SEISMICITY OF THE SINAI SUB-PLATE

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A B S T R A C T

We have compiled a list of earthquakes, that have occurred since the turn of the century with magnitude M>4 in the Levant. The list is complete for magnitudes M>5. For the whole Sinai subplate, Dead Sea transform and Cyprean arc we obtain b-values 1.02, 1.0 and 1.07, respectively. The major and moderate events, are distributed in a belt like shape surrounding the Sinai subplate, and are in accordance with the geological borders, with less clear definition on the western side. The dispersion of the moderate events emphasizes the complexity of the processes accompanying the relative plate motions in the region.

ΣΕΙΣΜΙΚΟΤΗΤΑ ΣΤΗΝ ΥΠΟΠΛΑΚΑ ΣΙΝΑ.

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Π Ε Ρ Ι Λ Η Ψ Η

Εχουμε συντάξει κατάλογο σεισμών, που έχουν γίνει από τις αρχές του αιώνα με μέγεθος M>4 στη θάλασσα του Λεβαντίνου. Ο κατάλογος είναι πλήρης για μεγέθη M>5. Για όλη την υποπλάκα Sinai, για τη Νεκρά Θάλασσα και το Κυπριακό Τόξο υπολογίσαμε τιμές της παραμέτρου b ίσες με 1.02 , 1.0 και 1.07, αντίστοιχα. Οι ισχυρότεροι και ενδιαμέσου μεγέθους σεισμοί, είναι κατανεμημένοι σε μία ζώνη γύρω από την υποπλάκα Sinai, και είναι σε συμφωνία με τα γεωλογικά όρια, με λιγότερο σαφή προσδιορισμό στην δυτική πλευρά. Η διασπορά των ενδιαμέσου μεγέθους σεισμών επιβεβαιώνει την πολυπλοκότητα των διαδικασιών που συνοδεύουν τη σχετική κίνηση των πλακών στην περιοχή.

INTRODUCTION

The recognition of seismic activity in the Levant has been wellknown since ancient times (Willis, 1928; Sieberg, 1932; Amiran, 1951; Shalem, 1952). The first researchers faced the difficulty of gathering information from ambiguous historical records. As was previously suggested by Montessus de Ballore (1906), the Levant Fracture Zone was identified as the major seismogenic element in the area (Lartet, 1869; Dubertret, 1932;

Quennell, 1959), and later confirmed by the establishment of the plate tectonic theory as a sinistral transform between the Arabian and the African plates (Wilson, 1965; Freund, 1965; Freund et al., 1970; Ben-Menahem et al., 1976; Garfunkel, 1981). Several studies related the activity to several main faults, but their interpretation did not refer to global plate tectonics (Arieh, 1967; Wu et al., 1973; Arieh and Rotstein, 1985; Jackson and McKenzie, 1988; Van Eck and Hofstetter, 1990). Ben-Menahem et al., (1976) considered the Sinai subplate as a splinter of Africa. Their study, which defined seismically the geologically accepted borders of the Sinai splinter, has been the only research which regards the entire Sinai subplate.

The tectonic setting of the E. Mediterranean was the subject of many studies (McKenzie, 1970, 1972; Ben Menahem et al., 1976; Joffe and Garfunkel, 1987). The Sinai subplate is delimited in the south by the divergent Suez rift, with an unclear extension towards the Mediterranean (Garfunkel and Bartov, 1977), and by the Dead Sea transform, thus bi-forking the northern continuation of the Red Sea (Fig. 1). The Cyprean arc convergent zone separates the Sinai subplate from the Anatolian plate (McKenzie, 1970, 1972; Woodside, 1977; Rotstein and Kafka, 1982; Kempler and Garfunkel, 1991).

Table 1. Catalog of earthquakes in the East Mediterranean region, occurred in the present century, with magnitude greater than 5.5 (after Arieh et al., 1985). Zone: Cyp - Cyprus; DST - Dead Sea Transform; Med - E. Mediterranean; Suz - Gulf of Suez.

DATE	TIME	MAGNIT.		GEO.COORD		ZONE
yearmody	hrmn sec	M_L	m_b	Lat	Long.	
19030329	2230 0.0	5.5	5.6	32.1	35.5	DST
19030719	1807 54.0	5.7		34.2	29.0	Med
19180929	1207 5.0	6.2	6.4	35.2	36.1	DST
19211005	1909 45.0	5.5	5.5	36.4	35.2	Cyp
19220402	047 0.0	5.5	5.0	34.7	34.8	Cyp
19240218	1703 56.0	6.0	5.9	34.5	34.0	Cyp
19240227	2004 20.0	5.7	5.0	32.7	36.2	DST
19270711	1304 7.0	6.2	6.1	31.8	35.5	DST
19280222	1750 55.0	5.5	5.0	32.0	35.5	DST
19400724	2215 27.0	5.7	5.0	34.6	34.1	Cyp
19410120	337 7.0	6.0	5.9	35.2	33.6	Cyp
19450921	154 5.0	6.4		34.4	28.9	Med
19490617	420 56.0	5.5		34.4	28.5	Med
19510130	2307 23.0	5.7	5.7	32.3	33.4	Med
19510408	2138 08.0	5.7		36.5	35.7	DST
19521015	1750 44.0	5.6	5.5	34.8	32.8	Cyp
19530910	406 0.0	6.2	6.1	34.7	32.3	Cyp
19540913	2146 32.0	5.5	5.4	31.0	35.4	DST
19550912	609 22.0	6.1	6.0	32.2	29.5	Med
19560316	1943 28.0	5.5	5.5	33.3	35.3	DST
19561218	1753 3.0	5.2	5.5	31.5	35.5	DST
19590613	1201 50.0	5.5	5.4	34.8	32.9	Cyp
19610915	146 10.0	6.0	5.9	35.0	33.9	Cyp
19690331	716 0.0	6.6	7.0	27.7	34.0	Suz

Some of the strong events were investigated, such are the Jericho earthquake on 11/7/1927, M=6.25 (Ben-Menahem et al., 1976; Vered and Striem, 1977); the Dead Sea earthquake on 23/4/1979, M=5.3 (Arieh et al., 1982); or the Shadwan shocks of March, 1969, M=6.7 (Ben-Menahem and Aboodi, 1981; Jackson and McKenzie, 1988). However, these works do not provide a systematic tectonic overview of the seismicity of the Sinai subplate from the plate tectonics prospective. The lack of a complete catalog has, until now, prevented a comprehensive study of the region. In recent years new detailed catalogs have been published (Ben-Menahem, 1979; Arieh et al., 1985; Riad and Meyers, 1985; Turcotte and Arieh, 1986). Furthermore, the recently installed Israeli Seismic Network (IPRG Bulletins 1981-1991) and those in Jordan (JSO 1983-1991) systematically recording the events in the Sinai subplate since 1981 and 1983, respectively, thus contributing to a more complete and accurate documentation of the local activity.

In this study we take advantage of the improved database to achieve a more systematic and homogeneous coverage of the seismicity in time and space, and discuss the completeness aspect. This approach is necessary for a more reliable tectonic interpretation. Finally, in light of the new catalog, the characteristic seismicity of the Sinai subplate is discussed.

SEISMIC ACTIVITY AND COMPLETENESS OF THE CATALOG

The Sinai subplate is the main tectonic element concerned in this study and, therefore, is the region from which the earthquakes are selected (Fig. 1). Our earthquake list includes about 360 events dating from the beginning of the century until 1991, with magnitude range of 4.0 to 6.6 (Table 1; Fig. 2). The recognition of a catalog completeness is of great importance in any seismicity study and essential for deriving tectonic conclusions. In the present case a special problem arises because we include events dated from the turn of the century, when several seismic stations functioned, until present when the region is well covered. Figure 3 illustrates the degree of completeness by presenting the time occurrence of events in the Dead Sea transform versus their local magnitude. In general, fewer lower magnitude events were recorded at the beginning of the century than during later periods of comparable length. Later, their number gradually increased, although from time to time there was an apparent increase or decrease in the rate of seismicity, due to the installation of new seismographs. Lack of recordings is evident also in remote and unpopulated regions, such as Gulf of Suez, Gulf of Eilat and east Mediterranean, while the seismicity of inhabited regions is better documented (Fig. 2). At this level, it is unclear whether it is an artifact of the catalog's incompleteness or due to inactive areas.

The other aspect of completeness is the frequency-magnitude relations (Table 1; Fig. 4). The deviation from linearity are below magnitude 5, signifying that our catalog is complete for M>5 events. During the last decade the detectability increased, and therefore the completeness is below M=4 events.

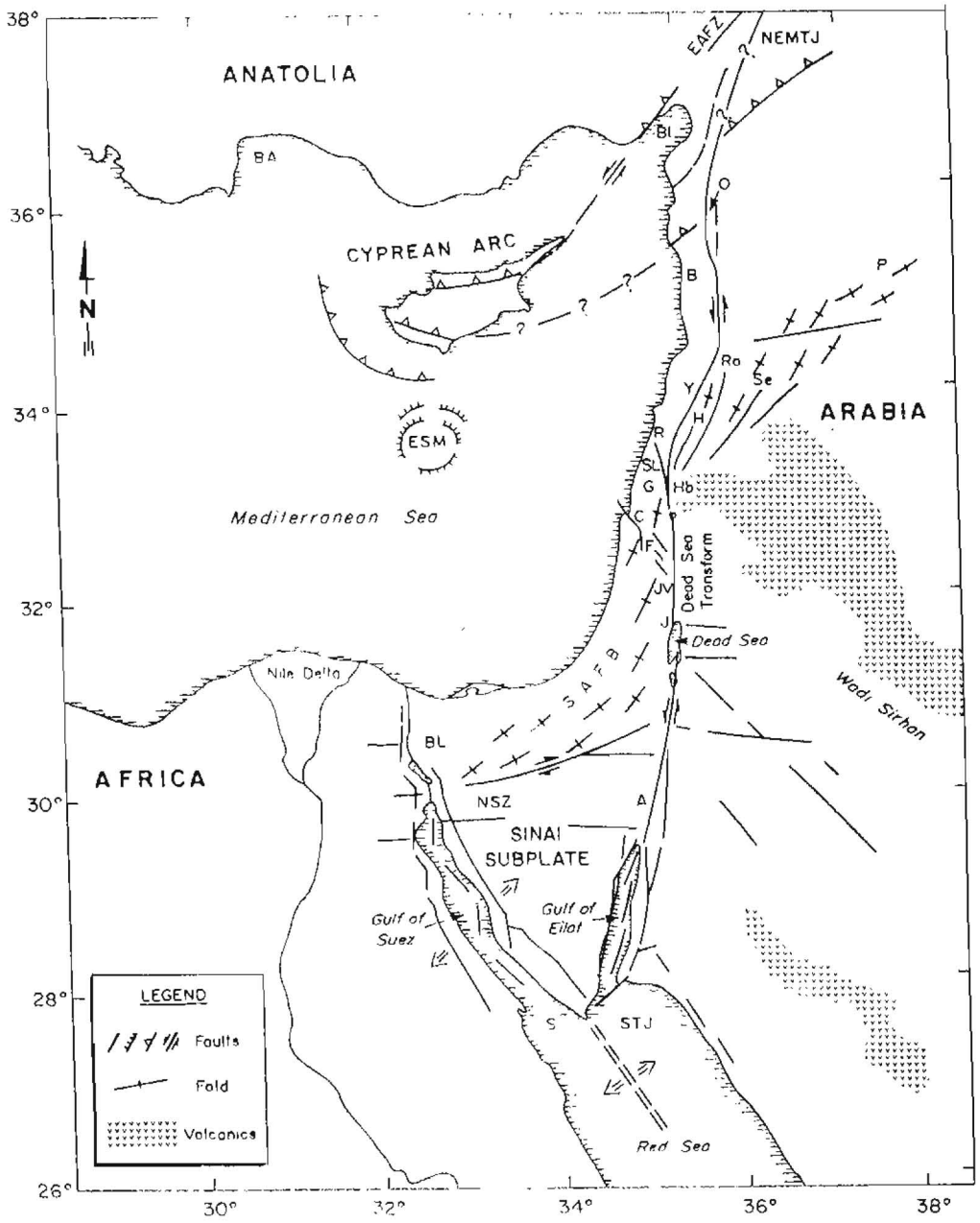

Fig.1. Map of the studied area (modified after Garfunkel (1981) and Kempler & Garfunkel (1991)). Element or locality acronym: A-Arava valley; B-Banias; BA-Bay of Antalya; BI-Bay of Iskenderun; BL-Bitter Lakes; C-Carmel fault; EAFZ - East Anatolian fracture zone; ESM-Eratostenes seamount; F-Faraa fault; G-Galilee; H-Hasbaya; Hb-Hula basin; NEMTJ-Northeast Mediterranean triple junction; J-Jericho; Jv-Jordan valley; NSZ-Negev shear zone; O-Orontes valley; P - Palmyrides; R-Roum fault; Ra-Rachaya; S-Shadwan; SAFB-Syrian arc fold belt; Se-Serrhaya fault; SL-South Lebanon; STJ-Sinai triple junction; Y-Yammouneh bending.

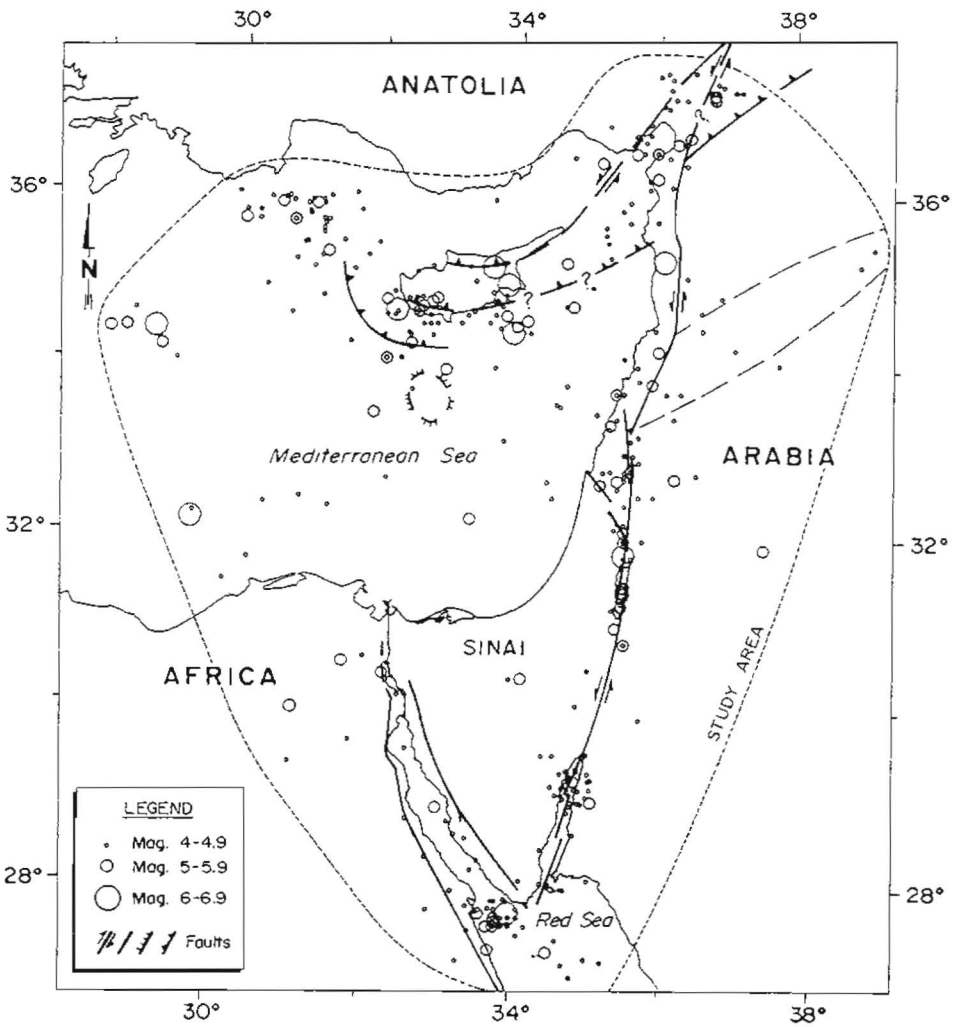

Fig.2. The seismicity map of the Sinai subplate.

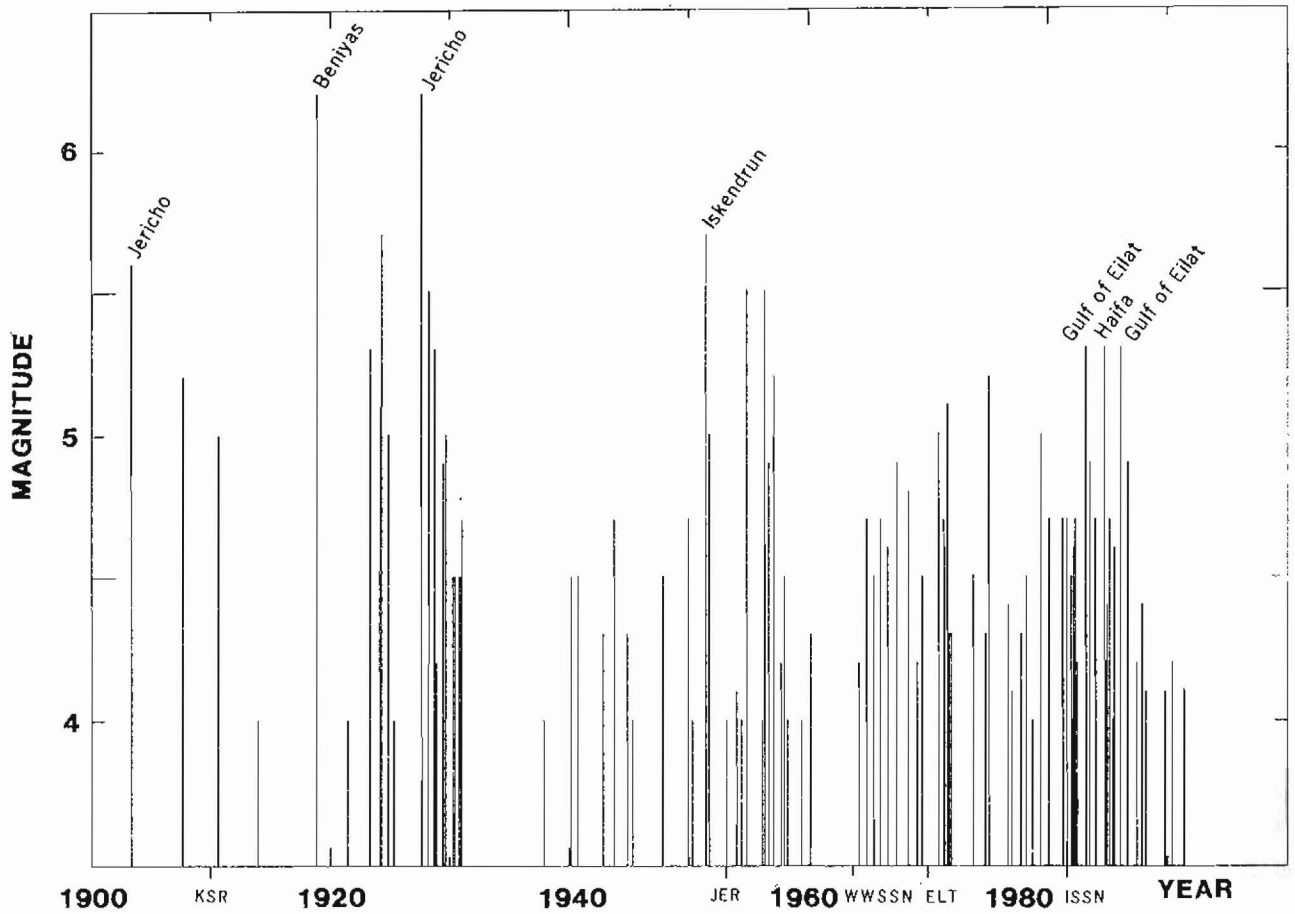

Fig.3. Magnitude-time plot of events in the Dead Sea transform region (after Arieh et al. 1985). Note the apparent gradual increase of seismicity with time. Installations of stations KSR, JER, WWSSN and ISN are signed by arrows. Some important events are also indicated.

FREQUENCY-MAGNITUDE RELATIONSHIP

Previous researchers (Arieh, 1967; Ben-Menahem et al., 1977; Ben-Menahem and Aboodi, 1981; El-Isa et al., 1984; Shapira and Feldman, 1987; Van Eck and Hofstetter, 1989) calculated b-values, using the Gutenberg-Richter relation, obtaining typical values between 0.8 to 0.9. In this work we calculate the b-value using the maximum likelihood method (Weichert, 1980). As was pointed by the latter and Johnsotn and Nava (1983), caution should be taken when the maximum likelihood method is applied in the case of many empty intervals in the data set and at the high magnitude end. Excluding foreshocks and aftershocks, we conclude that our earthquake catalog may be considered complete for earthquakes of $M>5$ from 1900 onwards. For lower magnitude the data are considered complete for $M>4.5$ since 1945 and 4.0 since 1969 (Arieh et al., 1985).

For the entire Sinai subplate and for the magnitude range of $4.6<M<6.6$, we find that $b=1.02\pm0.03$, typically to heterogeneous tectonic region, that includes compressional, extensional and transformal deformation zones. The Cyprean arc yields $b=1.07\pm0.06$ for $4.6<M<6$, with a good correlation to values found in the Hellenic arc by Hatzidimitriou et al. (1985). In the Dead Sea transform we find a value 1.00 ± 0.07 for $4.7<M<5.7$, higher than those found in previous works. This higher b-value presumably reflects the presence of various deformational regimes within the Dead Sea transform region, and probably $b=1$ is best representing the Sinai sub-plate.

DISCUSSION AND CONCLUSIONS

We determine the status of the Sinai region, in the context of the plate tectonic model, a subplate. Its northern, eastern and southern borders are well defined (Joffe and Garfunkel, 1987; Kempler and Garfunkel, 1991). Exceptional is the western region where no clear structural element exists to form a plate border (Fig. 1). Generally, seismicity tends to occur along plate borders (i.e., trenches and mid-oceanic ridges), margins and in intraplate zones (Kasahara, 1981). However, the appearance of the Sinai seismicity is insufficient to resolve these regions. Moreover, the close proximity of convergent, divergent and transformal style of deformation causes intensive strain within a relatively small area. For that reason we integrate seismicity with structural data to define a seismogenic belt along the geologically accepted borders of the Sinai subplate (Fig. 2). Both the plate borders and the plate margin domains are included within that belt. The intraplate region, where some minor activity occurs, is accepted here up to a certain degree. The reason is that the exact transition between the margins and the intraplate is unresolvable with the present data.

To conclude, the seismic scheme supports our established geological knowledge about the Sinai subplate borders. Also, it emphasizes the complexity of the structural processes accompanying the plates motion in the region, but that kinematic aspect of plate motion is yet to be investigated.

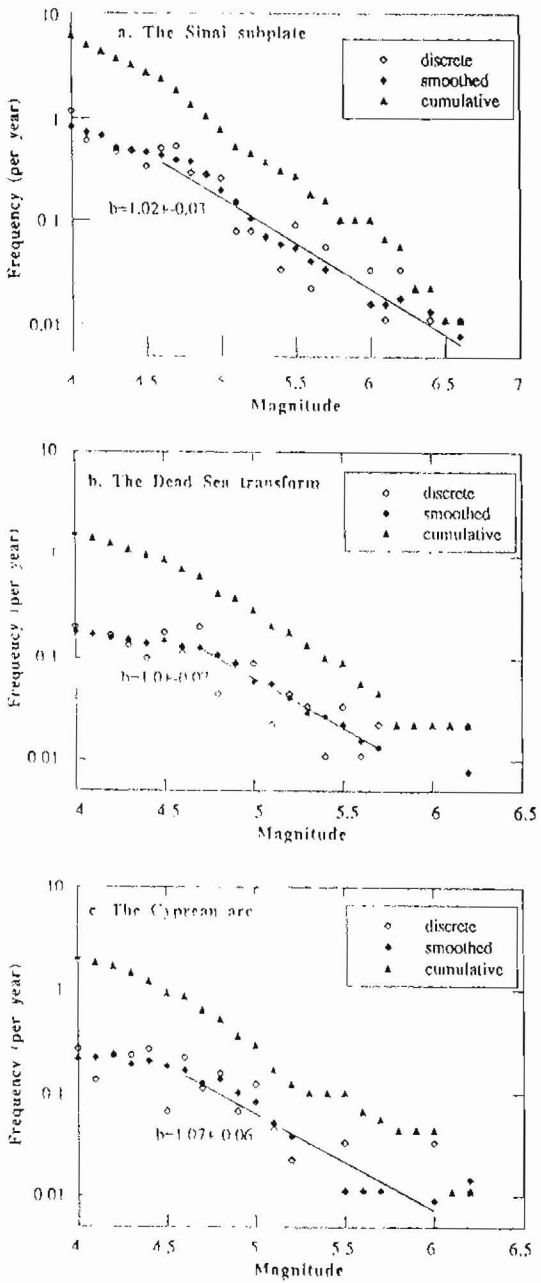

Fig.4. Frequency-magnitude plot of events. Cumulative data based on discrete counts. Calculation done with smoothed curve according to maximum likelihood method (Weichert 1980). (a) Sinai subplate. (b) Dead Sea transform. (c) Cyprean arc.

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