KAB

NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 1-75/76

SEMIANNUAL TECHNICAL REPORT
NORSAR PHASE 3

1 July – 31 December 1975

Prepared by
K. A. Berteussen

Kjeller, 13 February 1976

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 2551

VII.7 On the M_s-m_b Relationship of Earthquakes

The purpose of this study is to estimate the M_s-m_b relationship using data from VLPE, ALPA, NORSAR and PDE, and assess the impact of network magnitude bias effects (Ringdal, 1976) on the results. We assume that there exists a linear functional relationship between M_s and m_b of shallow earthquakes of the form

$$M_s = \alpha \cdot m_b + \beta + \varepsilon \qquad (1)$$

where α and β are unknown coefficients and ε is a random variable that is normally distributed with zero mean and an unknown variance. Generally, the formula (1) can only be used as an approximation over limited magnitude ranges; for example, Gutenberg and Richter (1956) estimate α=1.6 using only very large events, while Evernden (1975) finds a value of α=1.0 below magnitude m_b=5.0 down to at least m_b=3.0.

This study is restricted to the magnitude range of most interest for current seismic discrimination studies, i.e., approximately m_b=4.0 to 6.0. The data base consists of 52 randomly selected shallow Eurasian earthquakes (Turnbull et al, 1975). Magnitudes of these events have been available from PDE and NORSAR (m_b), and from VLPE, ALPA and NORSAR (M_s). In addition, we used the maximum-likelihood technique of Ringdal (1976) to modify the PDE m_b estimates; we denote these modified estimates by PDE(m-l) m_b values. The assumptions required to obtain the PDE(m-l) estimates are described in detail by Turnbull et al (1975).

In order to examine the variations of the M_s-m_b slope as a function of estimation techniques of M_s and m_b, a total of nine cases were run based on the given event population. In each case, the M_s values estimated by either VLPE (averaging), ALPA or NORSAR were combined with the m_b values of NORSAR, PDE and PDE(m-1). One case is shown in Fig. VII.7.1, while complete results are summarized in Table VII.7.1. The following points are noteworthy:

1. Four of the runs produce a virtually identical slope ($\alpha \approx 1.37$). These are precisely those four runs that combine "consistent" M_s and m_b values, i.e., values free of network bias effects. (NORSAR or ALPA M_s versus NORSAR or PDE(m-1) m_b).
2. A consistently high value of the slope (1.66 or 1.64) is found when PDE m_b is plotted against a consistent M_s.
3. A consistently low value of α (1.23 or 1.24) results when VLPE M_s is plotted against a consistent m_b.
4. When PDE m_b is plotted against VLPE M_s, α is again high, showing that the network bias effects in PDE magnitudes dominate those of VLPE.

Hence, the behavior of the computed slope agrees well with what could be expected from network bias considerations (network magnitude are expected to produce a bias that is largest for small events). It appears that the most accurate linear functional relationship between M_s and m_b for the given data set (ranging in m_b values from about 4.0 to 6.0) has a slope of approximately 1.4.

Considering more closely the four cases of consistent estimates, it is interesting to note that the value of the orthogonal standard deviation σ is lower when using PDE(m-1) m_b versus either ALPA or NORSAR M_s compared to when NORSAR m_b is used ($\sigma \approx 0.26$ vs $\sigma \approx 0.31$). It would be interesting to compare PDE(m-1) m_b to the VLPE-ALPA-NORSAR combined network with the network bias reduced by maximum likelihood processing; however, we have not been able to do this, mostly because of the lack of reliable VLPE data for some stations.

F. Ringdal
L.S. Turnbull (Texas Instruments, USA)

REFERENCES

Evernden, J.F. (1975): Further studies on seismic discrimination, Bull. Seism. Soc. Am., 65, 359-391.

Gutenberg, B., and C.F. Richter (1956): Magnitude and energy of earthquakes, Ann. di Geofis., 9, 1-15.

Ringdal, F. (1976): Maximum-likelihood estimation of seismic magnitude, Bull. Seism. Soc. Am. (in press).

Turnbull, L.S., D. Sun, J. Battis and F. Ringdal (1975): Near and far field studies, Semiannual Report 5B, Texas Instruments Incorporated, Dallas, Texas.

Table VII.7.1

Estimated relationship M_s-m_b for various combinations of M_s and m_b measurement procedures.

m_b	M_s	No. of Points* NP	Slope α	Intercept β	σ Orthogonal
PDE	VLPE	52	1.54	-3.58	0.238
	ALPA	41	1.66	-4.33	0.253
	NORSAR	35	1.64	-3.95	0.276
PDE Maximum Likelihood	VLPE	52	1.23	-1.73	0.262
	ALPA	41	1.37	-2.57	0.257
	NORSAR	35	1.37	-2.25	0.259
NORSAR	VLPE	52	1.24	-1.67	0.309
	ALPA	41	1.37	-2.48	0.321
	NORSAR	35	1.39	-2.14	0.305

* The missing data points (NP<52) are due to lack of available data for NORSAR or ALPA M_s for some events, and not due to nondetection at these stations.

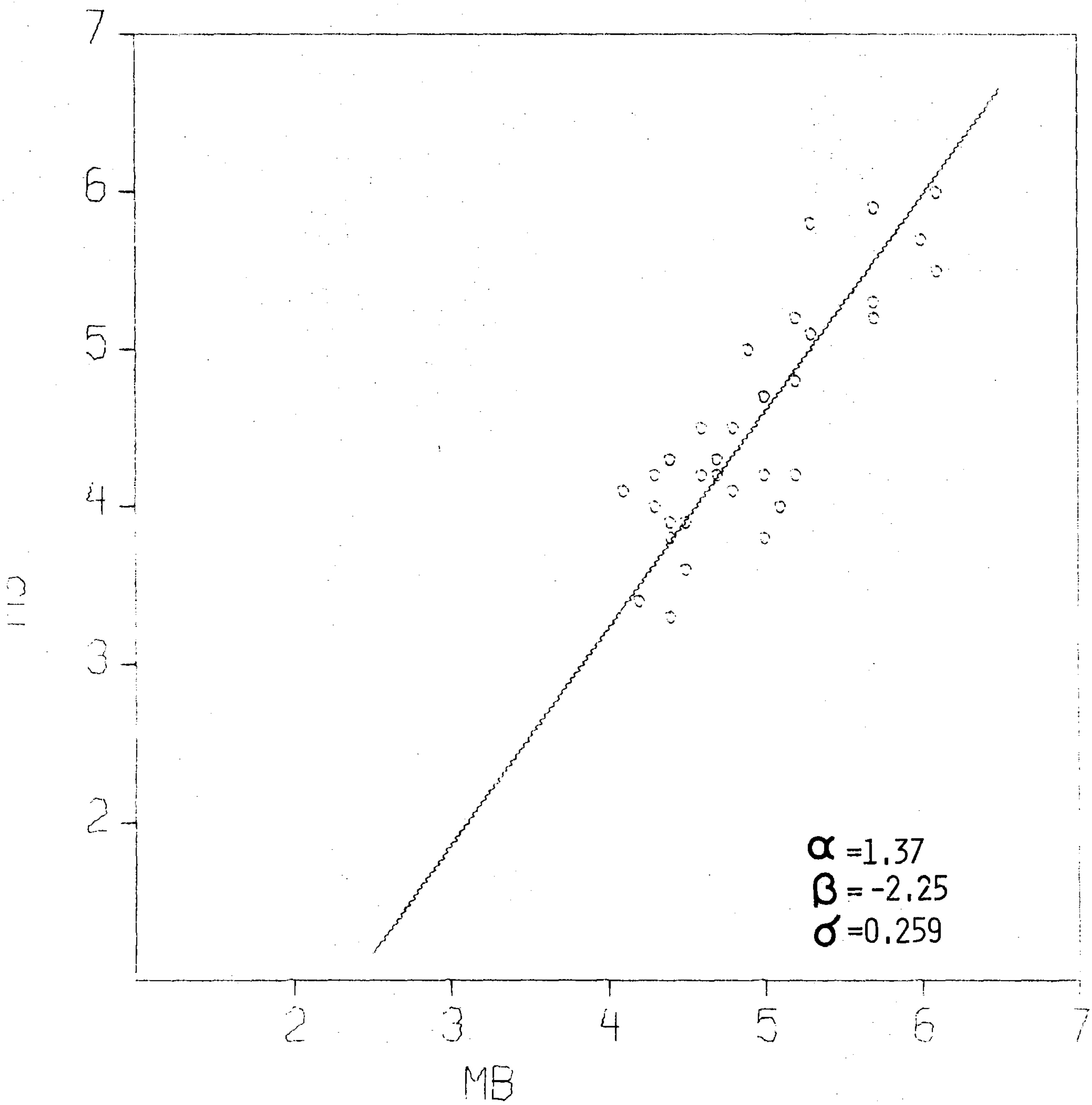

Fig. VII.7.1 PDE m_b modified by maximum likelihood processing plotted against NORSAR M_s.