Egyptian Geophysical Society
EGS Journal, vol. 2, No. 1, 123-133 (2004)

CRUSTAL DEFORMATION MEASUREMENTS AND SEISMICITY OF THE MIDDLE PART OF THE NILE VALLEY IN EGYPT

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قياسات تشوهات القشرة الأرضية والنشاط الزلزالى فى الجزء الأوسط من وادى النيل فى مصر

الخلاصة: تتم مراقبة تشوهات القشرة الأرضية فى الجزء الأوسط من وادى النيل بنظام القياسات المتكررة بأجهزة GPS على الشبكة الجيوديسية المكونة من ثمانى نقاط والمثبتة فى المنطقة منذ عام ١٩٩٩م وتتميز هذه المنطقة بوقوع زلزال تاريخى قوى عام ١٧٧٨ م وعدد من الزلازل الحديثة أقل من ٥ درجات على مقياس ريختر. وقد تم عمل التحليل الميكانيكي لحركة الزلازل على الصدوع فى مراكز النشاط لزلزالى ١٤ ديسمبر ١٩٩٨ بقوة ٤,٨ ريختر و ٤ يونيه ٢٠٠٣ بقوة ٥ ريختر باستخدام إتجاه حركة الموجات الأولية، وتبين أن زلزال ديسمبر ١٩٩٨ حدث على صدع من النوع العادى وأن زلزال يونيه ٢٠٠٣ على صدع ذى حركة أفقية.

هذا وقد تم تحليل ثلاثة أرصاد جمعت بواسطة الـ GPS خلال الفترة من ٢٠٠٠ إلى ٢٠٠٣ وذلك لحساب اتجاهات الحركة ومعدلات الإجهاد وتبين نتائج التحليلات أن معدلات الحركة الأرضية تتراوح بين ١–٥ مم فى العام. كما تم حساب معدلات الإنفعال والقص الأساسية للقشرة الأرضية فى مواقع النقاط الجيوديسية بالمنطقة، ومن النتائج التى تم الحصول عليها أمكن تقسيم المنطقة إلى جزئين: جزء جنوبى يتميز بقيم تضاغط من الإنفعال الفراغى، والقص، وجزء شمالى ذو قيم شد من الإنفعال الفراغى والقص. وتجدر الإشارة إلى أن الجزء الشمالى حدثت به الزلازل المشار إليها سابقاً خلال فترات الرصد الجيوديسى، كما أمدتنا الدراسة بمعلومات مهمة عن تحركات القشرة الأرضية وعلاقتها بالنشاط الزلزالى والوضع التكتونى فى الجزء الأوسط من وادى النيل.

ABSTRACT: *Monitoring of the crustal deformation in the middle part of the Nile Valley in Egypt is being carryied out using a GPS network of 8 geodetic points. In this area, the 1778 strong historical earthquake and few recent events of magnitude (M <5) were located. The focal mechanism solution is made for the December 14, 1998 (M = 4.8) and June 4, 2003 (M = 5), which occurred in the study area using the direction of the first P-wave motion. The result indicates that the December 1998 event was a normal fault and the June 2003 event was a strike-slip fault.*

Three campaigns of GPS measurements during 2000-2003 were collected for this area and used to derive the velocity vectors and strain components. The horizontal velocity vector is estimated in the range of 1-5 mm/yr. The dilatational, maximum shear strains and the principal strain rates were also estimated. These analyses illustrate that the area can be separated into two zones, namely, the southern zone where the compression strains and high maximum shear strain rates are predominant, and while extension strain and low maximum shear strain rates prevail at the northern zone, where the recent earthquakes took place. This study provides valuable information about the present state of the crustal deformation and its relationship to seismicity and tectonics in the middle part of the Nile Valley.

INTRODUCTION:

The study area is located along the Nile Valley between latitudes (25^O 30^- and 27^O 30^- N) and longitudes (30^O 30^- and 33^O 30^- E). The major tectonic trends in this area are the NW-SE lineaments of which the Nile River has been performed. The lineaments are trending parallel and sub-parallel to the Red Sea. A plateau of the Eocene sediments occupies the area and is characterized by low relief topography with general inclination towards the west direction (Said, 1962). Elevation of the plateau ranges between 210 to 280 meters above the sea level and performs on its eastern side a sharp scarp facing the Nile Valley area. The Nile Valley lies along a seismo-active belt according to Gorshkov (1963). The presence of slipped masses and thick breccias at the foot slopes occurred by the trigger action of earthquakes. Similarly, the numerous reentrants along the cliffs that bound the Nile Valley in its middle course assuming the shape of rhomb (Nag Hammadi, Tall El-Amarna and Assuit) or sphere as (Tahta) explained its origin to wrench faulting (Said, 1981). Omara and El-Tahlawi (1972) recorded NW-SE, NE-SW and few N-S or E-W sedimentary dykes in the Eocene limestone plateau around Assiut. They suggested that the regional fracture pattern and these dykes represent filling of joints (tension gashes) structurally control these dykes in response to lateral movement along faults. Youssef et al. (1994) reported that, the NW-SE faults, affecting the Eocene rocks around Assiut, were developed by the post-Eocene movement. The study area has been focused by many workers (Bakheit, 1989: Youssef et al. 1994 and Attia,1995).

Recently, great efforts have been done to explore the Nile Valley and specially the middle part area for oil and gas, delineate the historical places such as temples, establish new industry, as well as big economic projects and construct new cities along the plateau surrounding the Nile Valley. Consequently, due to the importance of this area light should be thrown on the seismicity and its relationship to local tectonics, as well as on the crustal deformation in order to avoid the construction of big projects on the active dangerous portions in the concerned area.

2. Seismicity

Egypt is one of the historical countries. Thus, reports of the historical earthquakes were found in old documents and have produced an extended earthquake catalogue over the past 4800 years. The historical and recent earthquakes, which were located within the study area, are shown in Fig. (1). The June 1778 earthquake was felt over a wide area in the Nile Valley region and was followed by many aftershocks (Kebeasy, 1984). Kebeasy et al. (1987) related the damage at the Luxor and Karnak temples with the historical events. Another historical strong quake, caused damage in several localities along the Nile River, occurred in 27 BC (Fig.1). Such historical events are often poorly located. Therefore, the instrumentally recorded seismic activity of precisely location is often used to acquire the epicenters of the historical ones. Data of the National Seismic Network in Egypt indicate that the recent activity in the middle part of the Nile Valley is of magnitude less than 5, some of them took place in the epicentral area of the 1778 historical event. For magnitude > 4, there were three events occurred in that region (Fig. 1): The14 December 1998 earthquake (M = 4.8) is located at Latitude 26.63° N; Longitude 31.03° E and its maximum intensity is estimated MM 5 based on the Modified Mercali (MM) scale (Hassoup et al., 1999). The same epicentral location has been affected by another felt shock (M = 4.5) on 30 April 1999. The ground acceleration induced by the April 1999 event was observed in Assiut and Sohag Universities buildings using accelerographs of type (IDS- 3602A) (Hassoup et al, 2000). On June 4, 2003 another earthquake of (M = 5) took place with epicentral coordinates (Latitude 31.97° N, Longitude 27.08° E). This epicenter is also located with the epicentral area of the 1778 historical event.

2.1. The focal mechanism solutions

The focal mechanism solutions are obtained for the 14 December 1998 and 4 June 2003 earthquakes on the basis of the seismogram records of the National Seismic Network. The other events recorded from the study area are of smaller magnitude and have been detected by little number of stations. The P- and S-phases on the seismograms studied here are impulsive providing an accuracy of 0.02 and 0.1 s for measuring the P- and S-arrival times, respectively. Using the PINV software developed by Suetsugu (1995), data of the first P-wave motion are plotted on a lower hemisphere, where orthogonal planes were added by hand-fit “mouse of the PC” to separate these data into quadrants of compression and dilatation. Takeoff angles were calculated using the local velocity model along the Nile Valley area in Egypt as determined by Marzouk (1988). The focal mechanism solutions of the 14 December 1998 and 3 June 2003 earthquakes are shown in Fig. (2). The first is normal fault trending nearly in the northwest-southeast direction. The tensile stress axis (T axis) trends in the east-west direction. The second solution shows nearly north-south strike slip event with T axis trending in the east-west direction. The focal mechanism solution parameters of these two earthquakes are listed in Table (1). This first nodal plane is a favorite fault plane based on the local geological structures.

3. GPS measurements in the middle part of the Nile Valley

Monitoring of the crustal strain perturbations in space and time is an important key to understand the physical process in crust as well as to forecast the crustal activity. Dense GPS measurements with long time span are an ideal tool to realize this. The program for monitoring crustal deformation was early initiated in Egypt in 1983. The terrestrial geodetic techniques were applied in the local geodetic networks, which were established around the active faults in the northern part of Aswan Lake (Abdel-Monem 1991 and 1997; Mahmoud 1988; Sakr 1998; Sakr et al., 2002; Tealeb 1990 and 1996; Vyskočil 1991; Vyskočil et al., 1991 a&b; Vyskočil and Tealeb 1995). The GPS technique has recently been employed for measuring local and regional geodetic networks in Egypt since 1997. The regional geodetic networks are distributed in Aswan, the Greater Cairo, Gulf of Suez-Sinai Peninsula and middle part of the Nile Valley regions (Abdel-Monem et al., 1999; Mahmoud 2001 and Sakr et al., 2002).

The GPS network in the middle part of Nile Valley consists of 8 sites, which were established in 1999 to cover three provinces in Egypt (e.g., Assiut, Sohag and Qena) (Fig. 3). Three GPS stations were established in Assiut at Wadi El-Assuity and along the Assuit- Kharga road. Other three GPS stations were located in Sohag at Geheina, East Sohag and west of Berba village. The remained two stations were established in Qena along the Qena-Safaga and Qena-Qift highways. All sites are situated on hard bedrock. The Nile River runs in the middle of this network. The initial geodetic measurements were performed in April 2000 and were repeated in Septmber 2001 and January 2003 using GPS receiver’s type Trimble 4000SSI. The sampling interval and elevation were fixed throughout the survey at 30 sec and 15^o, respectively. The GPS observations were carried out during a three-day campaign (seven to nine-hour-session per day).

Table 1: Parameters of the focal mechanism solutions

Date	Plane 1			Plane 2			P-axis		T-axis	
	Strike	Dip	Rake	Strike	Dip	Rake	Plunge	Az.	Plunge	Az.
14/12/1998	294	41	-81	102	50	-98	83	322	4	198
04/06/2003	203	75	-178	112	88	-15	12	66	9	158

3.1. Data analysis

Adjustment and baseline analyses were performed using Geomatic and Gpsurvey 2.3 software packages and deformation programs. The IGS precise ephemeris was applied in the calculation of the baselines. This is briefly the processing of data adjustment in order to determine the deformation parameters. The displacement vectors at each GPS station were determined under an assumption that free network approach and all the stations in the network are minimized. Horizontal components at each station were computed from the difference of adjusted coordinates of the stations from one epoch to another and from the last epoch to the first epoch. The displacement vectors for each epoch of observations were calculated from the coordinate changes. Considering the confidence limit, most of these displacement vectors can be mainly attributed to the movement within the study area in those epochs of measurements. The strain tensor parameters: dilatations, maximum shear strains and principal axes of strain were calculated. The horizontal components of the velocity vectors with 95% confidence error ellipses are shown in Fig. (4). The error ellipses mean here the standard error in all direction around the observed site. The horizontal components of the velocity vectors can be further used to estimate the strain and stress field in the area.

For demonstrating the horizontal displacement field in grid, the area is divided into blocks based on magnitude and direction of the movements. It is seen in Fig. (5) that magnitudes of the movements are distributed inhomogeneously over the area. There are large movements trending to the west in the southern part. In contrast, the movements are relatively of small magnitude in the northern and eastern parts. Moreover, there is a rotation with the movement anti-clockwise and clockwise in the northwest and northeast of the area, respectively (Fig. 5). This study demonstrates also the horizontal displacement vectors, but their rates are very small. In addition, the dilatational and maximum shear strains are estimated within the observation period (Figs. 6 and 7). These figures suggest that the area can be separated into two zones, the southern part where the compression strain is predominant and the northern part of an extension strain prevails. Areal compressional and extensional strains are about -0.11 and +0.03 ppm/yr, respectively (Fig.6). The maximum shear strain is also calculated and its rate is about 0.01 ~ 0.14 ppm/yr (Figs.7). It increases towards the south direction and decreases towards the north direction with high and low values of maximum shear strains located in the southern and northern zones, respectively.

Distribution of the principal axes of the strains (Fig. 8) shows a contraction trending nearly in the east west and northeast-southwest directions in the southwestern part. The extension is predominant in the eastern part with nearly east-west and northwest-southeast directions. The network was firstly divided into nine triangles and secondly is considered as two blocks of which a homogeneous plane strain was assumed. In the first configuration the station displacement and strain parameters (principal strain rates, maximum shear strain rates and dilatation) are determined as shown in Table (2). In the second configuration these parameters are calculated, as well as the velocity of rigid block and its rotation as listed in Table (3). The calculated parameters are the maximum principal strain rate (ε_1), minimum principal strain rate (ε_2), direction of the maximum principal strain rate (α), annual rate of maximum shear strain (γ_{max}) and dilatation (Δ). However, the strain analysis is calculated for the period from April 2000 to September 2001, September 2001 to January 2003 and from April 2000 to January 2003. This study demonstrates the period from April 2000 to January 2003 as the longest time span of our measurements.

4. Results and Discussion

Egypt occupies the northeastern corner of the African plate, which moves in the northward with rate about 10 mm/yr and colliding the Eurasian plate (Park, 1988). The differential motion between Africa and Arabia is dominated by left lateral motion along the Dead Sea transform fault with rate nearly 10-15 mm/yr (McClusky et al., 2000). Said (1990) classified the area of Egypt into four structural units the Arabo-Nubian block, stable shelf, unstable shelf and the Gulf of Suez graben. The middle part of the Nile Valley lies in the stable shelf, which is characterized by continental and marine deposits with the Nubian sedimentary cover of different natures.

Egypt is not a major seismic zone, but earthquakes represent a significant hazard. The seismic activity is concentrated at the northern part of the Red Sea- Gulf of Suez- Gulf of Aqaba zone. Intermediate earthquakes occurred also in the northeast of Egypt, southwest Cairo and Aswan regions, as well as in the southwest part at the boarder between Egypt and Libya.

Table 2:The displacement and strain parameters of the observation period from April 2000 to January 2003.

Triangle No.		Stations displacement				Principal strain rate and std. dev. (σ)		
		dn	σ	de	σ			
1	1	1.55	1.55	-19.35	3.3	ε 1	0.9418E-07	0.2588E-07
						ε 2	0.2045E-07	0.2538E-07
	2	-7.4	1.55	-39.95	7.4	α	-66.7011	0.1408E+02
	6	-4.4	2.3	14.55	3.3	Δ	0.1146E-06	0.3625E-07
						γ_{max}	0.7373E-07	0.3625E-07
2	1	1.55	1.55	-19.35	3.3	ε 1	0.5362E-08	0.2385E-07
						ε 2	-0.2138E-07	0.2793E-07
	2	-7.4	1.55	-39.95	7.4	α	39.0194	0.3934E+02
	8	14.1	3.3	-17.05	2.3	Δ	-0.1602E-07	0.3673E-07
						γ_{max}	0.2675E-07	0.3673E-07
3	1	1.55	1.55	-19.35	3.3	ε 1	0.4361E-07	0.1149E-07
						ε 2	-0.6187E-07	0.1838E-07
	6	-4.4	2.3	14.55	3.3	α	14.1260	0.5888E+01
	7	20.5	1.2	-10.65	3.25	Δ	-0.1826E-07	0.2168E-07
						γ_{max}	0.1055E-06	0.2168E-07
4	1	1.55	1.55	-19.35	3.3	ε 1	-0.2078E-07	0.1046E-07
						ε 2	-0.6750E-07	0.2252E-07
	7	20.5	1.2	-10.65	3.25	α	40.2153	0.1523E+02
	8	14.1	3.3	-17.05	2.3	Δ	-0.8829E-07	0.2483E-07
						γ_{max}	0.4672E-07	0.2483E-07
5	2	-7.4	1.55	-39.95	7.4	ε 1	0.7521E-09	0.5719E-07
						ε 2	-0.3092E-06	0.2265E-07
	3	-0.5	2.0	9.6	2.4	α	10.1369	0.5685E+01
	5	-17.6	2.5	31.45	3.35	Δ	-0.3085E-06	0.6151E-07
						γ_{max}	0.3100E-06	0.6151E-07
6	2	-7.4	1.55	-39.95	7.4	ε 1	0.8688E-07	0.1264E-07
						ε 2	-0.5375E-08	0.3619E-07
	3	-0.5	2.0	9.6	2.4	α	96.2616	0.1190E+02
	6	-4.4	2.3	14.55	3.3	Δ	0.8151E-07	0.3833E-07
						γ_{max}	0.9226E-07	0.3833E-07
7	3	-0.5	2.0	9.6	2.4	ε 1	0.1406E-06	0.4034E-07
						ε 2	-0.1093E-07	0.2960E-07
	5	-17.6	2.5	31.45	3.35	α	119.6800	0.9460E+01
	6	-4.4	2.3	14.55	3.3	Δ	0.1297E-06	0.5003E-07
						γ_{max}	0.1515E-06	0.5003E-07
8	4	-7.45	2.5	28.9	3.35	ε 1	-0.3251E-09	0.7538E-08
						ε 2	-0.2860E-07	0.4173E-07
	5	-17.6	2.5	31.45	3.35	α	-66.8540	0.4296E-+02
	6	-4.4	2.3	14.55	3.3	Δ	-0.2893E-07	0.4240E-07
						γ_{max}	0.2828E-07	0.4240E-07
9	4	-7.45	2.5	28.9	3.35	ε 1	0.1609E-07	0.1872E-08
						ε 2	-0.7286E-07	0.9641E-08
	6	-4.4	2.3	14.55	3.3	A	-54.2218	0.3163E+01
	7	20.5	1.2	-10.65	3.25	Δ	-0.5676E-07	0.9821E-08
						γ_{max}	0.8895E-07	0.9821E-08

Table 3: Annual rate of block velocity, rotation and strain parameters of the observation period from April 2000 to January 2003.

Block		Translation and std. dev. (σ) in mm			Rotation and std. dev. (σ) in degree		Principal strain rate and std. dev.(σ)		
I	St.	Tx	3.1	1.8	Rotate	σ	ε 1	0.1025E-08	0.2175E-08
	4				-0.059	0.01	ε 2	0.8045E-08	0.551E-08
	5						A	37.5209	0.7784E+03
	6	Ty	11.5	1.8			Δ	0.18265E-07	0.5925E-08
	7						γ_{max}	0.2180E-08	0.5925E-08
II	1	Tx	-3.1	4.0	0.023	0.01	ε 1	0.23835E-07	0.2567E-07
	2						ε 2	0.12965E-07	0.1628E-07
	3	Ty	-11.5	4.0			A	26.5240	0.8013E+02
	8						Δ	0.36795E-07	0.3041E-07
							γ_{max}	0.1087E-07	0.3041E-07

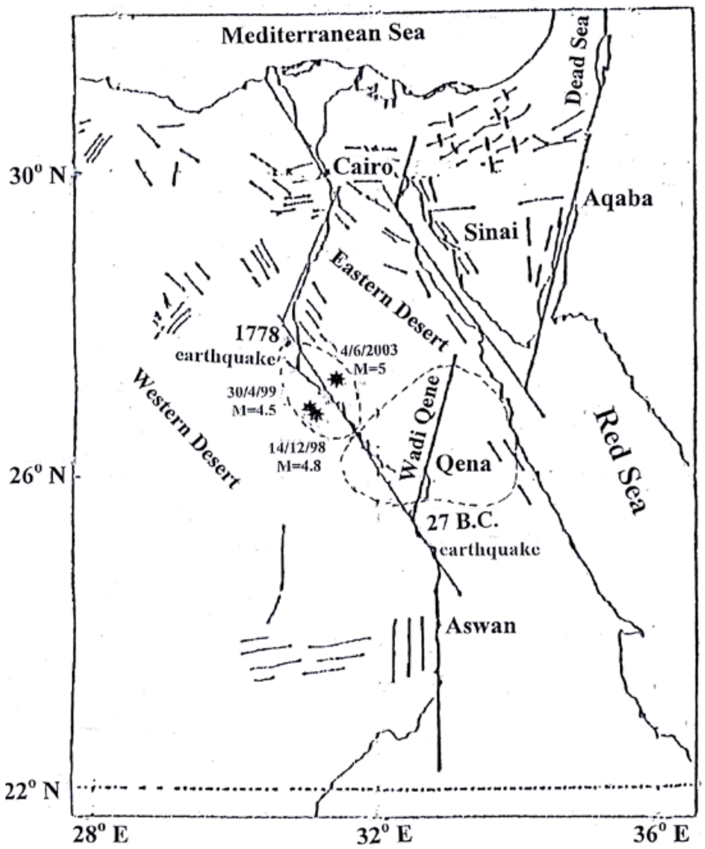
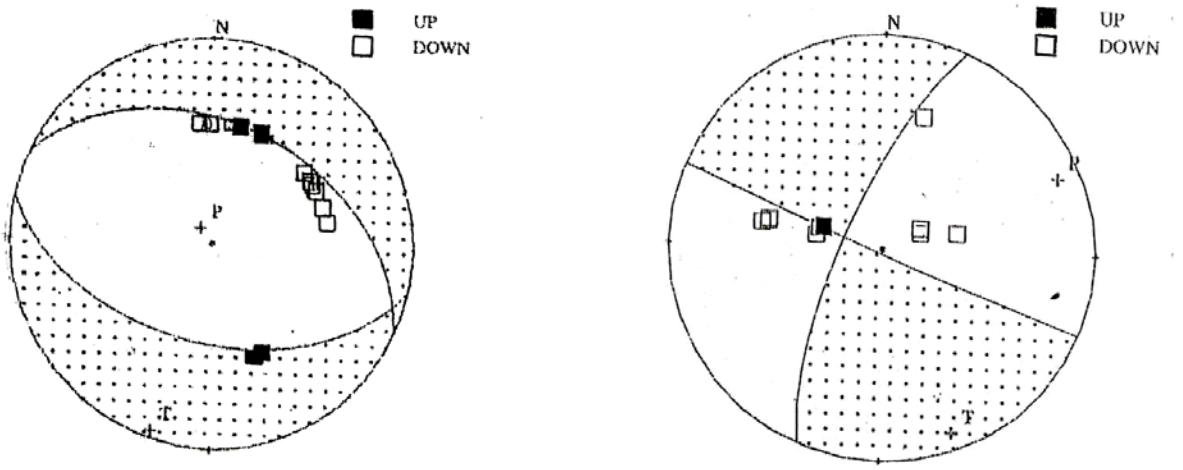


Fig. 1: Regional structural map of Egypt and seismicity within the study area. (Dashed lines are historical earthquakes and stars are recent earthquakes)



14/12/1998 earthquake

4/06/2003 earthquake

Fig. 2: The focal mechanism solutions of the 14 of December 1998 and 4 of June 2003 earthquakes.

The December 14, 1998 earthquake is significant as it is located in the epicentral area of the 1778 historical event, which was discussed by Kebeasy (1984). The focal mechanism solution of the December 1998 event indicating a normal fault striking in the northwest-southeast trend (Fig. 2). Its epicentral area is occupied by the northwest southeast lineaments as major structures (Youssef et al., 1994). This indicates that there is a good correlation between our result from the focal mechanism solution and tectonic setting of the area. Unfortunately, the subsurface structure is poorly investigated in the study area. Moreover, there was a lack in the aftershock activity associating to the December 1998 earthquake (Hassoup et al., 1999). Such data are important to support the present correlation between the focal mechanism solution and tectonic setting. The absence of aftershock sequence occurred also with the June 4, 2003 earthquake that its focal mechanism solution shows a north-south strike slip event (Fig. 2). This trend is also consistent with the tectonic setting inferred from geological investigations (Said, 1990) (Fig. 1). Results of the focal mechanism solutions of these two events are well correlated with the results of the crusal deformation as will be discussed later.

Youssef et al., (1977) and Youssef et al., (1994) studied the area around Assiut and reported that, this area is affected by two main fault sets. The NW-SE faults are dissecting the area into sequence of graben and horst structures and the N 75° E set of shear, which was developed by the youngest tectonism (i.e., opening the Red Sea).

Lanteaume et al., (1986) studied the structural synthesis of the area between Sohag and Assiut in both the Eastern and Western Desert and concluded that the domain of the middle part of Egypt underwent two phases of deformation after the Eocene regression. The first phase was of north 50°-60° tension affecting the previously structural basement overlain by a sedimentary assemblage. The second phase was north 20° compression, expressed by potential dextral north 140° strike-slip movement and by sinstral north 70° strike-slip faults. El-Hakim, (1978) studied the region around Qena and found that, many tectonic features as faults and folds characterize the region. These structures are controlling the Nile bend near Qena.

The crustal deformation processes could occur during the accumulation of the energy within the earth’s crust as well as its release produce earthquakes of certain magnitude. Figs. (6 and 7) show that the earthquakes are located in the area of low magnitude surface crustal deformation. This suggests that the accumulated strain in that area had been totally released by the recent earthquake activity (e.g., co-and post-seismic deformation). The values of dilatational and maximum shear strains, which are here estimated (Figs. 6 and 7), are too small and may be correlated with the assumption of the stable shelf introduced by Said (1990). This correlation faces difficulty as the observation period is relatively short (only 3-year duration). Thus, employing a program for continuous observation by the GPS in that area is very important to discuss not only this correlation but also the inhomogeneous distribution of the horizontal displacement vectors over the study area (Fig. 5). The movement delineated by these vectors is rotated with variable magnitudes anti-clockwise and clockwise in the northwest and northeast of the area, respectively. It suggests also the classification of the area into two zones:

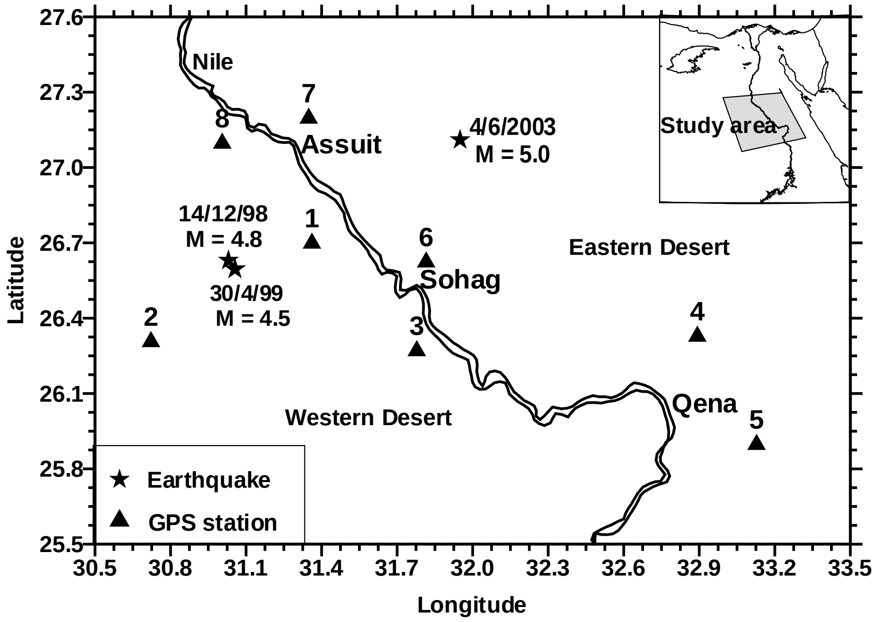


Fig. 3: GPS geodetic network and location of recent earthquakes in the middle part of the Nile Valley.

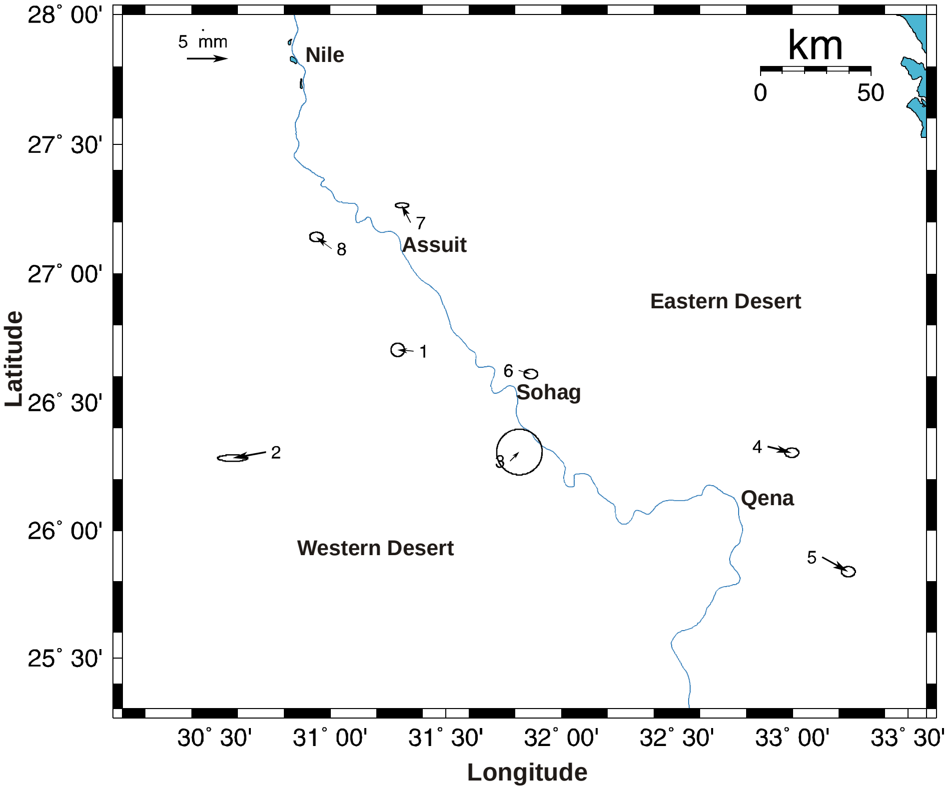


Fig. 4: The displacement vectors for the period

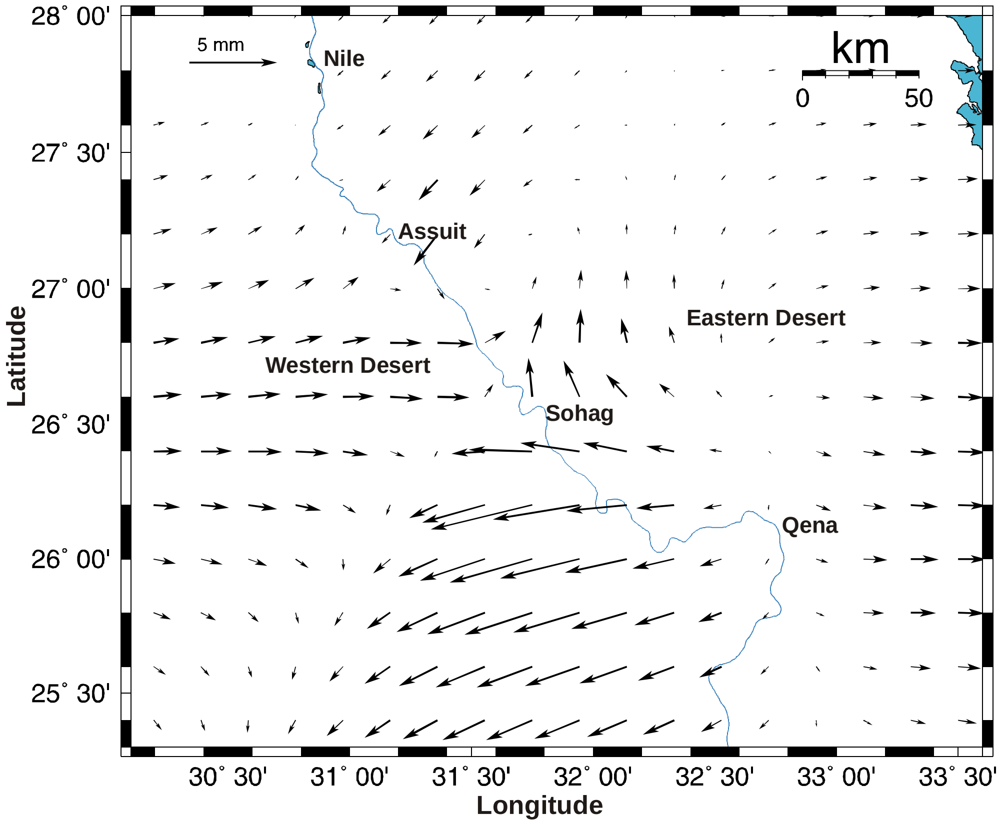


Fig. 5: The horizontal displacement vectors in grid points for the period from April 2000 to January 2003.

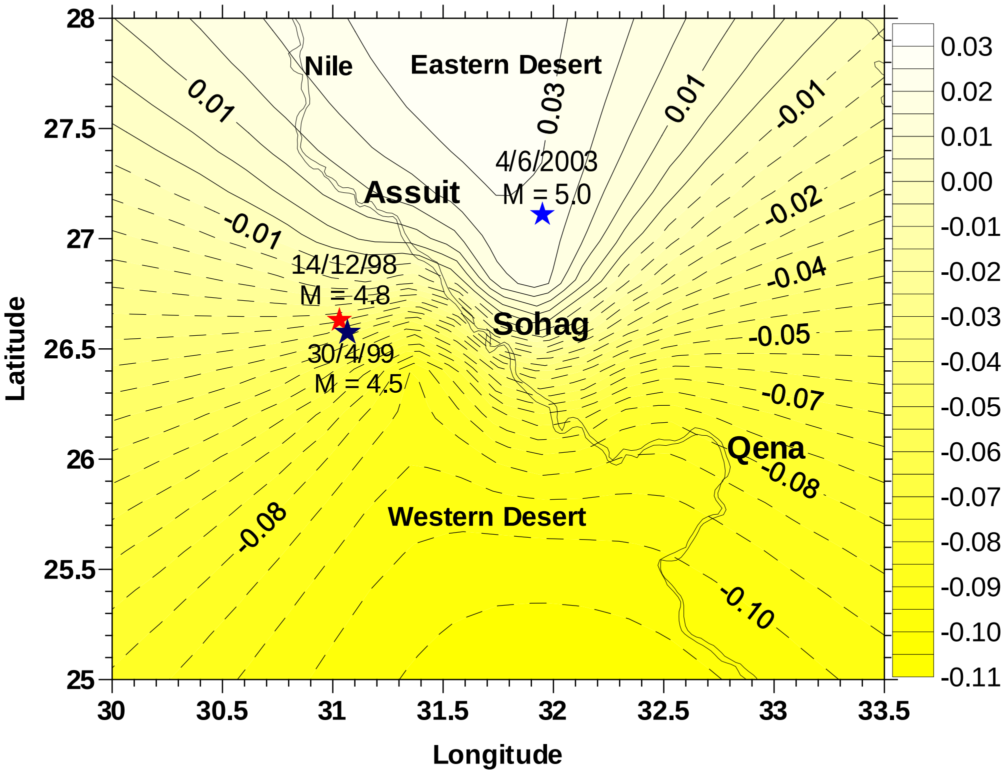


Fig. 6: Distribution of the dilatation strain for the period from April 2000 to January 2003. (Star is earthquake epicenter).

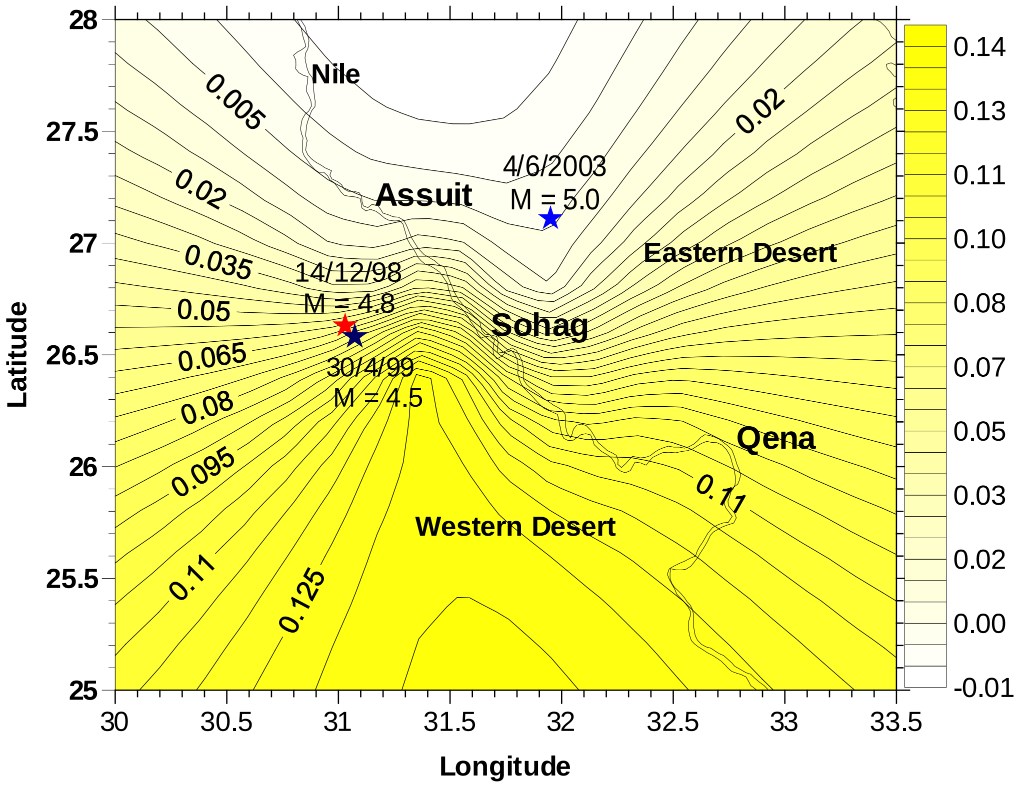


Fig. 7: Distribution of the maximum shear strain rates for the period from April 2000 to January 2003. (Star is earthquake epicenter).

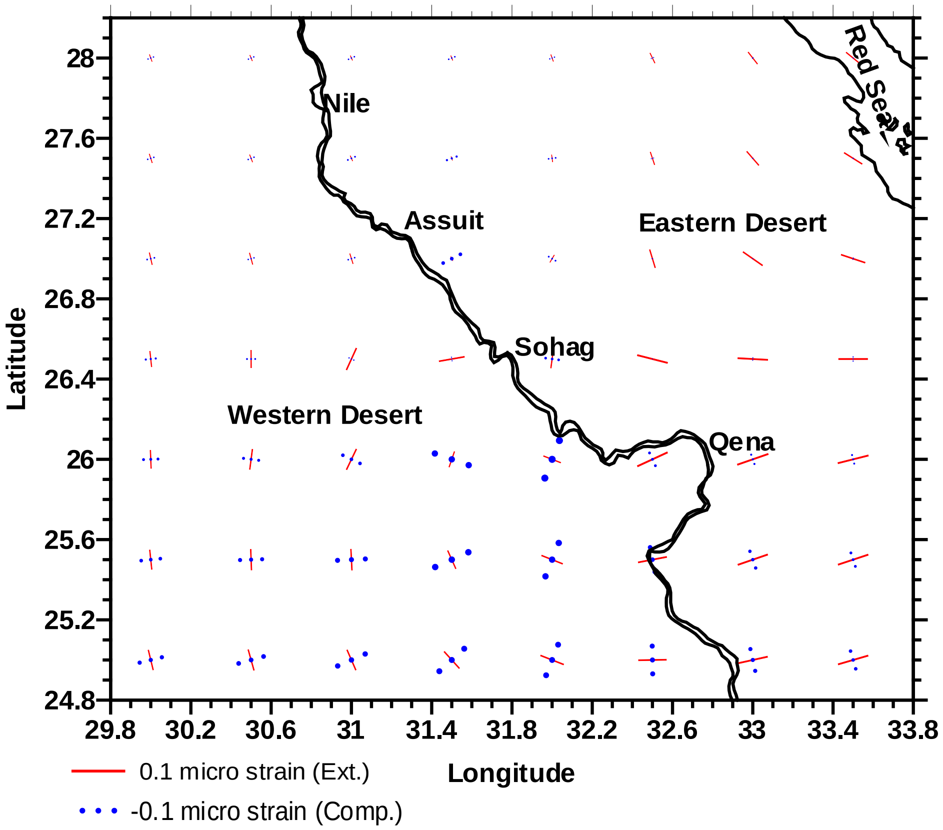


Fig. 8: Magnitude and orientation of principal axes of the strain rates for the period fromApril 2000 to January 2003.

a- the zone of compression strain (southern part).

b- the zone of extension strain (northern part).

There is a variation in the geophysical observation characteristics of these two zones, which can be summarized as follows:

1- The seismicity is only observed in the northern zone.
2- Different strains characterize these zones; areal compressional and extensional strains in the southern and northern zones, respectively.
3- There is a difference in magnitude of the maximum shear strain characterizing these zones. Rates of the horizontal displacements and strain values at the southern part (Qena area) are about 5 mm and more than 0.1 ppm/yr respectively.
4- In contrast, they are less than 2 mm and 0.01 ppm/yr, respectively in the northern part (Assuit and Sohag areas).

The higher rates of the horizontal displacements and strains values are usually related to the presence of the tectonic features such as faults and folds, which were located by many geologists (El-Hakim, 1978) at the Nile bend near Qena. The lower values of the displacements and strains rates (Figs 5, 6 and 7) may be interpreted as a result of discharge of energy release after the occurrence of the earthquakes at that area. These variations, as well as the contrast between the principal axes of strains between eastern and western banks of River Nile may be related to running the River Nile as a major structure (Fig. 1). Generally, the middle part of Nile Valley is affected on a regional scale by the ENE-WSW extension contemporaneous with N 20° W-S 20° E compressive stress from mid Tertiary to the present time (Youssef et al., 1994). Distribution of the principal axes of the strain shows a contraction trending nearly in the eastwest and northeast-southwest directions in the southwestern part of the area (Fig. 8). The extension is dominated in the eastern part with nearly east-west and northwest-southeast directions.

On the other hand, the compressional strain rate is high in the southern part of the studied area. This part is aseismic at the present time. It may generate earthquakes in future and the present observation of higher strain field may be corresponding to the pre-seismic stage of the earthquake cycle (strain accumulation). According to the fact that, the crustal deformation processes could occur during the accumulation of the energy within the earth’s crust as well as its release produce earthquakes of certain magnitude, the monitoring of crustal deformations are considered as valuable information about the seismic activity. This information could benefit for the seismic hazard assessment and minimizing the losses due to earthquake damage. The present study is the first work demonstrating crustal deformation monitoring in the middle part of Nile Valley. The time interval from the first campaign to the third is relatively short (three years). So, the continuous of GPS measurements are needed for providing more information about the recent crustal movement in that area.

5. Conclusion

This study is an attempt to delineate the crustal stress and strain field using the GPS measurements, as well as the focal mechanism of recent earthquake activity in the middle part of the Nile Valley. Based on the earthquake data from the National Research Institute of Astronomy and Geophysics, the focal mechanism solutions are carried out for two larger earthquakes occurred recently in the area. Several parameters of the crustal deformation measurements are determined by analyzing the GPS network data. These parameters are discussed in light of the focal mechanism analyses, geological data and tectonic setting.

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