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Long period channel waves from records of Friuli (Italy) earthquakes in 1976

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Abstracts

We present a study of a group of long period waves excited by the earthquakes of Friuli (Italy) in 1976 and recorded between longitudinal and transverse body waves by Long-period seismographs at epicentral distances up to about 3 000 Km. The spectral analysis has permitted us to determine periods of the main phases which make up the wave group. In regard to the longer period phase, which appears first in the recordings, the velocity obtained by the dromochrones equals 8.4 Km/s. The group velocity is instead 7.4 Km/s. Such phases have been considered as being longitudinal channel waves in the astenosphere. Such hypothesis explains the inconsistencies which had appeared in previous studies on channel waves in the astenosphere.

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Riassunto

Presentiamo lo studio di un gruppo di onde a lungo periodo originate dal terremoto del Friuli (Italia) nel 1976 e registrate tra le onde longitudinali e le trasversali da sismografi L.P. a distanza epicentrale di circa 3000 km.

L'analisi spettrale permette di determinare i periodi della fase principale del gruppo d'onda.

Per quanto riguarda la fase a più lungo periodo, che appare prima nelle registrazioni, otteniamo dalle dromocrone una velocità pari a 8.4 km/sec.

La velocità di gruppo è invece 7.4 km/sec.

Tali fasi sono considerate come onde longitudinali canalizzate nell'astenosfera. Questa ipotesi elimina le difficoltà apparse nei precedenti studi sulle onde canalizzate.

Introduction

The longitudinal channel waves in the astenosphere (P_a) were discovered for the first time by Caloi (1953). Further results on the subject have been presented for example, by Caloi (1954, 1965), Gutenberg (1953, 1959, 1959), Khorosheva-Magnitsky (1961), Guidroz-Baker (1963).

These waves, with periods in the range between 5 s and 20 s, have been observed between longitudinal and transverse body waves on seismographs recorded at epicentral distances between 3 000 - 15 000 Km, for earthquakes at focal depth of not over 250 Km.

The velocity by the dromochrone is 8.0 - 8.3 Km/s.

An aspect of the channel waves which still causes concern is the minimum epicentral distance (3 000 km) where such phase was observed. If the ideal condition for channeling is represented by the fact that the energy is supposed to be let in the layer parallel to its limiting surfaces (or at least with such inclination as to force it to rythmically return within the layer), then, for normal earthquakes, channel waves should be observed even at

those distances where body waves P_n are clearly detected, thus much closer than 3,000 Km.

Another aspect of the results raises perplexities. In fact the velocity of the P_a waves should be equal the minimum velocity within the channel. Presently such value, relative to earth models (Haddon-Bullen, 1969; Mizutani-Abe, 1972; Press, 1970), based on new information obtained by the observations of free oscillation is indicated at 7.7 Km/s. Whereas, the velocity values (8.0 - 8.3 Km/s) obtained in the studies above mentioned on the channel waves are systematically higher.

Caloi (1965) was aware of this discrepancy and corrected the values obtained from the dromochrones and considered them as values of apparent velocity. Such correction, which is — 0.2 Km/s for a minimum at a depth of 150 Km, alothough it reduces the discrepancies, does not solve such discrepancy completely. Furthermore, the initial hypothesis which is the basis of the correction is not fully justified unless one admits the existence of a sloping channel.

Herein we intend to assume P_a is a group of long period waves, which so far has not been examined, and to study those excited by the 1976 Friuli earthquake which were recorded by L.P. seismographs at stations with epicentral distance up to about 3,000 Km, shortly after the P_n and before S_n.

PRINCIPAL CHARACTERISTICS OF THE WAVES

The stations whose recordings have been used as well as the epicentral distances are given in table 1.

Figure 1 shows some of the seismograms which have been recorded following the earthquake of 6/5/1976 at Athens and Ponta Delgada stations, at a distance of 1,250 Km and 3,300 Km respectively. In the first case, shown in figure 1 a, these waves are clearly marked whereas in the second case, shown in figure 1 b, their amplitude appears considerably reduced.

The initial part of the recordings (preceeding the S phase) obtained at some stations for the same earthquakes has been digitized.

TABLE 1

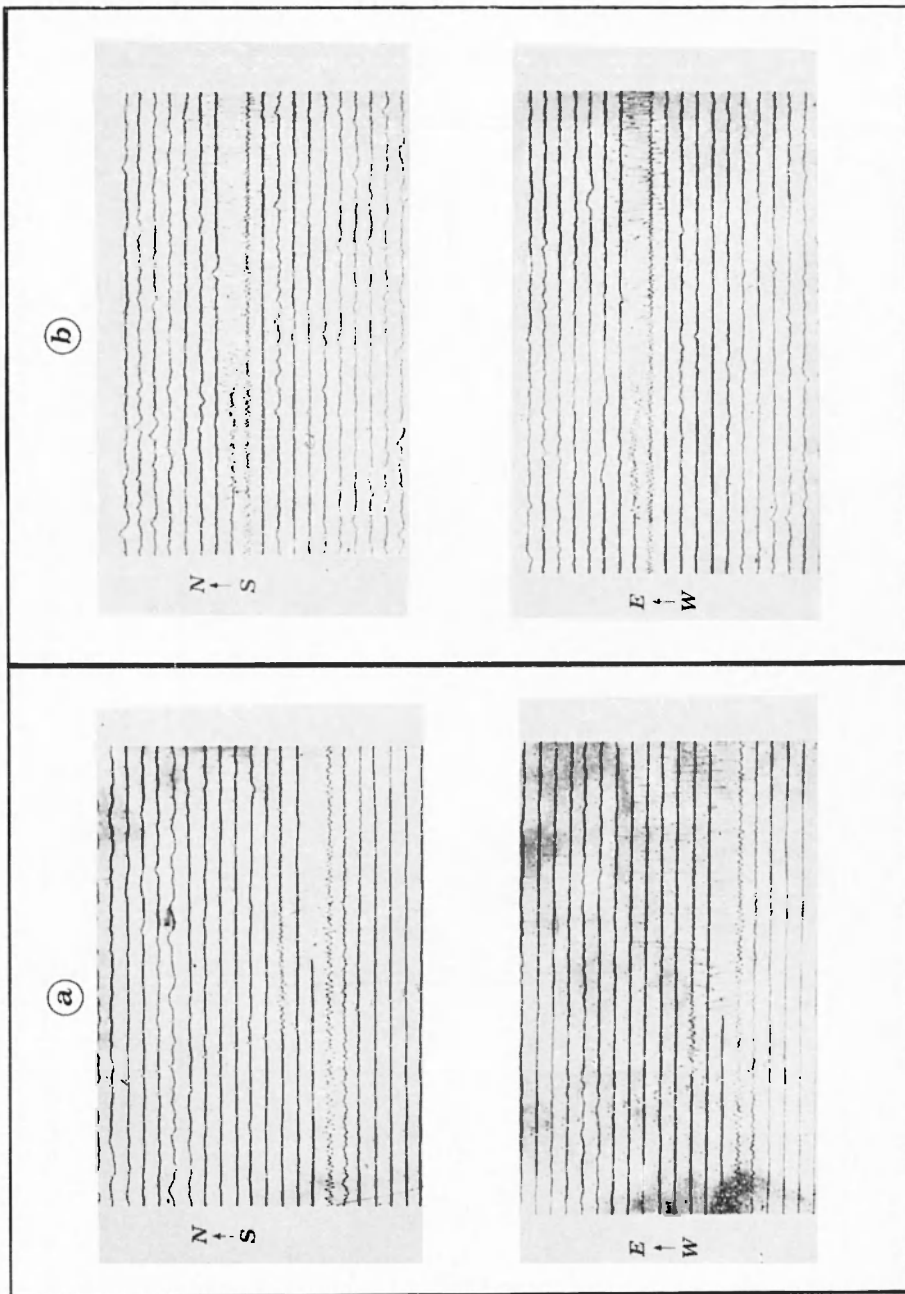| EARTHQUAKE	SEISMIC STATION	Δ (Km)
Sept. 15th, 1976	Moxa	500
H = 03.15.19	Krakow	660
	De Bilt	870
φ = 46°16'36"	Uppsala	1540
λ = 13°08'27"	Eilat	2650
M = 6.1		
Sept. 15th, 1976	Krakow	650
H = 09.21.18	De Bilt	870
	Uppsala	1530
φ = 46°20'42"	Kajaani	2180
λ = 13°10'26"	Eilat	2660
M = 6.0		
May 6th, 1976	Gottingen	630
H = 20.00.15,5	Uzhgorod	740
	De Bilt	870
φ = 46°16'30"	Lvov	910
λ = 13°06'00"	Athens	1270
	Kongsberg	1510
M = 6.4	Eskdalemuir	1520
	Nurmijarvi	1760
	Valentia	1810
	Porto	1830
	Pulkovo	1890
	Sochi	2110
	Kajaani	2190
	Eilat	2660
	Kevo	2730
	Ponta Delgada	3310

Figure 1 - Friuli earthquake of 6/5/1976. Initial part of the recordings of the horizontal components at the seismic stations of:
    a) Athens (△ = 1250 Km);
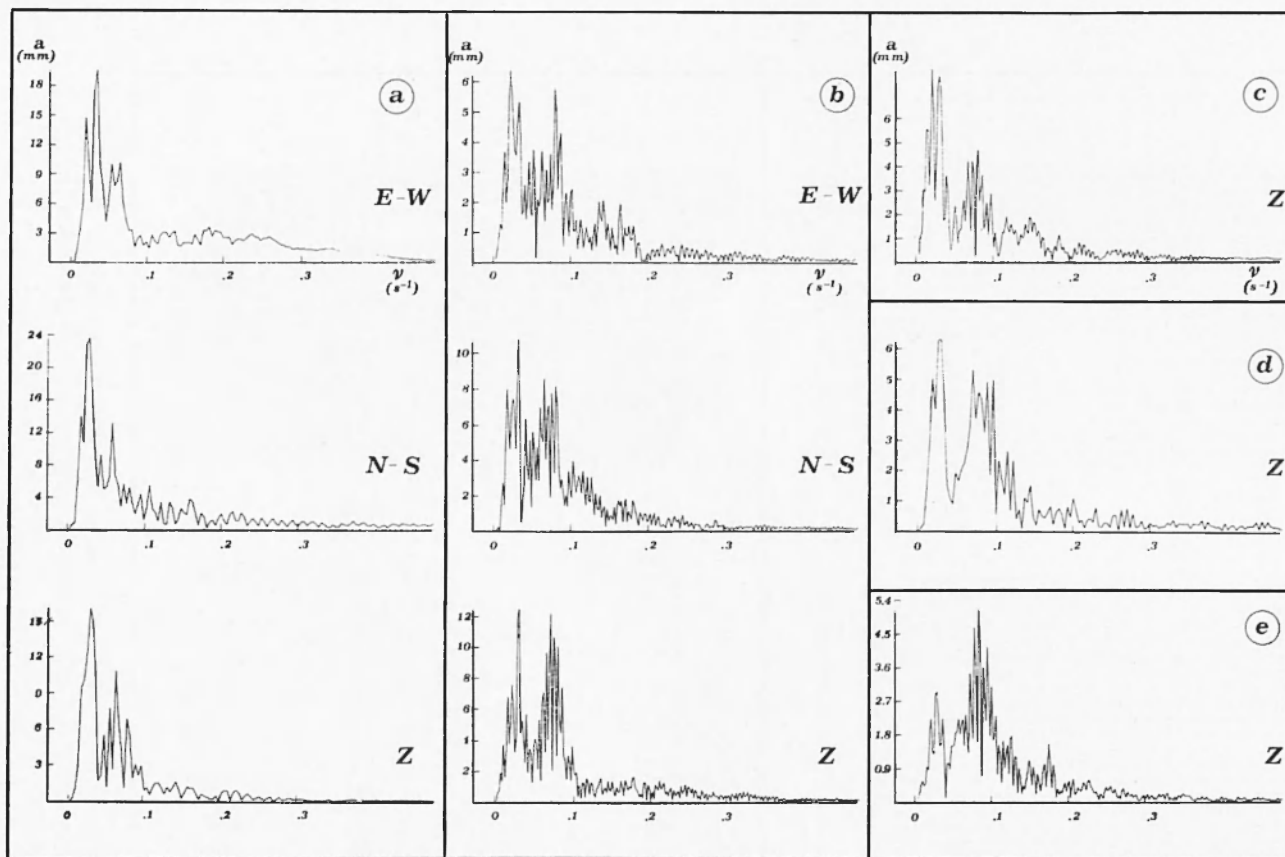   b) Ponta Delgada (△ = 3300 Km).

Figure 2 - Fourier transforms of the part preceeding phases S of the recording obtained at some seismic stations for the same earthquakes. The ordinate shows the recorded amplitude.

a) Athens (ATH), earthquake of 6/5/1976;
b) Nurmijarvi (NUR), earthquake of 6/5/1976;
c) Eskdalemuir (ESK), earthquake of 6/5/1976;
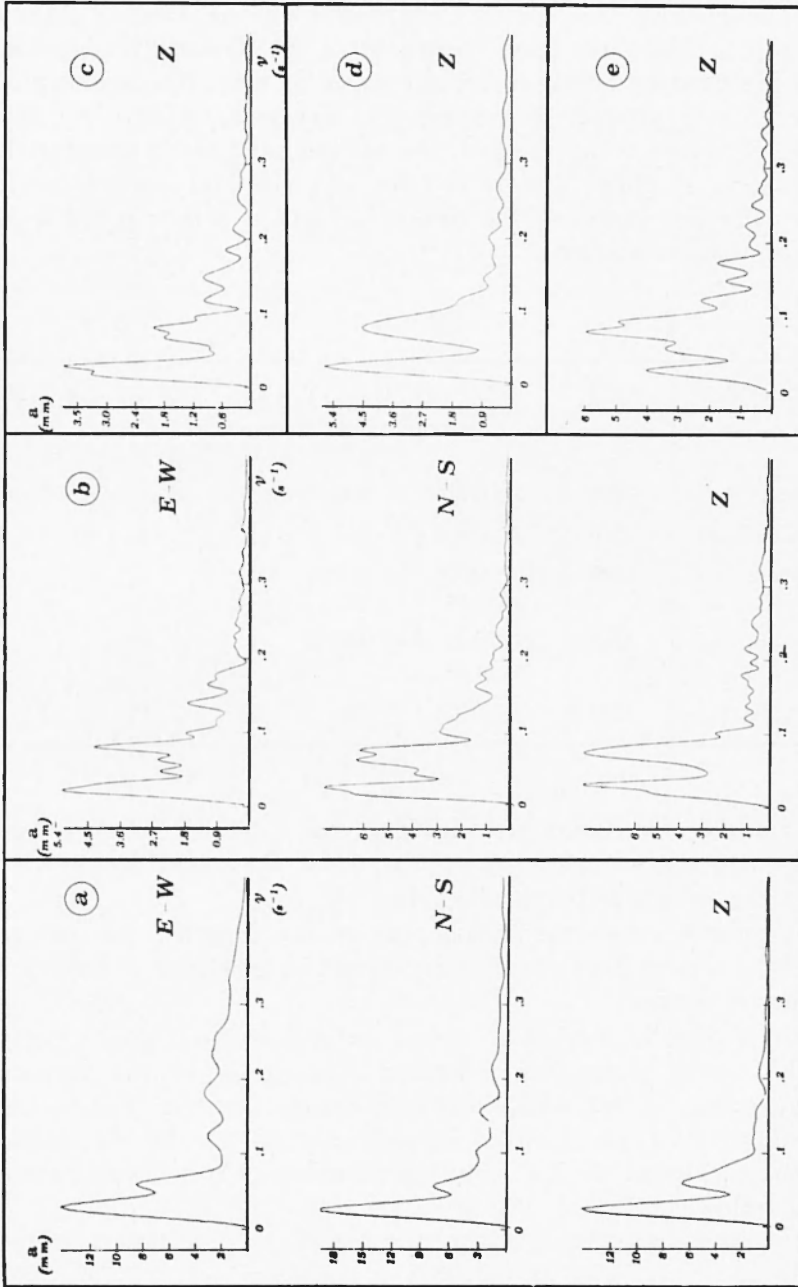d) and e) Uppsala (UPP), earthquakes of 15/9/1976 ($H = 03.15.19$ and $H = 09.21.18$).

Figure 3 - Smoothing of the spectra shown in Figure 2.

The Fourier transforms carried out on the data is shown in figure 2. The smoothing (figure 3) of the spectrum, obtained with the Ormsby (1961) filter, allows us to mark the separation between two groups of frequencies, the first, relative to the group of waves being studied, the second relative to the initial, lingitudinal P_n phase. The mean value of the period T corresponding to the first group of the smoothed data is shown in table 2, for the various stations.

TABLE 2

Seismic Station	Δ (Km)	Earth-quake	T (s)	T_1 (s)	T_2 (s)	T_3 (s)
Athens	1270	6/5/1976	40	51	37	/
Eskdalemuir	1520	6/5/1976	35	51	37	/
Uppsala	1540	15/9/1976 03.15.19	35	51	37	/
Uppsala	1530	15/9/1976 09.21.18	35	51	37	28
Nurmijarvi	1760	6/5/1976	29	57	43	30

Table 2 also shows periods T_1, T_2 and T_3 of the single waves composing the groups; they appear to be the main elements of the group of waves being studied.

Figure 4 shows the initial part of the digitized recordings which have been filtered in the frequency range which determines the waves group.

It is also important to obtain information on the velocity of the waves group being studied. The study of the various seismograms has allowed us to note clearly that the time of the first arrival of such waves is proportional to the epicentral distances (Figure 5). The resulting equation of the dromochrone is as follows:
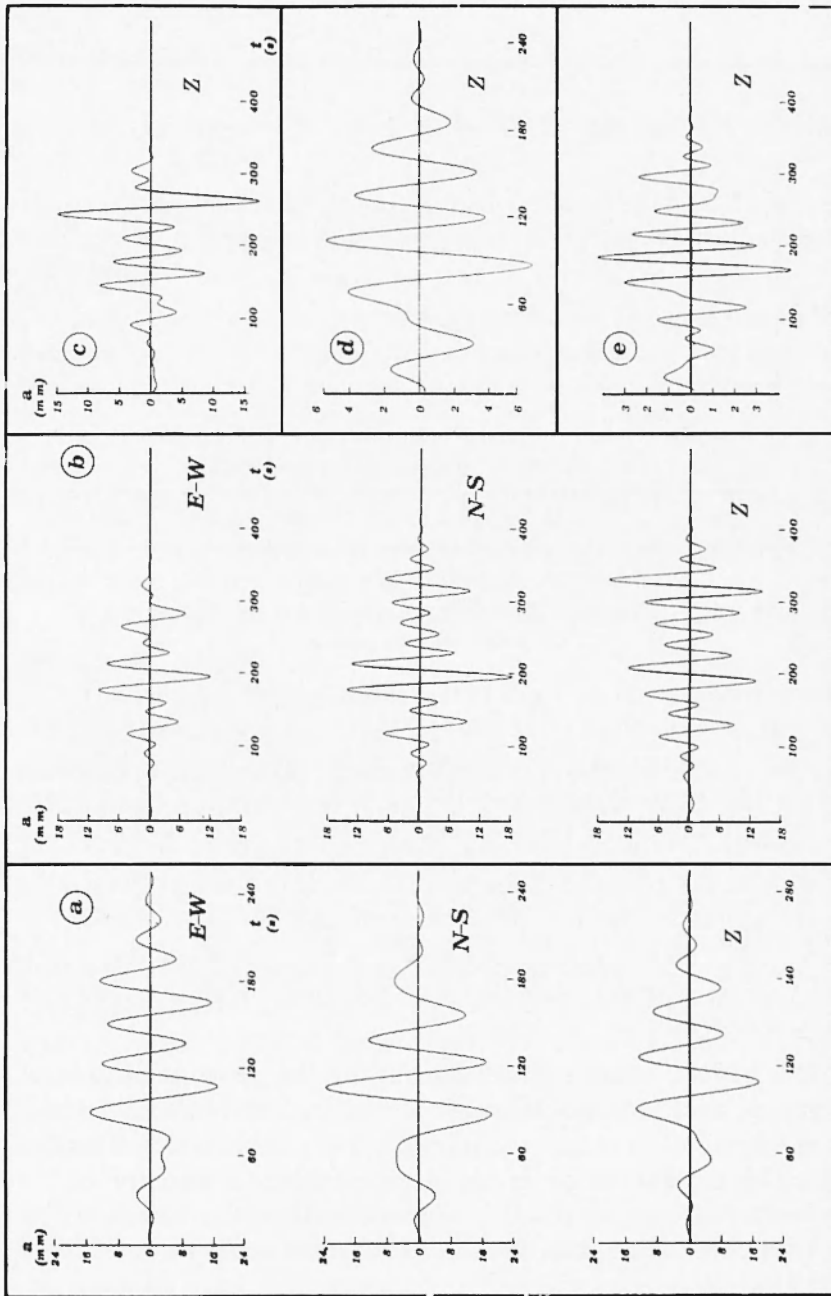
$$t = 0.2196\,\Delta + 0.6335 \qquad [1]$$

Figure 4 - Temporal filtered pattern of the wave group being studied as it appears in the istances as of Figure 2.
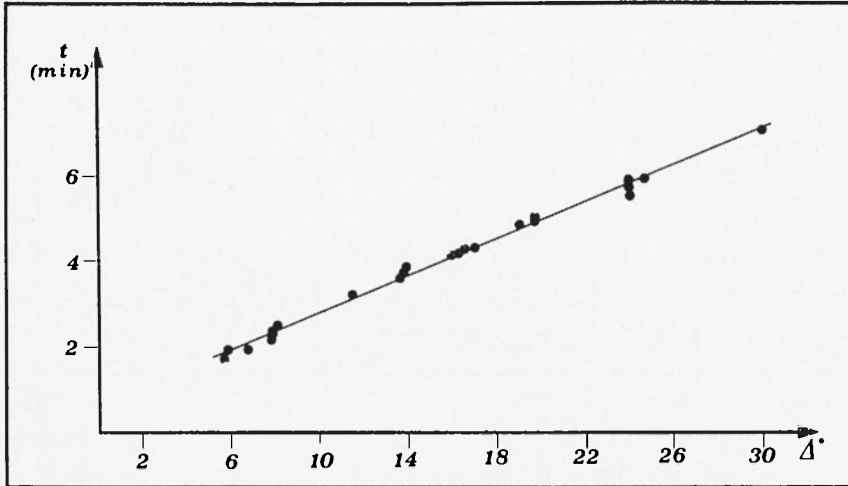
Figure 5 - Observed time-distance curve for the longer pe-
riod phase of the group.

where Δ represents the epicentral distance (expressed in degrees) and t is the time (expressed in minutes). The differences between the experimental values and the corresponding ones given by [1] are at most 0.3 min. The main cause of the scattering of the results can be found in the fact that even though the waves group is clearly singled out in seismograms, the first phase in the group is not often distinct. Relation [1] implies a phase velocity of (8.4 + 0.1) Km/s.

We have also considered the maximum wave amplitude of the group; we have utilized only the digitized and filtered seismo-grams (figure 4) in order to obtain homogeneous and significative data. The arrival times of the maxima give a velocity of 7.4 Km/s. It must be pointed out however, that the data are few for a reliable evaluation, therefore this value must be considered tentative.

CONCLUSIONS

The characteristics of the waves group under study have resulted as follows:

a) the group of waves is well detectable in all three components of the recording at epicentral distances between 400-3 000 Km;

b) there are three principal phases of the group and their periods are in the range 57-28 sec, with negligible variations with the azimuth and the distance of the station;

c) the group velocity appears to be 7.4 Km/s, while the phase with greater period, which appears first, has a velocity of 8.4 Km/s;

d) the amplitude of the phase with shorter period seems to increase as the epicentral distance increases.

Groups of waves with these characteristics have not been interpreted yet.

The velocity values indicate that these waves are longitudinal. We feel that they are being longitudinal waves channeled within the astenosphere. Therefore the phases which have been examined seem to be the expression to little epicentral distances of such channeled waves, which have been studied by other authors.

In conclusion, the low velocity channel which is responsible for the channeling seems to include waves with period from 60 sec to a few seconds; the energy seems to gradually move to higher frequencies as the epicentral distance increases. The latter phases, which are imperceptible (at the closer stations) compared to those at a longer period as the examined recordings shows, have been marked in previous studies on the subject whereby the analysis has been made in regardings at greater epicentral distances.

It is worthwhile pointing out that we have hereby obtained in regard to the P_a considered as wave group, a velocity value which is not greater than the minimum value in the astenosphere, contrary to what had appeared in the preceeding studies.

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