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WORKSHOP
GLOBAL GEOPHYSICAL INFORMATICS WITH APPLICATIONS TO RESEARCH IN EARTHQUAKE PREDICTIONS AND REDUCTION OF SEISMIC RISK

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ON INTERMEDIATE-TIME EARTHQUAKE PREDICTION IN CENTRAL ITALY

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On Intermediate-time Earthquake Prediction in Central Italy.

Abstract.

The possibility is investigated to diagnose the Time of Increased Probability (TIPs) of a strong earthquake in Central Italy by the algorithm CN. Apart from obvious practical interest this is essential for investigation of similarity in the origin of strong earthquakes worldwide.

1. Algorithm CN.

This algorithm is described in all details in [1,2]. We consider here the version specifically described in [2]. The algorithm is designed to diagnose the Time of Increased Probability (TIPs) from a set of traits of the earthquakes flow. The following traits are used: seismic activity, its variation in time, clustering of earthquakes, their concentration in space; their long-range interaction.

Some combinations of these traits are typical for the TIPs and some other combinations - for the periods outside the TIPs. These combinations, named characteristic features, were studied first for California and Nevada for the purpose of prediction of earthquakes with magnitude M ≥ 6.4. The following rule was data-fitted in paper [2]: a TIP is diagnosed if

1. $n_D(t) - n_N(t) \geq 5$
2. $\sigma(t) < 4.9$

Here $n_D(t)$ shows how many typical features of TIPs the earthquakes flow has at the time t, $n_N(t)$ is a similar number for features of the opposite kind; $\sigma(t) = 10^{-\beta(Mo-\alpha)} \sum 10^{\beta(Mi-\alpha)}$ (where $\beta = 1$; $\alpha = 5$; $Mi \geq M_o - 1.4$) is a function proportional to the total area of rupture in the sourcerces within 3 years before time t.

If both conditions are fulfilled, a TIP is declared for one year. Consecutive TIPs thus diagnosed may overlap and extend each other. The TIP during which a strong earthquake did not occur constitutes a false alarm, as well as a strong earthquake which occurred outside the TIPs diagnosed, constitute a failure to predict.

The algorithm is formulated in a normalized way so that it can be transferred from territory to territory automatically without additional retrofitting of parameters. In each territory only its boundaries and the value of M_o have to be defined with a certain degree of freedom. The algorithm was successfully transferred to several regions: Central Asia, Caucasus, Western Turkmenia, Kamchatka and Kuril island, E. Carpathians, Belgium, Cocos plate, Gulf of California, and N. Appalachians [1,5,6]. The results are following: TIPs occupy on the average about 24% of the time in a region and preceed 31 out of 40 strong earthquakes.

For the Italian territory only earthquake prediction based on clustering been considered up to now [4], therefore here we apply the CN algorithm to Central Italy.

2. Earthquake statistics.

The territory considered is shown in Fig. 1. The exact boundaries of this region are drawn on the basis of map of epicenters and the scheme of morphostructural zonation [7].

The region choosen includes the zone along which there is interaction between different lithospheric blocks (Fig. 2) as outlined by surface waves dispersion analysis [3]

We used catalogs [8, 9]. In the catalogs [8] the magnitude is not indicated for most of the earthquakes and its values are taken from [9], if given there. Tables 1-3 show the distribution of earthquakes over magnitude and time for different parts of the territory considered: Northern (lat. 48°-45°N), Central (lat. 45°-49,5°N) and Southern (lat. 39,5°-35°N). We see that the completeness of the catalogs for these territories is quite different. For Central Italy we may hope that the catalog is relatively complete since 1950 but for the Northern and Southern regions - only since 1976. Therefore, we can test our algorithm only for Central Italy.

Before 1971, magnitude is determined here only for a fraction of strongest earthquakes. The average number of all earthquakes indicated up to 1971 is about the same as for earthquakes with M ≥ 3 after 1971. Accordingly, we assigned M ≥ 3 to all earthquakes before 1971 with unidentified magnitude.

We consider here only normal earthquakes with focal depth H ≤ 100 km. We define as strong the earthquakes with M ≥ 5.6. Their list is given in Table 4. This threshold is chosen because such earthquakes recurr with average time interval of about 5 years (Table 5) as was the case in most of the regions considered previously.

3. Diagnosis of TIPs.

Algorithm CN developed by [2] was applied without any change of the numerical parameters. The material used for discretization included 5 moments of time immediately before each strong earthquake (Table 4), 4 moments of time - one year before the earthquakes in Table 1, and 13 moments of time separated at least by years from any strong earthquake.

Aftershocks were identified by the algorithm described in [10]. TIPs diagnosed are juxtapposed with strong earthquakes in Table 6 and in Fig. 3. We see that TIPs occupy 17% of time and preceed 3 out of 5 strong earthquakes. This seems encouraging for further monitoring of TIPs on the same territory. This monitoring would be a decisive test of applicability of algorithm CN in this region. In forward monitoring it is useful to keep in mind that if the threshold in condition (1) increased from 5 to 6 the total duration of TIPs is reduced to 12% without additional failures to predict. So, the TIPs above this threshold deserve more attention.

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Table 1

Distribution of earthquakes in magnitude and time.

Northen Italy.

Year	Magnitude :											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1940	10	.	.	.	.	.	.	.	.	.	.	.
1941	1	.	.	.	.	.	.	.	.	.	.	.
1942	8	1	1	1	1	1	1	.	.	.	.	.
1943	21	4	4	4	4	4	4	4	3	.	.	.
1944	2	.	.	.	.	.	.	.	.	.	.	.
1945	3	1	1	1	1	1	1	1	1	.	.	.
1946	3	.	.	.	.	.	.	.	.	.	.	.
1947	10	1	1	1	1	1	1	1	.	.	.	.
1948	15	.	.	.	.	.	.	.	.	.	.	.
1949	29	2	2	2	2	2	2	2	1	.	.	.
1950	6	.	.	.	.	.	.	.	.	.	.	.
1951	8	3	3	3	3	3	3	3	1	.	.	.
1952	8	1	1	1	1	1	1	1	.	.	.	.
1953	2	1	1	1	1	1	1	.	.	.	.	.

Table 1 (continued)

Year	Magnitude :											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1954	11	2	2	2	2	2	2	1	1	.	.	.
1955	15	1	1	1	1	1	1	1	.	.	.	.
1956	7	1	1	1	1	1	1	1	1	.	.	.
1957	10	.	.	.	.	.	.	.	.	.	.	.
1958	9	.	.	.	.	.	.	.	.	.	.	.
1959	17	3	3	3	3	3	3	3	2	.	.	.
1960	41	4	4	4	4	4	4	4	2	.	.	.
1961	17	.	.	.	.	.	.	.	.	.	.	.
1962	7	.	.	.	.	.	.	.	.	.	.	.
1963	16	1	1	1	1	1	1	.	.	.	.	.
1964	30	.	.	.	.	.	.	.	.	.	.	.
1965	16	.	.	.	.	.	.	.	.	.	.	.
1966	30	1	1	1	1	1	1	.	.	.	.	.
1967	25	2	2	2	2	2	1	1	1	.	.	.
1968	30	3	3	3	3	3	3	2	2	.	.	.
1969	17	2	2	2	2	2	2	1	.	.	.	.
1970	13	4	4	4	4	4	4	1	.	.	.	.
1971	29	8	8	8	8	8	7	2	.	.	.	.
1972	18	1	1	1	1	1	1	.	.	.	.	.
1973	14	4	4	4	4	4	3	2	.	.	.	.
1974	14	3	3	3	3	3	3	1	.	.	.	.

Table 1 (continued)

Year	Magnitude :											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1975	7	5	5	5	5	5	4	3	1	.	.	.
1976	628	174	174	174	174	174	154	61	21	11	5	3
1977	117	30	30	30	30	30	18	8	2	1	1	.
1978	56	26	26	26	26	23	19	6	1	.	.	.
1979	62	20	20	20	20	19	17	6	3	.	.	.
1980	62	12	12	12	12	9	8	4	1	1	.	.
1981	45	17	17	17	17	12	10	3	1	.	.	.
1982	54	15	15	15	15	12	10	2	.	.	.	.
1983	67	19	19	19	19	17	12	7	3	.	.	.
1984	59	18	18	18	18	17	15	3	1	.	.	.
1985	61	11	11	11	11	9	6	1	.	.	.	.

Table 2

Distribution of earthquakes in magnitude and time.

Central Italy.

Year	Magnitude :											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1940	107	6	6	6	6	6	6	6	2	.	.	.
1941	191	4	4	4	4	4	4	4	2	1	.	.
1942	59	.	.	.	.	.	.	.	.	.	.	.
1943	52	5	5	5	5	5	5	4	2	.	.	.
1944	2	2	2	2	.	.	.	.	.	.	.	.
1945	7	4	4	4	4	4	4	4	2	1	.	.
1946	9	2	2	2	2	2	2	2	.	.	.	.
1947	40	6	6	6	5	5	5	5	3	1	.	.
1948	45	7	7	7	6	6	6	6	5	1	.	.
1949	54	4	4	4	3	3	3	2	.	.	.	.
1950	52	5	5	5	5	5	5	4	3	1	.	.
1951	34	10	10	10	10	10	10	10	4	1	.	.
1952	17	8	8	8	8	8	8	6	.	.	.	.
1953	26	9	9	9	9	9	7	4	.	.	.	.
1954	17	4	4	4	4	4	4	2	2	.	.	.
1955	49	12	12	12	10	10	10	6	2	1	.	.
1956	96	17	17	17	16	16	16	10	4	1	.	.
1957	105	21	21	21	19	19	19	12	5	.	.	.
1958	61	6	6	6	3	3	3	3	1	1	.	.
1959	89	6	6	6	6	6	6	5	3	1	1	.
1960	82	21	21	19	17	13	10	3	.	.	.	.
1961	74	26	26	26	25	25	25	16	9	.	.	.

Table 2(continued)

Year	Magnitude !											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1962	83	28	28	27	26	25	24	16	6	4	3	1
1963	137	48	48	43	39	35	32	17	6	4	2	.
1964	86	18	18	18	14	14	14	10	4	1	.	.
1965	69	35	35	34	34	32	29	15	4	.	.	.
1966	63	16	16	16	10	9	9	6	.	.	.	.
1967	56	19	19	17	15	15	14	11	5	1	1	.
1968	60	29	29	27	24	21	16	9	1	.	.	.
1969	71	32	32	27	26	24	24	12	3	.	.	.
1970	113	39	39	37	34	32	26	13	1	.	.	.
1971	329	80	74	68	60	57	50	21	6	1	.	.
1972	355	183	144	129	112	76	62	25	5	2	.	.
1973	165	31	30	27	25	22	20	13	1	.	.	.
1974	208	74	67	61	53	50	44	16	3	1	.	.
1975	104	32	29	28	25	18	13	4	2	.	.	.
1976	137	61	49	49	41	39	36	14	5	2	.	.
1977	211	89	56	55	42	39	34	17	3	.	.	.
1978	108	61	66	65	46	45	38	14	5	.	.	.
1979	465	234	142	142	91	86	75	19	5	2	1	.
1980	745	234	213	185	159	141	120	60	24	6	1	1
1981	283	116	86	67	58	54	46	14	4	.	.	.
1982	185	95	83	74	68	57	49	16	5	1	.	.
1983	88	64	56	46	41	31	29	10	4	2	1	.
1984	211	143	134	127	107	98	84	33	8	4	3	.
1985	120	79	71	58	53	43	36	10	2	2	.	.

Table 3

Distribution of earthquakes in magnitude and time.

Southen Italy.

Year	Magnitude !											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1940	7	2	2	2	2	2	2	2	2	.	.	.
1941	20	1	1	1	1	1	1	1	1	1	1	1
1942	5	1	1	1	1	1	1	1	.	.	.	.
1943	3	1	1	1	1	1	1	1	.	.	.	.
1944	.	.	.	.	.	.	.	.	.	.	.	.
1945	1	.	.	.	.	.	.	.	.	.	.	.
1946	6	.	.	.	.	.	.	.	.	.	.	.
1947	67	.	.	.	.	.	.	.	.	.	.	.
1948	7	.	.	.	.	.	.	.	.	.	.	.
1949	41	1	1	1	1	1	1	1	1	1	1	.
1950	41	5	5	5	5	5	5	3	1	1	.	.
1951	4	.	.	.	.	.	.	.	.	.	.	.
1952	22	5	5	5	5	5	4	1	.	.	.	.
1953	8	3	3	3	3	3	3	1	.	.	.	.
1954	26	5	5	5	5	5	5	4	2	1	.	.
1955	38	1	1	1	1	1	1	.	.	.	.	.
1956	4	2	2	2	2	2	2	1	.	.	.	.
1957	18	3	3	3	3	3	3	2	2	2	1	.
1958	7	.	.	.	.	.	.	.	.	.	.	.
1959	17	3	3	3	2	2	2	1	1	1	1	.
1960	12	2	2	2	2	2	2	.	.	.	.	.
1961	7	5	5	4	4	2	1	1	1	1	.	.

Table 3 (continued)

Year	Magnitude ≥											
	0	3,0	3,1	3,2	3,2	3,4	3,5	4,0	4,5	5,0	5,5	6,0
1962	6	.	.	.	.	.	.	.	.	.	.	.
1963	9	1	1	1	1	1	1	1	.	.	.	.
1964	2	.	.	.	.	.	.	.	.	.	.	.
1965	7	2	2	2	2	2	2	2	1	.	.	.
1966	5	.	.	.	.	.	.	.	.	.	.	.
1967	7	4	4	4	4	3	3	3	3	1	.	.
1968	177	144	144	137	124	101	94	44	15	6	5	1
1969	22	5	5	5	5	5	5	1	.	.	.	.
1970	16	2	2	2	1	1	1	1	1	.	.	.
1971	21	4	4	4	4	4	4	3	1	.	.	.
1972	23	1	1	1	1	1	1	1	.	.	.	.
1973	10	1	1	1	1	1	1	1	1	.	.	.
1974	40	20	19	19	18	16	15	7	1	.	.	.
1975	12	4	4	4	4	4	3	1	.	.	.	.
1976	29	14	13	13	12	12	12	6	.	.	.	.
1977	28	17	16	16	15	15	15	8	3	1	.	.
1978	153	86	72	72	61	61	55	18	3	2	2	.
1979	107	54	34	34	23	23	21	6	1	1	.	.
1980	82	56	55	52	50	47	39	14	4	3	1	.
1981	36	30	27	27	26	25	21	14	5	1	.	.
1982	37	18	14	14	14	13	11	1	.	.	.	.
1983	13	13	13	13	13	13	13	7	3	1	1	1
1984	13	8	7	6	6	6	6	3	.	.	.	.
1985	17	14	14	13	13	13	11	8	2	.	.	.

Table 4.

Strong earthquakes in Central Italy,

M ≥ 5,6, 1950-1985.

No	Date	φ°, N	λ°, E	H	Magnitude in [7]	[8]	
1	21. 8.1962	41,13	15,12	40	5,8	-	-
2	21. 8.1962	41,13	15,12	40	6,0	-	-
3	19. 7.1963	43,15	8,08	29	5,6	-	-
4	30.12.1967	44,80	12,05	35	5,8	-	-
5	23.11.1980	40,86	15,33	18	6,5	6,28	6,7
6	7. 5.1984	41,76	13,89	16	5,4	6,43	5,7

Table 5

The average time interval between strong earthquakes.

Central Italy.

M ≥	5,0	5,1	5,2	5,3	5,4	5,5	5,6	5,7	5,8	5,9	6,0
Years	1,1	2	2	2,3	2,5	3,5	5,7	7	9	9	17

Table 6

Strong earthquakes and Tips for Central Italy.

Start of	Strong earthquake		End of false	Duration of
	Date	M	alarm	Tip, months
1. 1.1958			1. 1.1959	12
1.11.1961	21. 8.1962	5,8;6,0		10
	19. 7.1963	5,6		failure to predict
	13.12.1967	5,8		failure to predict
1. 3.1972			1. 5.1975	38
1.11.1979	23.11.1980	6,5		13
1. 5.1984	7. 5.1984	5,7		0,1
1. 6.1984			1. 1.1986	18

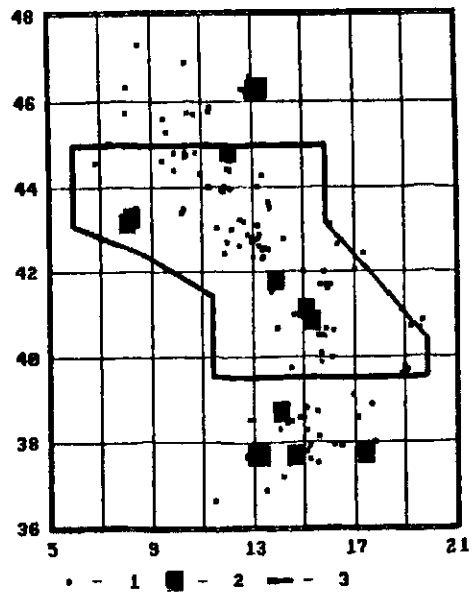

Fig.1 Region of Central Italy.

The boundarie are shown by solid lines.

1,2 - epicenters, 1950-1985, M ≥ 4,5 and M ≥ 5,6 respectively.

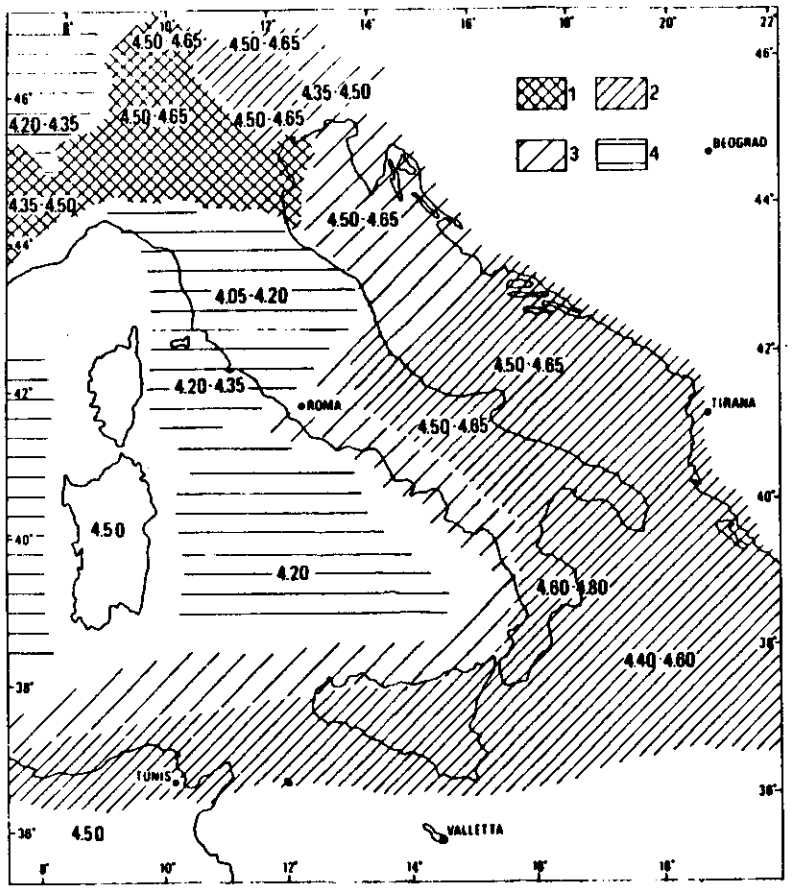

Fig.2.

Schematic regionalization of the elastic properties of the lithospheric sub-Moho layer, the ' lid', as deduced from surface wave dispersion analysis:

1. – lid thickness not exceeding 15 km;
2. – " " " " 45 km;
3. – " " " " 75 km;
4. – " " " " 105 km.

The numbers indicate the average S-wave velocity in the lid.

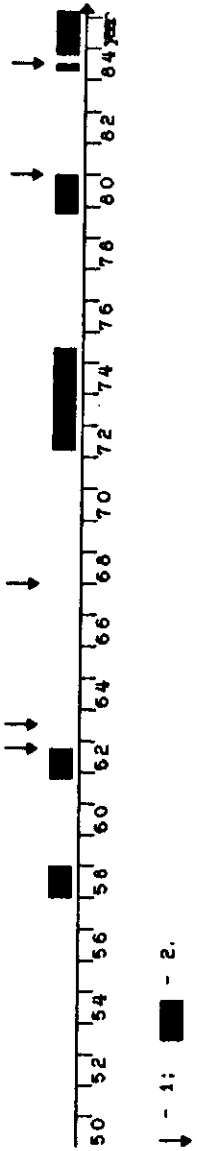

Fig.3 Tips and strong earthquakes.

1 - occurrence time of strong earthquakes; 2 - TIPs.