 m), which is fixed by the threshold of the spillway (Tulipe), was elevated to 115 m in autumn 1999. This New rating was reached and exceeded several times in particular in January 2003 (dimension 117.51 m).

The floods of this year have accumulated more than one billion cubic meters of water in Sidi Salem. The Mejerda experienced very strong floods in 2003 coupled with exceptional contributions after three years of drought. During this year, the reservoir of the Sidi Salem dam reached 117.51 m for the first time since the impoundment of the artificial lac, ie 2 m below the highest exceptional water level (119.5 m). In 2009, two seismic events occurred at 1 Km of the dam with magnitude of 3.5. In this year, the water level in the reservoir exceeded 117 m (Fig.8).

To better understand the relationship between the water level in the dam and the number of events within a radius of 15 km from the reservoir, we correlated the number of events and the variation in water level height as a function of time. This correlation was performed using Matlab. The graph shows that the number of events increases every time when the variation of the height of water increases and the height decreases when the number of events decreases. The first peak corresponds to the complete filling of the reservoir in 1987 (Fig 9).

In 1998, the graph shows a peak which does not coincide with an increase in the water fluctuation, it is an earthquake which is not therefore induced by the dam.

We suggest that this seismic activity resulted from the moment effect of loading of the reservoir and the postponed effect of pore pressure diffusion. The seismicity around the dam appears in relation to the water level in the dam.

Monitoring microseismic activity using a local monitoring network remains an important tool in managing the risk of induced seismicity. Unfortunately, despite of the importance of the reservoir, there is not seismic monitoring stations in the vicinity of the dam which allow us to determine seismic activity under 2 in magnitude and microseismic activities.

*4. Role of microsismic surveillance in preventing the risk of seismicity induced by the sidi salem dam*

Well dimensioned in terms of number, positions and types of sensors, this network can not only locate with sufficient precision but also characterize the ruptures induced and triggered by the dam site, including those of low magnitudes. Nowadays, experts recommend monitoring the microseismic activity during the period of an industrial project because this has several advantages, namely:

- in the exploratory phase, before operation, monitoring allows a better characterization of the natural seismicity at the site scale (seismic microzonation) in addition to the assessment of the natural seismic hazard and the determination of an initial or reference level of seismicity;

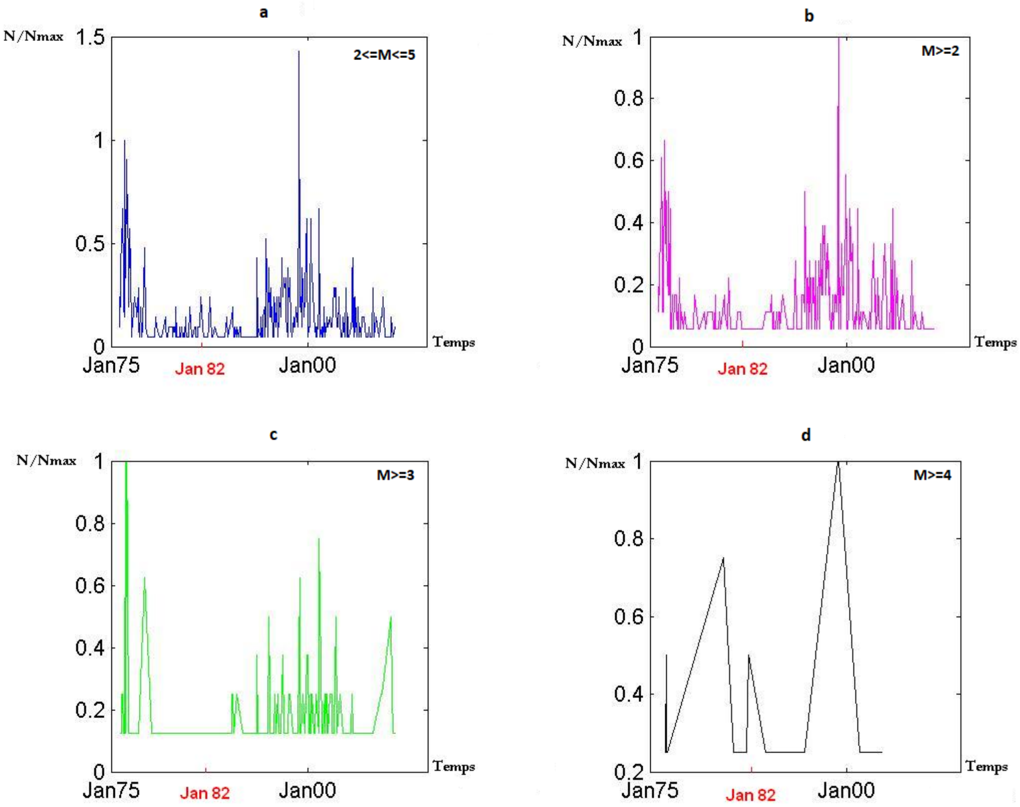


**Fig. 6.** N / Nmax = f (time) for different magnitudes within a radius of 100 km around the dam

With:
N / Nmax = Number of events per month divided by the maximum number of events per month
a: N / Nmax per month as a function of time for all magnitudes
b: N N / Nmax per month as a function of time for all magnitudes greater than 2
c: N N / Nmax per month as a function of time for all magnitudes greater than 3
d: N N / Nmax per month as a function of time for all magnitudes greater than 4

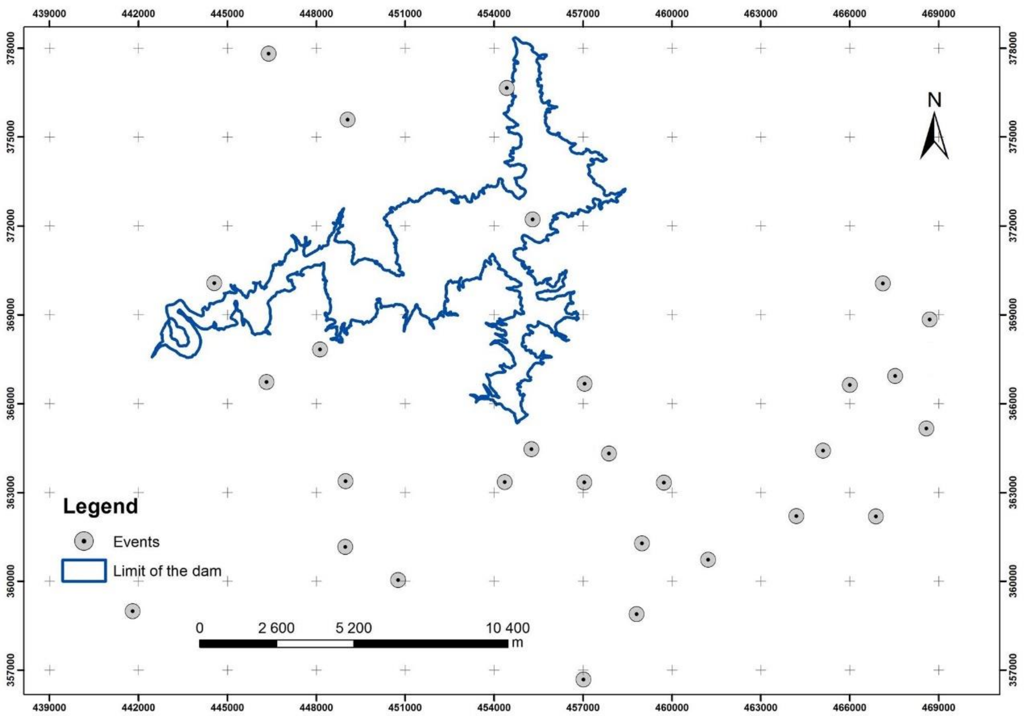


**Fig. 7.** Seismicity within a radius of 15 km from the Sidi Salem dam for the period (1982-2010)

- during operation: microseismic monitoring makes it possible to detect and monitor microseisms (Mw <2) that are not detected by regional and national monitoring networks. Recall here that on average, for an event of magnitude N, 10 events of magnitude N-1 can be detected.

It is therefore essential to install a local monitoring network for the collection and processing of available microseismic information. Likewise, microseismic monitoring makes it possible to detect, locate and also to study precisely earthquakes with a magnitude greater than 2 (Mw> 2) which are felt by the population during operation and recorded by the regional or national network, in order to determine whether it is indeed earthquakes induced by the dam or natural. The monitoring of microseismicity also makes it possible to implement an early warning system making it possible to associate the monitoring of the spatio-temporal distribution of the seismicity with the activity of the dam and consequently to be able to adjust or even stop the operations in progress. (For example: modification of the filling level of the dam) according to the activity detected.

- During and after the operation phase, monitoring the microseismic activity ensures that the Sidi Salem dam site returns to a state of equilibrium, with an acceptable level of seismicity.

In practice, the detection and localization capacities of surveillance networks are closely linked to the number, spatial distribution and types of measurement probes deployed. This sizing is guided by expected performance objectives and the state of the stress field conditions (for example: geology, urbanized areas) in addition to the corresponding financial costs. In particular, the depth accuracy of the locations can quickly deteriorate in the absence of sensors positioned in and around the area of influence of the dam.

Note that regional seismic networks are not suitable for the detection and localization of microseisms. But, it is necessary to use them in order to understand regional seismic activity, using historical and instrumental data. These networks can also be used to study large earthquakes produced by the dam site which is not equipped with a local monitoring network (as is the case in this work), but the location can then be Splotched by a mistake. In conclusion, a local monitoring network will better identify the origin of an earthquake, whether it is natural or induced.

The Sid Salem dam is located in Northwestern Tunisia a semi-arid region about 8 Km from Testour city. It is the biggest reservoir in Tunisia. This reservoir is the centrepiece of water mobilisation of northern Tunisia in an interconnected system ensuring the security and sustainability of the country's economic infrastructure. The earthquakes occurred in the area are characterized by shallow depth (the depth of seismic shocks is ranged from 1 to 5 Km).

This seismicity recorded in this study is monitored by the INM (National Institut of Metheorology) seismic network, the magnitude of all the recorded events is upper than 2.

This is due to the absence of monitoring seismic stations in the vicinity of the reservoir despite of its importance. The seismic data in the periode from 1976 until 2010 and in radius of 15 Km around the dam, showed that the number of events increased after the impoundment of the reservoir.

An event with magnitude of 5 in the Ritcher scale occurred in 1987 after the complete filling of the artificial lake. The seismicity has followed a quiescent periode from 1987 until 1991. We recorded in 1991 a seismic shock with magnitude of 3.3, the epicenter of this earthquake was located at the level of trajan bridge at Sidi Salem retaining tail. The seismicity is increasingly important from the year 2003. In 2009 two seismic events occurred at 1 Km from the dam with magnitude of 3.5 both of them.

The increasing of seismic activity at Sidi Salem reservoir for the chosen period seems to be associated to seasonal increasing of the lake water level. The water level exceeded 109 m 3 months during 1987, the level of water was 109.96 in April 1991 after a wet hydrological year 1990-1991. Moreover, the normal water level of the reservoir fixed 110 m was elevated to 115 m in 1999, this new rating was reached and exceeded several times in 2003 (117.5 m).

The flood of this year have accumulated more than one billion cubic meters of water after three years of drought. During this three years we showed that the seismicity has followed quiescent periode. In 2003, the water level in reservoir exceeded 117,5 m for the first time. In 2009, the water level reached 117,5 m, ie 2 m below the highest exceptional water level (119,5 m).

A clear correlation between the water level added to the fluctuation of the water level in the reservoir and the seismic activity can be shown in figure 5 and figure 6.

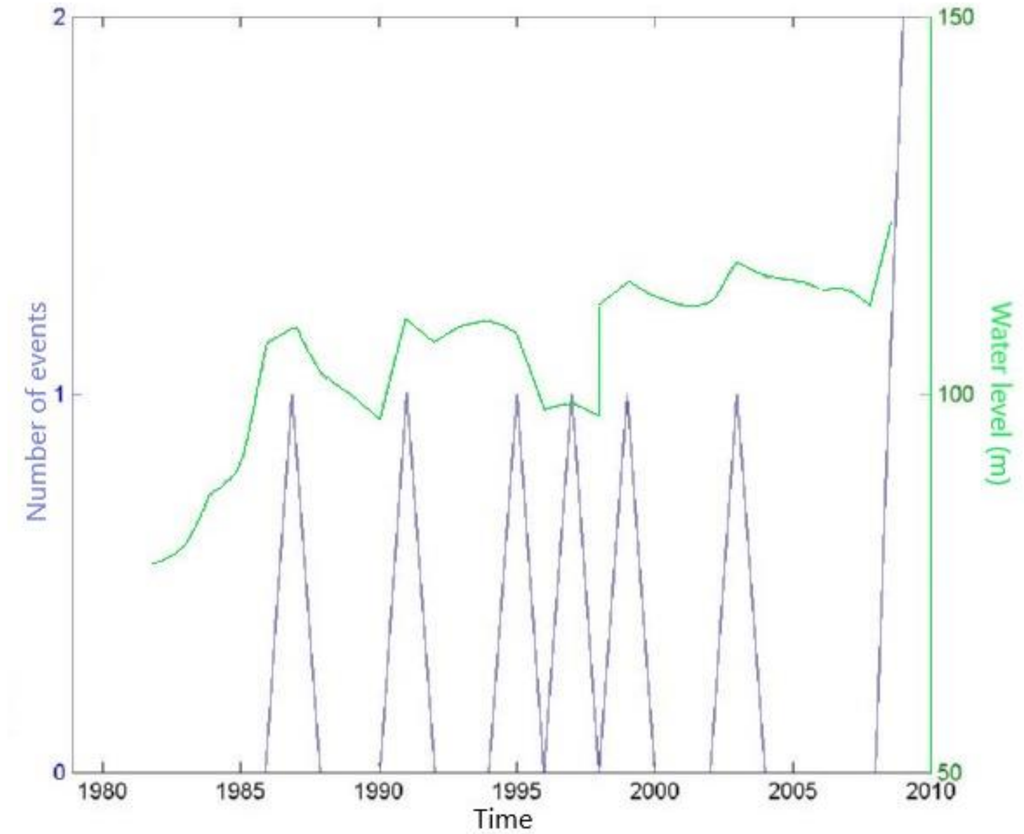


**Fig. 8.** Correlation between the number of events within a radius of 15 km around the dam and the variation in the water level of the dam as a function of time for the period (1982-2010)

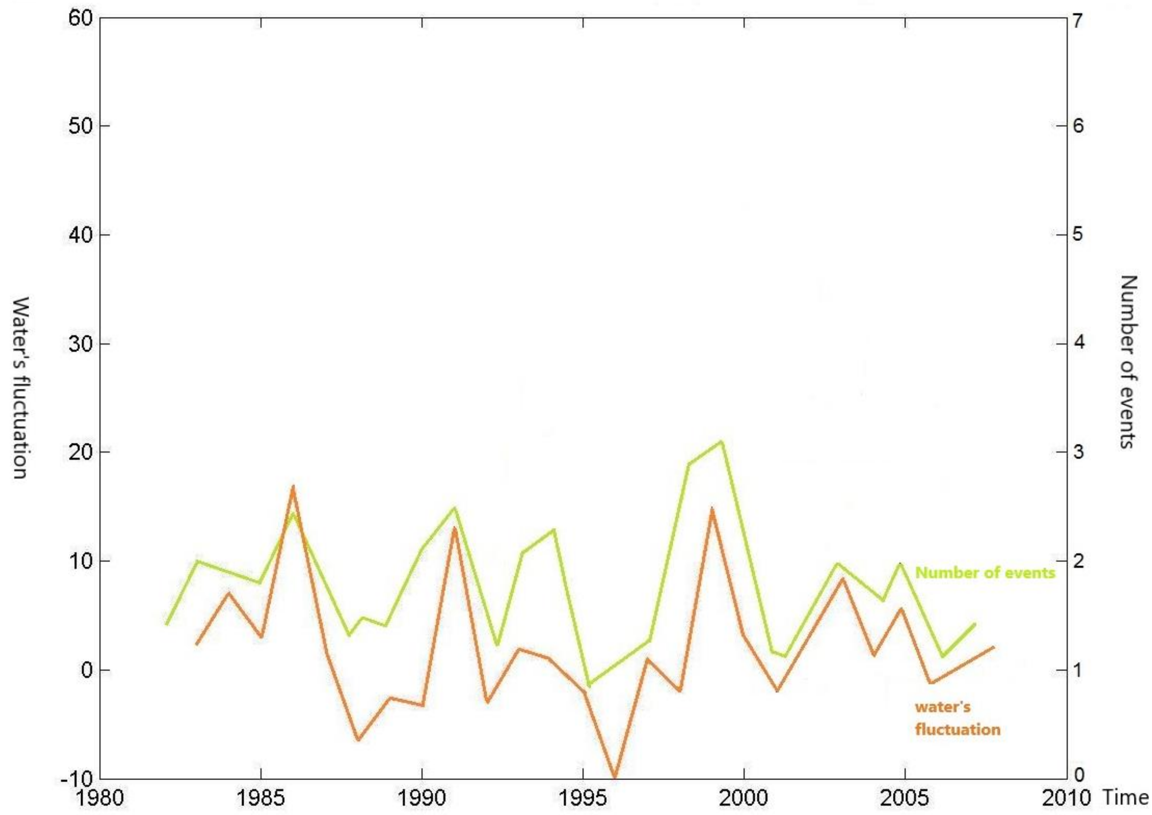


**Fig. 9.** Correlation between the water's fluctuation and the number of events 15 km around the dam for the period (1982-2010)

## 4. Conclusion

The seismicity at Sidi Salem reservoir appears to be an example of initial seismicity (Talwani 1997), the earthquake occurred in 1987 seems to be related to the first filling of the dam.

An increase of seismic activity around the lake has been noticed during the period from 1982 (date of the impoundment of the reservoir) until 2010. These seismic events occurred folowing the seasonal increasing of the dam water level which reached its maximum level many times.

The seismicity in the area has been monitored by seismic network operated by INM. Hence, the magnitude of all the recorded events is upper than 2 in the Richter scale. Unfortunately, despite of the importance of the reservoir, there is not seismic monitoring stations in the vicinity of the dam which allow us to determine seismic activity under 2 in magnitude and microseismic activities.

Therefore it should be noted that it is necessary to install "Accelerographs" in the center of the body of the dam and at different points of the lake. These devices are necessary to obtain quantitative data (Accelerate of the ground). This will allow us to follow the micro-seismic activity around the dam and thus the obtaining of numerous data which will allow us to make a more detailed analysis concerning the seismicity induced by the Sidi Salem dam and subsequently to make models (Catalli at al. 2016; Pavlou et al. 2016).

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