Earthquake activity controlled by the regular induced telluric currents

Gerald DUMA, Central Institute for Meteorology and Geodynamics, Department of Geophysics,
gerald.duma@zamg.ac.at, Hohe Warte 38, A-1190 Vienna, Austria
Tel 0043-1-36026-2503, Fax 0043-1-368 66 21

Introduction

From 1996 to 1998 remarkable observations were obtained at the ZAMG (Central Institute for Meteorology and Geodynamics, Vienna, Austria) regarding regional earthquake activity and the magnetic variations which were recorded at adjacent geomagnetic observatories: In many of the main earthquake regions worldwide, seismic activity changes in accordance with the geomagnetic secular variations (long term changes) as well as with the regular solar daily variations Sq (Duma, 1996; Duma, Vilardo, 1998). Moreover, this applies also to strong earthquake activity, i.e. to events with magnitudes exceeding M5 and M6.

Model calculations have revealed that the effect differs from all known observations, which have been frequently reported from the 1960s on, where regional magnetic anomalies were observed in seismic regions prior to strong earthquakes (e.g. Nagata, 1976). These anomalies can be well interpreted by changing magnetic rock properties and changing magnetization under increasing stress in a focal zone. Thus, up to now, those anomalies were considered as precursor phenomena, giving some indication of forthcoming strong earthquakes and possibly being suitable for the prediction of strong seismic events.

In contrary to this widely known process, the effect reported in this paper (referred to as the 'Magneto-Seismic Effect MSE' in the following) seems to actually regulate earthquake activity:
The long term geomagnetic variations and the seasonal variations, as well as the Sq-variations do not originate in the Earth's lithosphere, but have external sources, situated in the deep Earth's interior (magnetic dynamo) and in the ionosphere, respectively. But by electromagnetic induction they produce the telluric currents in the Earth's lithosphere and mantle, which are large scale and intense current systems, easy measureable e.g. in magnetotelluric surveys. Since the conductive lithosphere is exposed also to the Earth's main magnetic field, Lorentz forces [I . B] result which act on the current layers and superimpose the tectonic stress field. Modeling this process (Duma, Ruzhin, 2002), it turns out that the deformation energy provided to the lithosphere is surprisingly high and lies within the range of tectonic strains itself: for an area of 200 km times 200 km for instance, the energy amounts to a value equal to that of an earthquake with Richter magnitude M3,8.

Since the process affects significantly also strong earthquake activity, the MSE may be of high relevance for preventive safety measures and disaster mitigation.

Observations in the long term

In the recent 8 years, very consistent results concerning the Magneto-Seismic Effect have been obtained for numerous strong earthquake regions of the world, e.g. regions in Greece, Italy, China, Central Asia and California. Just a few examples are given here, in order to illustrate the effect.

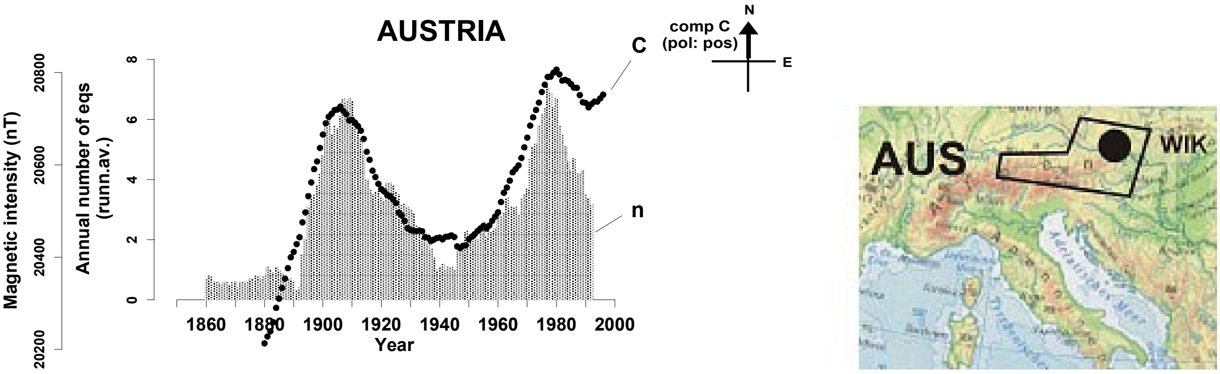

Fig.1 Region AUSTRIA (AUS): Annual number of earthquakes (n, runn. av.) versus the horizontal component C of the geomagnetic field, recorded at the geomagnetic observatory Wien-Cobenzl (WIK, Austria); C denotes the magnetic horizontal intensity H in this case (almost identical with the N-component); earthquake magnitude range 3.1 ≤ M ≤ 5.0, 380 events.

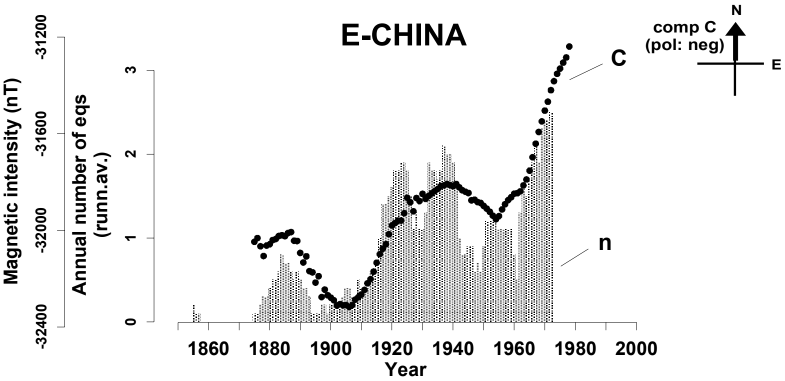

Fig.2 Region E-CHINA: Annual number of earthquakes (n, runn. av.) versus the horizontal component C of the geomagnetic field, measured at the geomagnetic observatory Sheshan (SSH, China); C denotes the magnetic intensity in N-direction (negative polarity) in this case; earthquake magnitude range M ≥ 6.0, 116 events, region 20-40°N, 100-120°E

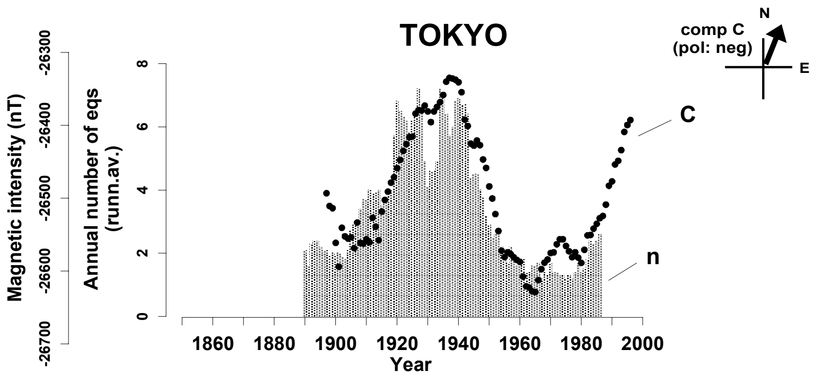

Fig.3 Region TOKYO: Annual number of earthquakes (n, runn. av.) versus the horizontal component C of the geomagnetic field, measured at the geomagnetic observatory Kakioka (KAK, Japan, Tokio); C denotes the magnetic intensity in N22E-direction (negative polarity) in this case; earthquake magnitude range M ≥ 6.0, 347 events, catalogue JMA, circular region r=300 km (around Tokyo), center 35°N, 140°E.

The quantities displayed in the graphs are the annual earthquake frequencies and the annual magnetic mean values as measured at nearby observatories. In all cases it turns out that it is a horizontal component (and not the vertical component) of the regional magnetic field which fits the changes of seismic activity in the long term best.

Observations in the daily range

Additional observational results which were obtained in the daily range, i.e. regarding earthquake activity with respect to the time-of-day of occurrence, reinforce the hypothesis of a significant interaction between geomagnetic and seismic performance. The example Mt.Vesuvius (Fig.5) moreover shows that the process plays an important role in volcanic seismicity, too.

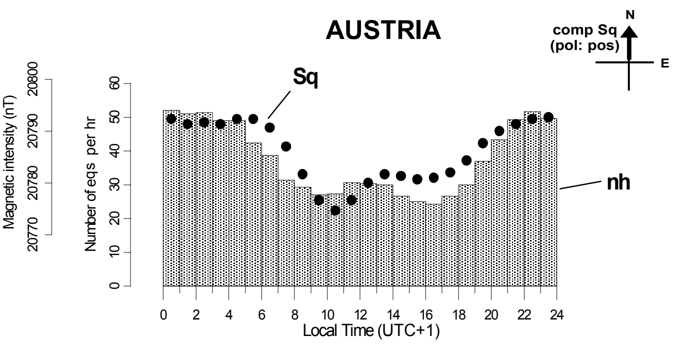

Fig.4 Region Austria (AUS): Number of earthquakes per hour origin time (nh, runn.av.), period 1901-1990, versus a mean magnetic Sq variation (1986) of the horizontal intensity H, measured at the geomagnetic observatory Wien-Cobenzl (WIK, Austria, geogr. lat. 48°N); earthquake magnitude range 2.5 ≤ M ≤ 5.0, 938 events

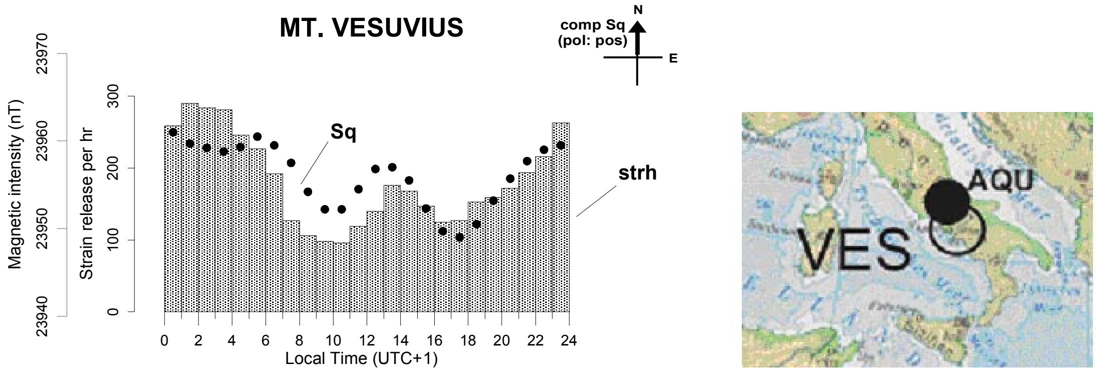

Fig.5 Region Mt. VESUVIUS, Italy (VES): Strain release of earthquakes per hour origin time (strh, runn.av.), period 1972-1996, versus a mean magnetic Sq variation (1986) of the horizontal intensity H, measured at the geomagnetic observatory L'Aquila (AQU, Italy, geogr. lat. 42°N); earthquake magnitude range 1.8 ≤ M ≤ 3.4, 1402 events; the region is only 10 km times 10 km surrounding the volcano (Duma, Vilardo, 1998)

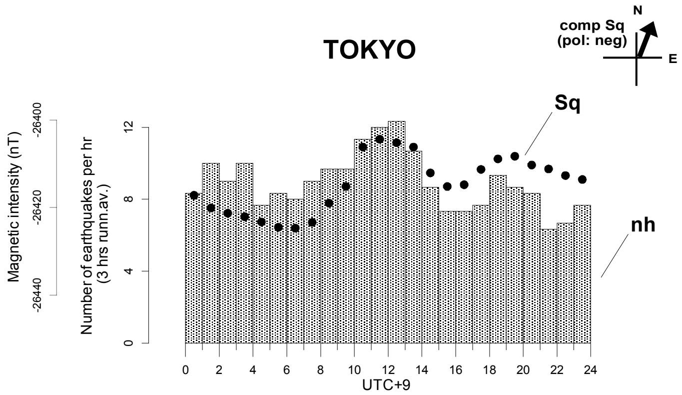

Fig.6 Region TOKYO: Number of earthquakes per hour origin time (nh, runn.av.), period 1980-1990, versus a mean magnetic Sq variation (1991-1993) in N22E-direction (negative polarity), measured at the geomagnetic observatory Kakioka (KAK, Japan, Tokio, geogr. lat. 36°N); earthquake magnitude range M ≥ 5.0, 214 events, catalogue JMA.

Observations in the seasonal range

Only one example is given below which may demonstrate that similar conditions hold also for the regular seasonal magnetic variations and the average earthquake frequency per month in a certain observation period, here from 1970 to 1990.

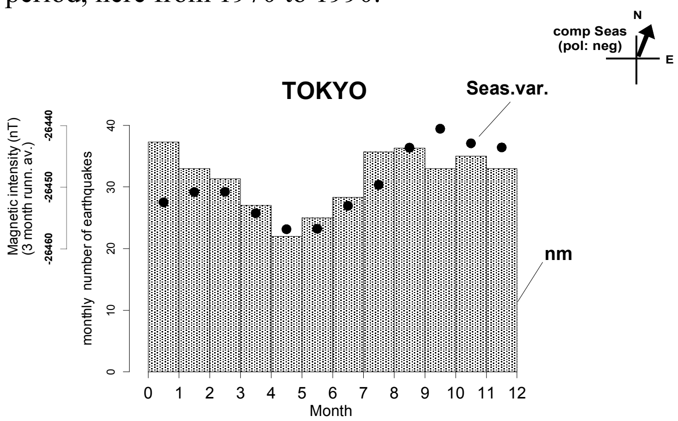

Fig.7 Region TOKYO: Number of earthquakes per month (nm, runn.av.), period 1970-1990, versus a mean seasonal magnetic variation (1991-1993) in N22E-direction (negative polarity), measured at the geomagnetic observatory Kakioka (KAK, Japan, Tokio, geogr. lat. 36°N); earthquake magnitude range M ≥ 5.0, 377 events, catalogue JMA.

The process, the model and implications

An assessment of the impact of the MSE on a seismic region is illustrated here only for the solar Sq-variation in the diurnal range:

The ionospheric current systems (Fig.8) generate, by induction, very similar telluric current vortexes in the Earth's lithosphere and mantle, with some 10-20% reduced intensities (Matsushita, 1968). The magnetic moment, built up by the Sq-induced current rings, interacts with the horizontal intensity H of the Earth's main magnetic field (Fig.9). A torque results from this process, acting on the current sheet, i.e. on the lithosphere.

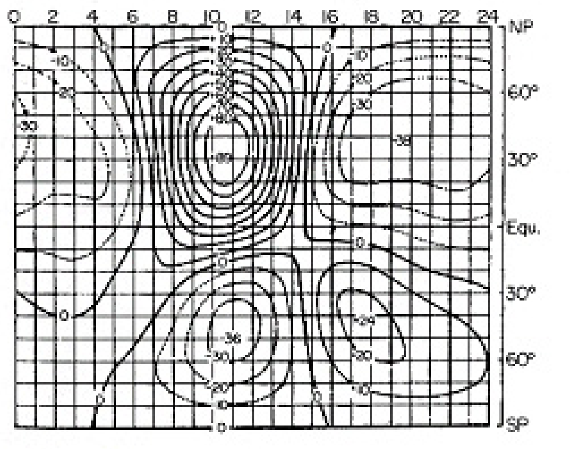

Fig.8 Ionospheric current system (Chapman, Bartels, 1940; currents in 10^3 Amperes) which causes 'the magnetic quiet-day solar daily variation' Sq

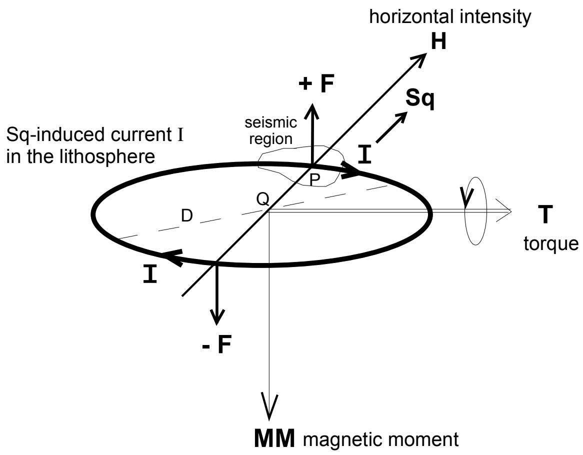

Fig.9 Model of electric current flow in the lithosphere in presence of the main magnetic field of the Earth (horizontal intensity H). A torque is generated, which acts on the Earth's lithosphere (Lorentz forces F). Center of vortex: Q, center of seismic region: P

The measured magnetic Sq-variation is proportional to current I, therefore it reflects the changes of the torque T with the time-of-day, as the telluric current vortex moves westwards with a rate of 15° longitude per hour. The vortex center Q is situated at a latitude of about 30°N in the northern hemisphere.

Given a current loop of 1000 km radius and a current of 60 kA (flowing in the vertical cross section of 1500 km width and 0-500 km depth), the magnetic moment ($MM = \mu_0 \,.\, I \,.\, D^2 \,.\, \pi / 4$) amounts to MM = $0{,}24.10^{12}$ Am^2 (=Vsm), and with a magnetic horizontal intensity of H = 30 A/m (30.000 nT), the torque becomes T = MM . H = $7{,}1.10^{12}$ VAs (=Joule). This energy is equal to the energy released by an earthquake of Richter magnitude M = 5,4 taking into account the usual relation logE = 4,8 + 1,5.M. And if we consider just a part of the entire current ring, e.g. a section of 200 x 200 km on the Earth's surface (assumed size of any earthquake zone), we end up with an energy of a M = 3,8 earthquake for this area, which is the maximum possible torque in the seismic region (at point P) during the time of day, about at noon, when current I flows at right angles to H. However, the interference with tectonic activity depends on the specific orientation of the stress field in each earthquake zone.

In addition to that, the analyses of the increase rate or decrease rate of earthquake frequency Δn in relation to the corresponding changes of the telluric currents ΔI have revealed, that the ratio $k = \Delta n/\Delta I$ (or $\Delta n/\Delta H$) is about the same in the three time ranges, in the daily, the seasonal and the long term range. This indicates that it is just one and the same mechanism which causes the changes of seismic activity in all three time domains. For the region TOKYO this factor amounts approx. to 3 more/less events $M \geq 5$ per year if the magnetic intensity N22E decreases/increases by 10nT/yr. This is an annual change of 15% in seismic activity (20 events $M \geq 5$ on average per year in the period 1970-1990), or a change of 100% in about 7 years.

According to the high energy rates involved in the Magneto-Seismic Effect, which are comparable to the energies provided by the main tectonic forces itself, it seems very plausible that the described process is the basic and general trigger mechanism which influences the temporal performance of regional earthquake activity, and of strong earthquake frequency in particular (Fig.2,3,6,7), to such a considerable extent.

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