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# Intrinsic and scattering attenuation in the crust of the Abu Dabbab area in the eastern desert of Egypt

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ABSTRACT

Fifty-five microearthquakes recorded by a digital-temporary seismic network in the Abu Dabbab area in the Eastern Desert of Egypt were used to estimate the direct S-wave ($Q_\beta$), coda ($Q_c$), intrinsic ($Q_i$), and scattering quality factors ($Q_s$). Sato's [Sato H., 1977] single-scattering assumption was used to fit the amplitude envelopes of the coda at seven central frequency bands (1.5, 3, 6, 9, 12, 18, and 24 Hz), obtaining a $Q_c$ varying with frequency as generally observed in tectonically active areas. Lapse time dependence was also studied for the area, with the coda waves analyzed at window lengths ranging from 10 to 40 s starting from the onset of the S-wave arrival. The direct S-wave $Q_\beta$ was estimated using the coda normalization method [Aki, K., 1980a]. The frequency dependence of $Q$ was investigated for the direct S-waves and coda waves. Results show a low quality factor and a high frequency parameter, indicating that the upper lithosphere of the Abu Dabbab area is seismically active and heterogeneous. Using the independent estimates of $Q_c$ and $Q_\beta$, the intrinsic quality factor $Q_i$ was separated from the scattering quality factor. The results suggest that intrinsic dissipation plays a predominant role with respect to scattering phenomena in the area; the obtained $Q$ values seem closer to those reported by analyzing volcano-tectonic earthquakes. This finding reflects that the cause of Abu Dabbab earthquake swarms might be igneous activity where the magma is ascending through joints or serpentinized joints that are dewatering.



## 1. Introduction

Seismic activity in Egypt is attributed to the relative motion between the African, Arabian, and Eurasian plates. The seismicity of Egypt is spatially distributed along different earthquake source regions (Fig. 1). One of these earthquake source regions is Abu Dabbab, 24 km from the western margin of the Red Sea. That area is characterized by microearthquake activity accompanied by earthquake sounds (Morgan et al., 1981). These microearthquakes periodically occur as earthquake swarms. Earthquake swarms generally originate from volcanic, igneous, or tectonic activities. The extremely tight clustering of microearthquakes suggests that the seismicity in this area is not directly related to regional tectonics, and there is no obviously related structural feature (Daggett et al., 1986). In particular, Daggett et al. (1986) referred one possible explanation of the swarm activity to the magma intrusion into the Precambrian crust, but there are no surface occurrences supporting this hypothesis. El-Hady (1993) attributed the swarm activity in the Abu Dabbab area to geothermal evolution. He determined the brittle-ductile transition depth in the area to be 9–10 km by the distribution of earthquake focal depths. However, the tectonic and magmatic processes in the area are still not well-known. It is also unclear if magma intrusion into the extensional faulting is temporally coupled or the tectonic and magmatic processes mechanically interact and potentially trigger each other. The magma intrusion in the crust is generally accompanied by high heat flows. The average value of eight heat flow measurements in the Abu Dabbab area is 92 mW/m$^2$, which is one of the highest values in the Eastern Desert of Egypt (Boulos et al., 1990). The heat anomaly may be derived from deep origins and conducted through fractures in basements.

The attenuation of elastic waves depends strongly on temperature. Attenuation is quantified by the quality factor, $Q$, or internal friction, $Q^{-1}$, which typically varies by orders of magnitude between ambient temperature and rock solids (e.g., Kampfmann and Berckhemer, 1985). For shear waves, the quality factor must vanish before the rock liquids are reached. Seismic attenuation is therefore a useful parameter to characterize the physical state of rocks within a volcano, where melt fluids are thought to reside at shallow levels in the Earth's crust.

The attenuation of seismic waves is a complex mechanism controlled by the intrinsic dissipation factor and the scattering

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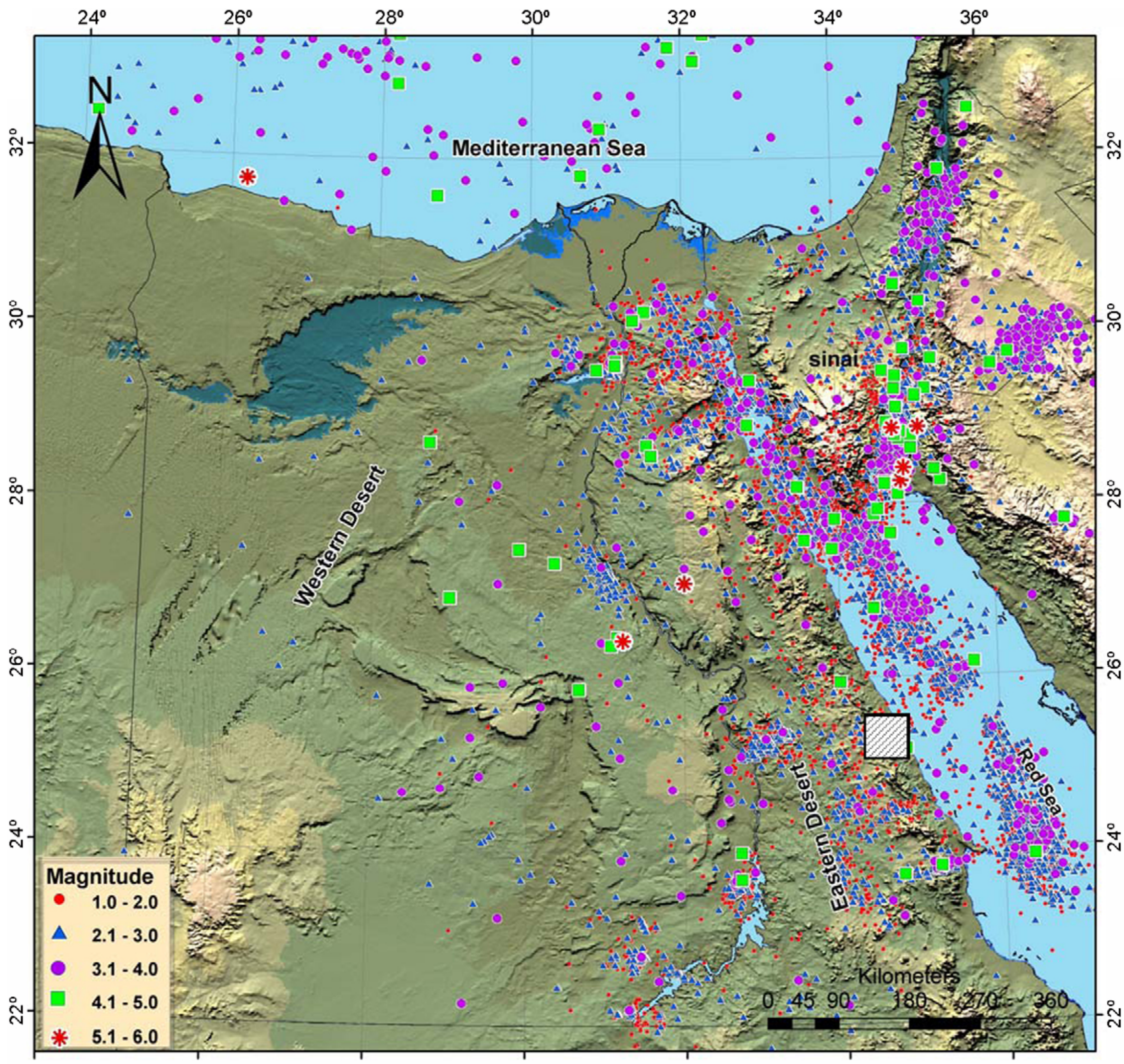


**Fig. 1.** Seismicity of Egypt from 1997 to 2007. The dashed square denotes the study area.

attenuation factor (Sato and Fehler, 1998). To estimate separately the amount of scattering and intrinsic losses from seismograms, it is necessary to study simultaneously the S-wave coda, which is generated by scattering processes inside the Earth, and the direct S-wave train. Sato (1991) derived an analytic formula, which included multiple scattering of any order in 2D space. Zeng (1991) found an integral solution for the multiple scattering coda excitations in a 3D uniform random medium. Hoshiba (1993) separated the intrinsic from the scattering attenuation parameter using multiple lapse time window analysis (MLTWA) applied to short-period data in Japan. Using Zeng's (1991) scattering model and the approximation of Abubakirov and Gusev (1990), Wennerberg (1993) introduced a method to estimate intrinsic ($Q_i$) and scattering quality factors ($Q_s$) from measurements of the direct S-wave ($Q_\beta$) and coda wave ($Q_c$).

In 2004, the temporary digital seismographic network was deployed around the Abu Dabbab area. Many earthquakes have been recorded, which provided an opportunity to measure the quality factor. In an attempt to establish the cause of peculiar seismicity in the area, we measured the intrinsic and scattering quality factors from independent estimates of $Q_\beta$ and $Q_c$ using the approach described by Wennerberg (1993). The $Q_\beta$ and $Q_c$ were estimated using the coda normalization method (Aki, 1980a) and the single-scattering model (Sato, 1977), respectively.

## 2. Area of study

The study area in the present work is illustrated by the inset square in Fig. 1. The main geological zones by Conoco (1987) are shown in Fig. 2. The Eastern Desert in Egypt consists essentially of a backbone of high and rugged mountains parallel to the Red Sea Coast, and much of the area is covered by Late Proterozoic basement rocks of the Nubian Shield (Said, 1962).

The basement rocks of the Eastern Desert of Egypt constitute the Nubian Shield that had been formed in the Arabian Peninsula before the opening of the Red Sea. It is generally accepted that the basement of the Nubian Shield was stabilized during the Pan African progeny around 570 Ma ago (El Gaby et al., 1988). The Precambrian basement complex, comprising about 10% of the total area of the country, is exposed mainly in the Eastern Desert and extends as a belt along the Red Sea Coast for a distance of about 800 km.

The evolution of the Nubian Shield has been interpreted in terms of classical geosynclines and mountain-building cycles for many years (Akaad and El Ramly, 1960; Sabet, 1961; El Shazly, 1964). The craton is characterized by igneous and metamorphic rocks including widespread acidic igneous intrusions. With the advent of the concept of plate tectonics, several models were proposed for the development of the Nubian Shield. These models included