UPPER CRUST P-WAVE VELOCITY IMAGING UNDERNEATH THE CENTRAL PART OF FRIULI-VENEZIA GIULIA REGION, NORTHEASTERN ITALY

İTALYA'NIN KUZEYDOĞUSUNDA FRIULI-VENEZIA GIULIA BÖLGESİNİN ORTA KESİMİNİN ÜST KABUK P-DALGA HIZININ GÖRÜNTÜLEMESİ

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ABSTRACT: The Method of Simultaneous Inversion is applied to the first arrivals of P-waves recorded by the Friuli-Venezia Giulia Regional Seismic Network for the period of 1984-1988. Three-dimensional(3D) P-wave velocity structure underneath the very complex structure dominated by normal and thrust faults is investigated. Inversion of the 2276 P-wave first arrivals produced a 3D velocity model with grid spacing laterally at the distance of 10 kms in the 60 km by 60 km area and vertically at five depth levels with 3km intervals. As result, the velocity reversal at the depth of 3 kms is related to terrigeneous sediments unit with the velocities of 5.0-5.3 km/sec at the northern part of the investigated area. About 4.7 km/sec velocity reversal due to thickening of flysch and molasse deposits at the southeastern part of the area and the high surficial velocity thereabout 5.7 km/sec at the northern part of Gemona are consistent with the negative and positive Bouguer gravity anomalies respectively.

Key Words: Simultaneous Inversion, 3D velocity imaging, upper crust, refined earthquake location.

ÖZ : Friuli-Venezia Giulia Bölgesi Sismik Örü Ağı tarafından 1984-1988 yılları arasında kaydedilen P-dalgası ilk varışlarına Eş Anlı Ters Çözüm uygulandı. Normal ve ters faylarla kesilen çok karmaşık bir yapı altında 3 Boyutlu P-dalga hızı yapısı araştırıldı. 3 boyutlu hız dağılımı, 2276 P-dalgası ilk varışlarının ters çözümü ile yüzeyde 10 km aralıklarla 60km x60km lik bir alanda ve düşey olarak 3km aralıklı 5 derinlik arayüzeyinde tanımlanan grid noktalarında araştırıldı. Sonuçta, çalışma alanının kuzey kesiminde 3km derinlikte 5-5.3km/sn hızlarla terrigeneous sedimanların yol açtığı hız terslenmesi gözlendi. Çalışma alanının Güneydoğusunda filiş ve molas depozitlerinin kalınlaşmasından doğan 4.7km/sn hızlı bir alan ve Gemona'nın yaklaşık kuzeyinde yüzeyde 5.7km/sn 'e ulaşan yüksek hızlar negatif ve pozitif Bouguer anomalileri ile uyum göstermektedir.

Anahtar Sözcükler: Eş-Anlı Ters Çözüm, 3-Boyutlu hız görüntülemesi, üst kabuk, iyileştirilmiş deprem lokasyonu.

INTRODUCTION

In the last decade, tendency is increased in the field of Seismology to investigate the crustal structure by using the data obtained from the locally dense seismic network in seismically active areas to satisfy the needs for covering the lack of the knowledge of the lateral heterogenity of the crust.

One of the approaches for exploring the velocity structure of the crust by means of such data is the use of Method of Simultaneous Inversion(MSI). This method provides the determination of earthquake locations and velocity structure of the crust simultaneously. The MSI was first applied by Crosson(1976), Aki and Lee(1976), and Thurber(1983) extended the method to one that calculates the P-wave velocity structure by using three-dimensional ray tracing iteratively and using the parameter separation (Pavlis and Booker,1980) in the inversion. Thurber(1983)'s approach is used in this study. The subject of this study is the application of MSI to events occurred in the Friuli-Venezia Giulia area which is characterized by a complex velocity structure and shaped by normal and thrust faults. We searched the refined locations of earthquakes and 3-D P-wave velocity structure by means of three-dimensional ray tracing using the data detected by the Friuli-Venezia Giulia Network.

Systematic influences can be introduced into the earthquake locations if the assumed velocity model differs significantly from the "true" earth structure as much as the earth's structure is still not known practically (Engdahl and Lee, 1976). We desire to use the P-wave arrival times to exploit the information about the earth's structure in order to improve the location of earthquakes. The MSI could clarify the hidden velocity structure if proper data and initial velocity model are used.

In the following, firstly the methodology of the way of velocity determination and the geodynamic characteristics of the area are given, then, the application of method for velocity imaging with refined hypocenter is outlined.

THE METHODOLOGY

There are several steps in the application of MSI. One of them is the selection of a suitable data set to obtain a reasonable ray path coverage in the area. Other steps are the selection of the initial velocity model, and the way of describing the velocity structure and the ray tracing algorithm. All of these steps are effective on the quality of solutions. There exist different approaches to describe the seismic velocity structure in the application of MSI. These approaches can be summarized as;

- using constant velocity layers (Crosson, 1976),
- using a large number of constant velocity blocks (Aki and Lee, 1976),
- using variably sized "ideal averaging volumes" (Chou and Booker, 1979),
- using defined velocity at a large number of "discrete points", in three dimensions; instead of a large number of blocks and describe the velocity between grids with linear B-spline function(Thurber, 1983),
- using the velocity defined at discrete points like Thurber(1983) but describe the velocity between grid nodes by cubic B-spline function(Michelini and McEvilly, 1991).

In this study Thurber(1983)'s approach has been used. The velocity is described in grid nodes and the velocity between the grid points was found by using the interpolation function. To calculate the velocity at a given point(x,y,z) an interpolation function is used,

$$V(x,y,z) = \sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{k=1}^{2} V(x_i\ ,\ y_j\ ,\ z_k\ )\ [(1-$$

$$\left|\frac{x - x_i}{x_2 - x_1}\right|)(1-\left|\frac{y - y_j}{y_2 - y_1}\right|)(1-\left|\frac{z - z_k}{z_2 - z_1}\right|)] \qquad (1)$$

where x_i , y_j and z_k represent the coordinates for the eight grid points around the point(x,y,z) (Thurber, 1983). It is a continuous function which is the product of linear functions in x, y and z.

The other important stage for the MSI is the selection of the appropriate initial approximation for the ray tracing process. Thurber and Ellsworth (1980) demonstrated a method for deriving initial solutions for ray paths and travel times in laterally heterogeneous media. They used a two-dimensional, laterally averaged velocity layer model which includes the ray path as an initial approximation for a three-dimensional ray tracing process.

AREA DESCRIPTION AND GEODYNAMIC OUTLINE

The study area is in the region where the External Dinarides, Southern Alps and the Adriatic Platform meet each other. The collision reflects the geological complexity of the overthrusting, thrusting and normal faulting union (Figure 1).

The structural arrangement of the region is the result of two orogenesis-Hercynian and Alpine that gave rise to elements differing widely in complexity. The fundamental elements of the region as geographical units from North to South can be given as below (Amato et al., 1976);

- Julian Alps : Two important faults with a general approximate E-W direction border the Alps to the North with the Fella-Sava line and to the So-

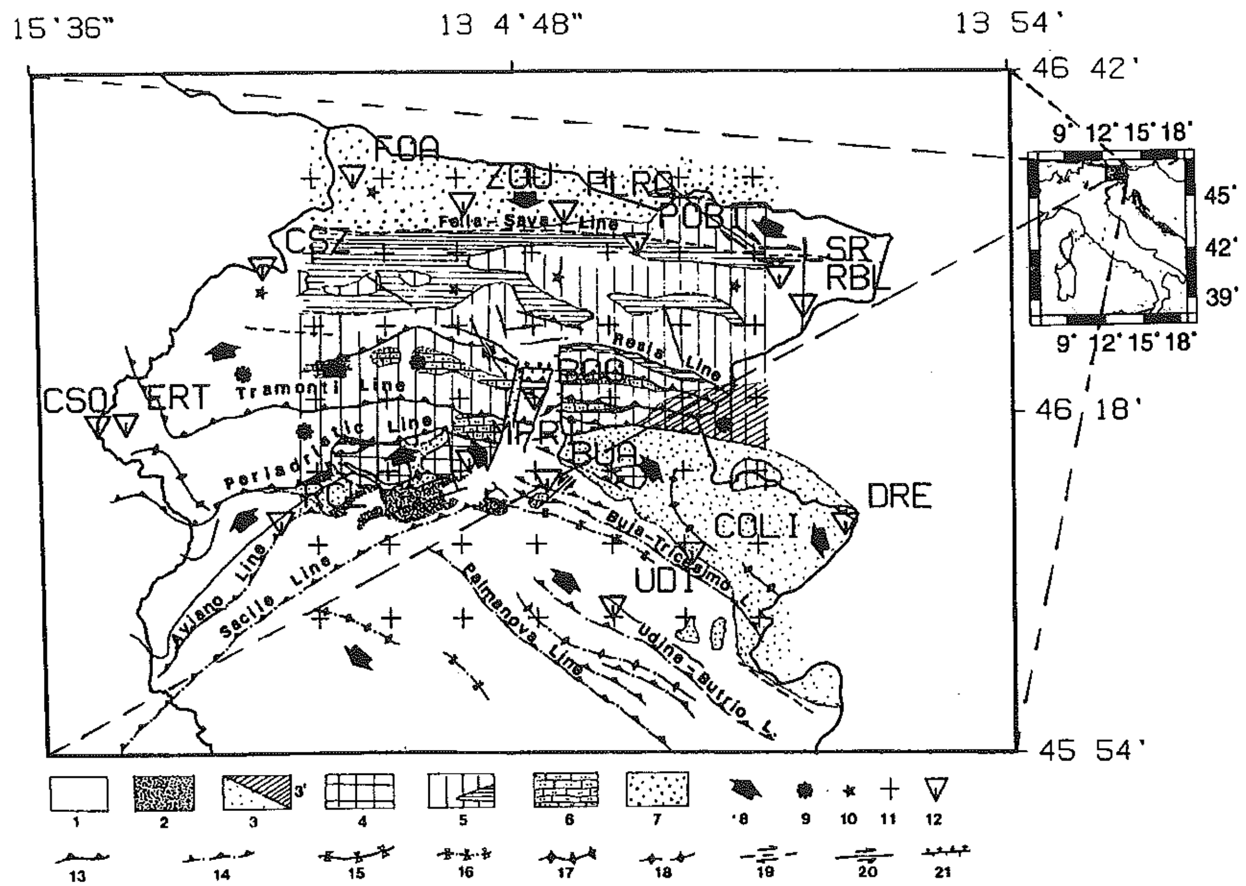

Figure 1. Study area and structural units(modified from Slejko et al., 1987; and Castellarin and Vai, 1982) : 1: Quaternary deposits, 2: molasse units(Jurassic and Cretaceous), 3: Eocene flysch, 3': Upper Cretaceous Flysch, 4: neritic units(Jurassic and Cretaceous), 5: Permo-Trias units with evaporitic units, 6: pelagic units, 7: Paleozoic units, 8: tilting (arrow towards relatively lowered area), 9: the area subjected to strong deformation with resulting increase of relief energy, 10: the area subjected to prevailing uplifting, 11: velocity grid nodes locations used in this study, 12: seismic network station locations, 13-14: outcropping-buried thrusts, 15-16: outcropping-buried syncline, 17-18: outcropping-buried anticlinal axis, 19-20: outcropping-buried strike-slip fault, 21: reverse fault.

Şekil 1. Çalışma alanı ve yapı haritası (Slejko ve diğ., 1987; ve Castellarin ve Vai 1982'den alınmıştır : 1: Kuvaterner çökelleri, 2: molas birimleri, 3: Eosen fliş birimleri, 3': Üst Kretase flişi, 4: neritik birimler(Jura ve Kretase), 5: evaporitik birimli Permo-Triyas birimler, 6: Pelajik birimler, 7: Paleozoyik birimler, 8: eğimlenme(ok yönü eğim yönünü gösterir), 9: röliyef enerjisinin artmasına yol açan kuvvetli deformasyona uğramış alan, 10: yükselmiş alan, 11: çalışmada kullanılan hız grid noktalarının yerleri, 12: sismik istasyon yerleri, 13-14: yüzeylenmiş-gömülü itkiler, 15-16: yüzeylenmiş-gömülü senklinal,17-18: yüzeylenmiş-gömülü antiklinal,19-20: yüzeylenmiş-gömülü doğrultu atımlı fay, 21: ters fay.

uth with Resia Valley line (Cavallin and Martinis, 1976).

- Pre Alps : From structural point of view they can be divided into two sectors seperated by Periadriatic overthrust. First sector to the north is characterized by the presence of thrust-belts elongated in E-W direction and overthrusted to the south. In Tagliamento valley the tectonics become more complex and E-W trend is cut by vertical faults in an approximate N-S direction. In the past, several destructive earthquakes occurred in this area including the 1976 Friuli Earthquake. All these earthquakes may be associated with the thrust belt of the Periadriatic system(Aric et al.,1976 and Finetti et al.,1976). Southern part of the Periadriatic overthrust, there are mesozoic anticline outcrops verging to the South. This province strongly deformed by geodynamic forces, which appear to be still active. The Tagliamento River marks the junction of the Alpine and Dinaric System.

A highly faulted area in the region encompassed by Gemona in the North and by Maiano and Tricesimo in the SW and SE respectively (Cavallin and Radrizzani, 1987). This area coincides with the sector of the Friuli Plain which suffered the largest amount of destruction and damage by earthquakes and corresponds to the convergence region of the Alpine and Dinaric trends. In the North, the seismic section UDI 76-01 intersects the major overthrusts of the Periadriatic system and Buja-Tricesimo in the South (Figure 2a). The Buja overthrust meets another overthrust, trending SW-NE, evidenced by the seismic lines recorded in the area. The total vertical displacement caused by Buja-Tricesimo overthrusts which can be considered the northwestern appendix of the Dinaric system, is nearly 2km. Although the first movements of the Alpine orogeny are datable to the Paleocene-Eocene witnessed by the flysch deposits, the orogenic process which formed these overthrusts probably started during the Oligocene-Miocene and has continued during the successive phases of the Alpine orogenesis (Cavallin et al., 1984).

A deep trough, which developed in the area is limited by Tricesimo overthrust and by the Buttrio reverse fault. This trough is indicated by the negative Bouguer anomaly and it is confirmed by the seismic sections (Figure 2b). It is assumed that this trough was filled with sediments of Oligocene to Quaternary age.

In Friuli the neotectonic activity mainly involves overthrusts with large compressive components, as indicated by shortening in the sedimentary cover(Carulli et al., 1990).

According to the geodetic observations, the Alpine arch increases its potential gravitative energy, which results not only in an isostatically pushing-down of Moho, but also in a north- and southward spreading of the limbs of arch(Figure 3) (Van Bemmelen,1976). These are quasi-steady processes of creep, which need not lead directly to seismic relaxiations. The same can be said of the underthrusting tendencies of Adriatic spur. The movements along (a) and (b) in Figure 3 have probably been going on since the beginning of the Molassic phase of Alpine orogeny; they cause accumulating stresses underneath Friuli along the southern foot of the East Alps, which are intermittently released by earthquakes. The direct cause of these earthquakes is neither the slow creep along (a) nor that along (b), but has to be sought in the sudden isostatic adjustments along (c), which are accompanied by rifting processes in the crust. In other words the foot of the southern limb of the Alpine arch occasionaly breaks through the supporting floor, formed by the lower part of the continental crust.

APPLICATION VELOCITIES WITH REFINED HYPOCENTER

We used the Friuli-Venezia Giulia Seismometric Network's data for the period of 1984-1988. The estimated initial locations of these earthquakes had been obtained by using the HYPO71 (Lee and Lahr, 1975) code on a IBM 3090 Computer at Osservatorio Geofisico Sperimentale (OGS). The seismic network is located in the nothern part of Adriatic Sea known as Friuli-Venezia Giulia region. The network was consist of 15 telemetric stations in 1984. Each station has three component digital(120 samples/sec) instrument with the reading accuracy of 0.1sec.

We selected the data according to the number of observations, quality of estimated initial location, magnitude and spatial distribution recorded in the above time period. The events recorded at more than 10 stations and magnitude equal to or more than 1.8 are selected for this study. Then the event which has A and B quality in the data set was selected. Therefore the estimated locations of earthquakes having vertical error more than 5 kms and lateral error more than 2.5 kms were eliminated. Afterthat the events which proved unstable in the one-dimensional inversion were deleted from the data set. The stations and the initial epicenter locations are given in Figure 4. The area covered by the stations is thereabout 100 km by 60 km. There is an event clustering just at the northern part of Boldano (BOO) station. The velocity structure model which is used for estimated locations by OGS and consists of two layers and a halfspace (Table 1)(OGS, 1989).

The P-wave velocity structure underneath the middle of the Friuli-Venezia Giulia area was examined throughly using MSI. For earthquake relocation, we started with assuming a simplified velocity model of the Earth's crust to calculate arrival times of P-waves propagating through the model. The differences between the observed and calcula-

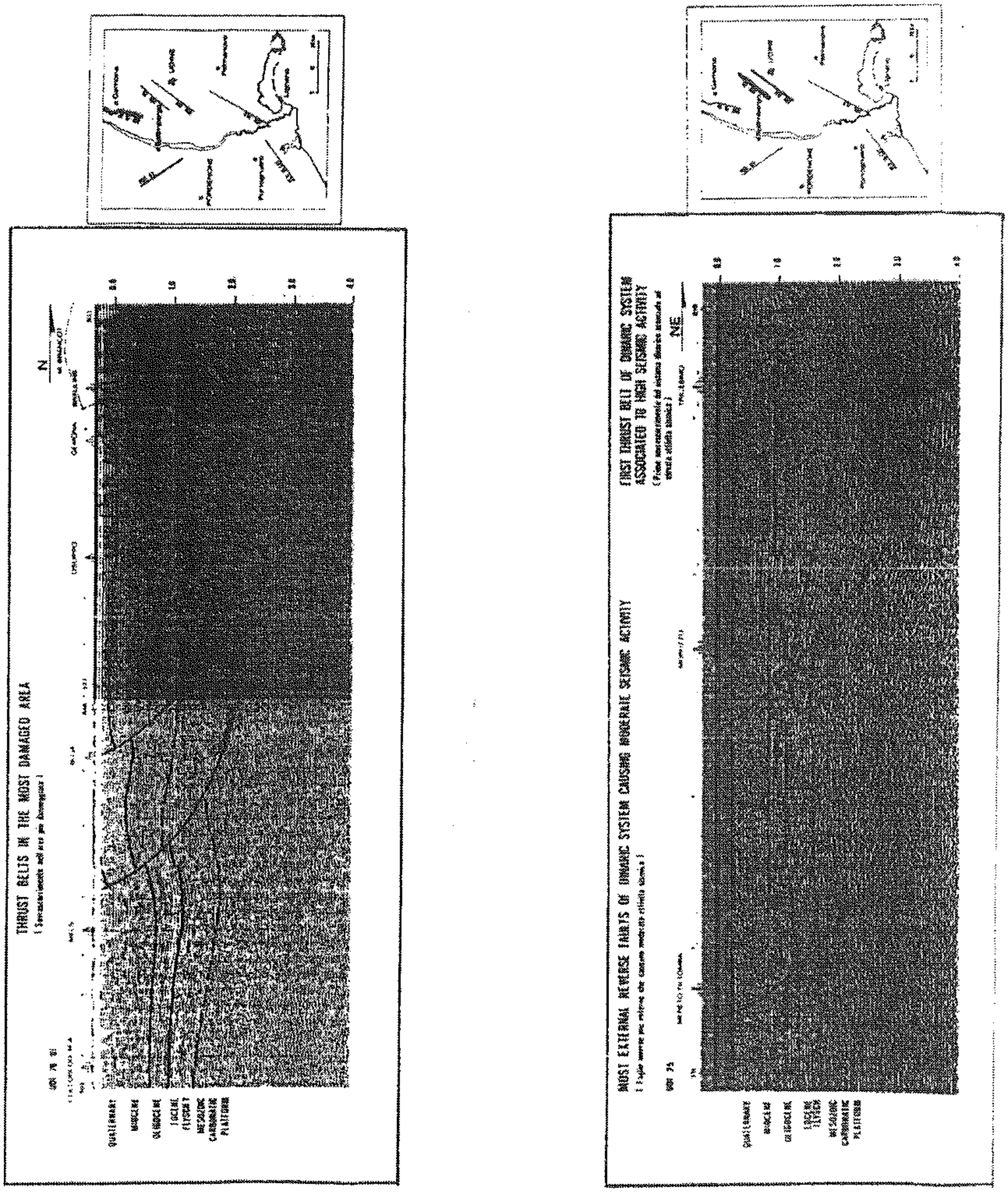

Figure 2. Seismic section showing the evidence of high degree tectonization in the Friuli area with, a)overthrusts of Cividale-Tricesimo-Maiano and of Buja, in the northern edge of the section an overthrusting connected with the Periadriatic system is also visible, b)structural highs developped through the reverse fault system of Buttrio, Terenzano and Lavariano. On the edge of the section the cividale Tricesimo-Maiano overthrust is also visible (Amato et al., 1976).

Şekil 2. Friuli bölgesinin, tektonizmaya uğradığını gösteren sismik kesitler. a) Cividale-Tricesimo- Maiano ve Buja itkileri. Kesitin kuzey kesiminde, Periadriatic sistemi ile bağlantılı itki de görülebilir, b) Buttrio, Terenzano ve Lavariano ters fayları boyunca gelişen yapısal yükselimi göstermektedir.

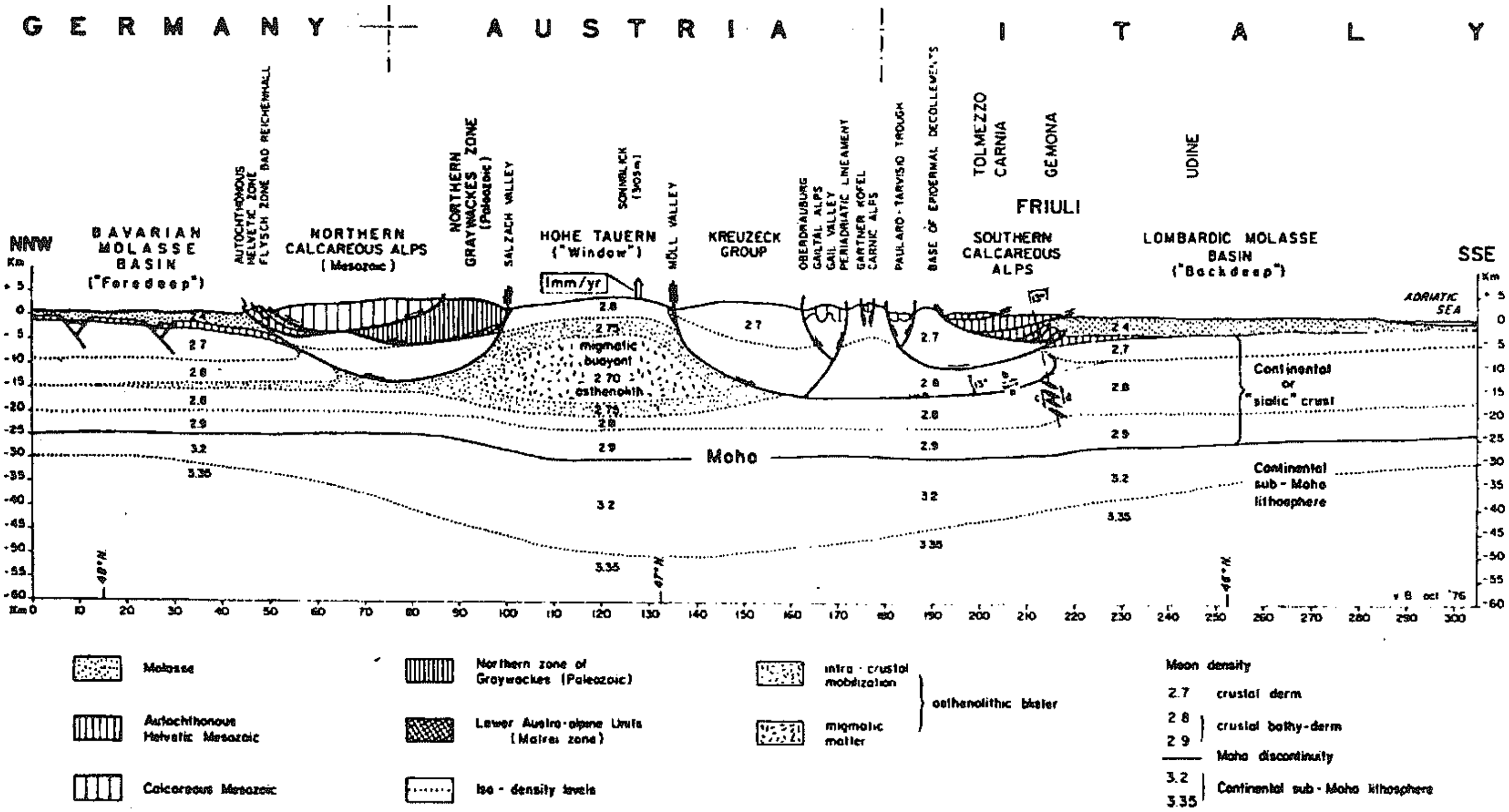

Figure 3: N-S cross section across the Eastern Alps(13° E) and the faulting mechanism of the Friuli earthquake of May 6, 1976 (Van Bemmelen, 1976) .

Şekil 3: Doğu Alpleri, 13° D boylamında kesen derinlik kesiti ve 6 Mayıs 1976 Friuli depreminin faylanma mekanizması(Van Bemmelen, 1976) .

ted arrival times are due to errors in assumed velocity model and errors in the initial locations of earthquakes. Lateral and vertical ray path coverage of the area is satisfactory(Figure 5a and 5b).

We investigated the P-wave velocities at 245 grid nodes which are defined horizontally as 7 by 7 with 10kms and vertically at five depth levels with 3km intervals(Figure 4). The velocity between the grid points are calculated by interpolation as described in the previous section. One of the important stages in MSI is the selection of the appropriate damping factor corresponding to the data set. The damping factor obtained by looking at the trade off curve between the solution and data variances after one iteration for different damping values. The damping value where the data variances makes the solution variance minimum is used in the calculations (Eberhart-Phillips, 1986 and Eberhart-Phillips

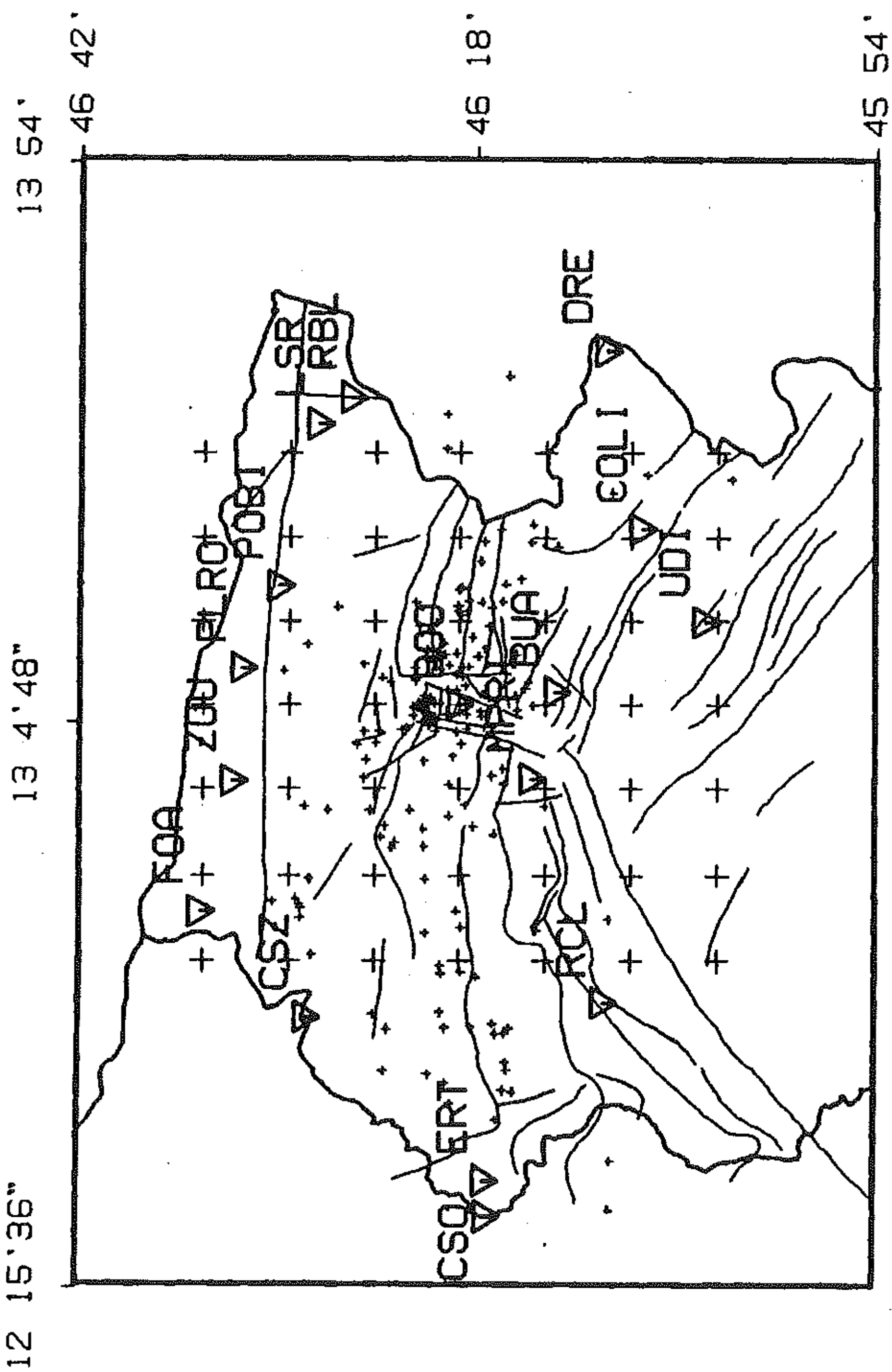

Figure 4: Velocity grid nodes with the interval of 10kms(+) and earthquake locations of OGS(+) used for velocity imaging.

Şekil 4: Çalışma alanı ve Friuli-Venezia Giulia Sismik Örü Ağı ile bölgede yer alan fayların konumları. + ; hız görüntülemesinde kullanılan ve 10km aralıklı olan hız grid noktalarının yerlerini göstermektedir. + ; OGS'in deprem lokasyonlarıdır.

P-wave velocity (km/sec)	Depth (km)
5.85	h ≤ 22
6.68	22 < h ≤ 38.9
8.00	h > 38.9

Table 1. The P-wave velocity-depth model which is used for earthquake location by O.G.S. and consists of two layers and a halfspace.

Tablo 1. O.G.S tarafından depremlerin yerlerinin belirlenmesinde kullanılan, iki tabaka ve yarı sonsuzdan oluşan hız-derinlik modeli.

1989). The damping value is found as 25 for our data set. By the help of previous geological and geophysical studies and earthquake locations of OGS, a two-dimensional velocity model is proposed. The resolutions for the velocity grid nodes at five depth levels range from 0.78 to 0.98 for this velocity model (Table 2).

A relatively high velocity at the western part of Gemona and lower velocity at the southeast which can be seen at 0., 3., and 6.km depth levels are in agreement with the positive and negative anomalies on the Bouguer anomaly map, respectively (Figure 7).

P-wave velocity (km/sec)	Resolution	Depth (km)
5.32	0.92	0.0
5.25	0.91	3.0
5.93	0.87	6.0
6.47	0.72	9.0
6.29	0.89	12.0

Table 2: The P-wave velocity and resolution values obtained for 2-D velocity model at 0., 3., 6., 9., and 12km depth interfaces.

Tablo 2: İki boyutlu hız modelinde; 0., 3., 6., 9., ve 12km derinlikteki arayüzeylerde elde edilen P-dalga hızı ve rezolüsyon değerleri.

Although resolution by itself is not an indicator of the "correctness" of a given velocity value, the velocity error decreases steadily as resolution increases (Thurber,1981). Large errors are due to peripheral grid nodes and the grids where the lateral velocity is changing abruptly. Grid points with low resolution can have accurate velocities and nodes with high resolution are certainly not guarantied to have accurate velocities. The area is characterized by thrust and normal faults and have a complex velocity structure with rapid lateral variations; and all of these observed features are reflected to the velocity grid points. The velocity grid nodes and contour lines are shown in Figure 6a-e corresponding to five depth levels at 0., 3., 6., 9., 12kms.

The diagonal resolution elements of the velocity grid points are change from 0.01 to 0.83 in our three-dimensional model. Velocity grid nodes for depth level of 6.0km, grid numbers 99 to 197, and their diagonal resolution elements are given in Tablo 3 as an example.

The number of earthquake occurences versus depth is given in Figure 8. One of the two relative cumulations is between 2-5km and corresponds to the sedimentary units and basement contact. The depth of second cumulation follows the Periadriatic overthrust line. It is dipping towards to North and becomes almost lateral in depth following the complexity of velocity in the middle of the area.

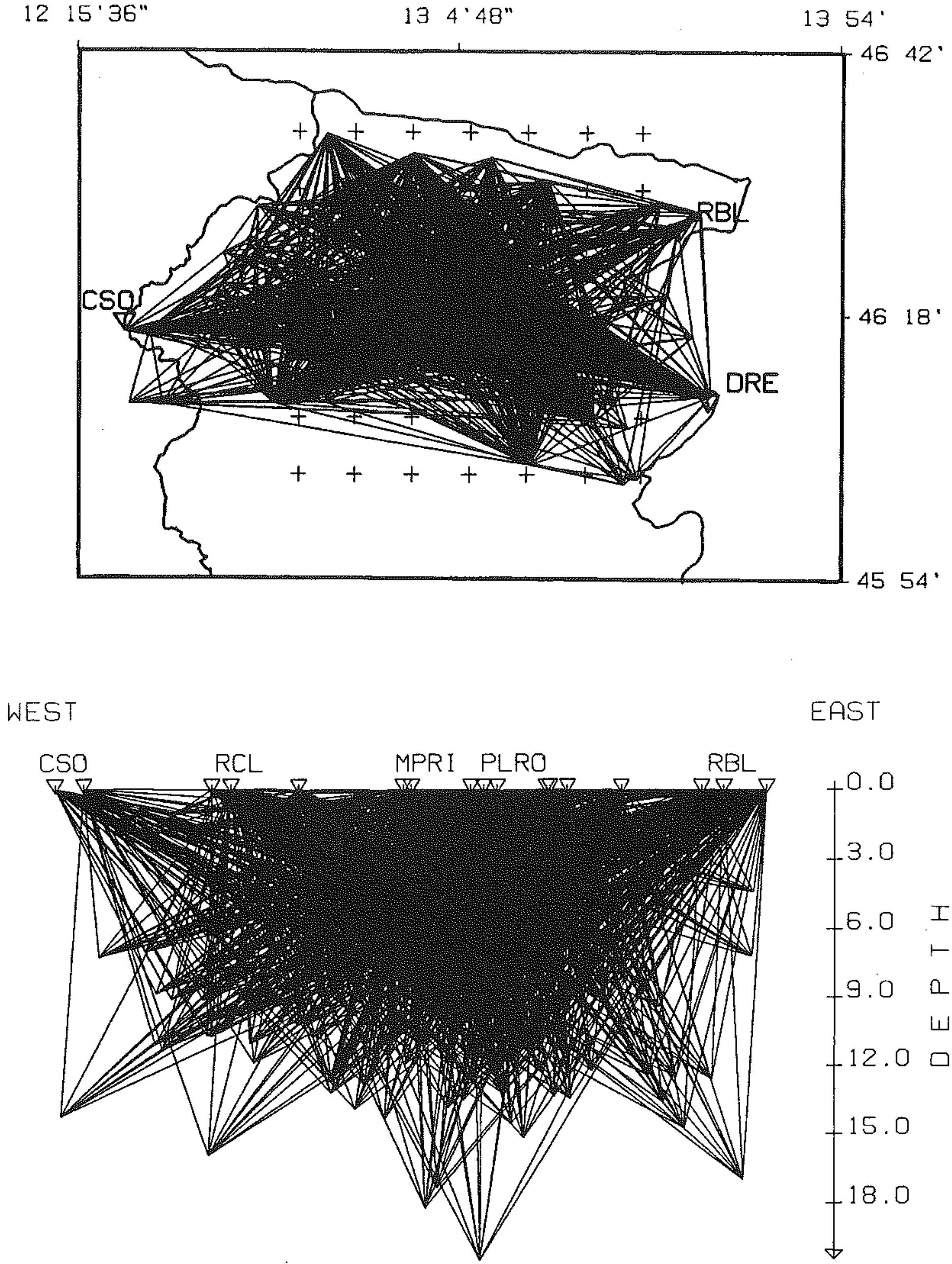

Figure 5. The ray path coverage; a) on surface, b) in depth.

Şekil 5. Işın yollarının dağılımı; a) yüzeyde, b) derinlikte.

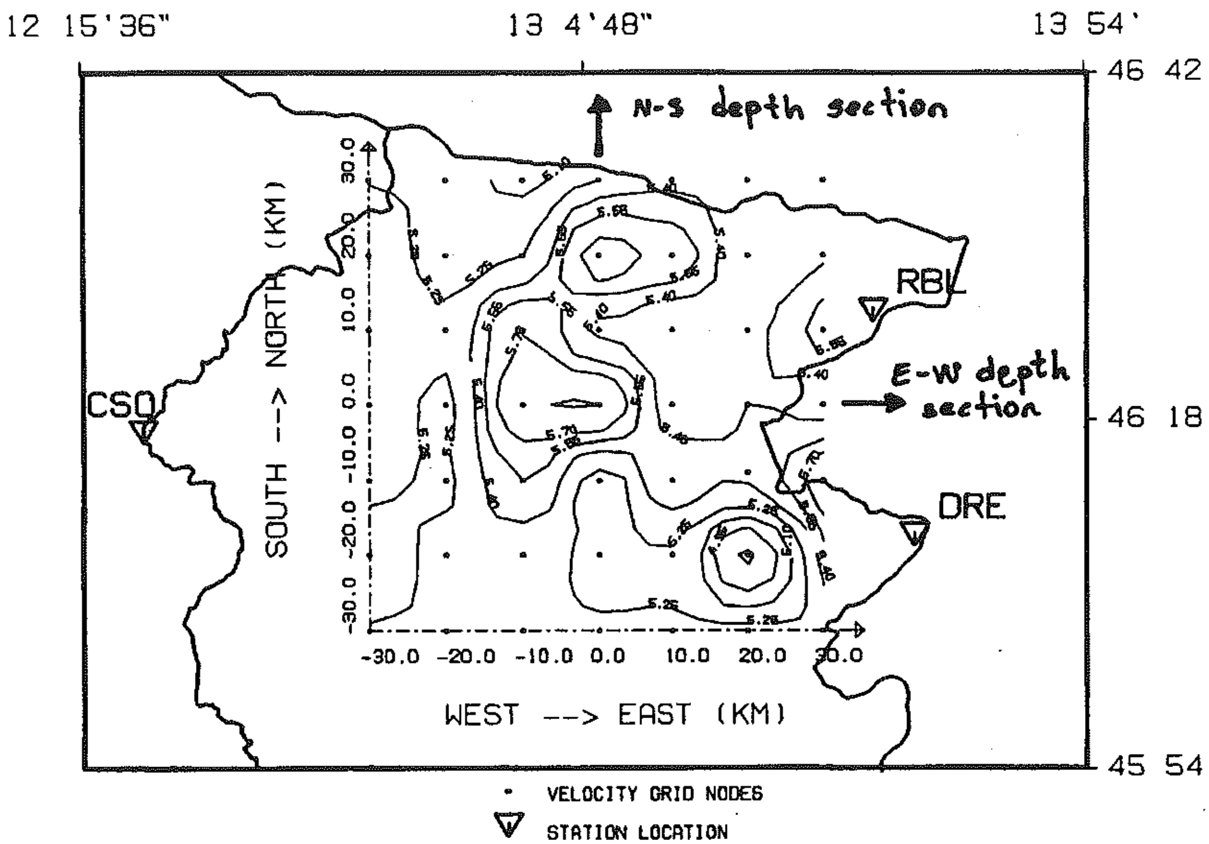

Figure 6 (a)

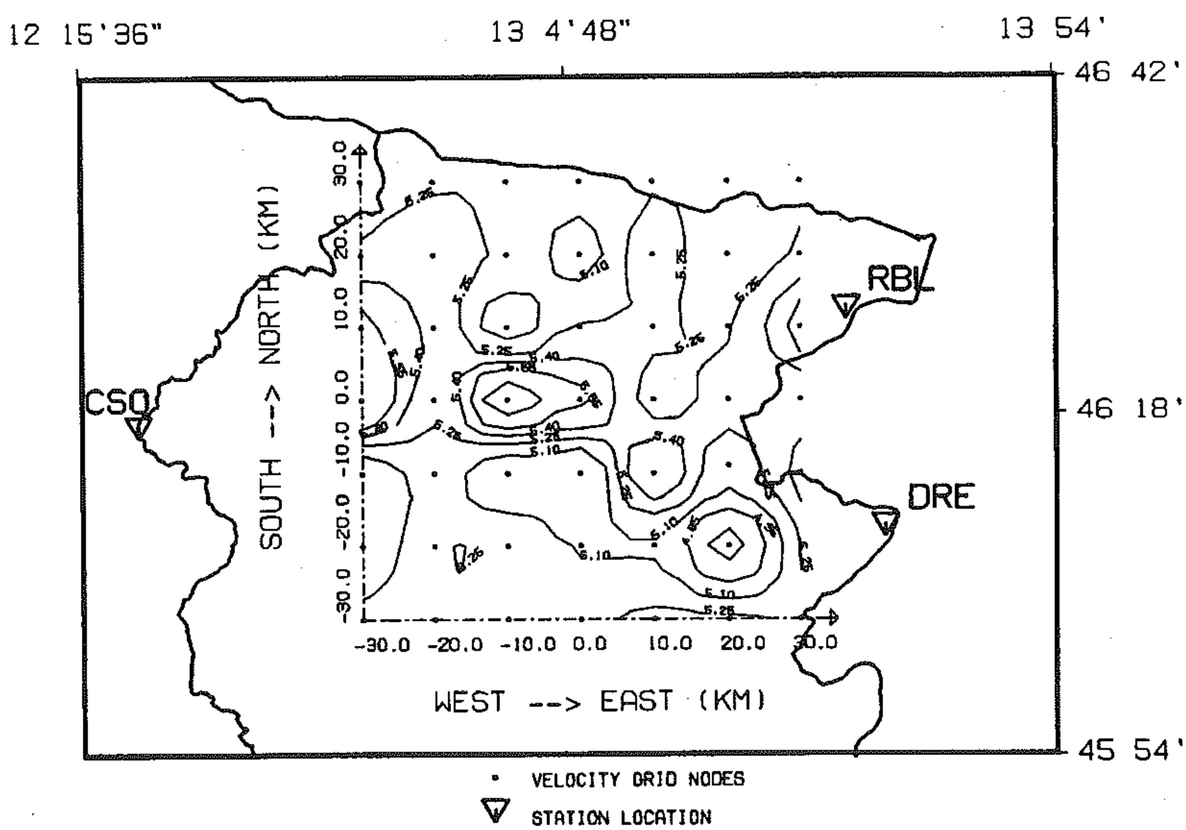

Figure 6 (b)

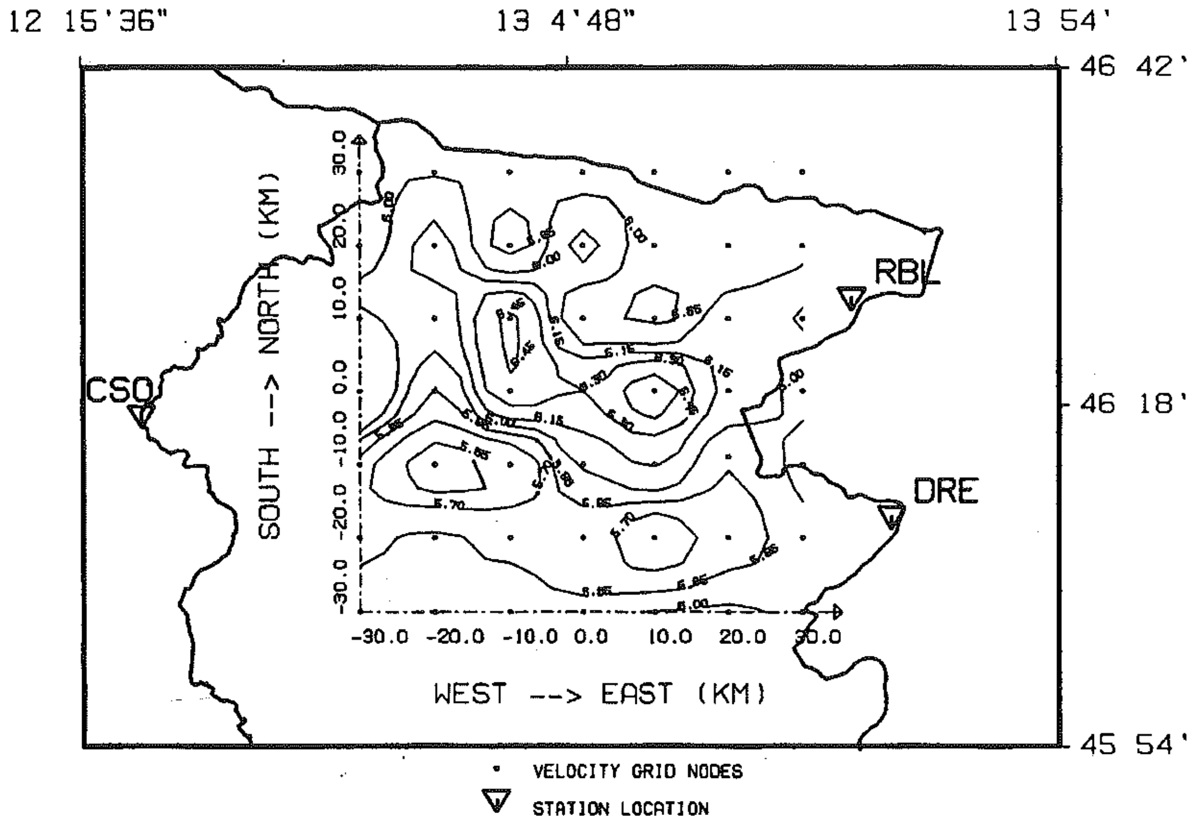

Figure 6 (c)

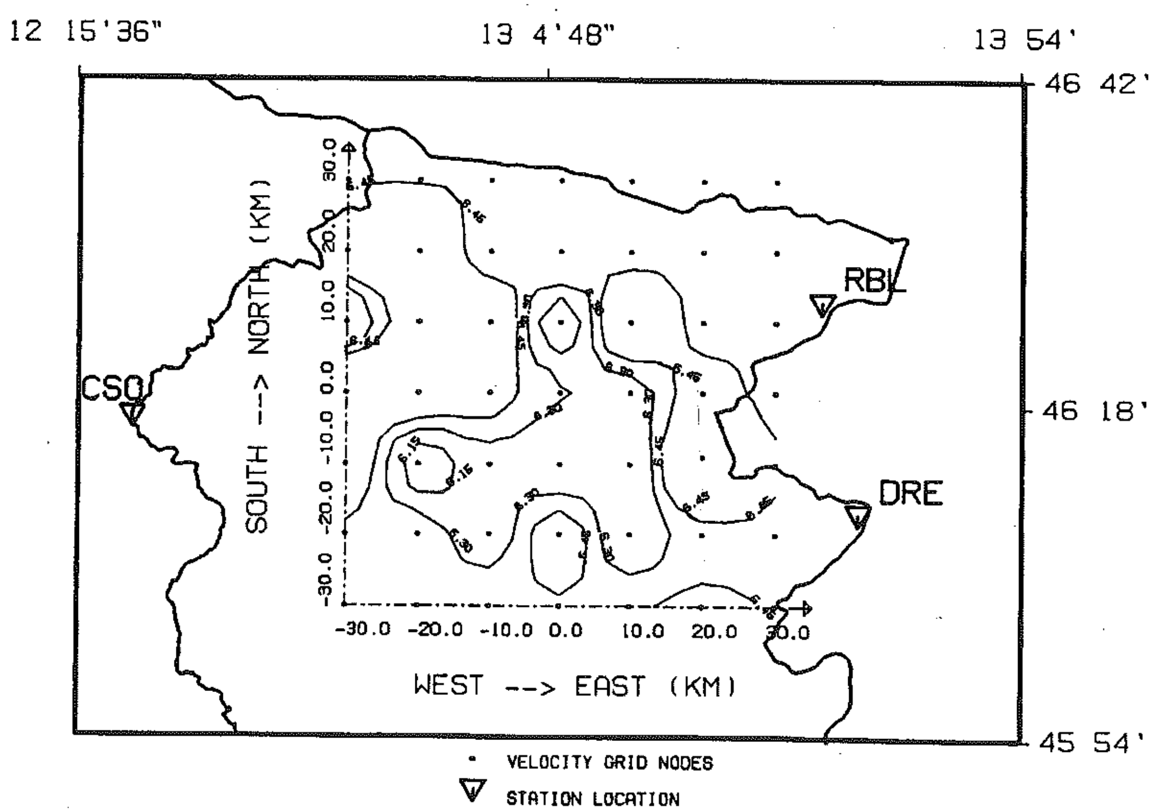

Figure 6 (d)

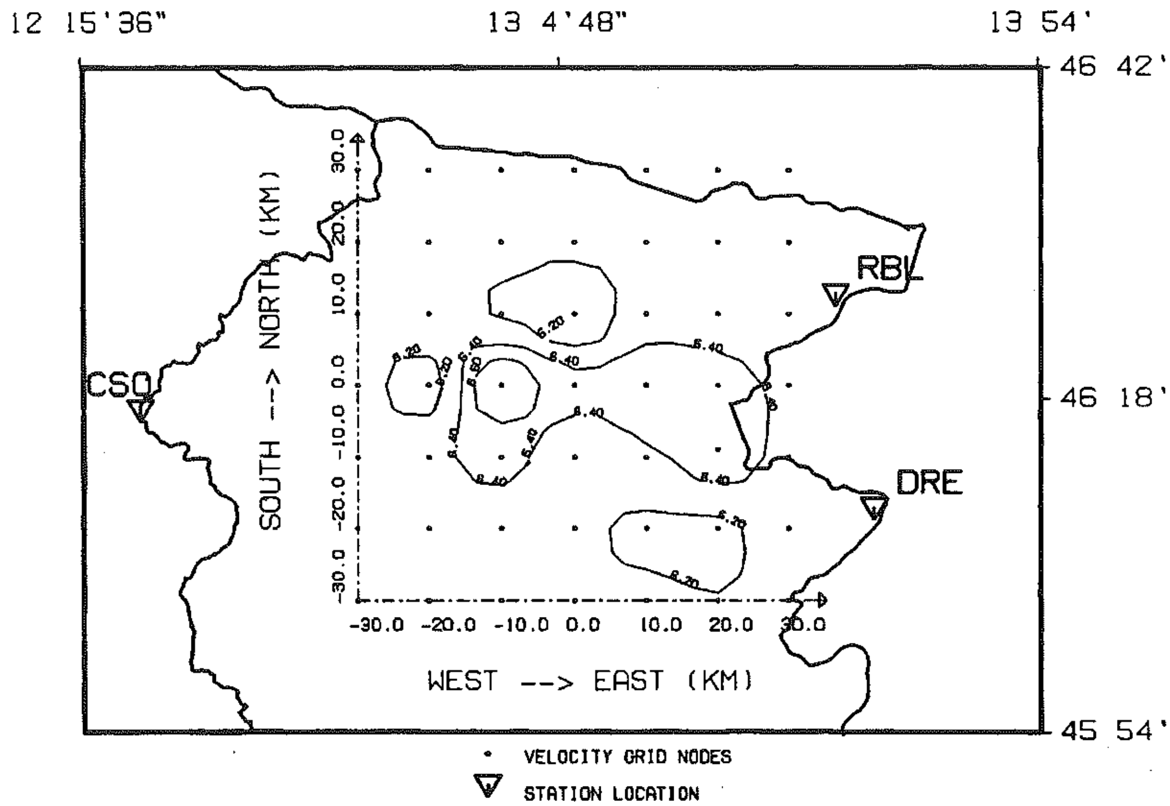

Figure 6. Velocity countours of velocity imaging for five depth levels; a)0km, b)3km, c)6km, d)9km, e)12km. Bold arrows show the cross section locations(Özer, 1993).

Şekil 6. Beş derinlik arayüzeyi için hız görüntülemesi ile elde edilen hız conturları; a)0km, b)3km, c)6km, d)9km, e)12km. Koyu oklar, D-B ve K-G doğrultularında alınan derinlik kesitlerinin yerlerini göstermektedir(Özer, 1993).

The velocity-depth distributions for E-W and N-S directions(see Figure 6a for locations) with the hypocenters projected to the cross-sections are given in Figure 9a and 9b, respectively. General features of these sections may suggest that the Paleozoic series together with the crystalline basement is highly tectonized as it is also pointed out by Gentile and Slejko(1990). The velocity reversals at about 10km, both at Figure 9a and 9b, and higher velocities between MPRI and PLRO stations at the Figure 9a can be seen. These properties are identical to the velocity pattern in the depth section of the profile D"-T, Trieste-Obersee(Figure 10) which is obtained by the Italian Exploration Seismology Group and Institute of Geophysics, ETH Zurich(1981). In our depth sections the thickened flysch with the velocity of 4.7 km/sec at the eastern part, and northward to the carbonates with the plastic and/or evaporitic units velocity range from 5.1 to 5.7 km/sec was found. Beside this, a high surface layer velocities with maximum value of 5.7 km/sec is observed in the middle of the area following approximately E-W direction at the northern part of Gemona (Özer,1993).

CONCLUSIONS

The study area is characterized by E-W, NW-SE, NE-SW trending overthrusts and N-S directed vertical faults. The data recorded by the Friuli-Venezia Giulia Regional Seismic Network for the period of 1984-1988 is used to obtain the upper crust P-wave velocity structure and refined hypocenters simultaneously for the area. In the light of the previous geological and geophysical studies a 2-D velocity model is obtained after the proper damping value determined for the data set. The resolution values range from 0.78 to 0.98 for the 2-D model. Then the lateral velocity variations at 245 grid nodes and hypocenter of the earthquakes calculated simultaneously. Refined hypocenters meshed on to the velocity contours at the E-W and N-S profiles.

(km)	-30.	-20.	-10.	0.	10.	20.	30.
-30.	99 (0.01)	100 (0.01)	101 (0.01)	102 (0.05)	103 (0.02)	104 (0.02)	105 (0.02)
-20.	106 (0.06)	107 (0.08)	108 (0.06)	109 (0.35)	110 (0.42)	111 (0.16)	112 (0.09)
-10.	113 (0.39)	114 (0.47)	115 (0.51)	116 (0.74)	117 (0.76)	118 (0.50)	119 (0.50)
0.	120 (0.65)	121 (0.44)	122 (0.74)	123 (0.81)	124 (0.76)	125 (0.46)	126 (0.26)
10.	127 (0.48)	128 (0.65)	129 (0.71)	130 (0.69)	131 (0.67)	132 (0.51)	133 (0.18)
20.	134 (0.25)	135 (0.49)	136 (0.41)	137 (0.50)	138 (0.21)	139 (0.29)	140 (0.04)
30.	141 (0.01)	142 (0.03)	143 (0.02)	144 (0.02)	145 (0.01)	146 (0.01)	147 (0.01)

Table 3. Diagonal resolution elements(in parenthesis) of the velocity grid nodes numbered 99 to 147 for depth interface of 6km. The values -30,-20,......,20,30 indicate the distance of velocity grid points to the origin selected in the middle of the area.

Tablo 3. 6km derinliğindeki arayüzeye ait hız grid noktalarının (99-147) diyagonal rezolüsyon değerleri(parantez içinde). -30,-20,......,20,30 değerleri, hız grid noktalarının çalışılan alanın ortasında seçilen orijin noktasına uzaklıklarını göstermektedir.

The velocity reversal at about 10km and higher velocity in the middle part of those sections identical to the Figure 10 and Figure 3, shows the rifting process in the crust as Van Bemmelen (1976) pointed out.

The initial epicenter distribution of earthquakes are not homogeneous in the area subjected to the velocity imaging. Beside this, the area is characterized by thrust and normal faults, and show a complex velocity structure with lateral rapid variations. All these features reflect to the calculated velocities and their resolutions. Therefore diagonal resolution elements of velocities are change from 0.01 to 0.83 in our 3-D velocity imaging.

Since our data set is from 1984 to 1988 the authors suggest that recompiling the data recently obtained may improve the velocity imaging. Creating a block diagram including geological structures, velocity contours and hypocenters with the focal mechanism of the shocks in the area would be very useful for enlightening the geodynamic process in the area.

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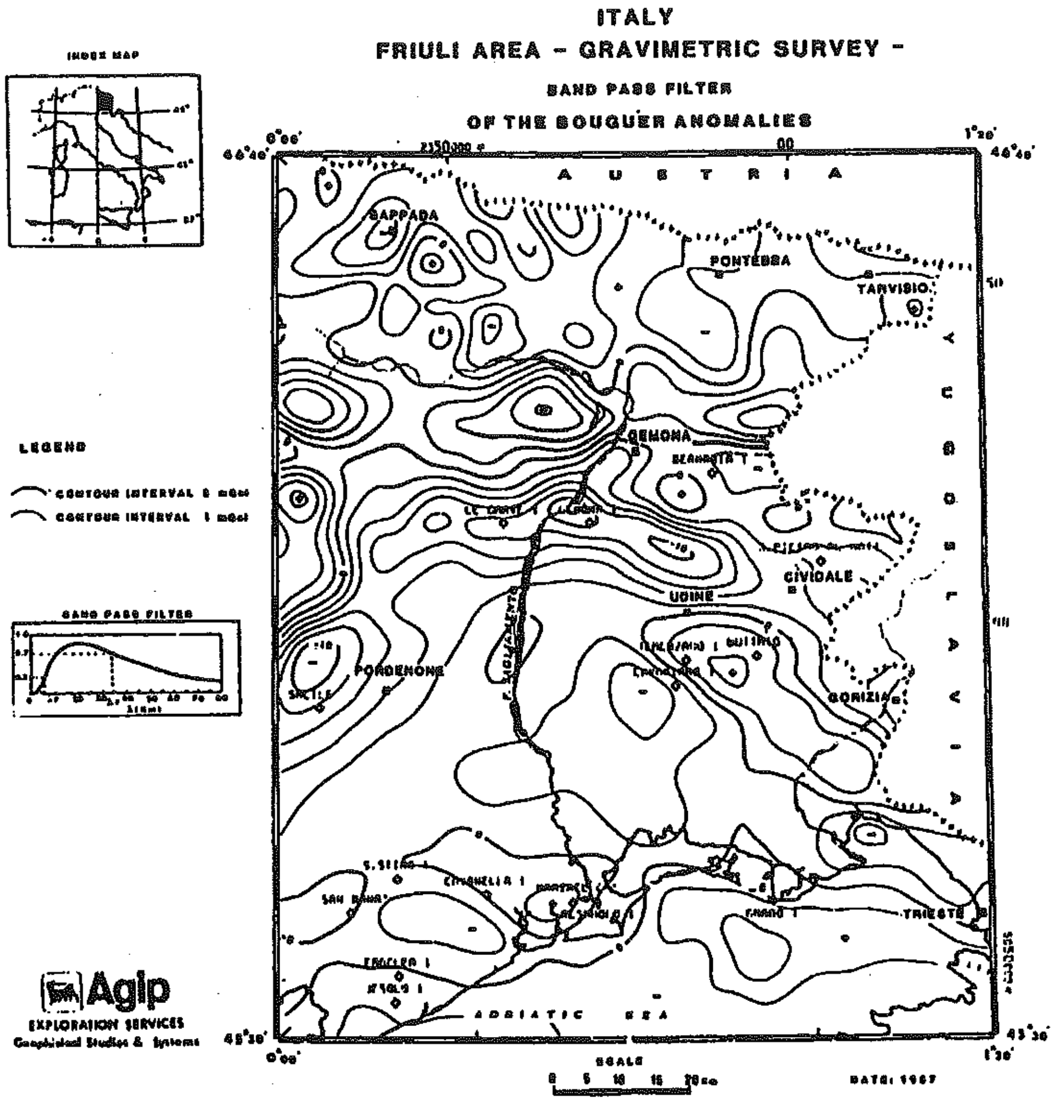

Figure 7. Bouguer anomaly map for Friuli-Venezia Giulia area(Cati et al.,1987).
Şekil 7. Friuli-Venezia Giulia bölgesinin Bouguer anomali haritası(Cati et al.,1987).

developed by Prof.Dr.C.H.Thurber and mainly used for the calculations throughout this study to investigate the 3-D velocity imaging. Lastly, one of the authors, Naşide Özer would like dedicate this study to Prof.Dr.Hüseyin Soysal's memory whom is the first academic visor of her. The referees provided helpful comments on earlier versions of the manuscript.

ÖZET

Friuli-Venezia Giulia Bölgesi Sismik Örü Ağı tarafından 1984-1988 yılları arasında kaydedilen P-dalgası ilk varışlarına Eş Anlı Ters Çözüm Yöntemi(MSI) uygulanarak, yeraltı hız görüntülemesi ile birlikte iyileştirilmiş deprem yerleri elde edilmiştir.

Çalışma alanı, External Dinaridler, Güney Alpler ve Adriatik platformlarının birbiriyle buluştuğu bölgede yer alır. Bu çarpışma, alanda itki, ters faylanma, normal faylanma ve düşey faylanma birimleriyle karmaşık bir jeolojik yapıya yol açar.

Bilindiği gibi, yeraltı hız görüntülemesinde, istasyon ve deprem dağılımlarının homojen olması gerekmektedir. Veri kalitesi ve kullanılan ışın yollarının görüntülemesi yapılan alanı yeterince kapsaması rezolüsyonu etkiler. Bölgede,1984-1988

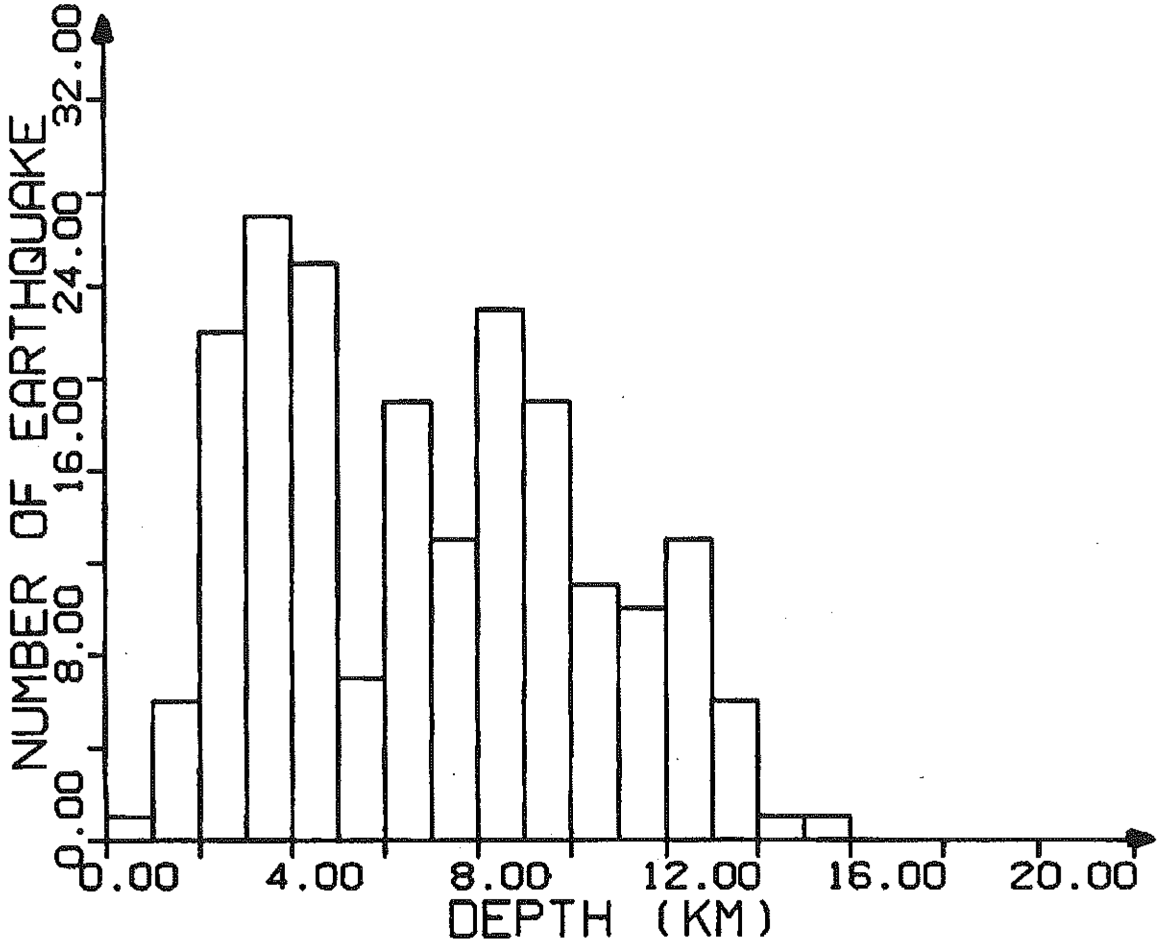

Figure 8. Histogram showing depth versus number of earthquakes for the relocated earthquakes.

Şekil 8. İyileştirilmiş deprem yerlerinin derinlikle-deprem oluş sayısını gösterir histogram.

yılları arasında oluşmuş depremlerden en az 10 istasyonda kaydedilmiş, A ve B kalitesindeki depremler seçilmiştir. OGS(1989)'in global hız modeli ile O.G.S tarafından yapılmış deprem çözümlerinden yararlanılmıştır.

Önce veri seti için uygun sönüm değeri, 2-Boyutta tek iterasyon sonucu elde edilen veri ve çözüm varyanslarının değişimine bakılarak belirlenmiş ve 25 olarak alınmıştır. Daha sonra, bölgede daha önce yapılmış jeolojik ve jeofizik çalışmalardaki değerlendirmeler ışığında başlangıç hız modelleri oluşturularak, 2-Boyutta 0.,3.,6.,9.,12km arayüzeylerindeki hızlar belirlenmiştir. Elde edilen bu hız modelinden yararlanılarak yanal hız değişimleri , x, y doğrultularında 10km aralıklı 7 x 7 hız grid noktalarında ve düşeyde 3km aralıklarla beş arayüzeyde elde edilmiştir. Elde edilen 2-Boyutlu ve 3-Boyutlu model için 6km arayüzeyindeki hız grid noktalarına karşılık gelen rezolüsyon değerleri Tablo 1 ve Tablo 2'de verilmiştir. Bu değerler, 2-Boyutta 1.78'den 0.98'e değişirken, 3-Boyutta 0.01'den 0.83'e değerler almaktadır. Deprem dağılımlarının homojen olmayışı ve alanın karma-

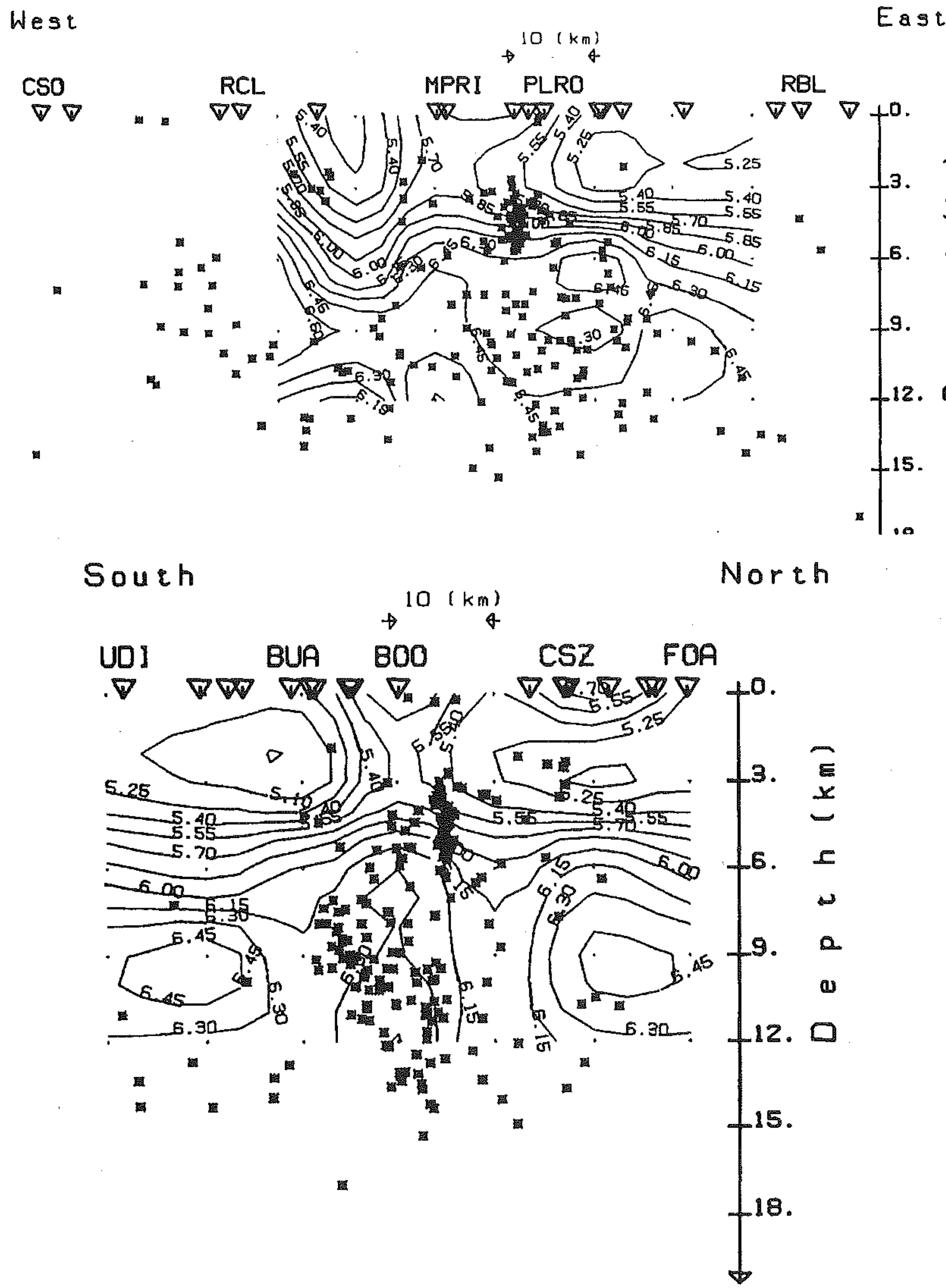

Figure 9. Velocity-depth cross-sections(Figure 6a) for E-W (a) and N-S (b) with the projected hypocenters. Small dots indicate the velocity grid nodes.

Şekil 9. D-B(a) ve K-G(b) doğrultusunda hızın derinlikle dağılımını gösteren kesitler(Şekil 6a). Deprem içmerkezleri kesitler üzerine izdüşürülmüştür. Küçük noktalar hız grid noktalarını göstermektedir.

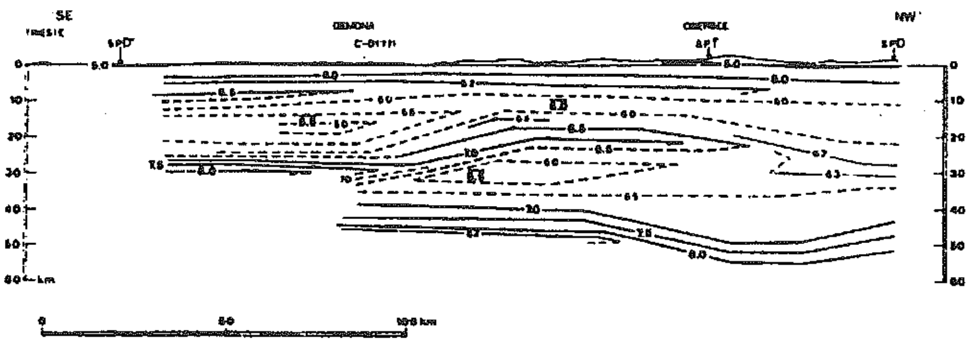

Figure 10. Depth section of the profile D"-T, Trieste-Obersee (1978). Dashed lines indicate low-velocity layers(Italian Explosion Seismology Group and Institute of Geophysics, ETH, Zurich, 1981).

Şekil 10. D"-T, Tireste-Obersee (1978) profilinde alınmış derinlik kesiti. Kesik çizgiler düşük hız tabakalarını gösterir (Italian Explosion Seismology Group and Institute of Geophysics, ETH, Zurich, 1981).

şık bir yapıya sahip olması-yanal hız değişiminin belirgin oluşu bu değerlere etkendir.

Görüntüleme sonucunda, alanın güneydoğusunda kalın fliş ve molas depositlerine bağlı olarak daha düşük hızlı, yaklaşık 4.7km/sn ve Gemona'nın yaklaşık kuzeyinde yüzeylenen yaklaşık 5.7km/sn hızlar Bouguer anomali haritasında negatif ve pozitif anomalilere karşılık gelmektedir. D-B ve K-G doğrultularında alınan derinlik kesitlerinden de izlenebileceği gibi, Güney Alplerle External Dinaridlerin karşılaştığı yer kabul edilen orta alanda(Tagliamento kanyonu) yüksek hızlar yüzeye kadar ulaşmaktadır. 2-5km arasındaki deprem kümelenmesi olasılıkla, sediman-temel sınırına karşılık gelmektedir. D-B doğrultusundaki dış merkez yığılmalarının, kuzeye dalan ve derinlerde yataya yakınlaşan Periadriatik sistemin etkisinden kaynaklandığı söylenebilir. Yaklaşık 10km derinlikteki göreli hız terslenmesi D"-T,Trieste-Obersee kesiti ile uyum sağlamaktadır.

Çalışmada 1984-1988 yıllarının verileri kullanılmıştır. Yazarlar, 1988'den günümüze kadar olan deprem verileri ile veri setinin yenilenmesi, bunlara MSI'ın uygulanmasıyla elde edilen hız görüntülemesinin ve iyileştirilmiş deprem yerlerinin de kondurulacağı ve bölgede oluşmuş büyük depremlerin odak mekanizma çözümlerinin, jeolojik yapıların da eklendiği bir blok diyagram oluşturulmasının bölgenin jeodinamiğine ışık tutacağı görüşündedirler.

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