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DETERMINATION OF THE ATTENUATION MODEL FROM LOCAL AND REGIONAL EARTHQUAKES IN ALBANIA

EDMOND DUSHI [a], VALBONA LAME (MUDA) [b]
Geosciences Institute, Polytechnics University of Tirana [a]
Department of Physics, Physics and Mathematics Engineering Faculty, Polytechnics University of Tirana [b]

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PERMBLEDHJE

Sizmiciteti lokal dhe ai rajonal në Shqipëri monitorohet nëpërmjet instrumentimit me bandë të gjerë. Mungesa e një funksioni frekuencial të shuarjes për Shqipërinë çoi në përpjekjen për të përcaktuar një model të përshtatshëm bazuar në të dhënat BB dhe teknikat e mirënjohura spektrale. Në këtë studim, u aplikua metoda Coda(Q) duke përdorur programin Coda-Q, si pjesë e Sistemit Analizues Sizmik Seisan ver. 8.2.1. U përftua modeli i shuarjes në trajtën $Q(f) = Q_0\, f^{\alpha}$ ku Q_0 = 81 (±σ = 8), α = 0.84 (±σ = 0.08). Për një përcaktim më të mirë të gradientit vertikal janë marrë në konsiderat intervale të ndryshme të koheshtrirjes së sinjalit. Duke përdorur këtë model në të ardhmen, mund të përcaktohen me saktësi të kënaqëshme parametrat spektral për burimet sizmike (termetet).

SUMMARY

Local and regional seismicity in Albania is monitored through broad band (BB) instrumentation. The lack of a frequency dependent attenuation function for Albania leaded to efforts towards the determination of an adequate model based on BB data and well known spectral techniques. In this study, Coda (Q) method is applied using Coda-Q program, as part of Seisan ver. 8.1.2 seismic analysis system. Attenuation model of the form $Q(f) = Q_0\, f^{\alpha}$ is obtained where Q_0 = 81 (±σ = 8), α = 0.84 (±σ = 0.08). For a better determination of the vertical gradient, different lapse times are taken into account. Using this new attenuation model, a better determination of source parameters for local earthquakes in Albania, will be achieved.

Key words: coda wave, lapse time, quality factor, attenuation

INTRODUCTION

Attenuation properties of certain region define the way the seismic energy is spread out of seismic sources. It depends on the heterogeneity scale of the local geology, local topography and on physical properties of the medium (1). It is physically defined as the summation of the loss factors from intrinsic anelasticity and scattering.

Quantities expressing attenuation are the quality factor Q and anelastic-attenuation coefficient γ, used to describe this effect on seismic waves. These parameters are dependent on frequency and vary from place to place.

Instrumental seismology in Albania provided the bases for the attenuation properties study. Quality factor Q, was primarily estimated for northern Albania (2), and further on the mean anelastic attenuation coefficient γ is determined to improve the local magnitude scale used by ASN, (3). These studies were limited from the analogue recorded data and simplified computation techniques.

After the year 2000, the improvements through BB digital instrumentation utilization, insured application of modern analysis (6), on good quality digital recorded data.

The goal of this paper is to apply spectral methods on recent seismological data. We aim to determine a new frequency attenuation mathematical model to be used further in other spectral analyzes to correct for attenuation effect.

	Date			Time		Coordinates		Depth	No.	rms	Magnitude	Location
yy	mm	dd	hh	mm	ss	NS	EW	(km)			Mc	
2008	02	6	00	52	52,2	41,64	19,51	40	3	0,2	3,0	Gjiri Lalzit (det)
2008	02	16	00	43	16,7	40,36	19,99	0	2	0,2	3,3	Zhulaj
2008	03	5	04	08	22,1	39,93	19,50	38	3	0,0	4,1	Deti Jon
2008	03	5	06	48	14,9	40,20	19,83	5	3	0,1	4,2	Palase
2008	03	6	06	46	24,9	40,20	19,75	5	3	0,0	4,1	Palase
2008	03	31	08	06	49,7	41,27	21,05	40	4	0,2	3,5	Elbasan
2008	04	8	07	37	26,9	40,14	19,95	3	3	0,5	3,8	Borsh
2008	05	14	19	17	57,2	41,08	20,40	40	3	0,2	3,9	Elbasan
2008	05	15	23	52	17,8	41,39	19,69	12	3	0,5	3,4	Vore
2008	05	18	22	49	06,2	41,76	19,74	40	4	0,9	3,1	Shengjin
2008	05	21	19	04	21,2	40,83	19,57	40	4	0,1	3,9	Divjake
2008	05	27	00	44	04,0	41,99	19,86	38	3	0,1	3,7	Puke
2008	05	29	13	39	24,1	42,28	19,96	15	3	0,3	3,1	Lekbibaj
2008	05	30	20	40	47,1	41,63	19,37	35	3	0,4	3,1	Ulqin
2008	05	31	11	42	46,7	41,64	20,02	16	3	0,1	3,7	Burrel
2008	06	2	08	05	48,7	41,61	20,48	5	3	0,5	3,6	Bulqize
2008	06	25	18	05	29,7	41,43	19,50	30	4	0,7	3,8	Jube
2009	01	8	12	04	05,4	41,86	20,65	10	6	1,3	5,0	Gostivar
2009	01	31	12	19	41,9	40,37	19,68	0	5	0,4	4,0	Selenice
2009	02	28	17	36	29,7	41,50	19,57	5	5	0,6	3,4	Jube
2009	03	7	18	51	19,7	41,18	19,50	11	5	0,3	4,3	Hajdaraj
2009	03	9	00	30	12,4	41,94	20,07	20	4	0,9	3,4	Dom Gjon
2009	03	10	08	32	56,1	41,21	20,52	8	4	0,8	3,8	Gezavezh
2009	03	10	22	10	29,9	41,32	20,44	5	4	0,7	3,5	Gezavezh
2009	03	11	02	48	48,3	40,11	19,43	40	4	0,1	4,7	Palase
2009	03	12	18	55	46,9	41,35	20,06	15	5	0,6	3,4	Shkalle
2009	03	18	16	20	37,5	41,14	19,96	12	5	1,0	4,2	Kavaje
2009	03	19	15	37	29,1	42,99	18,84	40	4	0,6	3,6	Mal i Zi
2009	03	25	12	23	25,9	40,17	19,82	40	4	0,2	4,7	Palase
2009	03	30	19	48	50,1	41,10	19,63	10	4	0,9	2,8	Rrogozhine
2009	04	1	07	28	59,4	40,99	19,67	38	4	1,3	2,8	Vidhaz
2009	04	2	05	45	20,5	41,09	19,61	15	4	1,0	3,3	Gjiri i Durresit
2009	04	6	00	31	28,2	41,47	19,14	18	4	0,6	3,8	Deti Adriatik
2009	04	7	13	49	50,9	41,44	19,48	20	3	0,1	3,8	Gjiri Lalzit
2009	04	7	16	00	31,4	41,43	19,57	25	3	0,3	3,5	Koder
2009	05	21	12	11	02,2	41,05	20,50	5	5	1,0	3,4	Perrenjas
2009	05	21	13	26	06,0	41,04	20,45	13	5	0,6	3,4	Perrenjas
2009	06	4	22	36	12,5	40,07	19,83	5	7	0,9	3,2	Himare
2009	06	5	21	32	59,6	41,94	20,11	17	3	0,2	3,5	Spaç (Burrel)
2009	06	12	10	12	35,2	42,01	20,07	26	3	0,1	2,3	Thirre
2009	06	14	05	12	52,6	41,45	19,74	15	7	0,8	3,0	Kashar (Tirane)
2009	06	15	14	43	07,8	39,89	19,74	38	7	0,2	3,4	Ftere(Sarande)
2009	06	20	10	21	09,8	41,29	19,98	48	4	0,1	3,0	Elbasan
2009	06	20	17	00	10,3	41,16	20,17	11	4	0,9	3,1	Kuturman
2009	06	21	06	07	32,7	41,40	20,16	0	4	0,6	2,7	Elbasan
2009	06	21	17	35	05,3	41,20	20,22	10	4	0,4	3,3	Elbasan
2009	06	21	19	05	16,3	41,22	20,20	10	4	0,3	3,5	Elbasan
2009	06	24	02	24	32,9	41,69	19,90	5	4	0,5	2,5	Ulez
2009	06	24	03	28	55,1	41,74	19,44	38	5	0,7	3,3	Deti Adriatik
2009	06	27	00	45	10,1	41,18	20,27	3	5	0,4	3,4	Elbasan
2009	06	27	23	24	40,5	40,61	19,17	38	7	1,0	3,2	Visoke
2009	09	6	21	49	41,9	41,50	20,43	5	6	0,5	5,5	Gjorice*
2009	09	15	08	37	40,1	41,14	19,52	5	6	0,6	4,3	Synej
2009	09	17	22	53	06,9	39,84	20,20	5	5	0,4	4,3	Piqeras
2009	11	11	03	43	30,4	40,09	20,28	77	5	0,1	4,1	Memaliaj

Table 1. Earthquake used in Coda Q single way backscattering analyze.

MATERIALS AND METHOD

A number of 55 earthquakes with local magnitudes in the interval 2.3-5.5, recorded by Seismological Network of IGJE-o (Institute of Geosciences) during 2008-2009 are used in this analyze, (Tab 1). Since 2003, ASN operates a VSAT telemetry network equipped with 7 BB sensors, (Fig 1).

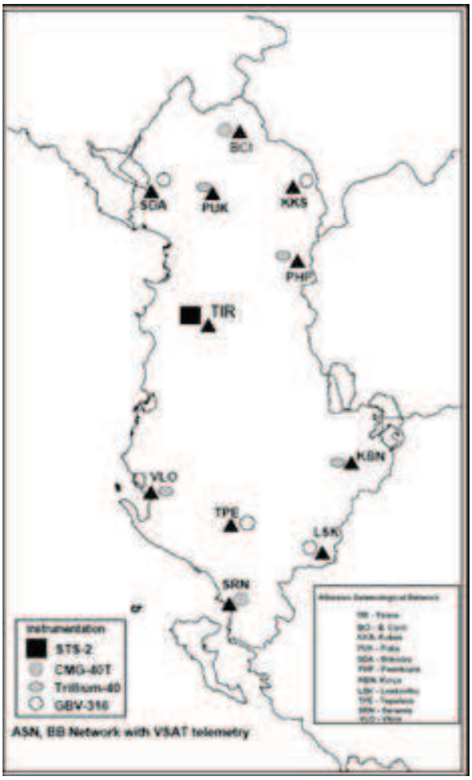

Figure 1. Albanian Seismological Network

Frequency response of these sensors is flat in the frequency range 0.033Hz - 40 sec. Data were digitized with 100 Hz sampling rate. Only events with minimum SNR are accepted and computed with Seisan 8.1.2, (6). Earthquakes are located inside the area confined between 38.0-43.0N and 19.0-21.0E (Fig 2), with focal depths between 0-70 km. Only seismic events recorded from more than 2 seismological stations with RMS values in the interval 0-1.3 sec, are considered. To perform this analyzes, Coda (Q) method is applied, as a standard spectral method (5). Coda waves compose the later part of a local or regional earthquake seismogram.

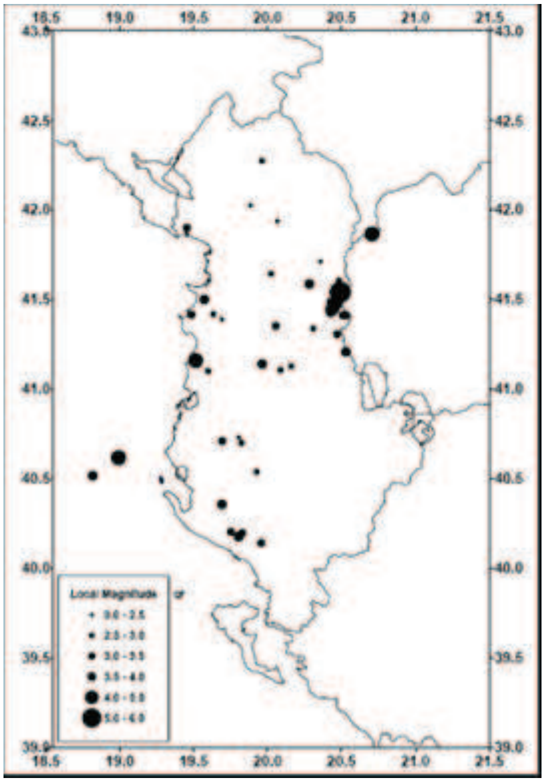

Figure 2. Earthquake epicenter distribution

The decay of these waves provides a quantitative estimate for attenuation, widely referred to as Coda Q (Q_C). The decay of coda is due to geometrical spreading, intrinsic attenuation and scattering. These effects are connected to properties of the medium and local geology. As anomalies decrease with the depth inside the earth, less attenuation is observed and greater values of Q_C are achieved. Coda spectrum of small and moderate earthquakes depends only on the lapse time from origin. It has no dependence on the size of the event and path characteristics due to an average scattering effect of the medium between hypocenter and recording site. It was proposed a single backscattering model explaining coda as superposition of secondary waves from randomly distributed heterogeneities, (5). Coda amplitude, decrease with lapse time at different frequencies. In general cases, Q increases with frequency, following the relation:

$$Q = Q_0 \left(\frac{f}{f_0}\right)^{\alpha}$$

Here, Q_0, is the quality factor at the reference frequency f_0 (generally f_0 = 1 Hz) and α is the frequency parameter close to 1, varying from region to region depending on the heterogeneities of the medium. Hence, the seismic data are first band-pass filtered in order to calculate the attenuation. We have taken in consideration the Coda of S-Waves, as dominant phases at local and regional distances recorded from ASN. The amplitude of S-Coda at lapse time *t* from the origin of the event, for a band-pass filtered seismogram at a central frequency *f*, is related to the attenuation parameter Q by the following equation:

$$A(f,t) = K(f) \cdot t^{-\beta} \cdot e^{-\pi f t / Q_C}$$

$K(f)$, is the coda source factor at frequency *f*, which is independent of time and radiation pattern, β is the geometrical spreading parameter equal to 1.0, 0.5 and 0.75 for body waves, surface waves ore diffusive waves respectively (5), $Q_C(f)$, is the quality factor of coda waves. As S-Coda waves are backscattered body waves, β=1.0 and the equation above takes the form:

$$\ln A(f,t) = \ln K(f) - \ln(t) - \frac{\pi f}{Q_C(f)} t$$

$$\ln(A(f,t)t) = \ln K(f) - \frac{\pi f}{Q_C(f)} t$$

From above, $Q_C(f)$ can be determined from the slope ***b*** of the strait line of least-squares regression between $\ln(A(f,t)t)$ with t, using the relation: $Q_C(f) = \pi \cdot f / b$.

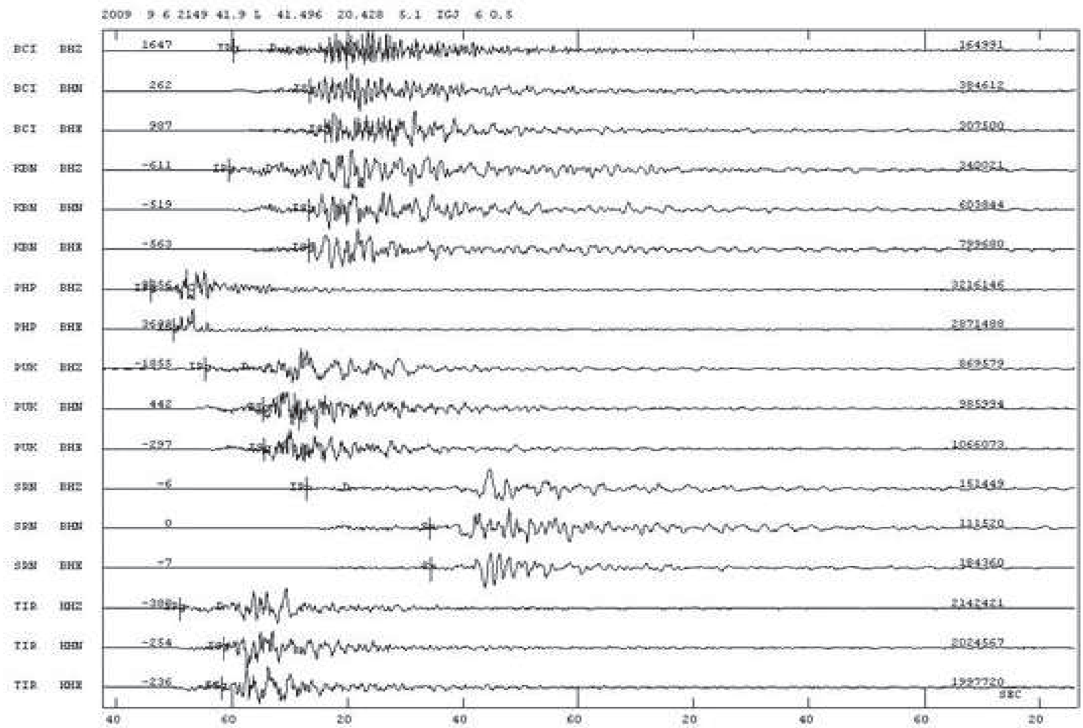

Figure 3. BB recordings for September 6, 2010 at 21:49 (GMT) earthquake, (M=5.5) ate NE Albania.

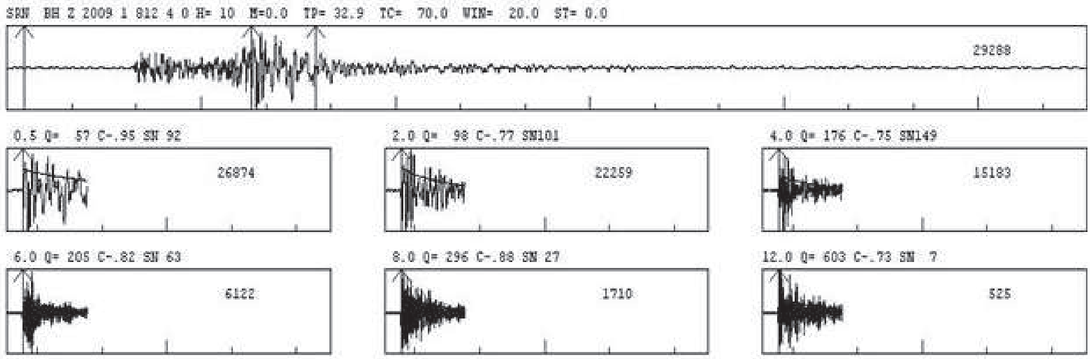

Figure 4. Band-Pass filtered wave forms, for vertical component of event 20090108_12:04 of SRN station, at different filter bands and center frequencies

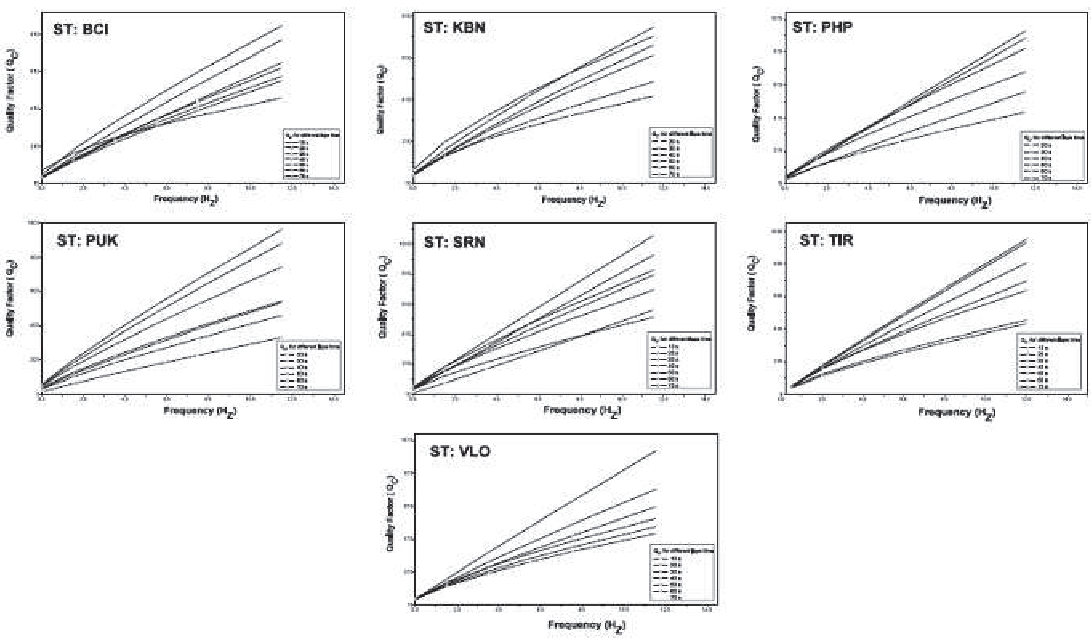

Figure 5. Attenuation curves ploted for Q=Q(f), for different laps time values in the interval 10-70 s, for each of the 7 BB station of ASN.

RESULTS AND DISCUSSION

Coda-Q routine, implemented in Seisan ver. 8.2.1 analyzing system (4) has been used for analyze. All the selected seismograms, as shown in the example of Figure 3, are band-pass filtered at central frequencies f_C: 0.5, 2.0, 4.0, 6.0, 8.0 and 12.0 Hz, (Fig. 4). The average results, for achieved Q_C values, are listed in (Tab. 2).

Attenuation curves showing the frequency dependent variation of Q_C, for different lapse times are plotted in Figure 5. We have used 7 different lapse times in the range 10-70 s, with a step of 10 s, in order to reveal the variation of the quality factor with depth and thus the attenuation model. This model is expressed by $Q_C = Q_C(f)$ functions, determined for each of the cconsidered stations. A clear uniform increase of the Q_C value with frequency is achieved, as it was expected from theoretical considerations, mention above. The increase of the quality factor with depth is due to the decrease of heterogeneities passing to a more isotropic medium, though a soft variation at different frequency bands taken throughout all lapse times is present, for which we think is mainly due to the lateral heterogeneities. Coda-Q routine is used to calculate the average Q_C function with frequency, for each recording points, where mean Q_0, α and their confidence intervals are calculated averaging both E-W and N-S components.

Lapse Time (sec)	0.5 Hz (0.25-0.75) Q_C ±σ	2.0 Hz (1.25-2.75) Q_C ±σ	4.0 Hz (2.75-5.25) Q_C ±σ	6.0 Hz (4.25-7.75) Q_C ±σ	8.0 Hz (5.75-10.25) Q_C ±σ	12.0 Hz (9.25-14.75) Q_C ±σ
10	42(2)	110(7)	185(11)	253(14)	317(18)	438(24)
20	45(3)	127(9)	215(15)	293(20)	365(26)	500(35)
30	48(4)	141(13)	244(22)	337(30)	424(38)	587(53)
40	47(2)	150(7)	270(12)	382(18)	488(23)	555(23)
50	49(3)	161(9)	293(17)	417(24)	536(31)	764(45)
60	51(3)	164(9)	296(18)	418(26)	535(33)	754(47)
70	57(6)	165(18)	287(31)	398(43)	504(55)	704(76)

Table 2. Average QC at different frequencies and lapse times

Stat.	$\overline{Q_0}$ – interval	Q_0 ±σ	α- interval	$\overline{\alpha}$ ±σ
BCI	72-119	87(4)	0.5-0.9	0.84(0.03)
PUK	33-108	75(2)	0.81-0.93	0.84(0.02)
PHP	62-98	81(5)	0.75-0.98	0.84(0.04)
TIR	67-92	83(4)	0.75-0.94	0.84(0.03)
KBN	85-128	96(8)	0.6-0.83	0.84(0.06)
SRN	41-109	84(8)	0.77-1.06	0.84(0.05)
VLO	76-87	81(8)	0.71-0.96	0.84(0.08)

Table 3. Parameters of $Q_C = Q_0 f^{\alpha}$ attenuation function

Results are listed in Table 3 and graphically plotted in Figure 6. In average, due to small range variation of Q_0 values for all recording sites and a constant frequency term, we can approximate the attenuation effect by the frequency attenuation function Q_C = **81**[$f^{(0.84)}$]. As conclusion, Coda (Q) method applied on waveforms in a wide frequency range, 0.2-15 Hz, determines the frequency attenuation function for Albania; Analyzing different increasing lapse times for each reference frequency, depth attenuation structure is determined, giving information on the lateral heterogeneities and complex geological structure of the crust in our country; Averaging Q_0 and α a mean attenuation function as shown above can be achieved to be 7. accurately used in further spectral computation to correct for the attenuation effect on the recorded seismological data from ASN.

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