



INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION



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WORKSHOP ON PATTERN RECOGNITION AND ANALYSIS OF SEISMICITY

(5 - 16 December 1983)

PATTERN B ("BURST OF AFTERSHOCKS")
A LONG-TERM PREMONITORY SEISMICITY PATTERN

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SEISMICITY AND PREDICTION
PATTERN B ("BURST OF AFTERSHOCKS")

A LONG-TERM PREMONITORY SEISMICITY PATTERN

INTRODUCTORY LECTURE

NOTE: THIS IS ONE OF SEVERAL PREMONITORY SEISMICITY PATTERNS.

IT IS RELATIVELY BETTER (BUT NOT FINALLY) CHECKED.

HERE WE GIVE THE KNOW-HOW IN RESEARCH (ANALYSIS OF EXISTING CATALOGS) BUT NOT THE READY RECIPE FOR ROUTINE PREDICTION.

OBSERVED PHENOMENA: A STRONG EARTHQUAKE IS PRECEDED BY A GROUP OF WEAKER EARTHQUAKES CONCENTRATED IN SPACE-TIME. USUALLY IT IS A MAIN SHOCK WITH ABNORMALLY LARGE NUMBER OF AFTERSHOCKS ("BURST OF AFTERSHOCKS").

IS IT RELIABLE AND USEFUL FOR PREDICTION? TO ANSWER, WE NEED:

TO GIVE A FORMAL (REPRODUCIBLE AND UNAMBIGUOUS) DEFINITION OF THE BURST OF AFTERSHOCKS.

USING THIS DEFINITION - TO MAKE "RETROSPECTIVE PREDICTION", THAT IS TO COMPARE BURSTS OF AFTERSHOCKS AND STRONG EARTHQUAKES IN THE PAST.

TO ATTEMPT FORWARD PREDICTION BY MONITORING NEW BURSTS OF AFTERSHOCKS.

HOW TO DEFINE MAIN SHOCKS AND THEIR AFTERSHOCKS
IN THE CATALOG?

EARTHQUAKES IN THE CATALOG ARE GIVEN AS $(t_i, \varphi_i, \lambda_i, h_i, M_i)$,

i - SEQUENCE NUMBER,

t - ORIGIN TIME ($t_i \geq t_{i-1}$),

(φ, λ) - EPICENTER,

h - DEPTH,

M - MAGNITUDE

DEFINITION: EARTHQUAKE WITH NUMBER j IS AN AFTERSHOCK

OF THE EARTHQUAKE WITH NUMBER i ($j > i$) IF:

$$t_j - t_i \leq T(M_i),$$

$$|h_j - h_i| \leq H(M_i),$$

THE DISTANCE BETWEEN THEIR EPICENTERS IS $\leq R(M_i)$,

$$M_j \leq M_i.$$

PROCEDURE:

THE FIRST EARTHQUAKE IN THE CATALOG IS A MAIN SHOCK.

ITS AFTERSHOCKS ARE EXCLUDED FROM THE CATALOG.

THE FIRST OF REMAINING EARTHQUAKES IS SECOND MAIN SHOCK ETC.

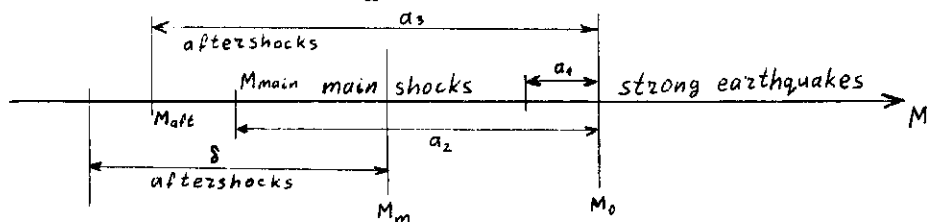
PATTERN B - FORMAL DEFINITION.

STRONG EARTHQUAKES: $M \geq M_0$; WE ARE LOOKING FOR THEIR PRECURSORS.

MAIN SHOCKS: $M_0 - a_2 = M_{\text{main}} \leq M \leq M_0 - a_1$

AFTERSHOCKS: $M_0 - a_3 = M_{\text{aft}} \leq M \leq M_m$,
(or $M_m - \delta \leq M \leq M_m$)

WHERE M_m IS MAGNITUDE OF MAIN SHOCK



$b = b(e)$ - NUMBER OF AFTERSHOCKS IN FIRST e DAYS
AFTER MAIN SHOCK

PATTERN B: $b \geq \bar{b}$

TIME OF INCREASED PROBABILITY OF STRONG EARTHQUAKE (TIP):

STARTS WHEN PATTERN B APPEARS,

ENDS WHEN A STRONG EARTHQUAKE OCCURS

OR τ YEARS EXPIRE.

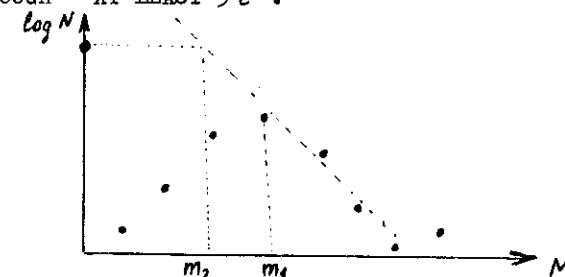
ERRORS: FALSE ALARM - PATTERN B NOT FOLLOWED BY A STRONG EARTHQUAKE WITHIN τ YEARS,

FAILURE TO PREDICT - STRONG EARTHQUAKE NOT PRECEDED BY A PATTERN B WITHIN τ YEARS.

FREE DECISIONS

REGION: BOUNDARIES SHOULD NOT CROSS DENSE CLOUDS OF EPICENTERS, NOR BE CLOSE TO EPICENTERS OF STRONG EARTHQUAKES.

CATALOG: SHOULD BE COMPLETE FOR MINIMAL MAGNITUDE OF AFTERSHOCKS M_{aft} (or $M_{\text{main}} - \delta$) DURING SOME TIME-PERIOD. THIS PERIOD SHOULD BE LONG ENOUGH - AT LEAST 5τ .



CATALOG IS COMPLETE FOR $M \geq m_4$. SOMETIMES

UNIDENTIFIED MAGNITUDES (O ON TAPE) CAN BE REPLACED BY m_2 .

MAGNITUDES: BEWARE OF DIFFERENT MAGNITUDE SCALES BUT

DON'T LOOK FOR THEIR PRECISE CONVERSION:

OFTEN EVEN THE SIMPLEST CHOICE - MAXIMAL

OF ALL VERSIONS OF M - IS ACCEPTABLE

INTENSITY IS USUALLY UNRELIABLE FOR ESTIMATION OF M

PARAMETERS OF THE ALGORITHM

DEFINITION OF AFTERSHOCKS: $T(M)$, $H(M)$, $R(M)$

MAGNITUDE INTERVALS: M_0 , a_1 , a_2 , a_3 (or δ)

PATTERN B: e , \bar{b} , τ

VALUES SHOULD BE FIXED, IF POSSIBLE, PRIOR TO DATA PROCESSING.

THE MORE PARAMETERS ARE DATA-FITTED, THE LESS IS STATISTICAL SIGNIFICANCE OF RETROSPECTIVE PREDICTION, SO THE LESS RELIABLE WOULD BE FORWARD PREDICTION.

STANDARD VALUES (ALL PARAMETERS EXCLUDING M_0 , \bar{b}).

$R = 50\text{km}$, $H = 100\text{km}$ does not depend on M

M	2.5	2.5- -2.99	3- -3.49	3.5- -3.99	4- -4.49	4.5- -4.99
T(M) (days)	1.43	2.85	5.7	11.41	22.81	45.63

M	5- -5.49	5.5- -6.49	6.5- -6.99	7- -7.49	7.5- -7.99	≥ 8
T(M) (days)	91.25	182.5	365.25	730.5	913.1	1095.75

$a_1 = 0.1$, $a_2 = 1.0$, $a_3 = 3.5$, $e = 2$ days, $\tau = 3$ years

THE CHOICE OF M_0 (MAGNITUDE THRESHOLD FOR STRONG

EARTHQUAKES) - guidelines:

THE AVERAGE INTERVAL BETWEEN STRONG EARTHQUAKES SHOULD BE MUCH LARGER THAN τ (ABOUT 3 TIMES).

THE EARTHQUAKES WITH $M \approx M_0$ SHOULD BE NOT TOO NUMEROUS: M_0 SHOULD BE CHOSEN IN A MINIMUM OF A HISTOGRAM $N(M)$

THE CHOICE OF \bar{b} IS NOT POSSIBLE PRIOR TO RETROSPECTIVE PROGNOSIS. GUIDELINES:

THE NUMBER OF MAIN SHOCKS WITH $b \geq \bar{b}$ SHOULD BE MORE THAN THE NUMBER OF STRONG EARTHQUAKES BUT NOT TOO LARGE.

MAIN SHOCKS WITH $b \approx \bar{b}$ SHOULD BE NOT TOO NUMEROUS:

\bar{b} SHOULD BE CHOSEN IN A MINIMUM OF A HISTOGRAM $N(b)$.

QUALITY OF RETROSPECTIVE PREDICTION

T - PERIOD OF THE RETROSPECTIVE PREDICTION

T_a - PART OF THE PERIOD T COVERED BY

τ - INTERVALS AFTER EACH PATTERN B
(OVERLAPPING PARTS ARE COUNTED ONCE).

n_a - THE NUMBER OF STRONG EARTHQUAKES WITHIN THESE
INTERVALS.

n - TOTAL NUMBER OF STRONG EARTHQUAKES.

COMPETING HYPOTHESIS: STRONG EARTHQUAKES ARE
UNIFORMLY DISTRIBUTED AND INDEPENDENT OF
PATTERNS B.

PROBABILITY:

$$P = \sum_{j=n_a}^n C_n^j \left(\frac{T_a}{T} \right)^j \left(1 - \frac{T_a}{T} \right)^{n-j}$$

SHOULD BE SMALL (< 0.1) TO REJECT THE
COMPETING HYPOTHESIS.

THIS IS NOT THE CONCLUSIVE TEST, SINCE
WE DATA-FITTED SOME PARAMETERS AND STRONG
EARTHQUAKES ARE DEFINITELY NON-UNIFORMLY
DISTRIBUTED.

ANOTHER COMPETING HYPOTHESIS: STRONG EARTHQUAKES
AND PATTERNS B ARE INDEPENDENT, BOTH ARE
MORE FREQUENT DURING THE PERIODS OF LARGE
SEISMIC ACTIVITY.

THE CHECK: RETROSPECTIVE PREDICTION FOR INVERSE TIME,
TAKING AS TIPS THE τ -INTERVALS BEFORE PATTERNS B.

STABILITY TO VARIATION OF PARAMETERS IS ADDITIONAL CON-
FIRMATION OF RETROSPECTIVE PREDICTION.

USUAL VARIATIONS:

M ₀	±0.3
R	± 50km
ℓ	up to 30 days
τ	± 1 year
\bar{B}	- NEAREST MINIMUMS OF A HISTOGRAM N(b)

OTHER TESTS:

TRANSFER TO ANOTHER TERRITORY

VARIATION OF REGION BOUNDARIES

CONCLUSIVE TEST: CURRENT MONITORING OF THE PATTERN B
AND FORWARD PREDICTION.

Note: N - TOTAL NUMBER OF STRONG EARTHQUAKES
K - NUMBER OF "PREDICTED" EARTHQUAKES
T - DURATION OF THE TIME INTERVAL
Ta - DURATION OF TIPS DURING THE INTERVAL T.

